The Linked University Consortium for Environment and Development – Industry and Urban Areas (LUCED-I&UA)

PROCEEDINGS OF THE INTERNATIONAL CONFERENCE

ENVIRONMENTAL MANAGEMENT & TECHNOLOGY

'A Clean Environment Towards Sustainable Development'

4 - 6 August 2003
Putrajaya, Malaysia

Organised by:

Malaysian University Consortium for Environment and Development – Industry and Urban Areas (MUCED-I&UA)

In collaboration with:

- Danish University Consortium for Environment and Development – Industry and Urban Areas (DUCED-I&UA)
- Southern African Consortium of Universities for Development and Environment – Industry and Urban Areas (SACUDE-I&UA)
- Thai University Consortium for Environment and Development – Industry and Urban Areas (TUCED-I&UA)

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Preface

The LUCED-I&UA International Conference in Putrajaya, Malaysia is the climax of the cooperative work between the participating countries; Denmark, Malaysia, South Africa and Botswana, and Thailand. Despite LUCED-I&UA being young of age, only nearly three years in existence, there have been major breakthroughs in the networking, capacity building and collaborative research inter and intra consortia. This conference testifies the collaboration work undertaken within the LUCED in scientific research and capacity building of academia. The LUCED programme has also generated interests from the other institutions of higher learning in Malaysia, apart from the participating four universities, namely, Universiti Malaya, Universiti Kebangsaan Malaysia, Universiti Putra Malaysia and Universiti Teknologi Malaysia. There are positive developments to sustain the LUCED programme by the respective consortia, and expand the involvement of participating institutions of higher learning. Research focus and the funding obtained by members of the consortia have also synergised collaborative efforts that make the LUCED programme to attractive and sustainable.

The purpose of this Conference is to provide some exchanges, presentations and discussions in the fields of Environmental Management and Technology. Topics covered by the conference are, non-exhaustively, environmental education, environmental management, environmental modeling, environmental monitoring and analysis, environmental technology, health and safety, hydrology, solid waste management and urban environment. This conference is a showcase where research activities are presented, through oral and poster sessions. It allows the meeting of young scientists with industrial peoples and specialists, and the development of innovative and new research in together with industry. It is hoped that this proceedings will serve as a source of information for further collaborative activities.

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Comparison Of Environmental Impact Assessment Of Highways In Malaysia, South Africa, Thailand, And Denmark

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ABSTRACT: The objectives of doing comparative analyses of EIA systems in Malaysia, South Africa, Thailand and Denmark are to inform policy makers with a view to improve EIA in the home countries, extend knowledge of methodological procedures and to increase international understanding of environmental problems. The EIA procedures are aiming to provide individual approvals of different projects and assess and mitigate the potential environmental impacts. Some procedures are written in the EIA legislation but EIA administration and procedures are often based on the national tradition and therefore difficult to overview. In order to overcome some shortages the idea appears to select a type of activity that was present in all countries and the choice become highways. In the paper we compare the EIA systems in the four countries across four different themes: Relation to standard EIA procedure, EIA system and surrounding environmental regulation, form of public participation, and scope of and methods in the analyses of environmental impacts. Important findings are; that a participation in international environmental conventions is reflected in the EIA issues, EIA will expand on issues where environmental legislation is considered insufficient, cultural determined issues will be enclosed in the EIA, and public access and public participation in the decision process are present in all four countries but in very different ways.

Keywords: EIA comparison, Malaysia, South Africa, Thailand and Denmark, highways.

ANALYTICAL FRAMEWORK

Relation to standard EIA procedure. There are many similarities between the EIA systems. Most EIA systems are comprised of – in one way or another – a screening, scoping, EIA report, public participation, decision and monitoring. But there are also many differences between the systems and the way they are used in practice in different countries. In order to avoid describing in length all the elements where EIA systems are similar, we compare the EIA systems to a standard EIA system and focus on the elements where the EIA system in each country deviates from the 'standard procedure'. The standard procedure we use is developed through discussion in the team and through literature review. Christopher Wood develops a framework consisting of 14 evaluation criteria, which he finds vital to the quality of an EIA system (Wood 1995). Our approach is different since we have chosen to describe deviations from a 'standard EIA system' and describe the problematic issues that emerged through the study process.

When it comes to specific activities concerning the highways we will also include national or international EIA guidelines for highways. A national guideline will indicate the specific natural, cultural and social problems that by experiences are relevant for a highway project.

EIA system and surrounding environmental regulation. All four countries had some sort of environmental regulations before the EIA systems were introduced. Some of them have a land use planning system with a long tradition, and all countries introduced environmental regulation during the 1970's and 1980's. In none of the countries was the intention that the EIA system should replace the existing environmental regulations. The EIA system should function with the existing environmental legislation. This relationship is important firstly because there are huge possibilities for unclear competences and overlap of competences, when more regulatory systems have to function jointly, which can destroy administrative efficiency. Secondly, the EIA systems capability to integrate all relevant elements of the surrounding regulatory systems is important for the potential effectiveness of the EIA systems.

Form of public participation: Public participation is a central element in EIA. How public participation is formally laid down in the system and how it is carried out in practice has, firstly, huge importance for how the EIA system actually works, and, secondly, is a useful indicator for the political culture in the country (Lund 1990). On the basis of Lund's analyses of the concept of public participation we distinguish between three forms: legitimatising participation, instrumental participation and democratic participation. *Legitimatising participation* is when the sole purpose of the participatory process is to legitimate the process, but it does not have any influence on the content. *Instrumental participation* is when the public is utilised as information providers to improve the quality of the EIA reports, but where the public's prioritisation of problems and benefits is disregarded. D*emocratic participation* is when the views and the priorities of the public are taken into account in the decision making process.

Scope of and methods in the analyses of environmental impacts: EIA is about the environment, and the basis of the entire process is that important environmental impacts are identified and investigated properly. Scope is the step of the EIA process where all possible environmental problems should be considered. Significant problems will be studied and mitigated. The environmental problems taken into consideration are important for assessing the validity of the assessments made in the reports. The issues treated in the final EIA report indicate environmental problems that are considered important in the country.

Method

The study is based on a review of EIA literature about the four countries, a review of the legislation and guidelines on EIA in the four countries, semi-structured interviews with university experts and professionals in the administrative system, and a case study of an EIA on a road in each of the four countries. National experts on EIA participated in the reviews of the national legislations, and the different findings have been discussed with experts in the national systems. In each country an EIA on a road project has been examined. In analysing the EIA reports, we especially focused on the environmental issues and adequacy of the used methods for investigation of the environmental consequences of the proposed project. Furthermore, it should be examined if the specific EIA operates with the national environmental objectives.

A single case study has been chosen from each country, and these are not in themselves conclusive, but they serve as illustrations of how the systems work, and as point of entrance to get into discussion with the national experts. Apart from Denmark, the countries investigated have a federal structure, and in some of the countries, especially South Africa, the variation between the provinces can be substantial.

The EIA System in Malaysia

Current layout and relation to surrounding legislation: The core of the EIA system in Malaysia is section 34(A) in the Malaysian Environmental Quality Act and the 1987 EIA order Prescribed Activities (Environmental Quality Act 1998). The system includes most normal steps of EIA systems: screening, scoping, public participation, environmental reports, review, and decision). There are a number of special issues in the Malaysian EIA system.

1. Malaysia is a federal state, and the division of competence is put down in the ninth section in the constitution. According to this list many environmental important aspects are within the jurisdiction of the states, e.g. matters of land, water, rivers, freshwater fishing, forest and agriculture. The 1987 regulations are federal law, but the 1987 order on prescribed activities includes a number of activities that according to the constitution is under state jurisdiction.
2. Public Participation in the process is limited, and is mainly on the behest of the project developer. According to an EIA handbook (DOE 2000), public participation is essential in the preliminary assessment process, but only in ways we would assess as instrumental public participation, and the form of the public participation is left to the project proponent. The terms of reference for the detailed EIA are required to be displayed for public comment. In the detailed EIA study, public participation is recommended for the same reasons as in the preliminary assessment and as in the preliminary assessment it is completely at the behest of the project proponent. When the review panel receives the detailed study, it puts up public notice as "it considers appropriate", stating the nature and location of the project, and where copies of the report can be obtained, and the cost of each copy. The public then has the possibility to forward comments in writing within 45 days.
3. EIA is meant to follow the integrated planning concept. But in projects both requiring land approval from the State Executive Committee and an EIA there seems to be two parallel processes. An application for land alienation or land conversion must be submitted to the Land Office, who refer them to the relevant agencies for comments. DOE are usually asked for comments on environmental aspects. At the same time an EIA must be prepared in a process co-ordinated by Department of Environment. The consequence is allegedly that the project is often approved by the state first, and that the "EIA report only were prepared after commitments have been made to the site, design and technologies. It is not surprising therefore, that owning to this lack of coordination and integration, an EIA is often regarded as a mere formality" (Institute of Advanced Studies: Planning for Environmentally Sound Development in Malaysia in Kanniah 1999). Generally it seems that the EIA process is commenced when the planning process is almost complete (Kanniah 1999 & Fauzi, interview), or even after the bulldozers have started (Sahabat Alam Malaysia 2000), although the EIA handbook states that the EIA procedure should be initiated early in the project planning (DOE 2000).
4. Implementation of the conditions in the EIA approval seems to be the weakest link in the Malayan EIA system. The conditions in the approval given by the Department of Environment is to be implemented by the agency under which jurisdiction the condition falls, be it a state, a department responsible for the sewage system, or water supply or any other department. The coordination of all these authorities is extremely difficult (Fauzi, interview).

EIA of the New Pantai Highway in Kuala Lumpur

The New Pantai Highway is a 19.6 km limited access highway intended to relive the pressure on other major roads in Kuala Lumpur. The main part of new highway is an extension of existing roads, but some kilometres of the road is new alignment of the road. The highway project is privatised. In December 1996, Maxtro Engineering issued the report from the preliminary EIA. The approval conditions are not accessible to the public.

The public participation in the preparation of the EIA report was through interviews using standard questionnaires. The analysis was made on the basis of 185 questionnaires from 11 different localities in the vicinity of the project.

The EIA system in South Africa

Current layout and relation to surrounding legislation: EIA is mandatory in South Africa. The requirements are laid down in Environmental Impact Assessment Regulations from

September 1997 (Republic of South Africa 1997). The system includes most normal steps of EIA – systems: screening, scoping, public participation, environmental reports, review, and decision. There are a number of issues specific to the South African EIA system.

1. Administratively, the Republic of South Africa has several levels: The national state, the province level and the municipality level. The national level is responsible for issuing the general regulation for EIA and the national guideline. The provinces are responsible for the bulk part of EIA's. But where the national environment is affected or national governmental authorities are the applicant the authority moves up to the national level. The authority can also be moved down to the local authorities.
2. The regulation leaves, in principle, no room for a screening process. According to the regulation all changes of for example land use is subject to an EIA – whatever limited scale – and a scoping report has to be prepared.
3. Public Participation is mandatory, but the regulation does not state where in the process it should take place, only that it must take place (Republic of South Africa 1997). But the guideline document (DEAT 1998) states that public participation should take place during scoping and review of a full environmental report. Judged by the guideline document substantial weight is put on public participation. However, due to the imprecision of the law the degree of public participation varies from project to project (Mohamed, interview).
4. The EIA process allegedly fulfils the task of integrating most of the complex environmental legislation in South Africa. Only in relation to the South African land use planning there seems to be risks of conflict and duplication of work.
5. Monitoring is not mentioned.

EIA of Extension of Cape Flats High Way.

The "Cape Flats Freeway Extension" is an approximately 8 km extension of the Cape Flats Freeway, and is proposed as a limited access highway. It was proposed initially to construct it as a two or four lane main road, and on a later stage upgrade to highway standards. The project was proposed by Cape Metropolitan Council. In 1996 they commissioned a consortium of two private companies to investigate the feasibility of the route. The preparation of the EIA report was prepared by a member of the consortium, except for the public participation report, which was prepared by a different company. All concerned local and regional authorities were involved in the decision making process (Provincial Administration of the Western Cape, Cape Metropolitan Council, South Peninsula Municipality, Cape Town Municipality). In December 2001 no construction had so far commenced.

The public participation process included letter drops, public meetings, and workshops for special interest groups and representatives of authorities and individual consultations with farmers in the Philippi section. A questionnaire, advertisements, collective meetings and workshops the interested and affected parties were identified, and the consultant attempted to identify their interest and views. The views on the project in general were recorded, but emphasis was especially put on their requirements to mitigating measures. Assessing the public participation process it is clear that it is a democratic participation, in the sense that the publics views on necessary mitigating measures are feed into the decision making process.

The EIA system in Thailand.

Current layout and relations to surrounding legislation: The National Environmental Quality Act from 1992 upgraded the status of the National Environmental Board (NEB) with the Prime Minister serving as Chair, and the Minister of Science Technology and Environment as one of the two Vice Chairs. Other Board members are the ministers of key agencies such as finance, industry, and agriculture and Permanent Secretaries of related agencies. Up to eight positions were reserved for "members qualified in environmental matters" of whom "no less than half shall be representatives from the private sector". There are two separate tracks in the approval process, one for government agency or public sector, and the other for the private sector.

The EIA for the government agency or public sector project must be undertaken during the feasibility study. The report is filed with Office of Environmental Policy and Planning (OEPP) and reviewed by the Ad Hoc Experts Committee for Public Projects, and the Committee then passes the comment to The National Environmental Board (NEB). NEB may ask the opinion of the Office of Environmental Policy and Planning (OEPP) or other experts. The report (with comments) is then submitted to the Cabinet for decision. There is no time limit for the process. For the private sector projects, the EIA report is to be submitted to the Office of Environmental Policy and Planning (OEPP). The OEPP can only "comment" on the EIA report; the decision to approve or disapprove the report lies with the Ad Hoc Experts Committee. The OEPP has fifteen days to comment on the "correctness" of the EIA and another fifteen days to make a complete review. The Ad Hoc Experts Committee, which includes a representative of the licensing or permitting agency, must complete its review within forty-five days or the EIA report is considered approved. If it is rejected, the EIA report is to be revised and resubmitted to the Committee. An additional thirty days are allowed for this second review. (Yap 1994).

1. In Thailand the Terms of Reference for the EIA are decided on and prepared by the project proponent but approved by OEPP. Section 51 of The National Environmental Quality Act grants the minister the authority to require that licensed specialist prepare the EA report. An ad hoc committee has been set up to approve the registration of specialists or consulting firms. (Yap 1994).
2. Public participation in EIA is not institutionalised in the legislation. Some in the government argue that public interest is taken into consideration through the potential representation of NGOs on the National Environment

Board, which reviews the EIA for public sector projects. NGO representatives may also be invited to the Ad Hoc Experts Committee that reviews the EA Report for private sector projects. Others consider that making the EIA report or its Executive Summary public is sufficient notification. The legislation does have some provisions that have implications for local communities and public interest groups with respect to development projects. Section 6 grants rights and duties to individuals “for the purposes of public participation in the enhancement and conservation of national environmental quality.” These include the right to be informed and obtain information and data from the government on “matters concerning the enhancement and conservation of environmental quality, except where the information or data involves officially classified material, such as secret intelligence pertaining to national security, or secrets pertaining to rights to privacy, property rights, or the rights in trade or business which are duly protected by law”. Under section 8, NGOs and non-profit organisations or juridical persons directly engaged in activities concerning environmental protection or conservation “without any objective to be involved in politics” may register with the Ministry of Science Technology and Environment. NGOs may also propose nominees to represent the private sector in the NEB. Registration of NGOs may be revoked if their activities cause “disturbances or (are) contrary to public order or unsuitable”.

Finally, the EIA process as defined in the legislation assumes that NGOs or environmental professionals can articulate the interest of the public or effected communities. There appears to be a genuine lack of confidence on the part of government officials and environmental professionals in the ability of local groups to participate in an informed and meaningful way as part of the project planning. Even the participation of NGOs on the NEB or Ad Hoc Experts Committee would appear to come rather late in the process. (Yap 1994)

EIA of the Southern Outer Bangkok Ring Road Inter-city Motorway Project.

The Southern Outer Bangkok Ring Road Inter-city Motorway Project, which is a part of the Outer Bangkok Ring Road Project has a total distance of 35 kilometres. The road has six traffic lanes, and the shoulder is wide enough for future expansion to eight lanes.
To comply with Ministry of Science, Technology and Environment's regulations, it is imperative to study and assess environmental impacts of the project. The scope of environmental impact assessment complies with the guidelines of the Office of Environmental Policy and Planning (OEPP). Four factors have to be scrutinised, which are:

- Physical Resources: The study includes topography, geology, meteorology, air quality, noise level, vibration, hydrology, soil removal, landfill and construction and water quality.
- Ecological Resources: The study includes aquatic and terrestrial ecosystems.
- Human Use Values: The study encompasses land use, transportation network and navigation, utility systems, flood control and drainage.
- Quality of Life Values: The study is composed of socio-economic conditions, resettlements and way of life, public health, aesthetics, tourist attractions, historical buildings, places of interest, safety and proposing measures to arrange meetings for public hearings and public relations activities.

The study contains comparative study of alternative routes, among others the route crossing Chao Phraya River by a suspension bridge or a tunnel (Department of Highways 1998).

The study indicates that negative impacts will take place during construction. The extent of the impacts will be low to moderate. However, positive impacts on land use, transportation networks, socio-economic conditions, and safety will be realised when the road is open. The study details about meetings and public relations are provided by interviews made by private employed sociologists.

The EIA system in Denmark.

EIA system and relation to surrounding legislation:

EIA became compulsory in Denmark in 1989 implementing a directive from the European Union. The Danish EIA system has been adjusted several times in the 90ties.
The EIA system has been integrated into the planning system and environmental permit system, which have existed since the beginning of the 1970’s in Denmark. Therefore, the EIA system in Denmark has two tracks: one integrated into the environmental permit system, and one integrated into the planning system. The Danish implementing principle was that the existing system should be changed as little as possible. But besides this the Danish EIA system is in many ways a standard EIA procedure (Ministry of Environment and Energy 2001).

1. The Danish EIA system is an implementation of an EU directive. The EU directive sets out the general aims and stipulates a number of requirements. As the EIA directive is a minimum directive it even allows the member states to go further than the requirements in the directive. Each member country decides for them how to implement the directive in their national legislation. The Danish Government, at all levels, is responsible for that actual implementation fulfils the requirements of the directive.
2. The EU directive prescribes in its Annex 1 which type of major projects should always be subject to an EIA. Annex 2 lists other type of projects that might have significant impact on the environment. Denmark has implemented the directive in such a way that all projects in Annex 2 must be screened for significant environmental impacts, using the criteria in Annex 3 to assess the impacts.
But there is one general exemption from this: The directive will not be in force in cases where projects are

approved through a legal act. However, the objectives stated in the EU directive for example public access to information has to be obtained through the legal process. The article in the directive has been made on request of the Danish government because a directive that restricts the work of the Danish Parliament (Folketinget) is contradictory to the competence of the Danish Parliament. When a project is proposed through a "Project" act in the Parliament it is exempted from the EIA procedure. On the other hand it is anticipated that the same assessments will be executed during the legal process. There are no rules regarding which type of projects can be approved by "Project" acts, but normally these acts deal with highways and other infrastructure projects.

3. The EIA competence is normally located at the regional council level. In most cases, the competence to issues other necessary permits is also at the regional council level. But not always, for example environmental permits for minor industries are located at the local council level. But the coordination between the regional councils and the local councils seems to be working rather smoothly. Further, it is not always the regional council that has the responsibility for the EIA process. For example the Ministry of Transport is responsible for projects on the sea, and in case of projects that requires a 'Country-Planning Directive' the responsibility is within the Ministry of Environment. The integration with the existing planning system and environmental permit system is secured by stipulating in the relevant statutory orders that for projects subject to an EIA the other permits may be issued before the EIA permit is given.
4. Compared to the three other countries a special aspect of the Danish system is that it is the authorities that are responsible for preparing the EIA report. The authorities use information obtained from the project proponent, but writing the final report is the responsibility of the authorities.
5. The possibilities for public participation are legally secured in different step of the EIA process. If a project is subject to an EIA a short hearing phase is mandatory in the scoping phase to allow the public to come with ideas and suggestions. After the draft EIA report has been prepared, it has to go through a public hearing phase of no less than eight weeks. After the public hearing phase, the raised objections have to be processed, and a final decision has to be taken by the regional council. The decision has to be made public with a motivation for the decision and a guideline for how to object on the decision. The timeframe for complaining is four weeks. Before the regional plan amendment is final approved by the politicians there shall be a public hearing about the project. After the regional council has approved a regional plan proposal it shall be published and comments to the plan have to be given within eight weeks.

EIA of the highway from Herning to Århus.

In 1990, the Danish Parliament adopted a "Project" act regarding the establishment of three major roads in Denmark. One of the roads was a 75 km. high-class road Herning-Silkeborg-Århus. This road is problematic from an environmental point of view as the nature around Silkeborg is one the most beautiful areas in Denmark, and contains a number of legal protected areas, among others the valley of Denmark's biggest stream: the Gudenå. An EIA was prepared for the road and published in 1992 by the Directorate of Roads (Vejdirektoratet 1992). An analysis showed that the expected issues from general high way guidelines were covered by the report. The EIA recommended as a least destructive alternative that the road should cross the Gudenå valley North of Silkeborg. In January 1993, a proposal for a Construction Act (anlægslov) was sent to the Parliament, but later that month there was a change of Danish Government. The new coalition government wrote into its 'Statement of government' (regeringsgrundlag) that no roads would be built through legal protected areas. As a consequence the stretch around Silkeborg crossing the Gudenå Valley could not be built. But it was decided to build the rest of the road as a four-lane highway.

In 1996, the Directorate of Roads initiated an investigation of different alignments of the road through or around Silkeborg (but not the earlier Northern alignment). The report was completed in 1998, and in late 1998 and early 1999 and number of public meetings about the alignment was conducted. At the public meetings – especially a public meeting attended by the Minister of Transport is said to have been important (Würtz, interview) - it became clear that the citizens of Silkeborg were very much against a highway through the forests close to Silkeborg. They preferred the Northern alignment. In early 2000, it was decided to undertake a thorough EIA assessment of two alternatives: the Northern alignment and an alignment through Silkeborg following the trace of the existing ring road. The EIA report was published in August 2002, and a number of public hearings were conducted (Vejdirektoratet 2002). The EIA reports consisted of a main report integrating all the findings, a report describing the environmental assessments, a report containing visualisations, and a CD with visualisations of each of the alternatives. This material has been handed out for free from town halls and public libraries in the area. Further, the reports can be downloaded from the website of the Directorate of Roads.

The reports describe the two main alternatives: a four-lane highway through Silkeborg and a four-lane highway North of Silkeborg and their environmental consequences. Within each of the main alternatives a number of sub-alternatives were investigated. The reports seem to be thorough and well-written documents. We have interviewed a number of the affected parties, including the Danish Association for Conservation of Nature, NGOs with high professional capacity, and everybody has praised the reports as very thorough and informative in relation to the issues dealt with.
What has been criticised, though, is the absence of a thorough analysis of a railroad from Århus to Silkeborg as an alternative solution.

Public participation: Throughout the process a number of public hearings have been conducted, and citizens have had possibilities to object. In the public hearing phase of the year 2002 EIA report, three public meetings with a total of 830 participants were conducted, and according to the Directorate of Roads (DOR) they have received around 100 written objections towards the project. As far as we can assess relevant objections from the public during the public hearing phase has influence on the final design of the road:

- If a citizen during the public hearing phase proposes an alignment of the road that has not been considered earlier, and claim that this alignment has fewer problems than the other possibilities, DOR investigates the proposal, and prepares a short report on the alternative. DOR prefers to have considered all the alternatives in advance, as ‘that is their job’, but in some cases citizens have proposed alternatives not earlier considered (Munch, interview), and DOR has investigated the proposal.
- Many of the objections are related to very specific problems.

For example, a lady during the public hearing process wrote to DOR and claimed a small wetland area South of the village Voel, where the proposed alignment of the highway would cut through the Southern corner, was used for recreation and educational purposes. DOR had not been aware of the use of the wetland during the planning process. As a consequence of the new knowledge DOR will probably move the highway somewhat, so the highway does not cross the wetland (Munch, interview). During our interviews in the area we were told about a number of examples where DOR had made adjustments to the project, to meet the demands of one or a few households – changing the slope of an embankment to hide the highway from the views of a farm house, adding noise-barriers at a short stretch and so on.

All the stakeholders we interviewed found that the EIA process had been useful and that it had provided a lot of information.

Discussion

Importance of political process: There seems to be a lot of evidence for the EIA procedure is implemented in a way consistent with the political culture in each country. For example, the requirements and possibilities for public participation during EIA processes in Thailand and Malaysia are quite limited, as are the possibilities for public participation in these countries in general. But it also seems that the EIA procedure can work as a vehicle for introducing more public participation in EIAs in the two countries, because there is some sort of pressure for living up to standard EIA procedure, where public participation is an important element. In South Africa, it seems that the amount of public participation changed when the majority government came into charge. The public participation in EIA´s is also an indicator for possibilities for public participation in general.

Participation: The legal prescriptions for public participation in the four countries are quite different, and the way they are implemented even more different. In Malaysia, public participation is required in the EIA handbook as means to improve project design, whereas the public have only limited possibilities for commenting on the project itself. Further, the conditions in the final decision are not accessible for the public. The case study showed that the affected people during the preliminary EIA were questioned about their conceptions of how the road would affect them. We will characterise the public participation process in this case as instrumental public participation. In South Africa, the legal prescriptions for public participation were quite imprecise, only stating that some form for public participation was required. But the actual public participation in the case study was very extensive, and used methods that allowed people without many resources to express their views. Furthermore, the views of the public seemed to have great influence on the final decision. That is, a public participation process, that we will characterise as democratic participation. In Denmark, the requirements for public participation in the EIA procedure is very precise, but they are implemented in a way so that it requires quite some resources to participate in the process: ability to read the formal documents and ability to express one’s views at public hearings or formal letters to the authorities. But the case study showed that the public participation had been quite extensive, and had had quite some influence on the detailed design of the project.

Relation to surrounding legislation: Denmark has a complicated system, but it is consistent. South Africa has a dual system that isn’t consistent. Malaysia and Thailand seems to have the EIA as the only integrative system.

Scope of EIA assessment: Analysis of the EIA reports has shown that they in a number of areas cover the same issues. For example, they all include a study of the loss of valuable ecosystems and of change of land use. But there are also a number of differences between the EIA reports, which are quite illustrative towards what is perceived as environmental problems in the four countries (see Table 1). The South African EIA includes an analysis of the impact on the road on ‘security from intrudes’, which is connected with the serious security problems in South Africa; but security from intruders is not included in any of the other countries, because this isn’t considered a problem in these countries. The Danish EIA includes two issues not included in any of the others: increased emission of green house gases and the saving of time for traffic. Green house gases became an issue in Denmark already in the late 1980s, and national policy goals was adopted at that time, even though the international political discussions about binding targets for reduction of green house gas emissions was only just started at that time. So the inclusion of green house gas emissions in the Danish EIA report was probably due to the national policy goals, which were adopted due to the linkages between an international scientific discussion about green house effect, and the Danish policy process. None of the other EIA studies include impact on green house gas emissions even though those studies were done some years later, and the international political discussion about green house gases had developed considerably in the meantime.

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Table 1: Comparison among EIA reports of roads. The coverage of selected environmental issues in the case studies of Malaysia, South Africa, Thailand and Denmark

The issues selected are the ones where there are differences between the four countries. Yes indicates that the environmental issue is dealt with in the EIA report; No indicates that it is not dealt with.

Selected environmental issues	Malaysia 1996	South Africa 1998	Thailand 2002	Denmark 2002
Increased emission of greenhouse gases	No	No	No	Yes
Quality of surface water	Yes	No	No	Yes
Light Pollution	No	Yes	No	Yes
Saving of time for traffic	No	No	No	Yes
Security from intruders	No	Yes	No	No
Public transport as alternative to the road.	No	Yes	No	No
Aesthetic considerations	No	Yes	Yes	Yes

Important Of Environmental Management For SME In Thailand

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ABSTRACT: Small and Medium Enterprises (SME) are major contributions to Thai economy for a long time. It is estimated that 80% of factories registered with the Department of Industrial Work are SME and they contributes to more than 50% of GDP in Thailand. Regardless about their importance on Thai economy, SME in Thailand are still struggle for survival in international market. Most SME developed from family business without much professional management skill. Some can survive and improving themselves into the international market. Some barely managed themselves in local market. The importance and dynamism of SMEs is one of the distinguishing features of the industrial sector in Thailand. They are an important source of employment for low income earners, and therefore, politically as well as economically, provide an important function in alleviating the effects of poverty. They play a crucial role in the production-consumption cycle. Their presence and contribution is increasingly becoming significant in the trade, environment and supply chain linkages. They pose difficult pollution abatement problems. They are not the major polluters in most sub-sectors, but they often pollute more per unit of output than large firms operating in the same sector. They are therefore under pressure to adopt more environmentally sound, and efficient manufacturing processes. Environmental Management is therefore one of an important tool for SMEs to improve their environmental performances. Many terminology of Environmental Management are being used in Thailand, for example Cleaner Production, Clean Technology, Pollution Prevention and Green Productivity etc. However, the concept of the tool is built around prevention of wastes and emissions at the point of generation. What cannot be prevented needs to be treated and thus rendered environmentally benign before discharging it to the recipient environmental media. This applies to both materials as well as energy wastes. They are very useful in waste prevention and management. This paper will present our experiences on the implementation of Environmental Management on some SME in Thailand and the challenging in dissemination of the tool to other SME.

Keywords: Environmental Management, SME, Food Industry.

INTRODUCTION

SMEs is one of the important features of the industrial sector in Asia. They are an important source of employment for low income earners, and therefore, politically as well as economically, provide an important function in alleviating the effects of poverty. SMEs account for 10-50% of the total industrial sector output in Asian countries. They make up over 90% of the number of enterprises in Asia; employ over half the workforce; contribute about half the GDP and provide about 35% of exports. Figure 1 shows the %SME in Asia.

Most SME in the region employ less than 100 permanent staff but might need many hundred of temporary staff especially in food industrial sector. In Asia SMEs employ 40-80% of employee in industrial sector.

SMEs pose difficult pollution abatement problems. They are not the major polluters in most sub-sectors, but they often pollute more per unit of output than large firms operating in the same sector.
They have limited resources at their disposal (both technical and financial) and often find themselves unable to afford the changes necessary to meet environmental regulations and product controls. Besides, there are many non-tariff barriers in term of quality and environment start to be implemented in many developed countries. In order to export to certain countries, a certain standard need to be fulfilled. ISO 14000 standard is one of a very important standard to be needed in certain sectors of industries.

Therefore, environmental management in SME will be a vital role for their survival.

IMPORTANT OF SME IN FOOD INDUSTRY IN THAILAND

The food processing industry is one of the key manufacturing sectors in Thailand, generating exports worth 428 billion Baht (10 billion US$) or equivalent to 7.9 % of GDP or 14.47 % of total export value. There are about 9,349 food factories in Thailand and most of them are SME. Labor involved in food industry sector from both agricultural farming and manufacturer were estimated to be more than 20 million. It was estimated that about 80% of local input (raw materials, labor, etc.) were used in food industry here. Global market value of food industry is about 500 trillion US$ and in the year 2002, market share of Thailand was only 2.4%. There are still plenty of rooms for improvement to increase the global market share.

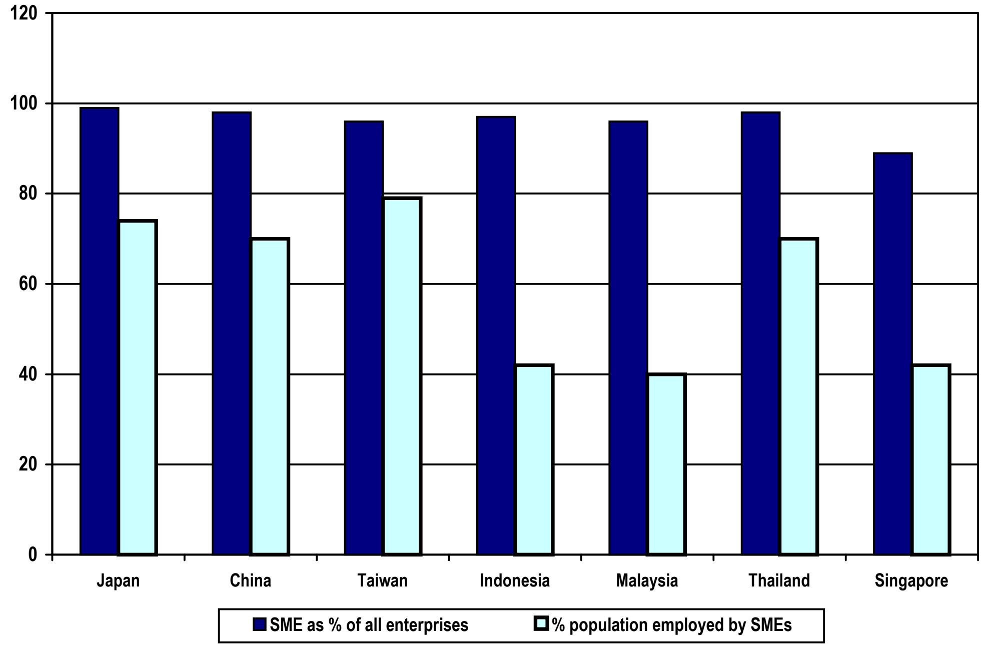

Figure 1 SME in Asia (Source: APO 2000)

ENVIRONMENTAL MANAGEMENT IN INDUSTRY

There are quite a few terminologies concerning Environmental Management in industry at present, namely, waste minimization program, cleaner production, cleaner technology, pollution prevention, green productivity, environmental management system, and so on. The concept of Environmental Management is built around prevention of wastes and emissions at the point of generation. What cannot be prevented needs to be treated and thus rendered environmentally benign before discharging it to the recipient environmental media. This applies to both materials as well as energy wastes. They are very useful in waste prevention and management. One of the most used at present is ISO 14000 series of standards. It is a set of voluntary standards that has been designed to help enterprises meet their environmental management system needs. They have been under development by the International Standards Organization (ISO) since 1991. The standards define the key elements of a management system that will help an organization address the environmental issues it faces. The management system includes: (i) setting of goals and priorities (ii) assignment of responsibility for accomplishing them (iii) measuring and reporting on results and (iv) external verification of results.

Environmental Management practices in terms of pollution prevention, CT or GP has been widely implemented in Thailand. During the last decade hundreds of factories were involved in such programs. The programs were mostly initiated and implemented by foreign donors. However, during the last few years, most programs were implemented by supporting from the Thai government.

ENVIRONMENTAL MANAGEMENT IN FOOD INDUSTRY IN THAILAND

Environmental Management is one of an important tool for increasing competitiveness of industry both in Europe and Asia (Hofman Peter, and Koottatep S.). Chiang Mai University in collaboration with Thai Research Fund and Thai Food Institute implemented a number of Environmental Management program in food industry. About 20 factories were implementing Green Productivity Program from the projects.

Characteristics of the factories are as shown in table 1. Most of the factories are small and medium scale industry. Their investments were in the range of 5-180 million baht. The canning factories produce all kinds of canned fruit such as pineapple, corn, fruit-salad, palm seed, lychee, etc. The fruit and vegetable preservation factories produce salted ginger, salted vegetables, and salted fruit etc. Sea food factories produced frozen shrimps, squid and fish products. Most medium scale factories export their products. The capacities of the factories are in the range of 1-150 tons per day. They had never done any activities concerning GP practices before.

Problems identified from the programs were summarized in Table 2. There are 4 important categories concerning problems in the factories. Most factories used too much water in their production activities, especially in washing of raw materials and cleaning at the end of the day. Good house keeping was not generally practiced in most factories. Water hoses were too big and without valves in stopping water flow when water was not needed. Pressurized floor washing tools were not available. Leakage could be seen everywhere and there was no waste segregation system in the factories. There were a number of opportunities of recycling wastewater from one process to another, such as cooling water and washing water could be used for other purposes. In many cannery factories chemicals have been used extensively in the production process. For example in longan and lychee canning, a lot of calcium chloride and citric acid have been highly used for hardening of products. A lot of syrup has been leaking and it will introduce high BOD content in their wastewater. Many factories turn on the lights in the production area even during the day time. This is due to the fact that there was no energy saving consciousness during the factory design stage. Transparent roof tiles could save a lot of energy. Most food factory processes will need boiling or heating of their materials prior to canning. Factories discharged a lot of high temperature wastewater down the drain. They should provide energy recycle facilities to trap this waste. The most important factor affecting the performance of the management system in the factories is human resources. Training or further education should be provided to the factory staff on a regularly basis.

From the options generated among the factories, the options were classified into 7 groups, as shown in Table 3. The low hanging fruits options were good house keeping and improving operating procedure. About half of options generated were in these categories. Most factories saved a lot of money from these groups of options. The investment was rather low compared to the benefit obtained.

Table 1 Characteristics of Factories involved in the GP Practices

	Canning Factories	Food Preservation Factories	Sea Food Factories
1. No. of Employee	46 -600	17 - 1,500	50-300
2. Investment Cost (million Baht)	5 - 180	5 - 159	100-300
3. Product	Fruit salad	Preserved fruit	Frozen Shrimp, Squid
	Palm seed	Preserved vegetable	
	Sweet corn	Preserved ginger	
	Lychee		
	Pineapple		
	Tomato		
	Baby corn		
4. Capacity (Ton/day)	1.4 - 69.6	1 - 150	5-15
5. GP Practices	None	None	None

Table 2. Problems identified and GP options in the Factories

Problems Identified	GP Options Generated
1. Water Using	
1.1 No recycle facility for cooling water	1.1 Build storage tank for recycle & floor cleaning
1.2 No recycle machine for can washing process	1.2 Install recycle can washing machine
1.3 Too big water hose for floor cleaning	1.3 Change hose size from big to smaller hose
1.4 No valve at the end of water hose	1.4 Install valve at the end of water hose
1.5 No jet floor cleaning	1.5 Install spray gun for floor cleaning
1.6 Pipe leakage	1.6 Change pipe connection
1.7 segregation of wastewater	1.7 Separate brine wastewater from normal waste
1.8 Too much water washing raw material	1.8 Set specification for raw material through supply chain
2. Process	
2.1 Use too much chemical substance for soaking process	2.1 Recycle soaking solution
2.2 Spillage of syrup	2.2 Install syrup collection system
2.3 Too much ice used in the process	2.3 Improve efficiency of ice machine
3. Energy	
3.1 Use too much energy in lighting	3.1 Change some of the roof tiles into a transparency material
3.2 Hot wastewater discharge directly into sewage drain	3.2 Use heat exchanger in recycling hot water
3.3 Too much energy in desalination	3.3 Install solar still for desalination
3.4 Too much energy cost due to peak load	3.4 Run generator during peak time
4. Workers	
4.1 Worker s had no awareness on good house keeping	4.1 Training course required

Table 3. Categories of Options used in GP implementation.

Improving Techniques	Number of options
1. Good House Keeping	5
2. Improve Operating Procedure	2
3. Recycle, Reuse and Recovery	5
4. Resources Conservation	1
5. Input Material Changes	1
6. Process and Equipment Changes	1
7. Design for Environment	-

REDUCTION OF WASTEWATER GENERATED IN THE PROCESSES

By using good house keeping practices deriving from GP activities, wastewater generated from many sources could be reduced. Table 4 shows amounts of wastewater generated per ton raw materials of many processes in the factories. In the case of a lychee factory, chemical wastewater generated from soaking was reduced from 1.38m3/ton raw materials to 0.96 m3/ton raw materials. Washing wastewater was reduced from 5.55 m3/ton RM to 3.10 m3/ton RM. Proper maintenance of the can washing machine could reduce wastewater from 0.38 m3/ton RM to 0.20 m3/ton RM. In terms of money the factory could save about US$ 7,392 per season. In the case of the selected pineapple factories, options in solving generation of wastewater were to change rinsing system on conveyor belt into soaking system. Overall wastewater generated was reduced from 2.45 m3/ton raw materials to 1.01 m3/ton raw materials. In the case of a palm seed factory, wastewater was reduced from 6.29 m3/ton raw materials to 4.35 m3/ton raw materials, by changing the washing process and using good house keeping practices.

CHEMICAL REDUCTION

There are a number of opportunities of saving chemicals through changing a few processes. For example, a lychee factory could reduce calcium chloride and citric acid in the soaking process by one third or equivalent to approximately 60 US$/day by using the chemicals twice in the soaking process. More chemicals could be saved by using a continuous counter current soaking system.

PRODUCTIVITY IMPROVEMENT IN GINGER FACTORY

Greening the supply chain was performed through the setting of raw material specification. The suppliers were offered the incentive program. Those who delivered raw materials with soil content less than 8%, the purchasing price will be 0.10 Baht per kg higher than market price. Those with soil content less than 5%, the price will be 0.20 Baht higher per kg.

After the program, soil content in raw material was reduced from12.11 % to 9.01 %.

Production information before and after implementation is as shown in table 5. Raw ginger purchased during the year 1999 was 4,232 tons while in the year 2000 it was 4,610 tons. The amounts of soil in raw materials were 480 tons and 414 tons respectively. Percent soil contents was reduced from 11.37% to 8.95%. Products increased from 57,695 cases to 71,836 cases. Yield of production improved from 64.87 kg/case to 58.4 kg/case equivalent to the increasing of productivity of 10%. Groundwater used was reduced from 5,524m3 to 4,439m3 or equivalent to 19.63% reduction. Electricity consumption was reduced from 131,581 kWh to 121,287 kWh or equivalent to 7.82 reduction. It could be easily seen that with GP implementation, production could be increased and raw materials and energy consumptions could be reduced

Table 4 Wastewater Reduction through GP

Factory	Before Implementation waste / unit RM. (m^3/ton)	After Implementation waste / unit RM. (m^3/ton)
1. Lychee factory		
1.1 Saving chemical through soaking process	1.38	0.96
1.2 Changing washing process	5.55	3.10
1.3 Maintenance of washing machinery	0.38	0.20
2. Pineapple factory		
Change whole process	2.45	1.01
3. Palm seed factory		
3.1 Adding valve at the end of hose in soaking process	0.79	0.38
3.2 Good house hold keeping workers in washing process	2.54	2.02

Table 5. Production Information Before and After GP Implementation

Item	Year 1999	Year 2000	Change	
			Increase	Reduce
1. Raw Ginger (kg.)				
Ginger+ Soil	4,232,107	4,610,688		
Soil	480,213 (11.37%)	414,575 (8.95%)		65,638 (2.95%)
Ginger for production	3,742,894	4,196,133		
2. Products (cases)	57,695	71,836		
3. Yields (kg./case)	64.87	58.4		6.4
4. Working days	112	117		
5. Groundwater use (m3)	5,524	4,439		1,084 (19.63%)
6. Electricity (kWh)	131,581	121,287		10,294 (7.82%)

SUMMARY

GP has been proved to be a useful strategy in improving overall management performances in the food industries in

Thailand. Waste could be reduced through simple good house keeping and productivity could be improved through proper management system.

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Plastic Waste Management: Need For A Paradigm Shift In Malaysia

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ABSTRACT: Over the last century, plastics have become a major new material used widely for a variety of products world wide, including replacements for human body parts, to the construction of supersonic aircraft and spacecraft. The growth of plastic production has taken place at the expense of more traditional materials, such as steel, aluminium, paper and glass. It is estimated that 30% of used plastics are eventually discarded into the environment, and since conventional plastics are produced from petrochemical compounds and are non-biodegradable it becomes an environmental hazard when land filled. Plastic waste generated and quantity generated is a growing concern in many developing countries, including Malaysia. Plastic industry in Malaysia, which began in 1950, registered a 15% growth per annum. The plastics produced are mainly used by the packaging industry (35%), while electrical and electronic industry used 30%. Other users are households (12%), automotive industry (8%) and construction (7%). Concurrently, the total resin consumption has reached 1.20 million metric tons in 2000, while the per capita consumption increased from 20kg in 1989 to 55 kg in 1997. It is estimated to reach 60kg in 2003. The growth is expected to continue and the plastic industry is projected to achieve double-digit growth for the fourth consecutive year in 2002. In the year 2000, Malaysians used about 600,000 tonnes of plastics, while recycling was extremely low. Hence, 99.99% of the household plastics end-up in the 230 landfills. Plastic components in the Municipal Solid Waste (MSW) from urban areas average 18%, but in some areas (Labuan) it can go as high as 48%. Research in plastics is concentrated in the development of bio plastics using renewable resources and organic waste. Since the costs of bioplastics are currently much higher than conventional plastics due to raw materials costs and production expenses, hence the need to use materials that are available at low cost, such as palm oil mill effluent and kitchen waste. Biodegradability of degradable plastics (Environmentally Degradable plastic, EDP) is another area of scientific investigations. Results obtained from oxidative exposure, composting trials and microbial analysis showed positively EDP is biodegradable. Physical and chemical analysis, including Fourier Transform Infra Red (FTIR) spectrum confirmed the biodegradability.

INTRODUCTION

Over the last century, synthetic plastics have become the major new materials for everything from replacements for human body parts to the construction of supersonic aircraft and spacecraft. So much so, that plastic production has grown up to a point where the total volume of plastics produced worldwide now exceeds that of steel. The growth has also taken place at the expense of more traditional materials, such as steel, aluminium, paper and glass. The important points that need to be considered are the use of raw materials, energy requirements and pollution during production while generating industrial waste.

Plastic waste generation and quantity generated is a growing concern in many countries including Malaysia. Plastic waste contributes the third highest waste volume in Malaysian Municipal Solid Waste (MSW) next to putrescible waste and paper. In the year 2000, plastic waste in MSW of Kuala Lumpur was 24.4% by weight and most of the plastic waste was dumped into landfills. Landfills in Malaysia are reducing in its useful life as the amount of waste generated is growing every year by 2% and they have become an undesirable option of getting rid of plastic waste because of the properties of plastics (Agamuthu, 2001). Thus, efforts are being made to divert some plastic wastes from landfills, or to use degradable plastics.

PLASTIC USAGE

The plastic industry in Malaysia started in the 1950's and has since enjoyed tremendous growth, registering an average of 15% growth per annum over the last 10 years due to the increased applications, robust economy and increased demand (Agamuthu, 2000). In Malaysia the market for plastic is dominated by the packaging industry (35%) followed by the electrical and electronic industry (30%) (Figure 1). Whereas other market segments are households which used about 12%, the automotive industry used 8%, construction (7%), agriculture (3%) other sectors (5%). (Malaysia Plastic Manufacturers Association, MPMA, 2001).

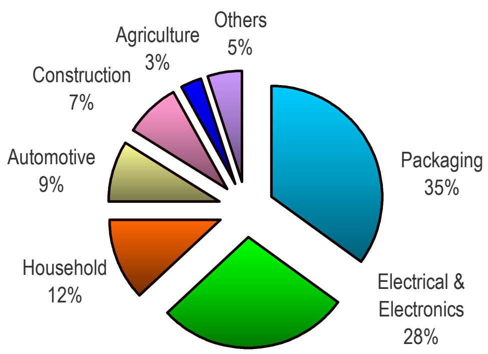

Figure 1: Market segments in Malaysia in year 2000
Source: Malaysian Plastics Manufacturers Association (MPMA), 2001

The relation between resin consumption for plastic production and per capita consumption of plastic is very close (Figure 2). In 1989, resin consumption was 300, 000 metric tonnes and it increased to 1.1 million metric tonnes in 1998. Recession in 1999 caused the consumption to decline and it is estimated that it will rise up to 1.4 million tonnes in year 2003 (Agamuthu, 2000). From year 1999 to 2000, total resin consumption increased by about 13% from 1.06 million tonnes to 1.2 million tonnes. Similarly, the per capita consumption has increased from 20 kg in the year 1989 to 55 kg in 1997. During the economic downturn, the usage reduced by 5%. It is postulated that the per capita plastic consumption will increase to 60 kg per capita in 2003. This is not far from the developed countries per capita consumption, which is between 80 to 100 kg (Agamuthu, 2000). In year 2000, the per capita consumption for Malaysia was 55 kg (MPMA, 2001)

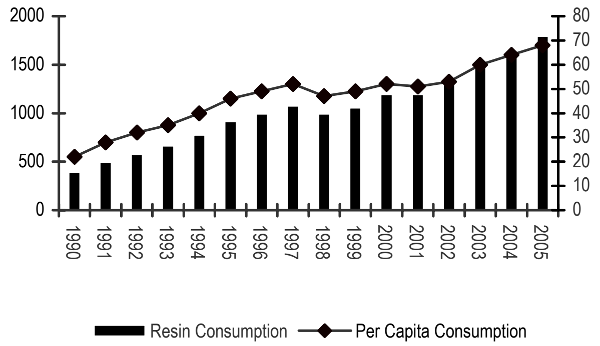

Fig 2. Resin Consumption and Per Capita Consumption in Malaysia
Source: MAPA, 2001

Performance of the Plastic Industry

As a result of the country's economic improvement, the turnover of plastics industry grew by 15% from RM 6.3 billion in 1998 to RM 7.2 billion in 1999 (Figure 3). The robust growth resulted in strong expansion in export by 20% from RM2.46 billion in 1998 to RM 2.97 billion in 1999. The turnover in 2000 was also impressive at 20% growth, from RM 3.5 billion (first half of 1999) to RM 4.2 billion (first half of 2000). Again the export sector was the main contributor for the robust growth, recording 25% jump (MPMA 2001/2002).

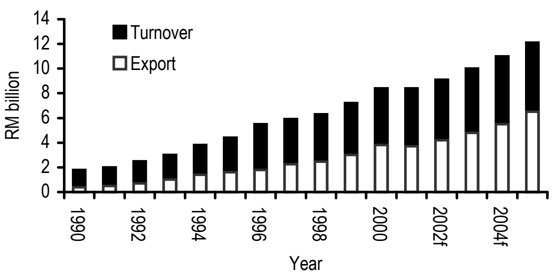

Figure 3. Turnover of the Plastics Industry

Besides the strong surge in exports, the recovery of the worlds electrical and electronics industry has stimulated the demand for the plastic parts and components. The demand from this sector increased by about 25% during the first half of 2000. Based on a recent report, the electronic industry is expected to grow by double-digit because of the worldwide embrace of the internet and exponential growth in e-commerce.

The export sector performed extremely well in 1998 and 1999 (Figure4). Throughout the crisis period, external demand for Malaysian-made plastic products was favourable. Despite the global financial crisis, external demand by major trading partners such as Japan, USA, EC and Singapore was able to support not only exports from Malaysia but also from other crisis-hit economics as well.

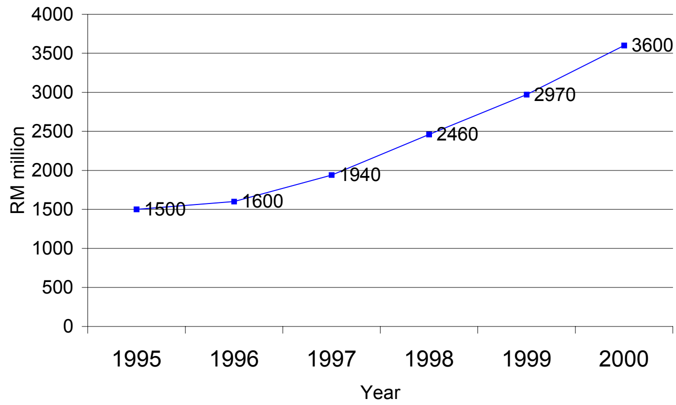

Figure 4. Export Performance

The types of plastic product exported in 1999 are shown in Figure 5. Films, sheets and foils were the major components exported (Figure 5).

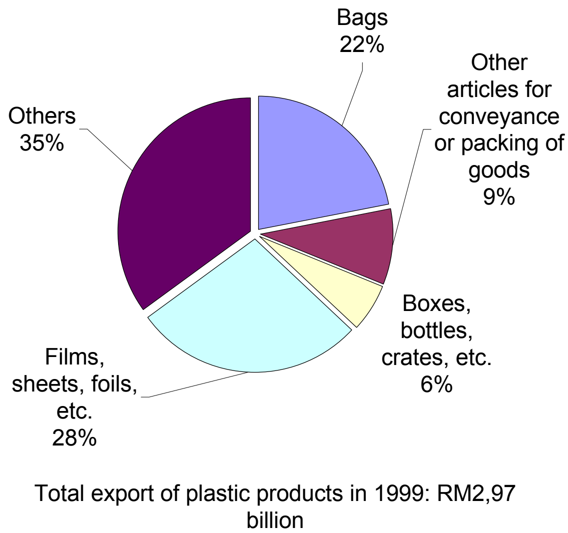

Figure 5. Export of Plastic Products by Types in 1999

The estimated consumption of plastics in 1999, by resin type, is shown in Figure 6.

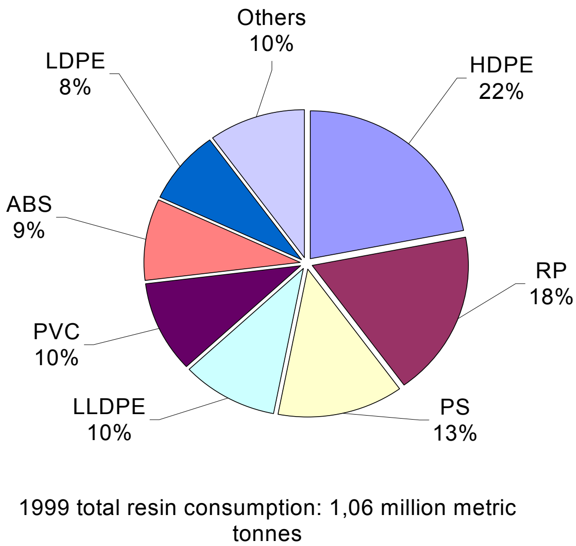

Figure 6. Resin Consumption by Types

Polyolefins (PE and PP) still dominate the country's usage. The materials are mainly used in the consumer packaging industry and household products.

PLASTIC WASTE GENERATION

In year 2000 Malaysians used 600, 000 tonnes of plastic. This is an increase of 7% compared to 1999, when about 560, 000 tonnes of plastic waste was generated. This trend will continue because plastic consumption in our daily lives will increase and plastic waste produced will increase too. A report from the Ministry of Housing and Local Government (MHLG) revealed that only 8,613 kg of plastic was collected for recycling in year 2000 (The Star, 8th April 2001). Therefore, about 99.99%, of plastic waste generated are being discarded into landfills or worse still, some end up in rivers or seas. The bulk of the waste disposed on land, which includes plastic wastes, are dumped into 230 landfills in Malaysia. Most of the plastic wastes discarded are plastic bags and household containers (Agamuthu, 2000).

A recent study done by MHLG showed that the composition of plastic waste in Kuala Lumpur's Municipal Solid Waste (MSW) in the year 2000 was 24.4%. This study was done on middle income residential areas. The same study also showed that in Labuan the plastic waste composition was even higher, 48.0%. Table 1 shows the MSW composition in Kuala Lumpur and Labuan in year 2000 (MHLG). The most probable reason why Labuan's plastic waste was higher than Kuala Lumpur is because of its status as a duty free port. Residents and visitors to Labuan have higher spending power to shop, hence more grocery bags and plastic based apparatus are discarded.

Table 1: Municipal solid waste composition in Kuala Lumpur and Labuan (% weight)

Waste Type	% Solid Waste	
	Kuala Lumpur	Labuan
Vegetable & putrescible garbage	45.7	19.1
Paper & paper products	7.1	11.4
Plastic	24.4	48.0
Textile	2.1	4.8
Rubber	1.4	0.8
Wood	0.7	0.8
Yard trimmings	3.8	0.6
Glass	3.3	8.0
Metal	6.6	6.2
Others	4.9	0.3

Source: MHLG, 2000

In Malaysia, the average amount of plastic in urban waste was about 18%. Table 2 shows the plastic contents in a few locations in Petaling Jaya. From here it can be concluded that the more affluent areas produce more plastics wastes. This was most probably because the ability of occupants to spend more in supermarkets and department stores. Table 2 also shows that even though weight wise plastic wastes are low, by volume the wastes occupied more space. This is because plastics have lower density and take up more space for relatively little mass as compared to other household and industrial waste components. As space for landfill is dwindling, the growing amount of plastic waste is a major concern for authorities.

Table 2: Plastic Component in wastes from a few locations in Petaling Jaya, Malaysia

Location	Plastic component in waste	
	By Weight	By volume
Kampung Tunku	7.5%	16.7%
Section 17	8.1%	18.1%
Section 12	14.0%	31.4%
Sg Way Low Cost	6.6%	14.7%
PKNS Low Cost	4.8%	10.7%
Pantai Dalam (KL)	20%	-

CONCLUSION

The need to use biodegradable plastic is due to new environmental regulations, societal concerns and increased environmental awareness. Composting is one of the waste management options that are most environmentally friendly and it is able to divert some waste from landfills. Since more than 60% of average Malaysian's MSW is organic in nature and potentially compostable, composting is one good option. Thus, using biodegradable polymers in the packaging of organic or biodegradable materials, such as kitchen waste, enables this waste to be directly composted without the need to separate the contents from the packaging. For example biodegradable plastic garbage bags can be directly composted. Consequently, this can take off some of burden from landfills.

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Tangible Outcome from Investment in Higher Education and Research Related to Environment and Development

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ABSTRACT: During the period 1998-2003 four university consortia, two in SE-Asia, one in Southern Africa and one in Europe cooperated on capacity building in higher education and research in environment and development. Some 500 students and 140 faculty worked with colleagues and fellow students in other countries and cultures and results were achieved in mainly three areas of activity: 1) Curricula development, e.g. new courses and curricula developed and implemented and new learning principles adopted; 2) Human resource development, e.g. training of teachers who returned to the home university and used their updated skills to introduce new courses and projects with students and colleagues inside and outside university; 3) Research, e.g. joint projects between at least two consortia and turn-out of for example new PhD candidates ready to fill positions in society. In all three areas of activity, joint projects with industry and city administrations were used to produce results that are tangible, both academically and practically.

Keywords: Environment, development, capacity building, curricula, human resources, university consortia, development hubs

INTRODUCTION

In the period 1996-1998 it was discussed in Denmark how to improve international environmental assistance through strengthening of the Danish resource base defined as the public sector, industry, consultants and universities. An international commitment to do so was made already at the world summit in Rio de Janeiro in 1992 and DANCED, the then Danish Cooperation for Environment and Development under the Ministry of Environment had been in existence since 1994. Based on an interview investigation among stakeholders in Denmark, it was concluded that Danish capacity to fulfil the international obligations and new challenges was limited. A general upgrading of qualifications with emphasis on cross-sector and multidisciplinary skills was necessary and the number of qualified persons available for international aid programmes should be increased. As one way of doing so, higher education and universities as part of the Danish resource base could become more involved and better exploited.

Therefore, in 1998 two Danish University Consortia for Environment and Development, DUCED were established; DUCED-I&UA, (5 Danish universities) specialising in industry and urban areas; and DUCED-SLUSE (3 Danish universities) specialising in sustainable land use and natural resource management. In their 3 year (1998-2000) pilot phase of existence, these two consortia focused on 1) Curriculum developments to upgrade Danish higher education (regarding environment and development), 2) International networking to enhance Danish university curricula and to assist in capacity building in selected co-operation countries, and 3) Joint research to underpin 1) and 2).

This paper deals with DUCED-I&UA during the pilot and consolidation (1998-2003) phases, including the establishment of LUCED-I&UA, i.e. Linked University Consortia for Environment and Development. LUCED-I&UA, cf. box 1 comprises four consortia, namely MUCED-I&UA in Malaysia (4 universities), SACUDE-I&UA in southern Africa (5 universities in South Africa and one in Botswana), and TUCED-I&UA in Thailand (4 universities). This means a family of 19 universities striving at capacity building in environment and development through joint activities and relevant reach-out to other institutions and businesses in the regions and countries involved. DUCED-I&UA commenced operation by a grant from DANCED in February 1998 and could start sending students and faculty (N to S) to cooperation countries already in 1998 due to a very positive attitude of the 14 universities in the cooperation countries. MUCED-, SACUDE-, and TUCED-I&UA had their contracts signed with DANCED during year 2000, which meant that the sending of faculty and students from S to N was delayed 2-3 years, compared to the N-S exchange starting already in 1998. Financing has been from DANCED (and later DANIDA, Danish International Development Agency) as well as from the participating universities.

Box 1: LUCED-I&UA, Linked University Consortia for Environment and Development-Industry and Urban Areas.

19 universities in four consortia, five countries and 3 continents

Botswana:	University of Botswana
Denmark:	Aalborg University, Copenhagen Business School, Roskilde University, The Royal Danish Academy of Fine Arts-School of Architecture, The Technical University of Denmark
Malaysia:	University Kebangsaan Malaysia, University of Malaya, University Putra Malaysia, University Technology Malaysia
South Africa:	University of Cape Town, University of Durban-Westville, University of Natal, University of Western Cape, University of Witswatersrand
Thailand:	Chiang Mai University, Chulalongkorn University, Mahidol University, Prince of Songla University.

The question to be raised here is what is the tangible outcome of these investments in university consortia regarding capacity building in environment and development? What follow is a summary and some reflections on the five year period 1998-2002 during which the LUCED-I&UA consortia have cooperated. Mobility, curriculum development, human resource development, and research will be used as lead themes in the presentation. Lessons learnt from the first six years of LUCED-I&UA operation will be discussed in terms of for example mutual responsibility, sustainability and multiplier effects in international university networking, including reach out to business and society.

INCREASED MOBILITY

ICT, Information and Communication Technology has become a tool for better research and education (more comprehensive problems and set of data handled with ease) and it has improved communication so that costly transportation and number of face to face meetings can be reduced. To some extent can distance learning replace class room lecturing and relax the issue of being present at the same time and place for students. But virtual reality is not going to replace physical reality and it is still an issue that learning and innovative research and management require social interaction and reflection on interaction between theory and practice. For these reasons the increased mobility of faculty and students is a measure of potential progress in capacity building because it enhances social, intercultural and professional advancement in both disciplinary and interdisciplinary studies.

In the period 1998-2002 mobility increased steadily within LUCED-I&UA, cf. table 1, DUCED (2001-3). The table excludes administrative activities and shows how the flows of students and faculty developed, using inflow and outflow from DUCED-I&UA as the bench-mark. The reason for this is that initially only DUCED had an externally financed budget for mobility of students and faculty, which limited S-N mobility. After starting activity in 2000, the other consortia could give S-N interaction high priority. Increased mobility within and between these consortia is not included in table 1.

Table 1 (upper part) shows how the number of Danish students seeking challenges in the cooperation countries rose over time and stabilised at around 100 per year since 2001. The activities behind these numbers are mainly joint courses of 3 weeks duration and projects of 3-5 months duration. The faculty numbers reflect the presence of Danish supervisors at joint courses and projects in the cooperation countries. The lower part of table 1 shows how both faculty and students from the cooperation countries increasingly used the opportunities for studies in Denmark since their grants from DANCED (DANIDA) became available in 2000. The background for this mobility relates to curriculum development, human resource development, and research; cf. below. Thailand in particular has used this opportunity for capacity development in research and education through increased S-N mobility of both faculty and students.

Table 1: Increasing N-S and S-N mobility through LUCED-I&UA network activities. F=faculty and PhD students; S=students. Administrative activities are not included.

Number of persons	1998-2000	2001	2002
From DUCED			
to MUCED , F/S	6/55	-/11	3/32
to SACUDE, F/S	-/32	2/30	4/20
to TUCED, F/S	3/78	8/61	10/52
Total, F/S per year	**3/55**	**10/102**	**17/104**
To DUCED			
from MUCED, F/S	-/-	14/--	9/5
from SACUDE, F/S	-/-	6/30	11/31
from TUCED, F/S	-/-	10/13	53/47
Total, F/S per year	**-/-**	**30/43**	**73/83**

CURRICULUM DEVELOPMENT

Curriculum development comprises activities such as introduction of new courses, new study curricula, and new learning methodologies (pedagogical principles), for example PBL (problem oriented and project based learning). There is no fixed recipe for PBL and experimentation and optimisation are inherent activities wherever it is applied; for example, group work as part of PBL is in itself an issue and group psychology and group leadership are among the interesting questions still being worked with in theory and practice. But it should be stressed that research based education and reach out from universities are activities that are maintained or even enhanced when implementing PBL or other new learning principles.

At universities, in society at large, and in business it seems accepted that learning and ability to learn and use knowledge are important challenges in order to be successful in what is termed “knowledge societies and global economies”. While new learning principles have been on the agenda for some 30 years and new universities even established on the basis of introducing such new methodologies in research and education, the process of understanding and applying these new ideas is still in development. It is a common and highly relevant issue in the LUCED-I&UA context to be active partners in this development. Significant consortia resources have therefore been invested in curriculum development in all four consortia.

ECTS, European Credit Transfer System offers a useful way of assessing and comparing investment in curriculum development. 60 ECTS points equal one year of full time student work and the system is now used extensively in Europe. It is used here to account for curriculum development in LUCED-I&UA in the period 1998-2002, cf. table 2, DUCED (2001-3).

ECTS points earned by students following courses and doing studies on environment and development/industry and urban areas are listed in table 2. Only activities with involvement of DUCED-I&UA students and faculty are included. This means that courses and study activities performed exclusively in MUCED-, SACUDE- or TUCED-I&UA context are still to be accounted for and will increase the LUCED-I&UA score of ECTS points for the years 2001-02. For courses there is a relatively constant activity level during the whole period, indicating (Danish) student interest in environment and development issues as introduced in LUCED-I&UA context. For joint courses the interest and activity level has been on the increase ever since the beginning (there is for each course an almost even mix of DUCED- and cooperation country participation for both students and faculty). For TFS the number of Danish students going abroad is considerable throughout the period, while the number of LUCED students coming to Denmark is on the increase since year 2000, TUCED-I&UA taking the lead.

Table 2: Curriculum development in LUCED-I&UA with DUCED-I&UA involvement

ECTS points earned	1998-2000	2001	2002
DUCED courses	7500	2891	2985
Joint courses	600	1360	2950
TFS:			
-DUCED in MY, SA and TH	3870	1450	930
-SACUDE in DK	-	-	60
-TUCED in DK	-	210	450
Total ECTS/year	**3990**	**5911**	**7375**

The variety of themes and topics used in the many joint courses are illustrated by the list in box 2. It should be noticed that these joint courses serve the purpose of exposing students to real life problems in the host country and bringing students and business (public and private) in contact with each other. Students get an opportunity to not only get good cases for their projects but also make provisional preparation of their professional careers. Additionally, to many students this exposure is very valuable regarding maturation and possible future commitment to jobs and problems related to environment and development.

Box 2: Joint course, JC and reach-out activities

Range of JC themes and places 1998-2002

Cleaner technologies, Malaysia and Thailand
Environmental management and regulation, Malaysia and Thailand
Co-housing communities, Denmark
Informal settlements, South Africa
Industry and Environment, South Africa
Sustainable development, South Africa
Urban environmental planning, Thailand
Urban metabolism, Denmark
Community participation, Malaysia
Environmental impact assessment, Malaysia
Integrating LCA and EMS, Malaysia
Urban development and cultural environment, Thailand

The TFS programme means a very demanding and dedicated action by students in order to not only plan but also carry out and report on a project tied to a real life problem and often under conditions very different from those found in university laboratories in the home country. As illustrated in box 3 the work with industry represents a very important university reach out already at the education level, possibly equally rewarding to students, industry and university. Such educational activity may lay the ground for further joint research activity.

Box 3: Results and reach-out in graduate student TFS (Training and Field Study) projects.

University-Business in TFS collaboration in Thailand

Thai and Danish students and faculty as well as staff from a local industry were involved in a project focusing on environmental improvements to traditional production of saa-paper (mulberry-bark paper) through the introduction of cleaner production, environmental management, and optimisation of on-site wastewater treatment.

The company benefited through new insight as to optimisation of resource use in several of the production steps, suggestions for optimised wastewater treatment, an overview of the environmental aspects of the production, and strengthened capacity/capability to deal with environmental issues related to the production (Larsen & Lehmann, 1998; and Larsen, 1999). The work was conducted in close co-operation between staff and management from the factory and students/faculty from tthe university.

The Danish students gained deeper insights into development and environment issues as well as into the social and cultural aspects of working abroad. Faculty and students from the Thai university were introduced to new and different ways of learning, e.g. problem based learning. The exchange has later been reflected upon as having been an “eye-opener” and resulted in a paradigm-shift in teaching methods for at least one Thai faculty (Bregnhøj & Lehmann, 2000).

HUMAN RESOURCE DEVELOPMENT

Training of faculty (as visiting scholars) in relation to environment and development (with focus on industry and urban areas) has been an activity on the increase during the period 2001-2002, cf. table 3, DUCED (2001-3).

Table 3: Human resource development in LUCED-I&UA with DUCED-I&UA involvement. Training of faculty and junior staff

MM/y Man Months/year	**1998-2000**	**2001**	**2002**
DUCED, DK and abroad	-	30	30
MUCED in DK	-	15	7
SACUDE in DK	-	3	-
TUCED in DK	-	20	94

For DUCED-I&UA it means that 5 assistant professors (at five different universities) are specifically spending time in research and teaching on environment and development and that tenured university positions are waiting ahead, given continued student interest in this area. For MUCED-, SACUDE- and TUCED-I&UA faculty members visited Denmark to train themselves on research and educational topics. Obviously this development is on the increase and will require continued co-operation to meet the demands from the consortia members. An example of a very successful exchange (human resource development) between TUCED- and DUCED-I&UA is shown in box 4.

Box 4: Teacher training and reach-out to industry and society

Human resource development & reach-out

SM, junior staff at Thai university went to a Danish university in the period September 2001-January 2002 to study GIS applications. Part of the stay was spent at the local municipal administration to practise GIS as apprentice and co-worker. Upon return to the home university, SM established a learning laboratory with 7 work stations and offered a new course in GIS application to urban and environmental planning. The course is offered repeatedly since inception and has been full-signed in each case. An international workshop with faculty speakers from both Thai and Danish universities was held in Bangkok in 2002. Participants from universities and business rated the conference as very good, Mahidol (2002).

RESEARCH

Research is carried out by faculty and PhD students in all four consortia. LUCED-I&UA (2003) gives an overview, listing 6 joint research networks with subprojects and 16 other projects in progress or being initiated within the four consortia. The joint research networks are driven with major input from young faculty and PhD students as well as graduate TFS students whenever feasible in the curriculum context. The networks cover the following themes (short titles):

1. Environmental Management
2. Nutrient and Resource Recycling
3. Public Participation
4. Water Resource Management
5. Chemical Assessment of the Environment
6. Environmental Impact Assessment.

Research has become more and more a vital element in developing new courses and curricula and new outreach from universities. Much of the increased mobility, cf. table 1 is in support of ongoing joint research projects. Table 4 illustrates how over the years research has become a significant DUCED-I&UA activity in terms of MM/y, because both PhD students and assistant professors have been assigned to the consortium with the specific goal of increasing future educational and research capacity in environment and development, i.e. making the consortium activities sustainable over time.

Table 4: Research in LUCED-I&UA with DUCED-I&UA involvement

MM/y Man Months/year	1998-2000	2001	2002
DUCED, 3.PhD	36	-	-
DUCED, 7 PhD	-	84	84
DUCED, 5 Ass. Prof.	-	30	30
LUCED scholars in DK	-	10	48
MUCED, PhD in DK	4	0	2
Total	**40**	**124**	**164**

It is interesting how the number of LUCED research scholars to DUCED was on the increase in 2001-2002, thus indicating a need for continued joint action to meet capacity building needs in the cooperation countries and sustaining the DUCED needs for project data and input from the other LUCED consortia. Box 5 gives an example of a joint MUCED-DUCED PhD project with very useful advances in knowledge obtained in both Malaysia and Denmark and with the multiplier effect that now the new Ph.D. is employed in teaching and research at the biggest university in Malaysia and thereby effectively adding to Malaysian capacity in environment and development.

Box 5: Joint Ph.D. programs to enhance capacity building in the home countries

Research & multiplication

SU was PhD student 1999-2002 in environmental engineering at Malaysian university and chose to spend 3/4 time in Malaysia and 1/4 in Denmark, thereby gaining access to equipment, knowledge and experience that would otherwise be very difficult to mobilise in order to complete studies and thesis, Talib (2002). The co-operation between the Malaysian and the Danish university created multiplier effects such as several TFS projects carried out by Danish students in Malaysia and international training courses with both Malaysian and Danish speakers and participation of both industry and other universities. After defending his thesis, SU got employment at another Malaysian university and is now actively involved in environmental teaching and research. By maintaining ties to LUCED-I&UA he is actively multiplying the effect of the first international aid investment in the LUCED-I&UA network.

UNIVERSITIES AS DEVELOPMENT HUBS

LUCED-I&UA was established as an international university network to enhance capacity building in environment and development. Some of the experiences over the past 6 years indicate the usefulness of LUCED-I&UA as not only another international aid project but also as a role model for other programme areas. University networking seems a basic structure with the potential for long term impact and local ownership in capacity building. This applies not only in environment and development but also in other sectors such as agriculture, land use and natural resource management, health and many more. Generally, as described above, universities can play the role of primary providers in capacity building in curriculum development, human resource development, and research. The examples show how this can be done in co-operation with society and business, thereby multiplying the effect of the individual activities and securing an up-to-date adjustment of learning principles and topics for research in higher education.

Continued education is also on the LUCED-I&UA agenda as an area of joint action with public and private business. Mid-career professionals are offered the added value of international perspectives and exposures as part of the training programmes due to the LUCED-I&UA input offered locally through the home university.

Sustainability of the LUCED-I&UA network, e.g. financially and institutionally, is secured to a high degree due to the commitment of the participating universities. But this is an area where donor institutions and governments need to consider both budgets and responsibilities, for example regarding a balanced investment in national capacity development and maintenance of skills versus international aid financing. There is always a limit to the time and resources that universities can invest in international co-operation unless money is allocated for that particular activity.

It takes time to establish international networks. LUCED-I&UA shows how it took 3-4 years of operation before results really started to come, cf. tables 1-4. This means that the time frame for capacity building programmes can easily amount to 10 years, allowing time for both establishment and a period of regular running before the responsibility for continued operation is handed over to the national institutions and governments. Obviously, in most capacity building programmes the higher education component should be specific topic matter and after an initiation period, say 5-6 years, the financial and institutional sustainability question should be discussed and decisions made as to future responsibilities. Donors, governments and universities are necessary partners in this discussion.

A conscious use of university consortia in national and international development strategies is shown in figure 1. Much of the inspiration comes from research on innovative societies and is mainly carried out by social scientists in good co-operation with business and society. Background for the figure is found in Hansen et al (2003).

In figure 1 each of the two boxes illustrate auto-learning and innovative societies (e.g. within country borders) that have established active links between universities and society, and where the universities in a certain field, e.g. environment and development have established a consortium to share responsibilities and resources, nationally and internationally. The line between the two consortia is vital to both societies, because the international interaction is necessary to keep the society up-to-date on new challenges and knowledge.

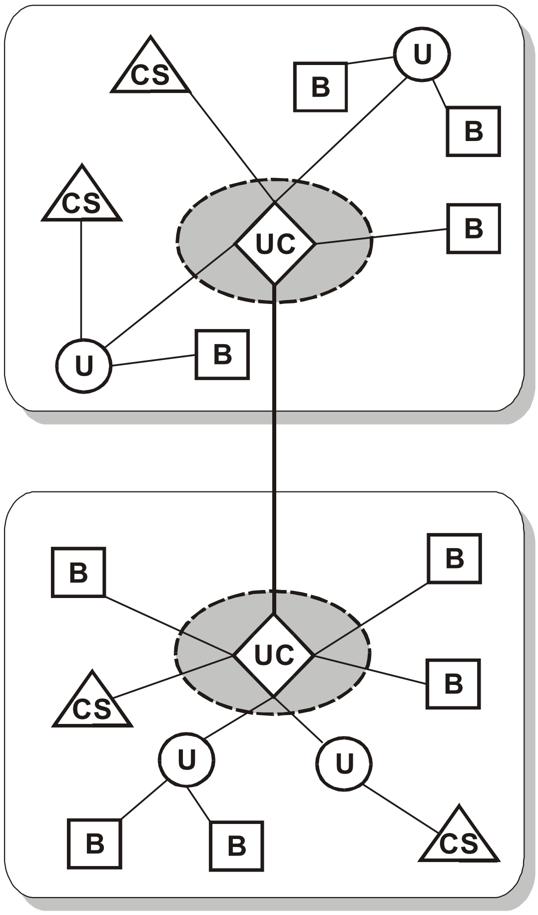

Figure 1: Auto-learning and innovative societies
UC=university consortium, U=university,
B=business, CS=civil society

Universities with existing networks can play an important role in this needed international interaction. LUCED-I&UA possesses some of the characteristics of such international university consortia networks. Potentially they offer to the national and international societies:

- New graduates and research results that match both academic standards and key requirements from society,
- A room for reflection on interaction between theory and practice that is prerequisite in development in all professional fields,
- A challenge to business-as-usual, in both government and business,
- A room for reflection on intercultural development (university campuses have an international atmosphere created by visiting faculty and students), thereby facilitating e.g. democratic development and public participation in decision-making.

CONCLUSIONS

Focus on higher education and research in international aid programmes may enhance chances of multiplier effects, financial and institutional sustainability, and value for aid money in the long run.

The LUCED-I&UA project 1998-2003 provided tangible outcome in terms of

1. More mobility for students and faculty as a cost efficient way of facilitating improved education and research in both donor and recipient countries.
2. Curriculum development, including new courses and study curricula as well as introduction of new principles in learning, e.g. problem oriented and project based learning. This process of changing existing learning methodologies (changing focus from teaching to learning) will continue for many years to come, but LUCED-I&UA has made a head start to the process at the 19 universities involved.
3. Human resource development, emphasising training of faculty to update existing curricula and learning methodologies. Some interesting results have been achieved in short time and due to the interaction with practice in both training and later dissemination of knowledge.
4. Research, where work is focused in selected areas of demand and on a PhD programme to attract talent to work in the field of environment and development and provide the candidates for job opportunities in practice and research.
5. Providing a role model for investment in higher education in international aid programmes. There is no panacea in this, but LUCED-I&UA has certainly provided experience that deserves further development and application in other professional fields and with other universities and countries involved.

LUCED-I&UA is ending by May 2004 under the present contract with DANIDA. It remains to be seen how an international panel will assess (end of 2003) the LUCED-I&UA results and how donors (including DANIDA) will use these experiences in future aid programmes. Tangible outcome is documented from the activities 1998-2002, but even more is expected in the future when new graduates and PhD's enter society and universities to do work and when mid-career professionals change their routines as a result of continued education. The lag phase in university programmes between investment and impact should be acknowledged but certainly not used to lower priority to education and research in future sector aid programmes.

A number of outstanding issues need further consideration by the LUCED-I&UA universities:

- Assessment of what happens after being involved in LUCED-I&UA activities? Employment of MSc and PhD graduates? Effect of faculty training? Multiplier effects?
- How to use distance learning more in the future and at the same time find the right balance between virtual and campus university studies; within each consortium, within LUCED-I&UA and in relation to other potential partners

- How to increase continued education of mid-career professionals in co-operation with external stakeholders
- How to continue LUCED-I&UA activities, institutionally and financially, in the latter case considering both external and internal financing.

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Promoting Sustainable Urban Livelihoods And Environments: The Role Of Government, Business And The Public

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ABSTRACT: In the light of WSSD, the appropriateness of the 'sustainable development' concept is reviewed. Two projects that have resulted from work carried out over the last two years in the Southern African Consortium of Universities for Development and Environment (SACUDE) and its Danish counterpart (DUCED), with the explicit focus on urban and industrial concerns, highlight the issues of fragmented environmental knowledge and initiatives at the local government level, and a poor culture of collaboration and participation between local government, business and the public. The paper calls for the creation of a culture of learning and promotes the role of universities in attaining such a culture.

Keywords: Sustainable development, local government, environmental education, polluter pays principle, culture of collaboration, public participation, culture of learning

INTRODUCTION

This paper reflects on two projects that have resulted from work carried out over the last two years in the Southern African Consortium of Universities for Development and Environment (SACUDE) and its Danish counterpart (DUCED), with the explicit focus on urban and industrial concerns. It also has as a backdrop the Johannesburg 2002 World Summit for Sustainable Development (WSSD) and its ambiguous legacy. Heralded as the largest United Nations' gathering ever, with heads of state from hundreds of countries (the United States being a notable exception), it was considered a ceremonial success and perhaps even a diplomatic success. Measured in terms of tangible results, the general impression was that little – if anything at all – was gained (Fincham *et al.* 2002).

In the light of WSSD, the paper reviews the appropriateness of the 'sustainable development' concept. Does the contested nature of the term make it unsuitable as a framework in which to look at forging sustainable urban livelihoods and environments? It then goes on to consider the two projects. They focus, respectively, on the request to the University of Natal to facilitate an *Environmental Education and Sustainable Development Campaign* in the Msunduzi Municipality and on the lessons to be learnt from riverine pollution caused by industry in the same municipality. The question we pose here is, Does the government strategy of directing development at the local level, in terms of the new Municipal legislation (Republic of South Africa, 2000), provide a strong platform for business, local government and the public to make that development feasible?

SUSTAINABLE DEVELOPMENT

The World Commission on Environment and Development, better known for its publication, the Brundtland Report or *Our Common Future,* appeared in 1987. It provided the most well used definition of sustainable development, namely 'development that meets the needs of present generations without compromising the ability of future generations to meet their own needs.' Historically, the conservation and management of natural resources, and of development were considered mutually exclusive and as conflicting needs within society. The Brundtland definition provided a new choice by implying that it is possible and desirable to achieve a balance between these two entities.

Sustainable development is about integrating social, political, economic and ecological concerns in decision-making (Figure 1). All are essential if sustainability is the goal. However, it is difficult to work in these spheres in a way that treats each equally. Invariably, economic concerns carry the day. What is required is a new ethic that elevates socio-political and ecological concerns to parity with that of the economic imperative – the triple bottom line in other words.

Arturo Escobar (quoted in De Gruchy 2002, p. 33) would argue that all these factors cannot be met, because development is a '…top-down, ethnocentric and technocratic approach…a force so destructive to Third World cultures, ironically in the name of people's interest'. It is against this cautionary statement that one must, nevertheless, acknowledge that policy makers and the legacy of WSSD mean that the sustainable development framework is important. It has wide formal and international recognition. With the projects set out in this paper it is hoped to show how the three areas in Figure 1 can more effectively addressed.

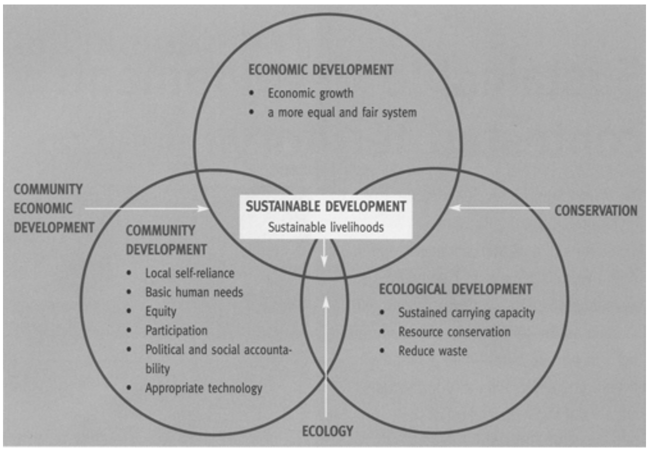

Figure 1: The Sustainable Development Challenge (Fincham *et al.*, 2002; p. 20)

THE MSUNDUZI MUNICIPALITY

The research outlined in the paper took place in the Msunduzi Municipality in which Pietermaritzburg, the second largest city in KwaZulu-Natal Province of South Africa is to be found (Figure 2).

Figure 2: The Msunduzi Muncipality within its broader context.

The municipality, as with most in the country, was formed after amalgamation of previously separate transitional local councils (TLCs). They constitute areas that are both 'urban' and 'rural' in nature with new sets of social, economic and environmental challenges (Table 1).

The area and populations have increased, and the social fabric and infrastructure placed under stress. The majority of the facilities and services are still concentrated in the area previously under the old TLC. The added burden of service provision is not commensurate with an increase income (rates), as the added population represents marginalised communities. What will dictate how development occurs is the Integrated Development Plan (IDP) for the Municipality. The IDP is defined as '…a participatory process aimed at integrating sectoral strategies in order to support the optimal allocation of scarce resources between sectors and geographic areas and across the population in a manner that promotes sustainable growth, equity and the empowerment of the poor and the marginalized' (The Msunduzi Municipality, 2002, p. 5). The IDP represents the 'vehicle' for implementing the strategy of locally based development in terms of the Municipal Act.

Table 1: The changing nature of local government responsibility: Comparisons between Pietermaritzburg TLC and the Msunduzi Municipality (MM)

FACTOR	TLC Area/Nr.	TLC % Total	MM Area/Nr.	MM % Total
Area (km^2)	150	18	649	100
Population	176 590	34	523 470	100
Employed	75 600	85	129 740	61
Unemployed	13 240	15	84 630	39
Education facilities	Number	T:P[1]	Number	T:P
▪ Primary	77	1:40	129	1:100
▪ Secondary	35	1:35	61	1:100
▪ Technical	4	1:30	4	1:8582
▪ University	1		1	
Clinics	Number	C:P[2]	Number	C:P
	26	1:6792	33	1:15863

Sources: Calculated from figures in the IDP (the Msunduzi Mucipality, 2002) and local fieldwork

[1]Teacher:Pupil Ratio [2]Clinic:Population Ratio

AN ENVIRONMENTAL EDUCATION AND SUSTAINABLE DEVELOPMENT CAMPAIGN

As a result of the field-based course into urban environmental management that has been run from Pietermaritzburg over the last three years, the University of Natal has become more closely associated with the business sector and the local Msunduzi Municipality. Students have benefited from interactions with these sectors and in turn research undertaken (for example, Khumalo 2002) has begun to build recognition of the importance of the University as a key sector in future development debates and actions. One of the recent outcomes of collaboration has been the request to the University to facilitate an *Environmental Education and Sustainable Development Campaign*.

As emerged in the Khumalo study, environmental education is identified as critical to fostering a concern for development and environmental issues within the implementation of the Msunduzi Integrated Development Plan (The Mzunduzi Municipality, 2002). The Council's Local Agenda 21 Committee was tasked with addressing the issue. Its strategy was to attempt to consult with various environmental actors, seeing its business as one of carrying out an 'Campaign'. A questionnaire was designed and sent out from the Committee to solicit a picture of the concerns that difference stakeholders have within the Municipality. It was at this point that the University of Natal was asked to play a facilitating role in 'taking the process forward'.

To gain a background to the thinking of the Committee, the findings from the questionnaire were interrogated. Table 2 summarizes the findings.

Table 2: Concerns perceived to be important in an Environmental Education Campaign

INSTITUTION	A	B	C	D	E	F
Government	5	6	1	3	2	1
NGO's	4	1	7	3	2	-
Business	2	3	-	3	-	4
TOTAL	11	10	8	9	4	3

Source: Ngotho *et al.* (2003)

A = Solid waste, B = Water & sanitation, C = Governance and environmental justice, D = Pollution, E = Public participation, F = Biodiversity conservation

In all, returns to the questionnaire were received from 20 organizations. Of these, seven were either local or provincial government departments, ten were NGOs and three, private businesses. It is interesting to note the focus of all on solid waste disposal, since it is a well-known concern in the city. In this and the water and sanitation category, the dominance of government is also apparent – they are issues that are germane to infrastructural development. Another finding of note is the strong focus of non-government agencies and business on the governance/environmental justice issues. Equally significant is the limited articulation of concerns about public participation and conserving biodiversity.

An important factor to emerge from the initial assessment of the questionnaire was the general consensus of participants that the issues they had identified needed urgent attention. In a similar vein, there was an association between the issues an organization identified and its core business. For example, the Department of Water Affairs identified with the water-related issues, the engineers with storm water drainage issues and the activist NGO organizations with governance and environmental justice concerns. Plotting a way forward for a campaign on these results will prove challenging as we will suggest in the discussion.

ABUSING URBAN RESOURCES: EDIBLE OIL INDUSTRIES AND WATER RESOURCES MANAGEMENT

Polluter Pays Principle (PPP)

Industries and businesses are vital for creating employment and supporting the economy. However, some are polluting water, air and land resources due to failure to treat their by-products despite the requirement by law. In the past, governments have depended on command and control approach where industries are expected to adhere to stipulated standards on environmental pollution and waste management. Some of these requirements have inadequately addressed the problems. The PPP is one alternative to this approach. It has been defined as an economic principle that serves as an incentive to polluters to reduce pollution by internalising the costs of pollution into the costs of production. As a result, the end-product should more accurately reflect the true production costs (including environmental costs), with this higher cost being transferred to consumers wishing to purchase such a product on the open market (Taviv *et al.*, 1999)

Methodology

Pole's (2002) research focussed on factors affecting the implementation of the polluter pays principle in the Bayne's Spruit, a small urban stream in Pietermaritzburg. The historical context for this case study was set by conducting a review of newspaper reports on pollution of the Bayne's Spruit by companies engaging in the production of edible oils. Rather than treating or alternatively discharging effluent to the municipal sewer if on-site treatment works are not available, the allegation is that these companies dispose of their effluent via the stormwater drain system, which subsequently discharges into the Bayne's Spruit. This information was supplemented by a review of Department of Water Affairs and Forestry (DWAF) records on recent inspections conducted by the department in respect of the edible oil companies, as well as historical documents relating to the largely unsuccessful attempts to prosecute these companies. The available bio-monitoring and water quality data were also reviewed to show a pattern of persistent discharge of industrial effluent.

Of particular interest in this case study was that in addition to impacts to the river system, this activity was having a direct impact on marginalized communities downstream. In addition to a number of informal settlements, three community gardens have been established along the banks of the Bayne's Spruit. In the case of the former this stream may be the only source of household water, while for the latter the stream is the sole source of irrigation water. For several years' local residents, including those of the nearby Sobantu community have complained of the persistent foul odour associated with the water and the fact that pumps and irrigation equipment is frequently clogged by oil. The study sought to document these reports and highlight the fact that once again, marginalized communities were bearing the impacts of unregulated and unsustainable industry.

FINDINGS

Based on the evidence collated by Pole (2002), pollution of the river has severely affected the riverine ecosystem and community livelihoods downstream, including farming, fishing and recreation. Presentation and analysis of findings reveal cases of negligence and profit driven attitude by the owners of the industry. This has occurred despite the fact that the polluter pays principle is incorporated into the national legislation (National Environment Management Act (NEMA), Republic of South Africa, 1998; National Water Act (NWA), Republic of South Africa, 1998) and local Industrial Effluent By-laws (IEBs). It has occurred despite the fact that these represent criminal offences. The critical research question was thus to consider why, in the light of a progressive legislative framework, such persistent and blatant pollution of the environment was occurring.

Pole (2002) outlines several factors contributing to this situation, grouped according to four themes:

The oil industry

- Characterized by an uncooperative attitude and lack of environmental ethic; the industry is contravening the national legislation and municipal industrial effluent by-law requiring them not to discharge effluent to river systems or stormwater drains.
- Profit maximization; many respondents indicated that the industry is failing to install pollution control and treatment facilities due to their interest in making profits. Without the Municipality or the Department of Water Affairs directing them to do so, there was little incentive to change behaviour.

In relation to the Pietermaritzburg IEB's

- Permission to discharge effluents for many industries was granted under old by-laws which did not incorporate the polluter pays principle; permission to discharge to sewer in these cases was not withdrawn with the commencement of the new by-laws in 1998. As a consequence some industries operate under conditions which are inconsistent with current principles of environmental management.
- Perception of institutional paralysis; the municipality accepts that it has primary responsibility for addressing river pollution within their area of jurisdiction. However, some interviewees felt that the council is not controlling pollution properly within their jurisdiction.
- Perception of reluctance to deal with edible oil industry; the city council felt pressure not to prosecute industry because of the importance of industry from a local economic and employment perspective.
- Perceptions of corruption; officials allow the pollution to continue. *Note: Pole comments the perceptions had no physical evidence so they are reported as perception by the interviewees.*

In relation to national legislation

- Local authority is not directly empowered to implement the NEMA and NWA. Only when a local Catchment Management Agency has been established will this function be devolved to the local level.
- Responsibility for monitoring rivers: There has been a hiatus between the promulgation of new legislation and the implementation of the proposed water resource management structures. As a consequence gaps exist in executing this responsibility between DWAF, the provincial Department of Agriculture and Environmental Affairs, the Municipality and Umgeni Water (a local water services body).

Enforcement

- Lack of administrative and enforcement capacity; the legislation exists but the City Engineers Department, as well as the City Health Department, do not have adequate staff to investigate and initiate prosecution.
- Access to company premises; the technical difficulty of positively establishing the identity of a company polluting the Bayne's Spruit from a shared storm water drainage system is exacerbated by difficulties experienced by the enforcement authorities in gaining access to the premises of companies suspected of discharging the effluent. High perimeter walls encircle these companies, and armed guards control the gates.

DISCUSSION

A number of common threads run through the two cases examined.

Fragmented environmental knowledge and initiatives

It is not surprising that coherent, holistic knowledge about environmental issues does not exist within most organisations. Those issues that fit most closely with the core business of an organisation tend to predominate. The result is different perceptions of priorities and of funding needs. So the question remains, how does one begin to address the problem? One approach is to look more forcefully to tertiary organisations such as the universities to provide professional training courses that can begin to provide a knowledge base that goes beyond the particular organisational context. In this respect, it is exciting to see government approaching and committing staff to training of this nature. As the knowledge sector in the Remman and Smink (2001) model, universities must engender greater belief in the role they can play in creating more educated professionals New professional courses have emerged on issues around urban environmental management, for example, a new module on *Urban river rehabilitation.* The first of its kind, it now attracts local government, private sector and community participants locally and nationally.

Creating a culture of collaboration

South Africa, as with many nations, is undergoing a process of radical change. That process offers opportunities for developing a new frame of reference for organisations Collaboration or lack of it, manifests itself within and outside of institutions. Furthermore, the different sectors, government, private enterprise and the NGO community often see themselves in conflict with each other. Facilitating discussion with these groups usually revolves around breaking down stereotypic views, the one of the other. In this respect the 'knowledge sector', including those undertaking environmental research can play a facilitative role, building frameworks that allow for commonality to surface rather than conflict – although experience has dictated that conflict is a critical factor to overcome in making collaboration possible. Again, it is noteworthy that the University has been viewed as that sector that can provide the dispassionate facilitation to address these issues.

Making public participation a reality

The experiences cited in this paper and ongoing research in the field suggest that a major problem exists in soliciting and meeting aspirations in the development process. The Local Agenda 21 Committee questionnaire showed that few see this as an issue, yet it remains one of the key reasons for 'buy in' for so many state interventions and the reason why so many initiatives simply do not function. The IDP process signals new opportunities to make public participation a reality. As in the case with the National Constitution (Republic of South Africa, 1996), NEMA and NWA, the enabling legislation is there, but the capacity to implement and act upon it is lacking. So, it signals to the research community a vital area that needs to be incorporated into research and its social outcomes. The education of the electorate will be decisive in this respect, but models for making it happen need to be cogently argued and developed.

Creating a culture of learning

According to Senge and Scharmer, (2001, p. 240), "…a learning community is a diverse group of people working together to nurture and sustain knowledge-creating systems, based on valuing equally three interacting domains or activity: (a) research: a disciplined approach to discovery and understanding, with a commitment to share what is learnt; (b) capacity-building: enhancing people's awareness and capabilities, individually and collectively, to produce results they truly care for; and (c) practice: people working together to achieve practical outcomes". Creating a learning community is a daunting but inevitable challenge for stakeholders in Msunduzi. The challenges exist for stakeholders to go beyond self-interest and to reach out to others. This will involve compromises and sacrifices for the good all. Complexity of environment and development issues is overwhelming. However, it is time to demystify this complexity. Assessing our actions and/or failures that impact on the environment and listening and learning from each other's knowledge and experiences, provides such an opportunity.

CONCLUSION

Urbanisation, its opportunities and challenges, is a reality, globally and locally. In either context, the promotion of positive, living urban environments will revolve around a new, collaborative process of governance. It will require an increasingly astute public who know their rights and are willing to be involved in creating the kind of futures to which they aspire. Within the developing country context of the work outlined in this paper, there are many opportunities to link theory and practice in ways that have not been possible in the past. That is so because the new legislative framework allows for the participation of local people in the management and allocation of resources. Empowering people to participate will not be easy and will involve knowledge of what are the challenges. Identification and proposing actions are key roles for researchers. The examples cited in this paper highlight the complex nature of the challenge and a need for education and research to go hand in glove with each other. Environmental education and related research within the urban context emerge as critical components to sustainable urban environments of the future.

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Waste And Chemical Management In Botswana: Towards A More Sustainable Environmental Management

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ABSTRACT: Botswana like most developing countries is faced with many challenges and opportunities that include chemical and waste management. When Botswana attained independence in 1966, we had a very small population with very small generation of biodegradable waste. As a result of rapid economic development, Botswana has started to produce some waste that is not biodegradable and has long residence time in the environment. Some of this waste include plastics, batteries, scrap metals, used oil, and waste paper, glass, medical/clinical waste, old tyres among others. Medical/clinical waste has been a problem in Botswana more especially the transportation and disposal aspects. Clinical waste that has been identified compromise, biological waste, infectious waste, Sharps, Chemical waste, Body fluids/excreta, radioactive waste. Oil waste has resulted from various industrial activities that have been very difficult to store and reuse. Oil sales are projected to grow to 12.7 million litres by the year 2005 with a growing recovery of 6.34 million litres. Paper, glass and packaging waste continue to be a menace to our environment. 1996, it has been estimated that waste from paper was generated as follows: packaging material 18 600 tonnes, paper for writing and printing as7 100 tonnes and miscellaneous paper accounted for 13 000 tonnes. Paper recycling is at an infant stage in Botswana. Quantity of glass generated is about 93 tonnes per annum. Scrap metals are piled up on private premises, dumped in the bush, abandoned in the streets or brought to communal landfill sites, or individuals keeping such scrap metals in their backyards. It is estimated that by 2005, 832 600 tyres will be required vehicles and 306 000 will go to scrap. Accidental fires on tyres are a common occurrence around most landfills in Botswana. Because of an appreciable level of industrial and mining activities, chemical pollution and management has become important in Botswana. Disposals of chemicals into the environment has been unsatisfactory and some of the chemicals are hazardous. Chemicals that go into our environment include: High risk chemicals: quartz, chalk, cryolite; tar, creosote, pitch coke, bituminous products; BTX compounds; white spirits, solvents and thinners; diesel and petrol fuel, lead, chromium and compounds, CFC compounds, soap, surfactants, pesticides and disinfectants. Low risk chemicals: nickel, aluminium ores; lubrication greases and oils; inorganic chlorine compounds; Iodine, Fluorides, Bromides and their compounds; selenium and compounds; mercury; aluminium, strong inorganic acids and bases, essential oils, tepenes; photographic chemicals; rubber and plastic additives. Botswana needs well-articulated environmental legislation to deal with the above environmental concerns in order to realise sustainable environmental management.

Keywords: Waste management, Botswana, chemical waste, landfills, environmental management

INTRODUCTION

Overview Of Waste Management In Botswana

The Botswana's Strategy for Waste Management defines waste as 'anything which is no longer useful and needs to be got rid of. Indiscriminate dumping of 'waste' and widespread littering have become serious environmental problems in Botswana in recent years (Gould, 1995). As Gould (1995) rightly observed, metal waste, cans, used tyres and batteries and waste oil are despoiling towns, villages and once pristine countryside. Indiscriminate littering is exacerbated by what has been dubbed the 'throwaway syndrome", whereby some perpetrators claim that they are creating jobs for litter pickers (National Conservation Strategy (Co-ordinating) Agency 1994a: 4). The haphazard waste disposal is not only an eyesore; it is also dangerous to humans, wildlife and livestock.

The attention that is given to the waste management problem is manifest in several studies that have been undertaken by the Department of Sanitation and Waste Management (DSWM) in conjunction with the German Technical Co-operation Organisation (GTZ). Among the studies undertaken are:

- Study on the Management of Medical wastes (1995)
- Study on the Recycling of Metal Wastes (1996)
- Study on the Management of Oil Containing Wastes (1996)
- Waste Management Botswana-Paper, Glass, Packaging Waste (1998)
- Study on Battery and Tyre Wastes (1999)

Other initiatives towards sustainable management of waste are by local NGO's in the form of workshops such as the 1995 Workshop on Waste Recycling organised by Somarelang Tikologo-Environmental Watch Botswana in May 1995 and publications such as Botswana's Strategy for Waste Management (1998) and Guidelines for the Disposal of Waste by Landfill (1997).

Types Of Wastes That Exist In Botswana

Used Oil

The term used oils may be used to cover; liquid or semi-solid product consisting totally, or partially hydrocarbons or synthesised hydrocarbons; oily residues from tanks and oil water mixtures and emulsions (NCS/GTZ, 1996). Oil sales are projected to grow to 12.7 million litres by the year 2005 with a corresponding recovery of 6.34 million litres. The projected figures are estimated as the mining sector has a very large impact on relatively small sales volume. Opening up or closing down of a mine will alter the projected figures drastically. The latter can result in an increase or decrease of 20% on the projected figures. The disposal of waste lubricants is proving more difficult for the oil industry, as customers and government look to the oil companies to offer solutions. The oil waste referred to include:

- Used motor, hydraulic and gear oils
- Waste oil emulsions
- Drilling and cutting oil waste
- Hydrocarbon wastes from production and refining
- Wastes contaminated with oil to some degree
- Garage oil separator slops and sludge
- Leaded sludge from fuel storage tanks
- Electrical insulation oils
- Heat transfer fluids

By 1995, 5,8 million litres of oil were sold annually. The estimated waste lubricating oil in Botswana was 3,0 million per annum. Mining and government activities are the main generators of oil containing wastes (NCS/GTZ, 1996). Waste generators of waste lubricants in 1995 were (estimates):

- Mining 1,0ml
- Construction 0,5ml
- Government 1,0ml
- Privatisation 0,5ml

However, it is observed that recently the major oil importing companies, Somarelang Tikologo (an Environmental NGO) and Environmental Systems have organised themselves in an undertaking to collect used oil from all over the country. Tanks are now provided at key sites such as filling stations and other easily accessible sites for all those needing to dispose of waste oil. This process is managed by Somarelang Tikologo through a committee made up of Government representatives from Ministry of Commerce and Department of Sanitation and Waste Management, the oil companies as well as the collector, Environmental Systems. A legally registered trust to handle this endeavour is in the process of being formed and a levy on all oil imports will be charged to cover the costs. This is a clear demonstration that the Government of Botswana realises the importance of combating environmental problems in partnership with the private sector and NGOs.

Paper, Glass, Packaging waste

There are three types of packaging waste from plastics and these are:

- Plastic bags used for shopping
- Plastic containers for foodstuffs and beverages
- Plastic containers, drums and bags used for hazardous substances (e.g. oil containers, pesticides)

The life of a landfill can be shortened by an overabundance of plastic shopper as they take many years to decompose. The public indiscriminately disposes of these bags and containers due, largely; to lack of awareness about the environmental hazards they pose and also because plastic shoppers are freely available in shops. In order to cut down costs by plastic manufacturers, the durability of the plastic shoppers is forever decreasing leading to a situation whereby 2 or 3 bags are used to get the necessary strength when carrying heavy loads (Gwangwa, 1995).

Paper

The current figures for the consumption of paper products also provide the basis for an estimation of waste paper generated over time. According to 1996 import statistics (cited in NCS/GTZ, 1998) consumption of paper and cardboard products and the corresponding generation of waste was; packaging material 18 600 tonnes, paper for writing and printing including newspapers 7 100 and miscellaneous paper accounted for 13 000 tonnes.

While paper recycling is at an infant stage in Botswana, it is noted that a few companies, for example Pyramid Holdings, are involved in paper collection. Very limited amounts are collected and therefore in most schools, government departments and tertiary institutions, paper is still disposed at landfills or waste dumps. Where collection of paper is done, it is taken either to South Africa or Zimbabwe for recycling.

Glass

Waste glass is generated from packaging material for liquid products. In 1996 waste glass constituted a quantity of about 93 tonnes (NCS/GTZ, 1996). Products on the market are either bottled in Botswana or imported as already packed goods. Over and above liquid products, glass packaging for other uses (i.e. jars, bottles for sauces and spices and for imported alcoholic drinks such as wine and spirits) make up a considerable portion of waste glass. According to the production statistics of The Coca-Cola Company, 85% of its produce is filled in returnable bottles; the remaining 15% is filled in cans (NCS/GTZ, 1996). Significant quantities of waste glass are also generated when a new production line, for new labels and bottle shape, is introduced. In this context in 1997 alone 200 000 bottles were destroyed and supplied to recyclers because of labelling failures and other deficiencies (NCS/GTZ, 1998).

In Botswana, glass recycling is still at a very small scale. Limited collection is undertaken through Somarelang

Tikologo, and environmental NGO that is in the forefront of environmental conservation movement in Botswana. The glass collected is taken across to South Africa for recycling, as there is no local recycling facility for glass in Botswana. Coca-Cola company also encourages a deposit scheme to encourage the return of bottles. The company has not been so successful due to low rates of returns because of low incentives as well as unwillingness of some distributors to offer space for returnables.

Medical/clinical wastes

Medical/clinical waste is defined as 'any waste which consists wholly or partly of human or animal tissue, blood or other body fluids, excretions, drugs or other pharmaceutical products, swabs or dressings, or syringes, needles or other sharp instruments, being waste which unless rendered safe may prove hazardous to any person coming into contact with it (NCS/GTZ, 1995). The sources of clinical waste are primarily hospitals, clinics, laboratories veterinary and vaccine institutes. In addition, small amounts of clinical waste arise from funeral undertakers, and those engaged in such pursuits as acupuncture, chiropody, cosmetic piercing, tattooing, accident scenes, private dwellings, home-based care and private medical practitioners within residentially designated areas.

Categories of clinical waste are:

- Biological waste
- Infectious waste
- Sharps
- Chemical waste
- Body fluids/excreta
- Radioactive waste

It has been difficult to estimate the quantity of clinical waste produced in healthcare facilities. Some of the problems identified by the 1995 Study on the Management of Medical Wastes are shortage of staffing and lack of weighing facilities.

In response to inadequate management and disposal of medical waste in hospitals, clinics, and private practices, a Medical Waste Management Plan has been drawn up and is being finalised. A Code of Practice for Medical Waste has also been produced. It is proposed that the two documents will be one of the requirements for Medical Practioners to be licensed in Botswana. The Department of Sanitation and Waste Management in association with GTZ has undertaken pilot studies aimed at ensuring acceptable medical waste management practice at both Princess Marina Hospital and Deborah Retief Memorial Hospital (DRM) in Mochudi. A report on the DRM pilot study is currently being finalised. The establishment of medical waste incinerators is also being vigorously pursued to reduce risk of infection resulting from poor disposal of medical waste. An incinerator donated to the DRM hospital is being used in a pilot study by the DSWM in conjuction with the Department of Mines towards the establishment of national standards for incinerators. This is to ensure that incinerators licensed for use do not lead to pollution of the environment.

Metal wastes

Scrap from motor vehicles

The table below gives an indication on the increase of registered motor vehicles in Botswana from 1978-1995.

Year	Number	Increase/annum	% Increase/annum
1978	19 221	-	-
1979	21 278	2 057	10,7%
1980	26 473	5 195	24,4%
1981	29 963	3 490	13,1%
1982	33 120	3 157	10,5%
1983	36 800	3 680	11,1%
1984	41 005	4 205	11,4%
1985	44 194	3 189	7,7%
1986	48 651	4 457	10,1%
1987	51 298	2 647	5,4%
1988	56 819	5 521	10,7%
1989	62 402	5 583	9,8%
1990	73 175	10 773	17,2%
1991	76 873	3 698	5,1%
1992	83 434	6 561	8,5%
1993	90 618	7 184	8,6%
1994	96 838	6 220	6,8%
1995	104 811	7 973	8,2%

Adopted from NCS/GTZ: 1996

By the year 1996, almost 98% of all cars and 80% of all light delivery vehicles (LDV) and lorries could be found within Gaborone, Francistown, Lobatse and Selibe Phikwe as well as within a 100km radius of each of these urban centres (NCS/GTZ, 1996). By inference, it is only logical to say these are the areas that produce high amounts of scrap from motor vehicles. The scrap metals are pilled up on private premises, dumped in the bush, abandoned in the streets or brought to the communal landfill sites. Individual persons have a tendency to keep their scrap metals in their backyards. In spite of all the waste dumped the scrap has a substantial value and could be used as a source of secondary raw material.

Scrap from household equipment

According to the 1996 'Study on the Recycling of Metal Wastes', approximately 103 000 refrigerators, 65 000 air-conditioning units, 4 800 washing machines and 77 000 electrical ovens have been imported into Botswana in the period between 1985 and 1995 (NCS/GTZ, 1996). Bearing in mind an average lifetime of 15 years as well as the fact that import rates of household equipment were very low 10 to 15 years ago, not many devices are expected to become scrap within the next few years. The reasons advanced for this scenario are that people tend to utilise the equipment for other multiple purposes such as cupboards and storage containers at the end of its lifespan. Apart from exposing the cooling liquid of broken refrigerators to the atmosphere, no major harm or increasing amounts of waste are expected to come from household equipments.

Scrap from electronic devices

According to the statistical data provided by CSO, Botswana has imported in the last decade some 58 000 television sets, 400.000 radios, tape recorders and approximately 32 000 computers (NCS/GTZ, 1996). It has also been reported that there are no scrap from electronic devices that were discovered at the dumpsites. The only notable amount of electronic scrap may come from government offices, parastatals and business companies. There have been reports of storerooms and cupboards full of old computers and electronic equipment.

Scrap from cans

The consumption of canned food generates 6 500 tons of metal scrap each year (NCS/GTZ, 1996). Four major types of cans are beverage cans filled in Botswana (Kgalagadi Breweries) and those imported with content (soft drinks, cider) and preserve cans, filled in Botswana (Beef from BMC) and imported with content (mainly vegetables and fruits). Beverage cans account for 90% of all cans consumed in the country. On the contrary to consumer goods with a long lifespan such as refrigerators and television sets, the generation of scrap and waste from canned food takes place immediately after consumption. Thus to estimate the can scrap generation in a given time, the consumption of can has to be estimated.

Battery and tyre waste

Tyres

Tyre waste refers to tyres or tyre material that is not used and is disposed of as waste (NCS/GTZ, 1999). A scrap tyre is defined as a 'tyre that can no longer be used for its original purpose' but a repairable tyre is not a scrap tyre. The generation of tyre waste is related to vehicle per capita and place of use. The quantities of tyres used at any time are proportional to the quantities of vehicles that use them and therefore the waste generated. By the year 1999, about 63% of all the vehicles were registered in the main towns with Gaborone being dominant (43%) followed by Francistown (14%) and Lobatse (7%). Close to 60% of all vehicles in the country are registered in Gaborone or within a 70km radius of Gaborone. It is projected that in 2005 there would be 47 400 registered passenger cars, 65 000 light delivery vehicles and 35 000 trucks. Approximately 832 600 tyres will be required for all these vehicles. Out of the 832 600 tyres required, 306 000 will go to scrap.

The Government of Botswana is major consumer of tyres and as a strategy and a way forward, she must seriously consider using retreaded tyres whenever possible in order to reduce the load of tyres going to the landfills. It is noted that now and then there are accidental fires on tyres and as a result toxic gases are released to the atmosphere and they could propose very health problems to communities living close to the landfills.

Batteries

Batteries are classified into two main groups; primary and secondary dry cell batteries and primary lead batteries. Primary and secondary dry cell batteries are used in portable household equipment such as radios, torches, and other portable electrical equipment. Primary lead acid batteries are used mainly in vehicles, solar power storage systems and other industrial equipment. Lead acid waste batteries are linked to the number vehicles that are registered in Botswana. The vehicles are increasing on annual basis at a rate of 10-15% per annum. Thus the number of waste lead acid batteries is also increasing. It is estimated that by the end of 2002, 980 tonnes of scrap lead acid batteries will be produced and in 2005 there would be 1079 tonnes. In Botswana, almost all household dry cell batteries are disposed with domestic waste, that is, in the towns and villages, waste ends up at the landfill, but in those villages without landfills, it is disposed indiscriminately.

Oil containing wastes

At the moment it is not profitable to collect and reprocess waste oil with few disposal options (Mphusu, 1995). The most practicable options of managing oil waste in Botswana are burning on-site, burning as fuel (blended with coal and furnace fuel) and dust suppression on roads. The dumping of oil is the cheapest but has the highest environmental costs, re-refining is the costliest and affected by low crude prices, burning oil as fuel includes collection and transport which carry high cost implications. Therefore burning as waste is regarded as the most cost effective.

Various organisations have taken the problem of contamination of the environment as part of their corporate responsibility and installed skimming devices and storm water treatment such as rope skimmers to recover oil from storm water and effluent in order to prevent damage to the environment.

Paper, glass and packaging waste

Kgalagadi Breweries and Kgalagadi Beverages packs are cans and returnable bottles for beer and soft Drinks; KBL does not recycle but it reuses bottles. The bottles that are broken during bottling process are taken to RSA for recycling. Packaging paper used goes to Waste Paper Recycling Botswana. KBL has several on going projects on Waste Management including: Minimising wastewater usage in the plant.

Clinical Waste Management

The current storage of clinical waste is unsatisfactory as in some cases clinical waste containers are inadequate or inappropriate. At times some sharps boxes being used in the private sector do not have non-return flaps and are not strong enough. In some cases the bags used for clinical waste are too large to be fed into the incinerator being used, as a result they split and spill their contents, presenting a risk of injury or infection. Handling of bags with clinical waste is reported to be chaotic, being left to ancillary staff members with little or no adequate training.

Health posts normally dispose of their clinical waste by burning. Disposal of sharps containers is by incineration or open burning, and in some instances the containers are sent to the landfill without treatment. Mercury from broken thermometers is collected and returned to some of the larger hospitals. In some clinics broken thermometers are incinerated, creating emissions of dangerous mercury. Most hospitals and clinics make an attempt to segregate potentially infectious wastes from general wastes-some with more success than others rarely with 100% effectiveness. Failure to segregate clinical waste from general waste observed in some hospitals has resulted in mixed waste ultimately finding its way to the landfills

Metal wastes

There are currently two types of recycling activities for metal scrap in Botswana:

Use of functioning components from scrap as spare parts

Not all components of scrap vehicles, machines and other equipment are useless. Still functioning components are used as spare parts for other devices of the same type. Commercially operating car breaking companies are reported to buy motor vehicles that have had major accidents from insurance companies or from private owners to utilize undamaged parts. The undamaged parts are removed from the wreck and sold as second hand spare parts. The refrigeration firms use certain spares from old refrigerators (e.g. compressors) to repair others. It is also reported that cooling liquids from old refrigerators or air conditioning units are extracted to make use of the liquid in other units.

Different materials are recovered and sold or processed as secondary raw material.

Because of their high unit prices, metals such as aluminium, copper, and copper alloys, lead and zinc are recovered and sold to a scrap dealer or metal workshop. Radiators Botswana (Pty) Ltd. in Francistown buys copper and aluminium scrap. Collect-a-Can (Pty) Ltd. takes care of metal scrap from beverage cans. Entrepreneurs and schools are assisted to establish their can collection operations. SEGWANA as the distributor of over 90% of all beverage cans assists Collect-a-Can by transporting can scrap from all over the country to Gaborone.

Scrapcor (Pty) Ltd in Gaborone buys all sorts of metal scrap in large quantities from big companies and Parastatals like Botswana Power Corporation and Botswana Defence Force as well as from private individuals. They scrap is cut into pieces and sorted into different materials and shipped to South Africa.

Battery and Tyre waste

Scrap tyres

Tyre Services (Pty) Ltd. and Botswana Tyre Corporation (Pty) Ltd. are the two Corporations with retreading plants in Gaborone and Francistown. Tyre Services buys around 50 to100 tyres per month at P120-P200 per tyre for truck tyres. Retreading is mainly on truck tyres and very little retreading is done on car and L D V. Waste from the operation that includes buffing dust from the removal of the old tread and scrap tyres (non-retreadable), is landfilled. The buffing dust is sold in South Africa where it fetches P320.00/tonne.

Botswana Tyre Services has a retreading plant in Gaborone and collecting and distributing outlets in Palapye, Francistown and Maun. The retreading plant can treat up to 75 tyres a day and is currently not working at full capacity. As with the Tyre Services, retreading is mainly on truck tyres. Scrap tyres that are still in a usable condition are sold at most tyre outlets. The low-income section of the society are said to be the main consumers.

Batteries

There are at present two forms of lead acid battery recycling activities in Botswana namely trade-ins and buying of old batteries. Trade-ins is mainly by battery distributors while some scrap metal dealers buy from the general public. The trade-ins and buying old batteries take place only in the main towns. In the smaller towns and villages old batteries are disposed of by throwing in the bush or landfilling. Almost 100% of used dry cell batteries are either landfilled or disposed indiscriminately. The old lead batteries are exported to South Africa for recovery of the lead.

Transboundary movement of waste

Waste could be transported from one place to another crossing various kinds of boundaries that include geological, environmental and political boundaries. As many nations are inundated with different types of waste and cannot keep it any longer within the environment, then they transport it to other countries either for a price or illegally.

There is growing evidence of illegal shipments of hazardous waste across international borders. For example some toxic waste was buried in a village in Nigeria. The waste degraded the containers and was released to the environment. The results were catastrophic leading to some very serious pollution problems like affecting the health of the community and others losing their lives (Miller, 1992). Botswana has to guard against being used as a dumping ground of hazardous waste as this will pose threats to the environment

Most of the hazardous waste produced by MDCs is dumped in the LDCs. The MDCs use their economic and political powers to encourage the illegal trade of dumping hazardous waste. The illegal trade of disposing hazardous waste is a multi-million dollar business venture. It therefore calls on the developing world to be vigilant against the prom of hazardous waste.

Botswana is a signatory to the Basel Convention that regulates tranboundary movement of hazardous waste and their disposal. All movement of waste through the country is subject to the controls laid down in this convention. Documentation relating to allsuch movements have to be notified prior to their movement taking place to the DSWM as well as a movement document detailing the goods being transferred as well as movement document detailing the goods being transferred as well as the transport and packing used. The Basel Convention is incorporated in to the country's Waste Management Act of 1998.

Impacts of waste on the environment

There is presently no information that has been collected on the effect of hazardous waste in Botswana. However, as noted in the subsequent sections, the studies that have been carried out identify some of the likely environmental problems as:

- Hospital wastes causing injury, infection and death, either by deficient disposal methodologies at poorly controlled sites or by inadequate incineration or open burning, which may release dangerous compounds into the environment.
- Chemical wastes from factories contaminating water and making it unfit for drinking or other use.
- Gas generated at disposal sites causing explosions and deaths.
- Household waste, if deposited on unsuitable sites, contaminating water.
- Waste oils, especially from the transport sector, leading to pollution of underground and water surfaces.
- Poorly controlled disposal sites presenting a risk of injury to those who work there or those who enter the area for the purpose of scavenging.

Other studies and reports also indicate that most pit latrines are not designed and constructed up to the appropriate standards for effective treatment of waste and control of pollution. Some of the problems associated with the pit latrines include:

- Poor siting, that is, the pit latrine is located in an area where it contributes to groundwater pollution. For example, many boreholes have been abandoned in most settlements due to water pollution by nitrates. This has been in most cases attributed to pit latrines. An example is the contamination of Ramotswa well-field by seepage of pollutants from the pit latrines.
- Poor design and construction practices, where for instance, the pit latrine is not lined in a porous environment, thus leading to pollution as elaborated above.

For the more affluent sections of the community on-site disposal consist of septic tanks with a soak away systems. Problems elaborated earlier with regards to pit latrines are also applicable for the septic tank mode. In this case, such problems are exacerbated by the use of water in flushing and transporting the pollutants to the water resource.

Legal aspects of waste management

The Botswana Waste Management Strategy states that waste management in Botswana will be undertaken in a manner that adequately protects human health and the environment consistent with the affordability and available expertise of the country. It incorporates the following principles:

- Principle of Prevention: environmental pollution must be minimised as far as possible measures should be taken before damage occurs
- Polluter Pays Principle: Costs of preventing, eliminating, or compensating for damage to the environment must be borne by the party responsible
- Principle of Co-operation**:** co-operation amongst all social groups is necessary in order to solve environmental problems.

Botswana’s waste management objectives therefore consist of:

- Minimising and reducing waste in industry, commerce and private households.
- Maximising environmentally sound waste reuse/recycling
- Promoting environmentally sound waste collection, treatment and disposal

The other relevant pieces of legislation include the Public Health Act and the Atmospheric Act. The Public Health Act of 1981 that empowers Health Officers to require ‘nuisance’ to be ‘remedied’. Nuisance is, inter alia, defined as:

- A rubbish bin, refuse-pit in such a state to be offensive or to be injurious or dangerous to health
- Any accumulation or deposit of refuse,….or any other matter which is offensive or which is injurious or dangerous to health’

The Atmospheric Pollution (Prevention) Act of 1971 is also relevant given that some of the clinical waste is treated by means of incineration.

The Act defines an industrial process as ‘any process prescribed by the Minister which is involved in any trade, occupation or manufacture devoted to the production by various means, including any process involved in metallurgical operations, operations for the generation of power, and a waste management facility and unlikely that it would include a health care facility. The Minister has the power to prescribe the processes that shall be industrial processes under the act, but it would appear that they would be ‘Industrial processes’.

The Act has the power to require registration of **industrial processes** within **controlled areas** that are capable of emitting 'objectionable matter.' Registration is subject to satisfying the Air Pollution Control Officer that the Best Practicable Means of preventing or reducing such emission is employed. The plant producing emissions is required to be 'properly operated and maintained at all times.' There is no provision for the application of any specific emission criteria. Due allowance may be made for the 'unavoidable' emissions during plant start up. These Acts serve as a strong foundation for introduction of legislation requiring clinical waste to be handled according to a Code of Practice.

Waste Management Strategies And Future Scenarios

Waste oils

The Department of Waste Management and Sanitation is considering a proposal or strategy for waste oil handling in Botswana. The strategy addresses short term (1-2years), medium term (2-5years) and long term (5-10 years) issues with regards to waste oil. Short-term waste handling proposal suggests that the current collection, storage and back hauling should be continued. Environmentally acceptable disposal measures should also be encouraged. These include use of oil in the following activities: timber preservation, fire fighting, concrete product mould release and direct combustion as a substitute fuel.

The medium term strategy recommends that the Botswana Oil Industry Association set up a national collection depot that is capable of providing a fuel product that has been centrifuged and filtered to remove insoluble impurities. Gaborone or Lobatse are suggested cities where the depot could be built. In addition the strategy, suggests that the Botswana Oil Industry Association negotiates to supply substitute fuel to consumers such as Lobatse Clay Works and Debswana Diamonds.

The long-term strategy recommends that a cement kiln be constructed in Botswana. Cement kilns are generally accepted as an environmentally sound technology for used oil disposal. Botswana Development Corporation has plans to construct a cement kiln in the Morupule-Palapye area. It has to be ensured that the kiln will be able to waste oil and that there is consistent supply of high used oil in order to ensure viability.

Tyre wastes

To address the tyre waste in future, the Department of Sanitation and Waste Management have suggested several actions through studies that have been carried out. These include the following:

- Local authorities setting up scrap tyre collection points at landfill sites and at the tyre distribution points;
- Conduct awareness campaigns on how best to utilise tyres, that is how driving styles affect tyres, use of correct tyres, pressure, etc.
- Marketing of products produced from waste tyres
- Government interventions, that is carrying research on the best ways of handling tyre wastes, offering technical advise and institutional support, setting up of tyre cutting operations at landfill sites, and signing of appropriate international conventions

The implementation of these actions will ensure that tyre wastes are managed at acceptable levels.

Batteries

The strategies that are being developed address mostly the lead acid batteries waste. These include:

- The need to introduce a levy and possibly subsidy to encourage the current batteries dumped and in circulation The dry cell batteries waste is expected to decrease as more people tend to use electricity and solar power. The dry batteries waste when compared to the lead acid batteries waste will be insignificant in the long term. However at present, almost 100% of dry cells used in Botswana are not rechargeable and are discarded as waste.
- Conduct awareness campaigns on the importance of recovery and recycling of lead acid
- The need for Government to construct a recycling and recovery centre for waste batteries. The centre has to accept all types of scrap lead batteries, either full or already emptied. Payment at agreed rates should be made to the individuals and companies that will deliver to the centre.

Metal Wastes

The management strategies that can be implemented to address the metal waste issues will be largely centred on the installation of local recycling centres and government intervention. A study on metal wastes recommends that recycling centres be established with the assistance of Government in Gaborone, Francistown, Lobatse and Selebi-Phikwe. The rational of establishing the centres in these four areas is that 90-95% of the registered vehicles are in these centres and also the greater bulk of households/electronic equipment are in these areas. The centres are expected to operate at market levels involving all stakeholders, that is scrap dealers, car breakers, etc. At present 52% of scrap from beverage and preserve is collected by Collect-A-Can (Pty), Ltd Botswana.

A government intervention as a strategy is to ensure that enabling conditions for the management of metal wastes are created. The interventions should include making the recovery and recycling compulsory especially of scrap from beverages and food industries and encouraging private sector companies to establish recycling plants for electronic devices. The private sector companies have a role to play in the waste from electronic devices given that small quantities of waste are produced.

Paper, Glass, Packaging Waste

Paper, glass and packaging waste is expected to increase as the economic activities improve. It is projected that the paper waste will increase from 25,000 tonnes in 1996 to 59,000 tonnes in 2007. About of 50% of paper waste is for disposal.

Plastic waste will increase from 10800 tonnes to 29000 tonnes in 2007. Out of the 29000 tonnes only 35% is likely to be recovered. The remaining 19000 tonnes will either be land filled or indiscriminately dumped.

Consumption of glass will reach approximately 29100 tonnes by 2007. Out of this, 36% will be returnable bottles and the remainder will be glass waste (i.e. 20,000 tonnes).

The strategies that can be implemented to address the glass, paper and packaging include:

- Public awareness campaigns on reduction and reuse of paper, glass and packaging waste
- Training of personnel in central and local Government to supervise and promote recycling
- Ensuring the existence of viable transport systems, appropriate permission or licensing for the transportation of wastes
- Separation of waste at source or landfill sites

Medical wastes

Medical wastes are projected to increase and are expected to be compounded with the increase in the number of people infected HIV/AIDS. The wastes will be generated from the home-based programmes, clinics and hospitals. The strategies that have to be implemented to address the medical should address education of the stakeholders on the risks of handling, storage and disposal of medical wastes.

Awareness campaigns of the risks in handling clinical wastes at all levels including households with home based care programmes; patients, medical staff, administrative personnel and management should be carried out. Clinical waste should be stored in unique identified containers that are clearly labelled on what type of waste is in the container. When the waste is being transported in public it should be done using designated vehicles that have lidded leak proof containers.

Waste should be disposed in incinerators at hospitals. A study on clinical wastes recommends that centralised incineration facilities should be introduced in major urban areas. Households with home based care programmes, medical and dental practitioners should be offered the facility to take sharps containers and clinical waste to the nearest incinerator. This also applies to the veterinary and x-ray wastes. They should set-up veterinary and x-ray recovery units for the waste that they generate.

Chemical management

Overview of chemical management in Botswana

There are industries in Botswana that make use of chemicals in the manufacturing and production processes. These include diamond mining, chemical products, leather and leather products, printing and publishing, rubber and rubber products, spinning weaving and furnishing, tanning and dressing of leather manufacturers, wood and wood products, ceramic products and paper and products. All the chemicals that used in these industries are imported. Table 1 shows the products of the chemical and allied industries that were imported in 1998.

Table 1: Products imported in 1998

Products Imported	Quantity In Kilogrammes
Inorganic chemicals; compounds of precious and rare metals	2,310,376
Organic chemicals	1,477,921
Pharmaceutical products	3,211,372
Fertilisers	7,144,844
Tanning or dyeing extracts; tanning and their derivates	5,199,712
Essential oils and resinoids, perfumery, cosmetic or toilet	4,526,778
Soap organic surface active agents, washing preps	4,155,951
Albuminoidal substances; modified starches; glues; enzymes	1,610,739
Explosives, pyrothenic products; matches; phyrophoric alloys	4,006,495
Photographic or cinematographic goods	348,383
Miscellaneous chemicals	6,120,951
Total in kilograms	40,113,522

The Community Health Division in Ministry of Health in association with Danish Toxicology Centre VKI Danish Environmental Protection Agency in 1999 performed risks assessments with regards to health and the environment of chemicals used in Botswana the assessments ranked the chemicals into three categories, that is:

- High risk chemicals
- Low risk chemicals
- Chemicals where the assessment was inconclusive because of missing data

High risk chemicals include asbestos, quartz, chalk, cryolite; tar, creosote, pitch coke, bituminous products; BTX compounds; white spirits, solvents and thinners; diesel and petrol fuel, lead, chromium and compounds, CFC compounds, soap, surfactants, pesticides and disinfectants.

Low risk chemicals comprise nickel, aluminium ores; lubrication greases and oils; inorganic chlorine compounds; Iodine, Fluorides, Bromides and their compounds; selenium and compounds; mercury; aluminium, strong inorganic acids and bases, essential oils, tepenes; photographic chemicals; rubber and plastic additives.

Chemicals where the assessment was not conclusive because of absence of data consist of various nitrogen containing compounds, textile dyes, pigments paints, varnishes, putty; printing inks; turpentine oil, pine oil, rosins and resins.

High Risk Chemicals

Mineral Fibres

The mineral fibres that are imported include silica sand, quartz sand and quartz, chalk, asbestos, cryolite and quartz. The volumes that are brought in vary from one year to another. Figure 1 shows the mineral fibres that were imported in 1996 and 1997. Chemical and rubber industry are the main importers of silica sand, quartz sand and quartz. Construction industry and general retailers are the main traders of asbestos. The asbestos is brought in mostly as pipes, ducts and flat and corrugated sheets. A variety of industries import quartz and it is difficult to ascertain what exactly they use the quartz for.

BTX compounds

The BTX compounds are imported into Botswana by trade wholesale and retail dealers (CSO 1998). The compounds include benzene, toluene and xylenes. The volumes that are imported from vary yearly. Table 2 shows the compounds that were imported in 1996 and 1997. Benzene, toluene and xylenes are used mostly as a solvent or thinner in paints, vanishes, lacquers, waxes etc. (DANCED, GOB, 1999).

Figure 1: Mineral fibres imported in 1996 and 1997

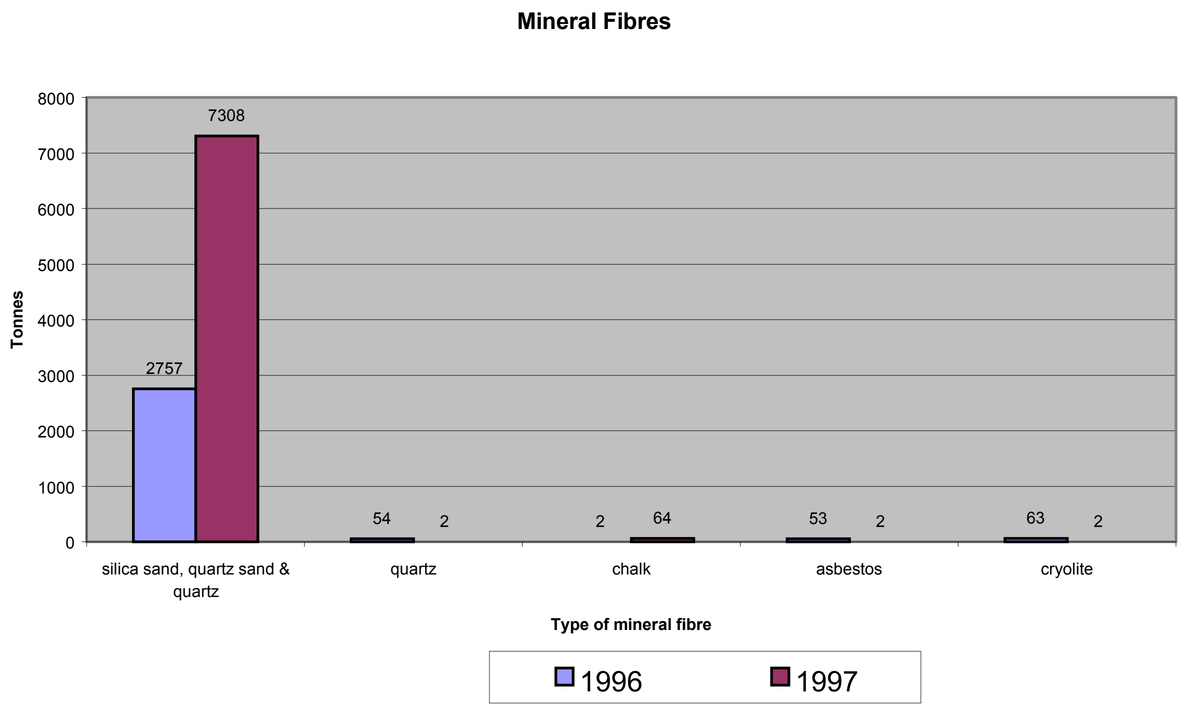

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Table 2: Imported amounts of BTX compounds

Substance	1996 m^3 per annum	1997 m^3 per annum
Benzene	31	34
Toluene	37	64
o-Xylene	4	3
m-Xylene	1	0
Xylene (mixed isomers)	23	27

Petrol and diesel fuels

Large quantities of petrol and diesel are imported to cater for the privately owned and government vehicles (including trucks and heavy vehicle such as trains). In 1997 there were 98,171 registered vehicles. 282,000 m^3 of petrol and 161,000 m^3 of diesel were imported during that year (CSO 1998, DANCED, GOB, 1999). Out of that petrol, 266,000 m^3 was leaded and the remainder was unleaded.

Leaded petrol has at most 0.4 g PB/l and unleaded has 0.015 g/l. This translates to a total of 106 tonnes of lead that were used in that year. The number of vehicles registered has since increased and this invariably has resulted in the increase in the use of petrol and diesel.

White spirits, solvents and thinners

Chemicals industry, wholesalers and dealers import white spirits, solvents and thinners. They use them in the manufacture of paints and degreasing metal handling and processing. The amounts that are imported vary depending on the demands of that particular year. For instance in 1996 and 19997 990 m^3 and 1355 m^3 were imported.

Lead compounds

Lead oxides, lead carbonate and leaded petrol are major types of lead that is imported in Botswana. The issues that relate to leaded petrol have been discussed in the section on petrol and diesel. Lead oxides and carbonates are used mostly as pigments in paints. An average of 200 tonnes of lead oxides are imported per year. About 4.5 and 5.5 tonnes of Lead carbonates were imported in 1996 and 1997 respectively. It is estimated that 0.613 tonnes of lead compounds are emitted to air per annum. A total 5.42 and 1.2025 tonnes are emitted to waste water and soil respectively. The estimations are based on the European Union Technical Guidance Document of 1996.

Chromium compounds

Chromium compounds are used in tannery industries. The Botswana Meat Commission's Tannery is the major user of the compounds. It uses an average of 600 tonnes of chromate per annum. Trade statistics of 1996 show that 3 tonnes of sodium dichromate, 16 tonnes of potassium dichromate and 19 tonnes of pigments and preparations based on chromium were imported. In 1997, 25 tonnes of sodium dichromate and 14 tonnes of pigments and preparations based on chromium were imported. Potassium dichromate was not imported.

CFC compounds

CFCs are used as refrigerants and aerosols pellants and as fire extinguishers. The main refrigerants and aerosols pellants that are utilised include CFC –11, -12 and –502. Halon –1211 and –1301 are used in fire extinguishers. As per the requirement of the Montreal Protocol 6 tonnes of CFCs are used per annum. It is anticipated that the use of CFCs should have stopped at the end of 2001.

Soap, shampoos and surfactants

Soaps and shampoos are imported to cater for the hygiene and cleaning requirements for households, industries, hospitals, schools, etc. The tonnes and volumes that are imported are determined by the demand and a result they vary yearly. Table 3 shows the tonnage and volumes that were imported in 1996 and 1997.

Table 3: Import of soaps, shampoos and surfactants

Chemical	Import 1996 (tonnes/year)	Import 1997 (tonnes/year)
Soaps	7425	9035
Surfactants	1772	1883
Shampoos	150*	521*

* $m^{3/}$ year

There is no detailed information on the types of surfactants and their chemical identity that are imported. It is assumed that there are no regulations on what type of surfactants one has to import.

Pesticides

The pesticides are imported include insecticides, fungicides, herbicides and rodenticides. The Pest Management Section (PMS) in the Ministry of Agriculture uses significant amounts of pesticides when handling outbreaks of locusts, armyworm and quelea birds. Table 5 shows the type of pesticides that PMS use. Individual farmers also use the same pesticides as PMS.

Table 4: Pesticides used by the Pest Management Section

Pesticide	Pest controlled	Estimated volume used (litres/year)
Fenitrothion	Locusts and armyworm	25000
Deltramethrin	Locusts and armyworm	1000
Alphamethrin	Locusts and armyworm	50
Fenithion	Quelea birds	2500
Flucomafen	Rodents	No data
Difenacom	Rodents	No data

Aluminiumphosphate is used for large-scale storage of grain. Pirimiphosmethyl, Methacrifos and Malathion are used for small-scale storage of grain.

There are internationally banned or severely restricted pesticides that are used in Botswana. These include Aldrin, Hexachlorobenzene (BHC), Chlorade, Ethylene dibromide and Lindane.

Low Risk chemicals

Nickel, Aluminium and Lead Ores

Nickel ores are imported by BCL Limited. BCL processes the imported ores along the ores that are mined locally. In 1997, 433 tonnes of nickel ores were imported and these were processed alongside the 2 million tonnes of ore that are excavated annually by BCL (DANCED, GOB, 1999). Generally in nickel processing, 50000 tonnes of matte are produced and 300 tonnes of butyl xanthate are used annually.

Construction companies, individuals and wholesalers generally bring in aluminium and lead ores. In 1997, construction companies and wholesale/retail traders imported 435 and 108 tonnes of lead respectively. A wholesale/retail dealer imported 28 tonnes of aluminium ore in the same year (DANCED, GOB, 1999).

Tar and creosote

Tar and related chemicals are largely used in the tarring of roads. A limited amount is used in roofing and flooring. 18,937 and 20, 309 tonnes were brought into Botswana in 1996 and 1997 respectively. Wood and wooden industries are the largest users of creosote. They use it in protecting wood. In 1996 and 1997 they imported 343 and 311 tonnes respectively (DANCED, GOB, 1999).

Lubrication greases and oils

Lubricating grease and oils are used mainly by automotive, machinery and other industries using grease for machinery. About 13760m^3 and 10600 m^3 were imported in 1996 and 1997 respectively.

Inorganic chlorine compounds

Inorganic chlorine compounds are used in the following industries:

- Diamond mining
- Chemicals and rubber industries
- Metal industry
- Textiles

Diamond mining uses 27-37% of the inorganic chlorine compounds that are imported. The inorganic chlorine compounds that are imported include Magnesium chloride, chlorine, calcium hypochlorite and hydrogen chloride. It is estimated that 1118 tonnes were imported in 1996 and 1588 tonnes in 1997. Magnesium chloride is the main part of the imported chlorides. Its main uses comprises the following among others: source of magnesium metal, chemical intermediate for magnesium oxychloride in cement; catalyst; flocculating agent, agent in fire extinguishers, agent in textile manufacturing, fire proofing agent for wood, component of refrigerating brines, in disinfectants.

Chlorine is used in bleaching fabric, manufacturing of synthetic rubber and plastics, purifying water, disinfection, water purification, processing of meat, vegetables and fruits. In addition it is also used as an agent to control biofouling in cooling systems, antifreeze, refrigerants, disinfections in laundries and dishwater.

Calcium hypochlorite is used as sanister in swimming pools, deodorant, fungicide, bleaching agent in textiles and component of toilet sanister. Hydrogen chloride is used in industries such as food processing (for example hydrolysing of starch and proteins in the preparation of various food products); pickling and cleaning of metal products, breweries, manufacturing of paints, dyes and dyestuffs, leather tanning, textile and rubber

Iodine, Fluorides, Bromides and their compounds

Iodine, Fluorides, Bromides and their compounds are used mainly in insectides; preservation of wood; breweries as antiseptic; plastic and rubber manufacturing; diamond mining and metal production industry.

Selenium and selenium compounds

Selenium and selenium compounds are used in chemical and rubber industry in Botswana. In 1996 and 1997 the industries imported 19 and 20 tonnes respectively. In the chemical industry the compounds are used in several chemical processes that include dehydrogenation of organic compounds and being an oxidising agent in the manufacture of drugs and other chemical products.

Mercury

Mercury is not imported in large quantities. About 33 tonnes were imported in 1996 and 1997 the import were negligible. The group of trades known as manufactures imports mercury.

Aluminium and aluminium compounds

Chemical and rubber industry, freehold farmers and manufactures of vegetable and animal fat/oil are main users of aluminium and aluminium compounds. It is estimated that 18 tonnes were imported in 1996 and 2 tonnes in 1997 respectively.

Strong inorganic acids and bases

The main strong acids that are imported are sodium hydroxide, sulphuric acid and hydrochloric acid. Sodium hydroxide and sulphuric acid are used in the quarrying, mining chemical and rubber industries. Hydrochloric acid is used in chemical and rubber industry. Table 5 shows imports of 1996 and 1997

Table 5: Strong acids and bases that are imported to Botswana in large amounts

Substance	Import 1996 (Tonnes/Year)	Import 1997 (Tonnes/Year)
Sodium hydroxide	3727	1307
Sulphuric acid	788	993
Hydrochloric acid	134	81

Essential oils, tepenes

Essential oils comprise oils of citrus fruit and oils from other vegetable origin as of mints and lavandin. Chemical and rubber industry imports most of these oils. The industries use them in the manufacture of soaps. Retailers and wholesalers also import the oils and shampoos products. In 1996 and 1997 109 and 142 were imported respectively.

Photographic chemicals

The photographic industry imports photographic emulsions. The emulsions are used in the development of photographic films. The most commonly used chemicals include N, N-diethyl –p-phenylenediamine, α-naphthol, Hydroquidon, p-methylaminophenol, Sodium sulfite, Borax, Potassium bromide and Benzotriazole. About 33 tonnes and 111 tonnes of photographic emulsions were imported in 1996 and 1997 respectively.

Rubber and plastic additives

Rubber and plastic additives are imported either by the chemical industry or wholesalers and retailers. Rubber accelerators, pasticisers and anti-oxidising preparations and other compound stabilisers are the main products that are imported. A total of 55 tonnes of rubber and plastics additives were imported in 1997 and 43 tonnes in 1997.

Chemical management in institutions and industries in Botswana

This section looks at chemical management in factories, farms and distributory sectors. The discussion is anchored upon the findings of a ''Baseline Study on Chemical Safety Awareness'' undertaken by Community Health Services-Environmental Health Unit (Ministry of Health). The survey was undertaken on 54 establishments (Factories/Farms/Distributors). Amongst the parameters considered were; job health and safety analysis, the training of workers in chemical safety and storage of chemicals both at home and the workplace.

Natural and synthetic chemicals are currently utilised in large and increasing amounts in Botswana. Most chemicals, used regularly and in large amounts cause no or only a limited risk to human health and the environment. Nevertheless, the use of some types of chemicals causes or has the potential to cause unacceptable and irreversible harm, thus the use of such chemicals needs to be managed. Botswana at present does not have legal obligation for the control of emissions from factories and therefore really no legal back-up for demanding information from the industries.

Chemical Management in various working environments

Casual labourers' working conditions

Casual labourers, both males and females, generally work in excessive conditions of chemical exposure without appropriate clothing or access to information. In some of the cases some females work with their small children and are somewhat unaware of the hazard caused by the nature of work. The education level of most of the workers is low therefore the appreciation of safety signs, which are often inadequate (Table 6) and in most cases written in English is very minimal. This undermines the management efforts towards improving safety in the workplace.

Table 6: Safety and Hazard Signage

Scenario	Yes	No	Total
Safety signage on premises	33%	67%	100%
Safety signage on containers	65%	35%	100%
Safety signage on the equipment	31%	69%	100%

Emergencies and Accidents

Out of the 54 establishments visited during the study, only 48% of them had emergency facilities like fire fighting equipment, emergency doors, collection points in case of fire and emergency drills. Failure to provide protective clothing, adequate information with regards to safety and lack of emergency plans and facilities expose employees to chemical accidents. Thirty-five percent of the respondents have had or have seen their colleagues involved in accidents in factories. The accidents have been categorised below (Table 7)

Table 7: Chemical Accidents

Accident	%
Skin Contact	40
Eye contact	24
Inhalation	29
Swallowing	6
Total	100

Disposal of Chemical Waste

Chemical waste is a major predicament in factories as there is no specific method for disposing it off. The current practice in big corporations is to create ponds where natural sedimentation takes place. The smaller firms have resorted to burning or dumping and burying at their local dumpsite. Floor washings, that may contain chemical powders and spills, are channelled to the municipal drainage systems. There is also a habit in some factories to sell to their employees and the general public empty chemical containers. Some members of the public do not have adequate knowledge of the chemicals and are quite unconscious of the dangers involved. Such empty containers have been used amongst other things for storing; toothbrushes, paraffin, and foodstuffs.

Using paint containers for plants may be harmless but when such containers are used for water and foodstuffs it reveals inherent lack of knowledge on safety measures. There are of course other factories that return the containers and chemical wastes such as used up engine oils and other liquid wastes to the general suppliers. The contention is that chemical waste disposal is a very thorny issue for which solution must be sought immediately.

Storage of Chemicals

Factories in Botswana use various ways to store chemicals as shown in Table 8.

Table 8: Storage of Chemicals

Scenario	Yes (%)	No (%)	Total (%)
Store on the floor	56	44	100
Store on shelves	43	57	100
Store on lockers	59	41	100

With the exception of the mines, power plants and multinationals where every care has been taken to abide by the international standards of storage of chemicals, inconsiderable attempt has been made by most of the factories in this issue. Chemicals stored on the floor or shelves without any apparent order pose a serious danger to the employees working in the area. The same is also true for improper storage of domestic chemicals, the following discussion narrows down to the general public awareness with regard to the dangers associated with improper chemical handling.

General public

In general, the public at large lacks sufficient knowledge on handling the chemical products that they obtain from the shelves. It must be noted, however that these chemicals can actually pose harm when not properly handled. These products do contain harmful chemicals, which when taken in or not properly used do cause damage to the human body. Examples of such chemicals are insecticides, herbicides and disinfectants. The general public is not in the habit of using protective clothing while spraying since in most cases the effects are not felt immediately. Some members of the public indiscriminately purchase non-prescription drugs available off the shelves of pharmacies. Some of such products like laxatives and aspirins are habit forming leading to addiction if not regulated

Impacts of chemicals on the Environment

This discussion in this section is based on the findings of the 1999 study on 'Risks to health and the environment of chemicals used in Botswana' undertaken by DANCED and Community Health Services Division-Environmental Health Unit (Ministry of Health). The danger that a chemical exposes to human health and the environment are based on the inherent properties of the chemical. The intrinsic properties determine the potential of a chemical for mobility, transformation, uptake and toxic effects (Ministry of Health, 1999). The following elements were considered in describing the actual potential risk of a chemical:

- Human Health Hazard
- Environmental Hazard
- Used Amount
- Use Pattern

The current EU classification criteria were used in determining the intrinsic hazards of chemicals. The reason being that there is fairly large amount of regularly used chemical substances already evaluated, the information is readily available in the EU ''List of Dangerous Substances".

The study sought to identify health hazards for three groups of the population as to the possibilities of:

- workplace exposure,
- general population exposure and
- consumer exposure.

Data on which company is importing what specific chemicals to Botswana was inaccessible to the study. This made the effort of establishing the use patterns of the products complex. In addition, it was not possible to acquire information on the number of workforce in each trade, which makes it difficult to undertake a quantitative assessment of number of exposed workers. At all stages of the priority setting and the risk assessment, some of the chemicals were not assessed due to lack of data. Depending on the volumes used, they might have been set aside for later assessment.

The study conducted a gross overview of the hazards of the imported chemicals. The study finds that most hazardous chemicals constitute about 50% of the total volume of imported chemicals and this is true for both chemicals that are health and environment hazards. Health hazardous chemicals constitute about one third of the imported amount while non-hazardous are about one sixth. About half of the imported volume are of no or low hazards to the environment and about 17% are of no or low health hazard. Only about 1-2% of the imported volume is of uncertain hazards. The important data on the most hazardous chemicals shows that the main volumes of hazardous chemicals are petrol (51-54% of the hazardous chemicals). The remaining covers a wide range of other types of chemicals with various uses.

Legal aspects of chemical management

Factories' Act

The main piece of legislation in the management of chemicals in Botswana is the Factories Act. The Act covers the following:

- An employer who is occupying a factory within the meaning of the Factories Act should be aware of the detailed rules laid down by the Act. The aim of the Act is to protect the safety, health and welfare of persons employed in the factories.

The requirements include the following:

- All factories must be registered with the Chief Inspector of Factories. Special safety rules deal with fencing of dangerous machinery, training and supervision of inexperienced workers, care of hoists and inflammable substances, steam boilers, prevention of fires, the extraction of dangerous fumes, the provision of protective clothing and appliances.
- Provision must be made for the supply of drinking water, washing facilities, and first aid facilities
- Accidents causing the death of an employee, the disability of the employee from earning wages for

three days or more and certain dangerous occurrences must be reported immediately to the Chief Inspector of Factories.

- Any occurrence of certain listed industrial diseases must be similarly notified.
- Issues such as cleanliness, overcrowding, ventilation, lighting, and drainage of floors and toilet facilities are dealt with under sections 13,14, 15 and 16 of the factories act. The Act also provides specific and detailed regulations and volatile paints under statutory Instruments 55, 1974

It is worth noting that the Factories Act does not distinctively and clearly address issues relating to the handling of dangerous chemicals. While the law deals sufficiently with mechanical machinery, dangerous fumes and inflammable substances, it is very silent on the subject of hazardous chemicals.

Chemical management strategies and future scenarios

For effective transport, storage and management of chemicals, the Government of Botswana should adopt a national action plan on chemicals and the plan should comprise all aspects on management of chemicals (Carl Bro a/s, 2001). Specific recommendations on how to handle chemicals have been made at Government, Ministerial and Unit level.

Government Level

The recommendations have been made as follows:

- That the Government of Botswana through the Ministry of Health, adopts a national action plan on chemicals.

The action plan should compromise all aspects of chemicals that are marketed, i.e. manufacture, importation, transport, marketing, use and disposal of chemicals. This pertains to requirements in connection with issuing of licences to industries, limit values for the working environment and for quality standards for chemicals in the environment.

- The action plan should describe the main activities to be conducted regarding chemicals management within the next 5 years The action plan should be adjusted to the NDP cycles or even merged with NDP.
- The action plan should be informed by the activities and findings of the project "Support to Management of Chemical Substances" funded by DANCED for the period July 1998-June 2001.

Ministerial Level

Carl Bro a/s (2001) recommended that the work on chemical substances and products bill and the work on standards for safety data sheets and on classification and labelling be finished as quickly as possible.

Regarding future legislation the following recommendations were made:

Table 9: Chemicals in Botswana, their possible human and environmental pacts

Chemical Substance	Human Health	Environmental Hazard
Asbestos, quartz, chalk, cryolite	Asbestos dust may cause cancer in humans by inhalation. Occupational exposure is likely where asbestos-containing products are used, e.g. in the construction sector. Use of asbestos in banned in the EU. According to the Department of Mines dust is a general problem in Botswana due to the dry climate and soil conditions. This is exacerbated by the fact that dust prevention is not common on workplaces. Silica and quartz sand also constitutes a risk to the workers, in case the respirable components of the sand is inhaled.	The substances, asbestos, quartz, chalk, are not considered as dangerous for the environment. Cryolite is classified as dangerous for the environment with the following risk phrases: 'toxic to aquatic organisms' and 'may cause long term adverse effects in the aquatic environment.' However the risk of effects to organisms in the aquatic or terrestrial environment is considered as negligible.
Ores of Nickel, aluminium and lead (Ni, Al, Pb)	Ores of Nickel (Ni), Aluminium (Al) and Led are all toxic metals, related with human health hazards. Nickel is a respiratory tract carcinogen in workers in the nickel-refining industry. Allergic contact dermatitis is common among persons in the general population. Aluminium appears to be poorly absorbed	Nickel, aluminium and lead are toxic to organisms in terrestrial and aquatic environments. The mining industry releases significant amounts of these substances.

	in humans. Among retired workers exposed to aluminium flake powders, the calculated half-lives were between 0.7 and 8 years. One of the major risks connected to exposure to lead is toxicity to the nervous system .	
Tar, Creosote, pitch, pitch coke, bituminous products	Coal tar is used for tarring of roads and may cause cancer in humans. Workers occupied with road construction are highly exposed. Creosote may cause cancer in humans. High exposure levels are likely in wood preservation factories.	Coal tar and creosote contain substances that are highly toxic in the environment. Environmental exposure is probably high at road construction sites and at wood preservation facilities.
Benzene, toluene and xylenes (BTX)	High exposures to BTX as well as other solvents are common in the work environment in Botswana. Also the general population is exposed through petrol, domestic use of solvents.	BTX compounds degrade relatively quickly. Ground water pollution is a risk where solvents are spilled on soil.
Petrol (gasoline) and fuel oils	Petrol and diesel are probably carcinogenic to humans. The general exposure potential for workers and the public is high.	Pollution of soil and groundwater near filling stations is probably widespread. Petrol and diesel exhaust contributes to the general deterioration of the environment particularly in cities.
White Spirits, Solvents, thinners, etc	The population at large is expose through the use of solvents. Exposure is also common in the workplace.	Although this group of substances contain toxic and not readily degradable compounds the environmental impact is assumed to be limited.
Inorganic Chlorine compounds	Under normal use conditions the risk of human health effects in the work environment is low.	Only limited and local environmental effects are expected
Other halogens (I, F, Br) and their compounds	Exposure to toxic compounds probably occurs in the work environment.	Only limited and local environmental effects are expected.
Selenium (Se) and Compounds	Selenium compounds are toxic by inhalation and ingestion. Exposure is likely in the rubber and chemical industries	Toxic effects from the use of selenium may be found in wastewater from the mines and industries.
Mercury (Hg)	Mercury is highly toxic to human beings but the use in Botswana is probably limited.	Mercury is well-known environmental toxicant.
Chromium (Cr) and compounds	The use of chromium in Botswana is mainly due to the use in tanneries. It may cause cancer by inhalation and sensitisation by skin contact.	High concentrations of chromium may be present in wastewater from tanneries and certain metal processing industries
CFC compounds (Freon)	The human risk is limited to occasional and accidental high exposures	CFC gases are assumed to cause depletion of the ozone layer. The use is restricted according to the Montreal Protocol
Textile dyes	Some dyes are skin sensitisers and carcinogenic.	Dyes may be very toxic and slowly degraded in the environment. High concentrations are possible in wastewater and sludge from textile dying.

Pigments paints, vanishes, putty etc.	This group includes highly toxic as well as non-toxic substances. Significant exposure of workers is expected.	High concentrations may be found in industrial waste and wastewater from manufacture and use. Printing inks
Printing inks	Printing inks may contain carcinogenic compounds and high exposure is possible in the work environment.	Possible environmental exposure is through waste paper and rags used for cleaning of printers.
Soap surfactants, etc.	Estrogenic effects from nonylepenolethoxylates and nonylphenoles are a possible risk.	The risk of toxic effects in the aquatic environment of surfactants is high, because of the high volumes that are released into the atmosphere.
Pesticides, disinfectants	Occupational exposure of farm workers to pesticides is most probably as adequate protective equipment is rarely used. The general population may be exposed through food and drinking water.	Exposure and effects on non-target organisms are likely by wind drift and spills.
Rubber and plastic additives	The risk of human effects is present at high exposure levels in the manufacturing of rubber and plastic products	and there are no major environmental effects expected.

- The legislation should include provisions for establishment of a Board/Authority to advice the Minister on all aspects pertaining to chemicals in relation to human health and the protection of the environment.
- Chemicals Data Base and procedures for notification by manufacturing and importers of information on the manufacture, import and use of chemicals in Botswana to the National Chemical Database.

- Ministry of Health takes the necessary steps to have Attorney Generals' Chamber to draft the legislation on chemicals
- System for classification of chemical substances and products comprising of three main danger categories based on intrinsic properties, namely, physical-chemical hazards, human health hazard, and danger to the environment. The three main categories are divided into subcategories to be defined in the future BOBS standards on classification and labelling.
- Obliging manufacturers and importers to gather information on the chemicals they sell in order to classify them in the danger categories and subcategories prior to placing the chemical on the market in Botswana.
- Requiring that the packaging/container of hazardous industrial and consumer products are labelled in both English and Setswana according to the classification assigned to it by the manufacturer or importer.
- Promoting and protecting the right of consumers and the public to information on the chemicals they are exposed to.
- Requiring that chemicals supplied to an industrial user shall be accompanied by a safety data sheet comprising of 16 headings in both Setswana and English, free of charge.
- Requiring that the container in which a chemical is placed on the market in Botswana must be strong, solid, whole and can be adequately closed through the lifetime of the chemical.
- Providing for certain chemical substances and products which are found to present an unacceptable risk to humans or the environment be restricted or fully banned, for industrial use and/or private sector uses.
- Requiring that chemicals are not sold under conditions which gives the buyer false or misleading information about the risk implied in using the chemicals.
- Requiring that toxic chemical substances and products are stored safely in locked compartments, and always out of reach of children, and
- Providing for enforcement powers to make the provisions of the Bill effective.
- The Environmental Health Unit should continue the cooperation with Botswana Bureau of Standards on elaborating standards on classification and labelling of chemicals and on safety data sheets.
- The standards for classification and labelling of chemicals should based the EU Directives and the Standards From South Africa.
- The Standard on safety data sheet should be based on the corresponding ISO standard.

Unit Level

Education and Training

At this level Carl Bro a/s (2001) recommends that staff maintains and further develops the skills on toxicology and risk assessment. More training of staff is required and that should include staff from other agencies like Customs Officers and Health Officers in the Districts.

The National Chemical Database

The reports also recommends to file all data available from safety data sheets in order to maintain skills and utilise the database for consideration of cases and planning purposes. Further officers should be trained to secure sustainability.

Cooperation with other stakeholders

A network has been established through the project and the following items were identified for future cooperation:

- Ozone Depleting Substances: cooperation with Department of Meteorological Services on a regulation and on substitution of the substances which will be banned.
- POPs: cooperation with Ministry of Agriculture, National Conservation Strategy Coordinating Agency and Department of Sanitation and waste Management on implementing the POPs convention
- PIC procedure: cooperation with the Ministry of Agriculture on implementing the procedure
- Convention on chemical weapons: cooperation with Botswana Defence Force on implementation of the convention.
- Transport of Dangerous Goods: cooperation with Department of Road Traffic on reviewing the Road Traffic Act and implement the UN regulations for transport of dangerous goods.
- Chemical waste: cooperation with Department of Sanitation and waste Management on chemical waste
- Cleaner technology: cooperation with BOCCIM and individual companies on introducing cleaner technology.

CONCLUSION

The subject of chemical and waste management is quite intricate and requires a lot of resources both human and financially. For Botswana to move towards sustainable environmental management, the new Ministry of Environment Wildlife and Tourism has an enormous challenge to the whole nation towards changing our behaviour to the environment. More refined pieces of legislation should be in place to protect the environment.

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Chemical Analysis Methods For Environmental Samples in TUCED-I&UA Chiang Mai University

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ABSTRACT: A group of analytical chemists at Chiang Mai University is developing flow based analysis methods for environmental samples. The flow injection analysis (FIA) is the dominant work. This technique is environmental friendly. It consumes little chemicals, low cost and high sensitivity. It can be operated continuously or automatically. The technique can be combined with preconcentration and solvent extraction.Research carried out over the last 3 years will be discussed.

INTRODUCTION

Environmental sciences comprise a lot of chemical substances. The determination of each species is necessary to monitor and assess the situation in many studies. It is a difficult task which to select from so many analytical techniques that have been evolved every day. Most techniques are expensive and need sophisticated equipment, but one class of techniques that are not so expensive and required simple equipment. In most cases you can construct them by yourself. Moreover, it is environmental friendly since it produces very little waste.

This technique in flow injection analysis (FIA) or flow based analysis in general term. This technique can also incorporated with other techniques to enhance its capability for analytical methods. This paper is reported about research on FIA by a group of chemists of TUCED-I&UA Chiang Mai University, Department of Chemistry for the last three years.

FIA FOR METAL IONS

1. Determination of cadmium, copper, lead and zinc by flow voltammetric analysis (Jakmunee *et.al.,* 2001) This work used flow analysis technique with voltammetric system to determine cadmium, copper, lead and zinc. Mercury film working electrode was prepared by on-line mercury deposition on a glassy carbon electrode. The four elements were analyzed simultaneously by anode stripping voltammetry after a sample was flowed through the electrochemical cell for deposition of the metals on mercury film. Detection limits for cadmium, copper, lead and zinc were 4,7,1 and 15 ppb., respectively, for deposition time of 20 second. The system has been applied to determine the trace metals in drinking water and wastewater system.

2. Flow injection samples pretreatment for determination of lead by flame atomic absorption spectrophotometry (Jakmunee *et.al.,* 2001). Utilizing an in-valve minicolumn, packed with a solid phase extraction resin (Sv-spec^{TM}), lead was preconcentrated and separated from the matrix. A 1M nitric and solution and 0.005M EDTA solution of pH 7 were suitable for sorption and desorption step respectively. A concentration efficiency of 11 min^{-1} was achieved. A linear calibration was obtained for 0.1-5.0 μg Pb and a single standard calibration can be applied. This method has been applied to the determination of lead in certified reference materials, leachates and digests of tin tailing samples.

3. Simple flow injection FAAS for speciation of Cr(III) and Cr(VI) with C_{18} solid phase extraction in-valve column (Grudpan *et.al.,* 2001). A mixture of Cr(III) and Cr(VI) is flowed to merge with a stream of diphenylcarbazide (DPC) (0.01% w/v) in HNO_{3+} (1.0M), before passing through a C_{18} SPE in-valve column. Cr(V) reacts with DPC to form complex which retain onto the C_{18} column and enters the FAAS. The signal obtained then corresponds to Cr(III). When switching the valve to elution position, methanol as an eluent desorbs the Cr-DPC complex from the column and entering to FAAS: The signal is for Cr(VI). A sample through-put of at least 25 samples/h^{-1} can be achieved. The procedure was applied to speciation of Cr(III) and Cr(VI) in wastewater samples from industrial areas. The results agree very well with those obtained by an ICP-AES method.

4. Simple flow injection system with bead injection for trace iron determination (Jitmanee *et.al.,* 2002). A simple and low cost flow injection system with bead injection was developed for determination of low concentration (μmol^{-1}) of iron in water samples. Chelax-100 chelating resin beads, trapped in a jet ring cell, were employed. The intensity of red complex of 1,10-phenanthroline with Fe^{2+} was monitored using colorimetric detector with a LED green light source. Amount of total Fe (Fe^{2+} and Fe^{3+}) and Fe^{2+} can be evaluated by with and without reduction of Fe^{3+} using ascorbic acid. Lowest detection of Fe^{2+} were 0.50 and 0.45 μmol^{-1} for sample loading time of 3 and 5 min., respectively. Working range was up to 3.90 μmol^{-1} using 0.3% w/v 1,10-phenanthroline.

FIA FOR OXYGEN, ANIONS AND ORGANIC MOLECULE

5. A reverse-flow injection analysis method for the determination of dissolved oxygen in fresh and marine waters (Muangkaew *et.al.*). Manganese(II) sulfate is injected into a continuously flowing stream of sample and subsequently merges with a reagent stream of sodium hydroxide and sodium iodide. Manganese(II) hydroxide that is formed react with dissolved oxygen in the sample to form an oxidized manganese hydroxide floc. Addition of 10% sulfuric acid dissolves this floc, and under acidic conditions, the triodide ion formed is detected by photometry in a flow through cell at a wavelength of 440 mm. This method is rapid (48 measurements/h), and detection limit is 0.25 mgl^{-1}. The method has been applied to on-line measurement of DO in sediment respiration reactors.

6. Flow injection double solvent extraction determination of anionic surfactant (Praditwiengkum *et.al.,* 2002). It is based on the Abbott's methylene blue method. A sample through-put of 30 injection h^{-1} with 1.5% RSD (0.40 mg $SDSl^{-1}$) and a detection limit of 0.02 mg $SDSl^{-1}$ can be achieved. The procedure has been applied to determine anionic surfactants in real water samples.

7. Stopped-flow injection simultaneous determination of phosphate and silicate using molybdenum blue (Grudpan *et.al.*). A stopped-flow FI system should be arranged for low degree of mixing (of reactants) and low dispersion so that good signals of rate changes will be observed. Simultaneous determination of phosphate and silicate by the stopped-flow FI techniques is proposed, using a laboratory-made semi-automatic stopped. FI analyzer with LED-based photometer. It is based on kinetic separation of phosphate and silicate using molybdenum blue. The procedure has been demonstrated for the application to water samples. The results agree with that of a standard method.

8. Cost effective flow injection analysis systems for acetic acid (Grudpan *et.al.,* 2000). The flow systems can be assembled with different types of components, including a clinical saline bag and laboratory-made detectors, resulting in various degree of automation, varying from very simple ones to fully computerized control. The flow injection titrations are based on neutralization and are monitored by either spectrophotometry or conductometry. The flow injection procedures can be performed under conditions at non-steady or steady states.

APPLICATION IN REAL SITUATION

9. Automated monitoring system for quality of treated wastewater from a power plant by incorporating flow injection analysis (Kunawanakit *et.al.,* 2000). They developed an automated monitoring system for quality of treated wastewater from a power plant by incorporating FIA, measurements for pH, conductivity, dissolved oxygen and water level are made by using sensors/probes. The FIA procedures are for sulfate, phosphate and iron. The on-line monitoring system accommodated in a nut, at the sampling site, 10km from the control station, is automatically operated by making use of process logic control.

CONCLUSION

It is clear from the research results that FIA or flow based analysis is really an interesting, inexpensive, versatile and not a sophisticated equipment. The applications are imminent and show great potential for real time analysis of environmental monitoring techniques since it could be developed into an automatics process for chemical analysis for the period of days or weeks.

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1 Environmental Management

Principle Of Precautionary As An Ethical Implementation To Environmental Management

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ABSTRACT: This paper is an attempt to present to the reader the introduction part about how man is related to nature, focusing on Western and Eastern Environmental philosophy. The modern values of self-egoism, utilitarianism and competition are also discussed. The traditional values are replaced by the contemporary values, created the new culture, the culture of consumerism. " As we had learnt from our past knowing in history that, the overused natural resources were the important factor to destroy civilization." Can late lessons and early warning of the philosophers and the Environmentalists be taken as the principle of precautionary? The second part is emphasizing on the answer to the question, what is the precautionary principle? The argument about the pro and con of the principle as the remedies for the global environmental crisis will be stated. Deconstructive the terminology of precautionary principle and how this principle itself implies ethical attitude and concepts.The third part is to relate the precautionary principle as an ethical Implementation to environmental management through environmental education for the sustainable development.

Keywords: Environment philosophy, Utilitarianism, Self-egoism, Principle of Precautionary, Ethical concepts and precautionary principle, Clean Technology, Environmental management, Environmental education, Sustainable development

INTRODUCTION

His holiness, the Dalai Lama has passed his message to us that, " the world grows smaller and smaller, more and more inter-dependent- today more than ever before life must be characterized by a sense of Universal Responsibility, not only nation to nation, but also human to other forms of life (K. Chatsumarn. 1998, 7)

Universal responsibility implies pure moral attitude, which relates to the right action of human behavior .The message, which His holiness, the Dalai Lama conveyed to us, emphasis on the importance of Precautionary Principle.

The anthropocentric world view of thinking justified only what is right and useful to mankind. This view makes men alien to the eco-centric . The destruction of the environmental world is the result of the prejudice of the anthropocentric to eco-centric. Might is Right is an ancient Greek ethical concept. Socrates (469-399 B.C), the great philosopher had a dialogue with Thrasymarcus, the sophist, to find out the truth. The strong has the right to exploit the weak, hasn't he? Socrates may dispute this notion but Henri Bergson (1895-1941) proclaimed it. He justified the class rule, one class oppressed by another as a natural condition, and war as an inevitable law of nature. If we look closely in nature and in man, we shall discover the truth. Unfortunately, we cannot breakthrough the natural pattern that Bergson pointed it out in his philosophy. Can we able to breakthrough the natural pattern with love, wisdom and compassion? Can love bring back the right action to human beings and also toward the other forms of life? That is to make peace not war, with nature and man

Martin Heideggar (1889-1976) explained how insensitive human was in relation to nature. Human's attitude towards eco-centric was very low and this low attitude appeared in his behavior and conduct. The example which he has given that of the establishment of hydroelectric plant on the River Rine. The river is interpreted as the reserve power to be used for the community. The community fails to realize that the River Rine has possibility of its own beyond that of a being standing reserve of power for humankind.

The environmental crisis which man has created today in every corner of the world caused great misery, despair, fear, and health problems. The rapid and massive growth of industrialization has a bad impact on the ecosystem. Thailand is now facing the heavy deterioration of natural resources due to modern industrialization and the poverty of the people. Therefore, economic growth may not mean well being in the long term. In addition, the destruction of the natural resources kept increasing and human beings are not taking any proper response to conserve the environment. Karl Marx (1818-1883) said: "Man has lost himself and his pride within the structure of technologies and the economics of capitalism". We should be aware of the warning coming from Michael Foucault about the danger of the system and society. How can we make this chaotic world sustainable in natural resources and peaceful for everyone to live happily without fear, worry and in good health?

There were numerous cases which demonstrated the tragedy which man has done to the Earth. The air pollution coming from Mae Moh, Thailand's coal mine, has caused over 600 cases of respiratory problems to human, as well as hundred of cattle and crops were dying as a result of the pollution (Soase, Clair M.2000, 99). Forest covered 80 percent of Thailand 50 years ago, but now only 20 percent is left. It

Caused danger to the biodiversity. The explosion of chemical gas in Bhophal has also caused hundreds of people died and morbid. The heavy bombardment in the Iraq war recently had caused thousands of human deaths and heavy destruction to the environment. In addition, the planting of genetically modified crops are not ban in some countries. It is still unproven by scientist that it is harmless to the human body in the long term. The ozone depletion in the atmosphere causes cancer to many British women (Diffey, B.L.1992, 2267). The rapid growth of population and the lifestyle of consumerism will be reducing the world resources. Lastly, the uneven distribution of the limited natural resources will be inviting violence and war.

East meets west: Environmental Philosophy

Environmental philosophy had been mentioned before Rachel Carson wrote, "The Silent Spring", and Anne Naess hang himself under the cliff to protest the government's policy on environment. The outstanding philosophers which were W.G.Leibniz, Albert Einstein, Henri Bergson, William James, and A.N. Whithead have taken part in environmental philosophy. The word "Ecology" had found in the work of Whithead and Bergson. (Robert, Jason.S. 2000, 192). William James was the farther of environmental philosophy.

The natural philosophy had been studied since long ago. There are a numbers of theories which had described how nature works, for instance, Leibniz's theory of monad. The theory formed the picture of how nature works, how thing relates and depends on each other. Einstein had paid attention on this theory. Later his discovery on the theory of relativity offered him so much privilege. Theory of relativity has given to us the knowledge of the interval relation between space and time. The concept of absolute time, and absolute simultaneity, and absolute space are rejected (I. Frolov.1989, 356). A coherent philosophy had been developing on the foundation of the development in physical theory. (Sterling, Stephen R 1992, 81)

Einstein's theory proof: there is relation. By the term relation, it means a necessary moment seeing the connection of all phenomena. The relation of things to objective; things do not exist outside relation. The existence of each thing, its specific features and properties and its development depends on the total sum of its relation to other things and process. (I.Flov.1998, 357) Heisenberg, one of the founders of quantum mechanics confirmed: By its intervention, science alters and re-fashion the object of investigation, in other words, method and object can no longer be separated. The scientific world, view in the true sense of the word (Sterling Stephen.R. 1992, 80)

Phenomena world had explained in term of relation. The British empiricist George Berkley (1685-1753) proclaimed: To be is to be perceived. The notion of relation takes part. Mure: "When we try to pick out anything by itself, we find it hitched to everything else in the universe" (Steiguer, J, E, 1990, 12).In another words, There is no independence observer of reality but only a participant in the reality. As Copra says: The pattern scientist observes in nature are intimately connected with patterns of their mind; with their concepts, thoughts, and values. (Copra, Fridj of 2001, 77). The natural has perceived in term of relation repeated again: "To speak of organism and environment in isolation from each other is never true to the situation, for no organism can exist in isolation from an environment, and an environment is what it is in relation to an organism. The properties attributed to the environment belong to it in the context of that interaction". (Rosenthal and Buchholz, 1996, 40)

The Ecological world view system, points to an altogether more complex, dynamic, and fascinating model of the world. Instead of a world analyzed into discrete parts, we see relative wholes, which, by virtue of their organization, are greater than the sum of their parts. Developments at the leading edges of physics, mathematics, chemistry, biology, and neurophysiology are giving rise to a new holistic science which extends the common idea that' everything is related'. (Stephen Stering, R.1992,81) If it is true that the world order work closely knitting together, the disconnection of one part can destroy the other part as well. The more we destroy the ecosystem the more we pay the price.

Henri Bergson (1859-1941), is a French philosopher who enriches the modern environmental philosophy with the idea of "*e'lan vital*" or vitalism. He is famous for his "creative evolution and the psychological time". Bergson commented that Darwin's evolution theory is too mechanical to account for the process it described. Instead, he considers these developments to be due to the operation of "*e'lan vital*" or vital impetus which enacts the changes that occur in evolution. (Vesey, G.1990, 44)

Bergson's theory of evolution gives the new idea of looking at the nature. The mechanism materialism of Darwinism was replaced by the organism in his evolution theory. The theory is being used to explain society in term of organic order. It is an organic order because society comprised of individuals. The vitalized plays an important role to explain the development of the entities and how they generate and distribute their energy for the balance and harmony of the system. The organic world view is found in ecological environmental ethics.

The environment world can be compared with the biological system. In this conceptual framework, cells, like organisms and groups, are at the same time units and complexes, individuals and communities.... The unit of survival is not the organism, but the organism and its environment (Stering, Stephen R. 1992, 80). The organism can be found in Lovelock's Gaia theory as thus: "the planet (Gaia) as a living organism which optimizes conditions for it's (her) survival". When an organism benefits the environment as well as the organism itself, then its spread will be assisted. Eventually, the organism, and the environmental change associated with it, will become global in extent. The reverse is also true; "any species that adversely affects the environment is doomed"; but life goes on. (Lovelock, James 1986, 28)

Look closely into the ideas of Eco-feminist: Mechanism represented the notion of oppression, rational, domination and power, i.e. Man oppresses the natural world in imperialistic economics and industrialization. Women and nature are linked to each other and identified with femininity and corporeality-opposite and inferior to masculinity. The resistant from women must have taken place (Herles. Cecilla, 2000, 120). Organism promoted the sensitivity in human perception because life is in everything.

William James (1842-1910), an American pragmatism and environmentalist convinced if that is the fact, we must perceive in experience. The so called, 'growing' world is the world that we actively experience. James idea of pragmatism said that the thought inspires that conduct, because it first foretells some particular turn to our experience, which shall call for just the conduct from us. The indeterminacy and change is real feature of the world. Change and development is everywhere the rule. Perhaps it is universal and the structure are relation appear throughout the experience of man. Reality is explained as process and development in interrelation, conceitedness, transactions, and entanglement as constitutive of reality. It is based on rigorous attention to what is actually there in experience, and not what this or that philosophy we should find. (Robert, Jason.R. 2000, 194)

The cores of his philosophy as mentioned are suitable for the explanation of human beings in relation to nature in environmental philosophy. Environmental issues are founded in man's experience. It is as real as part of your body. His philosophy focuses on the relation of thought and conducts which is good enough for environmental education. Environmental pragmatism is the called forth environmental protection.

Pragmatism convinced to us that, the environment is above all not something "out there" somehow separate from us, standing ready to be used up or preserved as we deem necessary… We cannot talk about environment without talking about experience, the most basic term in pragmatism…

Environment, in the most basic sense, is the field where experience occurs, where my life and the lives of other arise and take place… Environment is as much a part of each of us as we are part of the environment, and moreover, each of us is a part of the environment-a part of experience-with which other beings have to contend… The world, in this view, is a continuum of various environments. (Parker, 1996, 21)

Environmental pragmatism promoted environmental philosophy relevant to environmental policy, and a call for moral pluralism, emphasized on a practical level.

The Asian perspectives in environmental philosophy take root from the philosophers, religions, and the radical contemporary thinkers. Confucius (551-479) taught about how man behaves to man and to heaven (natural order). The way lies within his virtues practice (i.e., kind, benevolent, sincerity). Confucius 'Analects stated clearly: "All things are nourished together without injuring one another, the course of the seasons, and of the sun and moon, are pursued without any collision among them". (Legge. James, 1892, 22) so, kind and benevolence are the precept for human behavior.

Lau Tze, (604-521B.C) his philosophy on the Tao of the Universe, and how nature relates to human beings. The natural beauty has offered the tranquility and peaceful atmosphere to understand the truth. Tao can be explained in different meanings, i.e., the way, nature and non-action. Man and nature are one. The whole universe lies within, for the person who lives in Tao. Everything is united in everything. Deep ecology is modern Taoism in my opinion. The beautiful mind of Taoism: The man, who rests in Tao, sees thing as thing, not a thing to him (Legg, James 1891, 28).

Mahatma Gandhi (1869-1948) was one of the non-violent practices. He concerned and cared for "nature". In his ashram, poisonous snakes were permitted to live inside and outside human dwellings. Anti-poison medicines were frowned upon. Gandhi insisted that trust awaken trust and that snakes have the same right to live and blossom as the human. (Nass. Arne1992, 259).

The cultures of the tribal people are closed to nature. The evidence can be found in the well-known Chipco movement of the mountain people, who protect the forest in India. The American Red Indians also believe that spiritual form is in everything in nature.

The Akka, one of the mountain tribes in the northern part of Thailand, embrace the forest like one of the members of the family. The elderly Akka's view on forest protection is: "We hill tribes preserve the forest to protect people and animals against danger, disease, injury, soldier, and bad spirit. Having a forest belt around the village will bring happiness to the community. Big trees are like mothers, and little is like children, needing to be encouraged into flower and growth". (Marcus, C.1995, 80).

The Japanese Shinto has also worshipped the power of water as the source of life. (Look Japan, 2003, 7)

Buddhism prohibited lay persons to kill any living beings. The Buddha preaches the principle of non-violence: "Let everyone cultivates a friendly and compassionately mind towards all beings". (Feer. Leon M, 1890, 40)

The relationship of man and nature in Buddhist philosophy is also explained under the law of causation. Life exists on the basis of the composition of the natural elements (i.e., Earth, water, fire, air). The decay of life happens when the elements are in the stage of flux and changes. The environmental crisis is reflected in the cause-effect relation. If we are not able to comprehend the change and destroy the Earth or Environment; the bad effect will come to us when the time is ripe. The middle way, guided by wisdom and compassion, is the pillars in Buddhism. Monks were prohibited to cut down trees unnecessary. To quote a passage from Dhammapada: "Let him not killed any living being, nor let him approved of others killing, after having refrained from hurting all creatures, both those that are strong and those that tremble in the world (Muller, Max, 1928, 65) The middle path in Buddhist philosophy is also a good guide for human conduct in relation to the eco-centric world. Food is not for enjoyment in the hedonistic sense rather than for living. So, let us eat food with respect to the lives of the "others" (plants and animals).We shall consume less and this is the way to cultivate the mind.

J. Krishnamurti, Indian Philosopher in his metaphysical sentence: "There must be a total and fundamental change in man's consciousness. The first step is the last step. The change in man's consciousness implies action. The environmental problems today need action. Thought is preventing us to see the fact, and caught in unnecessary argument and conflict. Thought is common to man. There is no eastern and western thought. Then, we shall benefit from these philosophers and wise man in their way of thinking, acting and living rightly.

Can late lessons in the past and early warning from the environmentalists be taken as the precautionary principle?

Historical evidences had shown us the greediness of human beings in exploited natural resources. Lebanon in the old days was plentiful and famous for cedar woods. Ancient Egypt Empire demanded a lot of wood from Lebanon's forest for the navy power and the temples. It was told that Antigonous (Alexander the great's general who saved Macidonia and Egypt after his death) had an ambitious mind to build up his marine power. So, he sent eight thousands men to cut timber in Lebanon and Taurus mountains (Starr, Chester 1989, 50). Macidonia in ancient time was also covered with forest. King Philip used to bribe the Athenian politicians by sending wood for building their houses. This custom was prohibited when the Roman ruled Marcidonia. Imperialism was practiced in many civilizations in the ancient time and destroyed most of the natural resources. In the end, the overuse of natural resources was one of the factors that destroyed the civilizations? (i.e., the ancient Cambodia Kingdom). Another example, the source came from the Chinese text: "The bull mountain was once covered with lovely trees. As it was near the capital of a great state, people came with their axes and choppers, they cut the woods down, and the mountain had lots its beauty." (Waley, Arthur. 1993, 84).

The example of excessive use of natural resources, in the old days at Phuket Island, Thailand, can be found in the work of Ian Morson. He wrote: "The Island once was covered with heavy jungle with only a few clearings, where rice was cultivated. There were also the small tin mines which operated on the pit system……..Wild animals were plentiful". The remarks by foreigners who visited Phuket during that time were. " In a very dark wood often traversed by rhinoceros I found their dung….At breakfast I was treated to some rhinoceros hide….Towards evening I met a wild elephant from whom I had to escape. A tiger visited our house but was satisfied with only a goose that it carried away to its hiding place". (Morson, Ian. 1993, 49). Phuket Island nowadays has no more tin, wild animals and the dense forest disappeared. The primitive island as it was described in the book shows that there were no roads, only paths that were shared by men and elephants had turned it to a tourist place.

The dying of the Aral Sea is also the result of the excessive abstraction of water for irrigation purpose from the Amu Darya and Syr Darya River. Large amount of water run off from the sea, from an average of 55 cubic kilometers in 1950s to zero in the early 1980.The water has provided the livelihood for the region's farmers, but at considerable environmental cost. Soils have been poisoned with salt; over watering has turned pastureland into bogs, water supplies have become polluted by pesticide ….. The quality of drinking water and sanitary is taking a heavy toll on human health. While it is easy to see how the problem of the Aral Sea might have been avoided, solutions are difficult. A combination of better technical management and appropriate incentives is clearly essential. (Soares, Clair M2000, 40).

Have we learnt anything from the past?

The main stream of thought in the present time accepts and promotes the notion of consumerism; profit making, competition, globalization and free-market. Industrialization demand heavily on oil and fuel, fertile lands for agribusiness farming, pure water, and etc, to meet the needs and want of the world populations. Shall we able to cope with the requirement of the people and nations without causing any harm to the environment? The answer to me is no. Today environmental crisis proof the failure of human control of the economic development upon the finite resources. The distribution of wealth is not equal, as we have known some companies are wealthier than the nation. Poverty is one of the main problems of environmental devastation in developing countries. (Soares, Clair.M.2000, 30). People are not going to change their habitual way of consumerism. Competition is connected to the value of self. Self-interest in the positive sense means freedom but in the negative sense means exploit, destroy, heavy consumption, accumulate…. etc.

Liang Congjie, famous Chinese environmentalist said that: "Society is becoming increasing money-oriented. Everyone dreams of making a fortune, and longs for a luxurious life. Few realize that this is possible, only through natural resources and energy. (Hua Zhang, 2001, 12). To preserve the natural resource we must pro the notion of common-interest as post-normal science has suggested. E.F Schumacher advocated local materials for local used which was a very good-idea. (Miller, Lynn H.143). But I would like to add in a moderate way and recycle. The suggestion from the Patriarch Demitrios was if man limits his material needs he conquers spiritual perfection and freedom, but also he saves the Creation (Athens Correspondence). The "Improving mental culture" is advocated by Thoreau with one word, simplicity, simplicity, and simplicity. Absolutely, environmental degradation is an inseparable link with consumerism.

Mill (1806-1876), British's social philosopher believed in the scarcity of the natural resources. A similar view appeared in classical economist, i.e., Multus and Neo-Multus (1766-1834). The limited growth of population is important as the resources are finite. Herman Daly in his work, "The Steady State Economy" agreed with Mill in this view. Mill's utilitarianism aimed at the wide distribution of wealth for the good of human beings. What is good implied useful and happy. The rule of utilitarianism had been successfully implemented in the British system of education and the improvement of the prison conditions. The rule had been misused since long ago as Man had narrowed down the rule and applied it for the benefit of self-interest, the group-interest, the nations, the regions, and so on. That is why; rule utilitarianism was attacked as a target for the environmental crisis. In paradox, the idea of utility had been promoting as the world solution for environmental crisis lying deeply within the principle of precautionary in its aims and goal. The key concepts of utilitarianism stressed on the long term and extended to the people as much as possible. When the rule was applied to distribute X, everyone will receive minimum only. Utilitarianism does not lead to consumerism. If we do not misuse the rule of utilitarianism, we may be able to fully receive the benefit from the implementation of the rule.

However, practical utilitarianism also has a problem in evaluation between the usefulness and the value. Human beings are incapable to recognize the value of natural resources i.e., The Aral Sea in Central Asia. When it comes up to this point, human has to have foresight, and use his intelligence. Ethics cannot avoid the dilemmas. Human has to find the way out. Fortunately, environmental issues, deal mostly with facts in experiences. It is not things in dreams. So, is it time now for us to change our habitual way of living?

Contemporary Environmentalists proposed the esthetic as a way for man to feel friendly with nature; the beautiful landscape should not turn to be a place for agriculture and farmland. William Repton: "Land which is merely fertile is a barren prospect" (Berry, RJ.1993, 115).That is why, Thoreau (1817-1862) stressed on the idea that: "Nature merited respect and reverence in its own right, regardless of the uses to which humanity might put it". Aldo Leopold in his famous book: "Thinking like a mountain", said: "In wildness is the salvation of the world. Perhaps this is the hidden meanings in the howl of the wolf, long known among mountains, but seldom perceived among men."(Steiguer, 1990, 16) Is the good, the truth and the beauty the same thing? The ancient Greek ethical question; which till now we are not capable to understand. This is a reason why we had destroyed so vastly, the beautiful nature. Shall we be able to stop now?

What is the Precautionary Principle?

Sometimes we are like the weather. It pays no attention to criticism. Anonymous

The first issue of environmental concern was the acid rain, more correctly as acid deposition in the early 1980. The result of this catastrophe urged and awakened the environmentalists to the danger and destruction of our ecosystem. One of the many issues which are connected to the environmental destruction is the idea of 'the common'. The good example of the common can be found in, 'The Frail Ocean ', the author exclaimed his views that, "A sea common to all would reward those nations that could best exploit it resources, whether to fish, trade, or project naval power" (Marx,Wesley.1998,65).

And again Collin Clark comments on the common property as thus: "The tragedy of the common constitutes perhaps the most powerful bias against sustainable development. As population and technology expand, the implication of our inability to solve the problems spread from local to global scales. Government institution capable of dealing with common property problems may exist at local and national levels, but they are often weak and subject to political influences. At the international level, no institutions having any power of enforcement exist at all and we must rely on the cooperation and good will of each individual nation to deal with these problems. (Steigure, J.E.1990, 183)

During the past decade the precautionary principle has been widely accepted as a popular view for the environmental deterioration in the global communities. The principle was first mentioned at the second International Conference on the Protection of the North Sea (1987) from possible damaging effects of the most dangerous substances. The principle stated that: "In order to protect the North Sea from possible damaging effect by the most dangerous substance, a precautionary approach is necessary which has been translated into requirement for Zero concentrations in certain substance".

However, the principle was only codified for the first at the global level in Principle 15 of the 1992 Rio Declaration on Environment and Development, which stated that: "Where there are threats of serious or irreversible damage, lack of full scientific certainly should not be used as a reason for postponing cost-effective measures to prevent environmental degradation".

The Precautionary Principle related to sustainable development in the Maastricht Treaty (1992) stated as follows: "The absence of certainty, given our current scientific knowledge, should not delay the use of measures preventing a risk of large and irreversible damage to the environment, at an acceptable cost"

In fact the Precautionary Principle adopted from the German concept of "*vorsorgeprinzip*" (literally means foresight planning) and the application of the meaning of the term appeared in 1970 for domestic policy. (Douma, 2003, 5) The precautionary principle has seven distinct elements which are: "First, Pro action: the readiness to take action in advance of scientific proof where inaction may be socially or environmentally costly". "Secondly, Cost-effectiveness and action: to include in conventional CBA an examination of possible environmental costs and a presumption in favor of high environmental quality". "Thirdly, Safeguarding ecological space: Leaving wide margin of tolerance in environmental capacities". "Fourthly, Awarding the environment intrinsic value: The grant of natural rights which may well challenge conventional views of the human's nature relationship". "Fifthly, Shifting the onus of proof imposing a duty of care on those who intend to develop the environment". "Sixthly, Futurity: A recognition that the future is uncertain, but that it needs to be given due weight". "Seventhly, Paying for ecological debt: On implication that past ecological exploitation should be compensated". (Dr.Marc Saner. Ethics and Policy Center.Carloton University. Canada)

Pro Et Con of Precautionary Principle

Precautionary Principle has been facing by the critics from the expertise. From the engineer's perspective on Principle of Precautionary, Prof. Poul Harremoes, Technical Univeristy of Denmark, states that:

" The principle is ambigious in that it has several conflicting interpretations. However, the essence is that it is dealing with different levels of incertitude, i.e., Determinism, which is a desirable ideal; statistical uncertainty, which can be described and provide a rational basis for decisions; scenario uncertainty, which cannot be described in statistical terms, but can be illustrated by plausible cases (like best or worst); recognised ignorance, when the uncertainty is realised but not described in any kind of detail; indeterminacy, when we know that we cannot know; and finally: not-recognised ignorance, when we do not even know that we do not know. Any analysis building up to a decision must constructively deal with both the result and with its uncertainty and the potential importance of ignorance. In case of significant uncertainty, both the level of proof and the burden of proof must be considered. The reasons are as follows: Evidence of absence is not absence of evidence. So, risk assessment from ignorance can be dangerous. Determinism, which assumes that there is a unique cause-effect relationship between the influence and the result, can only be a reliable basis for decision making if uncertainty is small. Practically, It is never found, it is just an ideal. Statistical uncertainty needs to be quantified. In case of significant scenario uncertainty, we must go over to a qualitative assessment of how we will stay on the safe side. From this we move straight on to ignorance. Indeterminacy is the situation where the relationships are inherently unidentifiable, due to chaotic properties that make predictions impossible. In conventional product liability the burden of proof is on the offended. In such cases the tradition is to require scientific proof, which is a real challenge. The question is whether this is fair in all cases. It should be considered when the burden of proof should be with the polluter and what level of proof should be chosen. These issues are basic concepts but in practice there are no simple answers. The trend to day is to require the involvement of stakeholder and the public in order to address the ethical issues on the political scene. This will serve as a guide to the experts in their analysis of the very basics on which to apply science and engineering. In doing so, the dissemination of adequate information to the public is essential. (Harremose, Poul 2003)

What is the problem of the scientific investigation? Why sciences are not able to find the unknowable which later on have an impact on either environment or human health?

Funtowicz and Ravetz may help to answer these questions.

The problem situations that involve post-normal science are ones where, typically, fact are uncertain, values in dispute, stakes high, and decision urgent. Because applied science and professional consultancy are inadequate, something, extra must be added onto their practice which bridges the gap between scientific experts and a concerned public. This is post-normal science, comprising a dialogue among all the stakeholders in a problem, regardless of their formal qualifications or affiliations. For the quality assessment of the scientific materials in such circumstance cannot be left to the expert themselves, in the face of such uncertainties, they are amateurs too. Hence there must be an extended peer community, and they will use extended facts, which include even anecdotal evidence and statistics gathered by a community. Thus the extension even anecdotal evidence and statistics gathered by a community. Thus the extension of the traditional elements of scientific practice, facts, and participants creates the element of a new sort of practice. This is the essential novelty in post-normal science. In this way we envisage a democratization of science, not in the sense of turning over the research labs to untrained person, but rather bringing this relevant part of science into the public debate along with all other issues affecting our society. (Funtowicz and Ravetz, 1992, 254-255,)

The cost-benefit should incorporate ideally, all costs and all benefits from many factors which co-exist with in the problem: "human health, ecosystem damage, recreation cost, etc". (Harremose, Poul.2000). But in reality, the implementation of being used, the precautionary principle is still not coming up to the utility of the whole dimensions, i.e., the oil company and the coal mine were both fossil fuels.

Some critics has said that the border line between science had a barrier which made science as not able to give all the answers, as the environmental issues required knowledge from different kind of science. The absolute confidence of not being harm with the consumer and the environment is still in the stage of uncertainty, i.e., plastic container. Is it harmless to human health in the long term? The good point of the principle is to bring scientist to put ethics into science. In the same time the private pay more attention to public well-being concerning to the scientific research and the environment. The precautionary principle also invited the improvement of the traditional regulatory system related to the environmental issues. The state of art in clean technology for industrialization and citizen compound are initiated. And take precaution for people on the street in environmental matters. Last view from Ted Schettler, Science Director for the Science and Environmental Health (SEHN): "We are talking about enormously complex interactions among a number of systems. Now we're starting to think that some of these things are probably unknowable and indeterminate, he says adding that: "the precautionary principle doesn't tell you what to do, but it does tell you [what] to look at".

Deconstructive the Principle of Precautionary.

Prof Harremose said clearly: "we need to interpret the principles which already exist, and apply them in a practical and commonsense way, in accordance with the principles, so that we pave that way for their administration. The problem is only at the level that we need support. Just as environment employees in a private company need support from the board. This is already happening in industry to an impressive extent". (Harremoes.P.1988, 34)

The principle of precautionary had developed to meet the urgent called of the public in the environmental issues, i.e. found in the conventions and treatises in many regions of the world. Precautionary principle implies ethical notions, such as duty and responsibility, clean, care and concern, protection, , awareness and etc. The principle need to be deconstructed in the factual situation which the principle implemented.

Can the Precautionary Principle be used as the remedies from the environment destruction?

With issues such as acid rain, hazardous waste, the scarcity of air and water pollution, greenhouse effect, and the ozone layer depletion caused the urgent need to the co-operations among the international communities. The "clean technology" and "the precautionary principle" have been imposing in industrial practices for sustainable environment management for more than a decade, the achievement of the goal have not yet arisen. Where are the problems laid?

The cost-effective of the clean technology, though expertise advise to use appropriate technology suitable for the environment of each circumstance and country But in particular complicated case new production equipment is needed, i.e., Hong Kong harbor cleaning water treatment. (Harleman, Donald.1997, 49) The fundamental pollutions come within the society. So, individuals should apply to take precaution action immediately to safe the local environmental resource at the source. Besides, the generous aids from the nations which have a position to do so, whether in terms of knowledge and technologies are necessary and important. The "Global Common" must be deeply concerned and practice within the precautionary principle, with mutual understanding, justice, and democratization for the well-being of the sentient beings. Environmental policy of the institution and the enforcement by legal system must be effective and efficiency in command and control. Unfortunately, these fully accomplished the goal.

Principle of Precautionary in its attitude which is hidden in the top brains of the initiators has an ethical aspect which may be rather ideal. Thought needs action to make thing exist. Without ethics, attitude and behavior the goal of the precautionary principle can not be achieved.

Precautionary Principle and Sustainable Development

What is sustainable development?

Sustainable development is not a fixed state of harmony, but rather a process of change in which exploitation of resources, the direction of investments, the orientation of technological development, and institutional change are made consistent with future as well as present needs. (Steinger, J.R.1990, 125)

We could not go back to a small world as E.A Shumaker suggested. Globalization means the world of commerce, communication, information, policy and natural resources. How can the rule of the game be made without bias? How can the rule be implemented in a fair term and democratization? The following passages are the report about the environmental crisis in this era.

Wilfred Kreisel, head of WHO's environmental health division reported to the UN summit in New York, 1992 that: The globally efforts to curb environmental degradation are altogether inadequate. Air pollution in the developed world is significantly less than it was, but the opposite applies in developing countries, where quality is now a matter of grave concern" to WHOM. We have the knowledge and the means, what is lacking is political will. (McGregor, Alan. 1997, 189)

The burning of fossil fuels for the global demands for energy is a major cause of global warming due to carbon dioxide (CO_2) emissions. Global warming will be inducing rising sea level in some part of the world. European communities agreed to sign an international treaty to cut carbon dioxide levels by 20 percent by the year 2010. The United State the world's biggest CO_2 emitter is not. To the Bush administration, scientific uncertainly over global climate is too great to justify the cost of remedial measures, while models to predict global climate change have their shortcomings (Marx, Wesley. 1998)

The scarcity of clean water for drinking, agribusiness and household used will be one of the future international problems. The shortage of water in some part of the world had been discovered. In China fifty cities face acute water shortage as groundwater levels drop 1 to 2 meters a year. (Soares, Claire M. 2000, 39) The fertilization and pesticides for agriculture can damage the ground water. (Pringle, Laurence, 1982, 37) The reported in USA on studies of some chemical contaminants found in drinking water indicated twenty-two were known or suspected carcinogens (cancer-causing substances) (Pringle, Laurence). Water is essential for life, and water is more valuable than gold. It is sad that millions of people are not able to afford minimum clean water to drink.

Sustainable development under the state of flux, which faced with the environmental problems, demanded the contribution and good cooperation from both sciences and regulatory system. Frank Joyce has commented on the tax solution for environment control was in efficient because it has not covered cost of the pollution (Nagel, G.1994, 141). However, the legal system is necessary for the environmental control. The world's pollution came from many sources but a major source is in industrialization. The growth of the industrialization in one country may give people more wealth but the environmental damage is also a value.

Precautionary principle may be ideal tools for environmental management in our 21st century, to be the world in formations, communications and knowledge. They are necessary and important. The environment education should equally promote the idea of improving the culture of the mind for the young generation. Principle of precautionary for the sustainable development can be our hope for our salvation and the protection of our nature.

The lost of biodiversity in Libu island, Satun province, Southern Thailand.(photo: Isara, 2003)

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Negotiating Environmental Services In GATS: What Is In It For Human Development In Developing Countries?

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ABSTRACT: The current GATS negotiation is an interesting "experiment" when contrasted to the previous GATT/WTO negotiations, as members agreed to a gradual process of liberalization, based on successive rounds of negotiation. The traditional most-favored nation rule in WTO has been made more flexible. Environmental services trade is a sub-sector in GATS, and has received attentions from observers outside the negotiating circles for various reasons. This paper analyzes environmental services under GATS, and establishes linkages between freeing environmental services and human development. The central questions are: (1) could this "new" negotiation procedure benefit developing countries, if not why not and how to enable the realization of such benefits? What possible benefits are there for developing countries? And (2) what implications does trade in environmental services have for human development, if not how developing countries safeguard their interests? Selected Asian countries are cited as examples and policy implications are drawn for developing countries' strategic responses to GATS and human development interface.

Keywords: environmental services; GATS; WTO; human development

INTRODUCTION

The multilateral process of trade negotiation under the auspice of the World Trade Organization (WTO) has promised to deliver increased economic welfare to all trading partners. WTO is the place where the walls of traffic and non-tariff barriers to trade are supposed to be knocked down in order for goods and services to flow across national boundaries without artificial barriers—for whatever reasons these barriers might have been created for—except those fall under Article XX of WTO. Being a multilateral institution, WTO is supposed also to be an authority in mediating trade conflicts, and to enforce agreed principles to make sure that interests of trading partners are balanced. In theory, global welfare would increase as a result of freer trade—for all. For this very reason drive to free trade has put trade as the highest priority, compared with other non-trade goals.

The expectation to redistribute the welfare gains from freer trade more equitably among trading partners and due consideration for other "non-trade" goals have been increasingly prevalent, especially from developing countries and non-state observers of the WTO process. Increasingly by the end of the Uruguay Round developing countries members began to feel that they are being "rushed", if not herded, through a standardized, rigid process of trade negotiation. In particular, increasing concerns for unequal capacity of developing member countries in sacrosanct trade negotiation become more visible and evident. Even with good intention, governments of the South at times cannot facilitate close participation of major stakeholders, thus depriving them of their rights to voice concerns and to make positive contribution to negotiation processes. Importantly, the required resources, information and knowledge for developing members to engage effectively in trade negotiations are apparently inadequate and/ or lacking. Having low capacity, how could developing countries members negotiate effectively and equitably with their counterparts within that very complex and resource-demanding process?

By the time WTO members began to negotiate services trade, such concerns heightened and the flexible progressive liberalization has been created and applied to GATS negotiation. The role of information is emphasized in GATS language, calling for assessment of potential impacts of freeing services trade on development goals defined by negotiating parties.

Increasingly, too, the question of transparency began to emerge and it was targeted directly at the whole WTO process. Cries for increased participation in the process come mainly from NGO corners. More or less, as a result, the WTO responded by providing the public better access to trade and activities information of WTO. Also, the General Agreement on Trade in Services (GATS) has been launched with a new negotiating approach, allowing greater flexibility for developing countries members to bargain and implement their pledged commitments. Indeed, compared to the traditional approach of horse-trading behind high walls, among negotiators, GATS is a new experiment, with high hopes that this new process of negotiation will give developing countries better chances of edging towards their aspired goals in the negotiations.

GATS AS A NEW NEGOTIATING EXPERIMENT

GATS negotiation process is meant to liberalize trade in all kinds of services in a progressive and gradual manner through successive rounds of negotiation. After making requests and offers, by agreed dates, countries negotiate the scheduled commitments, which are not to be revised after three years of entry into force of such commitments (see Chart 1 below)—with a price to the recourse (Article XX).

Basically, GATS negotiations adopt two main principles of WTO: most-favored nations (MFN); national treatment—but with the flexibility of reserving MFN applications under certain exceptions perceived to be crucial for countries. While GATS commits local, regional and central governments alike, it seeks to exempt services that are traditionally provided by governments on non-commercial terms. GATS also attempts to assure that "fair" competition is practiced should government services co-exist with private commercial services. In all cases, transparency, including provision of confidential information[1], is called for by GATS.

GATS tries to balance recourses of bound commitments and economic benefits of injured foreign investors through compensation (called compensatory adjustment) (Article XX). Specifically, The compensatory adjustments are to be applied on an MFN basis, following much the same as under GATT. However, the GATS innovates two new elements to this. If both parties cannot agree on the adjustments, a country, which believes it has a right to compensation may take the matter to arbitration. If the arbitrator finds that compensation is reasonable, the proposed changes in commitments may not be put into effect until the compensatory adjustments are made. If this requirement is ignored, then the affected party will have the right to retaliate by withdrawing commitments "substantially equivalent" to those findings -- and in which case, the withdrawal will apply only to the country making the change[2]

GATS provides similar general (Article XIV) and security (Article XIV bis) exceptions, although safeguards need to be negotiated in the near future, which aim to protect plant, animal and human lives. Subsidies are also important issues yet to be negotiated, in particular, the provision of subsidies, if any, in the context similar to national treatment: if subsidies are given to local firms, should foreign firms received the same treatment?

GATS classifies "services" into 12 categories (see Box 1), environmental services being one of them. These services are to be provided by four modes of supply—see Box 2. Among them, Mode 4 is the most debated, as many developing countries see opportunities to "export" their experts to developed countries, while developed nations continue to curb on foreign immigrants. Mode 4 exception is spelled out in scheduled commitments of developed countries. India sees many problems with the scheduled commitments of the North, which do not facilitate more liberal mobility of skilled personnel from the South. India wants more reciprocal honor from developed countries for the movement of natural persons, especially the removal of unnecessary steps in administration.

Agreeing on definitions for services has been difficult. Likewise, what is meant by "environmental services" has been in the debate for sometime and clarification of the term is very important for both camps of the negotiation. Basically definitions define the boundary for services, and what comes with it can be high stakes for both the North and the South. If environmental equipment trade is included in the environmental services sector, for example, exporting countries could seek better preferential treatments that might not have been possible under the "regular" trade in goods. Certain machines could be imported under a services project that allows foreign investors to import them without duty.

Initially, members adopted the definition provided by WTO, which classified environmental services into four categories: solid waste; sanitation; refuse and others.

Recently the European Union (EU) tabled another clearer classifications. (See Table 1). While most of categories of WTO definition emphasize end-of-pipe or clean-up services, the OECD/ Eurostat classification extends environmental services to cover "indirect" environmental services such as research, education and information.

Box 1: Classification of Services in GATS

1. Business services (including professionals and computer)
2. Communication services
3. Construction and related engineering services
4. Distribution services
5. Educational services
6. **Environmental services**
7. Financial services, i.e., insurance and banking
8. Health-related and social services
9. Tourism and travel-related services
10. Recreational, cultural and sporting services
11. Transport services and
12. Others, not included elsewhere.

Source: www.wto.org

1 This is a very crucial issue that negotiators need to pay much closer attention to, and any domestic reform needs to take this matter into account, as what is considered business "secrets" and information the "public" (which now includes foreign entities) is entitled to access is very tricky. A good example is the current conflict between the Thai government and protesters of the Thai-Malaysian gas pipeline project.

2 Article XXI. The equivalent rules in the GATT are in Article XXVIII. In accordance with Article XXI:5, the Council for Trade in Services has established detailed procedures for changes to schedules, including the timetable for negotiations on compensation and the choice and tasks of arbitrators.

Box 2: Modes of Trade in Services Supply

- Mode 1: Cross-border trade; i.e., services cross national boundaries
- Mode 2: Consumption abroad; i.e., supply of services in a country to customers from the other
- Mode 3: Commercial presence; i.e., foreign suppliers make presence in the other country
- Mode 4: Presence of natural persons; i.e., admission of a foreign national to provide services

Source: www.wto.org

It is important that these differences in the classification must be resolved by members of GATS in order to advance the negotiation on the scheduled commitments—although in practice, this has not been a major problem because countries seek to negotiate on sub-sectors of their common interest. There is yet another important reason why a prompt clarification for classification is crucial. The coverage of "services" implies not only the size of potential investment, and thus the commercial benefits that entail, but also the potential impacts such provisions might have on people, in particular the vulnerable groups. As increased competition implies greater participation of the private sector, what is not considered "beneficial" will not be undertaken by the private sector. This raises the issue of equity, as the expected coverage by the public sector provider is now not fulfilled for commercial reasons.

On the other hand, any intervention by the public sector in this particular situation will have to be careful so that it will not violate national treatment or undermine local competition, which is now participated more broadly by foreign suppliers of such services. As a result, a delay or change of entitled services to vulnerable groups could happen, while price rationalization is most likely to happen in this particular situation if the private sector investments fill the services gaps.

Implicit privatization of environmental services through GATS commitments raises another public skepticism of the scheme: financial wrong-doing in the transaction, from which those authorities involved might gain. This fear for corruption is plausible in many past experiences, in both developed and developing countries, once privatization is planned, and carried out. The fact that under GATS host countries not being able to put restrictions on transfer of profit may open ways for private investors to practise transfer pricing, which prevents host countries from reaping full benefits of liberalization. For instance, transfer pricing drains potential fund that might be able to expand services to serve marginal areas.

Another common ill-sentiment for privatization of environmental services stems from property rights issues. In the water supply sub-sector, for instance, the transfer of management rights from the state or state enterprises to a private firm is seen as giving a precious good at no cost to the firm to manage for profit. Although state enterprises may not always be understood to be psuedo-actors of the governments, at least people feel that the majority stake of the government in these enterprises gives legitimate ownership. Any profit made by state enterprises will go back into government coffer, not private pockets.

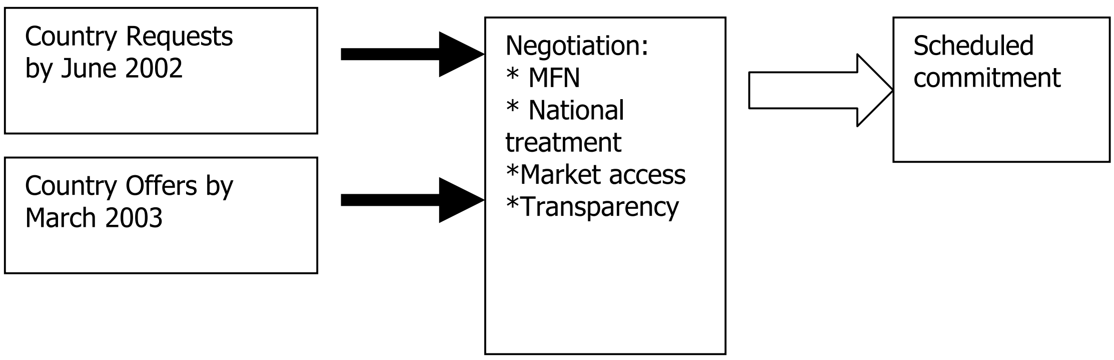

Chart 1: Negotiating Procedures in GATS

In the present context of GATS, a critical question is how nations may strike a balance between public and private services, and how domestic regulations are to be reformed or created to facilitate services trade liberalization—in which case the big issues are that of public participation and rights assured by local constitutions of vulnerable groups. These needed balance, necessary reforms and assured rights form the major thrust of actions as developing countries prepare to negotiate and implement their commitments. Potential impacts that could worsen the situations would certainly affect the essence of development, the so-called human development.

ENVIRONMENTAL SERVICES AND HUMAN DEVELOPMENT IN DEVELOPING COUNTRIES

The GATS preamble states, partly, that members of GATS:

Wishing to establish a multilateral framework of principles and rules for trade in services with a view to the expansion of such trade under conditions of transparency and progressive liberalization and as a means of promoting the economic growth of all trading partners **and the development** of developing countries (emphasis added)

The above aim of freeing environmental service trade—while implying, implicitly and automatically, that global welfare will be increased to every nation's common benefits—is to support development goals of nations. If freeing environmental services is to serve an overall development goal, an integration of non-GATS goals must be made to strike a balance. One of such goals is enhancing human development—defined by UNDP to be the four facets of development, i.e., empowerment; equity; productivity and sustainability (Asia Trade Initiative, 2003).

Environmental services in early days were meant to be end-of-pipe remedies for industrial pollution in industrial pioneer countries. In the current discussion preventive measures are also tabled for negotiation. As Western markets saturated, industries look elsewhere for new opportunities and to dispose of their excess capacity. It has been argued that freer environmental services trade will bring a large number of benefits to developing countries.

Firstly, freer trade in services comes with solutions to chronic environmental problems that developing countries have little capacity to deal with them alone using only domestic resources. Technologies are these solutions. There is a price tag to it, though. Technology transfer under GATS, unfortunately, is conducted on commercial terms, thus creating no added value to developing countries' needs, compared for example to cooperation under certain multilateral environmental agreements (MEAs) that normally provide "new and additional" financial assistance to assist pledged commitments to technology transfer by developed countries that are also members of these MEAs.

Secondly another clear benefit from freeing environmental services under GATS is movement of professional experts through Mode 4 from North to South. Developing countries could benefit from this natural movement of labor in two ways: in-service and on-the-job training for local trainees.

Thirdly, increased investment through private sector means would help fill the financial and technological gaps, which are truly in needs in addressing many of the environmental challenges formerly alien to developed countries but now common in developing countries. Many of the hazardous wastes, for example, are prevalent in developing countries that try to industrialize their economies, but which these countries are incapable of treating these wastes by themselves. Moreover, the existing gap between needs and actual investment calls for more investment from non-government sources. Studies from China (Hills, 2003), Pakistan (Qutub, 2003) and Thailand (Jesdapipat, 2003) commissioned by UNDP on environmental services and human development in these countries indicated such a big and growing gap.

Last, but not least, in most developing countries, governments are traditional care-takers of the environmental ills using public monies. And, in most of these countries politicians are sensitive to adding marginal burdens to tax payers for fear of political repercussions. Hence, cost internalization tends to fail, and consumers unknowingly pay for environmental clean-ups through their tax monies. Failing to internalize environmental costs into inputs and product prices would in effect impact human development conditions negatively. Health impacts are one of the many negative consequences. Community and individual health impacts are consequences of many local environmental problems that have not been adequately dealt with by governments and local communities. Lack of better employment options could sometimes turn local citizen in poor developing countries into de facto guardians of polluters. (Satirathai et al, 2003). Private sector participation in the provision of environmental services would thus create more transparency in the system and help promoting financial and environmental performance.

If the private sector investment benefits from freer trade in environmental services under GATS, to what extent this "new" role would be compatible with human development goals in developing countries? Or, what could possibly be potential gains in terms of human development resulted from increased private sector participation in addressing environmental services? Would sources of "new" investment make any difference, compared to the domestic source, if any?

Answers to these questions hinge upon how countries negotiate environmental services under GATS, taking into account prior assessments, if any, and necessary regulatory reforms that would implement the commitments. Assessments are crucial, but not every developing country has conducted them, according to studies cited above. It is most likely that competition created by services trade liberalization (which enhances efficiency goals in development—or the productivity aspect of human development by UNDP's terminology) may fail to support equity goals. Thus, some forms of government intervention might be needed to achieve better balance in implementing GATS commitments.

It follows that domestic reforms must take into account human development goals, which might not exclusively be compatible, at times, with financial goals of investors. In other words, not only do assessments using marginal analysis framework have to identify potential impacts of liberalization, they will have to recommend precise necessary reforms to current laws and regulatory regimes—which will be shaped to accommodate broader human development goals, and be an integral part of development policy. These are endogenous factors that developing countries would have to consider.

Developing countries' engagement in GATS negotiation, in particular of the current environmental services context, has to keep the whole GATS framework in mind, and developing countries have to focus on strategies that would produce best results for national human development interests and global trade in services—which must not be solely commercial-driven. Most developing countries do have needs and international commitments to address sustainable development (environmental services being part of promoting it). However, enhancing the commercialization of environmental services (especially the end-of-pipe businesses) without proper balance of social development needs could at best be a second-best strategy.

STRATEGIC RESPONSES: LESSONS LEARNT

The common features of proposed national strategic responses which came out of UNDP's regional studies on environmental services produce the following lists of recommendations (see Hills, 2003; Qutub, 2003 and Jesdapipat, 2003):

- Clarification of definitions for "environmental services" in services trade negotiations is urgently needed to provide a general scope for negotiations, and implementation of commitments. It has been clear that many of the current domestic resistances to open environmental trade a result of sectors that the general public regards as sensitive to them. Drawing a clear scope would facilitate the negotiations and would help frame the domestic discussions/ consultations.
- Sector-specific assessments of environmental services must be done within the overall framework of GATS negotiations, taking into account specific clauses and articles that might infringe upon human development initiatives/ goals. The role of traditional provision by the government sector and conditions for competition, for example, must be clearified.
- Establishing comprehensive data and information systems for environmental services seems to be an urgent task for every country in Asian region, as data on environmental services are scarce, unreliable and not easily accessible, including those that are in the public domain.
- Provide opportunities for research on issues related to liberalization of environmental services on economic, social, developmental and environmental aspects of countries.
- Establishing an expert group to assist negotiation, policy reform and to direct research to specific needs of users, such as negotiators.
- Development of a national overall strategy to negotiation and implementation of final commitments, with a view, among others, to enhance human development goals
- Explore a regional approach to negotiating and implementing environmental services commitments, based for example on existing economic integration/ cooperation such as ASEAN Plus Three (i.e., China; Japan and South Korea).
- Assess domestic institutional capacity and regulatory regimes, with a view to make these mechanisms transparent for services trade liberalization. Equally important, if not more, the reform of present investment policies should aim to sufficiently accommodate human development concerns.
- Reform current environmental policies to enhance the role of private sector in environmental protection, with a view to enhance competition and to internalize services costs into goods and services (e.g., treatment costs into services of fresh water supply), with a view of integrating human development goals into such policies for investment in environmental services
- Broaden the participation of the non-state entity, including that of the civil society and private sector, into the process of current negotiation, thereby creating and institutionalizing a forum for public consultation on GATS, this include the provision of resources to sustain an interactive communication among stakeholders participating in the dialogue
- Provide opportunities for capacity building that is an integral part of current negotiation mandates and in support of future implementation of commitments

CONCLUDING REMARKS

GATS negotiation gives developing nations a high hope to negotiate free trade with more flexibility. In reality, however, there has been little evidence that developing countries have gained from this new process, compared to the Uruguay Round, and their developed country counterparts.

What has been missing all along in the GATS negotiation is how to assure that the unfulfilled promises—that increased global welfare is good for all—will be met with more equitability. Following the original GATT/WTO framework, though with more flexibility in making and implementing commitment, members of GATS continue to "assume" that benefits from free trade will bring better welfare for all. The author wishes to argue that unless such commitments take into account other non-trade goals, such as human development, GATS negotiation might still produce results which could easily be too biased towards promoting trade-at-all-cost.

Hence, developing countries need to know precisely what kind of aspired human development goals they wish to have, and how current GATS would allow them to realize those goals. Should they feel strongly about results of a systematic assessment on potential impacts of liberalizing trade in services on human development, for instance, they must communicate the results to their counterparts, and negotiate for flexibility, which would allow them to strike a better balance between trade and human development goals.

Needless to say that the capacity to negotiate effectively simply does not come automatically with having a flexible mechanism, developing countries need to do sufficient homework before they make a commitment. In preparing for a negotiation, it is important to allow sufficient participation of stakeholders in the process. These tasks are immense, and the public sector cannot do it alone. How much developing countries will finally get out of GATS, in particular in environmental services sector, depends on how stakeholders can contribute to the process, not what negotiators feel important for their countries. There is a vacuum of data and information, which prevents formulation of good understanding and knowledge of the complex nature of the sector. This is the basic task that developing countries need to tackle alone at home. Without adequate understanding and knowledge, any most flexible process would produce results fall short expectations.

To jump over these hurdles should not be left to the task of developing countries government alone. WTO has a very important role to play too. A quick assessment is the key area in which WTO can assist members to undertake. And because GATS negotiation is a gradual liberalization, and many countries already have domestic regulations that are relatively progressive, the Council on Trade in Services should work closely with governments to assure that the experiment is hopeful for both developed and developing parties.

Table 1: Two Main Definitions of Environmental Services

1) WTO/CPC*	2) OECD/Eurostat
A. Sewage services (CPC 9401)	A. Wastewater management
B. Refuse disposal services (CPC 9402)	B. Solid waste management
C. Sanitation & similar services (CPC 9403)	C. Air pollution control
D. Other services	D. Noise and vibration abatement
➢ Cleaning services of exhaust gases (CPC 9404)	E. Remediation and cleanup of soil, surface water and groundwater
➢ Noise abatements services (CPC 9405)	F. Analytical services, data collection, analysis and assessment
➢ Nature and landscape protection services (CPC 9406)	G. Environmental R&D
➢ Other environmental protection services n.e.c. (CPC 9409)	H. Education, training, information

Source: *WTO, MTN.GNS/W/120, 10 July 1991

Table 2: Selected Economic Statistics for China, Pakistan and Thailand

Statistics	China		Pakistan		Thailand	
	1998	2000	1998	2000	1998	2000
Population	981 (1980)	1,271 (2001)	83 (1980)	141 (2001)	47 (1980)	63 (2001)
Average population growth (%)	0.9 (95/00)	0.7 (00/01)	2.4 (95/00)	2.2 (00/01)	1.0 (95/00)	0.8 (00/01)
GNP (mil. USD)	923,560	1,062,900	61,451	61,000	131,961	121,600
GNP/cap	750	840	470	440	2,160	2000
GDP growth (%)	7.8	8.0	1.2	4.4	-10.5	4.6
Service sector growth (%)	8.3	9.5	1.6	4.8	-10.0	4.0
HDI	0.59 (1985)	0.72 (1999)	0.4 (1985)	0.5 (1999)	0.68 (1985)	0.76 (1999)
Population in poverty (%)	3.1 (urban 1997)	3.7 (rural 1999)	32.2	na	12.9	na

Note: na = not available
Source: www.adb.org

Table 3: Trade and FDI for China, Pakistan and Thailand, Selected Years

Statistics	China		Pakistan		Thailand	
	1990	2001	1998	2000	1998	2000
Trade as % of GNP	29.7	44.7	28.7	34.3	66.5	112.1
Trade balance	2.2	2.0	-4.6	-2.5	-11.8	2.7
FDI (billion USD)	3.5	38.4	0.2	0.3	2.4	3.4
Official ODA flows from all sources (billion USD)	2.4	2.8	1.5	0.7	0.5	1.1

Source: www.adb.org

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Cleaner Production in Electroplating Industry – A Case Study

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ABSTRACT: Electroplating plants in Malaysia are mostly categorized as small and medium scale industries (SMIs) and there are more than 300 in number mostly situated in the Klang Valley [Lu, 1999]. This case study was conducted at a SMI plant – Metal Polishing Sendirian Berhad situated at Bukit Kemuning, Shah Alam. The plant started operation in 1998 and currently employs 33 staff. This plant was selected as a model plant by Standards and Industrial Research Institute of Malaysia (SIRIM) and Japan International Cooperation Agency (JICA) to devise cleaner production (CP) options. Through implementation of CP the plant is experiencing the benefits whereby operation cost was reduced by approximately RM 3200 per month. There was a decrease in the cost of electricity usage from RM 49,800 to RM 44,800 thus giving a reduction of 10% on the energy bill. A recycling policy was implemented whereby alkaline rinse water was reused and chrome rinsing water were 100% recycled. Chrome rinse or sludge was also reduced from 14m3 to 4m3. These caused the usage of city water supply to reduce from 979m3 to 576m3 (a reduction of 41%) with a saving of approximately RM 193 per month. Two personnel were redundant and were removed as the direct result of CP implementation. This gave a saving of RM 1200 per month. The CP usage resulted in increased efficiency, cost saving and the plant was able to achieve the ISO 14001 in the year 2002.

Keywords: *Electroplating, cleaner production, Malaysia*

INTRODUCTION

Electroplating industry in Malaysia is categorized under small and medium industries (SMIs). It is one of the most polluting industries in Malaysia whereby it contributes to a lot of environmental issues with the release of wastewater and gaseous emission.

The industry is problematic in the sense that it could not comply with environmental and waste disposal regulations in that many of them fails to install treatment systems and for those that have such system, it is often found to have malfunctioning systems or inadequate treatment facilities thereby contaminating the waterways and land with their waste discharges (DOE, 2001). Issues which are currently face by the industry and which are most probably likely to continue to face in the future are financial and technical constraints to pollution control and increase tariffs to encourage pollution control (DOE, 2001).

Cleaner Production

Cleaner production (CP) is defined by UNEP as – "*the continuous application of an integrated preventive environmental strategy to process, products and services to improve eco-efficiency and reduces risks to humans and the environment*".

Cleaner production was first mentioned at Rio Summit as an important strategy to take forward the concept of sustainable development [UNEP, 2002]. Agenda 21 made significant references to Cleaner Production and has in fact served as a guiding framework for the implementation of Cleaner Production whereby it also provided a direction and focus to the adoption of Cleaner Production on a multi-stakeholder and multi-partnership basis [UNEP, 2002]. Powerful combination of economic savings and environmental improvements which cleaner production brings made it to be recognized in Agenda 21 as a means of reconciling environmental protection and development [UNEP, 1995].

The government of Malaysia has done much with various collaborating bodies on the issue of pollution prevention that eventually come to the adoption of cleaner production in some of the most polluted industries in Malaysia. Bodies such as JICA, SIRIM, DANCED (Danish Cooperation for Environmental & Development, DOE (Department of Environment, Malaysia) come up with plans and proposals on various issues pertaining to the adoption of cleaner production in Malaysia. For example, the collaboration of JICA and SIRIM on the cleaner production model for electroplating industry which is the main focus of this case study. Whereas with DANCED, SIRIM also collaborated in the demonstration projects from three industrial sectors which namely electroplating, food, textile dyeing and finishing industry [Hamdan *et. al.*, 1999].

The Ministry of Science, Technology and the Environment, Malaysia also mentioned cleaner production in the National Policy on the Environment whereby industries will be encouraged towards self-regulation and self-help in pollution prevention and control, especially amongst the larger firms, which are capable of adopting clean technologies and have the financial resources to do so [DOE, 2002].

GENERAL OVERVIEW – METAL POLISHING SDN. BHD.

A case study was done on Metal Polishing Sdn. Bhd. Situated in Bukit Kemuning of Shah Alam with its main product as tri-nickel chrome plating. The company was established in the year of 1998 and was relocated to the current location in the year of 1999. The company currently is employing 33 people with operation of approximately 10 hours per day. It was one of the model plant selected under the JICA-SIRIM cleaner production project in 2001 and has been practicing cleaner production as its production policy [JICA-SIRIM, 2002]. In the year of 2002, it was awarded the prestigious ISO 14001 which stands for compliances with environmental laws and production policies imposed by the proprietor of the company.

Through the implementation of cleaner production, there was a mark improvement in terms of monetary gains and quality improvements. Better management system were implemented and newer technologies were being imposed as to substitute the older technologies used in before cleaner production.

PRODUCTION, ENERGY CONSUMPTION AND TOTAL SAVINGS

Before the implementation of cleaner production, total output was 1 million ringgit. But after the implementation of cleaner production, total output was reduced to 900,000 ringgit. Energy consumption was reduced from 197 kWh to 171 kWh after cleaner production. In total, electricity bills were reduced from RM 49,794.00 to RM 44,118.00.

Table 1. Efficiency of cleaner production implementation and savings achieved.

Items	Before cleaner production (July to Oct 2002)	After cleaner production (Nov to Feb 2003)	Savings
City water	979 m^3	576 m^3	403 m^3
Chrome rinse/ sludge	14 m^3	4 m^3	10 m^3
Electricity	197,000 kWh	171,000 kWh	26,000 kWh
Manpower	0	2 (shed)	2 workers shed

Table 2. Total savings in monetary term (RM) after 4 months of cleaner production implementation.

Total savings 4 months after cleaner production implementation (Nov to Feb 2003)		
Items	Amount	Savings in terms of RM
City water	403 m3 x 1.92 RM/m3	RM 773.76
Chrome rinse / sludge	10 m3 of chrome rinse + sludge	RM 534.47
Electricity	26,000 kWh x 0.258 RM/kWh	RM 6708.00
Manpower	2 workers x RM600/worker x 4 months	RM 4800.00
	Total	RM 12816.23

ELECTRICAL EQUIPMENT

List of the main electrical equipment, their ratings, and hours of utilization during the day:

Table 3. Main electrical equipment, their ratings, and hours of utilization

Equipment	Usage	Duration
Heaters	6000 watts x 40 NOS	16 hours
Rectifiers	20000 watts x 7 NOS	10 hours
Motors	2750 watts x 10 NOS	15 hours
Blowers	3750 watts x 1 NOS	10 hours
Compressor	2250 watts x 1 NOS	3 to 4 hours

BY-PRODUCTS/WASTE PRODUCTS

Alkaline rinse water produced was reused and chrome rinsing water was 100% recycled. There was no other utilization for the above waste produced.

ENERGY MANAGEMENT

The person responsible for energy management is Mr. Senthil Kumar who holds the position of QC Engineer with a qualification in electrical engineering. There is a ‘progress report’ on the energy management at the plant and there are energy program objectives to be achieved. Apart from that, there is also analysis done on energy use and there is also a formal energy efficiency target program implemented.

Energy Conservation Problems and Activities

Major energy problems as viewed by the plant management is the heating up and heat lost of plating bath during the operation hours and it indicated that there are potentials for energy conservation in plating bath. The plant was able to implement their energy conservation recommendations on the boilers in the plant. There was no decision making criteria for capital expenditures for energy efficiency projects and no feasibility studies been conducted for major capital investments.

ENVIRONMENTAL MANAGEMENT

The following systems for environmental management have been implemented or planned in the next 3 years ahead.

- Impacts assessment for new plant
- Environmental audits for sites
- Audit for production processes
- Annual environmental reports
- Environmental reviews of suppliers

EMPLOYMENT AND SKILLS IN RELATION TO CLEANER TECHNOLOGIES

A combination of in-house and external suppliers has been used for the design and development of cleaner production technology solutions. Trainings have been carried out in relation to adoption of cleaner technologies which includes environmental awareness courses for management, environmental awareness courses for engineers, and environmental awareness courses for shop floor staff. Trainings were also carried out for environmental management systems which relates to the awards of ISO 14001.

As a direct result of investment in cleaner technologies, jobs have been shed mainly on the semi-skilled workers. This is a direct result of the investment of cleaner technologies as cleaner production and better products are obtained and thus less manpower is needed for handling and checking.

Over the next 3 years, it is expected that investment in cleaner production would give more employment in the field of management, process engineering, skilled production, and semi-skilled production. It is also expected that more in-house expertise in cleaner process technology, environmental management, and environmental product design would be needed which

Steps have been taken by the plant to acquire specialist expertise in relation to cleaner technologies which includes the use of specialist consultants and the training of existing staff in environmental technology and management. It was also found that the plant did not face any difficulties in acquiring knowledge and skills in pursuit of cleaner technology initiatives.

CONCLUSION

Through the implementation of cleaner production, it is observed that Metal Polishing Sdn. Bhd. has gained much with the improvement of standard of products as well as comply with the environmental management systems recommended. Through the awards of ISO 14001, it further proves that Metal Polishing Sdn. Bhd. is indeed a plant which is actively pursuing the implementation of cleaner production and strives to be a model plant among its competitors.

includes as well the use of more environmental consultants.

INVESTMENT IN CLEANER PRODUCTION

Various improvements were made in energy management systems to reduce energy consumption and improve efficiency. Plating baths were lined with double lining and insulator to prevent heat lost, periodical maintenance on contact points or jigs, and periodical removal of impurities in the chrome plating bath were also implemented.

Apart from that, the plant had also invested in new process technologies for waste minimization, recycling and substitution for polluting substance. These included JICA sponsored ion exchanger, recycling of alkaline rinsing water to maximize the usage and the recycle of gloves. There was also a substitution of higher temperature chemicals to lower temperature chemicals.

No new products were introduced that minimize energy consumption and waste and to maximize scope for recycling but the feasibility will be investigated by the plant in the future. Same things also happen to the redesign of existing products in order to minimize energy consumption and waste, and to maximize scope for recycling whereby the feasibility will also be studied in the future.

End of pipe technologies for pollution control were fitted for existing processes that generate wastes whereby they constitute about 60 to 70 % of relevant production processes. Roughly about 30 to 40 % of the waste generating production processes have been redesigned as, or replaced by, cleaner technologies. In the future 3 to 4 years of time, it was foreseen that 50 to 60 % of the relevant processes are expected to be controlled by cleaner technologies. Currently 10 to 20 % of products have been redesigned or replaced to make them environmentally cleaner and it is foreseen that the plant will keep the proportion for the coming 3 years ahead.

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Environmental Management Systems – Some International Perspectives

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ABSTRACT: The aim of this paper is to discuss a number of issues related to ISO 14001, the international standard for environmental management systems (EMS). The standard is a process standard that leaves room for interpretation at company level as well as among lead auditors from certifying bodies. The paper questions whether the interpretation of the standard is uniform both at national and international levels. The paper also suggests changes of ISO 14001 in order to formulate more clear demands of environmental improvements, to include demand for publication of an environmental statement/report and to include product focus more clearly. Secondly the paper briefly presents a cases study of four companies in the automotive industry in South Africa, related to the discussions of ISO 14001 and compliance with environmental regulation.

Keywords:

Environmental Management System, ISO 14001, continuous improvements, regulation, product focus.

INTRODUCTION

The possible solutions to the environmental problems related to industrial production have moved to the companies' production processes. This implies new ways of managing environmental effects, where EMS is central and strategic planning necessary to secure continuous improvements of the environmental performance. The existing consumer patterns in the industrialised parts of the world, the global character of today's environmental problems and the expansion and increasing complexity of the global marketplace demand a response from all countries and from all levels of society. Through the 1990s and up until today, this development has resulted in an increasing pressure on industry, especially in the most developed countries. This pressure derives from the demand that companies should take responsibility for the environmental damage which they create and thus approach their way of managing the environment in a more systematic and proactive way (Welford, 1998).

Environmental concerns are being incorporated in an increasing number of business strategies in order to meet the environmental demands from the different stakeholders or to create a market demand for greener products. Many companies have integrated the responsibility for pollution prevention in their management system, where actions have to take place in order to reduce the environmental impacts. The increasing interest among companies for self-regulation in relation to their environmental impacts has resulted in a need for methods and tools to support reliability and the process of change towards systematic development of cleaner production processes and products. Since the middle of the 1990s, with the publication of ISO 14001 (ISO, 1996), more than 45,000 companies have obtained a certified EMS. ISO 14001 is an international standard which could have a number of opportunities for an organisation (ISO, 2002a):

- A structured approach to addressing the environmental bottom line
- To manage the impact of their activities on the environment better and to demonstrate sound environmental management
- Improved environmental performance
- Addresses not only environmental aspects of the production processes but also those of its products and services.
- Can improve environmental management and enables equal access to a growing "green" market place.

Internationally the implementation of environmental management systems is shown great interest. The number of ISO 14001 certificates increased with 60% from 2000 to 2001, and all in all 36,765 certificates have been issued by 31st December 2001 covering 112 countries (ISO, 2002b). Figure 1 shows the development in the number of issued certifications, which points at a continued interest in the next years.

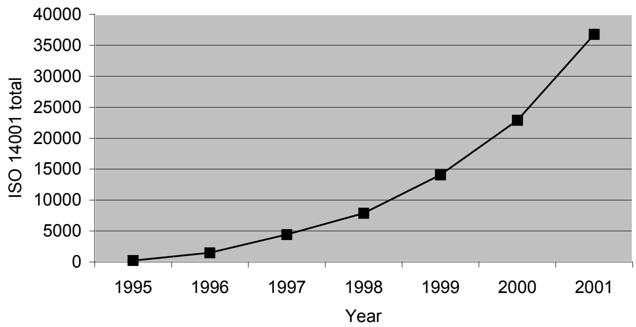

Figure 1. Total number of issued ISO 14001 certificates in the world Dec. 1995 to Dec. 2001 (ISO, 2002b).

APPROPRIATION OF ISO 14001

ISO 14001 is an international standard with the purpose of use in many different types of organisations. The standard does not, and is not intended to contain many specific requirements (Bell, 1997). ISO 14001 is a framework that companies are obliged to adopt in their organisation. However, the standard does not specify how the requirements should be met and they do not provide an indication of what goals it should strive to achieve (Schaltegger et al., 2003). ISO 14001 is a process standard not a performance standard which means the standard does not set up specific demands of environmental improvements. IS0 14001 is flexible with room for interpretations, such as implementation strategies, definition of scope, environmental improvements, internal and external dialogues and co-operation.

An EMS according to ISO 14001 can be considered as a travelling concept both at national and international levels and appropriated to different contexts. The concept of environmental management is shaped due to conditions, such as interests and demands of different stakeholders, the regulatory framework, market structure, organisational identity, educational systems, accreditation bodies, available equipment and production facilities. In the appropriation process, the interpretation of the surrounding environment shapes problem definitions and problem solving strategies. Not only ISO 14001 is translated from one language to another, when travelling, the whole concept and understanding of the environment is translated and transformed in order to perform in a new context.

ISO 14001 –SURVEYS

Several case studies show that organisations certified according to ISO 14001 result in environmental improvements and cost savings for the majority of the organisations. For instance in a case study with about 1,000 respondents it is concluded that *"Basically, a formal EMS does play a role in improving overall performance; it also affects the frequency with which various environmentally related options are used. Furthermore, certification of these systems does have a significant incremental impact on performance and on the reactive options the plants involved in the study considered"* (Melnyk et al., 2002).

Though, still more large-scale studies of the effects of ISO 14001, which should bring more general applicable results, need to be carried out in order to achieve a better insight in the benefits of EMS at international level and differences between countries. (Ammenberg, 2001), (Melnyk et al., 2002), (Morrow and Rondinelli, 2002). The validity of most existing quantitative studies measuring environmental performance in ISO 14001 certified companies can be questioned. First of all the number of certified companies that do not reply on questionnaires used in research are often high, and we do not know why these companies did not reply and what impact they would have made on the results if they had participated. Secondly it must be investigated how companies that are not certified act and perform compared with certified companies. Thirdly it is of importance in a study to know how long the companies have been certified. It can take some time to generate effects but the first years after certification organisations often achieve a number of environmental improvements, "the low hanging fruits", and over time improvements become smaller or are made in connection with technological jumps like investments in new technology. (Ammenberg, 2001), (Melnyk et al., 2002).

THE ROLE OF STAKEHOLDERS

A interesting question is how quickly and to what extent the environmental impacts from industry are reduced in order to move towards a more sustainable production. This will depend on the development in demands from stakeholders, the respondence? of industry and the internal dynamic in the companies in relation to their wish to be one step ahead and to have a reliable environmental image towards the stakeholders. (Jørgensen, 2001).

An important stakeholder in this regard could be the environmental authorities. Regarding environmental pressure from authorities, a common problem of several developing countries is weak administrative and institutional capacities, poor regulatory enforcement and centralised systems.

In countries with weak environmental enforcement of authorities, ISO 14001 is a system that could take the role of securing compliance with the environmental regulation for certified companies in the specific country. A country like South Africa is said to have one of the best environmental laws in the world, but the enforcement is low. Here ISO 14001 ensures that certified companies comply. Another question to be raised here is "what is the differences in regulatory demands of the environmental law in different countries?" In some countries both environmental law and enforcement is weak. For a company with a certified EMS in such a country it might be rather easy to comply with environmental regulation contrary to companies in other countries with more strict environmental regulation with more environmental demands and more control from authorities. As a consequence of this some parent companies have formulated their own environmental standards which all subsidiary companies must comply with no matter where they are situated in the world (Jørgensen, 2001). I will not go further into this question but point out that customers with suppliers certified according to ISO 14001 do not necessarily know anything about how strict environmental regulation is formulated in these countries. This means that customers to a certain extent should obtain knowledge about environmental demands in the countries of their suppliers in order to assess whether it is satisfactory.

Developing countries with limited resources for enforcement of environmental regulation could consider to concentrate on formulation of clear and appropriate environmental law and regulation towards industry and at the same time demand the most polluting companies to become certified according to ISO 14001. In this way it is the lead auditors from the certifying bodies who control and secure that these companies comply with the law.

PUBLIC ASSESS TO ENVIRONMENTAL PERFORMANCE IN INDUSTRY NEEDED

The fact that a company is certified according to ISO 14001 does not automatically inform stakeholders about how polluting the production is compared to other companies. With ISO 14001 the company is only committed to publish their environmental policy and that is most often not sufficient in order to assess and compare the environmental performance of for instance two different companies. EMAS registered companies have to publish an environmental statement which gives stakeholders a better opportunity to assess and compare environmental performances. With the increasing number of stakeholders concerned about the environmental impact and performance of industry, ISO 14001 could respond to this concern by integrating demand for environmental statements in the next edition of ISO 14001. An other way of providing public assess is practised in Denmark since 1995 with a demand for the most polluting companies to deliver an environmental report no matter if they are certified or not.

Public assess to environmental information about performance in the individual company through environmental statements/reports would probably motivate some companies to make an extra effort in order to comply with environmental legislation and conduct continuous improvements of their environmental performance.

ENVIRONMENTAL IMPROVEMENTS

Ananother issue of relevance to discuss is the demand for environmental improvements. What specific environmental improvements the company must live up to is a question of interpretation. ISO 14001 do not provide an indication of what goals the company should strive to achieve. Besides, with an ISO 14001 certification stakeholders do not know if the specific company is among the least polluting companies at national/international level or among the worst.

In relation to the specific formulation of aims companies often set up goals with environmental impacts per produced unit. But what happens when the production increases? If for instance a dairy cleans the pipes twice daily with detergents, and then production increases and they still clean twice daily then the result is that used detergent per produced unit or per amount of raw milk is decreasing. In practise the dairy has not made any environmental improvements, they have just increased production. Is this an environmental improvement? You could say no with the argument that the total use of detergents in the company has not decreased, on the other hand you could argue that it is an improvement because you produce more products with less environmental impact per unit. Another example could be that the dairy uses more energy in total when increasing production, but the energy consumption per ton raw milk might be the same or even decreasing. This means that environmental improvements can be reached in spite of the fact that the total environmental impacts have increased. When this is the reason for the environmental improvements, it should be stated in the environmental statement/report of the company in question, in order to inform the public about the preconditions of the improvements. Companies do expand their production, economic growth is the basis of most businesses. Therefore ISO 14001 should be clearer in the definition of environmental improvements and it should be discussed what kind of goals are most appropriate in order to reduce environmental impacts from industry.

THE ROLE OF THE AUDITORS

The certifying bodies and especially the individual auditors who certify and audit companies' compliance with ISO 14001 play an important role interpreting the standard. As mentioned earlier in this paper ISO 14001 leaves room for interpretation. Both at national and international levels studies show that auditors have different attitudes and opinions of the interpretation. In a comparative analysis of EMAS and ISO 14001 it is indicated that not all auditors demand continuous improvements with an ISO 14001 certificate (Kvistgaard et al., 2001). A Danish auditor has personally experienced differences in the interpretation of continuous improvements between Denmark and Thailand. He thinks that culture has an influence on the demands placed at companies in different contexts

Another example of differences: In Denmark companies must comply with environmental regulation when they are certified. But in an article from 2001 it is stated thatcomplying with regulation is not a necessary precondition for an ISO 14001 certification (Wätzold et al., 2001, p.39). In the next years many companies in developing countries must obtain an ISO 14001 certificate in order to enter the international markets. In this respect it is of great importance that the certificate has credibility and is not something you can pull in a vending machine (lead auditor, 2001). (Jørgensen, 2001).

At national level differences in interpretation between certifying organisations and between auditors in the same certifying body also seems to vary. Smink followed the certification of three car-dismantling companies, which were certified by two different certifying bodies. The auditor in the first company certified the company in only two hours and allowed a consultant of the dismantling company to answer some of the questions (which they are not allowed to do). The auditor from an other certifying body spent two days on each of the other car-dismantling companies. (Smink, 2002).

From interviews with one lead auditor from each of the three biggest certifying organisations in Denmark, it can be concluded that two of the three interviewees do not place demands regarding the environmental impacts of the products on their clients regarding ISO 14001. The third lead auditor demands/requires that the companies have conducted life cycle considerations. (Jørgensen, 2001).

Interviews with 13 auditors from the same certifying body (SWEDAC in Sweden) also show differences in their interpretation of ISO 14001 (Ammenberg et al., 2001). On the question *"How do you control that the requirement regarding continual improvement is fulfilled?"* the answers

varied:
- I focus on the environmental targets (8 auditors)
- I try to make a comprehensive judgement, where environmental targets constitute one part (4 auditors)
- I focus on procedures for handling non-conformance (1 auditor)

On an other question: *"Which criteria are approved for inclusion in the assessment of environmental aspects when determining the significant environmental aspects?"* the answers were:
- Only criteria related to environmental impact are approved (8 auditors)
- Criteria regarding economy, technical possibilities, legal demands, etc. are also approved in the assessment process (5 auditors).

The discussion in the above paragraph indicates that the interpretation of ISO 14001 vary more than the certifying bodies imply. ISO 14001 could be more clear regarding continuous improvements and regarding the assessment of the environmental aspects. As Georg points out: *"auditing is the key to making the organisation transparent, but an important prerequisite for auditing is, however, that things have in some way been made audible"* (Georg, 2003).

MORE PRODUCT FOCUS NEEDED IN ISO 14001

Companies complying with EMAS/ISO 14001 have recognised the responsibility for their own production, but not yet for the whole product chain (Christensen et al., 1999). In the mean-time consumers, wholesalers and authorities are increasingly considering producers as responsible for the whole life cycle of their products. In other words they put pressure on industries concerning increased product responsibility with a basis in life cycle thinking (Thrane et al., 2000). A Danish study of 107 companies complying with EMAS/ISO 14001 shows that EMS has proved to be a good basis for technological innovation and environmental improvements. In nearly half the cases EMS has resulted in cost savings, but the companies also stress the importance of improved image. Although half of the companies have a few aspects of life cycle thinking in the environmental review, the environmental focus is site-specific.

A more product-oriented approach is necessary because the most significant environmental impacts frequently appear in other life cycle stages. This is certainly the case for many food products, as the hot spot is often the primary production, where the demand for energy and land (space) is significant (SIK, 2001). For products with energy consumption during use, such as electronics, the usage stage will often be very important (Wenzel et al., 1997). The latter is also the case for a series of other products such as cars, textiles, chemicals, etc. Other groups of products may cause the largest problems in the disposal stage, such as PVC, products containing large quantities of heavy metals, e.g. some batteries, and various kinds of electronics, etc.

Only 28% of the ISO 14001/EMAS certified companies in Denmark place demands on suppliers and other network collaborations in order to have an EMS certification or other kinds of EMS. In general the formal EMS is not diffused up- and down stream the product chain. This indicates that life cycle thinking and demands for improvements by the suppliers are still not very common. (Kvistgaard et al., 2001). Concerning the possibility for substituting suppliers or customers to obtain environmental improvements there are also other barriers: price and quality are almost always more important than environmental considerations (Thrane, 2000).

An increasing demand for greener products should be promoted both with pressure from stakeholders, regulatory incentives and with initiatives from the individual companies. The companies more often ought to consider taking initiatives to inform and educate their market about their green products. (Jørgensen and Thrane, 2002).

To promote implementation of life cycle based management in industries, demands for product focus should be incorporated strongly in ISO 14001. In principle ISO 14001 holds demands for life cycle thinking in certified companies as the scope for the standard, among other things, states that: *"It applies to those environmental aspects, which the organization can control and over which it can be expected, to have an influence."* (ISO, 1996). For instance, companies producing energy consuming products to households must be considered to have an influence on the energy consumption of the products. Therefore use of these products must be an environmental aspect the company should include in their EMS. In practise this is not often the case.

CASE STUDY OF AUTOMOTIVE INDUSTRY IN SOUTH AFRICA

Case studies were conducted November 2002 in four companies in the automobile industry in South Africa. Two assembling companies (BMW in Pretoria and Delta Motor corporation in Port Elisabeth) and two tyre producers (Bridgestone Firestone and Continental, both situated in Port Elisabeth). Of the four companies only Delta Motor is yet not certified according to ISO 14001. The main purpose of the case studies was to answer the following questions:

- What are the incentives for becoming certified according to ISO 14001?
- What organizational changes have the companies gone through?
- Has the EMS promoted environmental improvements and greening of knowledge?
- How are the relations with stakeholders, and have they been strengthened?

These findings, will be further elaborated in (Smink et al, 2003) and (Jørgensen et al, 2003). Looking at the share of ISO 14001 certificates in different parts of the world it shows, that Europe (48%) and the Far East (35%) together hold more than 80% of the certificates. Other regions in the world have had a slower and/or a later start. In regions characterised by developing countries the share is very little and seems to stay low: Africa/West Asia (2,5%) and Central/South America (1,9%). (ISO, 2002b).

South Africa has been chosen because it belongs to a part of the world, where ISO 14001 is not widely spread at the moment. Today South Africa has by far the most ISO 14001 certificates in Africa (169 certificates by 31st December 2001) (ISO, 2002b). The incentives and barriers for ISO 14001 certification are viewed from the point of the industry in South Africa. It has been chosen to investigate transnational companies in the automobile industry, the supplier relations to the parent company and a business with increasing international environmental regulation, for instance to proper environmental dismantling of automobiles. In this paper it is chosen to discuss findings regarding environmental regulation.

The most difficult part of complying with ISO 14001 has been the environmental legislation. It takes a great amount of time for the companies to gain an overview of the legislation to comply with. They find the law very extensive and incomprehensive. Bridgestone Firestone has made an agreement with a lawyer to interpret the laws and express the essence in a few pages and in an easy language. The environmental manager has a close relationship with the head of the local environmental authorities and stays in direct contact with him to discuss environmental matters. At Continental they also have external assistance. They get a monthly update on any changes in laws in South Africa, including environmental legislation. At BMW they have joined a number of courses to achieve the necessary knowledge about the environmental regulation in South Africa.

In South Africa there are three levels of legislation: national, provincial and local/municipal. On the national level legislation is fragmented between various governmental departments. In absence of South African legislation it sometimes happens that the EPA guidelines for air pollution are used. As for smoke and water pollution, the Dutch intervention guidelines are often used. The enforcement of regulations is weak because of limited government resources (Williams, 2002). *"They (the municipality eds.) do not actually enforce anything, if we did not want to improve the environment we could do some nasty and horrible things"…"Basically it is entirely up to the company to ensure that they run according to strict regulations"* (Continental, 2002). For instance the companies have to contact the authorities themselves in order to ask for specific pollution permits. The companies also take their own water samples; the municipality does not have the resources to do it.

BMW has taken the initiative to a waste club including the major industries in the area. They discuss and inform about environmental issues. Next step for BMW is to get a government representative and local environmental authorities to participate. BMW wants to give companies guidance for improvements of environmental performance. For instance it is difficult for individual companies to have access to every new law, and BMW are willing to share their knowledge about it. They do not want to be a company with high environmental performance while the neighbours still dump stuff into the road and so on. (BMW, 2002). It is interesting that BMW, a transnational company, has put their own resources into organising the waste group caused by lack of enforcement from the environmental authorities.

The case studies show that the companies with a certified EMS have difficulties obtaining an overview of what to comply with and spend a lot of resources in order to secure compliance with legisltation. They complain about the complexity of legislation and the lack of enforcement of legislation.

CONCLUSION

This paper has discussed a number of issues related to the use of certified EMS according to ISO 14001. Some of the issues of concern have their basis in unclearness of the standard, the interpretation of the standard at company level and among auditors from certifying bodies.

First of all more large-scale studies need to be conducted in order to achieve a better insight in the benefits of certified EMS at international level and differences between countries. Such studies need to be aware that the actual number of respondents compared to the number of questionnaires sent out is satisfactory. It must also be investigated how non-certified companies perform compared to certified companies. It also has an impact on surveys for how many years the companies have been certified which might differ significantly between different trades of businesses and between countries.

When certified according to ISO 14001 companies must comply with environmental legislation, but it is important to bear in mind that national legislation and enforcement can differ significantly between countries. Customers who want their suppliers to be certified must gain knowledge about environmental regulation in the specific countries in order to assess whether it is satisfactory. Especially in developing countries with limited resources for enforcement of environmental regulation it is suggested that they concentrate on formulating a clear regulation of high quality and at the same time demand the most polluting companies to become certified according to ISO 14001. This way authorities let the auditors from the certifying bodies control that the companies comply. It is also suggested that ISO 14001 integrate a demand for publication of environmental statements/reports in order to provide public assess to environmental information about performance.

Regarding environmental performance companies often set up goals of impact per produced units. If the company increases production this might result in a reduced impact per unit, even though the total impact is not decreased. It is suggested that ISO 14001 should be clearer in the definition of environmental improvements.

The auditors from the certifying bodies interpret ISO 14001 and assess companies' compliance with the standard. Different surveys show that neither at national nor at international levels do the auditors make the same assessments of issues like continuous improvement and

environmental aspects. ISO 14001 should make these issues easier to audit homogeneously among auditors.
The final suggestion is to incorporate life cycle considerations more strongly in ISO 14001. A more product-oriented approach is necessary because the most significant environmental impacts frequently appear in other life cycle stages than in the certified company in question.

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Responsible Chain Management From A Dynamic Capabilities Perspective

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ABSTRACT: This strategy paper presents a theoretical discussion related to a PhD thesis on 'responsible chain management'. It discusses how a dynamic capabilities perspective can contribute to analysing how firms deal with the issue of responsible chain management and why they choose a certain strategy. It is argued that the dynamic capabilities perspective is valuable in this respect, primarily due to its focus on firm-specific characteristics, its ability to explain why certain capabilities are developed and its focus on how firms respond to changing surroundings. In continuation hereof, the paper introduces two capabilities-based frameworks, which might prove useful in answering the *how* and *why* questions respectively. The first is a capability assessment framework, which perceives responsible chain management as a capability-building process and hence assesses the nature of organisational capabilities relevant for different stages in the process. The second framework attempts to explain why firms choose a certain capability-building strategy. The final section evaluates the applicability of these frameworks.

Keywords:

Environmental responsibility, social responsibility, chain management, dynamic capabilities, capability-building process.

INTRODUCTION

This work-in-progress paper presents some of the theoretical considerations I am dealing with during the initial stages of my PhD thesis.

The topic of my thesis is management of environmental and social issues in global product chains. The topic is based on the notion that product characteristics represent an increasing concern for many firms. Whereas customer demands in the Western world have traditionally focused mainly on cost and quality of products, customers are thus nowadays paying increasing attention to the way the products are being produced, transported and disposed of (de Bakker & Nijhof 2002). Recognising this change in focus, a growing amount of Western firms are striving to produce and market environmentally and socially sound products (Min & Galle 1997). Until now, most firms taking up this challenge have predominantly paid attention to the production phase and are thus focusing on ensuring that their products – throughout the life cycle – are being produced with respect for the external environmental as well as for the workers involved. The task of 'responsible chain management' – as I will label this activity – often poses a considerable challenge for firms. This is the case, since they not only need to be responsible for their own production processes – which has so far been their main concern – but also need to take into account the environmental and social effects of production processes, which are not undertaken by themselves, but by suppliers. Both these tasks are anticipated to be further complicated by the fact that Western companies to an increasing extent establish production units as well as use suppliers in low-wage countries, where environmental and social issues have traditionally not been highly prioritised. I will argue, however, that since most Western firms by now have established the necessary technologies and routines for ensuring a satisfactory environmental and social performance of their own production processes, the major challenge facing many firms today is the task of ensuring environmental and social responsibility of their suppliers.

This challenge of supplier management is reflected in much literature on responsible chain management (which tends to deal mostly with environmental and less with social issues). As such, the vast part of this literature focuses on the way in which firms obtain environmentally (and socially) sound products by putting effort into managing the performance of their suppliers. These contributions are generally dominated by normative claims and seem to neglect theoretical applications. However, the majority of the contributions seem to omit – or at best pay very little attention to – the internal dimension of the firm, which is undertaking responsible chain management. The focal firm is therefore often treated as a 'black box'. I will characterise this omission as a shortcoming, since a firm's internal routines and processes are likely to affect the way it manages its suppliers. A firm undertaking supplier management thus needs to ensure that its own organisation is geared for a life-cycle strategy. Such a strategy often implies that environmental and social issues should be incorporated into the firm's logistics and purchasing decisions and eventually entering the strategic level, i.e. marketing and sales, research and development and corporate finance (Kolk 2000). As part of this process, the notion of life-cycle thinking should be communicated to the employees, and the necessary routines and tools should be developed. In other words, the concept of responsible chain management needs to be consolidated within the internal organisation in order for a firm to manage its suppliers efficiently (Cramer 1996).

Given the nature of much of the existing literature on responsible chain management, I believe there is a need for developing a theoretical framework, which can provide us with a better understanding of 1) how firms incorporate the notion of life-cycle thinking into their own organisation and into the management of their suppliers, and 2) why they choose to do it the way they do, i.e. why they choose one specific strategy over another. These two questions constitute the research questions of my thesis.

The aim of this paper is to present a set of theoretical elements, which I find suitable for these particular research questions, and which I will test empirically at a later stage in my PhD studies. The overall framework, which these elements build upon, is a *dynamic capabilities approach*.

In the following section, a very brief overview of part of the existing literature on responsible chain management will be given. Subsequently follows an introduction to the dynamic capabilities approach, which is followed by a presentation of two conceptual frameworks, which link the capabilities approach with issues of corporate responsibility, and which I find useful for answering my research questions. The final section presents a brief discussion of the applicability of the two frameworks.

RESPONSIBLE CHAIN MANAGEMENT LITERATURE

During the last decade we have witnessed a surge in literature, which seeks to link the field of corporate responsibility – particularly environmental responsibility – with buyer-supplier relations (e.g. Linnanen et al. 1995, Cramer 1996, Walton et al. 1998, Steger 1996). Much of this literature focuses on the supplier-related strategies and tools available for firms, which strive for environmental responsibility in their product chains.

Most of the literature agrees that companies are showing increasing interest in adopting responsible supplier management. It is possible to identify various reasons for this development. Firstly, the development of responsible chain management enables companies to respond more adequately to external criticism of their environmental and social performance. Secondly, greater improvements can be secured with a chain perspective than with improvements confined to an individual company. Thirdly, companies are confronted with increasing pressure to be responsible throughout the product chain from customers, suppliers, consumer and environmental organisations and other external actors. Finally, companies are increasingly recognising the potential benefits of subscribing to responsible chain management, either as a result of fewer costs or improved quality of the products (Cramer 1996, Business for Social Responsibility 2001).

Broadly speaking, most literature seems to distinguish between two main categories of supplier management strategies adopted by the focal firm. The first category is *requests*, which are often employed in order to ensure that suppliers do not provide the customer company with products that contain restricted substances; to ensure that suppliers are implementing environmental management systems; or to make suppliers explain their environmental and social practices. Such requests are often communicated through questionnaires or codes of conduct and possibly followed up upon by audits. The second category comprises *collaborative processes* whereby new products and technologies and changes in materials or processes etc. at the supplier are discussed/implemented, suppliers are equipped with tools and information resources to communicate about environmental and possibly social issues with their own suppliers, etc. Collaborative processes often take the form of face-to-face meetings, training, workshops and active partnerships. Most authors argue that whereas the former coordination mechanisms, i.e. requests, are fairly easy and cheap to employ and hence widespread among firms, collaborative processes require more resources. It is widely recognised that firms should primarily focus their collaboration efforts on suppliers of strategic products, and to a lesser extent on suppliers of volume products or critical products (Petersen et al. 2000).

THE DYNAMIC CAPABILITIES PERSPECTIVE

Despite the fact that most literature on responsible chain management focuses on how suppliers should be managed, a major argument in this paper is that this discipline involves an internal aspect as well. Recognising the need for an internal dimension to responsible chain management, I suggest that my research questions could be approached by applying a *dynamic capabilities perspective*. In this section, I will provide an overview of this strand of theory and present some of the arguments for applying this particular perspective.

The dynamic capabilities approach as it is presented here is based on the work of Teece at al. (1997)[1]. The approach can be categorised as part of the *resource-based* literature, which is part of the broad range of literature on *strategic management.*

Strategic management literature deals with the match an organisation makes between its internal resources and skills on the one hand and the opportunities and risks created by its external environment on the other (Grant 1991). During the 1980s, the dominant paradigm within this field of literature was the 'competitive forces' approach developed by Porter (1980). This approach takes point of departure in the actions a firm can engage in to create defensible positions against competitive forces. A second approach is the 'strategic conflict' approach (e.g. Shapiro 1989). Here, competitive outcomes are looked upon as a function of the effectiveness with which firms keep their rivals off balance through strategic investments, pricing strategies, signalling

[1] Teece et al. are not the only authors dealing with dynamic capabilities, but their framework as it is presented here is widely acknowledged and does probably constitute one of the most comprehensive works on dynamic capabilities developed to date. It should be recognised, however, that the framework as it appears here does still offer room for improvement – both in terms of further theoretical work and empirical testing (Teece et al. 1997).

and the control of information. Finally, a third type of approaches deals with the building of competitive advantage through capturing entrepreneurial rents stemming from fundamental firm-level efficiency advantages. Whereas both the competitive forces and strategic conflict approaches generally see profits as stemming from strategising – i.e. from limitations on competition which firms achieve through raising rivals' costs and exclusionary behaviour – this third approach sees competitive advantage as stemming from high-performance routines operating inside the firm, shaped by processes and positions (Teece et al. 1997).

One strand within this third type of approach is the 'resource-based perspective', which focuses on firm-specific capabilities and assets as well as the existence of isolating mechanisms as the fundamental determinants of firm performance (Teece et al. 1997). The resource-based perspective has experienced a revival during the 1980s, primarily due to a resurgence of interest in the role of the firm's resources as the foundation for firm strategy. This interest is mainly a result of dissatisfaction with the static, equilibrium framework of industrial organisation economics, which has dominated much contemporary thinking about business strategy (Grant 1991). The resource-based perspective recognises – but does not attempt to explain – the nature of the isolating mechanism, which enables entrepreneurial rents and competitive advantage to be sustained (Teece et al. 1997). In order to make up for the lack of an explanatory dimension, Teece et al. have developed another component of the resource-based perspective. This component not only *identifies* the dimensions of firm-specific capabilities that can be sources of advantage, but also *explains* how combinations of competencies and resources can be developed, deployed and protected. It is this approach, which has come to be labelled 'the dynamic capabilities approach'.

In short, the dynamic capabilities approach focuses on the development of management capabilities and difficult-to-imitate combinations of organisational, functional and technological skills. It integrates as well as draws upon research within fields of R&D management, product and process development, technology transfer, intellectual property, manufacturing, human resources and organisational learning (Teece et al. 1997).

The definition of capabilities used in the dynamic capabilities approach is based on Learned et al. (1969), who suggest that a capability of an organisation can be defined as 'its demonstrated and potential ability to accomplish against the opposition of circumstance or competition whatever it sets out to do'. The term 'dynamic' refers to 'the capacity to renew competences so as to achieve congruence with the changing business environment; certain innovative responses are required when time-to-market and timing are critical, the rate of technological change is rapid, and the nature of future competition and markets difficult to determine' (Teece et al. 1997). Important changes might stem from technological breakthroughs, major changes in the strategic behaviour of competitors, macro-economic developments and crises, or changes in the regulatory and legal contexts of doing business.

According to Teece et al., dynamic capabilities are an expression of three fundamental elements: processes, asset positions and paths. As such, the major argument is that a firm's competitive advantage is closely connected to its *managerial and organisational processes* (the way things are done in the firm, i.e. the routines or patterns of current practice and learning, both regarding internal matters and external coordination/integration) shaped by its *asset positions* (endowments of technology, intellectual property, complementary assets, customer base, external relations with suppliers and competitors) as well as its *paths* (previous investments and repertoire of routines as well as technological opportunities within the industry) available to it.

It is moreover worth mentioning that there are two fundamental characteristics related to the framework: the firm's competences and capabilities cannot be bought, but must be *built*, and competences can provide competitive advantage and generate rents only if they are based on a collection of routines, skills and complementary assets that are *difficult to imitate*.

By building a dynamic view of the firm, which is absent in most literature on strategic management, Teece et al. have attempted to break with the normative tradition of this field and thus tried to establish an acceptable descriptive theory of strategy, which can assist practitioners in the building of long-run advantage and competitive flexibility (Teece et al. 1997).

Based on the characteristics of the dynamic capabilities perspective just outlined, various arguments for applying this particular perspective to my research can be identified. Some of these will be mentioned here. First of all, my research centres on the way in which individual firms deal with the issue of responsibility, and it is therefore relevant to apply a theoretical perspective, which focuses on firm-specific characteristics, as is the case with the capabilities perspective. Secondly, since the dynamic capabilities approach aims at both identifying capabilities and explaining how they can be developed and deployed, its application is likely to enable me to answer both research questions, i.e. both the question of *how* firms undertake responsible chain management as well as the question of *why* a certain strategy has been chosen. Thirdly, the term 'dynamic' indicates that the dynamic capabilities approach differs from the relatively static representation of the firm as suggested by the mainstream resource-based literature and hence focuses on change and on what happens in a firm when it is confronted by a relatively large change in its environment (den Hond 1996). This focus on change represents yet another reason for applying the approach to the field of responsible chain management, which does indeed constitute a new reality for many firms.

THE CAPABILITIES APPROACH AND RESPONSIBLE CHAIN MANAGEMENT

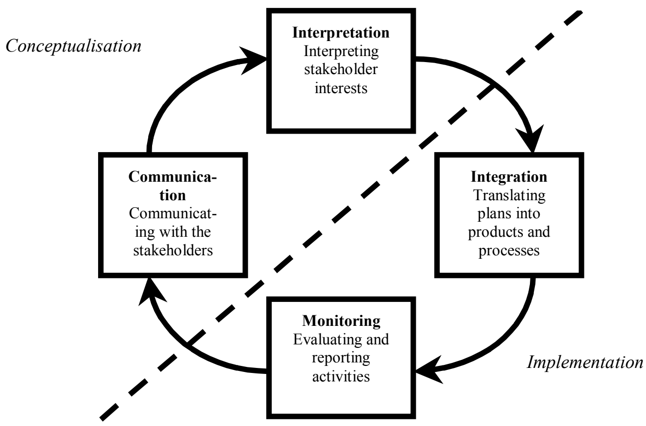
Following this brief overview of the dynamic capabilities approach, I will now turn to two conceptual frameworks, which have attempted to make the theory on capabilities operational with regard to issues of corporate responsibility.

A Capability-Building Process

In line with the dynamic capabilities approach, a major argument in my thesis is that issues of corporate responsibility are considered as originating from external pressure upon the firm. A firm's response to external pressure to adopt responsible chain management might represent a complex process, primarily due to the many actors involved and the complexity of the environmental and social issues. Accordingly, the firm might identify multiple ways of responding to the pressure from stakeholders (den Hond 1996). Some of the solutions might be possible to undertake with the firm's existing capabilities, whereas others will require the development of new capabilities. To understand how a firm acts upon external pressure, I propose to apply the capability-building process model of problem solving developed by Iansiti & Clark (1994)[2]. Thus, paying attention to the problem-solving process seems adequate when seeking to analyse how a firm learns about the details of the problem, considers potential solutions, seeks to effectuate adaptations in its capabilities and organisational routines or possibly develops new capabilities and routines (den Hond 1996). I find the particular model useful as it addresses the need to develop capabilities for problem solving as well as the need to coordinate problem-solving activities among a set of actors. According to the model, problems are solved in two phases. In the first phase, the problem in question is analysed, knowledge gaps are identified, potential solutions are defined, and the relevant knowledge and capabilities for solving the problem are developed through organisational learning. In the second phase, the implementation of one – or possibly several – solution(s) is undertaken, meaning that the new knowledge and capabilities are transformed into organisational routines and implemented into activities. An underlying assumption in this model is that a firm's activities are based on its capabilities and that these in turn depend on knowledge. From this follows that problem-solving activities are based on renewal or possibly the development of new capabilities and hence on the development of new knowledge.

A further underlying notion of the capability-building process model is internal and external integration. According to Iansiti & Clark (1994), external integration occurs in the conceptualisation phase, when a firm moves beyond its existing knowledge and frames capability-building activities, which are needed to respond to new external circumstances. A distinction is made between customer integration and technology integration with the aim of capturing the dynamics and complexity of a given industry. Internal integration, on the other hand, is required for implementation and thus associated with coordination, leadership and organisational routines.

Iansiti & Clark's model is used as a point of departure in a framework developed by de Bakker & Nijhof (2002). De Bakker & Nijhof have thus described and analysed a capability-building process related to the specific topic of my thesis, i.e. responsible chain management. In their work, they have suggested a further division of the process described by Iansiti & Clark into four interconnected stages resulting in a so-called 'capability cycle' (see figure 1). The cycle combines the concepts of capabilities, stakeholder theory and continuous improvement as known from quality management. It is argued that capabilities result from a continuous process of addressing and interpreting stakeholder interests. In other words, to the extent the firm is able to recognise its interdependence with its surroundings, reflect upon the ethical standards appropriate to the situation, and react in a timely and responsive manner, it possesses valuable, rare, inimitable and non-substitutable assets – or strategic resources.



Source: de Bakker & Nijhof 2002

Figure 1: The capability cycle

In the *interpretation* phase, signals from stakeholders are considered, and capabilities such as responsiveness, knowing how to act and ethical deliberation play a role. The role of managerial decision-makers is often important for the way in which stakeholder signals are perceived. The various expectations are then translated into organisational plans. In the *integration* phase, the organisational plans are turned into action. Processes and products are assessed from a life cycle thinking, and a way is found to meet the objectives that were set during the interpretation stage. As for the *monitoring* phase, the actions undertaken are evaluated and reported upon. Monitoring can be carried out either internally or externally. Finally, in the *communication* phase, a dialogue with stakeholders is organised. This dialogue can determine whether the issues have been sufficiently resolved. If so, new objectives can be set, and if not, an adjustment to the plans can be made.

[2] The model was originally developed for the development of new products and processes, but has been used for analysing other managerial fields as well.

As already mentioned, Iansiti & Clark (1994) emphasise the importance of considering both internal and external integration in developing capabilities. In their capability cycle, de Bakker & Nijhof also adopt such a distinction. They however broaden the scope beyond mere integration. From this follows that each of the four categories in the cycle can be regarded as having internal and external dimensions, which each includes a set of capabilities. This is illustrated in a 'capability assessment framework' (see figure 2). This framework provides a structure for assessing a firm's capability base required to address issues of responsibility throughout the product chain. Thus, by considering how well each cell in the framework is met by the firm's capability base, the firm can obtain an overview of its strengths and weaknesses in terms of organisational capabilities during the four stages of the capability cycle.

	Internal	External
Interpretation	• Determining a clear mission statement and company policy • Drawing up a code of conduct • Determining organisational responsibilities	• Discussing organisational responsibilities with e.g. customers, suppliers, special interest groups • Organising a stakeholder debate to produce a code of conduct
Integration	• Translating responsibilities into processes (e.g. selecting and training employees, sales structure) • Taking responsibility by changing characteristics of products (e.g. product safety, impact on environment)	• Getting other parties in the product chain to accept their responsibility • Assisting suppliers in living up to their responsibilities, e.g. by giving them advice or financial support
Monitoring	• First party auditing. An organisation audits itself • Keeping track of data relevant to responsible chain management	• Second party auditing. An organisation audits its own suppliers • Third party auditing. Audits performed by an independent auditing body
Communication	• Internally justifying organisational behaviour • Establishing management systems (e.g. ISO 14001, SA 8000) • Making relevant information available	• Dealing with questions or complaints from stakeholders – being held accountable • Labelling products to show that the products meet certain criteria

Source: de Bakker & Nijhof 2002

Figure 2: An illustration of a capability assessment framework

Capabilities-Based Strategies

The capability assessment framework just outlined is useful for at least two purposes: it can function as a guideline for developing new organisational initiatives in the field of responsible chain management, and it can be used to assess existing initiatives in order to evaluate their comprehensiveness (de Bakker & Nijhof 2002). As I see it, the framework does not, however, provide an explanation as to why a firm chooses a certain way – i.e. a certain set of capabilities – of responding to stakeholder demands. As such, even though the framework does in fact indicate that the signals from stakeholders influence organisational planning, it does not propose why a certain planning – or strategy – is chosen over another.

For this purpose, I find it relevant to turn to the work of den Hond (1996), who has developed a 'framework for capabilities-based environmental strategies'[3]. This framework treats environmental issues as a problem, which originates from external pressure upon the firm, and which the firm can solve by developing the appropriate capabilities. According to den Hond, some of the often-mentioned factors in explaining why a firm chooses a certain problem-solving strategy are the financial position of the firm (e.g. does the firm possess the necessary resources for investing in pollution abatement technologies and training programs for its employees?) and its organisational culture (e.g. a culture of being a front-runner with respect to technological and/or market innovation). It is, however, argued that despite the influence of these factors in deciding which environmental strategy to pursue, they provide partially unsatisfactory explanations, as it is too easily assumed that their presence lead to a non-problematic solution of environmental problems. It is argued that these factors are merely starting points for renewing a firm's capabilities and for developing new capabilities. Instead, den Hond has identified three other factors, which have an important impact on a firm's ability to develop an environmental strategy. These three factors are *complementarity*, *innovation potential* and *appropriability*, and they are closely related to the problem-solving process model as suggested by Iansiti & Clark (1994). As such, den Hond proposes that during the conceptualisation phase, the various options for problem solving are assessed based on the firm's perception of the existence of technological options for problem solving, which can improve its capabilities. During the implementation phase, the question of control over the selected problem-solving activities becomes relevant. This decision is primarily based on the extent to which the activities are complementary to the firm's core activities as well as on the degree to which the firm can appropriate the profits associated with the problem-solving activities. Based on these assumptions, den Hond proposes a matrix, which indicates how different combinations of the three factors affect the choice of a specific environmental strategy:

high	high	high	"mastering the environmental challenge"
high	high	low	"close cooperation"
high	low	high	"prepare business plan"
high	low	low	"specialised subcontracting"
low	high	high	"diversification"
low	high	low	"distant cooperation"
low	low	high	"standard subcontracting"
low	low	low	"keep the dog out"

Source: den Hond 1996

Figure 3: A matrix of capabilities-based environmental strategies

At one extreme we find a solution characterised by high complementarity with the firm's core activities, high potential for enhancing the firm's capabilities, and perceived opportunities for appropriating profits. According to the capabilities perspective, the firm should pursue such a solution and integrate it within the firm's hierarchy, since the solution enhances the firm's capabilities. The firm is therefore likely to pursue close control over the

[3] The framework has been developed with the aim of applying it to the issue of end-of-life product recycling. However, I will propose that it to a large extent can be applied to the issue of responsible chain management as well.

implementation of the problem-solving activities, and the required capabilities are hence developed in-house. By undertaking such a solution, the firm is 'mastering the environmental challenge'. In another situation, which is located towards the other extreme of the matrix, a firm might find that complementarity and technological options are low, but appropriability of profits is high. A likely response would be to buy in standard technology instead of developing it itself. If the technology has been developed by other firms, it is profitable for the firm to adopt it due to high appropriability of profits associated with its use. Such a strategy is labelled 'standard subcontracting'.

USEFUL THEORETICAL FRAMEWORKS?

Even though the two frameworks presented in the preceding section are both taking point of departure in the capabilities approach, they direct attention to different aspects of responsible chain management. The capability assessment framework assesses the nature of organisational capabilities relevant for undertaking responsible chain management. The framework for capabilities-based environmental strategies, on the other hand, is useful for gaining an understanding of why a certain way of dealing with responsible chain management is chosen. In other words, it provides an explanation for why a firm develops certain organisational capabilities for solving environmental and social issues. Following the notion of the dynamic capabilities perspective presented earlier, I will thus argue that the former framework deals with the *organisational and managerial processes* needed for responsible chain management, whereas the latter framework could be seen as an explanation of how *path-dependent factors* as well as *asset positions* influence the choice of processes. Given the *how* and the *why* research questions posed earlier, the inclusion of both frameworks in the thesis for empirical testing might therefore prove useful.

Despite their usefulness, the two frameworks might not suffice as the only theoretical contributions in the thesis. Various shortcomings related to the two frameworks could be identified along with various suggestions for adaptations or improvements. However, due to the limited space, only a few shortcomings and suggestions for improvements will be presented here. Firstly, although the capability assessment framework indicates a range of capabilities relevant for the organisation of responsible chain management, it does not translate the capabilities into concrete organisational aspects. As such, this framework could be considered a first step in identifying the organisational initiatives relevant for undertaking responsible chain management. To analyse the organisational implications of organising responsible chain management in greater detail, it might be relevant to extend the framework by drawing on a matrix for product-oriented environmental management developed by de Bakker (2001). This matrix provides a framework for identifying important system-technical and social-dynamic organisational elements involved in developing product-oriented environmental management, which resembles responsible chain management.

Secondly, regarding the framework for capabilities-based environmental strategies, I believe that the three factors proposed might not be able to provide an adequate explanation for responsible chain management strategy. I will thus argue that a firm's organisational culture, encompassing e.g. the perception of environmental and social issues as well as the traditions for dealing with these, constitutes an important explanatory factor as well. Besides organisational culture, also exogenous factors are likely to influence a firm's choice of strategy. Thus, by drawing on e.g. institutional theory it is possible to analyse how a firm reacts to the direct pressures of external stakeholders as well as how its social choices are shaped, mediated and channelled (Hoffman 2001).

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The Development Of Cleaner Production Practices Between Environmental Management And National Policy Development In Malaysia - The Case Of Electroplating Small And Medium Scale Enterprises (SMEs)

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ABSTRACT: Cleaner technologies (CT) have been introduced into the Malaysian SME-sector primarily by foreign donor supported project interventions. The establishment of the Environmental and Energy Technology Centre at SIRIM was funded by a grant from the Danish Co-operation for Environment and Development (DANCED), Ministry of Environment and Energy. Small and medium-scale enterprises (SMEs) were targeted within three sectors: Textile, food and electroplating industries. The paper illustrates the change process from the perspective of electroplating SMEs by reviewing the cleaner production options chosen, presenting figures on the results achieved, and discussing the experiences gained. Reviewing the approach and results of the Centre, as well as the status of cleaner production (CP) in Malaysia, the paper outlines the challenges for national policy making, when moving from promotion by project intervention towards sustainable practices in the SME sector at large.
The paper draws upon data collection conducted by the research project 'A Study on Promotion and Implementation of Cleaner Production Practices in Malaysian Industry - Development of a National Program and Action Plan for Promotion of Cleaner Production'.

Keywords: Cleaner production, environmental management, electroplating

INTRODUCTION

In 1987-95, the Council for Reuse and Less Polluting Technologies in Denmark, on basis of public funds, offered financial support for the development of cleaner technologies. By supporting pilot projects, the aim was been to establish and demonstrate the advantages of cleaner technologies. The financial support program became an important element of the new Danish environmental policy, as expressed in the 1991 amendments of the Environmental Protection Act (Miljøstyrelsen 1995).

Following the United Nations Conference on Environment and Development (UNCED) held in Rio de Janeiro in 1992, the Danish Government decided to set up a special facility to contribute to restoring the global environment in accordance with the UNCED recommendations (Agenda 21). The facility - part of the Danish Environment, Peace and Stability Facility (EPSF) - was managed jointly by the Danish Ministry of the Environment and Energy (DANCED) and the Ministry of Foreign Affairs (DANIDA). DANCED Activities were concentrated in two regions: South East Asia (Malaysia and Thailand) and Southern Africa.

In both regions, major project interventions were undertaken by DANCED to promote cleaner technologies in three selected industries: Textile, food and electroplating. In Malaysia, an Environmental and Energy Technology Centre at SIRIM was established at SIRIM Berhad (formerly known as the Standards and Industrial Research Institute of Malaysia), which is a government-owned company under the Minister of Finance Incorporated. Among others, SIRIM's role is to act as the national technology development corporation and as a vehicle for technology transfer to enhance the customers' competitiveness.

TRANSFER OF CLEANER TECHNOLOGY

These projects were based upon the expertise on cleaner technologies developed as a result of the support programme initiated by the Council for Reuse and Less Polluting Technologies in Denmark. The Danish Department of Environment had chosen to focus on three industrial sectors: Textile, food and electroplating, because these industries were perceived as contributing substantially to toxic emissions. They argued that only a selective effort targeting these sectors comprising quite a large number of factories would produce visible and significant results. One concern was the use of organic solvents which endangers the working environment and was assumed to pollute the atmosphere. The second concern was the emission of heavy metals, in particular chrome and other substances by the electroplating industry and the use of mercury, which complicates waste disposal. A third concern was the amount of organic matter in the waste water of the food industry, in particular fish processing plants.

Addressing these environmental hazards helped to build a knowledge resource base, which the Danish government decided to utilize in a general drive to promote system exports, and in a particular effort to market Danish environmental technologies. A basic rationale for DANCED funded projects was that they would prepare the market for delivery of hardware, thus supporting Danish industry. However, the transfer of cleaner technologies soon encountered problems. As an example, while the supply of an ion-exchange system to Malaysia was readily available from Danish companies, no support for this system could be found in Malaysia. Eventually, a local engineering company and also a local supplier were identified. Also, the economic downturn in Southeast Asia significantly reduced the prospects for Danish exports. The DANCED projects focused on capacity building, which did draw upon Danish knowledge resources on cleaner technologies in the training and education of staff.

THE CLEANER TECHNOLOGY CENTRE

A major project intervention funded by DANCED to promote cleaner technology was the Environmental and Energy Technology Centre at SIRIM in Malaysia (DANCED 1999a & 1999b). The first phase of the CT project established demonstration project and the three selected industries, and developed the organisational capacity of the Centre to audit and advice SMEs within these sectors. However, the objective of promoting CT beyond the demonstration projects was not sufficiently met. Thus, for the second phase, the emphasis shifted as reflected in changed title of the project: 'Cleaner Technology for Improved Efficiency and Productivity of the Malaysian Industry'. The revised overall objective stated the project should "*reduce the environmental pollution from the small and medium scale industries and improve their compliance with environmental regulations at the same time as it may improve their overall productivity"*. The improvement of the environmental performance and compliance with regulations of a significant number of small and especially medium scale industries were now to be motivated by the potential reduction of cost, increase of productivity and market opportunities. A key element in the second phase was to strengthen the CT Extension Service and Information Service established at SIRIM in applying a customer-oriented and market based approach towards the SME sector in Malaysia.

In 2000, a Swedish team evaluated all DANCED funded CT/CP activities in South East Asia (Malaysia and Thailand) and Southern Africa (Rodhe & Kogg 2001). In reviewing their basic findings that the implementation of project activities was achieved, while the continuation and the dissemination of cleaner technology practices in industry were quite limited, the evaluation team compared three different approaches adopted by DANCED.

APPROACHES IN CT/CP PROMOTION

The *centre approach*, which was adopted in Thailand and Malaysia, focuses on one organisation for the outreach in the country. The centre functions as focal point thereby attracting/channelling/making possible efforts by other contracting bodies after the initial establishing phases. It will include 'public services' such as information services and awareness raising seminars along with more direct CP work with companies. The evaluation team conclude Centres will have to face the challenge of finding new ways to generate income when the donor support is withdrawn, and particularly to be able to continue the public service activities. Also, attracting companies to joining CT projects has proved difficult.

The *three pronged approach* was launched in South Africa. Each project exclusively addresses one industrial sector, and it involves three types of local actors within that sector: An industry association, industry service providers (e.g. consultancies, research institutes etc.) and industry itself. The activities undertaken within a project are very similar to activities undertaken in the Centre projects, however, as only one industry sector is addressed, these projects can be more specialised in for example training and awareness activities. It relies on two different actors and attempts to embed the CP capacity and awareness in stable structures that already exists and that already have a natural connection to the companies that the project seeks to influence.

The *policy approach* recognizes that CT efforts worldwide traditionally have had a focus at the technical operations level in industry and the typical actors "owning" the CP agenda have been, and still largely are, found in the realm of engineers. A strong tendency today is to try to complement the activities directed straight towards industry with policy-oriented activity in order to increase the incentives for industry to implement CT measures. Although the relevance is high in doing so, the process engaged implies new challenges with for example new competence requirements including insights in policy making and ability for effective communication with a variety of professionals from the policy domain.

In suggesting the policy approach the Swedish evaluation team clearly recognises the limitations in terms of institutional capacity building of the DANCED projects. While the problem analysis of these projects may have identified the institutional capacity constraints, it has proven largely beyond their scope to address them efficiently.

CLEANER PRODUCTION IN MALAYSIA

Cleaner production is not new to Malaysia. Since the decade of 1990s, several cases have been reported on the success of many industries in adopting CP, particularly on waste minimization. There are a number of examples of progress from local and multinational companies (ENSEARCH 1998). In the Malaysian's Outline Perspective Plan Three (OPP3) 2001-2010, the importance of CP has been clearly recognized. In specific it touches on the utilization of energy and materials, and pollution intensity per unit of production resulting from industrial-urban based growth and development that has been identified as a national environment-related issue.

The CP component activity intends to support the present initiatives by the Department of Environment (DOE) in preventing, minimizing and control of industrial environmental pollution problems through legislative approach. In the past, the Malaysian Government has adopted the "end-of-pipe" approach for industrial pollution control, in which human resource; capital and environmental resources are invested in pollution discharge control at the end of the production line to meet the regulatory requirements. The emphasis of the approach has many limitations, primarily not providing incentive for further environmental protection initiatives, as well as – indirectly - discouraging industries from implementing cost-effective control measures.

Despite many promotional activities and incentives initiated by the government, the implementation of CP is still limited to certain quarters of industry, particularly owned by multi-national companies. Small and medium industries (SMEs) are still, in general, reluctant to adopt CP, mainly due perceived additional cost in adopting a new "cleaner" technology.

ELECTROPLATING SMEs IN MALAYSIA

In Malaysia there are more than 300 electroplating companies and the majority of them are small and medium scale industries (SMEs). About 30 per cent of them are located in the Klang Valley and Selangor. The electroplating process utilizes a wide variety of chemicals, depending on the types of metals that are processed for electroplating and the types of metallic coating that the facility applies to the processed substrates. Since parts are typically processed in a water–based solution containing a combination of these chemicals and are then rinsed, the chemicals purchased by an electroplating facility normally will find their way into one or more wastewater streams, can be emitted into the air through process exhaust systems, and can find their way into the soil through leaking from landfills and from past land disposal practices or poor facility maintenance.

Many electroplating facilities also generate concentrated wastes that may contain high concentrations (in the range of gm per litre) of toxic metals such as lead, cadmium, or hexavalent chromium, or other toxics such as chlorinated solvents and cyanide. These waste streams typically originate from stripping operations, unrecoverable contamination of electroplating solutions, or use of processing solutions with a finite utility life. Quantities of waste generated are so variable that a generalization cannot be made. Some facilities generate no more than a few litres of waste per day, while others generate 40 cubic meters per week.

Electroplating involves processing the part to be electroplated through a series of water-based solutions containing one or more chemicals that either clean, deoxidize, or coat the part. Because each processing step utilizes specialized chemicals that would react unfavourably with the subsequent process, every processing step is followed by a water rinse. The rinse water thus becomes contaminated with the processing chemicals and needs to be treated for purification prior to discharge. Rinsing is performed in either flowing-water rinse tanks or in counter flow or controlled-flow rinse tanks that conserve water usage. Certain processes are equipped with accessory equipment such as filters, heat exchangers, and air scrubbers. These accessories can be additional sources of chemical wastes, along with other operations such as process tank maintenance, pickling, de-rusting and etching of metallic parts, solvent degreasing, and production of de-ionised water for critical rinsing and tank makeup. The equipment used for electroplating operations can be as primitive as a series of tanks made from plastic drums and rectifiers, all the way to automated systems driven by computers, process controllers, and programmed hoists.

POLLUTION PREVENTION OPTIONS

The most commonly practiced pollution prevention option in electroplating is the utilization of drag-out rinses. These involve use of water bearing rinse tanks where parts are rinsed in after processing but before rinsing in a flowing-water rinse. The water and chemicals collected in the drag-out rinse are returned to process tank to make up for the evaporative losses.

The second most popular pollution prevention alternative is substitution. For example, there are several different chemicals available for zinc plating, including some that contain cyanide and others that do not. By successfully making enough changes to allow the use of non-cyanide zinc-plating process, cyanide can be eliminated from the facility.

The electroplating industry utilizes numerous recovery-and-recycle techniques to return a portion or all of the process chemicals to the origin. The typical plater will first evaluate the efficacy of drag-out rinsing; will determine if a viable, less polluting or non-polluting substitute exist; and will make those changes before investing in recovery-and-recycle equipment.

Recovery-and-recycle equipment is generally expensive, requires reduction of water usage to be economically feasible, and increases the maintenance workload and operational complexity of the electroplating facility. However, such systems can reduce the amount of solid waste generated by the electroplater and can often yield net saving in chemical costs that can often pay for the equipment in a matter of a few months.

Direct reuse involves the reuse of a waste material without processing it either as a feedstock in a production process or as a substitute for a commercial process. Recycled chemicals are used or reused in other industrial processes or are used as substitutes for other chemical products.

CP SUCCESSES IN MALAYSIAN SMEs

The DANCED funded demonstration projects made use of ion exchange and counter rinse (Hamdan Mokhtar et.al.). One was *Kilang Sadur Elektrik QUALITY Sdn. Bhd. (QEP)*, which is a typical SME providing commissioning plating for the automotive and electronic industries. When the law made it mandatory for all electroplating companies to have treatment plants, QEP installed a 20 gallons/min treatment plant, which cost around RM 300, 000. The pollution prevention installation at QEP comprises of two ion exchange units. One system is installed at the zinc plating line, while the other is installed at the chromate line. Three-stage counter-flow rinsing is implemented with the desired rinsing flow rate. The purpose of these units is to clean the final rinses and keep them completely deionised. Part of the deionised water is sent in counter-current flow with the product in process. The counter-current flow is balanced with the compensation for the evaporation from the various plating tanks. The rinse water becomes more and more concentrated with plating chemicals dragged out from the plating tank during the counter-current rinsing process. The rinse water with plating chemicals can be regarded as diluted plating solution and subsequently used for topping up the plating solution.

The overall benefits of the pollution prevention installations are to reduce the water consumption by about 80 per cent and to save plating and treatment chemicals especially from the systems installed in the zinc plating and chromating lines. In fact, the continuous wastewater stream from the zinc plating and chromating lines were almost eliminated. Wastewater is only produced during regeneration of the ion exchange units. At the present production capacity, regeneration takes place once a month. Currently, QEP has no problems in complying with the regulations; even through treatment is only carried out during weekends for just a couple of hours. With the reductions in wastewater and therefore in sludge volume, the waste management cost is reduced accordingly. With the ion exchange system, the final rinse tank is crystal clear with a conductivity of 0.2 us. The plated products were cleaned more effectively resulting in higher plating quality.

Metal Polishing Industries Sdn. Bhd. makes three layer nickel and chromium (bright and hard) plating on one production line with a capacity of 800 m^2 per day. The company was established in 1992 and relocated in 1998 to Bukit Kemuning Electroplating Park, Shah Alam, which includes a centralised wastewater treatment plant. It employs 33 people with operation of approximately 10 hours per day. It was one of the model plants selected under the Japan International Cooperation Agency (JICA) - SIRIM Cleaner Production project in 2001 (JICA 2002). In 2002, it was certified ISO 14001. The main customers are motorcycle-assembling factories. The plant has 1, 200 square meters of building area. There is a wastewater treatment centre in this electroplating park; therefore, the factory does not need its own wastewater treatment facility. The production line has 37 tanks starting from degreasing of raw materials to drying of final products. It is operated in 2 or 3 shifts continuously every day, depending on the volume of orders from clients.

Wastewater is sent to the centralised wastewater treatment facility in the electroplating park. The plant plans to reduce the volume of wastewater to save the cost of wastewater treatment. Exhaust air from the plant goes through ventilation units for a nickel/chromium plating line and it has no steam boiler. Sludge generated from the plant is sent to an external company for further treatment on commission. No recycling is practiced.

The post treatment of chromium plating is one target to improve productivity. As a result of poor washing after chromium plating, some additional work to wipe and repair is needed. Customers sometimes complain about defects in the products. Moreover chromium plating is carried out under undesirable conditions of operating temperatures, low speed of plating, etc. These may cause low productivity.

Existing problematic issues in the factory that need CP measures are summarized as follows:
The rinsing water consumption was 600-800 m^3/month, which is not so much as compared with the same industry in Japan. However, the high cost of wastewater treatment had decreased the factory's productivity. Therefore, it was through that reducing and minimizing the rinsing water consumption without degrading product quality was one of the main objectives for factory.
For reduction of water consumption, three CP options were worked out as follows:

1. *Control of city water flow rate to rinsing tanks*
   The inlet pressure of city water becomes higher during midnight than in the daytime. Therefore, it was necessary to control the valve operation frequently in order to prevent excess water flowing to the rinsing tanks. However, there are many valves to control and operators sometimes miss or forget to control them. To improve operation and control of the city water flow rate, it was studied and decided that by installing a pressure control valve at the inlet point of city water together with the flow meters at the inlet points of the rinsing tanks, this problem was solved.
2. *Reusing of rinsing water*
   Rinsing water in Rinsing Tank (alkaline treating tanks) was discharged outside the factory as wastewater. However, it was found that this rinsing water could be reused as rinsing water.
3. *Recycling of rinsing water*
   If the concentration of ionic contaminants in rinsing water can be lowered to a certain level, it is possible to recycle this rinsing water. It was also found that rinsing water from the chromium plating and nickel-plating tanks could be recycled by installing an ion exchanger system.

Generally, higher suspended solid (SS) concentration found in plating solution will lower product quality through the appearance of burn stains and will also lower the electroplating efficiency. The SS concentration in bright chromium plating solution was too high, and it was concluded that installing a filter unit for this bright chromium-plating tank would lower the SS concentration.

In this factory, a certain percentage of the product had gone out of specification because there were yellow remains and burn stains on the surface. This was a serious problem for the factory. After the factory audit, it was found that the main reason for the problem was the volume of rinsing water used which was too low. It seemed that actual operating volume was only 0.1 turn over per hour because measured electrical conductivity values (μ S/cm*)* of water of the three rinsing tanks were 1000, 200 and 100, which were too high. The concentration of SS in the bright chromium-plating bath was too high; possibly contributing to the problem with burn stains. These conductivity values could be reduced to less than 50 μS/cm if CP was introduced, with a chosen ion exchanger system installed to make full recycling of rinse water possible.

Reduction of chemical consumption is very important because it will not only reduce wastewater discharge but also increases productivity. Normally, chemicals used in the electroplating factory are lost through the following two routes. One is through the product. Some amount of chemicals in the drag out solution tends to adhere on the surface of the products. The other is through an incomplete chemical reaction itself. For reduction in chemical loss, it is very effective to return the dragged out solution to the original tank. There are various methods in use to return the dragged out solution to the original tank. In order to reduce the loss of chemicals, it is very effective to return the dragged out solution to the original tank.

In the first step mentioned above, only yellow remains and burn stains problems have been explained: however, there are other problems in these electroplating industries. These problems should be studied in future as a target for improvement or product quality. As a recommendation, it is judged that a suitable design and careful maintenance of hooks for raw materials and a suitably shaped design for raw materials can give 100 per cent production yield without any yellow remains and burn stains problems.

Among CP options, the following five CP measures were selected as suitable measures.

- Installation of a pressure controller for city water inlet line,
- Installation of area flow meters,
- Installation of a diaphragm pump,
- Installation of a filter unit, and
- Installation of an ion exchanger system

Total cost reduction of RM 93,000 per year was expected as follows:

- Reduction of rinsing water and city water by 6 per cent: RM 9,000 per year
- Reduction of labour cost for additional works to wipe and repair final product RM 84,000 per year.

After installation of an ion exchanger system for the post chromium plating rinsing tank, it was expected that the rinsing effects would be increased and the frequency of off-specification products decreased.

The total investment cost was roughly estimated at RM 326, 000 as follows:

Table 1

Total investment cost			**RM**
a.	Pressure controller	1 set	5,000
b.	Area flow meters	5 set	15,000
c.	Diaphragm pump	1 set	5,000
d.	Filtering unit	1 set	71,000
e.	Ion exchanger system	1 set	230,000
	Total		**326, 000**

The total investment for the CP introduction resulted in RM 216,000.

Table 2

Investment for CP Measures			
No.	**Item**	**Quantity**	**Amount (RM)**
CP 1	Installation of a pressure controller for city water inlet	1 set	5,000
CP 2	Installation of area flow meters	5 set	10,000
CP 3	Installation of diaphragm pump	1 set	9, 000
CP 4	Installation of a filtering unit	1 set	87, 000
CP 5	Installation of an ion exchanger system	1 set	105, 000
Total			216, 000

Note: In these investments, all cost of design, equipment & machinery, construction material, transportation, construction, operator manual, commissioning & training and spare parts are included.

Before the implementation of cleaner production, total output was RM 1 million. Afterwards, it was reduced to RM 900.000. Energy consumption was reduced from 193 kWh to 177 kWh after cleaner production. In total, electricity bills were reduced from RM 49,794.00 to RM 44,118.00.

Table 3

Total savings 4 months after cleaner production		
Items	**Amount**	**Savings in terms of RM**
City water	403 m3 x 1.92 RM/m3	773.76
Chrome rinse/sludge	10 m3 of chrome rinse + sludge	534.47
Electricity	26,000 kWh x 0.258 RM/kWh	6.708.00
Manpower	2 workers x RM600/worker x 4 months	4.800.00
	Total	**12.816.23**

CONCLUSION

The paper has shown the limitations of project interventions for developing sustainable cleaner technology practices. The DANCED funded Centre at SIRIM did develop its capacity as an implementing organisation, and it has helped to verify the potential gains for SMEs. However, the task to develop institutional capacity within the context of a wide range of stakeholders influencing environmental performance in industry requires a much broader effort at a different level. The fragmented regulatory efforts and promotional activities calls for a national policy development aimed at a focussed institutional capacity building to improve environmental management practices. In this process, a networking approach is needed to secure commitment and resources of all relevant stakeholders within the regulative network, the business network and the knowledge network (Lynge Madsen 2000).

The research project 'A Study on Promotion and Implementation of Cleaner Production Practices in Malaysian Industry - Development of a National Program and Action Plan for Promotion of Cleaner Production' (Institute of Environmental and Resource Management 2003), will explore a much wider scope of possible activities compared to the CP efforts directed straight towards industry. Actions can be taken in a wide variety of areas including the following:

- Increase the profitability of CP measures by for example environmental taxation
- Ease financing of CP investments
- Introduce legal incentives for CP
- More effective enforcement of legislation
- Raising attention to the issue by information
- Subsidies for CP services
- Benchmarking of company performance
- Training and education
-

Policies for improved environmental performance do not come ready-made. Notwithstanding the availability of policy guidelines, standards and management tools, there is no blueprint for social change. As stakeholders negotiate regulatory frameworks, institutional arrangements, performance practices and capacity building activities, a local reinvention of available concepts and procedures and their configuration is taking place. Listen to the statement of a businessman in electroplating industry, although it probably needs to be interpreted in a wider context. On how to succeed in electroplating, he told a Danish expatriate consultant: It is a matter of 'know who' rather than 'know how'.

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Strategies For The Use And Adoption Of Life Cycle Assessment For Environmental Management In Malaysia

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ABSTRACT: As Malaysia strives to achieve sustainable development; a comprehensive perspective is needed to ensure that policies for managing its environment are supportive in achieving economic efficiency, employment growth and environmental-friendliness. Life Cycle Assessment (LCA) is becoming increasingly popular and a useful tool to help understand the environmental impacts of policies, products and services and to control or avoid adverse environmental impacts. The life cycle concept uses the systemic approach where it gives holistic insight of environmental impacts and their interlinked and interdependent nature. There are many reasons for using and incorporating Life Cycle Assessment for environmental management as it can play a unique role in furthering sustainable development. Although the government is keen on encouraging the use of the ISO 14000 series of environmental standards including LCA for proactive efforts in maintaining the quality of the environment and market requirement, the adoption and use of LCA is still very sparse. The paper presents LCA survey results and major barriers in conducting LCA. Various strategies and recommendations are presented to assist the promotion and use of the life cycle assessment (LCA) concept and methodology for managing the environment in Malaysia.

Keywords: Life cycle concept and assessment, environmental management, systemic approach, strategies in LCA applications

INTRODUCTION

The early 1990s, has been a period of dramatic changes for environmental concern and preservation. Today greater emphasis is placed on pollution prevention in developing solutions to environmental problems. Additionally, broader concerns about products' environmental impacts, such as solid waste and materials acquisition, as well as the influence of international regulations on environmental problem solving have created new opportunities for environmental performance. Today, the management of environmental programs demands a radical change in culture to identify and manage the environmental vulnerabilities to ensure sustainability.

The responsibility for the conservation of the biosphere involves improving the relationship between production and resource consumption, and to stop growth in the consumption of non-renewable resources and in pollutant emission. Without us realizing, we may still be continuing on the path of increasing environmental destruction. Under the present conditions, even if all on earth were to meet the minimum requirements and even if we were to use the systematic improvement tools, this would only slow down the growth in resource consumption and emissions on this planet. It would not be enough to reverse the trend of destruction of our biosphere. Ironically we would be quite capable of destroying the biosphere – while complying with the standards – and would thus destroy all human civilization and ourselves. Thus this requires total reduction in emissions and in the consumption of non-renewable energy resources and raw material

One implication of the shift towards awareness of pollution prevention concepts is the incorporation of environmental considerations into the overall process of project, product, and service design, development, and evaluation processes. This is the best way to manage the areas where it affects or interfaces with the environment. A project, product, and services interfaces with the environment throughout all stages of its development from extraction of natural resources to obtain materials, to fuels used in manufacture and finally to the product's ultimate disposal.

ENVIRONMENTAL MANAGEMENT ISSUES AND CHALLENGES IN MALAYSIA

The tremendous transformation of Malaysian economy from purely agricultural-based in the 1960s to manufacturing, brought with it not only greater economic prosperity in Malaysia but unfortunately also increased resource depletion and environmental degradation. The latest Environmental Quality Report (DOE, 2000) notes that almost all aspect of the environment have been affected by development activities ranging from deforestation, to air and water pollution, to erosion and siltation and the generation of hazardous and toxic wastes. This is not surprising as the basis for Malaysia's growth and development has been its relatively rich natural resource base, both renewable and non-renewable. Basically, there are two major issues that need redress: the depletion of resources and the deterioration of the environment.

Air and water are the two major aspects of the environment that have been seriously affected in recent years. Toxic and hazardous wastes together with municipal solid wastes are also fast becoming a problem that needs to be addressed.

MANAGEMENT STRATEGIES

An early form of management response to impending environmental problems and depletion of resources was through legislation. In the early years after independence, environmental problems were considered less important. Rather, development priorities were regarded more important. In the early development projects, little or no consideration was given to environmental aspects. Many of the laws enacted prior to the 1970s were largely sectoral in nature focusing on specific activity areas. Extensive as they were, sector-based legislation did not encourage an integrated approach to environmental policy implementation and rendered them less effective and difficult to enforce. Thus, by early 1970s, it had become obvious that available legislation was unable to cope with pollution produced by modern industries. At the same time, the impact of development on the environment was becoming increasingly visible, with evidence of deterioration observable in many places in the nation.

Environmental issues began to be publicized in the media in the 70's mooted by concerned individual and environmental groups. Consequently, the Environmental Quality Act (EQA) was conceived. The EQA has been described as the most comprehensive piece of legislation concerning environmental management in Malaysia and was passed by Parliament in 1974.

While the main objective of the first strategy is basically to ensure that the existing industries and other pollution sources are subject to direct controls or "add-on" technologies, such remedial measures alone without the support of some form of preventive controls are inadequate. Following the introduction of the Environmental Quality (Prescribed activities) (EIA) Order 1987which became effective on April 1, 1998, and the efforts to ensure sustainable development, preventive approach in environmental management was emphasized. Subsequently to further overcome the national environmental challenges, there is a need to have more comprehensive strategy on planning and management of the environment and its ecosystems.

MOVING TOWARDS SUSTAINABILITY - LIFE CYCLE THINKING AND APPROACH

Life Cycle Thinking is in philosophy a strategic conception that also facilitates a more integrated approach. Strategic Life Cycle Thinking and approaches must be brought to the attention of decision-makers and policy makers, while harmonizing efforts and advancing the development of tools as practical steps toward sustainable development. The objective is to develop and disseminate practical tools for evaluating the opportunities, risk and trade-off associated with products, processes and services over their entire life cycle. Formulation of new policies could focus on the key areas of interest to link Life Cycle Thinking with environmental as well as social and economical aspects of sustainability and the integration of environmental management practices, concepts and tools for decision-making on greener products and services.

The lifecycle approach in general allows policy makers to optimize the use of raw materials and energy and the management of emissions and wastes across the whole lifecycle or individual products and services, which affect the environment. The key objective is to provide the service to society in the most efficient way while managing the environment in a more effective and holistic manner. Life-cycle Thinking is a way of addressing environmental issues and opportunities from a systems or holistic perspective.

The impacts of all life-cycle stages need to be considered in order to take informed decisions for development to change consumption patterns, policies and management strategies for the sake of preserving the environment.

LIFE-CYCLE ASSESSMENT (LCA)

Life-cycle assessment (or LCA) is a systematic approach used to manage the potential environmental impacts of product/process and service systems. It is applied methodologically to build a quantitative inventory of environmental burdens or releases, evaluate the potential impacts of those burdens or releases, and consider alternatives to interpret the results and/or improve environmental performance. LCA can be used to identify criteria life cycle stages of burdens for which additional environmental assessment tools (e.g., risk assessment, and environmental assessments) may be applied to fully understand the potential impacts and risks.

In any application, LCA considers the potential environmental impacts along the continuum of a product's life (i.e., cradle-to-grave) from raw materials acquisition to production, use, and disposal or recovery. The potential environmental impacts to consider include resource depletion, human health, and ecological health.

LCA should not be confused with life cycle thinking. Life-cycle thinking is a unique way of addressing environmental problems from a systems or holistic perspective. In this way of thinking, a product or service system is evaluated or designed with a goal of reducing potential environmental impacts over its entire life cycle. The essential difference is that life cycle thinking does not normalize the results to a functional unit, as is done as part of an LCA study. Additionally, with life cycle thinking the results may be expressed qualitatively or quantitatively. In an LCA, the results are generally quantitative in nature.

Fava et al., (1991) in the publication of "A Technical Framework for Life-Cycle Assessments" identifies the following three-component model for LCAs:

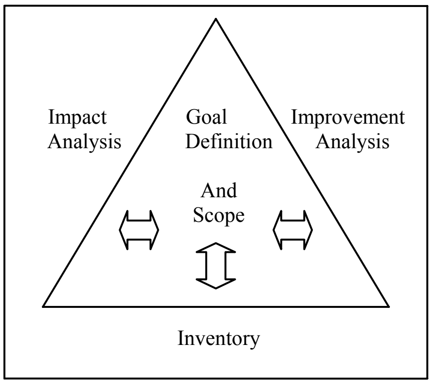

Figure 1: Elements of Life Cycle Assessment

1. An inventory of materials and energy used and environmental releases arising from all stages in the life of a product or process, from raw material acquisition to ultimate disposal.
2. An impact assessment examining potential environmental and human health effects related to resource consumption (energy and materials) and environmental releases.
3. An improvement assessment of the changes needed to effect environmental improvements in the product or process.

Due to its integrative approach, LCA can be used to prevent four common forms of pollution problem shifting:

- From one stage of the life cycle to another
- From one environmental medium to another and
- From one location to another.
- From the present to the future

There are many reasons for using LCA. It is integrative, scientific and quantitative; thus playing a unique role to play in furthering sustainable development. Policies based on LCA can aid businesses and governments making economic activities and development more sustainable. LCA is designed to provide the most scientific and quantitative information possible to support decision-making.

Under ISO 14000 four life cycle assessments standards have been developed. They are:

ISO 14040	General Principles and Framework
ISO 14041	Goal and Scope Definition and Inventory Analysis
ISO 14042	Impact Assessment
ISO 14043	Interpretation

The LCA standards have been written in a fashion to ensure flexibility in use of the standards within an organization; whether that application may be to help focus research, or internal prioritization.

LCA QUESTIONNAIRE SURVEY AND ANALYSIS

Life Cycle Assessment (LCA) has been introduced in Malaysia only in the late 1990s as one of the ISO 14000 series. However the application of the concept and methodology is still very low. To assess on the current status of LCA in the country, a LCA questionnaire study was carried out to evaluate the current state of LCA awareness, understanding and use in Malaysia. The goals of the survey were to obtain an indication of the level of understanding and application in the Malaysian industry and public sector and to obtain an idea about the barriers and success factors relating to its wider use. The survey was carried out with the collaboration of DOE (Department of Environment) Malaysia, and SIRIM Bhd. (Standards Management Department), the secretariat for the Malaysian Standards Committee and SC5–Malaysian Technical Committee on Life Cycle Assessment. A total of 150 organizations were chosen as survey respondents where 50 respondents answered and returned the questionnaires. The survey was conducted between March-April 2002. The results of the survey was analyzed and presented in the figures shown.

The result of the survey showed the level of awareness and use of LCA amongst organizations in Malaysia is still very low. However, the realization about its importance for future use and application are encouraging. Only 18% of the respondents have minimal knowledge in LCA. 20% have no idea about LCA, 20% thought of it as a concept or way of thinking while 42% acknowledge it as a scientific or technical tool according to ISO and SETAC and 74% had no LCA done in their organization.

More than half of the respondents (68%) would push forward the decision to start LCA in their organization if there was stimulation by governmental initiatives, e.g. liabilities and labeling. Overall, there are high expectations about the future usefulness of LCA for most of the respondents especially for ecolabeling and eco-management and auditing.

As for the most frequent applications of LCA according to respondent's knowledge, the full 100% of respondents agreed to using LCA for shifting from product to services, followed by procurement specifications, supplier screening, product development and others. The majority of the respondents also acknowledge the long term benefits of LCA.

However, there are many barriers to wider use of LCA as noted by the respondents. The survey indicated difficulty of communication of LCA results, methodological complexities and difficulties, problem in collecting quality inventory data, cost of implementing LCA and definition of systems boundaries as the main barriers. Majority of the respondents anticipate positively to the possibility of increase in LCA use in their organization in the future while others will only use it when the methodology is clearer and wait for wider spread of the LCA methodology. Almost all respondents (98%) are either not sure or do not know of any LCA performed in the country, reflecting on the very limited application of LCA on the whole in the country.

RECOMMENDED STRATEGIES FOR IMPLEMENTATION OF LIFE CYCLE ASSESSMENT (LCA)

It is clear that most organizations in developing countries like Malaysia, especially with respect to SMEs, may need significant technical and financial assistance to implement the LCA and EMS for environmental improvement.

Considering the various barriers Malaysia is facing in promoting LCA implementation, it is recommended that the strategies undertaken by the relevant authorities in the government be as follows:

- Enhance the capability and the capacity of human resources in promoting and conducting LCA and EMS programs
- Promote and implement LCA programs in organizations who have got ISO 14001 certification, since apart from having better environmental awareness, considerable data are usually available in those companies, rendering easier data generation and collection
- Establishing a mechanism in assessing, adapting and testing of practical application of LCA and EMS
- Enhancing transfer of knowledge and know how from those who have established LCA and EMS programs to those whose programs are under-development

Promote economic incentives development programs as economic instruments are being increasingly recognized as viable supplements for traditional "command and control" approach. Hence activities in the development of economic incentives are proposed as follows:

Specifically technical tasks suggested are to:

- Develop a national ecolabeling system to encourage private sector to move toward implementing LCA. The ecolabel criterion has to be developed based on LCA considerations and organizations with EMS implementation
- Evaluate the possibility of developing a national environmental fund to aid companies and industries to start environmental management programs including LCA
- Integrate environment and financial aspects through Environmental Management Accounting (EMA)
- Develop an award program for LCA implementation especially amongst the export oriented industries

Another important recommendation or approach is the development of partnership and mentoring programs between corporations and their suppliers that provide the necessary technical assistance, expertise and financial resources. Such partnerships have to be encouraged amongst the large organizations that require or encourage EMS certification and LCA application to help improve the environmental performance of the organization's suppliers.

At the national level, in order to develop the infrastructure necessary to implement the ISO 14000 series standards, technical and financial assistance will be needed. This could be addressed through the establishment of multi-lateral programs that provide the management, education and training necessary for the needed infrastructure in the country. The proposed recommended organizational infrastructure for LCA and EMS initiative in Figure 2.

The collaboration of the various national governmental agencies related to the national environment and trade like DOE, MOSTEC and MITI with SIRIM as the coordinator should be appointed for the national LCA initiative. The LCA Steering Committee with the aid of the Advisory Committee comprising of the academic and industrial sector, presides over the overall LCA activities. It should set up the three important LCA study committees i.e. the Inventory Study Committee, the Database Study Committee and the Impact Assessment Study Committee to implement the necessary work-studies of the LCA initiatives for the country.

The Inventory Study Committee collects the inventory data of important national resources and industrial product and discusses the LCI methodology. While the Database Study Committee will establish the overall public database system based on the Internet, the database itself and make the data input software. Finally, the function of the Impact Assessment Study Committee is to identify suitable requirements of suitable impact categories including impact assessment weighting factors applicable for the country.

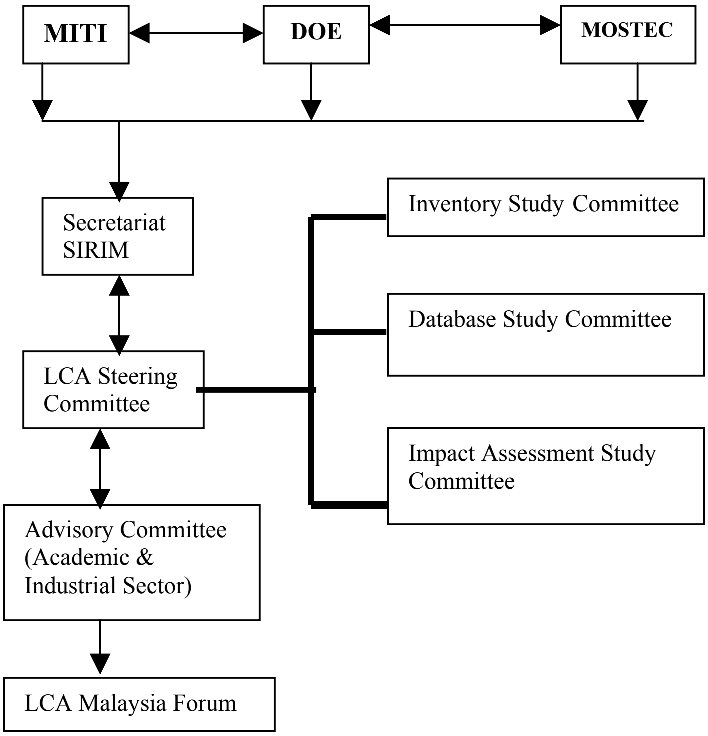

Figure 2: Recommended Organizational Infrastructure of Malaysian LCA and EMS Initiative

National lending institutions also should fund efforts that promote environmental protection. The financial and technical assistance rendered might be most effective if focused initially on EMS implementation for the more environmentally sensitive industry sectors in developing countries and further continue with the other voluntary ISO 14000 series of standard like LCA for further and continuous improvement.

CONCLUSION

Considering the history of environmental management and LCA in Malaysia, the low level of LCA knowledge is expected. Nevertheless Malaysia has had a significant involvement in ISO activities, having been a member of ISO Technical Committee since 1994 and also a member of the sub-committee on SC5 which deals with LCA.

The results of the survey clearly show that the knowledge and usage of LCA among the Malaysian organizations are still very low, even though the realization about its importance for future use and applications are quite encouraging. A general lack of environmental awareness, commitment and lack of drivers for chain management could be the main reason for the lack of LCA usage. From an organizational perspective, life cycling thinking is reckoned to be the more prominent use in their organization's internal use.

The incentives to start engaging in LCA in the organizations would be only if there were stimulation by governmental initiatives, e.g. liabilities and labeling and other outside pressure like the emerging green market and pressure by the NGOs and consumers. Other factors would be encouragement or requirement by multinational parent companies and other country ecolabeling schemes.

In light of the increasingly ecolabeling initiatives and other product oriented environmental policy world wide, it is without doubt that organizations especially those with representation and market in Europe will have to be more involved in LCA. If market driven environmental dynamics in production chains evolves, then maybe more enterprises may be forced or encouraged to adopt LCA as a management tool.

There are a number of barriers in relation to the adoption of the LCA as a potential decision support and environmental management tool. To overcome those barriers and to encourage wider acceptance and adoption, efforts are needed to educate and communicate in further scientific clarification and development of LCA and its relation in setting policies and environmental improvements. In conclusion, the survey indicated that experiences with LCA work in the Malaysian enterprises and organizations are still very sparse. Concerted efforts and promotional programs has to be garnered by the relevant bodies to integrate and adopt LCA as part of Malaysian environmental management strategies towards achieving sustainable development.

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Strategies For Implementing Co-Generation Based On Biomass Waste From Thai Industries

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ABSTRACT: Due to the large industrial development in Thailand the consumption of energy first of all based on fossil fuels has increased enormously, even though the economic development has slowed down since the economic crisis in 1997. It is therefore important to reduce the environmental impact of this consumption of energy, which can be done by energy conservation, higher efficiency in the production of energy or by using different kinds of renewable energy. This research project seeks to develop new strategies for the use of waste heat, as a part of the industrial process heat. By substituting process heat, generated by electricity or boilers using fossil fuels in individual industries, with process heat generated by a co-generation plant - using the industries own biomass waste as fuel - process heat can be delivered to participating industries by a small scale district heating network. Hereby, an *Industrial Materials Network* can be created, which is environmental as well as economical beneficial for both industry and society. Departing from a case study analysis in the industrial area, Navanakorn, in Thailand, such strategies for efficient materials and energy uses has been conducted and proved successful, and industries - as well as local and national governmental agencies, NGO's etc. - has shown interest in supporting the implementation of such scheme. In the research project, a *Guideline for large-scale implementation of Industrial Materials Network in Thailand* is developed. By following a series of Actions, the Guideline defines the initiatives there must be taken in order to secure the implementation. Chronologically, emphasis of the Guideline is to point out relevant stakeholders to pursue this development, and then areas and types of industries for Industrial Materials Network implementation. Hereafter, guidance to collection of data regarding consumption of materials and energy in Thai industries, as well as biomass waste generated by the surrounding community, is emphasised. The Guideline then illustrates how to study the Resources and energy End-Use found for appropriate selection of conversion Technology, determining the Design of energy system, which then follows. The organisational issues like ownership and organisational build-up is also emphasised, providing guidance to selection of the most appropriate Corporate Governance for participating industries. A last topic, which is dealt with in the Guideline, is financial issues, emphasising different sources and types of financing for Industrial Material Network implementation.

Guideline For Industrial Materials Network implementation

This Paper will work out a Guideline with the aim of establishing Industrial Materials Networks in Thailand. The purpose of the Guideline is thus to create a platform, from which new Industrial Materials Networks can emerge, thereby moving from the "pilot-project-level" of Navanakorn, to a level, which generally supports the implementation of such schemes. The Guideline consists of several *actions*, which each poses different assignments to be conducted by different stakeholders. Most of the actions outlined below are identical to the analysis made throughout the project report, in which an Industrial Materials Network were established for the case of Navanakorn. Other actions are consequence of further elaboration on the topic. Each action in the Guideline consist of *four parts* emphasising; 1/ The overall purpose of the action, 2/ The actual action to be taken, 3/ Important stakeholders in fulfilling the action, and 4/ The source to information. The four parts then again consist of different *steps* to be taken under each action. The Guideline as outlined below are approached on a general level, and only when found important for understanding the actions and steps taken, examples from the actual case study will be introduced.

The intention with the Paper is to develop a *dynamic* approach to the implementation of Industrial Materials Networks. Certain actions taken can therefore provide knowledge, which results in feed back and thus reconsideration of former actions taken. The Guideline which follows are meant to be an inspiration for stakeholders wanting to pursue implementation of Industrial Materials Networks in Thailand, and as such not a recipe which followed slavish ends in successful Industrial Material Network development. Many important areas and aspects of such implementation cannot be predicted exactly, and a countless number of variables make it impossible to include any possible situation, which can emerge. I therefore presume that stakeholders utilising the following Guideline, are capable of catching the ideas behind it and ad relevant actions when found important.

The target group for the present Guideline is all levels of stakeholders interested in exposing the potentials for Industrial Materials Network implementation in their community. This can be a municipality or a province facing increased pressure from waste generation in their area, or a more stable team of stakeholders (for instance industries and owners of industrial areas) wanting to pursue implementation of Industrial Materials Network for materials re-use and renewable energy production. The means of motivations can thus be differentiated, but the methods by which the potentials are exploited are the same, and can be found outlined in the Guideline Actions, which follows.

The figure below gives an overview of the different steps, which must be taken when implementing Industrial Materials Networks. Under each of the seven steps is a reference to the specific chapter in the project report, in which the background analysis are elaborated (not included in this Paper), as well as references to the similar Action outlined in the Guideline. In this way it is possible to get a more throughout description of how to approach Industrial Materials Network implementation, when studying the project report, and a more fast overview of the implementation steps when looking at the Guideline Actions solely.

Guideline Actions

⇒ Action 1: Project *Problem* Cycle approach.
⇒ Action 2: Stakeholder identification.
⇒ Action 3: Locate appropriate industries for Industrial Materials Network implementation.
⇒ Action 4: Map biomass waste and energy uses in relevant industries, as well as biomass waste from the community, etc.
⇒ Action 5: Make 1.Triangle analysis - technical feasibility; "Resources, End-use and Technology"
⇒ Action 6: Make 2.Triangle analysis - feasibility; "Transaction costs/Risk minimisation, Conditions for Inter-industrial Co-operation and Corporate governance".
⇒ Action 7: Financing; How to finance and commence the construction phase.

Action 1: Project *Problem* Cycle approach

Purpose of action

A first criterion for project proposals is to evaluate whether the project can help in solving an actual *problem* or *unsustainable practice*. It must thus be a problem or a critical situation, which initiates the project identification. In existing Project Cycle Manuals etc. this approach is not outlined as an important criterion for project identification. Often, projects are simply initiated by looking at which technologies developed countries for instance *can* transfer, and not whether this technology helps in solving a specific problem. Also in the LFA the importance of solving *problems* is underestimated (but initiatives regarding Team Building are, however, included).

When an appropriate identification of the project has taken place, it is hereafter important to emphasise whether the project potentials, which now are drafted, has a reasonable *validity* before proceeding with the project. Therefore, a *Monitoring phase* must be introduced very early in the project, so as to determine whether the project can succeed happens in an early stage of the project (and not *after* the implementation).

The Monitoring phase must be introduced in Action 2 and 3, in which stakeholder are identifies and relevant areas and industries are pointed out for Industrial Materials Network implementation. The Monitoring phase will, in Action 2, identify if relevant stakeholders actually *could* be identifies and *whether* project support where found among stakeholders. If not succeeding in this task the project must be cancelled, as it will be continued on unsustainable premises. If, on the contrarily, relevant stakeholders are found, the project can proceed to the next action. In Action 3, emphasis is on industrial areas and relevant waste generating industries. The Monitoring phase will identify *whether* it was possible to find appropriate areas for Industrial Materials Network Implementation, and whether the most appropriate types of industries for such co-operation *could* be identified. If the Monitoring phase proves the validity of the project until this stage, the project can proceed.

Action 2: Stakeholder identification

Purpose of the action

The purpose of Action 2 is to *identify* relevant stakeholders to initiate the process, and stakeholders capable of acting as leaders in the implementation of Industrial Materials Network.

The purpose is, however, not only to identify stakeholders but also to *create* the interest, as a pre-interest in the project cannot be expected. The stakeholder is not aware of the benefits in participating in Industrial Materials Network in advance. It is therefore important also to take actions in developing the interest by various stakeholders, and by campaigning activities etc. build bridges between different actors so that for instance the inter-industrial co-operation can find its roots.

Campaigning activities can also be used if the stakeholders resist, or by other means are reluctant, towards participation. Also if the target group is large campaigning activities can be appropriate means of communicating for instance the benefits of participating in Industrial Materials Network. Such activities can be used, whenever the project faces

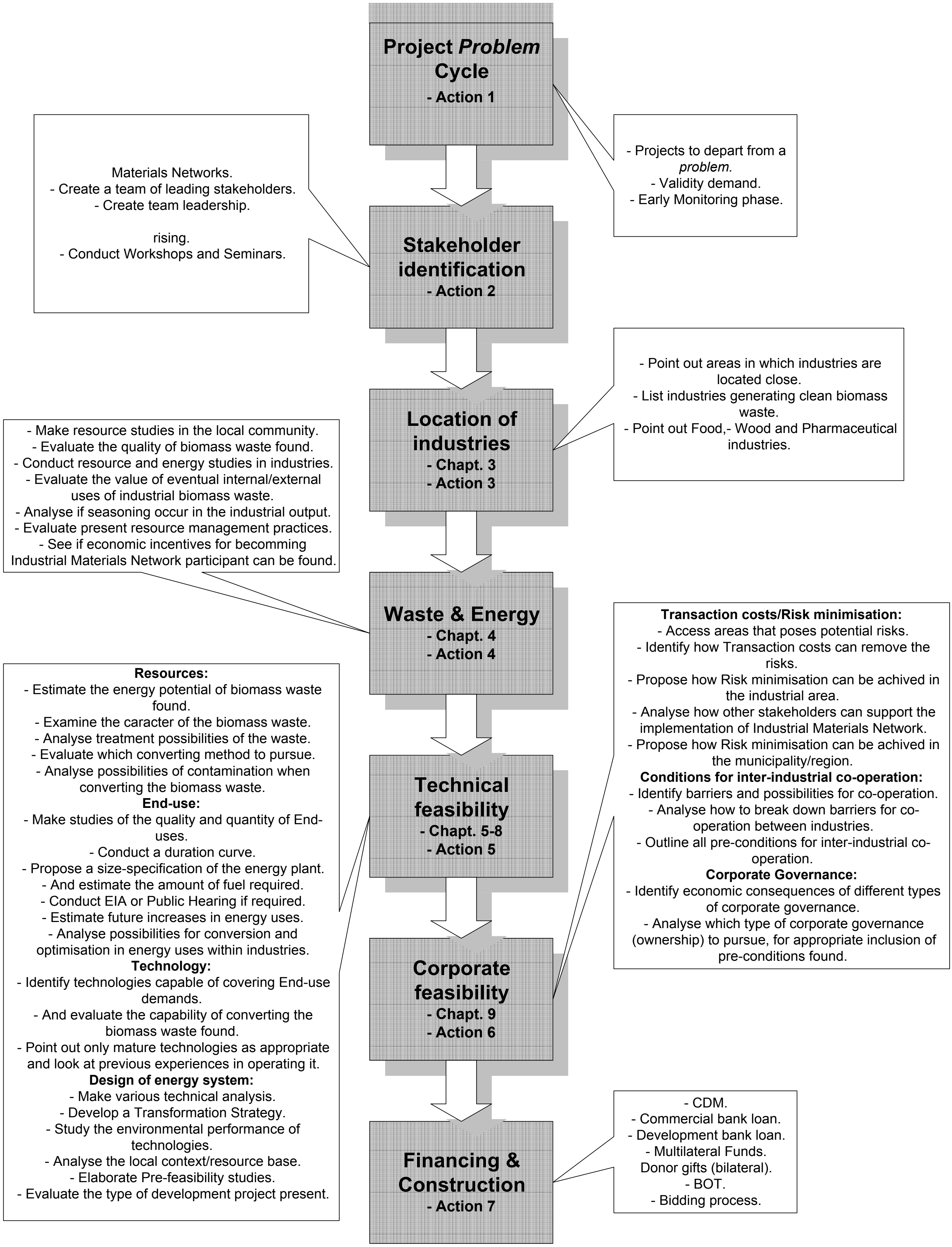


Figure 1: Guideline Actions

difficulties in delivering messages about the project. Campaigning and awareness activities are therefore used as a dynamic tool. As the Guideline below are means to be understood and used as a *process*, such dynamic tool is beneficial. If the project not is ready to proceed - due to for instance lack of support - some campaigning activities can be initiated and the project continue afterwards.

Campaigning and awareness rising activities can for instance be in the form of written material or web sites presented to industries, as well as factory visits by governmental agencies or NGO's etc. participating in the development of Industrial Materials Network implementation. This information can contain economic and environmental benefits for industries when joining an Industrial Materials Network. Later workshops and seminars can gather potential interested industries for further information and discussion. The most important aspect when looking for participants to join the Industrial Materials Network is campaigning and awareness rising activities and through such initiatives, find industries who wants to participate on a voluntary basis [Mr. Chaiwat Pollap, NEPO, Interview, Bangkok the 9-2-01 & Mr. Tannerat Worasute, DIW, Interview, Bangkok the 21-2-01].

However, prior to any actions taken a *team of leading stakeholders must be created* to pursue these initiatives. A stakeholder identification must be elaborated by stakeholder analysis, emphasising organisations/institutions etc. who can be prime initiators - and thus appropriate members of the Leading Team - and which of them who can take on leadership. Below, potential Leading Team stakeholders are outlined. The criteria for pointing to these specific stakeholders are their view upon the increasing amounts of waste, as being a *problem.*

Important stakeholders

Stakeholders already collecting/treating waste in the area examined.
-Local governmental institutions who look at the waste as a problem.
-Non governmental institutions who look at the waste as a problem.
-National governmental or quasi-national governmental institutions who look at the waste as a problem.

Example

Create a Leading Team

In Navanakorn three stakeholders were found to be very important for Industrial Materials Network implementation, namely *Main Office of Navanakorn*, *Pathum Thani Province* and finally the *Local FTI* (FTI Local Chapter). The Main Office of Navanakorn was found to be an important stakeholder due to its positive and trustful relation to industries - providing various service tasks to industries as for instance waste collection - and its financial capacity to support the project, as being owners of the Industrial Zone. Pathum Thani Province was found to be an important stakeholder due to its knowledge of local biomass resources, its interest in finding new waste management practices, and as being potential Fund contributor (can apply for economic resources through ENCON).

The Local FTI (Pathum Thani Local Chapter) was found to be a powerful stakeholder with the capacity to build bridges between industries, and promote the idea of Industrial Materials Networks. First by promoting implementation of Industrial Materials Network in different lines of businesses in the region, then later in sub-chapters across branches in the industrial areas pointed out. A Leading Team must therefore preferably consists of at least 1) Owners/leaders of the industrial site or area who service industries, the 2) Province in which the industries are located, and the 3) Local FTI. If owners/leaders of the industrial area not posses the same relation to industries as in the case of Navanakorn, it is important to find stakeholders who can undertake this role instead.

Create Team Leadership

But how must the Leading Team be build? The Local FTI must, together with for instance a large and powerful NGO - as for instance Thai Environmental Institute (TEI) or Energy for Environment Foundation (EFE) - take on a Team Leadership and create the Leading Team. They must present the ideas of Industrial Materials Network for owners/leaders of industrial areas, and representatives of the Provinces in which the sites are located. Stakeholders who find the idea of Industrial Materials Network useful and support the ideas behind it, must preferably be Leading Team members. When the Leading Team by means of this approach is established, they will pursue an identification of appropriate industries, as emphasised below.

Action 3: Locate appropriate industries for Industrial Materials Network implementation

Purpose of Action

The purpose of this action is to locate appropriate industries for Industrial Materials Network implementation. Materials uses and energy requirements are the main criteria for selection of industries, as emphasised more detailed in the following.

Materials use

In materials uses there are in principle four types of re-use strategies; The first one is *Internal Re-uses*, which for instance can be small pieces of wood re-used as construction support in the production of wooden furniture. The second one is *Cleaner Production*, which for instance can be a new moulding machine only removing the top surface of wood in processing activities. This leads to an overall reduction in wood uses and thus pressure on virgin materials. The third strategy is *External Re-uses*, which can be divided in two; by Specific External Re-uses materials are for instance re-used in another industry in the same line of business. Using wood industries as an example again, sawdust from one industry can be re-used as materials for particular boards in another industry.

Fourth, by General External Re-uses materials are re-used in a general matter, thus not necessarily attached to the specific line of business. This can for instance be wood waste used for generating energy. The purpose of this action is to focus on General External Re-uses, thus re-uses of materials which cannot be re-used elsewhere. This is, however, not a first priority, as Internal Re-uses, Cleaner Production and Specific External Re-uses rank higher. It is therefore a pre-condition in the following actions that appropriate initiatives are taken on this behalf, *before* commencing the actions as outlined below.

Energy requirement

Industrial demand for energy, here heat, is an important criterion for selection of industries. By substituting uses of fossil for process heat generation, with uses of clean biomass waste as fuels for supply of heat in a district heating network, economic and environmental benefits can be obtained for industries and the society. By means of this approach a heat market are "created", and the energy efficiency of the energy production will increase dramatically, as no waste of energy happens.

The selection of industries is thus made theoretically in accordance with estimations of energy uses and biomass waste generation in different lines of businesses. Hereby, certain types of industries are pointed out as being appropriate as Industrial Material Network participants. This is due to the fact, that a majority of process heat uses in these industries are less than 100 degrees C., which can be covered by water based heat (i.e. district heat), and that large amounts of mainly "clean" biomass waste are generated hereby appropriate as fuel.
Food, - Pharmaceutical and Wood processing industries are identified as most appropriate industries for Industrial Material Network development, using this method. Paper and tanning industries are also relevant industries, but the amounts of generated residues inferior compared to the industries above.

Focus on industrial areas

In order to find both waste generating industries and heat markets within a narrow spatial area, industrial estates or zones are favourable areas for pursuing Industrial Materials Network implementation.

Actions to be taken

Point out areas in which industries are located relatively close. This can preferably be in Industrial Estates or Zones, or other industrial area that provides the same possibility for a close location of industries. *List industries that presumably generate clean biomass wastes*. If not actually becoming Industrial Materials Network participants, some of these industries can supply biomass residues to the co-operating industries.

Finally, *point out Food, - Pharmaceutical and Wood processing industries* (paper & tanning industries), as being especially relevant as Industrial Materials Network participant, but conduct further studies and site visits in *all* industries found above (see Action 4).

Important stakeholders

Location of appropriate industrial areas not being Industrial Estates or Zones, can be done by the Leading Team in co-operation with the Ministry of Industry (MOI), who is responsible for registering all industries in Thailand. MOI can also support analysis regarding which line of business the industries belong to, by which a first theoretical selection of industries is made. The Leading Team can thus draw on knowledge from governmental institutions in their information gathering.

The source to information

Theoretical analysis (paperwork) based on knowledge concerning waste generation and energy uses in different lines of businesses.

Action 4: Map biomass waste and energy uses…

Purpose of action

From an industry's view generated by-products are regarded upon as *waste*, but when re-used within an energy system it becomes a new resource with a value. As mentioned earlier, this re-use can happen as *general* or *specific* re-use, here with emphasis on general re-uses. Thus, focus of the following section is analysis and estimations of *amounts and types of waste for further re-uses*.

A condition for appropriate Industrial Materials Network implementations are namely studies, which in details emphasise biomass waste generation and energy uses in the types of industries found by the action above, as well as biomass waste from the community. In this action, the theoretical selection of industries (which happened in Action 3), will be supplemented empirical data, making it possible to point out the most appropriate industries for Industrial Materials Network development, as well as industries for instance only supplying biomass residues to the Network.

Actions to be taken

- Make *resource studies* of Industrial Materials Network Supporting Resources or Systems within and outside the industrial area. These can for instance be relevant agricultural residues as well as organic household wastes and commercial/industrial wastes from the community (Supporting Resources). It can for instance also be the presence of a WWTP within the industrial area, contributing to sludge generation appropriate for energy production (Supporting Systems). Then specify the type and amounts of resources found.

- *Evaluate the quality of biomass* that comes from Supporting Resources or Systems when used for energy purposes. How large are the fractions of organic materials in household waste and commercial waste, and how much can be utilised when sorted? Are there furthermore other means of uses, which makes it inappropriate as fuel? This issue can be very context-depended, as organic fractions in household waste seem to "disappear" in certain countries or parts of countries, usually for uses as animal food or fertiliser. Thus, it is not sufficient to *estimate* the presence of biomass fractions, as an actual collection and analysis must be made in order to conclude whether these resources can be utilised for energy purposes.

- Make *resource and energy studies* in industries pointed out as relevant Industrial Materials Network participants. Identify types and amounts of biomass residues by studies of "raw materials input and waste" as well as "re-use of resources". Identify types and amounts of energy uses by studies of electricity and fuel uses (for process heat generation). Note the temperature of process heat uses. How much is steam uses and how much is water based heat uses? Also expose important issues as "operation hours per year", "the efficiency of technologies in use", "expected increases in production output" and "ownership, employees and markets".

- Determine the *value of internal/external uses of biomass residues from industries*. If residues have very high commercial value it is not likely that industries will utilise it internal for energy production. If the commercial value however is low - or even sometimes negative as being a cost factor - it is more likely that industries will seek other ways to improve the value of biomass residues, as for instance through the Industrial Materials Network for energy production. If external re-uses happen far away from the industrial area with long transportation distances as a consequence, preferably seek re-uses within the industrial site.

- Find out whether there are *seasonings in the industrial output*, which can affect the quantities of biomass available for energy production. This must be studied for all types of biomass found, but especially where agricultural residues are applied seasoning can occur (due to harvesting periods). A constant output of biomass residues also means a constant demand for energy, which is preferable when designing an energy system (compared to a very fluctuating output of biomass and energy demand).

- Evaluate present *resource management practices* within and outside the industrial site, i.e. in the Province, the Municipality and in the industrial area. If weaknesses or problems are found in these practices, biomass residues are more likely to be canalised to the industrial area for energy uses, as they represent a "problem" for various stakeholders. For instance, if the management of industrial waste is expensive for industries, they are more likely to pursue new means of waste management.

- Analyse whether local/provincial *economic incentives* for participating in Industrial Materials Network can be found, and which will support the implementation of Industrial Materials Network. This can for instance be as Property Tax reduction from the municipality in which the industrial area are located, or as reduction in Factory Tax given by the local MOI (which is now given to industries implementing ISO 14000). It can for instance also be economic support from the Province, by means of sources from ENCON, which can amount to 30 % of project costs (and 100 % for pilot projects) [Mr. Chaiwat Pollap, Energy For Environment Foundation (EFE), Interview, Bangkok the 30-4-03].

Important stakeholders

Several stakeholders have proved interested in participating in the process of elaborating resource and energy studies. Department of Industrial Works

(DIW) has initiated data collection in Thai industries, where focus is on the amounts of waste generated [Mr. Tannerat Worasute, DIW, Interview, Bangkok the 21-2-01]. This analysis can be used as background material for further studies, as the credibility can be questioned when conducted by a governmental body.

The Leading Team must thus take action in conducting the resource and energy studies, which now has to take place. The "mother organisation" of the Local FTI, Bangkok FTI, has the capacity (technical, personal, and economic) to pursue this task. The organisation has also proved interested in commencing such analysis. FTI has the capacity and interests in conducting energy and biomass waste audits in Thai industries, thereby laying the foundation for Industrial Materials Network implementations [Ms. Dominica Dacara, FTI, Interview, Bangkok the 19-2-01]. Also the Province, in which the industrial area or site is situated, can provide important information regarding Industrial Materials Network Supporting Resources i.e. agricultural residues, household waste, commercial/industrial waste etc., and its potential availability. Managers/owners of the industrial sites must also contribute with knowledge of biomass resources.

The National Science and Technology Development Agency (NSTDA) can - through the University Consortium - for instance also supports such data collection by collaborating with universities in which students, lectures and professors at universities all over Thailand join forces in data collection. Especially students - whom traditionally are used for various data collection in Thai industries - will be able to help in providing this task, whereas lectures and professors can finalise and sum up on analysis [Mr. Bundit Fungtammasan, NETDA, Director of Energy and Cleaner Technology Center & Ass. Professor at King Mongkut's Institute of Technology, Interview, Bangkok the 13-2-01]. Also in regards to for instance amounts and contents of organic compounds in household waste etc., within or outside industrial areas, the academia can provide such analysis, which further can support the implementation of Industrial Materials Network.

The source to information

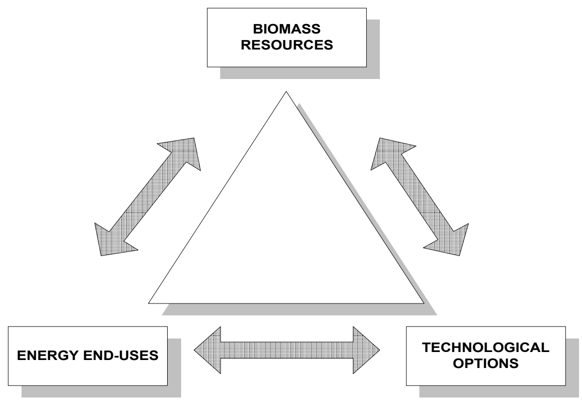
Interviews/site visits in industries will expose biomass waste generation and energy uses etc. in industries, as well as aspects as seasoning, operation hours per year, the efficiency of technologies in use etc. Information about Industrial Materials Network Supporting Resources and Systems will be *exposed by the knowledge given by Leading Team members*, i.e. the Province and Managers/owners of the industrial site. *Collecting and sorting of wastes* must be initiated, where the amounts and availability of organic fractions are in question.

Action 5: First Triangle analysis - technical feasibility

Purpose of the action

The results of the energy and resource studies conducted in Action 4 must now be exposed for further analysis, which ends in an optimisation of the Triangle; "Resource, End-use and Technology" as outlined below. The consequences of this optimisation are actions, determining the "Design of the energy system" which will end this Action 5.

Figure 2: Triangle analysis



The ideas behind the Triangle are to create optimisation between the specific need of energy found in industries, the type and amount of waste found and the conversion technologies. The inter-connection between the three determines the outcome - the optimisation - of the Triangle. If, for instance, most waste is on a liquid basis, certain converting technologies are more appropriate than others are as for example the gas engines in this case. As gas engines generates low qualitative heat, energy demands requiring large quantities of high qualitative heat (steam), cannot be fulfilled satisfactory. Thus, other means of conversion technologies must be examined together with a possible treatment of the fuel in order to cover the heat demands found.

<u>Resource studies</u>

As emphasised earlier wastes can be re-used by means of External Re-use, divided as Specific or General Re-uses, of which the latter can be raw materials - fuels - for energy production.
This fuel can be on a solid or a liquid basis. The focus of the section below is to study the *energy system*, by which the energy will be generated, which depends on the waste characterisation. If the waste is liquid it will normally be converted in a gas engine which cannot generate high qualitative heat for

industrial uses. If the waste is solid high qualitative heat conversion technologies can, on the contrarily, be implemented. How to approach the study of waste for appropriate selection of energy system will be emphasised in the following, including for instance how to transform liquid waste for uses as solid waste for high qualitative heat generation.

Actions to be taken

- *Estimate which conversion method is the most optimal when examining the* theoretical energy potential of all biomass residues found *(in MWh/year). If the energy outputs differs according to the way of conversion (whether for instance being* incinerated *or* digested*) preferably chose the method providing the largest energy output. This will improve the utilisation of biomass residues for efficient energy conversion.*

- Examine the character of biomass residues *(composition; content/structure and type; solid/liquid) which is important in order to determine, whether residues can be converted by the method most efficient as emphasised above. If biomass residues were found to be most appropriate for digestion - according to energy potentials - then analyse whether such conversion is possible when looking at the specific biomass character; Can all residues be converted by this method or are there large quantities of wastes, which cannot Is it furthermore possible to obtain the right mix of liquid contra solid organic waste for appropriate digestion?*

- *If energy potentials as well as the composition of biomass residues point to digestion as method, this would be an appropriate conversion method to pursue. And opposite, if energy potentials as well as the composition of wastes favour incineration as method, this will preferably be the method to pursue. If, on the contrarily, large amounts of wastes are on both liquid and solid basis - and energy potential of residues not very ambiguous - one way of determining the most appropriate conversion method is by looking into treatment possibilities of residues, as emphasised in the action below.*

- Analyse treatment possibilities of residues *with the purpose of preparing or transforming it for other means of conversion. If, for instance, digestion is found to be the most favourable conversion method, according to the composition of wastes (large amounts of residues on liquid basis), but energy potentials low when using this type of conversion method, a* treatment *can be applied. Is it for instance possible to dry liquid residues, with the purpose of incineration? If large amounts of liquid residues can be dried for incineration purposes, or kept on liquid basis for digestion with improvements in energy output, the latter method is superior. Treatment possibilities also depend on the economy; what is feasible energy-economically might not be feasible economically (in DKK). Therefore, analyse whether such treatment is feasible in the local context before continuing.*

- Evaluate which converting method to pursue *if biomass residues are of both liquid and solid composition. If the amounts of liquid and solid wastes are almost the same, preferable select a multi-fuel conversion method. If the energy system later on is enlarged, then expand it with a conversion method more in accordance with the "original nature" of residues. Whether the multi-fuel converting technology shall focus on liquid or solid wastes (digestion or incineration) mainly depends on which energy End-use to cover, as different conversion methods provide different energy services. It also depends on which possible environmental problems that can occur when applying different conversion methods, as emphasised below.*

- Analyse if biomass residues can lead to contamination when converted in certain ways *and therefore more appropriate for other means of conversion. In order not to create unwanted emissions through the development of an energy system, such analysis is a necessity. The results* can *change focus away from the most appropriate conversion method initially found, at least for some of the residues (from for instance incineration to digestion as means of conversion). The energy potential of household waste is for example highest when incinerated, but emissions of dioxin (caused by contents of organic bound chlorine in household waste), which can develop under incineration, makes this an inappropriate conversion method (two-step treatment are only applied on waste incinerating plants, not on biomass applications). In this case biological digestion is more appropriate as conversion method.*

The source to information

The tasks to be conducted are primarily *theoretical studies and analysis* (paperwork), combined with studies of biomass residues in the field, in order to evaluate its character.

End-use studies

Purpose of the action

Besides further analysis of "heat market" potentials and energy uses within industries, which is the purpose of the section below, it is also important to find out whether there is a local district heating network, by which generated surplus heat could be transmitted. It can also be favourable to find out whether other large heat customer's, as for instance a local hospital, is located in the area, or other special heat using facilities are located in the area. These activities can ad "heat market" potentials to that found in industries, as emphasised below, if the need for industrial process heat not is sufficient.

Actions to be taken

- *Elaborate more* detailed analysis on the quality and quantity of End-use demands *from the data given by Step 3, in which the quantity and quality of energy End-uses briefly were exposed. Study the energy consuming patterns of industries, showing for instance total uses of heat and electricity (in MWh/year), and by which temperatures (highest and lowest) process heat are required in the production processes to get a throughout picture of energy End-uses. Note industries that are obvious regarding a substitution in energy supply, as using process heat by temperatures below 100 degrees C., i.e. conversion from high qualitative heat uses (steam made by electricity or fossil fuel) to low qualitative heat uses (water based heat by district heat). Also note industries using process heat above 100 degrees C., and therefore* could *convert to water based process heat by for instance technical changes in processing activities.*

- *Departing from knowledge about operation hours per year and the quality and quantity of End- use demands,* conduct a duration curve for industrial energy uses*, showing the heat effect in MW and the operation hours per year. The purpose of such curve is to develop a tool appropriate for estimating how energy End-uses can be covered according to the energy consuming patterns of industries; is it possible to cover energy demands solely by district heat? Or if steam uses are required; can cascading of steam to other industries be established? Is it furthermore possible to cascade "waste-steam" from these industries to other industries again? As a result of the above analysis, now* propose a size-specification of the energy plant *(in MW heat and electricity) and* estimate the amounts of fuel required *(MWh/year).*

- *If the proposed energy plant exceeds 10 MW then Environmental Impact Assessment (EIA) must be conducted. If the energy plant will be established as a Firm-SPP, a Public Hearing must rightfully be initiated [Mr. Somkiat Sutiratana, DEDP, Interview, Bangkok the 24-4-03].*

- Estimate the consequence of future increases in energy uses within industries *(in MWh/year), which is important for appropriate design of the energy system regarding for instance plant flexibility. Expected increases in energy uses can partly be complied with by implementation of DSM strategies, which is the next action to be taken.*

- *Make throughout analyse of possibilities for implementing* conversion and optimisation initiatives in industries*, the latter especially relevant in industries using process heat exceeding 100 degrees C., and therefore not just adequate for conversion in energy supply. Thus, by conversion initiatives it is possible to transform energy demands consisting primarily of steam uses, to energy demands consisting primarily of water based heat uses. Combined with efficient uses of energy through optimisation initiatives, for instance effective uses of machinery's etc., this can lead to large reductions in total energy uses; both quantitative and qualitative.*

- *To give an example of* conversion and optimisation *strategies possible to implement, wood industries using process heat generated by electricity can be emphasised. In wood industries, process heat is often used for drying glue in "glue pressers", at temperatures just above 100 degrees C. By connecting the "glue presser" to a water borne system, and using a glue that harden by lower temperature levels, a conversion of the energy supply can taken place. Optimisations strategies can be achieved by various activities in wood industries. Especially in the areas of processing wood, compressed air and removals of sawdust such strategies are beneficial (see Chapter 3 in the project report). In the latter large energy savings can be obtained by implementation of a more adequate transportation system for sawdust removals.*

- *Identify emissions from present energy uses* (CO_2, NO_x and SO_2), that provide the data for later comparison to the alternative energy system. *Estimate the costs of the present energy uses*, with the purpose of making comparisons through the Pre-Feasibility Study.

The source to information

The tasks to be conducted are *theoretical studies and analysis* of data and information given by the actions taken in Step 3 (paperwork), as well as additional studies and monitoring in industries, as the information needed might exceed what is obtained in Action 4.

Technology studies

Purpose of the action

The purpose of the following section is to look into technologies capable of converting biomass residues found, into the type of energy required by industries. When the biomass waste and energy End-use has determined the selection of energy system - i.e. by which means the conversion must take place (process) - the appropriate selection of converting technologies can take place. This task is emphasised below.

Actions to be taken

- *Identify which technologies that are capable of producing energy services as required by industries* (steam, water based heat or both). If no steam but only water based heat are required, gas engines might for instance be a technical option. Opposite, steam and gas turbines are more appropriate technologies where steam demands appear.

- *Now evaluate the technologies in accordance with their capability to convert biomass residues* as found in the Resource analysis. The composition of biomass residues can be very different, thus analyse which technologies that are capable of converting the specific residues found. The composition can for instance vary according to the content of residues, and in relation to the moisture levels. Some combustion technologies for instance require fuel of a very harmonious structure (certain size-specification's of fuel), whereas the moisture level can be relatively high.

- If residues are very different in composition, preferably select a multi-fuel technology as being the most appropriate application. If, on the contrarily, biomass residues are very homogeneous as for instance being only wood residues only, the number of possible conversion technologies to chose between increase.

- *Finally, point out mature technologies and look at experiences in operating the specific technology*, when emphasising the energy demand to be covered and the composition of biomass fuels. Are there for example previous experiences in operating the technology - feed by this specific fuel - that points to potential weaknesses? The maturity of technologies is very important to bear in mind, as it affects plant reliability and thereby the creation of a stable energy production. Analysis must only be elaborated on technologies fulfilling this criterion.

The source to information

Theoretical studies of different converting technologies for biomass residues, combined with *expert interview* and *interviews with plant operators etc.*, emphasising the most appropriate technology for implementation in the specific context analysed.

Design of energy system

Purpose of the action

An optimisation of the energy system as a whole will appears in the following section, as opposed to the optimisations, which happens under each action taken (Resource, Technology and End-use) of the Triangle.

Actions to be taken

- *Make various technical analysis* emphasising the set-up in "Energy supply and location of energy plant", as for instance how to design the district heat network so all levels of energy requirements can be fulfilled, and how to implement cascading of energy practically. In analysis of "Composition of waste and specific plant design" it is possible to emphasise how certain types of biomass residues can be utilised especially beneficial, compared to for instance traditional combustion. This could for example be uses of liquid bio-oil (if any) as combustion stabilisation in a burner placed in the furnace, hereby reducing the influence of high moisture biomass or biomass with a very inharmonious content.

- In "Plant flexibility" the potential technologies for implementation are evaluated in accordance with their capability to start up and close down. If the conversion technology must not be operated on full load (emphasised in the duration curve), it is especially important to find a technology, which has such flexibility. Also elaborate analysis of "Flexibility in the capacity of meeting increases in End-use demands", which expose whether technologies can be over-dimensioned in order to prepare for future energy increases. Normally, over-dimensioning of biomass technologies is inappropriate as it affects plant economy relatively more, than when implementing traditional technologies. A slightly over-dimensioning *can*, however, be pursued by for instance up-scaling the Steam Turbine technology a little (must not exceed 20%). Otherwise, "up-scaling" - or more appropriate *preparation* for energy increases - can happen as implementation of for instance boilers or certain engines in modules. Elaborate "Back-Up system" analysis, which includes how to utilise existing fossil fuel boilers in industries as such, or whether other types of fuel in the area can feed an individual back-up boiler for energy production.

- If energy increases are expected in the future, and biomass residues found to be of both solid and liquid nature, then preferably *develop a Transformation Strategy for the energy system*. This will successive expands the energy system by implementation of other technologies using the biomass fuel in their "original form", as the energy demand expands beyond what can be limited by DSM initiatives. *Study the environmental performances of technologies* proposed for implementation (including Emissions analysis). Are there certain environmental advantages in implementing one technology over another? This could for instance be technology favourable by emitting lower levels of SO2 or NOx to the environment, compared to others.

- *Analysis of the local context must now be conducted*, which include studies of the local resource base regarding production of energy technologies. Are there appropriate technologies manufactured locally? If domestic manufactured technologies are available preferably select these, as they decrease technology costs (compared to imports from the West) and support the national industries. Now several technologies might be appropriate for implementation, but are they equal feasibly? *Elaborate a Pre-feasibility study of selected technologies for implementation,* showing the economic consequences of the different technical opportunities (includes Cost-Savings analysis and Sensitivity analysis). The Pre-feasibility study providing information that enables a final choice of technology to implement.

The source to information

Theoretical technical analyses emphasising the most appropriate energy system to implement, including performance of technologies. *Economic and environmental analysis* illustrating the feasibility of implemented technology and the emissions.

Important stakeholders

The optimisation of the first Triangle can be done by the Department of Energy Development and Promotion (DEDP), under MOSTE, or the academia. The main duties of DEDP is to develop and promote renewable energy and energy conservation, and to implement energy conservation programmes. DEDP has 12 regional offices for energy development and promotion in regions through out Thailand, who can aid in such analysis. Also large NGO'es can be included in these analysis, as for instance TEI or EFE, who has the capacity to conduct technical feasibility studies, energy audits, training, campaigns etc. [Ms. Patcharin Worathanakul, TEI, Interview Bangkok the 28-4-03 & Mr. Lars Ivarsson and Mr. Chaiwat Pollap, EFE, Interview Bangkok the 30-4-03].
The academia at Asian Institute of Technology (AIT) and King Mongkut's University, will also be very interested in helping with analysis in this phase [Mr. Bundit Fungtammasan, NETDA, Director of Energy and Cleaner Technology Center & Ass. Professor at King Mongkut's Institute of Technology, Interview, Bangkok the 13-2-01]. Again, this must be done as collaboration between the Leading Team and the stakeholders mentioned.

Several stakeholders have also expressing interests in providing the tasks as required in designing the energy system. This for instance includes making feasibility studies. Again, the academia at Asian Institute of Technology (AIT) and King Mongkut's University, will be able to provide this task. Also governmental agencies like NEPO (National Energy Policy Office) and DEDP, will like to participate with their knowledge in this phase [Mr. Chaiwat Pollap, NEPO, Bangkok, Interview the 9-2-01 & Mr. Boonthong Ungtrakul, DEDP, Interview the 7-2-01]. As for the analysis above, it must be done in collaboration with the Leading Team.

Action 6: Second Triangle analysis - feasibility

Purpose of action

When interested industries are pointed out the organisational build-up can commence. This include which stakeholders (industries) are the most relevant to embrace as Industrial Materials Network participants and owners, and which other stakeholders to include in the co-operation as for instance being potential financial contributors, etc. The purpose of this action is thus to minimise the economic risks of the project, and to establish appropriate co-operation between the stakeholders, including which ownership to pursue.

<u>Transaction costs/Risk minimisation</u>

Actions to be taken

- *Access which areas of the energy system that poses potential risks*. These risks can for instance be potential lack in fuel supply, turbulent conditions for transmission of electricity on the grid or lack of a stable heat market. *Identify how Transaction costs etc. can be used in removing potential risks* (Risk minimisation), by for instance inclusion of certain stakeholders or by limitations in the number of (vertical) trading partners, hereby reducing costs.

- Now *propose how Risk minimisation can be achieved in the specific context examined (industrial estate or area etc.),* **which can also point to important members and potential owners of the Industrial Materials Network. Risk minimisation can for instance be obtained by including only industries using process heat (district heat), as Industrial Materials Network participants and possible owners. This is important due to the creation of a stable heat market, and thus optimal uses of the district heat network, where heat customers has incentives to *stay* heat customers. Another example can be unfavourable high wheeling fees for transmissions of electricity on the grid, which can be meet by establishing an individual electricity supply system between Industrial Materials Network participating industries for Risk minimisation.**

- ***Analyse how other outside stakeholders can support the implementation of Industrial Materials Network*** by examining which interests/motivation they have in the scheme, again using the Risk minimisation approach. Then ***propose how Risk minimisation can be achieved in the specific context examined (municipality/region etc.)***, which can also point to the most important outside stakeholders to include, as well as to possible co-owners and financial contributors. If the province in which the industrial area is located for instance faces difficulties in managing waste, it is likely that the implementation of Industrial Materials Network will receive support from this stakeholder. Risk minimisation, in regards to fuel supply for instance, can here be obtained by the Province supplying biomass fuel to the Industrial Materials Network if other sources fail.

<u>Conditions for Inter-industrial Co-operation</u>

Actions to be taken

Emphasise potential Industrial Material Network members (the industries), their interests in joining the scheme and which ***barriers and possibilities for co-operation*** (lack of financial and technical capacity for instance) they see. Then propose how participation by other stakeholders than case industries (analysed above), can ***break down some barriers found***, by for instance acting as leaders, prime initiators or financial contributors. ***Outline all pre-conditions for co-operation*** in Industrial Materials Networks, as emphasised above. Discuss how the pre-conditions can be fulfilled so industries are willing to join the Industrial Materials Network? Which financial and organisational scheme must be established in order to secure participation, etc.?

<u>Corporate governance</u>

Actions to be taken

Create an overview of ***different types of Corporate governance***, and analyse ***which economic consequences*** this has on the corporate economy. ***Analysis which type of Corporate governance (and thus ownership of the Industrial Materials Network) to create***, in order to incorporate the pre-conditions as found above. This can also include strategies for transformation of power in the corporation established, etc.

The source to information

Action 4 information is used as background information for *theoretical analysis* (paperwork) of Transaction costs/Risk minimisation possibilities, which can be supplemented by *interviews* elaborated for further *analysis* emphasising the pre-conditions for Industrial Materials Network implementation. *Theoretical studies* (paperwork) also outline different types of Corporate Governance, whereas *economic calculations* are used for illustrating the corporate economy when applying different types of Corporate Governance.

Important stakeholders

Organisational issues can also be supported by NSTDA, and especially in the area of how to organise and manage the Industrial Materials Network, they can be helpful [Mr. Bundit Fungtammasan, NETDA, Director of Energy and Cleaner Technology Center & Ass. Professor at King Mongkut's Institute of Technology, Interview, Bangkok the 13-2-01]. It might also be beneficial to involve NSTDA in the area of conducting interview and mapping potential outside stakeholder, who could have an interest or by other means be beneficial for the Industrial Materials Network (Risk minimisation through fuel supply for instance). A Leading Team member, FTI, are also very important in this phase, as proved interested in elaborating *corporate feasibility studies* showing the expected economic results for involved industries, as a means of finding potential participants. This can provide a very important incentive for industries to participate in Industrial Materials Networks [Ms. Dominica Dacara, FTI, Interview, Bangkok the 19-2-01]. As for the previous steps taken, it is the specific situation analysed (context) that determines which stakeholders to pursue the different tasks proposed.

Action 7: Financing; How to finance and commence the construction phase

Purpose of action

When both Triangle analysis are finalised the energy facility is ready for implementation. This firstly requires financing and then secondly the actual construction. The purpose of the following section is to focus on some means of financing Industrial Materials Networks, as well as suggestion for commencing the construction phase.

Financing

CDM

Economic support for projects mitigating green house gasses in developing countries is the concept of Clean Development Mechanism. Two countries (developed and developing) working together can thus find new options in reducing their green house gas emissions, by for instance implementing a renewable energy facility in the developing country, financed by the developed country ["Co-generation Project Developing Guide", COGEN III. Programme, Romel M. Carlos et. al., First edition, Dec. 2002]. The credits for resulting mitigation of green house gasses are thereafter transferred to the developed county for minimum 7 years and maximum 21 years.

CDM as a source of financing the implementation of Industrial Materials Networks in Thailand faces promising perspectives. Several bilateral donors have expressed interests in establishing Industrial Materials Networks in Thailand financed by means of CDM. The combination of efficient renewable energy production and consumption, as well as waste minimisation initiatives - which happens within this co-operation - is initiatives bilateral donors would like to support in Thailand, especially if the carbon certificates are acquired by the donor country [Mr. Dieter Brulez, GTZ, Interview, Bangkok the 30-4-03 & Mr. Akira Shibuya, JICA, Interview, Bangkok the 6-5-03 & Mr. Karsten Gasseholm, DANIDA, Interview, Bangkok the 7-5-03].

Multilateral Funds

It is also possible to acquire financing for Industrial Materials Network implementation through Multilateral Funds, as for example by Funds under the UN. The major source of multilateral funding is the International Bank for Reconstruction and Development (IBRD) - better known as the World Bank - and its affiliates. From the World Bank Group Multilateral funding handed over as gifts to developing countries (by IDA) are not an option for Thailand, as being one of the more richer developing countries. Multilateral gifts are solely given to the poorest countries of the world [Mr. Martin C. Spicer, IFC, Interview, Bangkok the 5-5-03]. Funding from the World Bank Group, particularly directed to support the private sector, is as follows;

- Guarantees from the World Bank to support loans to the private sector.
- Investment and loans provided by the International Finance Corporation (IFC) exclusively to private sector enterprises.
- Political risk insurance offered by the Multilateral Investment Guarantee Agency (MIGA) to promote private investment flows to developing countries ["Co-generation Project Developing Guide", COGEN III. Programme, Romel M. Carlos et. al., First edition, Dec. 2002].

According to the International Finance Corporation (IFC) in Bangkok, the World Bank Group is interested in supporting the implementation of Industrial Materials Network in Thailand. The implemented energy facility must not be lower than 40 MW if the loans are to come directly from IFC, as the evaluating of the proposal will be to cost full. Alternatively the IFC can support Industrial Materials Network implementation indirectly, by lending resources to an external finance organisation - similar to for instance the America based *Fondelec* supporting renewable energy projects in Latin America and Eastern Europe - which then manage the evaluation of the projects etc. Another possibility is to apply IFC for support by "clustering" the applications of several similar project proposals, hereby lowering the costs of evaluating individual proposals. Today the IFC practices this in the field of WWTP implementations in Thailand [Mr. Martin C. Spicer, IFC, Interview, Bangkok the 5-5-03].

In Asia the Asian Developing Bank (ADB) is another source to multilateral Funds. ADB's mission is to promote investment and foster economic growth in Asia and the Pacific by lending funds and providing technical assistance to its developing member States ["Co-generation Project Developing Guide", COGEN III. Programme, Romel M. Carlos et. al., First edition, Dec. 2002].

Donor gifts (bilateral)

From bilateral sources it is also possible to help financing the implementation of Industrial Materials Networks, by means of donor gifts and partnerships between the two countries (the developed and the developing country). Where the above types of financing belongs to the category Project Financing, donor gifts belong to the category Project Programmes (projektleverancer). For the idea of Industrial Materials Networks to become a part of the Project Programmes by donors in Thailand, it most normally be included in the Country Programmes negotiated between the developed and the developing country.

If not included in the Country Programmes another type of donor gift, supporting the implementation of Industrial Materials Networks, can for instance be technical assistance or other means of facilitation by donors. Donors are not financing the energy plant etc., but facilitating its implementation (initiate training, awareness rising, communication between stakeholders, technical analysis, etc.) [Mr. Dieter Brulez, GTZ, Interview, Bangkok the 30-4-03 & Mr. Akira Shibuya, JICA, Interview, Bangkok the 6-5-03].

Developing Bank Loans

If local financing is pursued for Industrial Materials Network Implementation especially developing banks like Industrial Finance Corporation of Thailand (IFCT) are appropriate. Support to renewable energy projects and focus on SME are business objective for the bank, which is perfectly in line with Industrial Material Network schemes. According to Mr. Anat Prapasawad, Vice President of IFCT, the corporation will be interested in contributing with up to 60 % of the project expenses, and possible more is positive show cases are implemented in Thailand [Mr. Anat Prapasawad, IFCT, Interview, Bangkok the 8-5-03].

Commercial Bank Loans

Commercial banks still remain the most popular and largest source of financing energy projects in general, due to the ability of the bank to understand and appraise the credit risk exposures involved in unusual loan transactions. It is commonly that international and even local large banks employ staff of engineers to assist in the structuring of financing the project. The banks also have experienced and professional loan staffs with experience as to the acceptable practices and risks of particular industries. Commercial bank loans can be secured or unsecured loans, but may also involve a single lender, several lenders, or may be syndicated. The different types of commercial loans may vary depending on its use such as, construction loans, term loans, and bridge loans, mortgage loans or working capital loans ["Co-generation Project Developing Guide", COGEN III. Programme, Romel M. Carlos et. al., First edition, Dec. 2002].

BOT

BOT (Build Operate and Transfer) projects can be established both by donor gifts and by traditional Project Financing. In a BOT project a private company is given concession to build and operate for instance an energy facility, which normally would be build and operated by the government. The private company is also responsible for financing and designing the project. At the end of the concession the private company returns ownership of the energy facility to the government ["BOT Guidelines, UNIDO, 1996].
This system can also be utilised for Industrial Materials Network implementation, as a private company as the Leading Team can hold the concession, thereby getting the energy facility implemented. At the end of the concession, the ownership is transferred to industries participating in the Industrial Materials Network.

BOT is thus relevant when a passive ownership is found appropriate in the initial phase. Later, the ownership can become active and more responsible, when it is transferred to industries. This level of responsibility depends on whether the financing happens as loans or donor gifts, and which Corporate Governance is selected for participating industries. BOT is especially relevant when the Industrial Materials Network are based on Co-operative Society as type of Corporate Governance's, as this is based on a low initial financial contribution from participating industries, and all risks taken by the donor in the initial phase.

Project Financing, Donor gifts (Project Program =projectleverancer), CDM, Commercial and Developing Bank Loans, can be sources of BOT financing. When BOT is based on donor gifts it is not required that loans are paid back, but some kind of economic surplus must be generated to the circle of owners [Pers.Com., Tyge Kjær, RUC, 2003].

<u>Bidding process</u>

When the organisational build-up is finalised and the size and type of energy system decided upon, as well as the source of financing determined, an actual implementation of technical equipment etc. must begin, i.e. construction. To promote competition between interested tenders, hereby promoting effectiveness and efficiency, a process of competitive bidding can thus be initiated. Within such bidding process, tenders compete in order to acquire the project contract. Bidding as a tool is thus a means of getting the project implementation started.
It is for the Leading Team to initiate this bidding process, which is shortly described below.

- The first step in a competitive bidding process is to elaborate a project description in which all specifications are outlined (invitation to tenders). These specifications can for instance be size specifications, timing issues and performance requirements etc. Clear and transparent conditions for the evaluation process must also be emphasised in the project description.
- After the invitation-to-tender-document is finalised, a group of interested investors or

sponsors normally form a consortium to put together a responsive bid. The consortium elaborate their own studies of the project feasibility, and seek tentative loan commitments and preliminary contract prices from potential lenders, contractors and suppliers in order to structure the bids.

- Then an actual selection of bidders is pursued, which must be undertaken by highly qualifies technical, financial and legal advisers. Other factors than price will normally be included in the selection of bidders, as for instance reliability and experience.
- The project development can now take place, which include a formation of the Project Company, loan agreements and financial closing, construction and supply contracts, off-take and insurance contracts, M&O agreements etc.
- When the project reaches final closing the construction work and delivery of important pieces of construction equipment can begin. This ends with a specified completion test, which ends in a final acceptance.
- (In a BOT-project the following phases are also included; Operation and Transfer) ["Unido BOT Guidelines", UNIDO, 1996].

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Economic Impact Of Water Pollutant Emissions Produced By Malaysian Manufacturing Sector On Its Productivity Growth

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ABSTRACT: The positive impact of productivity growth made Malaysia one of the most remarkable growth record in modern history, led by manufacturing sector as an engine of growth of Malaysian economy since 1987. This study examines the economic impact of water pollutant emissions on Malaysia's manufacturing sector productivity growth. Autoregressive estimation was employed to time series data for the period 1985-2000 to estimate the sources of manufacturing sector productivity growth. Two models were generated from the production functions to measure manufacturing sector productivity growth. The results showed that industrial activities are related with the growth rate of water pollutant emissions that had impacted the productivity growth of the manufacturing sector in general and technological progress of the manufacturing sector in particular.
Keywords: water pollutant emissions; economic impact; manufacturing sector and productivity growth
JEL Classification Code: O120

INTRODUCTION

The Malaysian economy recorded a stronger growth with significantly improved economic and financial fundamentals in the year 2000. This performance has placed Malaysia in a stronger position to respond to the more challenging economic environment in the future. Real GDP recorded a growth of 8.5%, in 2000, well above the 5.8% achieved in 1999. While growth was supported by strong external demand, it was the rise in private consumption and the strong revival of domestic investment that mainly contributed to economic growth. The strong private investment was observed in several industries where levels of production and capacity utilisation had expanded in response to rising demand. As a result, labour market conditions also improved significantly in year 2000 with the estimated unemployment rate declined to 3.1%. Policy strategies to diversify the economic structure of Malaysia continued beyond the year 2000 to further deepen and widen the industrial base, to enhance the development of the services sector as a second engine of growth and to venture into new areas of growth. In 2000, value added from the manufacturing sector grew strongly by 21% with significant increases in production of both export and domestic-oriented industries, setting a new record for manufacturing production. Reflecting the overall growth of the economy, value added in the services sector also rose by 4.7%. Value added in the construction sector turned around to register a positive growth of 1.1%. In the agriculture sector value added remained positive despite sharply lower growth in palm oil production and declines in rubber and cocoa production (Bank Negara Annual Report, 2000).

Malaysia’s Productivity Performance

Following the contraction in 1998, the economy recovered in 1999 with a growth of 5.6 percent driven by a series of policy initiatives undertaken by the Government of Malaysia to stimulate the economy. On a quarterly basis the GDP registered a growth of 4.8 percent in the second quarter, 8.5 percent growth in the third quarter, and 10.8 percent in the fourth quarter (Productivity Report, 1999).

As the Malaysian economy continues to face the challenges brought about by the dynamics of globalisation, it has to be more resilient and competitive. To achieve this, economic fundamentals have to be strengthened with the emphasis on the productivity and quality driven growth strategies that enhance efficiency in the utilisation and management of productive resources. In this context, the enhancement of Total Factor Productivity (TFP) is imperative. By definition, TFP measures the synergy and efficiency of the utilisation of both capital and human resources. Positive TFP growth indicates efficient utilisation and management of resources, materials and inputs necessary for the production of good and services. For the period of 1989-99, the economy recorded a TFP growth of 1.6 percent resulting in a corresponding 3.8 percent average growth rate of productivity. In 1999 productivity grew by 3.9 percent from MYR21, 207 in 1998 to MYR22, 026 (Productivity Report, 1999).

The productivity growth contributed 70 percent to overall economic growth while employment contributed 29 percent. In terms of GDP, employment, capital and productivity as supported by government policy initiatives the economy in 1999 enunciated following the recent economic crisis improved domestic demand and stimulated recovery. This resulted in a higher GDP growth of 5.6 percent (1998: -7.5 percent) and productivity growth of 3.9 percent (1998: –1.8 percent). To improve competitiveness, industries need to incorporate productivity-driven growth strategies in their corporate objectives. These include the implementation of productivity and quality management system, improvement through benchmarking activities, intensifying the application of information technology, skill upgrading of human capital and quality products through research and development. For example quality systems such as MS ISO 9000 Certification helped companies achieve a high level of excellence. Until 1999, 1,858 companies used to be certified under the MS ISO 9000 systems (Productivity Report, 1999).

The sustainability of higher economic growth will continue to be driven by productivity through the enhancement of TFP. Development strategies of TFP will emphasise on quality of workforce, demand intensity, economic restructuring, capital structure and technical progress. To improve the competency of workers, investment in human resource development is pertinent. Until the end of 1999, 2.3 million employees had been trained under the Human Resource Development Fund (HRDF), with disbursements approved totalling over MYR680 million. In 1999, 13.8 percent of the employees were trained in technical areas, 28.7 percent in areas on productivity and quality, 14.7 percent in information technology and 5.2 percent in management (Productivity Report, 1999).

During the period of 1996-2001, Malaysia's productivity growth of 3.3% surpassed that of several selected OECD countries also, namely the United States (2.3%), United Kingdom (1.5%), Canada (1.4%), France (1.2%), Japan (1.3%), Germany (1.1%) and Italy (0.8%). At the East Asian nations' level, this percentage is also higher than that registered in each of that of South Korea (3.2), Singapore (2.0%), Thailand (-0.3%) and Indonesia (-0.8%), (Productivity Report, 2001).

Green Productivity Concept

Before the 1950s the common business response to environmental pollution was to ignore such problems. This was possible when the problems were relatively small and the awareness of health and environmental impacts was not high. In 1960s a common approach to pollution was to disperse concentration of the pollutants for example, by constructing tall smokestacks and extending pipeline into the sea to dilute water pollutants. It was soon realised that many pollutants were toxic even at small concentrations and some chemicals retained their toxicity for a very long period. These diluted pollutants accumulated in soil and water and eventually found their way to the food chain. When industries and communities began to exceed the environment capacity to assimilate their wastes, efforts were made to establish environmental standards in order to regulate the discharge of pollutants. In 1970s, this resulted in the use of treatment systems to ensure the discharge from industries and other enterprises met stipulated environmental quality standards.

The concept of Green Productivity (GP) is drawn from the integration of two important developmental strategies vies productivity improvement and environmental protection. Productivity provides the framework for a continuous improvement while environmental protection provides the foundation for sustainable development. Therefore, GP is a strategy for enhancing productivity and environmental performance for overall socio-economic development. It is the application of appropriate techniques, technologies and management systems to produce environmentally compatible goods and services. GP is applicable not only to the manufacturing sector, but also to other sectors like agriculture and services. It also addresses the interaction between economic activities and community development. As with large industries, it is also applicable in small-and medium-sized industries (SMIs) for the purposes of mobilising scarce organisation resources to increase productivity and protect the environment (National Productivity Report, Malaysia, 1998).

Malaysian Water Pollution Status

In the Seventh Malaysia Plan (1996-2000), an approximately RM1.9 billion was allocated in the Government's development budget for the improvement and protection of the environment as well as to conserve and promote sustainable resource use. However, environmental quality monitoring programmes of the Department of Environment (DOE) continued to supplement its enforcement work, and to uphold the Environmental Quality Act (EQA), 1974.

For the year 2000, a total of 901 stations located within 120 river basins were monitored. Out of these 901 monitoring stations, 388 (43.1%) were found to be clean, 391 (43.4%) slightly polluted and 122 (13.5%) polluted, (figure 1). And the estimated number of effluent-related sources for the year 2000 was 13, 992 comprising mainly of agro-based industries, manufacturing industries, pig farms sewage treatment plants. Of this number 6,457 sources (46.1%) were domestic sewage facilities, followed by the manufacturing sector (6,019, 43%), pig farms (1,045, 7.5%) and agro-based industries (471, 3.4%). The pollution load contributed by these four sectors significantly affect river water quality in Malaysia, figure 2, (Malaysia, Environmental Quality Report, 2000).

Based on the source inventory compiled in 2000, a total of 6,490 agro-based and manufacturing industries were identified. Out of 16 types of manufacturing industries, the main polluting sources were food and beverage industry with 1,538 sources constituting 23.7% of the total number, followed by electric and electronic industry (738, 11.4%), chemical–based industry (729, 11.2%), paper (571, 8.8%), textile (481, 7.4%), metal finishing and electroplating (343, 5.3%), crude palm oil mills (343, 5.3%) and raw natural rubber factories (128, 2%), figure 3, (Malaysia, Environmental Quality Report, 2000).

The objective of this paper is to study the impact of water pollutant emissions on productivity growth of Malaysian manufacturing sector.

Methodology and Estimation Procedures

An attempt was made to apply the conventional growth accounting framework utilized by Stiger (1947), Albramovitz (1956), Kendrick (1956), to this study developed by Solow (1956, 1957), finally brought to fruition by Kendrick (1961) and further refined by Denison (1962, 1979), Griliches and Jorgenson (1986), Jorgenson et. al. (1987) and Dollar and Sokoloff, (1990). The production of each industry is expressed as a function of capital, labour, raw materials and time. It is assumed that the production process is characterised by constant returns to scale for each industry, so that the proportional increase in all inputs results in a proportional change in industrial output. This approach provides more room for decomposition of contributions of factor inputs and technological change to economic growth. Likewise economists are more interested in intensive growth, which is expressed in the form of growth in output per worker (labour productivity). Furthermore, an economy's standard of living its not determined by its total output but by the amount of output available per person as stated by many economists like Dollar and Sokoloff, (1990). As with (Pittman, 1983; Chaston et al., 1997), yet the most obvious deficiency in the above mentioned growth accounting models is found to be the exclusion of externalities such as pollutant emissions generated by the manufacturing sector in the form of undesirable output. This paper will contribute to the available literature on growth accounting method in that it will draw methods calculate the real total factor productivity growth by internalising the pollutant emissions beside the input terms in the production function. Accordingly, total factor productivity growth became an indictor of green productivity, which takes into account economic development and environmental protection, as has been explained in the introductory part of this paper.

The main objective has been to apply the above-mentioned conventional growth accounting framework under assumptions of competitive equilibrium (where factors of production are paid the value of their respective marginal products) and constant returns to scale. The Divisia Index basically decomposes the output growth into the contribution of changes in inputs (such as capital, labour, materials input growth), an undesirable output (such as water pollutant emissions), and total factor productivity (TFP) growth. In other words, considering the data at any two discrete points of time, say T and T-1 the growth rate of output Q for an industry can be expressed as a weighted average of the growth rates of capital (K), labour (L), intermediate inputs (M) and water Pollutant emissions (WPE) plus a residual term typically referred to as the rate of growth of TFP. Hence the TFP growth of each industry is computed as the difference between the rate of growth of output and weighted average of the growth in the capital, labour, intermediate inputs, and water pollutant emissions where the weights are the respective shares of each input in the industry's gross output. It follows that

$$\overline{W}^{i}_{T} = [\ln Q_i(T) - \ln Q_i(T\text{-}1)] - \overline{W}^{i}_{K}[\ln K_i(T) - \ln K_i(T\text{-}1)] - \overline{W}^{i}_{L}[\ln L_i(T) - \ln L_i(T\text{-}1)] - \overline{W}^{i}_{M}[\ln M_i(T) - \ln M_i(T\text{-}1)] - \overline{W}^{i}_{WPE}[\ln WPE_i(T) - \ln WPE_i(T\text{-}1)] \quad [1]$$

$i = 1$ and $T = 1985\text{-}2000$

where the weights are given by the average value shares

$$\overline{W}^{i}_{K} = 1/2\,[(W^{i}_{K}(T) + W^{i}_{K}(T\text{-}1)],$$
$$\overline{W}^{i}_{L} = 1/2\,[(W^{i}_{L}(T) + W^{i}_{L}(T\text{-}1)],$$
$$\overline{W}^{i}_{M} = 1/2\,[(W^{i}_{M}(T) + W^{i}_{M}(T\text{-}1)],$$
$$\overline{W}^{i}_{WPE} = 1/2\,[(W^{i}_{WPE}(T) + W^{i}_{WPE}(T\text{-}1)], \text{ and}$$
$$\overline{W}^{i}_{T} = 1/2\,[(W^{i}_{T}(T) + W^{i}_{T}(T\text{-}1)]$$

According to Tham (1997), $\overline{W}^{i}_{K}$, $\overline{W}^{i}_{L}$, $\overline{W}^{i}_{M}$ and $\overline{W}^{i}_{WPE}$ denoting the shares of capital, labour, material and water pollutant emissions, Q output and T time of manufacturing sector and bar indicating a simple average over two successive time-periods, (T) and (T-1) and the average productivity growth term, $\overline{W}^{i}_{T}$, is the translog index of TFP growth.

Secondly, following Dollar and Sokoloff, (1990), Wong's (1993), Elsadig Musa (1998) and Jesus Felipe (2000), when constant returns to scale is imposed

$$W^{i}_{L} = (1 - W^{i}_{K} - W^{i}_{M} - W^{i}_{WPE})$$

Assuming $W^{i}_{K} = \alpha$, $W^{i}_{M} = \beta$ and $W^{i}_{WPFE} = \lambda$, the equation becomes

$$\ln\Delta Q_{i,T} = \alpha \cdot \ln\Delta K_{i,T} + \beta \cdot \ln\Delta M_{i,T} + \lambda \cdot \ln\Delta WPE_{i,T} + (1 - \alpha - \beta - \lambda) \cdot \ln\Delta L_{i,T} + \ln \Delta TFP_{i,T} \quad [2]$$

$i = 1$ and $T = 1985\text{-}2000$

where Q is the growth value of output, K is the capital input, L is the labour input , M is the materials input and WPE is water pollutant emissions of the Malaysian manufacturing sector, and α , β and λ are the elasticities of output with respect to capital, material and water pollutant emissions respectively.

For the purposes of this study, and to avoid multicollinearity between the input terms, equation [2] was transformed by dividing each term by L (labour input) and then the output elasticity was calculated with respect to capital deepening, material-labour ratio and dirty fuel emissions intensity, i.e. α, β and λ, respectively. According to Dollar and Sokoloff, (1990), the production function was of the form as follows: -

$$\ln(Q/L)_{it} = a + \alpha_1 \ln(K/L)_{it} + \alpha_2 [\ln(K/L)_{it}]^2 + \beta_1 \ln(M/L)_{it} + \beta_2 [\ln(M/L)_{it}]^2 + \lambda_1 \ln(WPE/L)_{it} + \lambda_2 [\ln(WPE/L)_{it}]^2 \quad [3]$$

It follows that

$$\alpha_i = \alpha_1 + \alpha_2 (K/L)_i$$
$$\overline{\alpha} = \alpha_1 + \alpha_2 \overline{(K/L)}$$
$$\beta_i = \beta_1 + \beta_2 (M/L)_i$$

$$\overline{\beta} = \beta_1 + \beta_2 \overline{(M/L)}$$
$$\lambda_i = \lambda_1 + \lambda_2 (WPE/L)_i$$
$$\overline{\lambda} = \lambda_1 + \lambda_2 (\overline{WPE/L})$$

Since the intercept (a) has no position in the calculation of the productivity growth rate indicators, equation [3] becomes: -

$$\ln\Delta (Q/L)_{i,T} = \overline{\alpha}.\ln \Delta (K/L)_{i,T} + \overline{\beta}.\ln\Delta (M/L)_{i,T} + \overline{\lambda}.\ln\Delta(WPE/L)_{i,T}+\ln\Delta TFP_{i,T} \qquad [4]$$

i = 1 and T = 1985-2000

Where $\overline{\alpha}$, $\overline{\beta}$ and $\overline{\lambda}$ are denoting the shares of capital deepening, material-labour ratio and water pollutant emissions intensity, Q output and T time of manufacturing sector and bar indicating a simple average over two successive time-periods, (T) and (T-1) and the average productivity growth term, TFP^i_T, is the translog index of TFP growth.

Thus, equation [4] expresses the decomposition of labour productivity growth into the contributions of capital deepening, increased usage of materials input per unit of labour, water pollutant emissions intensity and TFP growth. To calculate the total factor productivity average annual growth rate as well as the average annual growth rates of other productivity indicators in the model after the estimation of the production function equation [4] becomes

$$\ln\Delta TFP_{i,T} = \ln\Delta (Q/L)_{i,T} - [\overline{\alpha}.\ln \Delta (K/L)_{i,T} + \overline{\beta}.\ln\Delta (M/L)_{i,T} + \overline{\lambda}.\ln\Delta(WPE/L)_{i,T}] \qquad [5]$$

RESULTS AND DISCUSSION

An autoregressive estimator was applied to two models generated from a production function to measure the shift in the production functions of Malaysia's manufacturing sector. An annual time series data over the period of 1985-2000 for gross value of output, number of employment, value of fixed assets, cost of input and cost of water consumed by manufacturing sector obtained from the Department of Statistics were employed. The data were deflated by producer price index (1980=100) to obtain the real value of variables from its nominal data. The first model referred to as Model 1 which was attributed to Jorgenson et al, 1987 expressed the decomposition of growth value of output into contribution of changes in capital, labour, material inputs, water pollutant emissions and TFP growth. The second model referred to as Model 2 attributed to Dollar and Sokoloff, 1990 expressed the decomposition of labour productivity growth (output per worker) into the contribution of capital deepening (capital per worker), material-labour ratio (material per worker) water pollutant emissions intensity (water pollutant emissions per worker)

Analysis of the data for the Model 1 showed that estimated coefficients of capital, material and water pollutant emissions of manufacturing industry sector were significant at 5% level. In Model 2 the estimated coefficients for all the terms were significant at 5% level (Tables 1-2).

Table 1: Output Elasticity of Malaysian Manufacturing Sector Productivity Indicators 1985-2000, (Model 1)

Intercept	0.93154
	(0.7268)
Capital	0.21615
	(1.97635)*
Labour	0.04752
	(0.32630)
Material	0.71295
	(3.84300)*
Water Pollutant Emissions	0.02338
	(1.9654)*
Adjusted R^2	0.99120
Durbin-Watson	1.83970

Notes: Figures in parenthesis are T-values
*Indicates significant at 5% level

Table 2: Output Elasticity of Malaysian Manufacturing Sector Productivity Indicators 1985-2000, (Model 2)

Intercept	3.03300	
	(2.26800)*	
Capital Intensity	α_1	α_2
	0.18374	0.2948
	(5.72100)*	(6.79900)*
Material-Labour Ratio	β_1	β_2
	0.79526	0.70242
	(7.03500)*	(9.11800)*
Water Pollutant Emissions Per Worker	λ_1	λ_2
	0.02100	0.00278
	(1.97864)*	(1.96570)*
Adjusted R^2	0.99630	
Durbin-Watson	2.08590	

Notes: Figures in parenthesis are T-values
* Indicates significant at 5% level

Empirical Analysis

The analysis was carried out to compare the productivity indicators within the manufacturing sector for the entire period of 1986-2000. As stated in the (Economic Report, various issues), during this period the policy shifted from import substitution to labour intensive and export oriented industries with electronics and textiles as the main areas of emphasis and growth. The decade of 1980s saw further diversification of the economy into more advanced industries. The Heavy Industries Corporation of Malaysia (HICOM) was conceived in 1980. As a result of these polices the range of economic activities and sources of growth had become more diversified. The period of 1986-1996 witnessed further diversification of the economy into more advanced industries. During this period the economic structural transformation took place in the Malaysian economy, and the manufacturing sector became the engine of growth. In this period policy makers developed the first and second Industrial Master Plans and gave priority to the twelve industries to contribute more to Malaysia's industrial development. The results generated using the two earlier mentioned models are presented in the following section.

As was found by Maisom et al (993), Choong and Tham (1995), Tham (1995), Menon, (1998), Mahaderan (2001), Oguchi et al. (2002) and Elsadig et al. (2002) yet the overall capital annual growth rate of the manufacturing sector outweighed the problems of labour and materials. It showed clearly that there were direct effects of the government policies and plans that were applied to the manufacturing sector which were experiencing higher growth rates after the structural transformation that took place in the Malaysian economy in 1987. And the largest component of cost in the Malaysian manufacturing sector was the cost of materials; and shortage of skilled labour might cause a serious constraint on capital utilisation. Skilled labour is required to operate the new technologies embodied in new plants and equipment so that available capital stock may be utilised efficiently. Hence skills training and the deepening of skills are of vital importance for the full utilisation of capital. These studies concluded that productivity growth of Malaysian manufacturing is input driven rather than total factor productivity driven and mainly dependent on Foreign Direct Investment (FDI). And the performance of productivity growth after the financial crisis of 1997 was negative during 1998 as stated earlier and this supports our assumption about Malaysian productivity in general and that of manufacturing sector in particular is input driven rather than total factor productivity driven and based on FDI. This also confirmed by Lall (1995). As well as other Asian newly industrialised courtiers their productivity is input driven as stated by Young (1992, 1995) and Kim and Lau (1994). Sarel (1996) also paid his concerns to some East Asian countries that may face the same fate of the Soviet Union. This is because these countries invested primarily in labour and capital rather than in technology over the past few decades.

Though our main focus should be on the impact of water pollutant emissions on total factor productivity growth of the sector, and then the results generated using the two earlier mentioned models are presented in the following section.

Results of Model 1

The cost of water consumed by the manufacturing sector was introduced in the model as proxy data in the form of undesirable output to measure the impact of water pollutant emissions generated by the manufacturing sector on its productivity growth. In fact, the higher level of water pollutant emissions generated by the manufacturing sector impacted the growth rates of TFP, which is expressed as the technological progress of the manufacturing sector. TFP is the technological progress of the manufacturing sector, which comes from the quality of input terms such as capital, labour (as number of employment), and material inputs. However, the contribution of TFP growth to manufacturing sector productivity growth, in terms of its average annual growth rate was positive and very low during the entire period of 1986-2000, which was 0.00644 (see Table 3). The entire period of 1986 -2000 was the golden era of the Malaysian industrial development, and naturally it generated high level of water pollutant emissions due to the consumption of this water, which impacted the productivity growth in general and technological progress of the manufacturing sector in particular.

The growth rate of water pollutant emissions was very high during the entire period of 1986-2000, which was 0.18946 (see Table 3) that was due to the intensive industrial activities of the manufacturing sector during this period.

Table 3: Productivity Indicators of Manufacturing Sector, (Model 1), 1985-2000.

Total Factor Productivity	0.00644
Gross Value of Output	0.21153
Capital	0.19623
Labour	0.07973
Material	0.21374
Water Pollutant Emissions	0.18946

Results of Model 2

The second model expressed the decomposition of labour productivity growth (output per labour) into contributions of capital deepening (capital per worker), material labour ratio (material per labour) and total factor productivity growth. The performance of the manufacturing sector was measured using productivity indicators obtained from the estimated coefficients of this model. To study the impact of environment on productivity growth of the manufacturing sector, a water pollutant emission per worker was included in the model. The result was that there was decreasing growth rate in the contribution of labour productivity, capital per worker and even negative of material- labour ratio to the manufacturing sector's productivity growth during the period of study, i.e. 0.02769, 0.03302 and -0.02185 respectively. However, the contribution of water pollutant emissions per worker was very high that totalled to 0.10304. The decreasing growth rate was also contributed by TFP growth that totalled to -0.08652 in term of average annual growth rate, reflecting the negative impact of dirty fuel emissions on them through their qualities (Table 4).

The water pollutant emissions per worker had impacted and slowing down the contribution of TFP (technological progress) as well as the contributions of labour productivity, capital per worker and material-labour ratio of the manufacturing sector during the entire period of the study that witnessed the rapid industrial development in the Malaysian economy, which generated higher level of water pollutant emissions due to the industrial activities.

Table 4: Productivity Indicators of Manufacturing Sector, (Model 2), 1985-2000

Total Factor Productivity	-0.08652
Labour Productivity	0.02769
Capital Intensity	0.03302
Material-Labour Ratio	-0.02185
Water Pollutant Emissions Per Worker	0.10304

CONCLUSION

The manufacturing sector has been the engine of Malaysia's economic growth since economic structural transformation took place in Malaysia's economy in 1987. The sustainability of higher economic growth continued to be driven by productivity through the enhancement of total factor productivity. Total factor productivity development strategies emphasised on the quality of the workforce, raw material, capital structure and technical progress. The manufacturing sector is important in Malaysia's economic development. The instability of total factor productivity contribution to manufacturing sector industries in terms of average annual growth rates are dependent on the inputs used in the production of manufacturing sector industries, that were reported elsewhere to be insufficient and of low quality

This paper contributes to the literature of growth accounting method in the area of calculating the real total factor productivity growth by internalising the pollutant emissions beside the input terms in the production function. By this technique total factor productivity growth becomes an indictor of green productivity, which puts into consideration economic development and environmental protection, as has been explained in the introductory part of this paper.

The factor affecting the output growth of the manufacturing sector as identified using Jorggerson et al model are the individual contributions of capital, labour, material, water pollutant emissions and the combined contribution of the quality of these inputs expressed as the total factor productivity. In fact, the higher level of water pollutant emissions generated by the manufacturing sector impacted the growth rates of total factor productivity by internalised the cost of water consumption beside the traditional input terms in the form of undesirable output produced beside the original products of the sector in the model as shown in the result of model 1.

While the factors identified as influencing the labour productivity (that is indicated as a good measure of standard of living rather than output because it measuring output per person) of manufacturing sector from Dollar and Sokoloff model are the individual contributions of capital deepening, material-labour ratio, water pollutant emissions intensity and the simultaneous contribution of the quality of these factors expressed as the total factor productivity. The water pollutant emissions per worker had slowed down the contribution of TFP (technological progress) of the manufacturing sector more than that of the first model due to the problems of labour, during the entire period of the study that witnessed the rapid industrial development in the Malaysian economy, which generated higher level of water pollutant emissions due to the industrial activities.

Finally, putting together results of the two models this paper found that industrial activities are related to the growth rate of water pollutant emissions generated by the consumption of water in the production process of the manufacturing sector. This appears in the form of undesirable output that had slowed the productivity growth of the manufacturing sector in general and the contributions of total factor productivity of the manufacturing sector in particular.

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Debating Participation In Urban Environmental Planning and Management: Some highlights from the LUCED-PEP Seminar in Copenhagen June 11-13, 2003

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ABSTRACT: Many LUCED-I&UA participants are involved in studying, planning or advising urban environmental development or management projects and programs. In these projects, issues of public participation, stakeholder participation, and community participation are cross-cutting issues which we are all dealing with in one way or the other. This short paper intends to share some useful key concepts presented at the PEP seminar and to present some of the main issues that were debated .

Keywords: Participation, environmental planning and management, social innovation, new professional roles, cognitive regimes.

INTRODUCTION

The LUCED-supported research network "Public Participation in Environmental Projects" (PEP) was created by members of the LUCED network involved in studying, planning or advising urban environmental development or management projects and programs.

LUCED members of the PEP network (researchers & their students) can largely be divided into the architects, the engineers (environmental managers), the environmental planners, and the scholars.

The architects are involved in participation from an urban planning perspective. Public or community participation is pursued in local physical planning procedures, in neighborhood upgrading projects, in projects working with special target groups such as squatter settlements and their participation in environmental management projects and so on.

The engineers are approaching participation in relation to environmental management tasks such as waste handling, introduction of environmental management systems in enterprises, waste water treatment systems, water & sanitation.

The environmental planners are equally addressing questions such as community involvement in waste handling systems, upgrading of neighborhoods, or technology transfer issues.

As scholars we are all interested in improving performance and in understanding why projects turn out as they do.

An initial brain-storm meeting identified research and networking needs being of two kinds. One group (the majority of the PEP Network) of LUCED members are involved as technical specialists in urban planning or environmental planning & management projects where participatory strategies are to be followed. These members needed a forum to discuss technicalities about participation and some help in understanding more theoretically the "theories" of participation. Another smaller group of members have explicitly made the study of participatory processes a major focal point of their research and teaching. Their interest was to get access to more empirical case-data in order to further develop their research topics on participatory planning for sustainable development.

As an answer to this combination of interests, a workshop was organised at the Royal Danish Academy of Arts in Copenhagen, June 11-13, 2003 with the title: "Debating participation: Actors Shaping Sustainable Urban Development" (proceedings forthcoming). The point of departure was taken in the claim that much effort has gone into defining the principles of participation and how to do it, but that not so much effort has been directed at understanding what actually goes on when participation takes place in practice. This paper is an attempt to share some of the main ideas and discussions from this seminar in view of better understanding and further developing our own practice in studying and implementing participation in projects for sustainable urban development.

PARTICIPATION : DIVIDED OPINIONS

We, the technicians, planners, decision-makers, and university teachers, all know the rhetoric of participation. Successful environmental (or urban) planning, we say, must involve the stakeholders, the local communities, the public, the women, the poor. We probably also all know why we say this. It is politically correct, and it may even be a legal condition in our respective countries.

We also may be referring to – or at least we are familiar with - the arguments in favour of participation: Participation allows for better acceptance of projects, more support from the public, and "ownership" by the beneficiaries (Cernea 1992, World Bank 1996). Participation allows for technically better solutions because local knowledge and preferences can be integrated in the planning and decision-making process. It allows for cheaper solutions for the State, because tasks of producing public services can be transferred to the local communities through the mobilisation of local resources (Finsterbusch and Van Wicklin III 1987; Isham et al. 1995). Some advocates even claim that participation is a way of developing more democratic decision-making structures in society, and that it will empower the weak and enhance their capacity of making their voices heard and taking up collective action for their own common good.

We also know the reservations we may have in the back of our minds – or say out openly - about the feasibility of participatory strategies. Participation can be a tedious, cumbersome extra work load. It slows down performance. It is a lot of empty talk in the air at endless meetings. Most people do not want to participate. Or if they do, they mess things up, deviate discussions and agendas, contest decisions, or even clearly obstruct the project, barring the hard-ware people like engineers, architects, planners, and environmental authorities from getting on with their business. We also question if it is really more democratic, when we observe that it is only a few activists that really participate. And we are quite aware that they are mistakenly given credit as being the representatives of all community members, using this to their own personal advantage. Being cynical, we might ask, is the support to participatory strategies in reality not the mere manifestation of sociologists, anthropologists, human geographers, political scientists, and other "soft" professionals wanting to create well paid job opportunities for themselves at the expense of the hard ware professionals?

ANALYSING PARTICIPATION

The concept of *participation* is a very loose and bendable one (Pearse & Stiefel 1980, Marsden 1990, Lund 1990, Oakley 1991, Cernea 1992, World Bank 1996). It has been, and still is, interpreted in many different ways by different people. This makes it a difficult concept to work with scientifically.

When debating participation, a number of different aspects can be discussed as it is shown in Figure 1. One the one hand we have the "norms and forms of participation", i.e. the discourse or rhetoric about what participation should be and how we implement this in practice. A very fundamental aspect here is the underlying rationale or purpose of participation. The debate here essentially fluctuates between an *instrumental management* view of participation as a means to deliver certain collective goods and services (infrastructure, environmental management, etc.) or compliance with regulatory measures, or a *normative* view of participation as development goal, either as part of a *political strategy* of empowerment of marginalized and weak social groups, or as an element of practicing *good (democratic) governance*. This divide runs right through discussions of participation and urban (environmental) planning, too.

Other major aspects, or elements concern issues such as who is (or should be) participating in what kind of activities? What do (or should) they participate with? And how are (or should) the participation processes be handled (meetings, PRA[1] sessions, contracts, facilitation, etc.)? The very definition of the term participation can vary as different combinations of these elements.

On the other hand (below the dotted line), part of the picture is made up by our theoretical understanding of the term and of the practice of it as a social phenomenon. As it is, arguments for one or the other model of participation are not just referring to rationales and purposes, but also to such theories about what are the shaping factors of participation and the preconditions for its successful implementation. Discussions are also referring to assumptions about expected outcomes and impacts occurring when applying participatory approaches.

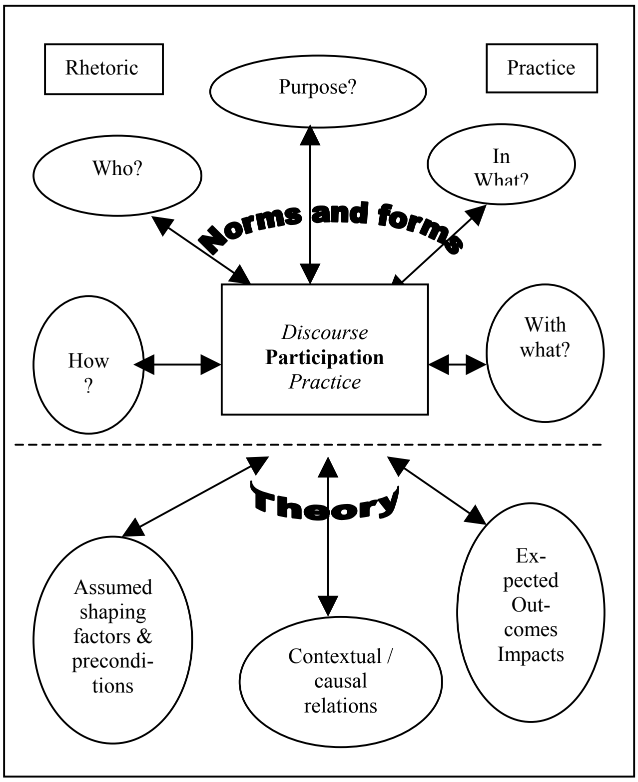

Figure 1: Debatable elements of "Participation"

However, these theories are not very well founded and explored, however (Lund S. 1990, White 1996, Lund & Ribiero forthcoming). They are mostly appearing as more or less implicit assumptions. It was this "black box" of participation that we intended to open up a little more with the PEP seminar.

[1] PRA: Participatory Rural Appraisal

PARTICIPATION: RHETORIC AND PRACTICE

Andrew Jamison's key-note presentation at the seminar gave a general description of the way participation has been addressed in Europe over the years and then went on to address the gap between the rhetoric and practice of participation in urban environmental planning in Europe.

Looking at the actual modes of public participation that have evolved in Europe, a number of characteristic patterns are emerging in relation to sustainable development (Jamison & Wynne 1998). In various technocratic projects of "ecological modernization", participation is primarily conceived in a top-down way with the public being given the role of the environmentally-conscious consumer, offered opportunities for ecological employment, and the participation of the pocketbook. Opposed to this are bottom-up approaches emanating from local initiatives, characterized by open-ended and highly diverse forms of participation (Jamison & Wynne 1998 : 15). For all forms it appears that they seem to be disconnected from the real sources of power and decision-making – and being often of temporary duration. A point which was taken up by Jesper Holm in his presentation on the experience of the Government initiated Agenda 21 process in Denmark (Holm & Wambui 2001)

In accounting for the gap between rhetoric and practice, Jamison pointed to the existence of cultural tensions between different policy domains (bureaucratic, economic, academic and civic). These tensions are due to the fact that the different policy domains have different rationalities or "principles" (order; growth, enlightenment, democracy), steering mechanisms (planning, commercial, peer review, public assessment), and types of ethos (formalistic, entrepreneurial, scientific, participatory). For example, where as in the bureaucratic domain agency is driven by a principle of *order*, steering of activities is done through *planning*, and the underlying ethos could be characterised as *formalistic*, things work very differently in the other domains. In the Economic domain, for example, the driving principle is one of *growth*, the steering mechanism being *commercial,* and the ethos being *entrepreneurial.* These, if not conflicting at least not-directly-compatible, policy cultures can be summarised as it is done in the following figure.

	Policy domains			
Dimension	Bureaucratic	Economic	Academic	Civic
Principle	Order	Growth	Enlightenment	Democracy
Steering Mechanism	Planning	Commercial	Peer Review	Public Assessment
Ethos	Formalistic	Entrepreneurial	Scientific	Participatory

Figure 2: Cultural Tensions in Science and Technology Policy *(From Jamison and Østby 1997)*

As it can be seen, the participatory ethos is only characterising policy-making within within the civic domain. The origin of the gap between rhetoric and reality of participation lies here.

What A. Jamison concluded from this was that public participation requires social innovation, such as

- spaces for interaction across social domains
- processes of communication or translation across "discourses" or domains (knowledge brokers such as for instance "green economists")
- change agents and political entrepreneurs
- enlightened civil servants
- political support "from above
- cultural mobilisation "from below"

This social innovation in turn implies new types of hybrid identities or social agents, such as

- organisers of networks (across sectors or within organisations)
- translaters & interpreters (across scientific fields, between policy domains)
- mediators & facilitators (consensus builders/dialogue makers; bridge builders/social innovators, i.e. people who create new forms of social activity)
- Brokers & entrepreneurs (product managers and product champions of participation)

The cases of environmental projects with public participation presented at the PEP seminar can in fact be reflected upon and compared by using Jamison's analytical framework. This goes for many of the DUCED student projects that have been made over the years, for that sake.

As it was, the notion of social innovation and creating "spaces for interaction" became one of the key-concepts of the conference during the presentations of public participation in on-going environmental planning projects. Hybrid identities became another key concept much referred to. I shall return to this further below.

PARTICIPATION AND NEW ROLES OF THE PROFESSIONS

For those of us who are technicians, be it engineers, architects, environmental scientists or planners, the divided opinions about the feasibility of participation as described above is a fact of life. Some techniciens stick to their identity as hard-core technical professionals, others believe in converting into soft new professionals who take an interest in understanding and actively communicating with various groups of the public, the users, or the local communities. The PEP group probably belongs to the latter group. But how do we understand this situation?

Applying Jamison and Østby's analytical framework, it is obvious that our point of departure as scholars falls within the academic domain. But we all play multiple roles. As consultants we enter the economic domain, as planners we join the bureaucratic one, and as activists we move within the civic domain. What unites us in the LUCED programme is our particular role as policy-relevant knowledge producers. This implies a special situation in the sense that our academic practice cannot be purely academical, due to the fact that we are operating in the "arenas of interaction" *between* policy domains. We are now becoming translaters and interpreters, mediators, facilitators, and brokers. This is why social innovation also within academia has become necessary.

An example from the many interesting presentations given at the PEP seminar was Jesper Holm's presentation on *Local Agenda 21 in Denmark* (Holm 2003, forthcoming). The Danish experience of government initiated community participation in Local Agenda 21 activities could be seen as platforms for instituting social innovation in order to bypass traditional barriers for a radical environmental development. A strategy of showing "the good examples" was followed. Creating links between eco-farmers and green consumers is an example of this. The development of an experimental bottom-up culture was supported by government funded, but locally implemented pilot projects based on local activists. Projects included activities such as mobilising clients and citizens in making renewable energy utilities; developing energy-saving measures, renewing urban areas with ecology projects; reducing the amount of traffic; etc. At the same time, an effort was made to make institutional changes. Cross-sectoral experiments within the local public sectors were carried out in order to assess institutional obstacles for paradigmatic change and to experiment with new and less costly environmental innovation options, with a focus on cleaner technology options, pollution prevention and cradle-to-grave perspectives instead of the more general carrying-capacity approach. Inputs, in addition to funding of activities, included support to networking, organisation, or training of activists.

The outcome of the Danish Agenda 21 initiatives was a policy paradigm shift from top-down environmental protection and restrictions. The emerging new paradigm is characterised by an "eco-modernistic" interactive bottom-up approach including citizens, NGOs and local authorities in more comprehensive and constructive efforts to re-build cities and infrastructures, focusing more positively on resource accounting, quality of city-life and environmental goods. This example, as several other presentations given at the PEP seminar, showed the importance of directing "social innovations" towards the creation of new forums for dialogue between authorities and local communities, and of following up on this by giving support to the establishment and organisation of local communities, empowering them thorough training and support for linking up and networking with potential allies.

Several other examples from presentations of urban planning given at the seminar also pointed to the importance of choosing the types of planning instruments and communication tools which are easily mastered by the participants, and which reinforce the sense of community, mutual trust and understanding, and efficient organisation for collective action.

It is worth noting, however, that activities have depended on the existence government funded facilitators to keep activitists going. Moreover, inclusion of important stakeholders amongst the big environmental NGOs, industries, trade unions, labour or farmers' organisations was minimal. Thus the Danish Agenda 21 campaign may well have shown social innovations and new forms of roles and alliances. But political commitment in Denmark is lacking for this to have impact on a larger scale. This observation rejoins the general European trend observed by Jamison and Wynne, mentioned above. It gives rise to a critical scepticism concerning one of the main assumptions of participatory strategies, namely that the consensus-seeking approach is always feasible. In fact, argues Holm, Danish LA21 initiatives have only been "exterior add-ons" to existing local environmental, social and business policies. Because of this, bureaucratic and corporate interests were not threatened, and this is why new discursive alliances from below have been allowed to grow. But the more fundamental issues concerned with changing consumption patterns, taking a stance on issues like GMOs and so on, have escaped the LA21 initiatives. They imply a shift towards issues which are basically *conflictual* and therefore not manageable on a consensus-basis. Here there is a need to rethink the participatory strategies.

Another major dilemma, which was referred to in several of the presentations, concerned the need for institutionalisation of the efforts in order to scale-up impacts and making activities sustainable. In doing this, the bottom-up involvement is lost in the process of bureaucratisation, professionalisation or corporatisation that inevitably follows. It was discussed if having community development funds which can be wisely allocated to new activists and initiatives would be a solution to this problem.

Some attention was also given to the issue of how well the poorest or weakest groups – who are often the very target groups of the development project in question – are actually being supported through the current participatory approaches. An example from Thailand showed that the participatory approach in fact leads to the creation of a new group of brokers and entrepreneurs who become the owners of the project where as other community members were excluded – or chose not to participate (Funder 2003, forthcoming).

Understanding the modes of "public participation" and the new roles for the professionals which are emerging these years, can be related to more general processes of change in the global society at large. At the time when the role of the state is being diminished in many areas, Jamison and Wynne argue that the quest for sustainability has led to both new forms of knowledge production and new modes of public participation (Jamison & Wynne 1998). They argue that there is a basically cultural process of public recoil and alienation from expert-led rational policy making and a documented common experience of public mistrust and disaffection from modern forms of policy discourse on riskes, environment and related issues. This has resulted in a need for an intermediary expertise between the social and the technical – an "environmental social science" – a "mode of knowledge production" that combines different disciplinary perspectives in a problem-oriented and context-dependent transdisciplinarity (Jamison & Wynne 1998: 9).

EMERGING COGNITIVE REGIMES

This leads to a final important aspect introduced by A.Jamison, namely the emergin cognitive regimes of sustainable development. A cognitive regime is an order of conditions under which knowledge is produced and applied in social processes (of sustainable development). A cognitive regime is composed by a type of agency (or actor), its forms of action, an ideal of science (or knowledge), its main sources of knowledge, and the type of tacit competences most held in value.

Andrew Jamison proposed a distinction between *residual, dominant, and emerging* regimes, relying on a perception of regimes evolving or changing over time *(Table 3)*.

Status	Residual	Dominant	Emerging
Type of Agency	Local NGOs	Transnational /Corporate	Hybrids networks
Forms of Action	Popularisation Resistance	Commercial Brokerage	Exemplary Mobilisation
Ideal of science	Factual Lay	Theoretical Expert	Situated Contextual
Source of knowledge	Traditions	Disciplines	Experiences
Tacit compet-ences	Personal	Professional	Synthetic (transdisciplinary, holistic knowledge)

Table 3 : Cognitive regimes of sustainable development *(from: A. Jamison, forthcoming)*

Jamison asserted to have observed an evolution where the environmental grassroots movements in the US and Europe in the 60's and 70's could be seen as a the main carriers of what could be classified as a "residual" cognitive regime today. Today, the dominant cognitive regime is carried by transnational corporations. A view which was later questioned by the Thai key-note speaker, Soomsook Boonyabancha. She felt that the residual NGO regime in Thailand was expanding side by side with the other cognitive regimes. This may well become the case in Europe for the conflictual issues mentioned by J. Holm. However, it is clear that the Danish Agenda 21 experience is an example of an attempt by local governance institutions "to address citizens needs, potentials and ambivalence, and excape the commonly rationalistic, and expert-oriented environmental requirements, exterior to laymen's everyday orientation" (J. Holm, *forthcoming*, p. 2).

Whatever is the case, the importance of referring to cognitive regimes when inquiring into the rhetoric and practice of participation lies in the extent to which these residual, dominant, and emerging orders of conditions under which knowledge is produced and applied influence or are being influenced by the development of rhetoric and practices of participation. Thus, in my own perception, the observation that agency is shifting from NGOs towards hybrids and networks, that the emerging ideal of science is situated and contextual, or that the experiential source of knowledge are assuming an increased strategic importance is helpful in seeing clearer where constraints and (new) opportunities lie for practicing participatory approaches.

To conclude, let me announce that there were many other interesting experiences and analyses presented during the PEP seminar in Copenhagen. The proceedings are under press. LUCED participants interested in receiving a copy are kindly requested to sign up on a list of distribution with the organisers.

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Challenges of an Organisation in Sustaining System Implementation and Its Continual Improvement (Environmental Management System)

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ABSTRACT: Since the first edition of the most widely recognised standard, ISO 14001:Environmental Management System (EMS) – Specification with Guidance for Use, being finalised and issued in Sept. 1 1996, over 10,000 organisations worldwide have had their EMS ISO 14001 certification. Preliminary evidence suggests that international trade influences, supplier preferences, public relation pressure, customer preferences, shareholder interests, environmental performance factors and compliance pressure are among some of the motivation factors (Darnall *et al.*, 2000). In order to stay competitive, continually meeting legislation requirements and improving its environmental performance, the implemented management system needs to be sustainable, and most importantly able to provide information for continual improvement; which in fact is the two basic concept that carries within the ISO 14001. Internal environmental management system (EMS) audit is a tool that will be used for this purpose, as required by the standard as well. In this study, the sustainability of the implemented system and identification of areas of continual improvement had been assessed through an EMS audit conducted on an institution, as a case study, on January 2003. Results showed that environmental training and awareness, continuous commitment and integration of management systems are the essential parts to ensure sustainability of the implemented system.

Keywords: environmental management system (ems), continual improvement, sustainability

INTRODUCTION

Environmental management system (EMS), can be defined as follows:

- A formal set of procedures and policies that defines how an organisation manages its potential impacts on the natural environment and on the health and welfare of the people who depend on it. It creates a system to assess, catalogue and quantify facility environmental impacts throughout the entire organisation. (Darnall *et al.*, 2000).
- A problem identification and problem solving tool that provides organisations with a method to systematically manage their environmental activities, products and services. It helps to achieve their environmental obligations and performance goals (Europawebsite on EMAS).
- A continual cycle of planning, implementing, reviewing, improving the processes and actions that an organisation undertakes to meet its business and environmental goals (USEPA website).

Many businesses have developed their own Environmental Management System since 1970s, in which the responsibility of managing the system normally relies on a single personnel (Darnall *et al.*, 2000). In 1996, a comprehensive set of standards for environmental management, ISO 14000 series was published by the International Organisation for Standardisation (ISO). This series of standards grew out of the ISO's commitment to support the objective of "sustainable development" discussed at the United Nations Conference on Environment and Development, in Rio de Janeiro in 1997. The ISO 14001 standard is one of the standard within the ISO 14000 series that specifies the requirements of an environmental management system (ISO website).

The five principles of the ISO 14001 EMS, consists of the following:

- Commitment and policy
- Planning
- Implementation
- Measurement and evaluation
- Review and improvement

These principles are basically derived from the Deming Model of Quality Management.

As mentioned above, the EMS will not only provide a framework in helping to create a system to manage an organisation's environmental impact, and improving it's environmental performance, it will also requires that periodic self-assessment or internal audit be carried out. This has been clearly stated in ISO 14001:1996 guidelines that an organisation shall establish and maintain programmes and procedures for periodic environmental management system audits to be carried out. The aims of the audit is to

1. Determine the conformity to the requirements, been

properly implemented and maintained; and
2. Most importantly, to provide information on the audit results to the management for continual improvement (ISO 14001:1996 guidelines).

Although, formal EMS procedures have been adopted by organisations worldwide, there are questions raised such as :

- Do EMS in practice focus on strategic priorities for improving sustainability, or merely on short term, limited improvements in regulatory compliance and pollution prevention efficiencies?
- Are EMS procedures sustainable?
- Are EMS goals and commitment sustainable across potential changes in management and organisation structure?

(Andrews *et al.*, 1999)

The objective of this study is to

- assess the sustainability, of the implemented environmental management system based on the ISO 14001 requirements;
- identify the areas of continual improvement through an environmental management system audit;
- To identify gap between ISO 14001 standard and problems encountered during implementation.

ISO 14001 SERIES

ISO 14000 series of environmental standards grew out of ISO's commitment to support the objective of "sustainable development" discussed at the United Nation Conference of Environment and Development at Rio de Janeiro in 1992. These standards are not intended to set environmental performance goals, but rather to specify the elements of a management system that provides a framework for an organisation to develop and maintain a reliable process that consistently meets environmental obligations and commitments (Woodside *et al.*, 1998).

The family of ISO 14000 series of standards or guidelines can be classified in two discrete categories that is, organisation evaluation and product evaluation. Standards or guidelines under the umbrella of ISO 14000 are,

1) Organisation evaluation
- Environmental management system (EMS) standards – ISO 14001 and ISO 14004.
- Environmental auditing (EA) standards – ISO 14010, ISO 14011 and ISO 14012.
- Environmental performance evaluation (EPE) – ISO 14031.

2) Product evaluation
- Environmental labels and declarations standards – ISO 14020, ISO 14021, ISO 14022, ISO 14023 and ISO 14024.
- Life cycle assessment (LCA) standards – ISO 14040, ISO 14041, ISO 14042 and ISO 14043.
- Environmental aspects in products standards (EAPS) – ISO 14060.

All of the standards or guidelines under ISO 14000 series are only as guidance except ISO 14001, the only standard intended for registration by third parties. Some unique characteristics of ISO 14001 are,

- It is comprehensive: all members in the organisation participate in environmental protection; the EMS consider all stakeholders and the process to identify all environmental impacts.
- It is proactive: it focuses on forward thinking and action instead of reacting to commands and control policies.
- It is a system approach: it stresses improving environmental protection by using single EMS across all function of the organisation.

(Transforming Strategies, TRST.com)

ENVIRONMENTAL MANAGEMENT SYSTEM (EMS) STANDARDS

Worldwide, there are few Environmental Management System (EMS) standards that are available for adoption by organisations that are interested in managing their activities in reducing the related environmental risks, among them are,

- British Standard BS7750 – which was first published in year 1993, reviewed and revised in Jan 1994 and subsequently withdrawn in September 1997. Developed by British Standard Institution, BS 7750 was the world's first standard for environmental management system.
- Eco-management and Audit Scheme (EMAS) – developed and first published in 1993 by the European Commission for countries of European Union (EU). Revision in March 2001 had strengthened and extended the scope of the scheme.
- ISO 14001 – being one of the guidelines under the ISO 14000 series; it is written to be applicable to all types and sizes of organisations and to accommodate diverse geographical, social and cultural conditions.

All of these three standards have similarities as the latter two are developed based on the British Standard BS 7750. However, the European-wide standard EMAS, has gone beyond in a number of ways as compared to ISO 14001. The differences in environmental management systems characteristics, however have no significant influence on the practical effects of the systems as suggested by an empirical research on the implementation of standardised environmental management systems in companies carried out by Freimann *et al.* (2001). The impacts and benefits of EMSs are fundamental rather than being conditioned by the general strategic orientations that lead to the implementation of one of the systems (Freimann *et al.*, 2001).

STATISTICS

During the initial introduction of the ISO 14001, 1998 data showed that 52.4% of the total 7,887 ISO 14001 certified facilities were located in Western Europe and 37% in Asia; however American certified companies only accounted for 3.7% of the total certified facilities of the world in 1998 (Delmas, 2002). The low number of American companies that are adopting the ISO 14001 could be linked to United States' institutional set up that might impede the diffusion of ISO 14001 within the country. This has been supported with survey data collected from studies conducted on a representable sample of certified facilities in the United States (Delmas, 2002).

The number of ISO 14001 certified organisations has increased tremendously since then. The statistical data collected by Mr Reinhard Peglau, of the Federal Environmental Agency, Germany (Dec 2002), showed that the total number of ISO 14001 certification or registration in the world now is 46,836; with Japan having the highest number of ISO 14001 certification, followed by Germany and Spain. Malaysia ranked in the second place within the South East Asia region , with the total number of 367 certifications. The high number of certification in Japan, is mainly due to the active promotion by the Ministry of International Trade and Industry (MITI) Japan after the experience learnt with respect to the ISO 9000 certification issue which resulted in loosing competitiveness to other registered firms. Similar scenario had happened in Taiwan (Corbett & Russo, 2001).

BENIFITS OR DRIVING FORCE OF EMS

There have been reasons in which a country is promoting, an organisation or firm is committed to, the adoption of a formal EMS and going for certification. Some of the common benefits in implementing EMS are given below,

a. assuring customers of commitment to demonstrable good environmental management,
b. maintaining good public/community relations,
c. satisfying investor criteria and improving access to capital,
d. obtaining insurance at reasonable cost,
e. enhancing image and market share,
f. meeting vendor certification criteria,
g. improving cost control,
h. reducing incidents that result in liability,
i. and others (ISO website).

A study that carried out in Chubu region of Central Japan,stated that among the reasons given by firms implementing the ISO 14001 EMS are as follows,

a. to improve the environmental aspects inside the firms,
b. enhancing the employees' environmental awareness and environmental capacity-building,
c. enhancing the firms' image among public,
d. improving the management system of the environment inside the firms.

However, respondents also showed that benefit of having more access to either local or international markets was not their main goal. Only 10% of the respondents think the ISO 14001 will give them new market opportunities (M.Mohammed, 2000).

In Hong Kong, the motivation factors to implement ISO 14001 is mainly are to gain larger market share (93% of respondents). Environmental legislation compliance only voted as the fifth motivation factor (50% of respondents) among the companies surveyed. The study also stated among the actual benefits gained by the certified companies in Hong Kong are cost reduction (79%), management efficiency and improvement of public image (71%), environmental impact reduction (43%) and increase in employees' environmental awareness (36%) (Chan & Li, 2001).

On the other side of the world, a survey carried out on eleven countries in Europe showed that the major forces that motivate companies to adopt EMS are national regulations (83.5%), organisations' directors or owners (70.15%), international regulations (64.5%), and voluntary agreements and local population (56.2%) (Rivera-Camino, 2001).

The monetary and non-monetary benefits of EMSs have been assessed in a survey conducted on more than 150 ISO 14001 certified companies in Switzerland by Hamschmidt and Dyllick (2001). Survey results showed that the empirically determined mean annual benefits is 167,000 Swiss franc (CHF 167,000) with average payback period of 2.2 years. However, these figures are based on bold estimate as only 6% of the companies surveyed measured the benefits, 47% estimate and 47% did not answer the questions. In the same survey, the most important non-monetary benefits of implementing EMS is the systematisation of existing environmental activities, which 76% voted to be of 'high value' to them. This follow by assurance of legal compliance (59%) and risk minimisation (58%) (Hamschmidt and Dyllick, 2001).

Hence, these studies showed that the influencing factors of implementing ISO 14001 are different among countries and the actual benefits obtained by these facilities are varied. Hence, we must keep in mind that since ISO 14001 is a voluntary standard, the driving force or influencing factors for adoption might change which has been observed in a study conducted in understanding the ISO 14001 adoption behaviour among four industries – chemical, electronics, electric machinery and electric power – of Japanese firms by Welch *et al.* (2002).

WHAT DISCOURAGE ORGANISATIONS FROM ADOPTING ISO 14001?

Disclosure of sensitive or confidential information has always been an issue for an organisation especially when it is of regulatory importance. However, ISO 14001 requires an organisation to provide information, which might be considered sensitive for example regulatory compliance to the certification body. The potential liabilities, for example non-compliance with applicable environmental regulations, discovered during the implementation of ISO 14001 might indeed discourage organisations from going into ISO 14001 implementation and certification (Wilson, 1998).

Another legal liability that would further keep organisations away from adopting ISO 14001 is the documentation of the details of the environmental aspects which is not regulated. The ineffectiveness in handling these environmental matters, for example records of system failures or minor spill, might still be used in legal proceedings as incriminating evidence (Mostek, 1998). In the United States, some lawyers who have had experience with the environmental Superfund argue that a government agency could subpoena internal audit records and use the evidence to prosecute an organisation (Lamphrecht, 1997).

In one interview carried out by Zutshi *et al.* (2002), with twelve environmental auditors primarily based in Victoria, Australia revealed that one of the main concerns over the implementation and certification to ISO 14000 within Australian organisations is the associated high non-compliance cost and resulted direct liability of company's top management (Zutshi & Sohal, 2002).

IMPACT OF ISO 14001 – EMS

For whatever reasons that drive the implementation of ISO 14001, most importantly, we would want to see what the organisations have benefited from EMS or ISO 14001 implementation. From a survey that was conducted by the International Islamic University Malaysia (IIU) on 137 ISO 14001 certified companies in Malaysia it was seen that, implementation of an EMS in these organisations did give positive impacts or benefits to these organisations especially in enhancing the reputation of the company. Other major benefits include reducing wastes, improved company's position in market place, looking for alternative technologies and other benefits (Sulaiman *et al.*, 2002).

The impacts of ISO 14001, according to a mail survey among ISO 14001 certified firms over different countries carried out by researchers at the Anderson Graduate School of Management at University of California Los Angeles (UCLA), showed that firms in the United States (U.S.) experienced less environmental benefits from registration compared to Taiwanese firms. This is simply because the U.S. Firms have historically been much tightly regulated than Taiwanese firms (Corbett & Russo, 2001). In another study carried out by researchers at the University of Oregon's Lundquist College of Business on a broad sample of facilities in the electronic industry, it was found that implementation of ISO 14001 registration programmes actually lead to reduced toxic emission in the United States and the dirtier facilities benefited more compared to cleaner ones (Corbett & Russo, 2001). Though simplistic, these two studies have pointed that ISO 14001 indeed does more for less environmental advanced or dirtier firms.

MAINTAINING THE SYSTEM

As mentioned before, Plan-Do-Check-Act (PDCA) model (Deming Model) from quality management is the basic principal of ISO 14001. Thus, checking is a very important step in ensuring successful system implementation and maintenance. One of the tool that is used for checking is the audit, which is stressed by ISO 14001, as well as EMAS. The importance of audit can be seen from a survey conducted by The Price Waterhouse LLP USA in April 1995, in which about 75% of the correspondent had some kind of auditing programme implemented. 94% of the respondents commented that an audit helped them to “improve their company's overall environmental program and made it proactive” (Hemenway, 1995).

Regular audits will not only assist organisations in identifying weak points but also offers many benefits, some of the prominent benefits are,

- ISO registration
- management decision support data
- liability assurance
- measurement tools
- compliance management
- educational process
- proactive management
- improvement in environmental performance
- reduced potential for liability

(Kim, 1997; Bragg *et al.*, 1998)

Internal environmental management system (EMS) audit is the tool required by ISO 14001 for an organisation to perform self-assessment on its system. The competence for internal auditors has been stated clearly in the ISO/DIS 14012 “Guidelines for Environmental Auditing – Qualification Criteria for Environmental Auditors” which include education level, training and experience required. Despite the requirements, it is suggested that organisations do not provide sufficient human and financial resources to their EMS audit function as one of the findings in the study carried out by Taylor *et al.* (2001) on ISO 14001 certified Australian enterprises. The resources committed to EMS audit are below reasonable levels in areas of budgets, qualifications, experience and training of EMS audit team members (Taylor *et al.*, 2001).

Apart from internal auditors competency level, another very important factor contribute to meaningful and useful audit results is the independence of the internal audit. The independence of internal audit has always been stressed in the world of accountancy, which stated that internal audit should be independent of management influence and staffing assessments should be rotated, should minimise bias and should not involve managing the business (Standards for the Professional Practice of Internal Auditing).

SUSTAINABILITY OF ISO 14001 – EMS

Being a voluntary standard, the ISO 14001, has left the substantive decision that make up the content of the EMS almost entirely to the discretion of the adopting organisation itself. Hence, there are questions raised in regards to its sustainability. In a two years data collection in Andrews *et al.* (1999) study on eighteen facilities across the United States, several of their intended participating firms have experienced changes in management or management priorities which has lead to weakening of commitment of environmental management system (EMS) implementation (Andrews *et al.*, 1999).

1. In a survey done on the ISO 14001 certified firms in Central Japan in Dec 1997 showed that the major difficulties faced by those organisations in adopting and maintaining ISO 14001in different stages are,
2. defining the firm's activities, services and products that interact with the environment and their impacts during initial stage;
3. documentation and staff training during implementation stage;
4. system review and monitoring and measurement after certification.

(M.Mohammed, 2000)

In an interview with one of the ISO 14001 certified multinational manufacturing facility in Malaysia showed that few main obstacles in sustaining the implemented system are,

1. Employees' commitment – which has only sustained till the certification and not beyond. Reasons have been given in not performing internal audit, late in replying Corrective Action Requests (CARs), slow progress in environmental management programmes and others.
2. Resources :-
   a. Auditing cost – the surveillance audit cost constitute a huge amount of the operating cost.
   b. Human or man power – the implementation and maintenance of the ISO 14001 system is not run by a specific group of personnel, for example the ISO group, but is the basic responsibility of the Environment, Health and Safety Department.
3. The mis-conception of the top management on the ISO 14001 system; in which they do not understand that ISO 14001 – EMS is a continual process and maintaining the system is as important, and is as difficult as implementation. Hence, top management support deteriorates after certification.

Similarly, Honda Transmission Manufacturing of America Inc. (HTM) has experienced a hard time to sustain and fitting the EMS into their existing corporate culture and day-to-day operating practices after certification. With time, HTM has overcome the problems and EMS is becoming part of the organisation's everyday business activities. This indeed was done in numerous ways,

1. Through continual education of all staff to raise environmental improvement's priority relative to production and business goals and to ensure managers and operating staff appropriately prioritise environmental targets;
2. Forming a delegated group of personnel comprised of junior staff members who have more time and enthusiasm for implementing EMS initiatives. Besides, HTM also provide recognition and rewards for individual and team environmental achievements;
3. Demonstrate environmental improvements in terms that put their value on par with production;
4. Setting realistic objectives and targets;
5. Improving on its document control.

(McManus & Sanders, 2001)

Thus, these showed that there is no simple way in managing environmental issues but continuous commitment of improvement.

CONCLUSION

The current study shows that, to develop, implement and maintain a sustainable environmental management system, the following criteria are important :

1. Employees' environmental training and awareness – since ISO 14001 is a organisation wide system which involves the participation of all employees, it is very important to ensure that employees are aware and competent in handling and improving the environmental management system and hence the environmental performance of the organisation.
2. Continuous commitment from both employees and top management are essential is ensuring the sustainability of the implemented system. Top management should include highest authority of management in an organisation where ultimate decisions are made. Besides, environmental elements or requirements should be integrated into the overall management system to avoid any negative implication due to management change. Long term employees commitment can only be obtained with strong environmental awareness and clear understanding of the purpose and goals of the EMS.

Apart from these factors, there are few areas within the ISO 14001 standard requirements itself that would pose barriers to the sustainability of the implemented system of an organisation.

1. Interpretation of the standard – Understanding of

the standard requirements in order to establish a flexible, practical and sustainable EMS is very important. However, this would be an obstacle to some organisations especially small to medium size organisations due to lack of resources. Problems in standard interpretation has been recognized by the Singapore Productivity and Standards Board (PSB) too and the view is shared by Lamphrecht (1997) which indicates that the standard with its many guides can be misleading (Quazi, 1999).

2. Environmental aspect/impact analysis – the methodology development of environmental aspects analysis has since been the most difficult area during system establishment. Due to the fact that the standard is developed to cater for all types of organisations, it has left the methodology development entirely to individual organisations. Theoretically, this is ideal as the nature of organisation and their priorities are different. However, in practice a list of 'significant' environmental aspects might be produced should the analysis method developed is not thorough.
3. There are basically two concerns when it comes to methodology development,
    a. What type of analysis to be used, qualitative or quantitative or both? In one of the local study carried out by Wang (2001) in assessing methodologies for identification of significant impacts based on a case study showed that integration of qualitative and quantitative analysis is the recommended method to be employed (Wang 2001).
    b. What criteria to be used in the assessment? Some organisations are using assessment methods with factors that cause environmental impact to be deprioritised hence not affected by the EMS (Ammenberg *et al.*, 2001).

Thus, it is the finding of this study at the center, that it would be beneficial to organisations implementing EMS if research can be carried out on the environmental aspect evaluation methodology and subsequently guidelines be drawn out.

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The Social Shaping Of Environmental Mangement Based On ISO 14001 In The Danish And Thai Textile And Garment Sectors

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ABSTRACT: The social shaping of ISO 14001 in Danish and Thai textile and garment sectors is discussed based on Danish case studies and evaluations and a Thai focus group interview. The precentage of ISO 14001 certified companies in the sectors are five times higher in Denmark, but covers only around 5% of the companies. Top management policy and government support are reasons and occasions for implementation in both countries, whereas customer requirement only is a reason in Thailand. Employees' role in the implementation is more developed in Denmark. In both countries companies have dialogue with the government about the interpretation of the regulation. In Denmark problems with the balance between consultant support and company-internal competence development are seen. The focus of ISO 14001 is more life cycle oriented in Denmark due to international policy and the manufacturing of textile and garment outside Denmark. A combined focus on ISO 14001 covering the interests of the companies in industrialised, developing and newly industrialised countries might be found through negotiations.

Keywords: Social shaping, environmental management, ISO 14001, textile sector, garment sector

INTRODUCTION

A number of companies in the textile and garment sector in a number of countries have during the recent years been certified in relation to the ISO 14001 standard for environmental management. This includes a number of companies in the Danish and Thai textile and garment sectors. Although ISO 14001 is an international standard much room is left to the company and the certification body in order to determine the focus of the system. It could be expected that a company will design its system based on its ability to identify and adapt to societal discourses about environmental concern (Lenox & Ehrenfeld, 1997; Forman & Jørgensen, 2001). This ability can be expected to be shaped by, among other things the competence of the company, its position within product chains, the national and international regulation in general and of textile and garment specifically. Insight into to the shaping of environmental management is important, when we want to understand why and how companies implement environmental management and want to understand the effect on the environmental impact of the companies and their products. Such knowledge is valuable in the shaping of future national and international regulation of these two sectors and their products and might also be useful in more general considerations of the shaping of national and international regulation of companies and products.

The textile and garment sectors are to a large extent very globalised in the sense that many products are designed in one country, the raw materials grown or manufactured in another country, the chemicals manufactured in a third country, the products manufactured in a fourth country and the products sold in a fifth country. An increasing part of the products sold in an industrialised country like Denmark are manufactured in developing or newly industrialised countries. Furthermore an increasing part of the products exported from Denmark have in different extent been manufactured in developing or newly industrialised countries countries, while design and distribution still take place in Denmark (Stranddorf et al, 2002). The employment in the Danish textile and garment sector decreased with around 40% during the 1990'ies (Om tekstil- og beklædningsbranchen, 2001). Thailand is, on the other hand a newly industrialised country, where textile and garment are manufactured and exported either to other countries for further manufacturing or to industrialised countries for final distribution. Despite the different role of the textile and garment sector in the two countries some companies in both countries have been implementing environmental management based on ISO 14001 during the last 5-7 years. It is therefore interesting to see whether this different role of the sectors in the two countries is reflected in the shaping of the environmental management based on ISO 14001. Futhermore it is interesting to see whether the shaping processes in such two countries seem to correspond, so that a combined product chain or supply chain focus on environmental management covering industrialised, developing and newly industrialised countries seem to be feasible in the future. It is here important to say that the two countries are not among the main exporters or importers to each other, so the analysis will mainly focus on the shaping of the environmental management in each of the two countries and afterwards compare the social shaping processes.

THEORETICAL AND METHODOLOGICAL APPROACH

The analysis are based on concepts and theories within social shaping of technology and corporate environmental practice. The concept of "corporate environmental competence" is used as a concept for assessing the environmental practice of a company or the product chains it is part of (Jørgensen & Forman, 2003; Forman & Jørgensen, 2001). The environmental competence of an organisation is defined as "the ability to address and reflect problems and solutions in relation to environmental problems and adopt to a more environmentally sustainable practice". When analysing the shaping of a company's ability to work with environmental issues, focus is on the establishment of a social practice in relation to the environment, rather than only on attitudes towards the environment formulated by actors in the company and its network. However, differences between the attitudes (called "the espoused theory by for example Argyris and Schön) and the practice (called "the theory-in-action") are relevant, because they might point to potentials and barriers in the development of the environmental competence. Another possible notion in stead of "environmental competence" could have been "environmental performance". The latter is used in ISO 14031, the ISO guideline from 1999 on environmental performance evaluation, and is also distinguishing between initiatives taken (environmental management) and the actual performance (environmental performance).

For such analyses of environmental practice a mixture of written materials and information from interviews is necessary. As part of systematising the collected data, the information might be grouped into discourses around different material aspects. By comparing companies or by comparing with analyses of the contemporary societal discourses also non-addressed issues can be part of the analysis.

After being grouped, the discourses should be reconstructed with focus on involved actors' roles in the shaping of problems and measures.

In this reconstruction the focus should be on:

- The reasons and occasion for the problems and measures to be addressed.
- The understanding of the problem and measures as seen by different actors involved or not involved – and the individual actor's interaction with other actors. And further what appears to have influence upon these views: other actor groups, existing systems, etc.
- How actors seek to recruit other actors to their understanding of the problem and the measures and what appears to have influence on these processes.
- How the understanding of the problem and the measures influences relationships in and around the company.
- The time, material and organisational links between the discursive processes.

The analyses are based on two different sets of data. The Danish data are based on case studies of 4 different textile and garment companies with ISO 14001 certification based on interviews and previous reports and overall analyses of environmental management in the sectors, while the Thai data primarily are based on a focus group interview with 9 companies with ISO 14001 certification combined with some statistics about the sectors. The data is presented in two tables for each Danish company and two tables for the 9 Thai companies, since there are no company specific data available from the Thai focus group interview. The tables reflect the social shaping approach and focus on:

- Occasions and reasons for implementing ISO 14001
- What the companies have seen as benefits and as obstacles during the implementation
- What resources have been allocated or developed during the implementation
- The focus of the environmental management system, including earlier or planned changes in the focus
- The internal interaction within the company and the external interaction with government, suppliers, customers and knowledge institutions like consultancy and universities.

CHARACTERISTICS OF THE DANISH AND THAI TEXTILE AND GARMENT SECTORS

Table 1 shows some key figures for the Danish and Thai textile and garment sectors as basis for the analysis of the shaping of the ISO 14001 based management systems.

Table 1: Key figures for the Danish and Thai textile and garment sectors (Chandrachai & Bunbongkarn , 2003 a & b; Om tekstil- og beklædningsbranchen, 2001)

Country	Average export value (2001) per company (Million USD)	No. of companies (2001)	Average no. of employees (2001)	No. of ISO 14001 certificates (percentage) (2002)
Thailand	1.7	3,100	100	22 (< 1%)
Denmark	10	320	40	15 (~5%)

Around 60% of the Thai textile export is garments, 3% are interior textiles and the remaining 37% are semi-manufactured materials like yarn and fabric for futher manufacturing in other countries. The main export markets are U.S.A., Japan, U.K., Hong Kong and United Arabic Emirates (U.A.E.) with U.S.A. covering almost 40% of the export with garment as the dominating part, while the export to Hong Kong and U.A.E. seems mostly to be materials for further manufacturing (Thai Textile Export 2002 & Thai Garment Expot 2002).

Around 66% of the Danish export is garments and the remaining 34% textiles, which covers a number of different products like medical textiles, interior textiles (including carpets) and fabrics. The main export countries are Germany (20%), Sweden (16%), Norway (11%), the Netherlands (6%) and Finland (5%) with garments as the main part, although around 25% of the export to Germany are textiles,

including fabrics for industrial use like in the car industry. The main import countries are China (12%), Germany (11%), Italy (8%), Poland (7%) and Turkey (5%). The import from China, Poland and Turkey is primarily garment (between 80 and 90% of the import) due to the lower wages in these countries (Om tekstil- og beklædningsbranchen, 2001).
It is obvious by comparing the statistics from the two countries that they to some extent play different roles in the value chains in the sectors. Thailand is mainly supplier to other countries due to the lower wages compared to the levels in the industrialised countries, while Denmark has a more mixed role with production of specialised textiles and high quality garment, including re-exporting garment, which have been designed in Denmark and afterwards manufactured in countries with lower wage levels. The different roles can also be seen from the fact that although the Danish companies in average are smaller than the Thai companies they have a much higher average export value (assuming that the industry in both countries are rather export oriented).

The number of ISO 14001 certified companies are rather low in both countries in the two sectors with Denmark having around 5% certified companies and Thailand less than 1%. The data analysed in the paper covers 30-40% of the certified companies in each of the countries.

ISO 14001 IN THE DANISH SECTORS

The emergence and stabilisation of environmental concern in the Danish textileand garment sectors can be seen as an interaction among the systems of production, consumption, knowledge and regulation (Karnøe & Garud, 1997).

Traditionally the textile manufacturing companies with wet treatment have been the only companies to be regulated due to their emissions of hazardous chemicals with the wastewater and later on the air emissions of formaldehyde. These companies are regulated by the municipal environmental authorities. The regulation of formaldehyde can be seen as a regulation of the sector due to the increased focus on formaldehyde and its carcinogenic effect. Later on voluntary regulation within cleaner technology emerged, later again implementation of environmental management systems and finally a product-oriented regulation was institutionalised with the formation of a co-operative sector policy network. Today all four types of regulation are present. These changes in regulation follow the overall tendency in environmental regulation at Denmark since the 1970'ies (Forman et al, 2003; Remmen & Rasmussen, 1999).

In the following the shaping of ISO 14001 in four different companies are characterised. In the final paragraph of the paper the companies are compared and the shaping in Danish and Thai companies is compared. Company A (see table 2) has developed its ISO 14001 system as part of a market strategy in order to profile the company on environmental concern. The company has decided to focus on the professional market like industrial laundries serving for example hotels and experience that environment as strategic parameter makes it possible to avoid mere price competition.
Company B (see table 3) is manufacturing textile

Table 2: The shaping of environmental management in Danish Company A

Company A	Interior textile company supplying textile service companies
Reasons and occasions for implementation	Wanted to use environment as a positioning parameter
Problems and obstacles	Not possible to set demands to cotton suppliers Problems with textile supplier about his right to use an eco-label on his own hand
Opportunities and benefits	Savings on waste, waste water, energy consumption Substitution of chemicals Key figures for impact
Resources required	Strong networking with and among suppliers
Changes in focus	Focus on eco-labelling of customerised products
Future plans	Eco-labelling as long-term market strategy
Interaction with actors	
Inside company	Independent product teams developed
NGO's and community	-
Government	-
Suppliers	Suppliers expected to build environmental competence supported by the company
Customers	Eco-labelling developed together with customer and his customer
Research, consultants etc.	-

fabrics for furniture, vehicles etc. and developed its ISO 14001 system encouraged by researchers. To day the ISO 14001 system is a prerequisite, when supplying some industrial customers. The company has experienced that it in some cases has to mediate co-operation between its own suppliers of especially chemicals and its customers. Customers' demands are then afterwards made Company B's demands to its suppliers, so that the company guarantee a certain environmental standard to its customers.
Company C (see table 4) had started its environmental activities and developed its own private eco-label as what could be called a so-called green entreprenuer before it started implementing ISO 14001. It was encouraged by a consultant to participate in a public funded project aiming at encouraging industry to implement environmental management systems.
Company D (see table 5) is selling interior textiles for the retail and the professional market. ISO 14001 was implemented, because the company saw a need for a more

systematic way of handling environmental issues. Although governmental demands to the contents of chemicals in the waste water was one of the starting points for the environmental activities in the company it is nowadays more proactive and have taken initiatives, which go further than the governmental regulation. It has obtained an eco-label on one of its product lines in order to make the environmental initiatives more visible.

Table 3: The shaping of environmental management in Danish Company B

Company B	Interior textile manufacturer for other industries
Reasons and occasions for implementation	Encouraged by researchers to participate in project
Problems and obstacles	Impossible to quantify LCA on products due to lack of data
Opportunities and benefits	Savings on waste, waste water, energy consumption Substitution of chemicals Key figures for impact
Resources required	Co-ordinator for environment and quality Knowledge about environment in the whole organisation
Changes in focus	Focus changed to product chain dialogue
Future plans	Promoting eco-labelling more towards customers

Interaction with actors	
Inside company	Employee participation as part of initial implementation
NGO's and community	-
Government	Support to research project Dialogue about focus
Suppliers	Demands to environmental impact of chemicals used
Customers	Advice them on handling of products and waste Use environment as part of sales work
Research, consultants etc.	Co-operation with researchers during implementation

IS0 14001 IN THE THAI SECTORS

The data from the focus group interview with Thai textile and garment companies (see table 7) does not allow to analyse the development of ISO 14001in the single company. Like for the Danish case studies there seems to be different occasions and reasons for the companies to implement ISO 14001. There do not not seem to be plans for a life cycle or product orientation of the environmental management systems. However, at least one company was asked by a customer in the EU to substitute the dye stuffs so they do not contain heavy metals as part of the EU company's life cycle and/or product oriented environmental management. There do not seem to be plans for making environmental reports in the Thai companies.

Table 4: The shaping of environmental management in Danish Company C

Company C	Green clothes manufacturer
Reasons and occasions for implementation	Encouraged by consultant to participate in project Wanted to manage the environmental activities more systematically
Problems and obstacles	Not used to systematic work Consultant had too much influence on EMS strategy EMS too little flexible in the beginning
Opportunities and benefits	Goodwill as front runner Supply chain management system developed Some measures can improve as well environmental impact as
Resources required	Co-ordinator for environment and quality
Changes in focus	Focus changed to recognised labels and standards, but keeping own label
Future plans	Increasing the amount of certified organic cotton Eco-labelled products of synthetic fibres

Interaction with actors	
Inside company	Employees disappointed about low level of involvement after implementation
NGO's and community	Interest from NGO's decreased No dialogue about green account
Government	Support to implementation project Dialogue about relevant laws and orders
Suppliers	Easier to co-operate with Danish suppliers than with foreign suppliers
Customers	Increasingly implementing ISO 14001 and ask their suppliers
Research, consultants etc.	Big interest from universities

DISCUSSION AND CONCLUSIONS

The discussion focuses on similarities and differences in the social shaping of ISO 14001 in the textile and garment sectors in Denmark and Thailand. Some of *the reasons and occasions for implementing ISO 14001* are the same in the two countries: top management policy and government support. A difference is seen with respect to the role of customer requirement, which is mentioned as one of the reasons for implementation in Thailand, but not in any of the Danish companies (neither in the case studies or in other

Table 5: The shaping of environmental management in Danish Company D

Company D	Interior textile manufacturer
Reasons and occasions for implementation	Wanted to manage the environmental activities internally
Problems and obstacles	Not possible to get information on all chemicals from suppliers
Opportunities and benefits	Savings on waste, waste water, energy consumption Substitution of chemicals
Resources required	Co-ordinator for environment and quality
Changes in focus	Product as new focus Eco-label obtaained to make efforts visible Transportation energy as new focus
Future plans	Setting demands to fabric suppliers' environmental performance
Interaction with actors	
Inside company	Internal co-operation with designers
NGO's and community	-
Government	Setting demand to chemicals in waste water Funding projects
Suppliers	Co-operation about testing of 'greener' chemicals
Customers	Dialogue about substitution of PVC
Research, consultants etc.	Co-operation with consultants in several projects

Danish companies in the sectors). This shows that companies in industrialised countries might not only set concrete demands for the environmental performance of the suppliers in developing and newly industrialised countries, but may also demand a systematic approach by demanding implementation of ISO 14001. Although customer requirement was not an initiator for implementation of ISO 14001 in the Danish companies some of them mention that they increasingly get questionnaires from industrial customers asking about environmental management. There seems also to be a difference with respct to *the role of the employees* in the implementation of ISO 14001 in the two countries. Where the Thai companies talks about creating environmental awareness in the company two of the Danish case studies describe an active role of sales persons and of combined teams of designers, purchasers and sales persons within environmental management. In one of the Danish companies the employees were disappointed, when the environmental manager said there was not need for the same level of participation of the employees any longer. This case

Table 7: The shaping of environmental management in 9 Thai companies

9 Thai companies	Details not known
Reasons and occasions for implementation	Customer requirement Corporate image Top management policy Government support
Problems and obstacles	Lack of knowledge Understaffed Lack of expert Internal coordination difficult
Opportunities and benefits	Cost reductions through waste reduction and energy savings Improved OHS Benefit to community
Resources required	Budget for investment in waste treatment Environmental awareness Responsible department
Changes in focus	-
Future plans	No plans about environmental report/account and LCA
Interaction with actors	
Inside company	-
NGO's and community	Exchange of knowledge on EMS
Government	Dialogue about interpretation of regulation Government support
Suppliers	Dialogue with some chemical suppliers Some suppliers asked to implement EMS
Customers	Some EU customers demand dyes without heavy metals
Research, consultants etc.	Co-operation about education and training

shows the problem with a system, which is so integrated in the daily practice that it no longer need to be reflected in the daily work. There seems to be some similarities in *the role of government* during the implementation of ISO 14001 with a dialogue between the company and the government about the interpretation of the governmental regulation, which can have an impact on the focus of the ISO 14001 system. There seem to be a difference with respect to *the role of consultants*. While lack of expert is mentioned as one of the obstacles experienced by Thai companies, two of the Danish companies mention a too dominating role of consultants in the implementation of ISO 14001. This has implied implementation of ISO 14001 systems that caused trouble afterwards in re-designing and for example make them more flexible by not mentioning names on processes, chemicals etc. in the procedures in order to prevent changes has to be made very often. It seems to be important to find the right balance between consultant support , where the company gets access to experience from other companies, and competence development inside the company itself. Where *the focus of the ISO 14001 systems* in the Thai companies seem to be on the company's own environmental impact several of the Danish companies has moved towards environmental management, where focus also is on the life cycle, including the role of transporation and of the suppliers, alhough a quantitative LCA is not possible. The life cycle focus is partly a result of the focus on Product Oriented Environmental Policy (POEP) in Europe, where focus also is on the environmental impact of the product during use and waste handling. Heavy metals in textile dyes make the product contain heavy metals, which is a problem during use, wash and waste handling. Since more and more of the manufacturing in countries like Denmark is closed and garments in stead manufactured in other countries a product focus implies demands have to be set to the suppliers in developing countries. Since most of the knowledge about the content and the development of the chemicals lie with the chemical suppliers a demand to a manufacturing supplier in a developinmg country implies a demand to the chemical supplier. There seems to be some difference with respect to *the relationship to the chemical suppliers*. Two of the Danish case studies describe a kind of development oriented co-operation with the chemical suppliers, whereas the Thai focus group interview mainly says that the chemical suppliers have the necessary knowledge. The Danish case studies show customers also have to be involved, when substitution of chemicals are planned, in order to ensure the quality of the changed product. However, also some of the Danish companies have problems obtaining information and alternative chemicals from the chemical suppliers. One of the Danish cases show that *a combined focus on ISO 14001 covering industrialised, developing and newly industrialised countries* is possible, but might need to be negotiated with respect to the distribution of the benefits. Company A asked a supplier to obtain an eco-label on some products, but would not allow the supplier afterwards to use the eco-label, where he wanted, since that could move customers away from Company A. A compromise was reached, where the supplier was allowed to sell the eco-labelled products at markets, where Company A did not have market interests.

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2 Environmental Technology

Simultaneous Removal of Organic Carbon, Nitrogen, and Phosphorus from a Domestic Wastewater Using an Anaerobic Sequencing Batch Reactor

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ABSTRACT: This research demonstrated the feasibility of using anaerobic sequencing batch reactors (An A^2/O^2 SBR) to achieve simultaneous removal of organic carbon, nitrogen, and phosphorus from a domestic wastewater. The effects of influent carbon to nitrogen (C/N) ratio, solids retention time (SRT), and maximum system loading capacity on process performance were investigated. It was found that a minimum influent chemical oxygen demand (COD) concentration of 300 mg/L and a corresponding COD to total Kjeldahl nitrogen (COD/TKN) ratio of 7 were required in order to obtain a satisfactory (over 90%) phosphorus removal level. Since the wastewater used was deficient in carbon, addition of glucose as an external carbon source was necessary to maintain the above influent COD/TKN ratio. Furthermore, the percent total phosphorus (TP) removal can be correlated either to the influent COD concentration or to the COD/TKN ratio in a quantitative manner using polynomial expressions. An increase in SRT from 20 to 30 days did not affect COD performance; however, it improved remarkably both TKN and TP removal efficiencies. On the other hand, an increase in the organic loading rate to a value of 0.63-0.66 kg COD/m^3-d or higher appeared to reduce significantly the ability of the system regarding the phosphorus removal, and to a lesser extent the nitrogen removal efficiency.

Keywords: anaerobic sequencing batch reactor, carbon and nutrient removal, solids retention time, maximum loading capacity.

INTRODUCTION AND BACKGROUND

Increasing population growth coupled with industrial and economic development have become the foremost causes of water pollution worldwide. Eutrophication is a form of water pollution that is mainly associated with the unconrolled discharge of nutrients (nitrogen and phosphorus) to receiving waters. The effects of eutrophication can be more serious and far-reaching than simply an increase in aquatic plant growth and may extend from stress or loss of aquatic life to interference with water supply treatment systems. Since conventional municipal wastewater treatment does not remove phosphorus and nitrogen adequately, in order to minimize the eutrophication potential it is necessary to introduce biological nutrient removal (BNR) processes prior to discharging to water bodies (Metcalf and Eddy, 1991).

A BNR process may be incorporated into any standard activated sludge treatment scheme since it typically consists of a sequence of anaerobic, anoxic, and aerobic zones. Various modifications have been proposed and applied, including the anaerobic/anoxic/aerobic (A^2/O), the five-stage Bardenpho, the University of Cape Town (UCT), and the Virginia Initiative Plan (VIP) processes (Martin, 1991). However, the above mentioned processes are characterized by significant land requirements and operational complexity. The sequencing batch reactor (SBR) system can serve as an attractive alternative solution, particularly when land availability as well as flexibility and simplicity of operation are of concern (Li, 1988; Torrijos *et al.,* 2001). SBR technology has been traditionally employed in the biodegradation of organic compounds from municipal and industrial wastewaters (Mangat and Elefsiniotis, 1999; Dockhorn *et al.,* 2001; Chin *et al.,* 2002). Although in recent years SBRs have been applied either in nitrogen or phosphorus biotransformation processes, limited data are available on SBR use in simultaneous nitrogen and phosphorus removal from wastewaters (Morling, 2001; Raper and Green, 2001).

This study introduces the concept of a five-stage anaerobic /anoxic /oxic reactor operating in a BNR mode. The modified sequence, involving a series of anaerobic/ anoxic/ oxic/ anoxic/ oxic cycles respectively, has been defined as "AnA^2/O^2". The "An" term refers to the anaerobic nature of the process (since the system is sealed to prevent any air entrapment), while the A^2/O^2 term refers to the alternating anoxic/oxic stages. It has been observed that organic carbon, nitrogen, and phosphorus removal are possible in a single tank, if the operating environment is properly modified to incorporate anaerobic, anoxic, and aerobic conditions into a time cycle (Arora *et al.,* 1985; Fongsatitkul *et al.,* 1997). However, further investigation is needed to identify the optimal operating conditions that are required to achieve simultaneous removal of all targeted compounds.

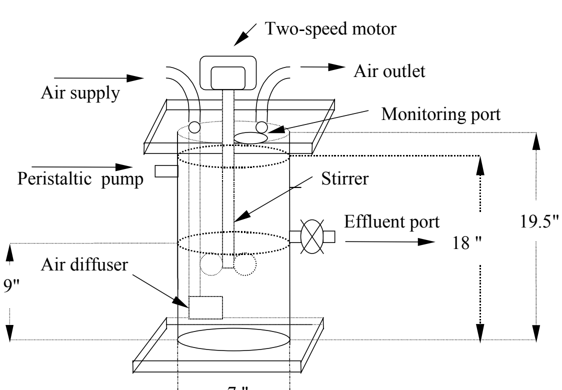
The overall objective of this research was to investigate the feasibility and effectiveness of an anaerobic sequencing batch reactor (AnA^2/O^2 SBR) in the simultaneous removal of organic carbon, nitrogen, and phosphorus from a domestic wastewater. In order to meet the above objective, a 24-month bench-scale research program was carried out. The findings from this program can be summarized in 3 distinct parts: (1) concept development, feasibility and optimal operating condition; (2) process optimization and maximum system loading capacity; and (3) system recovery using a step-loading reduction approach, and development of design criteria. The results from the first part have been published elsewhere (Fongsatitkul *et al.,* 1998). This paper explores issues related to process optimization regarding the influent carbon to nitrogen (C/N) ratio and solids retention time (SRT), as well as the maximum loading capacity with respect to chemical oxygen demand (COD) loading.

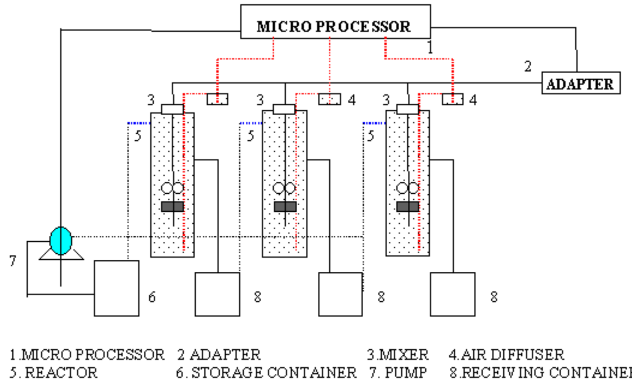
MATERIALS AND METHODS

The laboratory-scale experiment conducted involved the use of 3 identical SBR systems, operating in a parallel mode. The reactors were made of plastic (acrylic) material and had an internal diameter of 7 in (17.8 cm) and a height of 19.5 in (49.5 cm). The operating liquid volume was 10 L, while 5 L were wasted at the end of each operating cycle. Each reactor was equipped with a cover plate, a rubber stopper, an air diffuser and a stirrer. Other accessories included feeding pumps, influent and effluent containers, valves, air compressors, and microprocessor time controllers. A schematic representation of the SBRs employed in this study is depicted in Figure 1.

Figure 1: Schematic drawing of the SBR system

The reactors were initially seeded with sludge obtained from the Sri-Phraya Domestic Wastewater Treatment Plant, located in Bangkok, Thailand. In order to allow the biomass to get acclimatized, a step-by-step feeding approach was followed. That is, starting with a liquid volume of 5 L, the system was allowed to achieve at least 80% COD removal under a reasonably stable operation (i.e., no more than 5 to 10%





fluctuation in COD removal values), before a further increase in volume by 1 L was introduced. This process was repeated until the full operating liquid volume of 10 L was achieved.

The 24-hour cycle of SBR operation was consisted of the following: 5 hours filling, 5 hours operating on the first anoxic time, 3 hours on the first oxic time, 5 hours on the second anoxic time, 3 hours on the second oxic time, 1.5 hours settling, 0.5 hour drawing and 1 hour idle time. The air supply during the oxic periods was adjusted to maintain a minimum dissolved oxygen concentration of 2 mg/L. During the SRT optimization study, each reactor was operated at a different SRT; namely 20, 25, and 30 days, respectively. The reactors were fed with raw domestic wastewater collected from the same treatment facility mentioned previously.

The average COD, total Kjeldahl nitrogen (TKN), and total phosphorus (TP) concentrations of the raw domestic wastewater were 241, 53.5, and 8.2 mg/L, respectively. However, since the wastewater was found to be deficient regarding the carbon content (as discussed later), glucose was added as an external carbon source in a step-by-step fashion, until the COD in the feed reached a value of 543 mg/L. Furthermore, in order to determine the maximum system loading capacity at a 30-day SRT, the volumetric loading rates were increased gradually in a step-by-step fashion from 0.17-0.20 to 0.73-0.79 kg COD/m^3-d, until the system was overloaded. Each loading rate was maintained until a reasonably stable operation was reached, (i.e., exhibiting over 80% COD removal with no more 10% variation). This was usually achieved within 2 to 3 system HRTs.

Throughout this study, influent and effluent samples were collected twice a week and analyzed for COD, TKN, and TP. In addition, the influent flow rate, mixed liquor suspended solids (MLSS), and dissolved oxygen (DO) were measured daily. All analytical determinations were performed in accordance with the Standard Methods (A.P.H.A., 1995). Details for all analytical procedures followed can be found elsewhere (Srisawas, 1997; Karcharnubarn, 1998).

RESULTS AND DISCUSSION

Influent C/N Ratio and SRT Optimization

In order to explore the potential of the AnA^2/O^2SBR process in removing the pollutants effectively, all 3 reactors were initially operated at an SRT of 20 days. During the acclimatization period when a step-feeding procedure was followed, the average COD, TKN, and TP removal efficiencies were 93.2, 96.8, and 18.8 % respectively. Although all reactors, under reasonably stable conditions, achieved a high COD and TKN removal from the early stages of their operation (i.e., within 2 to 3 HRTs), the corresponding TP removal was significantly lower. This may be due to insufficient organic carbon available for the growth of phosphorus removing (Bio-P) microorganisms (Srisawas, 1997). It was therefore decided to increase the amount of influent organic carbon available by adding glucose as an external source in a step-by-step mode. The percent COD, TKN, and TP removal efficiencies for the first 30 days after the addition of glucose are depicted in Figure 2. It is obvious that TP removal improved dramatically (from less than 20% to over 50%) within about a week after glucose addition, while it exceeded the 80% level approximately one additional week later and, afterwards, it remained consistently high. At the same time, both COD and TKN removal efficiencies were always at high levels.

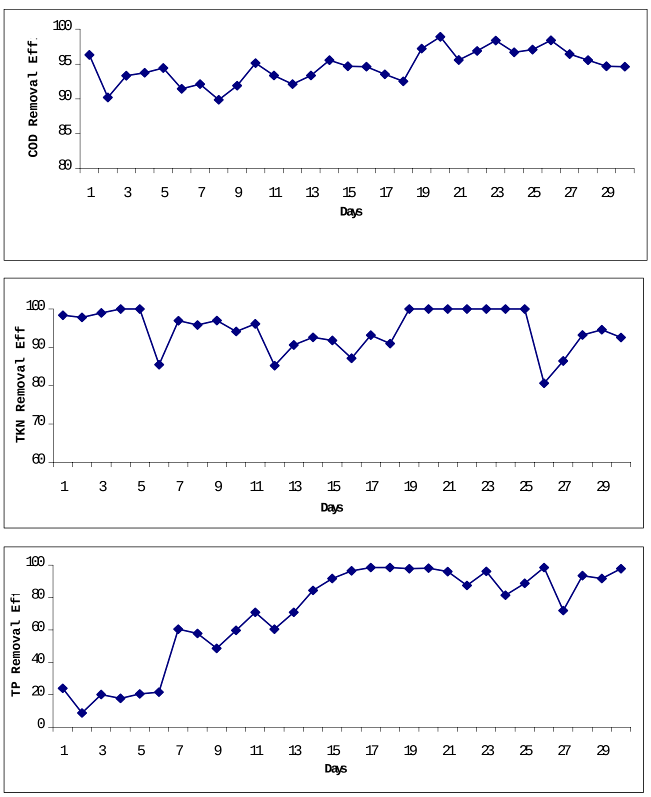


Figure 2: Percent COD, TKN, and TP removal efficiencies

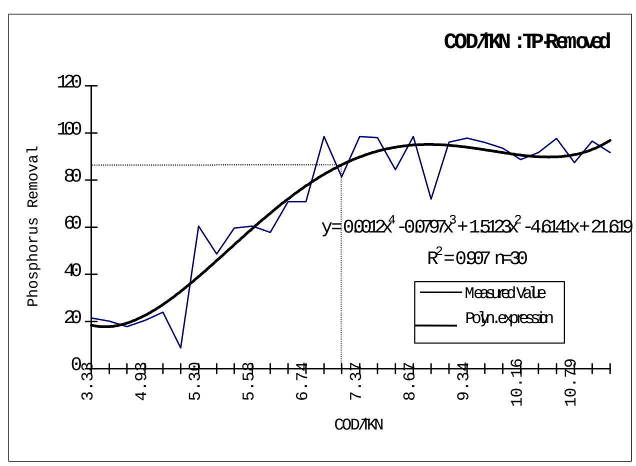
It was also observed that the TP removal efficiency could be correlated to the influent COD concentration as well as the COD/TKN ratio. Using appropriate regression analysis techniques, the following quantitative (polynomial) relationships were developed relating the influent COD concentration and the COD/TKN ratio to TP removal efficiency, respectively:

$$Y_1 = 0.0032\,X_1^3 - 0.2839\,X_1^2 + 8.7867\,X_1 + 0.6756 \quad (1)$$
$$(r^2 = 0.729,\ n = 30)$$

$$Y_2 = 0.0012\,X_2^4 - 0.0797\,X_2^3 + 1.5123\,X_2^2 - 4.6141\,X_2 + 21.619 \quad (2)$$
$$(r^2 = 0.907,\ n = 30)$$

Where: X_1 = influent COD (mg/L)
X_2 = COD/TKN ratio
Y_1 or Y_2 = TP removal efficiency (%)

The above quantitative relationships have been illustrated in Figure 3. It can be seen, for example, that at an influent COD concentration of 300 mg/L and a corresponding COD/TKN ratio of 7.2, an average of 85 % TP removal can be obtained. The effect of COD/TKN ratio on BNR processes has also been addressed in several previous studies. For instance, Manning and Irvine (1995) have reported that phosphorus removal was limited when the influent COD/TKN ratio was lower than 7.5. Barnard (1983) has pointed out that the COD/TKN ratio was the most important factor affecting both nitrogen and phosphorus removal efficiencies. Although he found that a COD/TKN ratio higher than 10 was required to stimulate phosphorus removal, the ratio had no effect on nitrogen removal. On the other hand, other researchers have suggested that a COD/TKN ratio of over 12 is required to support adequately the denitrification process (Barker and Dold, 1996; Wentzel and Ekama, 1997). Overall, the observations from this study regarding the COD/TKN ratio are in accordance with those presented in the cited literature.



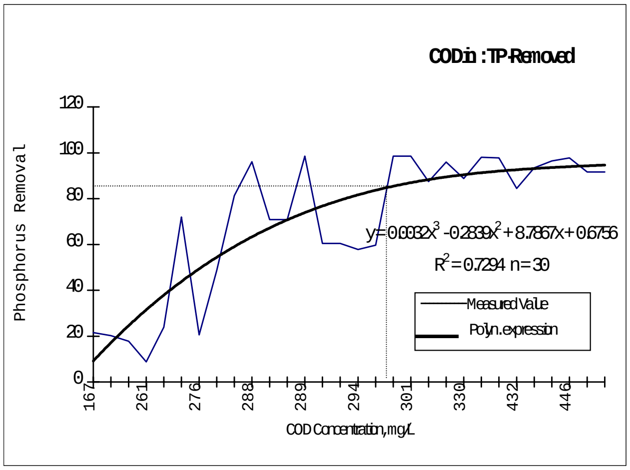


Figure 3: Phosphorus removal efficiency as a function of influent COD concentration and COD/TKN ratio

In order to investigate the effect of SRT on the process, 3 different system SRTs were applied, namely 20, 25 and 30 days using the 24-hour operating cycle described previously. Data shown in Figure 4 clearly indicate that although an increase in SRT did not seem to affect the COD removal behavior, it did result however in a considerable improvement in both TKN and TP performance. The reactor operated at a 30-day SRT exhibited average COD, TKN and TP removals of 95, 91 and 94 %, respectively.

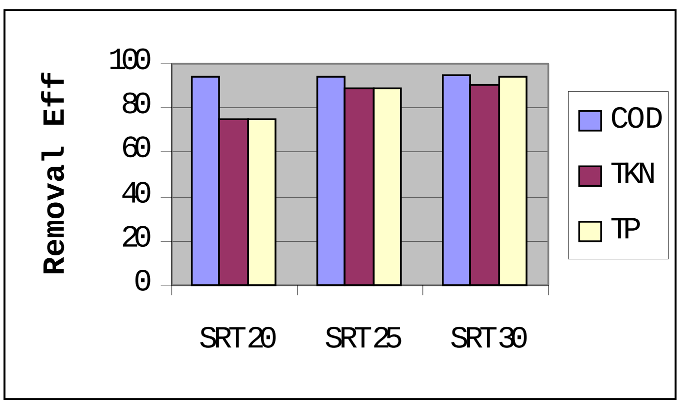
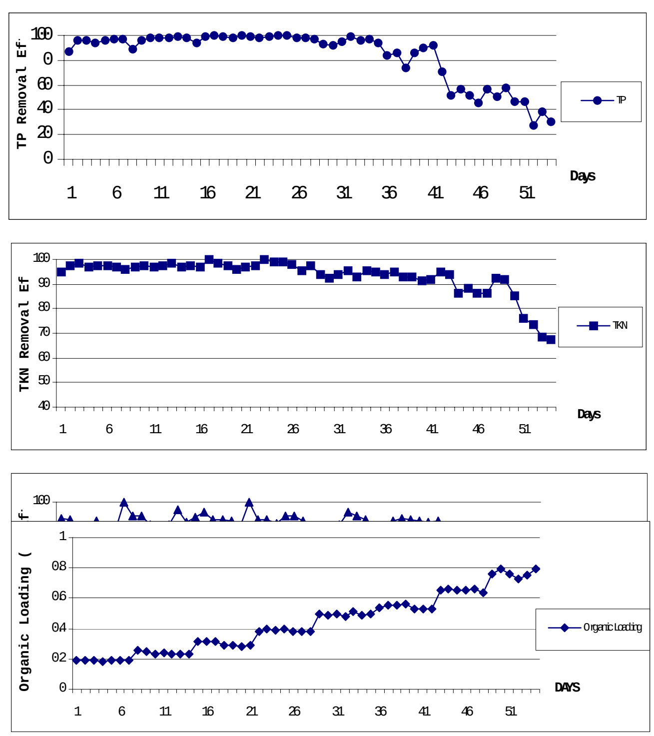


Figure 4: COD, TKN and TP removal efficiencies as a function of SRT

It can therefore be concluded that the effectiveness of the AnA^2/O^2 SBR process to remove organic carbon, nitrogen, and phosphorus simultaneously from the domestic wastewater is depended upon the following: (1) an influent COD concentration of over 300 mg/L; (2) a COD/TKN ratio of over 7; and (3) a system SRT of 30 days.

Maximum System Loading Capacity

The AnA^2/O^2SBR system was designed and operated to provide the optimal conditions to stimulate the growth of an effective consortium of bacteria to stabilize organic matter and nutrients (nitrogen and phosphorus) simultaneously. However, if the system is being constantly overloaded from an organic matter point of view, process failure may occur. As shown in Figure 5, the system operated at a 30-day SRT was loaded in a step-by-step mode starting from 0.17-0.20 kg COD/m^3-d until it reached the maximum loading rate of 0.73-0.79 kg COD/m^3-d. As the loading rate kept increasing, the TP removal efficiency appeard to be the first performance parameter to be affected. A sharp drop in TP removal from over 90 % to below the 60 % level was observed when the rate was increased to 0.63-0.66 kg COD/m^3-d, while the corresponding average COD and TKN removal efficiencies were slighly affected being 95.3 and 88.9 %, respectively. At the maximum a loading rate of 0.73-0.79 kg COD/m^3-d the average removal efficiencies obtained for COD, TKN, and TP were 93.3, 77.2, and 43.4%, respectively. This was considered to be a treatment system "failure" (i.e., exhibiting an average removal efficiency below the 50 % level for any given performance parameter). Since the percent TP removal was siginficantly lower than the corresponding COD and TKN removal percentages, it appears that the performance of the Bio-P bacteria is more drasticaly affected at high organic loading conditions than the performance of the microbial groups involved in carbon or nitrogen biotransformation processes.



TKN, and TP removal efficiencies

When the organic loading in the influent of any biological treatment process increases, it will eventually overload the system. Thus, it is important to monitor: (1) whether the system is close to the critical (or "failure" as defined above) point; (2) what operational tools are available; and (3) what changes in perfomance parameters actually occur under stressed conditions. In general, feed stoppage and influent loading reduction are recommended as short-term actions. In this 24-month bench-scale research program, the step loading reduction proved to be a practical and effective approach to recovery; however, further details will be provided in a follow-up publication.

CONCLUSIONS

The AnA^2/O^2 SBR process was successfully employed in the simultaneous removal of organic carbon, nitrogen, and phosphorus from a domestic wastewater. Overall, the C/N ratio in the influent was found to be a critical factor in achieving satisfactory TP removal. Since the wastewater used was deficient in organic carbon, glucose was added as an external carbon source. Results indicated that an influent COD concentration of at least 300 mg/L with a corresponding COD/TKN ratio of 7 were required in order to obtain a minimum 90 % TP removal efficiency. Furthermore, the relationship between the influent COD concentration or the COD/TKN ratio and TP removal efficiency can be expressed in the form of quantitative (polynomial) equations. It was also observed that a 30-day SRT resulted in the highest removal efficiencies for all parameters involved, within the SRT range investigated. Finally, an increase in the maximum loading rate affected much more drastically the TP removal efficiency than the corresponding COD or TKN percentage values.

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Co-composting Of Rice Straw And Hospital Sewage Sludge In Windrow-Type Composting

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ABSTRACT: The objective of this research work was to evaluate the feasibility on co-composting of rice straw and hospital sewage sludge in the windrow-type composting. The effects of carbon-nitrogen ratio (C/N) and moisture content were studied. The experiments were designed by varying the initial C/N ratio and moisture content in the range of 25 to 45 and 30% to 70% by w/w., respectively. Composted materials from all treatments were sampled every week and further analyzed for chemical properties. All experiments were carried out in plastic bins in which air was continuously supplied and the room temperature was controlled at 30 ^{0}C. The experiments clearly show that the pH and the volatile solid content of composted materials increased with increasing moisture content whereas their tendency decreased with increasing composting period. In addition, the change of C/N ratio of composted materials decreased at the initial C/N ratio of 25. The organic carbon evolution shows higher losses and higher values of biodegradability in mixture with lower amounts of sludge. The losses of Kjeldahl-N increased when the amounts of sludge in the mixtures increased. The highest C decompostion of 49.12% occurred in the vessel at a C/N ratio of 35 and 60 % of moisture content which coincided with the higher-nitrogen content in this treatment. All treatments with different C/N ratios and moisture content reached maturation at 63 days by the following indicator parameters: the total organic carbon, NH_4^+-N,and C/N ratio. Moreover, the C/N ratio was an important factor for biosolids composting. However, its effect was less influential than moisture content. Particularly, the enhancement of composting activities induced by C/N ratio decrement could be realized by increasing moisture content.

Keywords:

Co-composting, rice straw, hospital sewage sludge, windrow type composting, carbon-nitrogen ratio

INTRODUCTION

Composting is a natural process, which used biological process for conversion of organic matter into stable humus. Aerobic composting is the process where oxygen is essential for microbial activity. Windrow composting system which consist of rows of compost materials are turned, manually or mechanically, to improve aeration and mixing of compost constituents . Because of it high quality product of compost, aerobic composting is widely accepted for stabilizing organic matter (Liang et. al.,2002).

Sewage sludge originated from the domestic wastewater treatment process, is rich in nutrient such as nitrogen and phosphorus and contains organic matter that has valuable agronomic properties in agriculture. In Thailand, the sewage sludge is produced from 3 sources including; municipal sewage sludge, hospital wastewater treatment plants and industrial wastewater treatment plants. As sludge recycle is being more and more encouraged to be used in agriculture, a good knowledge of the agronomic value of product and an assessment of sanitary risks is proved to be necessary.

Hospital wastewater treatment plants and agricultural field in Thailand produce increasing amounts of liquid and solid wastes. The recycling of these wastes was needed to produce correct elimination. Thailand's agriculture growth rate during the past decade has been quite impressively increasing for an average rate of four percent a year (Department of agriculture Thailand, 2002). This high growth rate has been achieved largely through expansion of the cultivated land. Therefore, the higher waste from agricultural field and hospital sewage sludge has been occurred.

Composting is the most promising way to recycle organic matter from plant residues and agricultural wastes. It both reduces harmful environmental effects of waste management and results in a product, beneficial to agriculturee (USEPA, 1998). However, to promote the recycling of organic matter via composting, more research is needed to get information about the correlation between organic matter composition and the beneficial effects. And perhaps composting can be controlled in such a way to produce compost with the optimum organic matter composition.

The objective of this research work was to evaluate the feasibility on co-composting of rice straw and hospital sewage sludge in the windrow type composting.

MATERIALS AND METHODS

Twenty-five composts reactors were prepared using different ratio of rice straw and hospital sewage sludge. The composting ratios were determined by the value of carbon-nitrogen (C/N). The C/N ratios were 25, 30, 35, 40 and 45 for composting. The co-composting condition was controlled the moisture content of 30%, 40%, 50%, 60% and 70% (weight by weight) in each composting ratio. The properties of raw material used for the production of the composts materials were listed in table 1.

Table 1: The properties of raw material for co-composting.

Parameters	Hospital sewage sludge	Rice straw
Total organic carbon (% w/w)	46.70 ± 8.01	29.27 ±4.39
Total Kjdal-nitrogen(% w/w)	0.49 ±0.03	5.17 ±0.51
Amonia(% w/w)	0.00084 ±0.00015	0.475 ±0.392
Nitrate (% w/w)	0.00035 ±0.00005	0.0006 ±0.0007
C/N ratio	95.31 ± 8.01	5.18 ±1.71

Remark: 2 rapication of each run.

About 5 kg of each mixture was composted in 50 liter of a plastic bin using the windrow type composting. The reactor was supplied with air through the holes of two aluminum tubes which the air were continuously supplied and room temperature was controlled at 30 ^{0}C. The aeration rate was controlled in relation for temperature in small reactor which was 2.6 – 4.3 mg O_2/hr/g volatile solid (VS) (Eliot,1970). The composting seed was thermophilic bacteria from Chinmava Japan that have 2 x 10^8 CFU/g .The samples were taken from the middle of the reactor for analyzed compost. These samples were homogenised and reduced in size by a cutter. Part of the samples were dried and sieved in a cutting mill to particles size smaller than 1 mm. Composted materials from all treatments were sampled once a week and further analyzed the chemical properties

Analytical methods

The pH analysis of samples was done by extracting sample in water by H_2O 1: 10 weight by volume . Electrical conductivity (EC) was measured in 1:10 water extraction for compost (Bernal et.al., 1998). The total carbon of the composting samples was determined by the dicromate method, Nitrate-N, Ammonium-N and Total Kjeldhal Nitrogen was analyzed by follow Standard Method Soil Analysis 1996 (Black, 1965).

RESULTS AND DISCUSSIONS

Temperature

Temperature is a function of process which impact on microbiological community. Temperature also affects the moisture relationships, which in turn affects microbiological activity(Polprasert, 1989). The interaction between various parameters and temperature often make it difficult to separate cause and effect. Most data in experiments were indicated that the highest temperature was 50-60 ^{0}C in which moisture contents were 40%, 50%, 60% and 70% respectively. It was found that the temperatures rise initially and then leveled off. At point when microbial activity slows, temperatures begin to descend. During the composting, temperature rose but might remain below the range of 33 ^{o}C to 35 ^{o}C range at the end of composting.

Conductivity and pH

Samples obtained from the windrow systems were measured for their pH and conductivity .The results are shown in Figure 1 .The pH of composting was fluctuated within the range of 7.2 - 8.5. In this study, the pH of composting decreased to nearly 7 after 45 day of composted. It has been a general trend of pH values to decrease at the end of the composting cycle as the composts were mature. Electrical conductivity was an index of the concentration of dissolve salts in the compost. The results demonstrated that the electrical conductivity of composts has a wide variation ranging from 4950 µS/m to 1290 µS/m in the windrow system that was low hazard for crop growth (California Composting Quality Council,2002). It was observed that electrical conductivity increased with composting period . Figure 2 showed the electrical conductivity of composts when different moisture content and C/N ratio .

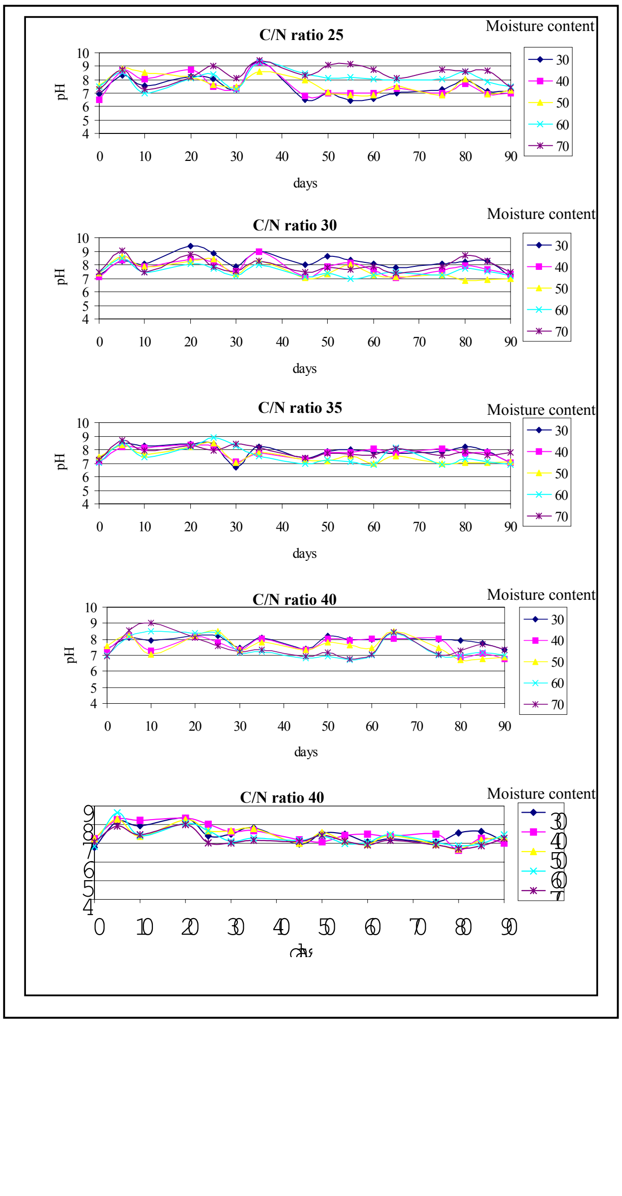

Figure 1: The relationship between pH and composting period of type composting at various C/N ratio and moisture content.

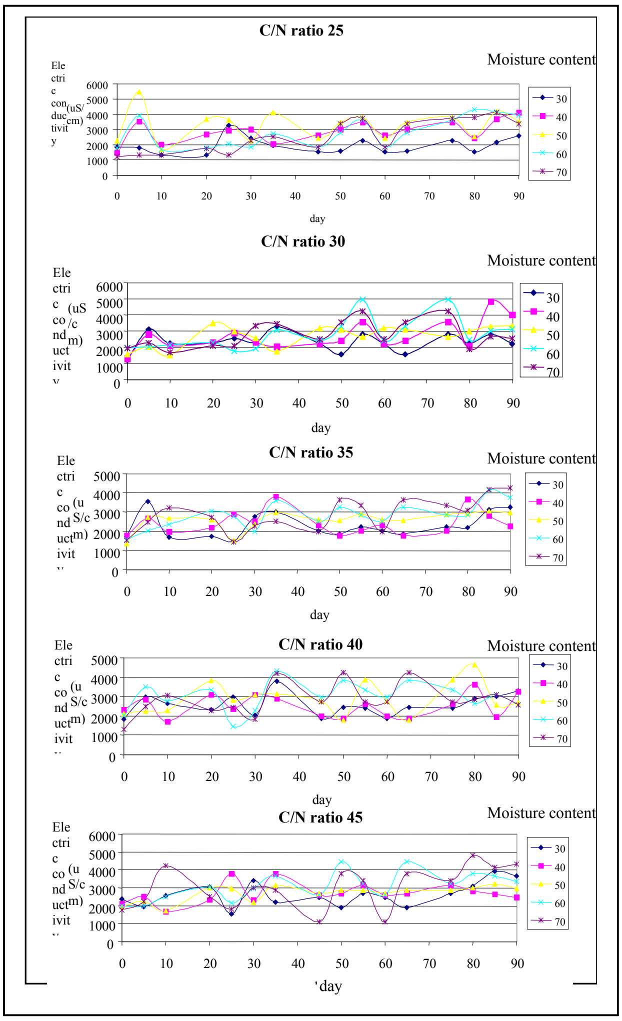

Figure 2: The relationship between electric conductivity and composting period of type composting at various C/N ratio and moisture content.

Volatile Solids (VS)

Figure 3 shows the volatile solids of type composting when moisture content and carbon/nitrogen ratio of composting were varied. It was indicated that the different moisture content caused differences in the VS reduction. However, the evolution of VS was similar for all mixtures. The VS content of composted materials increased with increasing moisture content whereas their tendency decreased with increasing composting period. At the end after 63 day ,at 70 % moisture content, the slowly decreased VS reached values of 43.32, 41.47, 39.63, 36.20 and 42.21 for carbon/nitrogen ratio of 25, 30, 35, 40 and 50 respectively.

Total Organic carbon

Carbon and Nitrogen are the parameters have been studied most during the decomposition process. One of the most interesting aspects of carbon determination was the evaluation of what fraction of total organic carbon is readily available for microorganisms(George and Frank, 2002).

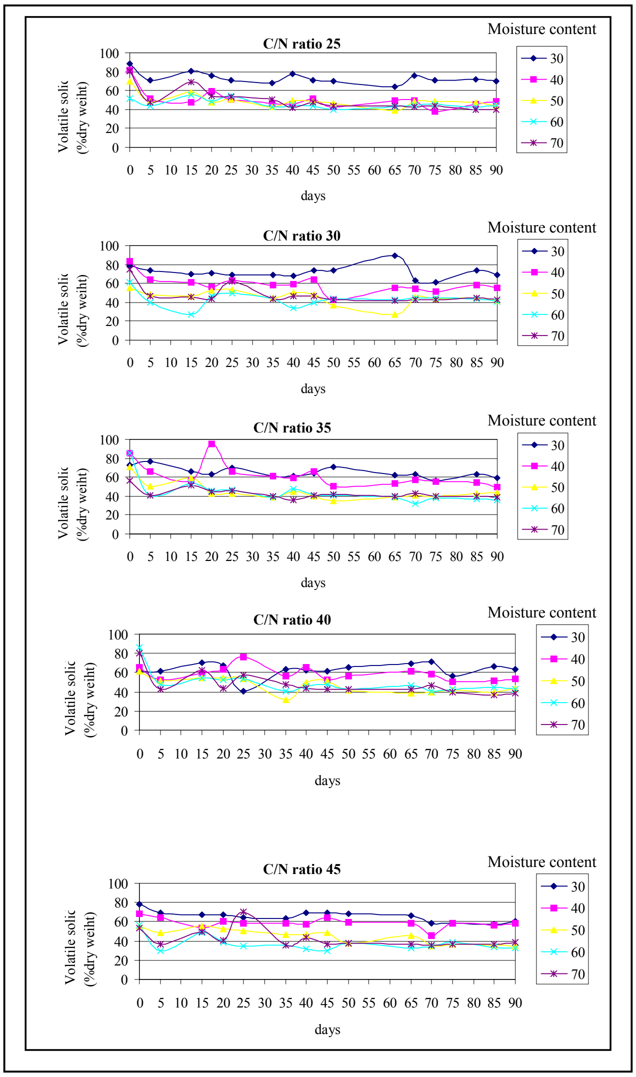

Figure 1: Percentage of...

Figure 3 : The relationship between volatile solids and composting period of type composting at various C/N ratio and moisture content.

During the composting period, the maximum carbon reduction rate of composting occurred during the third week of composting, which is caused by the presence of high concentration of easily degradable organic carbon in the compost. After the initially high reduction rate, there was a gradual decrement in all case before it became fairly constant.

The experiments clearly show that the carbon reduction of composted materials increased with increasing moisture content whereas their tendency decreased with increasing composting period. Figure 4 shows a similar trend of carbon degradation for all experiments. The carbon reduction at moisture content 70% decreased rapidly. The percent carbon reduced from 38% to 18% at 42 day for moisture content of 60% and C/N of 25. The highest C decompostion of 49.12% occurred in the vessel at a C/N ratio 35 and 60 % of moisture content, which coincided with the higher-nitrogen content in this treatment.

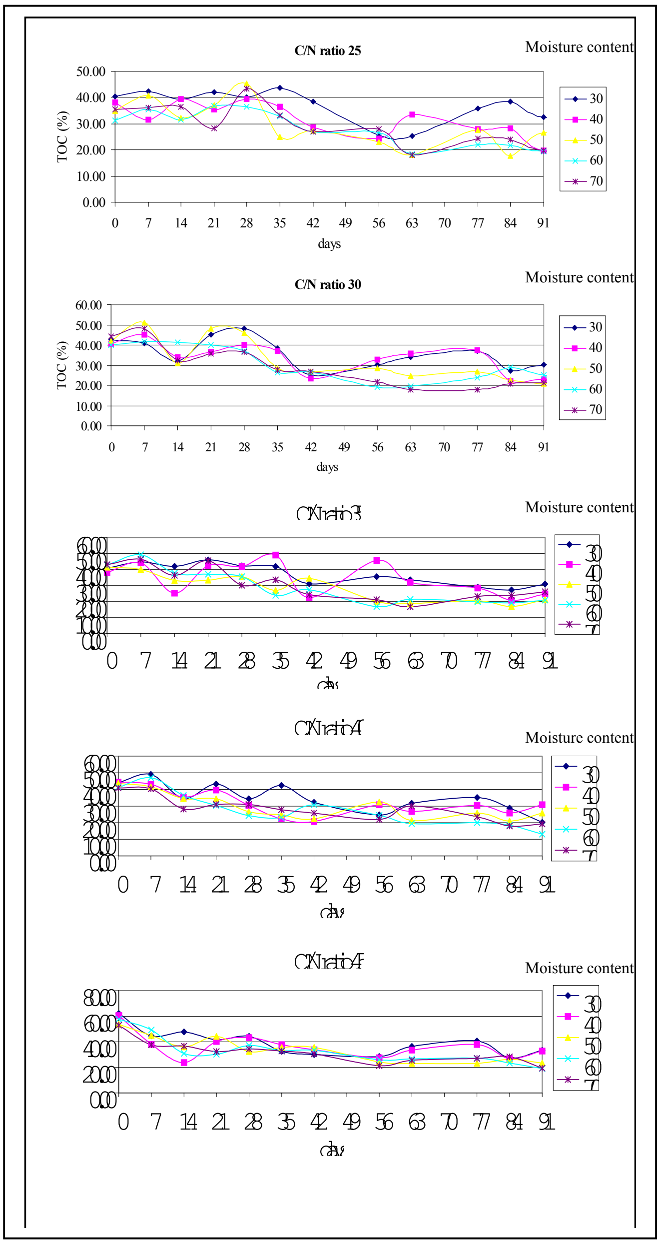

Figure 4: The relationship between total organic carbon and composting period of type composting at various C/N ratio and moisture content.

Changes of Kjeldahl-N content and C/ N ratio

The effect of raw material quality, was expressed by the C/N ratio of the compost. The results of this study were expressed in table 2.The larger decrease in C/N ratio was observed in the compost with the initial C/N ratio of 35 after 63 days of composting . This may imply that the optimum C/N ratio for the raw waste material is 35. Consequently, initial values of C/N in the mixtures decreased from C/N of 35 (Kjeldahl-N 1.19 %) to 8.02 (Kjeldahl-N 2.04%) after 63 days of composting. The initial values of Kjeldahl-N were significantly greater in the mixtures with higher amounts of sludge , due to the relatively high nitrogen content of the

Table 2 The Kjeldahl-N content rend C/ N ratio of compostig changes durig composting period.

C/N ratio : moisture content	25:30	25:40	25:50	25:60	25:70	30:30	30:40	30:50	30:60	30:70	35:30	35:40	35:50	35:60	35:70	40:30	40:40	40:50	40:60	40:70	45:30	45:40	45:50	45:60	45:70
Composting time (days)	Total Kjeldahl-nitrogen (% w/w)																								
0	1.52	1.34	1.31	1.35	1.42	1.32	1.27	1.30	1.26	1.53	1.10	1.06	1.18	1.24	1.19	1.10	1.13	1.13	1.06	1.03	1.35	1.31	1.13	1.28	1.15
7	1.55	1.38	1.56	1.53	1.53	1.56	1.35	1.32	1.22	1.44	1.30	1.10	1.12	1.28	1.21	1.21	1.14	1.10	1.33	1.03	1.13	1.06	0.95	0.99	1.07
35	1.15	1.62	1.88	2.04	1.92	1.44	1.09	0.91	2.43	1.96	1.03	1.19	1.68	2.12	1.80	1.72	1.62	1.68	1.80	2.03	1.40	1.79	1.86	2.12	1.83
63	1.36	2.17	1.90	1.60	2.00	1.95	2.06	1.62	2.11	1.94	1.75	1.57	2.03	1.88	2.04	1.25	1.86	2.06	2.00	2.20	1.38	2.01	1.98	1.98	2.61
91	1.20	2.19	2.28	1.90	2.78	1.89	1.86	2.10	2.37	2.28	1.21	1.80	2.17	2.09	2.12	1.46	2.13	2.08	2.59	2.64	1.72	2.33	1.98	2.26	2.37
	C/N ratio																								
0	26.60	28.57	26.64	23.09	25.03	32.43	31.96	32.49	31.95	28.92	37.10	36.14	35.16	34.53	36.34	39.99	39.45	38.54	38.81	39.74	45.97	46.10	47.41	45.05	46.07
7	27.39	22.91	26.16	23.16	23.65	26.24	33.39	38.92	34.30	33.25	34.45	40.08	35.81	38.42	38.52	40.50	37.91	37.70	35.45	39.29	39.39	35.78	47.20	49.96	35.27
35	38.09	22.52	13.20	16.24	17.29	26.63	34.00	31.59	10.88	14.23	40.56	41.20	16.05	11.28	18.68	24.63	13.79	14.65	12.79	13.69	23.24	21.09	19.05	15.60	17.85
63	18.58	15.49	9.50	11.52	9.08	17.44	17.32	15.25	9.23	9.20	19.15	20.51	9.24	11.35	8.20	25.39	14.40	10.32	9.69	13.62	26.44	16.67	11.64	13.39	9.79
91	27.13	9.06	11.71	10.19	7.10	15.95	12.37	10.03	10.65	9.29	25.63	13.81	9.82	10.03	12.36	13.87	14.44	12.37	5.03	7.30	19.36	14.09	11.78	8.45	8.19

composts. The N losses could be due to conversion of organic N to NH_4^+-N via the ammonification process. The NH_4^+-N content decreased after 35 days of composting**.** The decreasing trend to guaranteed that ammonification was ending and could be used as a criterion of compost maturity. The decrement in NH_4^+-N did not correspond to an increment in NO_3^-- N. This result also suggested that N was lost during composting. Most of the NH_4^+-N was lost through NH_3 volatilization due to the temperature that more than 55 ^{0}C and the high pH values more than 7 (Sanchez,2000).

Process kinetic

The operation parameter of composting after reaching compost maturity, was indicated by a C/N ratio of composting that less than 20, ammonia nitrogen/ nitrate nitrogen ratio of composting less than 0.05, constant temperature (± 5 ^{o}C) and effluent TOC concentration (± 5%). Form figure 3 and 4, the correlative degradation of composting as a function of time follows the first-order kinetics that can be expressed as:

$$\frac{dC}{dt} = - kC$$

where *C* is the quantity of biodegradable volatile solids at any time in kg, *t* is the time in days, *k* is the reaction rate constant (day $^{-1}$)(Hamoda,1998).
The efficiency of TOC reduction was related with t, C/N and moisture content , linear-regression analyses lead to the following relationships.

$$\ln TOC_{eff} = 2.810 + 3.74 \ln TOC_{inf} - 6.625\text{x}10^{-3} \ln t - 6.531\text{x}10^{-3} \ln C/N - 5.347\text{x}10^{-3} \ln \quad (1)$$

Where TOC_{eff} and TOC_{inf} are the effuent TOC and initial TOC concentration (%), respectively, M is a moisture content and t is a time (day)

Equation (1) could be rewritten as shown in Equation (2)

$$TOC_{eff} = 0.3588\ TOC_{inf}\, M^{2.384E\text{-}3}\ C/N^{\,1.952E\text{-}3}\ t^{\,2.418E\text{-}3} \quad (2)$$

The values of the correlation coefficient (R) for Equation 2 was 0.718.
It was likely that the relationships give in Equation 2 with TOC_{inf} and t terms adequately describe the co-composting. The equation experiment is able to describe the performance of co-composting of straw and hospital sewage sludge.

CONCLUSION

The experiments clearly show that the pH and the volatile solid content of composted materials increased with increasing moisture content whereas their tendency decreased with increasing composting period. It is illustrated that the moisture content and initial C/N ratio of composting material is effected to pH and the volatile solid content. During the composting period, the maximum carbon reduction rate of composting occurred during the first three weeks of composting which is caused by of the presence of high concentration of easily degradable organic carbon in the compost.
The initial values of Kjeldahl-N are significantly greater in the mixtures with higher amounts of sludge , due to the relatively high nitrogen content of the composts. In addition, the equation of total organic carbon is able to describe the performance of co-composting of rice straw and hospital sewage sludge

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A Case Study On The Treatment Of Wastewater Sludge From An Electronic Plant

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ABSTRACT: The process of manufacture and cleaning of electronic components can produce large quantities of waste, including hazardous waste, in the form of effluents, air emissions and solid waste. Direct disposal of these may cause environmental pollution, especially to surface and groundwater. Stabilization/Solidification (S/S) is a proven technology for the treatment of hazardous wastes. Selection of stabilization/solidification as a remediation technology is also supported by recent developments in the environmental regulations. This paper focused on the laboratory studies of S/S disposal of wastewater sludge from an electronic plant, which generates about 150 tonnes of wastewater sludge per year. Three types of cement with or without activated carbon (AC) were used in this research, which include, Ordinary Portland Cement (OPC), Ground Granulate Blast furnace Slag (GGBS) and Mascrete Cement (MC). The American Nuclear Society (ANS) method indicated only Fe, Al, Cu but these were below the Standard B, EQA, 1974 while other metals were not detected. A comparison between Toxicity Characteristics Leaching Procedure (TCLP) and Japanese Leaching Test (JLT-13) methods indicated that JLT-13 gave lower leaching. The percentage of cement and activated carbon influenced TCLP and JLT-13 results.

Keywords: Solidification/stabilization, activated carbon, OPC, GGBS, MC, ANS, TCLP, JLT-13

INTRODUCTION

Commonly encountered waste disposal scenarios include, where appropriate, incineration, physical, chemical or biological treatment, consignment to landfill and marine disposal. When wastes are consigned to landfill, problems arise often as a result of long-term release of toxic constituents into the surrounding environment due to fluid percolation through the deposit (EPA, 1996). The US generates about 260 million tonnes hazardous waste a year, while China generates 30 million tonnes and Malaysia 390,000 tonnes a year. The three major issues in hazardous waste management are lack of waste minimization and cleaner technologies, transboundary movements of hazardous waste and management of wastes from non-industrial sources (Agamuthu, 2001).

One group of technologies which aims to minimize both the release and mobility rates of such environmental pollutants is known as solidification/stabilization or S/S (Chan, 2000). In solidification the waste is incorporated into a monolithic solid with a reduced surface area over which leaching can occur. Solidification process do not necessarily imply that any form of chemical reaction has occurred. The term stabilization on the other hand describes disposaltechnologies which chemically alter hazardous wastes to produce less toxic or mobile forms.

The most important factor determining weather a particular solidification/stabilization (S/S) process and its process parameters are effective in treating a particular kind of waste, is the reduction in the short-and long-term leachibility of the waste (Freeman and Harris, 1995). The leaching mechanisms involved in solidified waste are very complex. The rate of leaching from a waste can be controlled by diffusion and convection in the waste matrix and surface phenomena at the interface, such as diffusion and leachant renewal in the aqueous solution. In this paper, the S/S of wastewater sludge from an electronic plant using cement was investigated. The efficiency of solidification was tested using TCLP, ANS and JLT-13.

MATERIAL AND METHOD

Collection of samples

The wastewater sludge was obtained from Matsushita Company, in Shah Alam, Selangor.

Sample preparation

Wastewater sludge (solid) was homogenized with cement by using a blender for 3 minutes. Water was added slowly into the wastewater sludge to promote hydration. The mixture was then mixed at high speed for 3-4 minutes upon attainment of the pre-determined water: cement ratio. The resulting waste-loaded grout paste was transferred to specified moulds. The mixture was hand-compacted to yield a good compaction. The moulds were covered with Lucite sheets and left undisturbed for 24 h at room temperature

($27-34^0$C) and relative humidity 92%. The specimens were removed from the moulds and further cured for 27 days under dry condition to simulate the curing condition as normally practiced before landfilling. In the first trial, 50% cement loading (three types cement) and 50% of wastewater sludge were used. In the second set of trials, AC (10% of the waste loading) was added to the cement, which was reduced in weight correspondingly, whereas the wastewater sludge remained as before at 50%, respectively. The solidified matrices from either trial were used for TCLP, ANS 16.1 (modified) and JLT-13 leach tests.

American nuclear Society ANSI/ANS (Leach Test)

This method gives substantially more information about the rate at which hazardous constituents leach from the solidified waste. The leaching procedure used in this study is a modification of that proposed by the American nuclear Society for solidified low-level radioactive waste in standard ANSI/ANS. During the test, the solidified specimens were suspended in the leachant by using nylon fishing line. The ratio of the leachant volume and the external geometric surface area of the solid specimens was maintained at about 10 ±0.2 during the leaching interval. Ultrapure water of resistivity = 18 Mohm-cm (processed by ELGASTAT@UHQPS) was used as the leachant in this test.

The leaching of samples was monitored over a period of 28 days (sampling at the 1^{st}, 3^{rd}, 7^{th}, 14^{th} and 28^{th} days) when the specimens were removed and placed into fresh leachant at the end of each leaching interval. The pH measurement for the leachant was taken at the end of each interval. The leachate was collected into plastic bottles, acidified with nitric acid and stored in refrigerator until metal analysis was carried out. Inductively Coupled-Plasma-Atomic Emission Spectroscopy (ICP-AES) model 2000 BAIRD was used to analyze the metal concentration in the leachate.

Toxicity Characteristic Leaching Procedure (TCLP)

The TCLP protocol was performed using the solidified samples which were manually crushed to a particle size smaller than 9.5 mm. Prior to the performance of the protocol, a test was carried out to determine the appropriate extraction fluid for the extraction procedure. The extraction fluid is a buffer of acetic acid and sodium hydroxide adjusted to a pH 3.00±0.05. The leaching procedure involves mixing a single batch of material with extraction fluid at a liquid to solid ratio of 20:1. The flasks were covered with parafilm capped with aluminium foil and then mechanically shaken for 18 hours continuously at 300 rpm and at temperature of 25±2°C in an incubation shaker. At the end of the 18 hours contact time, the leachants were then filtered through a 0.8 μm pore size borosilicate glass fibre filter, to separate the solid and liquid phase. Measurement of pH of the filtrate was taken by using Hanna instrument membrane pH meter, equipped with a standard glass electrode. The filtrate was collected in 100 ml polyethylene bottles, acidified with 1 ml of nitric acid and stored in refrigerator at 4°C until metal analysis was carried out by using ICP-AES.

Japanese Leaching Test (JLT-13)

For this test, the solidified waste matrixes were crushed to particle size between 0.5-5 mm after 28 days of curing. Extraction buffer of hydrochloric acid and sodium hydroxide at pH 6.00 ± 0.05 was used at a ratio of 10:1 (buffer : solid). The buffer was added to the crushed waste matrixes in a HDPE container and mechanically shaken for 6 hours continuously at 200 rpm. After 6 hours, the leachate was filtered using 0.45μm cellulose membrane filter. pH and heavy metals in the JLT leachate were determined as before.

RESULTS AND DISCUSSION

The untreated electronic industry wastewater sludge contained Fe which was at 834 mg/l followed by Al, Sn, Mn, Cu, Zn, Ni, Pb and Ti at concentrations of 785 mg/l, 239 mg/l, 74 mg/l 30.2 mg/l 18.1 mg/l 14.9 mg/l, 10.4 mg/l and 0.832 mg/l, respectively (Table 1).

Table 1: Heavy metal content in the wastewater sludge before solidification

Element	Concentration (mg/l)	TCLP limit (mg/l)	EQA 1974 limit (mg/l)
Cu	30.2	-	1.0
Al	785	-	-
Mn	74.0	-	1.0
Sn	239	-	-
Pb	10.4	0.75	0.5
Ni	14.9	11	1.0
Zn	18.1	4.3	1.0
Ti	0.832	-	-
Fe	834	-	5.0

ANS 16.1(modified)

Leaching rate

The leaching rate, l , was calculated using

$$l = \frac{a_n V}{A_0 S}$$

where a_n is the amount of constituent of interest (metal) leached during interval n (mg), A_0 is the amount of constituent of interest initially present in the specimen (mg), V/S is the specimen volume/surface area ratio (cm) . The leaching rate of the heavy metals of concern from (OPC, MC and GGBS) cement treated samples demonstrated a descending trend as the leaching time progressed (Figures 1, 2 and 3). The leaching rate for Fe was highest at 1.627 cm/day whereas the leaching rate for other metals were low at 0.07 cm/day.

Fe showed the highest initial leaching rate (and a subsequent steep decrease in the rate), followed by Sn, Ni, Mn, Ti, Al and Pb. The leaching rate of Fe with 50% OPC loading decreased 96% from 1.627 cm/day in the first interval to 0.065 cm/day in the final interval (Figure 1), whereas the leaching rate of Fe by using 50% MC loading decreased 96.5% from 1.499 cm/day in the first interval to 0.052 cm/day in the final interval (Figure 2) while the leaching rate of Al by using 50% MC loading decreased 98% from 0.380 cm/day in the first interval to 0.006 cm/day in the final interval (Figure 2).

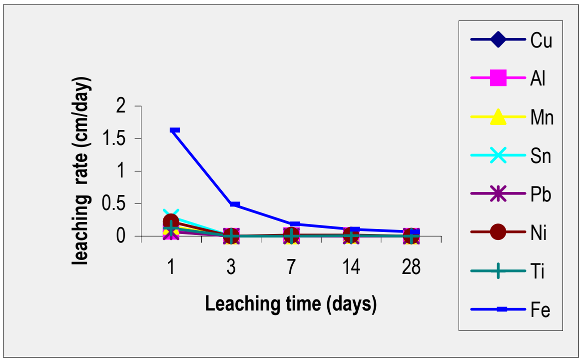

Figure 1: Leach rate of heavy metals, in OPC samples, at OPC/wastewater sludge ratio of 50:50

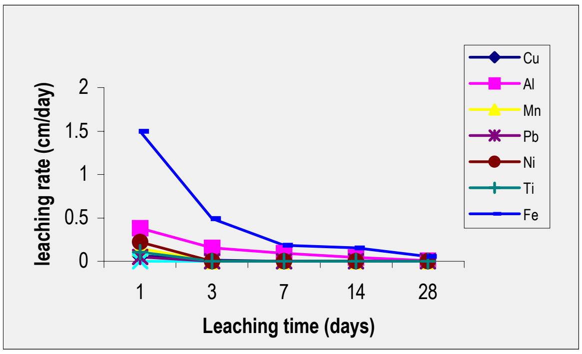

Figure 2: Leach rate of heavy metals, in MC samples, at MC/wastewater sludge ratio of 50:50

When solidified with GGBS, Fe still exhibited the highest initial leaching rate, followed by Al, Ni, Cu, Mn and Ti. The leaching rate of Fe by using 50% GGBS loading decreased 96.5% from 1.499 cm/day in the first interval to 0.052 cm/day in the final interval leaching of. Al also decreased 97.8% from 0.587 cm/day in the first interval to 0.013 cm/day in the final interval (Figure 3).

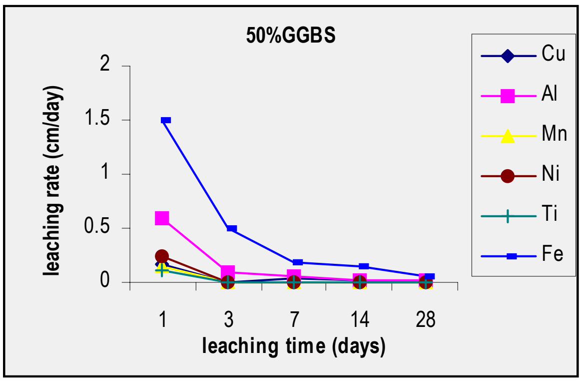

Figure 3: Leach rate of heavy metals, in GGBS samples, at GGBS/wastewater sludge ratio of 50:50

When 5% activated carbon was added to OPC, MC or GGBS, Fe still showed the highest initial leaching rate, followed by Al and Cu (Figure 4-6). The leaching rate of Fe in 45% OPC+AC loading, decreased 96.5% from 1.96 cm/day in the first interval to 0.069 cm/day in the final interval. The leaching rate of Cu, in 45% OPC+AC loading, increased 62.3% from 0.04 cm/day in the first interval to 0.106 cm/day in the third interval but Cu loading decreased 80% from 0.01 cm/day until 0.002 cm/day after the seventh interval on wards.

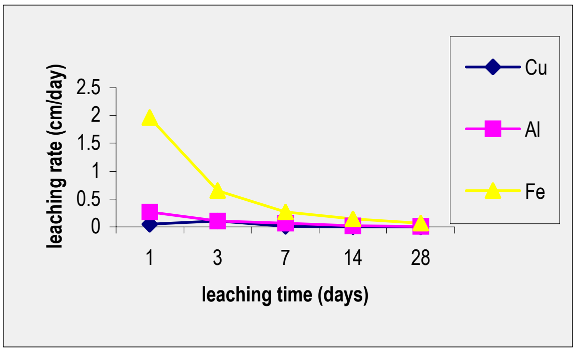

Figure 4: Leach rate of heavy metals, in OPC samples with AC additive at AC/cement/wastewater sludge ratio of 5:45:50

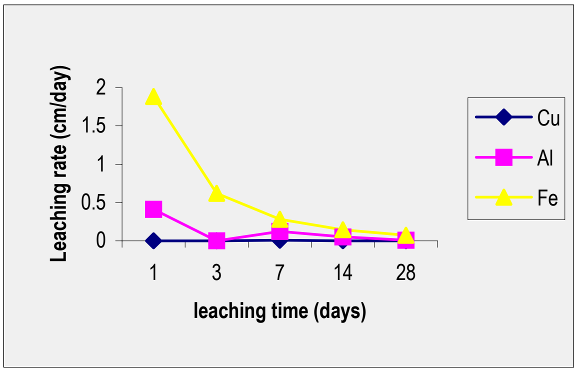

Figure 5: Leach rate of heavy metals, in MC samples with AC additive at AC/cement/wastewater sludge ratio of 5:45:50

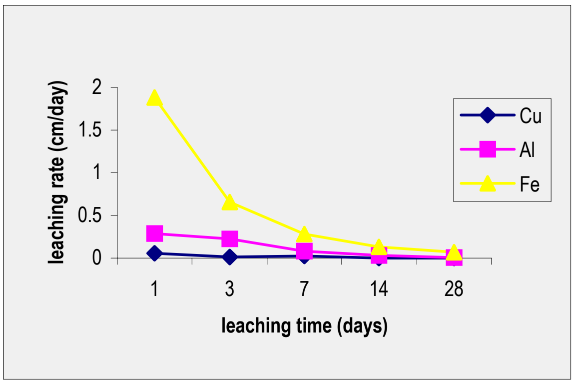

Figure 6: Leach rate of heavy metals, in GGBS samples with AC additive at AC/cement/wastewater sludge ratio of 5:45:50

The leaching rate of Fe in 45% MC+AC (Figure5) loading also, decreased 96.3% from 1.87 cm/day in the first interval to 0.07 cm/day in the final interval, while Fe when solidified with 45% GGBS+AC loading, decreased 96.8% from 1.88 cm/day in the first interval to 0.06 cm/day in the last interval (Figure 6).

Toxicity Characteristic Leaching Procedure (TCLP)

Wastewater sludge solidified with 45% OPC+5%AC stopped only Pb leaching whereas all other heavy metals leached beyond TCLP standard (Table 2). Mn was the highest metal leaching followed by Al, Fe, Zn, Cu, Ni, Sn and Ti. Fe was above the EQA standard B limit while Zn and Ni were below TCLP standard.

Table 2: TCLP results by using different types of cement

Element	45% OPC+ 5% AC	45% MC+ 5% AC	45% GGBS+ 5% AC	45% OPC+ AC	EQA standard B
Cu	3.35	2.44	4.20	-	1.0
Al	5.97	0.971	6.87	-	-
Mn	19.9	24.2	10.4	-	1.0
Sn	0.307	nd	2.32	-	-
Pb	nd	nd	0.11	0.75	0.5
Ni	2.28	3.64	1.9	11	1.0
Zn	2.50	1.81	2.3	4.3	1.0
Ti	0.132	0.116	0.142	-	-
Fe	5.92	4.51	4.87	-	5.0

Nd: not detected Unit: mg/l

When 45% MC+5% AC was used, it was found that Fe was below EQA standard B limit while Zn was above EQA standard B limit but it was still below TCLP standard. Mn was higher than EQA standard B limit. With 45% GGBS+5% AC it was found that Fe was below EQA standard B limit and Ni was above standard B but for TCLP standard Ni and Zn were below the limit.

Japanese Leaching Test (JLT-13)

In the JLT-13 leach method wastewater sludge solidified with 45% OPC+5% AC immobilized all heavy metals (Mn, Sn, Pb, Ni, Zn and Ti) except Fe, Al and Cu. Similar trend was observed with all other two types of cement (Table 3). Based on TCLP and JLT-13 results, it was found that JLT-13 gave 66.6% lower leaching rates.

Conclusion

The preliminary results obtained in this study support solidification/ stabilization as an option for electronic industry hazardous waste treatment. Based on TCLP results, wastewater sludge solidified with 45% OPC+5% AC stopped only Pb leaching whereas all other heavy metals leached beyond TCLP standard. Using 45% MC+5% AC and 45% GGBS+5% AC it was found that Fe was below EQA standard B while JLT-13 results, while 45% OPC+5% AC, immobilized all heavy metals (Mn, Sn, Pb, Ni, Zn and Ti) except Fe, Al and Cu. Similar trend was observed with the other the two types of cement. Based on ANS results it was found that GGBS performed better than MC or OPC. For TCLP and JLT-13 all the three cement types gave similar results. Based on TCLP and JLT-13 results it was found that JLT-13 gave 66.6% lower leaching rate.

Table 3: JLT-13 results for different cement types

Element	45% OPC+ 5% AC	45% MC+ 5% AC	45% GGBS+ 5% AC	JLT-13 standard
Cu	0.773	0.676	1.52	-
Al	3.39	4.49	4.52	-
Mn	nd	nd	nd	-
Sn	nd	nd	nd	-
Pb	nd	nd	nd	0.3
Ni	nd	nd	nd	-
Zn	nd	nd	nd	0.3
Ti	nd	nd	nd	-
Fe	5.87	5.86	5.86	-

Nd: not detected Unit: mg/l

Acknowledgements

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Study on The Adsorption of Copper (II) on Palm Shell Activated Carbon

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ABSTRACT

Granular activated carbon obtained from the palm shells was used to study the adsorption of copper ions. Adsorption isotherms of Cu(II) were determined at pH 3 and pH 5. The effects of the presence of complexing agents such as boric acid and malonic acid on Cu(II) ultimate uptake were also investigated. The results showed that Cu(II) can be successfully removed by palm shell activated carbon. Langmuir adsorption model was used to analyze the experimental data.
The presence of complexing agents was found to have a substantial effect on Cu(II) adsorption. Higher adsorption was obtained at pH 5 in presence of malonic acid with an ultimate uptake of 238-mg/g carbon, whereas the boric acid was found to be less effective for Cu(II) adsorption with an uptake of 225-mg/g of carbon at the same condition. However, most copper was removed at pH 5 without any complexing agents added, which comprised of 308 mg/g carbon.
At pH 3 the amount of adsorbed copper for copper and copper with added boric acid systems was almost equal, 185 mg/g carbon and 191 mg/g carbon respectively. Significant decrease was observed in adsorption of copper with malonic acid system at pH 3 – 87 mg/g carbon.

Keywords: Activated carbon, adsorption, copper ions, boric acid, malonic acid.

1.0 INTRODUCTION

High concentrations of heavy metals in the environment are extremely detrimental for the living organisms and ecosystems. Moving towards sustainable development, humankind is in a period when implementation of technologies that are safe, economically cost effective and environmentally friendly is of high priority. For the developing countries in order to combine steady economy growth and sustainability it is necessary to establish such technologies that are based on the use of “wastes” resources. This in turn would help to create a large scale recycling mechanism where utilization of waste products from industrial and agricultural sectors would achieve the most possible extent, thus reducing impact of pollution on the environment and helping to rationally consume natural resources.

In Malaysia sources of activated carbon as coconut and palm shells are readily available and in the important sector of the country’s economy of palm oil production this material is considered as a waste product. The latter fact as well as natural abundance of the material in this part of the world and generally uncomplicated processing to obtain activated carbon makes the palm based carbon extremely attractive low cost adsorbent which can be effectively used in the industrial wastewater treatment from heavy metals.

In a number of works various sources of activated carbons, such as coconut shell carbon, coconut tree sawdust carbon, carbon based on bagasse pitch, cassava peel, peanut husks, and rice husks were successfully used as adsorbents to remove toxic elements [1,2,4-8,10,11,13,14].

The initial objective of this study was to investigate the potential of the palm shell based activated carbon to remove copper (II) ions from aqueous solution at different pH values. Effect of complexation agents such as malonic and boric acids on the adsorption capacity was investigated.

2.0 EXPERIMENTAL

Blank solution - solution of sodium nitrate (Merck) with ionic strength of 0.15M served as a medium; pH was adjusted using diluted nitric acid to the necessary values of pH 3 and pH 5. Stock solution of copper nitrate (0.1M) was prepared by dissolving the electrolyte (Merck) in the blank solution. 1M solutions of both, malonic and boric acids were de-ionized water based and pH was adjusted with a high concentrated sodium hydroxide solution (Merck).

Activated carbon was provided by the Pacific Activated Carbon company (Johor, Malaysia). Particles size used for the study was between 20-18 meshes.

Flasks, each with a 100-ml of blank solution contained concentrations of copper ions in a range from 15 to 450 mg/L and 500 mg of activated carbon. The flasks were placed on a shaker for 24 hours, at temperature 28°C, and 200 RTM.

Three systems: (1) single - copper ions only; (2) copper and malonic acid, and (3) copper and boric acid, at pH 3 and 5 were studied. Proportion of acid concentration to copper ions concentration was 10:1 in molar ratio.
Samples were taken prior to the adsorption and afterwards the experiment and were analyzed using ICP equipment (Varian).

3.0 RESULTS AND DISCUSSION

The amount of adsorbed copper ions was calculated from the equation:

$$C_e/y = [C_e / (C_i - C_e)] \times [m_c/0.1] \quad (1)$$

where C_e is the copper equilibrium concentration (mg/L), y is the amount adsorbed (mg/g), C_i is the initial concentration of copper in solution (mg/L), m_c is amount of carbon (g) in 0.1L solution. Linear plots of C_e/y vs C_e show that adsorption obeys the Langmuir isotherm model. Langmuir constants were determined from the plots to calculate the maximal adsorption capacity.

Figure 1 shows the adsorption isotherm for single copper ions system at pH 5 and pH 3. Ultimate adsorption at pH 3 reached 185 mg Cu^{2+}/g of activated carbon, and at pH 5 it was 308 mg Cu^{2+}/g of carbon, showing a positive effect of higher pH that has been observed in other works as well.

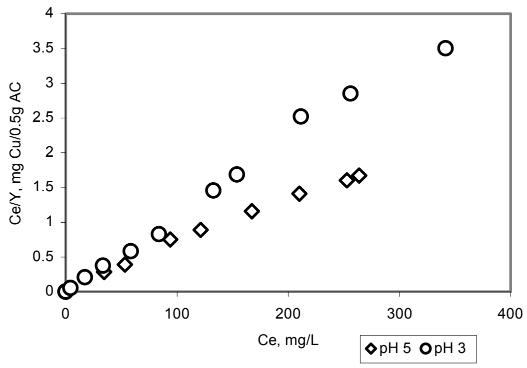


Fig.1 Adsorption of Copper (II)

Figure 2 demonstrates adsorption of copper ions in the system with malonic acid. Comparison of the results of the first system (copper ions only) to the one containing a complexing agent shows clear decrease in maximal capacity of copper adsorption at both pHs. Thus, adsorption at pH 5 reached only 238 mg Cu^{2+}/g of carbon, whereas at pH 3 the value was - 87 mg Cu^{2+}/g of carbon. Following spectrophotometer analyses on absorption of the solutions of copper without and with ascending proportions of malonic acid (1:0.1; 1:1; 1:10) and no carbon added showed that the absorption increases when malonic acid concentration is higher. This suggests that copper and malonic acid form complex ligands and its formation is more favorable to the process of adsorption of the copper ions onto activated carbon, particularly at lower pH, although such complexes are not stable [15].

In the system of copper and boric acid the results showed that at pH 3 the adsorption reached 191 mg Cu^{2+}/g of carbon and at pH 5 the uptake was 225 mg Cu^{2+}/g of carbon. If at pH 3 the carbon adsorption capacity was close to the one of copper only, at the same pH, then at pH 5 it was lower. However, comparing both systems: copper only and copper with added boric acid shows that the capacity values are more or less in the same range and therefore no significant effect of the boric acid was determined in the study.

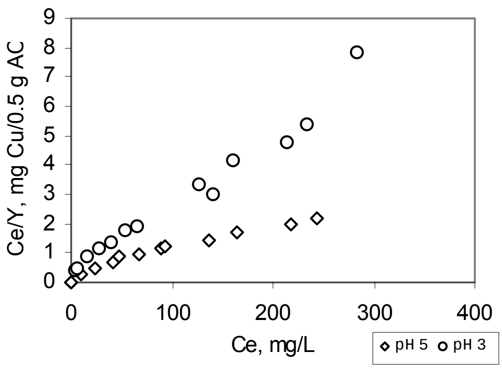


Fig.2 Adsorption of Copper and Malonic Acid

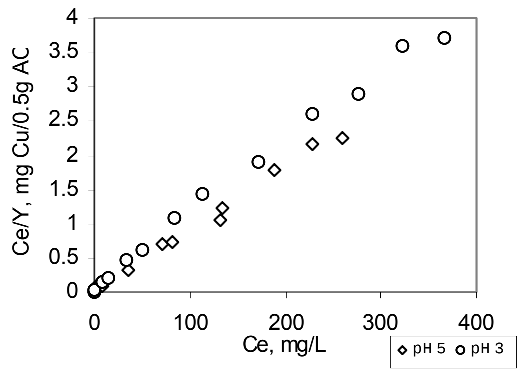
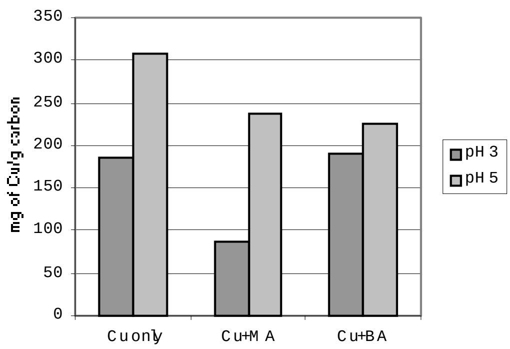


Fig. 3 Adsorption of Copper and Boric acid

The dilute aqueous solutions of boric acid contain basically undissociated $B(OH)_3$ molecules and in the water system, the conjugate base of boric acid is the tetrahydroxyborate anion $B(OH)^{4-}$, which is main anion in the solution of alkali metal borates [3]. Therefore, it is possible that copper may form complexes with boric acid, however at quite lower rate than with malonic acid, so it does not affect much the adsorption rate of copper on the background of single copper solution.

Fig. 1. Ultimate uptake of copper ions onto palm shell based activated carbon.



4.0 CONCLUSIONS

Palm shell is a waste from the industrial process of the palm oil production in Malaysia. Low cost activated carbon prepared from it is believed to possess properties to efficiently remove heavy metals ions from wastewaters. The Langmuir model was applicable aas it fit the experimental data on adsorption of copper. Effect of complexing agents on the adsorption of copper (II) was also studied. Results demonstrated successful removal of copper (II) from aqueous solutions especially at higher pH value. Unanticipated lower adsorption uptake was observed in the system of copper and malonic acid, whereas boric acid has not significantly increased ultimate uptake of copper ions onto activated carbon at both pHs.

Acknowledgments

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Effectiveness Of Limestone Filters In Removing Copper From Wastewater

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ABSTRACT: The objective of this study is to determine the field breakthrough time of limestone filters in removing copper from wastewater. The field breakthrough time was reached when the copper concentration in the effluent are higher than a specified breakthrough copper concentration. The limestone particles with 2 to 4 mm diameter, which contain about 95 percent $CaCO_3$ were used to remove copper from synthetic wastewater. The limestone was filled into 2 filters of 600 mm and 200 mm media height respectively. The concentration of copper in the synthetic wastewater was diluted to 4 mg/L and the flow rate at the influent was adjusted to 100 ml/min. The synthetic wastewater must be refilled twice a day to enable the filtering process operate continuously. In the preliminary stage of the experiment, a batch adsorption test was carried out to determine the coefficient of Freundlich adsorption isotherm. The field breakthrough time can be predicted when the Freundlich's adsorption capacity, flow rate, volume of limestone column, mass of limestone column, and volume of wastewater used per day are determined. The filtration results indicated that the 600 mm media height filter was able to remove approximately 90 percent of copper for 23 days and the 200 mm media height filter was able to remove not less than 60 percent of copper for 7 days. The results also indicated that the field breakthrough time of the limestone filter was achieved later than the theoretical breakthrough time.

Keywords: Limestone, filtration, copper, breakthrough time

INTRODUCTION

The potential of limestone to remove the heavy metal had been proved for several times (Aziz 1999). Aziz and Smith (1996) have studied the use of crushed dolomite in removing manganese from water. Their results indicated that rough solid media and the presence of carbonate are beneficial in the precipitation of Mn in water. Their batch studies were continued by conducting a laboratory scale filtration technique to prove that crushed dolomite could be used as a media for removing manganese from water.

Aziz et.al (2001) had studied copper removal from wastewater by batch study and filtration technique through low cost coarse media. The batch study has indicated that more than 90 percent copper could be removed from the wastewater influenced by the media and not solely by the pH. Batch experiments using limestone and activated carbon indicated both limestone and activated carbon gave similar removal of heavy metals (approximately 95%). Result of laboratory scale filtration technique using limestone particles indicated that above 90 percent removal of Cu was achieved at retention time of 2.31 h, surface loading rate of 4.07 m^3/m^2 per day and Cu loading of 0.02 kg/m^3 per day.

Analysis of the limestone media after filtration indicated that adsorption and absorption processes were among the mechanisms involved in the removal processes. This shows that limestone has potential to be used as an alternative or replacement media for activated carbon. Since limestone is considered cheap, it uses may be beneficial to industries in Malaysia, especially small and medium scale industries as post treatment replacing current treatment technology.

In this study, prediction of theoretical breakthrough time was made through absorption theory and the field breakthrough time of limestone filters in removing copper from wastewater was determined by using filter model. The field breakthrough time of limestone obtained from the experiment was then compared with the theoretical breakthrough time.

METHODS AND PROCEDURE

Filter Model

Two filter models with 800 mm and 230 mm height were made. The model filter with 800 mm height is made of stainless steel and the model is rectangular shape with 150 mm length and 150 mm width. The media height of the limestone is 600 mm. The second model is made of transparent plastic cylinder with 150 mm diameter. The media height of the limestone in the second model is 200 mm. The models were equipped with water tanks and pumps. The diameter of limestone particle used is 2 mm to 4 mm which contains 95 percent $CaCO_3$.

Batch Test

The batch test was carried out by putting different volumes of limestone into nine conical flask and shaking them with 300 rpm for one hour. Then, all the conical flasks were let to settle for one and a half hour. The copper concentrations at supernatant level of each conical flask were measured. The data obtained was used to plot the Freundlich adsoption isoterm graph. The constant in the Freundlich isoterm can be determined by substituting the value of C_e and x/m obtained from the isotherm graph to the following equation:

$$\frac{x}{m} = K_f C_e^{1/n}$$

Where,

x/m = amount adsorbate adsorbed per unit weight of absorbent
C_e = equilibrium concentration of adsorbate in solution after adsoption (mg/l)
K_f = empirical constant
n = empirical constant

The copper concentration used in the isoterm test must be same with the concentration of copper in the synthetic wastewater that was used in the filtration experiment. The ability of limestone to remove heavy metals may vary according to different concentration of heavy metals.

Prediction of Field Breakthrough Capacity of Limestone Filters

The time of field breakthrough capacity of limestone filter can be calculated if the mass of limestone column, flow rate, influent copper concentration, breakthrough copper concentration and the field breakthrough adsorption capacity are known.

$$t_b = \frac{(x/m)_b M_c}{Q[C_i - (C_b/2)]}$$

Where,

$(x/m)_b$ = field breakthrough adsorption capacity (mg/kg)
M_c = mass of limestone (mg)
Q = flow rate (ml/min)
C_i = influent concentration (mg/L)
C_b = breakthrough concentration (mg/L)
t_b = time to breakthrough (day)

RESULTS AND DISCUSSION

Retention Time of Wastewater in the Filter

The retention time of wastewater in the filters is influence by volume of limestone column, percentage of void and flow rate of the wastewater flowing into the filter. Table 1 shows the retention time of the wastewater in 600 mm and 200 mm filter media height. The longer retention time increases the time of the wastewater to react with the limestone particles. Thus, the quantity of the heavy metal remove from the wastewater will be increased. However, the volume of wastewater for filtering process would be decreased if the retention time of the wastewater in the filters were long.

Table 1: Retention time of the wastewater in 600 mm and 200 mm filter media height

Filter Media Height (mm)	Flowrate (ml/min)	Volume of Filter Media (m^3)	Percentage of void (%)	Retention Time, t (min)
600	100	0.0135	49.3	66.6
200	100	0.0035	49.3	17.3

Result of Batch study

Table 2: Batch test of copper adsorption

Vol (ml)	Mass (g)	Initial Conc, C_o (mg/L)	Final Conc, C_e (mg/L)	x (mg/L)	x/m
0	0	-	-	-	0
5	13.95	4.03	0.64	3.39	0.0002430
10	26.98	4.03	0.62	3.41	0.0001264
15	39.91	4.03	0.55	3.48	0.0000872
20	52.22	4.03	0.41	3.62	0.0000693
25	60.80	4.03	0.26	3.77	0.0000620
30	79.92	4.03	0.17	3.86	0.0000483
40	101.29	4.03	0.16	3.87	0.0000382
50	137.69	4.03	0.13	3.90	0.0000281

The objective of batch study is to determine the Freundlich adsorption coefficient (x/m) which are showed in Table 2. The data of x/m from batch test was used to plot Freundlich adsorption isoterm graphs (Figure 1) and the equation becomes;

$$\frac{x}{m} = 0.0002 C_e^{0.9477}$$

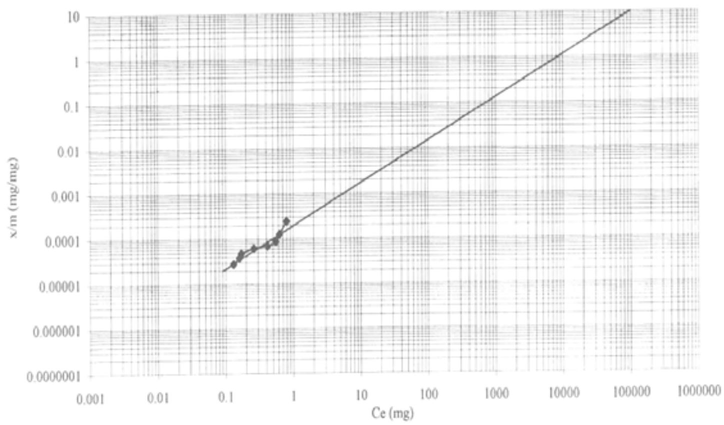

Figure 1: Freundlich Adsorption Isotherm

Predicted Time of Field Breakthrough for Limestone filters

The density of the limestone used is 2639 kg/m^3 and the prediction of field breakthrough capacity for 600 and 200 limestone filter media height is shown in Table 3. The flow rate of wastewater used is 144 liter/day. The prediction of field breakthrough capacity for 600 mm media height filter is 41 days and for 200 mm media height filter is 10 days.

Table 3: Prediction of field breakthrough capacity for limestone filters

Field Breakthrough Adsorption Capacity $(x/m)_b$	C_i (mg/L)	C_b (mg/L)	Volume of limestone column (m^3)	Time to breakthrough, t_b (days)
0.0007441	4.0	3.5	0.0135	40.91
0.0007441	4.0	3.0	0.0035	9.64

Effectiveness of the Filtering Process

The graph in Figure 2 shows the concentration of copper in the effluent against duration of experiment for 600 mm media height. The effectiveness of this filter was illustrated in Figure 3, where approximately 90 percent of copper has been removed from wastewater for duration of 23 days. After the period of 23 days, the effectiveness of the filter was dropped drastically.

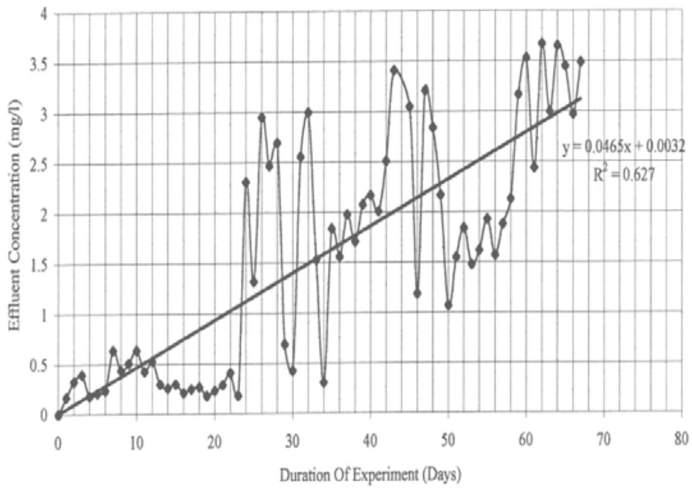

Figure 2: Concentration of copper in effluent against duration of experiment (600 mm media height)

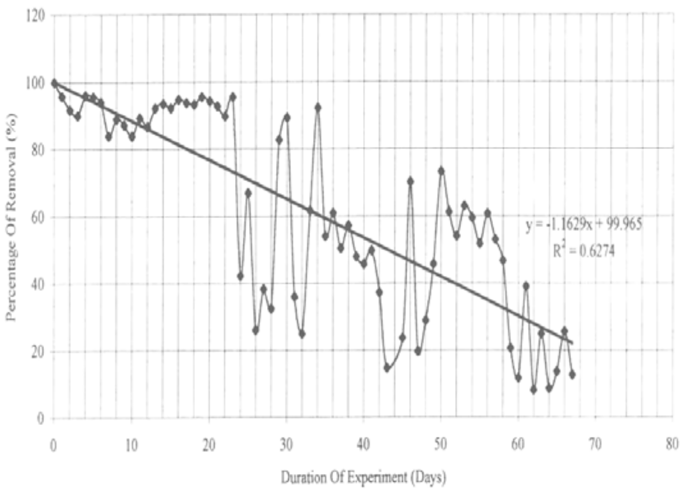

Figure 3: Percentage of copper removal against duration of experiment (600 mm media height)

The concentration of copper in the effluent against the duration of experiment for 200 mm filter height was given in Figure 4. The percentage removal of copper against the duration of experiment for 200 mm filter media height is shown in Figure 5. The 200 mm media height filter is able to remove at least 60 percent of copper for the duration of 7 days.

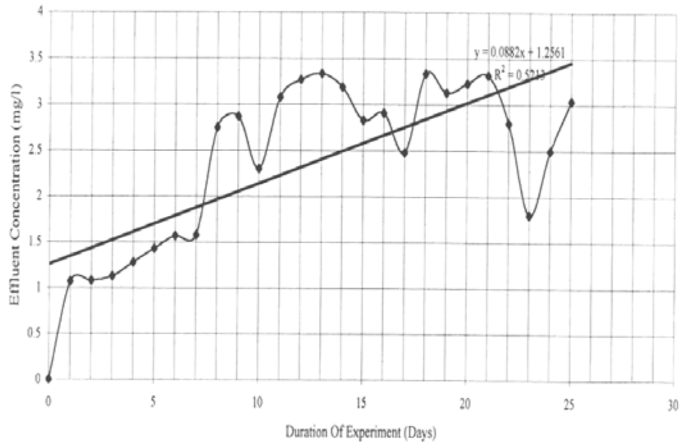

Figure 4: Concentration of copper in effluent against duration of experiment (200 mm media height)

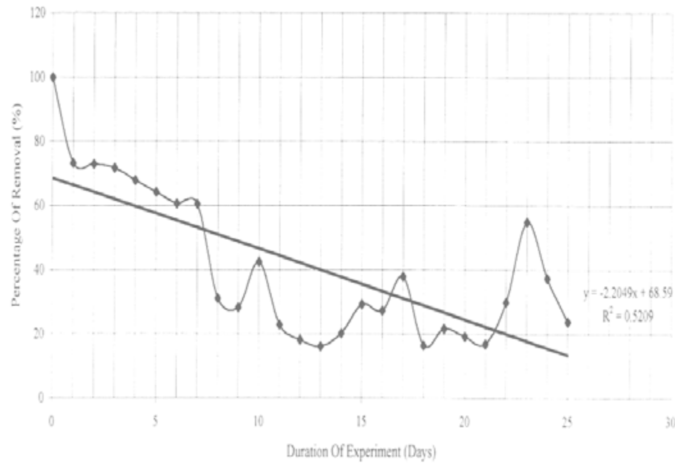

Figure 5: Percentage removal of copper against duration of experiment (200 mm media height)

The comparison between theoretical breakthrough time and field breakthrough time for 600 mm media height was showed in Figure 6. The theoretical time to breakthrough was achieved at 41st day. However the field breakthrough time for the limestone filter was achieved at 60th day. The field breakthrough time was achieved 19 days later than theoretical breakthrough time. Figure 7 indicated that the difference between theoretical breakthrough time and field breakthrough time for 200 mm media height is about 2 days. The field breakthrough time for both filter models was achieved later than the theoretical breakthrough time. This may be due to some factors such as retention time of wastewater in the filter, chemical properties of limestone used, uneven flow of wastewater in filter and the precipitation of copper in filter media.

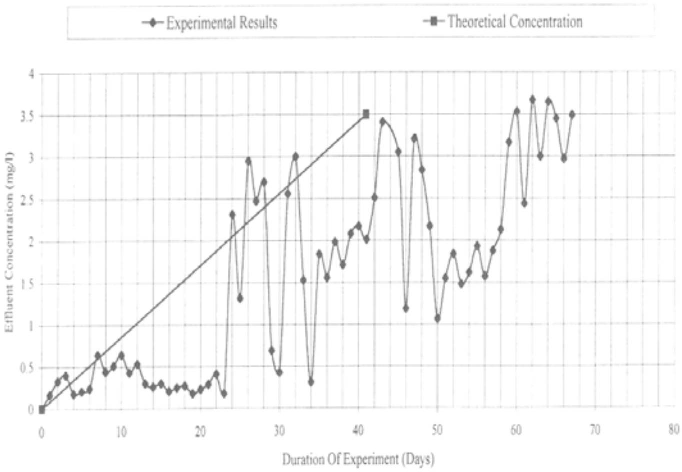

Figure 6: Comparison between theoretical breakthrough time and field breakthrough time (600 mm media height)

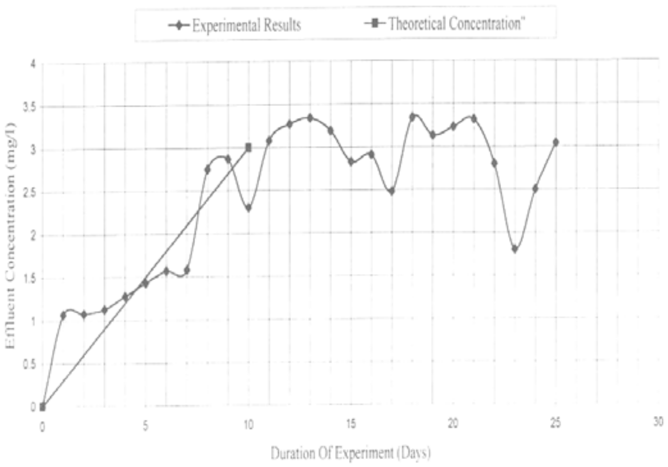

Figure 7: Comparison between theoretical breakthrough time and field breakthrough time (200 mm media height)

The flow rate of wastewater is the main factor influenced the percentage removal of copper. The flow rate will affect the retention time of wastewater in the filter. Longer retention time will increase the time for limestone to react with copper in the filter. The flow rate in the influent was adjusted to 100 ml/min. At certain time, the flow rate in the effluent would drop to around 80 ml/min because of inconsistent performance of pump and decreasing water level in wastewater tank. The reduction of the flow rate in the effluent had extended the retention time of wastewater in the filter.

The percentage of calcium carbonate in the limestone also will affect the effectiveness of the limestone filter. The limestone used in this study contain of 95 percent calcium carbonate. The flow of wastewater in the filter may be uneven due to the present of void in the limestone. The uneven flow in the filter may cause the uneven breakthrough capacity of limestone particle. The copper concentration in the effluent may be affected by precipitation during the filtering process. The precipitation will occur according to the type of heavy metals, concentration of heavy metals and the pH of the wastewater. The precipitation of heavy metals can be determined by using Figure 8. The pH required for copper concentration of 4 mg/L to precipitate is at least 7.5. The pH of the wastewater acquired from the study was less than 7.5. Therefore the precipitation did not occurred in this experiment. Due to these factors, the field breakthrough time achieved was slower than theoretical period.

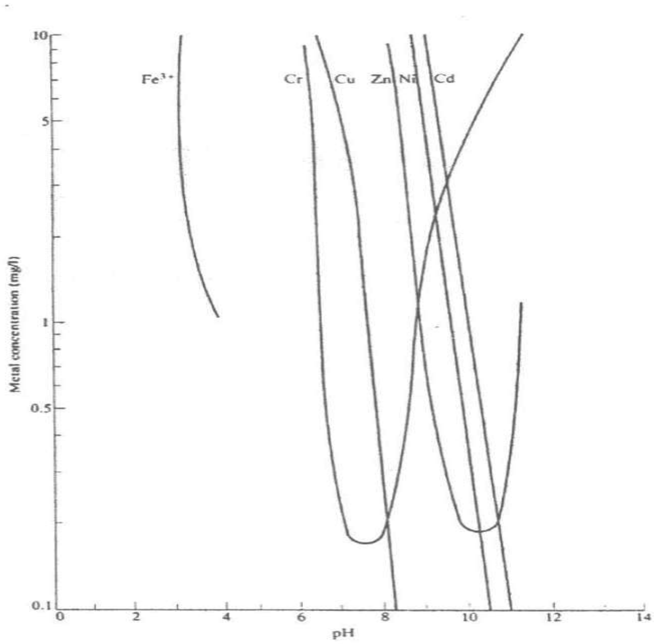

Figure 8: Solubility of metals against pH

CONCLUSIONS

The difference between the field and theoretical breakthrough time are very important. It would indicate the lifetime of the limestone filter in removing of heavy metals. The experiment indicated that the field breakthrough time achieved was slower than the theoretical breakthrough time. The filtration results shows that the 600 mm media height filter was able to remove approximately 90 percent of copper for 23 days. While the 200 mm media height filter was able to remove not less than 60 percent of copper for 7 days.

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Adsorption Of Acid Dyes Using Activated Carbon

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ABSTRACT: The adsorption of methyl orange in aqueous solution using commercial activated carbon was carried out in batch mode at constant temperature of 28 ^{o}C. Parameters that affect the adsorption process were studied. These were contact time, initial concentration of dyes and adsorbent dosages. The concentrations of dyes were analyzed using spectrophotometer at a fixed wavelength of 464 nm. The maximum adsorption capacity was found to be 138.894 mg/g of methyl orange dye with 55.9% adsorption being achieved. The isotherm data obtained is well described by Langmuir and Freundlich model.

Keywords: adsorption, activated carbon, Methyl Orange, Langmuir model, Freundlich model.

INTRODUCTION

The treatment of textile wastewater is one of the most difficult issues to be solved today. The dyestuff manufacturing and consuming industries are some of the leading consumers of water. The effluents from these industries contain a small proportion of dyes, which impart color to water and thus lower its aesthetic value. These dyes do not only add pollution problems to the water, but they are difficult to be removed since many of them are biologically non-degradable.

Due to their chemical structure, some dyes are resistant to fading on exposure to light, water and many chemicals and therefore are difficult to be decolorized in the aquatic environment (Poots et al.,1976a).

In the past, municipal treatment systems were used for the purification of textile dye effluent. Due to the recalcitrant nature of many dyes, these systems were found to be ineffective. The same is true when dyes are released into aquatic systems, anaerobic bacteria in the sediment are unable to mineralize dyes completely resulting in the formation of toxic amines (Nigam et al., 2000). It is therefore necessary for dye-containing effluents to be treated in an effective manner before being discharged into natural waterways.

Unless properly treated, the dyestuffs present in wastewaters can significantly affect photosynthesis activity due to reduced light penetration. The dye stuffs may also be toxic to certain forms of aquatic life due to the presence of metals and chlorine (Ramakrishna and Viraraghavan, 1997).

Besides that, wastewater that is polluted with dyes will also cause allergic dermatitis, skin irritation, cancer and mutation (Ray, 1986). Chromes dyes also hamper soil fertility by suppressing the growth of nitrogen fixing cyanobacteria.

Sorption is one of the several techniques that have been successfully employed for effective dye removal The first step to an efficient adsorption process is the search for an adsorbent with high selectivity, high capacity, and long life. It has to be available in tonnage quantities and at economical cost (McKay, 1982a).

Industries employ many methods of dye removal with activated carbon being the most widely used (Nasser and El-Geundi, 1991). Activated carbons are particularly useful and commonly used due to their large adsorption capacity, fast adsorption kinetics and relative ease of regeneration. It removes organics that cause odors, tastes, and other detrimental effects. In addition, as a recycling media, activated carbon can be used for solvent purification or recovery of expensive materials. The economics of carbon systems have been improving such that their usage is becoming more accepted.

The purposes of this study are (i) to examine the effectiveness of the adsorption of dyes on activated carbon, and (ii) to obtain information on the adsorption equilibrium of the activated carbon – dye system.

EXPERIMENTATION

Materials

Activated carbon was used as adsorbent whilst methyl orange was employed as the test dye throughout the experiment. Both adsorbent and test dye were obtained from the BDH Laboratory Supplies.

Stock solutions of 1000 ppm of Methyl Orange was prepared by dissolving 1 gram of accurately weighed methyl orange into 1 liter of distilled water and diluted when necessary. The stock solution is put in a shaker for half an hour at 175 rpm and 28^{o}C to make sure that all the dye has been diluted. Then, it was wrapped with an aluminum foil from top to bottom to avoid direct sunlight, and was put in a dark place to prevent possible fading of colour. The dye must be left for at least one day to make sure that the stock solution is homogeneous and is ready to be used.

Batch Kinetic Experiments

The experiment is carried out in batch mode. The adsorption-mixture, basically activated carbons with methyl orange concentration were shaked in a glass sample tube (fabricated by Hach Company, Colorado, USA) using an incubator shaker (fabricated by Sepilau Saintifik Sdn. Bhd. Selangor, Malaysia). The shaker has been set to carry out the experiment at constant temperature of 28 ^{0}C and 175 rpm. The dye solutions were decanted from the activated carbon after predetermined contact time. The adsorption-mixture was then put in the centrifugal separator (IEC Centra CL2, International Equipment Company, USA) for two minutes at 2500 rpm to separate the activated carbon from the dye. Decanted dye solution is then analyzed using the double Beam UV/VIS Spectrophotometer (UNIKON 933, made in Italy) with a 1.0 cm quartz cell at maximum wavelength of 464 nm and the final concentration of the dye solution is then read from the calibration curve. If the dye solution was too concentrated and cannot be analyzed by the spectrophotometer, the dye solution was further diluted with distilled water.

Effect Of Initial Dye Concentration And Contact Time

The effect of initial dye concentration and contact time were studied by varying the dye concentration from 50 to 400 parts per million (ppm). A fixed mass of 0.01 g of activated carbon was allowed to contact with 10 ml of dye solutions. Samples were taken at time intervals of 5, 15, 30, 45, 60, 120, 180, 240, 300, 360, 420, and 480 minutes. For each time interval, two samples were prepared and the final results were obtained by taking the average. Furthermore, three samples containing only initial dye concentration without activated carbon were used as control.

Effect Of Adsorbent Dosage

A range of adsorbent dosage from 0.005, 0.007, 0.01, 0.02, 0.03, 0.04, and 0.05 g were examined with 10 ml of 250 mg/L of methyl orange for two hours. The adsorption capacities were determined by measuring the concentrations of dye solutions before and after experimentation.

Method Of Calculation

a) The classic Langmuir equation gives

$$Q_e = \frac{K_L C_e}{(1 + aC_e)} \quad \text{……………..} (1)$$

Equation (1) can be re-arranged to give

$$\frac{C_e}{Q_e} = \frac{1}{K_L} + \frac{aC_e}{K_L} \quad \text{………………}(2)$$

b) Freundlich equation is given as: -

$$Q_e = K_F C_e^{1/n} \quad \text{………………..}(3)$$

Equation (3) can be re-arranged to give

$$\log Q_e = \log K_F + \frac{1}{n} \log C_e \quad \text{…………}(4)$$

The adsorption capacity, Q_e (mg/g) is calculated from

$$Q_e = \frac{V_o(C_o - C_e)}{1000m} \quad \text{..………}(5)$$

where:

Q_e = amount of dye adsorbed by activated carbon at equilibrium (mg/g)
C_e = residue dye concentration remaining after adsorption (mg/L)
K_L = aQ_{max}
a = constant for energy of the sorbent
n = Freundlich constant for adsorption intensity
m = amount of activated carbon used for dye adsorption during equilibrium (g)
K_F = Freundlich constant for adsorption capacities
C_o = initial dye concentration (mg/L)
V_o = initial volume of dye used

RESULT AND DISCUSSION

Contact Time

Figure 1 shows the adsorption capacity (Q_e) versus time (t). The value of C_o is 250 mg/L and pH is 6.3.

After about 2 hours, a plateau is reached indicating that the adsorbent is saturated with the dye molecules. The removal of dye increased with lapse of time and saturation is obtained in around 2 hours for Methyl Orange.

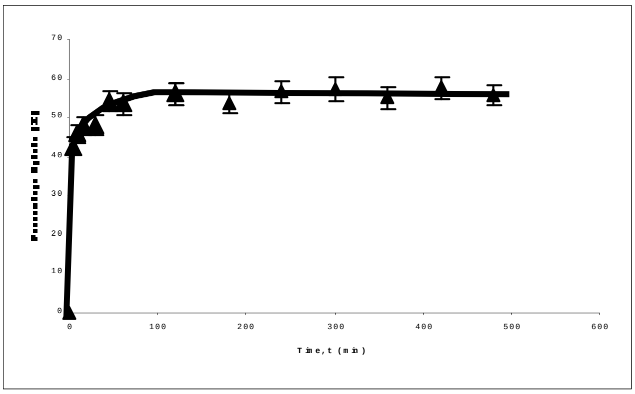

Figure 1: Typical plot of contact time of the adsorption of Methyl Orange on activated carbon.

Adsorption Isotherm

Equilibrium relationships between the activated carbon and dyes are determined and analyzed. Figure 2 shows a plot of C_e/Q_e (g/L) versus C_e (mg/L) with reference to Langmuir equation for monolayer adsorption, Equation (2). Figure 3 shows a plot of ln Q_e (mg/g) versus ln C_e (mg/L) with reference to Freundlich for heterogeneous surface binding, Equation (4).

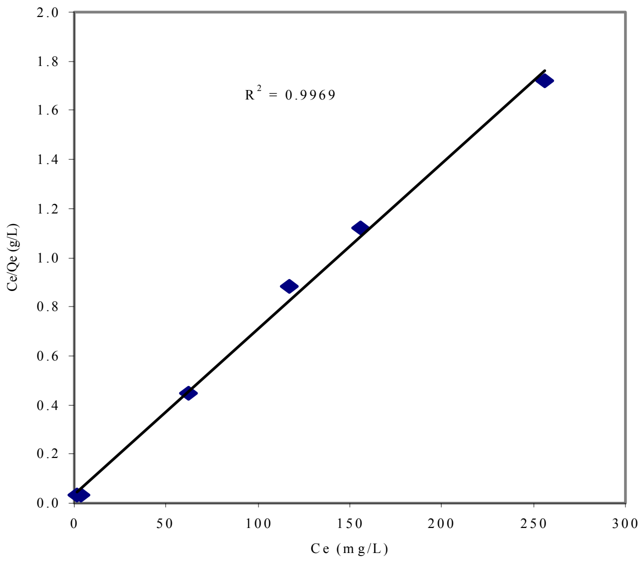

Figure 2: Linear Langmuir plots for the adsorption of Methyl Orange dye at 28^{o}C and pH 6.3 on activated carbon.

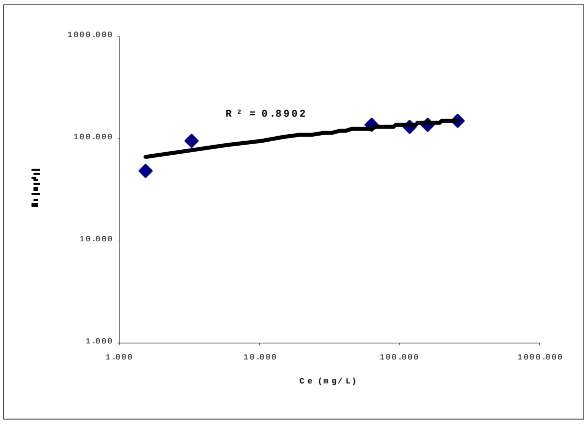

Figure 3: Linear Freundlich plots for the adsorption of Methyl Orange dye at 28^{o}C and pH 6.3 on activated carbon.

For Langmuir isotherm, the R^2 is 0.9969 and for Freundlich isotherm the R^2 is only 0.8902. This implies that adsorption of Methyl Orange on activated carbon follows the Langmuir assumptions of monolayer coverage and constant adsorption energy. This is supported by Figure 4 which shows that the Y-error bar of Langmuir isotherm is ±7%, which is more accurate than Freundlich isotherm with Y-error bar of ±17%.

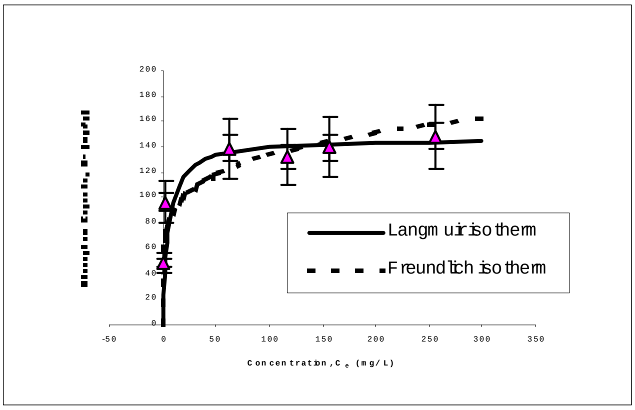

Figure 4: Langmuir and Freundlich isotherm curve of Methyl Orange by activated carbon using 0.01g of adsorbent in 10 mL of Methyl Orange solution at 175 rpm for 2 hours.

Effect Of Adsorbent Dosage

The effect of adsorbent dosage on the sorption of Methyl Orange is useful in establishing the optimum amount of adsorbent to be use in the removal of Methyl Orange. Figure 5 shows the effect of adsorbent dosage on the removal efficiency. The initial concentration of the methyl orange is 250 mg/L. The increases of dyes removal efficiency with increasing the adsorbent dosage is attributed to the increase in the number of available adsorption sites as adsorbent dosage increased. The decreases in adsorption density may be due to the shortage of dyes concentration in solution. Similar trend was reported for the adsorption of metal ions by other biosorbents such as yeast and fungal mycelia by-products (Fourest and Roux, 1992).

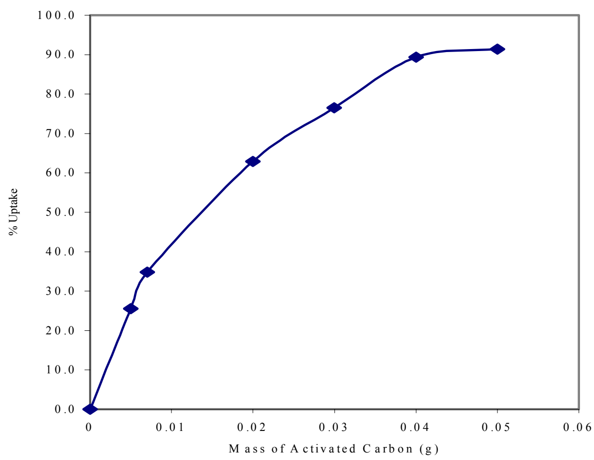

Figure 5: Effect of adsorbent dosage for the adsorption of 250 mg/L Methyl Orange for 2 hours.

CONCLUSION

In this experiment, equilibrium studies were carried out for the adsorption of Methyl Orange onto activated carbon in the concentration range of 50 - 400 mg/L at constant temperature of 28^oC. The results obtained showed that the Langmuir isotherm describe the equilibrium better than the Freundlich isotherm. The maximum adsorption capacity was found to be 138.894 mg/g of methyl orange dye with 55.9% adsorption being achieved. Furthermore the increase of amount of adsorbent will increase the adsorption capacity. The present study demonstrated that activated carbon is a very effective adsorbent for acid dye removal from aqueous solutions.

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Application Of Anaerobic Process For The Treatment Of Organic Fraction In Municipal Solid Waste

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ABSTRACT: The study focussed on the application of secondary continuous stirred tank reactor (CSTR) and combined with an anaerobic filter (AF) to treat leachate from a CSTR used for the primary hydrolysis and acidification of the organic fraction of municipal solid waste (OFMSW). The primary CSTR served as a hydraulic flush reactor (HFR) in which the solids and liquid retention time were uncoupled by recycling solids back to the reactor whilst the leachate, rich in organic acids, was flushed through. The composition of the leachate varied, depending on the food waste content in the primary OFMSW. A combination of both units acting as a two phase processes consistently removed 90 % of the organic content when operated at or up to an organic mass loading rate (OLR) of 2.3 $kg.m^{-3}.d^{-1}$. Subsequent removal efficiency decreased when the OLR was increased and this lead to system overloading at an OLR of 4.1 $kg.m^{-3}.d^{-1}$.

Keyword: Anaerobic digestion, anaerobic filter, continuous stirred tank reactor, hydraulic flush reactor, hydrolysis, leachate, organic fraction of municipal solid waste

Notation:

AF	anaerobic filter
C	carbon
CH_4	methane
COD	chemical oxygen demand
CSTR	continuous stirred tank reactor
d	day
HFR	hydraulic flush reactor
HRT	hydraulic retention time
L	litre
MSW	municipal solid waste
OFMSW	organic fraction of municipal solid waste
OSW	organic solid waste
Q	hydraulic flow rate
S_e	effluent
S_o	influent
SRT	solid retention time
TS	total solid
VS	volatile solid

INTRODUCTION

Organic fraction of municipal solid waste (OFMSW) has become a standard terminology to address the biodegradable component in municipal solid waste (MSW) (Mata-Alvarez *et al.*, 2000). Previously, organic solid waste (OSW) was used to refer the biodegradable component in the solid waste that contained moisture below 85 - 90%. However, using this definition, there are many agricultural and industrial wastes can be included under this criterion. For these OSWs, it is being normally referred as biowaste (Veeken and Hammelers, 1999), whereas, the residual of refuse after of OFMSW has been selected is known as grey-waste (Scherer *et al.*, 1999).

Stabilisation of OFMSW will enlighten the concern of waste generation by the municipality and problems faced by landfill operation, i.e. contamination of ground and surface water by the leachate, increasing land-use and hygienic issues to the surrounding population. Due to the large environmental impacts of landfill, many of them are due to close in most of the countries because of the evolution of legislation (Mata-Alvarez *et al.*, 2000). In fact, a European directive is being prepared to restrict this practice.

Currently, separate collection of fractions of MSW has increased significantly as it is being conveyed for biological treatments, which are considered as the cleanest alternative for the putrescent fraction (Mata-Alvarez *et al.*, 2000). Most studies on the stabilisation of OFMSW have included the application of the biological process; aerobic and anaerobic processes. The difference between both processes is that with anaerobic process, a variable amount of energy is recovered, whereas aerobic process or known as the composting process is a net energy consumer. In some places, the grey wastes from OFMSW are used for soil conditioning (Tchnobanogalous *et al.*, 1993), which by some means have to be closely monitored.

Anaerobic digestion mostly was applied for the stabilisation of solids content, in which are removed by sequels phases of hydrolysis, acidogenesis and methanogenesis. Study on anaerobic digestion of OFMSW on the pilot scale has been done by Bolzonella *et al.* (2003), which showed no predicament regarding process stability during the start-up phase. Nevertheless, leachate discharge by anaerobic digestion of OFMSW is not generally suitable to be placed onto neither the land nor water body. They are too wet, contain a notable amount of volatile fatty acids, which are

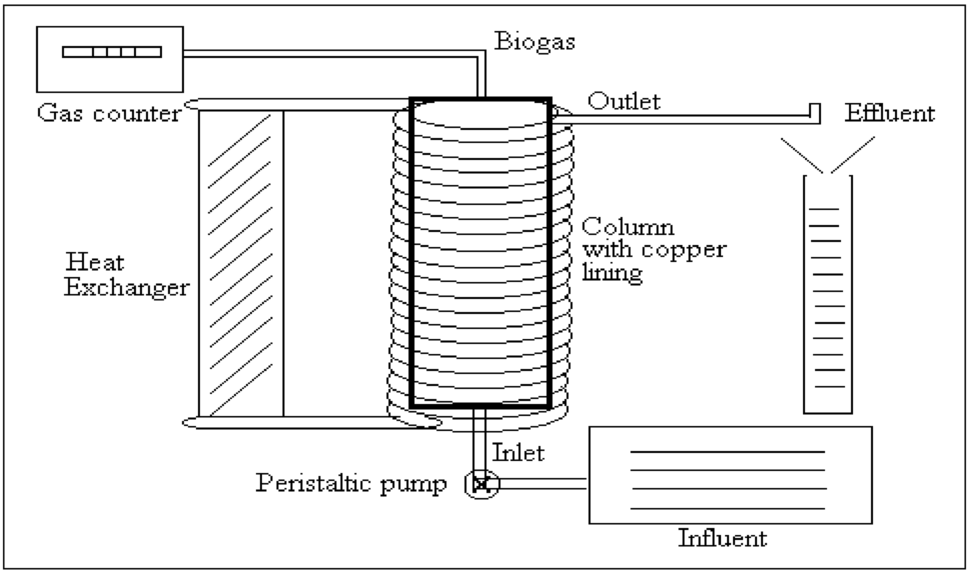

Figure 1 Anaerobic filter reactor set up for continuous feeding operation

somewhat phytotoxic and, if digestion has not occurred within the thermophilic range of temperatures, are not hygienic. Thus, it is generally accepted that post-treatment after anaerobic digestion is needed to obtain a high-quality,finished product (Poggi-Varaldo *et al.*, 1999). This study focuses on the treatment of leachate from the anaerobic reactor namely as hydraulic flush reactor (HFR).

MATERIALS AND METHODS

Leachate of OFMSW

Two types of substrate derived from the leachate of OFMSW, were being used in this experiment: first, a solid-free leachate and second, the actual leachate with solids composition. Leachate from OFMSW was supplied by HFR, which was operating as the anaerobic hydrolyser for OFMSW. The basic operation for HFR was based on the concept of continuous stirred tank reactor (CSTR).

OFMSW was firstly hand sorted, to pick out the non-organic material, wood and cardboard from a stock of municipal waste collected from Hampshire Waste Transfer Point, Southampton, UK. The sorted OFMSW was then shredded and turned into a slurry containing 10% total solids. The anaerobic hydrolyser was operating at 1d solid retention time (SRT) and 3 d hydraulic retention time (HRT) based on the study by Wang and Banks (1999). To achieve these operating parameters, one L of the reactor content was wasted and replaced with same volume of OFMSW slurry stock, followed by removal of another 3.33 L of filtered digestate. Filtration was done by pressing the extracted digestate through a mesh with a size of 60 μm. The amount of digestate filtrate was then replaced with same volume of distilled water. The filtered solids from the mesh were recycled back to the hydrolyser. The stock of filtered leachate was then kept in the freezer at -5^{o} C as the stock for further treatment by anaerobic digestion. To obtain the solid-free leachate, the stock of filtered leachate was defrosted and filtered again with Whatman-GF/C filter paper.

Experimental Set Up

The start-up operation was the acclimatisation of seed-sludge to the leachate in the secondary CSTR. 2.5 L of a fresh digested sludge taken from Southern Water, UK was inoculated in each reactor. Once the seed-sludge was confirmed as a viable inoculum, a small volume of the specific substrate was introduced into each reactor. The seed-sludge had first to be stabilised. The stabilisation could be monitored by the declining production of CH_4 without any addition of substrate. The acclimatisation towards substrates was monitored by production of CH_4 and total COD mass reduction in the reactor.

Acclimatisation to the readily biodegradable wastewater was carried out with caution because its biocompatibility was not confirmed, although it has most of the required nutrients. 250 mL of substrate was added when the seed-sludge had been stabilised (as shown by a consistently low CH_4 production). Effluent strength, pH and CH_4 production were monitored closely. At the end of the acclimatisation phase, when the total working volume of five L was reached in a reactor, the contents of the three reactors were mixed together and redistributed equally back to ensure uniformity at the start of the experimental run for the following batch operation.

The hydraulic flow rate (Q) was the variable for the changes of hydraulic retention time (HRT) in the system, which was based on a daily fed-batch operation. Mixing of disgestate was discontinued for one hour before the supernatant was removed. Sedimentation of solids was to uphold the biomass concentration in the system. The amount of supernatant removal was equal to the following feeding volume. The operation started at the HRT of 20d, and was reduced for every two d.

Anaerobic Filter Reactor

For higher loading of leachate for anaerobic treatment, anaerobic filter (AF) was used. It was set-up in an airtight 3.5 L polypropylene column. Figure 1 shows the set-up for the AF operation. Heat for the reactor was supplied by a thermocyclic system. Copper lining was placed around the column as the heating coil, while hot water at 55 ^{o}C from a boiler serve as the function of heat exchanger was circulated through the coil to heat the reactor up to 35 ^{o}C when placed in surroundings at room temperature.

Various sizes of plastic ring-pulls (8, 15, 20 mm) with inert surfaces were packed into the column to entrap and attach the biomass. These acted as the filter media for the substrate flowing through the column. Biomass acclimatised to OFMSW leachate in the previous CSTR was allowed to settle at full depth, then supernatant was removed by a siphon process. 2.5 L of compressed biomass was transferred from CSTR into AF. This inoculum was recirculated from the outlet back into the inlet by gravity several times to allow the unattached biomass to become lodged into the packing material. A peristaltic pump was set up with an electronic timer to manage the hydraulic flow for the reactor.

Chemical Analysis

Chemical analysis was carried out for total solid (TS), volatile solid (VS), chemical oxygen demand (COD), alkalinity in accordance with standard methods provided by the American Public Health Association (1991). Besides these standards water quality analyses for the discharge, another series of analyses for the concentration and profile of volatile fatty acids (VFAs) and biogas were also conducted. Volatile fatty acids (VFA) were determined using a gas chromatograph (GC) with a 15 m free fatty acid phase (FFAP) column packed with Chrom G (80-100 mesh), together with a flame ionisation detector (FID). Oven temperature was programmed from 145 ^{o}C to 220 ^{o}C at a rate of 8 ^{o}C min^{-1}. Nitrogen was used as the carrier gas at a flow rate of 30 cm^{3}.min^{-1}. The samples were initially centrifuged at a speed of 20 000 rpm, acidified with 10% (v/v) formic acid, and injected into the instrument. Composition of the VFA profiles was calculated according to the standard peaks provided by a known sample containing eight profiles of VFA from C2-C8.Composition of biogas was also analysed by a gas chromatograph (Cathometer head space analyser, Fisons Scientific, UK) with a dual column, one for O_2 and N_2 and another one for CH_4 and CO_2. The column was injected with samples of collected biogas. The composition was calculated according to the standard peak provided by a standard gas with a 65:35 ratio of CO_2:CH_4.

RESULTS AND DISCUSSION

Leachate from OFMSW

Treatment of the organic fraction of municipal solid waste (OFMSW) using a two-phase anaerobic-aerobic process has been considered successful by Wang and Banks (1999). This process incorporates the principle of a hydraulic flush reactor (HFR) in which the solids and liquids retention time in the hydrolysis acidification phase are uncoupled. The flushed liquid as the leachate is rich with readily biodegradable precursors for the following or extended anaerobic process.

Leachate produced in the first stage of two-phase operation of OFMSW treatment would also be useful for biological nutrient removal (BNR) in a wastewater treatment plant. Llabres *et al.* (1999) used the organic fraction of the hydrolysed and acidified product of OFMSW fermentation for enhanced biological phosphate removal (EBPR). This is a biological alternative to chemical phosphate precipitation. The leachate, also known as readily biodegradable COD (RBCOD), was added when the internal RBCOD in the system was insufficient and could adversely affect the phosphate removal process. Such integrated municipal waste management systems should be introduced as both treatment methods can share materials and equipment and yields can improve due to positive synergies. Within this context, the OFMSW fraction separately collected at source could be treated in a wastewater treatment plant. The solid phase from the first stage of the operation could undergo a second-methanogenic phase together with the excess sludge or could be used as a soil conditioner in agriculture after dewatering.

Three grades of leachate strength had been produced in this study. Table 1 lists the chemical composition of each grade of leachate. All compositions were different except for the solids content. TS and volatile solid (VS) content were in the range 6500 - 9500 and 3000 - 5000 mg.L^{-1}, respectively. It seems that hydrolysis of OFMSW into smaller particles was not affected by the percentage of food waste.

Low-strength leachate contained about 4000 mg.L^{-1} COD, medium-strength leachate was in the range 4000 - 6000 mg.L^{-1} COD, and high-strength leachate contained more than 7000 mg.L^{-1} COD. The different strengths of leachate were due to the amount of food waste in the OFMSW that was used as the substrate for HFR. In approximate terms, OFMSW with 5% (w/w) of food waste when fed to the HFR produced a low-strength leachate, while from 5% to 10% (w/w) of the food waste fraction led to production of medium-strength and high-strength leachate. Thus during the preparation of substrates for HFR, only OFMSW with a high content of food waste was selected.

The analysis of the solid-free leachate would explain the extended hydrolysis of the particulate material into soluble substances and the acidogenesis of solutes into VFA. Soluble COD and VFA content increased with the leachate strength. pH and alkalinity level were related to the presence of VFA. Typically, higher VFA content reduced both parameters. VFA analysis showed that acetate concentration was the highest in comparison with other fractions. The higher acetate concentration shows that the methanogenic phase was impeded, while the presence of other VFAs, ie. propionate to caproate, at lower concentrations indicates that the acidogenesis and acetogenesis phases were taking place.

Fed-Batch Operation for the Treatment of a Solid-Free OFMSW Leachate

An interesting observation was that the solid content of the leachate completely separated by gravitational settlement after defrosting. Based on this observation, it was decided that the following anaerobic process for leachate treatment should be started with solid-free leachate. As little was known regarding the effect of leachate on the anaerobic system this was also a safer way in which to proceed as the chances of toxicity would be reduced. Solid-free leachate was assumed to contain only soluble organic substances that would presumably not affect the bioreactor.

The solid-free high-strength leachate was selected as it had the highest content of soluble organic substances. An operational HRT of 20 d during acclimatisation until production of CH_4 was used consistently before collecting the experimental data.

Table 1. Chemical composition of leachate according to COD strength grading

Chemical composition	Low-strength	Medium-strength	High-strength
pH	6.0 - 7.0	5.0 - 6.0	4.0 - 5.0
Alkalinity (mg.L^{-1} $CaCO_3$)	1000 – 1500	500 - 1000	0 - 500
COD (mg.L^{-1})	4000	4000 - 6000	> 6000
Total solid (mg.L^{-1})	6500 – 9500	6500 - 9500	6500 - 9500
Volatile solid (mg.L^{-1})	3000 – 5000	3000 - 5000	3000 - 5000
Solid-free leachate			
COD (mg. L^{-1})	500 - 1000	1000 - 2500	2500 - 5000
VFA (mg. L^{-1})	10 - 250	500 - 800	1500 - 2000
Acetate (mg. L^{-1})	10 - 100	100 - 300	500 - 1000
Propionate (mg. L^{-1})	0 - 30	100 - 300	100 - 200
Butyrate (mg. L^{-1})	0 - 30	10 - 110	110 - 250
- iso butyrate	0	0 - 10	10 - 50
- n butyrate	0 - 30	10 - 100	100 - 200
Valerate (mg. L^{-1})	0 - 30	50 - 100	110-250
- iso valerate	0	0 - 10	10 - 50
- n valerate	0 - 30	10 - 100	100 - 200
Caproate (mg. L^{-1})	0	10 - 50	50-150

Table 2 Average parameters for the treatment of a solid-free leachate by CSTR associated with increasing hydraulic flow rate

HRT (d)	S_o (mg.L^{-1})	S_e (mg.L^{-1})	pH	Alkalinity (mg.L^{-1})	CH_4 : CO_2	CH_4 (ml.d^{-1})	Biomass (mg.L^{-1})	Wastage (mg.L^{-1})
20	2680 ±270	310 ± 20	7.4	1880	80:20	240 ± 30	10210 ±860	220 ± 60
18	3400 ±520	340 ± 20	7.5	1870	80:20	220 ± 20	9990 ±740	220 ± 60
16	2710 ±350	340 ± 30	7.4	1880	80:20	200 ± 30	8280 ±790	290 ± 60
14	3290 ±230	310 ± 30	7.4	1600	80:20	300 ± 20	8110 ±390	190 ± 60
12	2670 ±240	320 ± 40	7.3	1780	80:20	330 ± 30	8090 ±270	210 ± 10
10	2470 ±210	340 ± 30	7.4	1880	80:20	380 ± 50	7500 ±460	250 ± 30
8	3520 ±640	290 ± 20	7.4	2050	80:20	730 ±150	7900 ±540	70 ± 10
7	3400 ±580	280 ± 20	7.4	1990	80:20	780 ±150	9270 ±670	80 ± 10
6	4060 ±560	310 ± 20	7.3	1990	80:20	1110 ±130	8430 ±790	70 ± 10
5	3440 ±730	270 ± 10	7.4	1970	80:20	1080 ±230	8840 ±670	60 ± 10
4	3920 ±440	240 ± 10	7.3 ±0.1	1680 ±100	80:20	1530 ± 120	8220 ±560	70 ± 10
3	4050 ±600	260 ± 10	7.3 ±0.1	1880 ± 60	80:20	2280 ±350	8370 ±510	-
2	3350 ±480	250 ± 10	7.3 ±0.1	1340 ± 70	80:20	2680 ±460	8950 ±520	-

Operation Performances

Table 2 shows the average of 9 replicates for each daily fed-batch operation from an HRT of 20 d to 2 d. The pH and alkalinity of the effluent were consistent at 7.3-7.4 and 1300 - 2000 mg.L^{-1} respectively, at all HRTs and without any additional pH controlling substances. The ratio of CH_4:CO_2 in the biogas fraction was also consistent at 80:20.

Meanwhile, the effluent strength was consistent at each HRT, and was in the range 240-340 mg.L^{-1}. This indicates that almost all of the biodegradable substances were fully digested at all HRTs, and only the residual of recalcitrant materials was left. This was in spite of the fact that the

Table 3 Calculation of average performance for fed-batch operation of a solid-free leachate by fed-batch anaerobic CSTR

HRT (d)	S_o - S_e (mg.L^{-1})	COD Removal efficiency (%)	Total COD loading (mg.d^{-1})	OLR (g.m^{-3}.d^{-1})	Total COD out (mg.d^{-1})	Total COD removal (mg.d^{-1})	CH_4 yield
20	2370 ±270	88 ± 1	670 ± 70	130 ± 10	80 ± 5	590 ± 70	0.40 ±.04
18	3060 ±520	89 ± 2	950 ± 150	190 ± 30	100 ± 10	860 ±150	0.26 ±.04
16	2370 ±340	87 ± 2	840 ± 110	170 ± 20	110 ± 10	740 ±100	0.27 ±.05
14	2980 ±230	90 ± 1	1180 ± 80	240 ± 20	110 ± 10	1070 ±80	0.28 ±.02
12	2350 ±230	88 ± 2	1120 ± 100	220 ± 20	130 ± 20	990 ±100	0.34 ±.04
10	2130 ±220	86 ± 2	1230 ± 110	250 ± 20	170 ± 20	1060 ±110	0.36 ±.03
8	3230 ±640	92 ± 2	2190 ± 390	440 ± 80	180 ± 20	2000 ±390	0.37 ±.05
7	3120 ±590	93 ± 1	2420 ± 410	480 ± 80	200 ± 10	2220 ±420	0.36 ±.07
6	3750 ±580	93 ± 1	3370 ± 470	670 ± 90	260 ± 20	3110 ±480	0.36 ±.03
5	3170 ±730	91 ± 3	3440 ± 730	680 ± 150	270 ± 10	3170 ±730	0.34 ±.05
4	3680 ±440	94 ± 1	4900 ± 550	980 ± 110	300 ± 10	4590 ±550	0.34 ±.03
3	3790 ±600	94 ± 1	6760 ±1000	1350 ± 200	440 ± 20	6320 ±1000	0.36 ±.02
2	3110 ±470	90	8390 ± 1200	1680 ± 240	620 ± 30	7770 ±1190	0.34 ±.01

influent strength fluctuated with high standard deviation values, due to inconsistent food content in OFMSW.

Production of CH_4 as shown in Figure 2 occurred at an exponential rate. Reduction of biomass content was observed at the beginning of the operation. However these losses seemed to be recovered at HRT of 8 d and less.It was also noted that the biomass wastage began to decrease, from 250 mg.L^{-1} to 70 mg.L^{-1} at an HRT of 8 d and below. This means that optimisation of the granulation process was beginning to occur at this loading. As calculated in Table 3, the organic loading rate (OLR) for a HRT of 8 d was 0.44 kg.m^{-3}.d^{-1}, suggesting that this is the minimum OLR that should be used for the treatment of solid free leachate in a fed batch anaerobic reactor. This was the necessary loading in order to achieve the optimum biomass flocculation and to regain the biomass growth. There was no biomass wastage when the operational HRT was less than 4 d and at this point the biomass had to be recovered by centrifugation during effluent withdrawal.

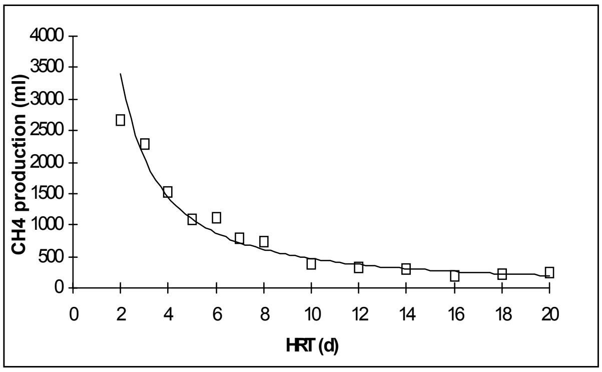

Figure 2 Production of CH_4 at each HRT for the fed-batch operation of a solid-free leachate

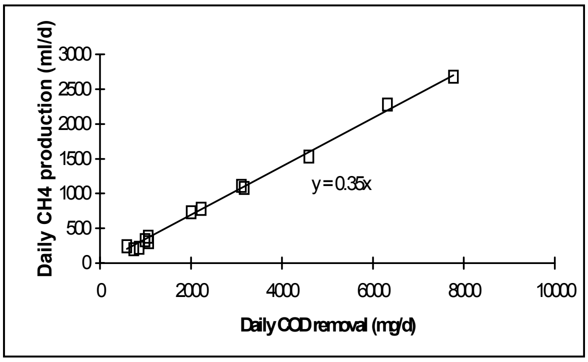

Figure 3 Overall CH_4 yield for the fed-batch operation of a solid-free leachate

The CH_4 yield as shown in Table 3 was slightly reduced immediately after start up when the HRT was 20 d. The yield was about 0.40 $10^3 m^3 CH_4.kg^{-1}$COD removed at a HRT of 20 d, a significantly high value, then reduced to 0.26-0.27 $10^3 m^3 CH_4.kg^{-1}$ COD removed to an HRT of 12 d, and increased again to the normal range up to the end of the experiment. A possible explanation is that higher production of CH_4 at the beginning was due to residual undigested organic content in the supplementary seed-sludge that was added during acclimatisation to increase the biomass population. It also could be assumed that an OLR of less than 0.25 $kg.m^{-3}.d^{-1}$for the fed-batch operation with solid-free leachate might lead the reactor to starvation as indicated by loss of biomass and lower yield of CH_4 during the operating HRTs from 20 d to 10 d. CH_4 production during the same operational HRT period follows curve line, as shown in Figure 2. This might also support the assumption of starvation. No further investigation was undertaken on this matter. Meanwhile, Figure 3 shows the overall CH_4 yield for this operation at a value of 0.35 $10^3 m^3$ $CH_4.kg^{-1}$ COD

Table 4 Comparison of operation performances for three types of leachate by fed-batch operation at HRT of 20d

Parameter	Low strength leachate	Medium strength leachate	High strength leachate
S_e (pH)	7.2	7.2	7.2
S_e (alkalinity)	2100	2100	2100
S_o COD ($mg.L^{-1}$)	4050 ± 610	7280 ± 750	9680 ± 670
S_e COD ($mg.L^{-1}$)	430 ± 20	420 ± 10	460 ± 20
COD removal efficiency	89 ± 1 %	94 ± 1 %	95 %
$CH_4 : CO_2$	80:20	80:20	80:20
CH_4	150 ± 10	330 ± 20	500 ± 70
Total COD loading ($mg.d^{-1}$)	1010 ± 150	1820 ± 200	2420 ± 170
Total COD out ($mg.d^{-1}$)	110 ± 10	110 ± 10	120 ± 10
Total COD removal ($mg.d^{-1}$)	900 ± 150	1720 ± 190	2310 ± 160
CH_4 yield	0.17 ± .03	0.19 ± .02	0.22 ± .07
S_o VS ($mg.L^{-1}$)	3290 ± 200	4880 ± 180	4820 ± 120
S_e VS ($mg.L^{-1}$)	400 ± 20	450 ± 60	470 ± 80
VS removal efficiency	88 ± 1 %	91 ± 1 %	90 ± 2 %

Table 5 Average parameters for the treatment of a high-strength leachate by anaerobic CSTR

HRT (d)	S_o ($mg.L^{-1}$)	S_e ($mg.L^{-1}$)	$CH_4 : CO_2$	CH_4 ($ml.d^{-1}$)	VS in ($mg.L^{-1}$)	VS out ($mg.L^{-1}$)	Biomass ($mg.L^{-1}$)
20	7700 ±570	420 ±60	80:20	480 ±20	4600 ±410	510 ±40	12810 ±470
18	7920 ±300	440 ±50	80:20	530 ±20	4500 ±190	510 ±20	13870 ±1600
16	7370 ±340	460 ±50	80:20	720 ±40	4600 ±410	510 ±40	12810 ±470
14	7490 ±330	450 ±10	80:20	840 ±40	4740 ±460	510 ±20	13870 ±1600
12	9630 ±640	510 ±20	60:40	1170 ±100	5040 ±550	500 ±70	12670 ±900
10	9840 ±630	510 ±10	60:40	1650 ±230	5600 ±610	490 ±90	13160 ±830
8	9610 ±590	510 ±10	60:40	2050 ±70	4730 ±640	450 ±30	12970 ±450
6.5	8740 ±320	500 ±50	60:40	2230 ±200	4720 ±520	500 ±90	13410 ±1350
6	8690 ±600	560 ±80	60:40	2450 ±260	4680 ±230	410 ±100	13450 ±1270
5.5	8290 ±1060	500 ±50	60:40	2430 ±270	4290 ±620	560 ±170	13920 ±520
5	8130 ±520	550 ±70	60:40	2520 ±200	4490 ±770	570 ±140	14380 ±390
4.5	7420 ±270	570 ±90	60:40	2350 ±140	3010 ±290	480 ±30	14720 ±800
4	7810 ±160	590 ±70	60:40	2860 ±100	3510 ±410	470 ±30	14040 ±460

removed according to the slope of CH_4 production against COD mass removal.

Fed-Batch Operation for the Treatment of an OFMSW leachate

Before proceeding with the anaerobic treatment of the OFMSW leachate, new seed-sludge was introduced because the previous seed-sludge failed to digest the unfiltered leachate. The same acclimatisation procedure was carried out as for the low-strength leachate. A high-strength leachate was subsequently used for the following experiment after preliminary tests had been run on all three types of leachate at an HRT of 20 d. Table 4 compares the results for the preliminary tests. It shows that high strength leachate can be treated and if possible this should be used within a treatment system as it gave a greater COD removal efficiency and CH_4 yield. Furthermore, there was no significant difference in the VS removal efficiency. Thus, the following experiment concentrated on the treatment of high-strength leachate.

Table 6 Average parameters for the treatment of a high-strength leachate by anaerobic CSTR associated with increasing hydraulic flow rate (Q)

HRT (d)	S_o ($mg.L^{-1}$)	S_e ($mg.L^{-1}$)	$CH_4 : CO_2$	CH_4 ($ml.d^{-1}$)	VS in ($mg.L^{-1}$)	VS out ($mg.L^{-1}$)	Biomass ($mg.L^{-1}$)
20	7700 ±570	420 ±60	80:20	480 ±20	4600 ±410	510 ±40	12810 ±470
18	7920 ±300	440 ±50	80:20	530 ±20	4500 ±190	510 ±20	13870 ±1600
16	7370 ±340	460 ±50	80:20	720 ±40	4600 ±410	510 ±40	12810 ±470
14	7490 ±330	450 ±10	80:20	840 ±40	4740 ±460	510 ±20	13870 ±1600
12	9630 ±640	510 ±20	60:40	1170 ±100	5040 ±550	500 ±70	12670 ±900
10	9840 ±630	510 ±10	60:40	1650 ±230	5600 ±610	490 ±90	13160 ±830
8	9610 ±590	510 ±10	60:40	2050 ±70	4730 ±640	450 ±30	12970 ±450
6.5	8740 ±320	500 ±50	60:40	2230 ±200	4720 ±520	500 ±90	13410 ±1350
6	8690 ±600	560 ±80	60:40	2450 ±260	4680 ±230	410 ±100	13450 ±1270
5.5	8290 ±1060	500 ±50	60:40	2430 ±270	4290 ±620	560 ±170	13920 ±520
5	8130 ±520	550 ±70	60:40	2520 ±200	4490 ±770	570 ±140	14380 ±390
4.5	7420 ±270	570 ±90	60:40	2350 ±140	3010 ±290	480 ±30	14720 ±800
4	7810 ±160	590 ±70	60:40	2860 ±100	3510 ±410	470 ±30	14040 ±460

Operation performances

Table 5 shows the results for the fed-batch operation of a high-strength leachate treatment. Operational HRT's varied from 20 d to 4 d. The HRT was reduced by 0.5 d after the experiment reached a HRT of 6.5, in order to allow a greater degree of acclimatization to the increasing OLR and thus reduce the risk of upsetting the reactor through a shock load induced by sudden an increment in loading rate. Like in previous set up, the operating HRT ended at 4d when the biomass could no longer be recollected by gravitational settlement. A slightly longer settlement period of three hours rather than two hours was required to separate the biomass at the HRT of 4 d.

The effluent at all HRTs showed consistent pH and alkalinity levels of 7.2 and 2100 $mg.L^{-1}$ $CaCO_3$ respectively, without any addition of pH controlling substances. Although the influent strength to the reactor was inconsistent, the effluent strengths obtained at all HRTs were more consistent, in the range of 420-590 $mg.L^{-1}$. This indicates that the process was operating at optimum efficiency. It also means that the CH_4 production should be at an exponential rate as was shown for such optimum substrate removal in the previous experiment. It is also possible to assume that the substrate contains the nitrogen for biomass growth. It has been well established that OFMSW leachate contains a high concentration of ammonia nitrogen and organic materials as well as other inorganic compounds (Bae *et al.*, 1997), which probably explains this.

The effluent VS concentration is another form of biomass wastage measurement. Consistently low VS in the effluent indicates that good granulation of biomass population can be achieved with this leachate as the substrate. The low concentration of VS in the effluent also indicates that a high degree of VS removal had been achieved. Another indication of high VS removal was the biomass content which was also measured as VS. As there was no significant increment of biomass, as shown in Table 6, then the indication is that solids were not being accumulated throughout the operation.

Table 7 shows the operational performance. Substrate removal was above 90% although the OLR reached about 2.0 $kg.m^{-3}.d^{-1}$. This suggests a higher OLR could be applied for the treatment of such a substrate. The CH_4 yield was below 0.30 $10^3m^3CH_4.\ kg^{-1}$ COD removed at the beginning of the experiment. The overall CH_4 yield for this operation was 0.33 $10^3 m^3 CH_4 . kg^{-1}$ COD removed, as shown in Figure 4 by the slope of CH_4 production against COD mass removal.

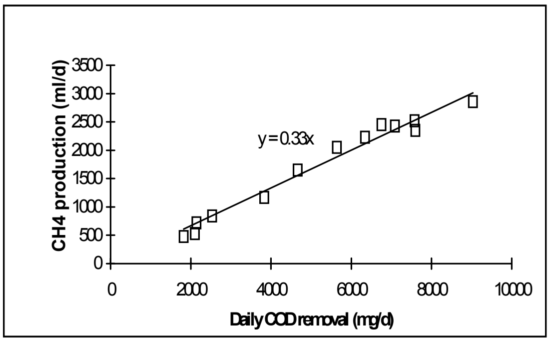

Figure 4 Overall CH4 yield for the fed-batch operation of a high strength leachate

Continuous-feeding operation for the treatment of an OFMSW leachate

The operation was changed from a CSTR to an anaerobic filter (AF) to provide a higher OLR in order to pursue the kinetic investigation. The AF with a 3 L working volume was set up and fed continuously. *Q* was measured by the volume of substrate fed into the reactor within 24 hours.

Table 7 Calculation of average performances for fed-batch operation of an OFMSW leachate by fed-batch anaerobic CSTR

HRT (d)	S_o - S_e ($mg.L^{-1}$)	COD Removal efficiency (%)	Total COD loading ($mg.d^{-1}$)	OLR ($g.m^{-3}.d^{-1}$)	Total COD out ($mg.d^{-1}$)	Total COD removal ($mg.d^{-1}$)	CH4 yield
20	7280 ±580	95 ±1	1920 ±140	390 ±30	110 ±20	1820 ±140	0.27 ±.03
18	7480 ±350	94 ±1	2220 ±80	440 ±20	120 ±20	2100 ±390	0.25 ±.01
16	6910 ±350	94 ±1	2280 ±100	460 ±20	140 ±20	2140 ±110	0.34 ±.02
14	7040 ±340	94	2700 ±120	540 ±20	160 ±5	2530 ±120	0.33 ±.02
12	9120 ±650	95 ±1	4040 ±270	810 ±50	210 ±10	3830 ±270	0.31 ±.04
10	9330 ±620	95	4920 ±310	980 ±60	260 ±10	4660 ±310	0.35 ±.04
8	9100 ±580	95	5960 ±360	1190 ±70	320 ±10	5640 ±360	0.36 ±.02
6.5	8240 ±310	94	6730 ±250	1350 ±50	380 ±40	6340 ±240	0.35 ±.03
6	8130 ±600	94 ±1	7210 ±490	1440 ±100	460 ±60	6750 ±500	0.36 ±.02
5.5	7790 ±1050	94 ±1	7550 ±960	1510 ±190	460 ±50	7090 ±960	0.34 ±.02
5	7580 ±530	93 ±1	8120 ±520	1620 ±110	550 ±70	7580 ±530	0.33 ±.04
4.5	6850 ±260	92 ±1	8230 ±300	1650 ±60	630 ±100	7600 ±280	0.31 ±.03
4	7220 ±180	92 ±1	9760 ±200	1950 ±40	730 ±80	9030 ±230	0.32 ±.02

Table 8 Average parameters for the treatment of an OFMSW leachate by anaerobic filter with 3.0L working volume (*V*) associated with increasing hydraulic flow rate (*Q*)

HRT (d)	Q ($L.d^{-1}$)	S_o ($mg.L^{-1}$)	S_e ($mg.L^{-1}$)	pH	alkalinity	$CH_4 : CO_2$	CH_4 ($ml.d^{-1}$)	VS in ($mg.L^{-1}$)	VS out ($mg.L^{-1}$)
3	1.0	5470 ± 170	550 ± 20	6.8	850	60:40	470 ± 40	2780 ± 380	270 ± 10
2.5	1.22	5600 ± 110	600 ± 70	6.8	850	60:40	590 ± 70	3450 ± 660	440 ± 80
2	1.5	6860 ± 970	1400 ± 380	6.7	800	60:40	820 ± 90	3900 ± 670	660 ± 180
1.8	1.71	5860 ± 60	2540 ± 600	6.3	600	60:40	570 ± 60	3960 ± 730	690 ± 170
1.5	2.0	6240 ± 80	6100 ± 100	5.5	450	-	-	4240 ± 450	4020 ± 500

Adjustment of *Q* determined the operational unit of HRT. Since only a single AF unit was available, more replicate samples were taken and the 'continuous feed' was given as a series of pre-quantified volumes within 24 hours to make up the volume required for a constant *Q*. Mass-balances for each batch of influent and effluent were carried out, and the CH_4 production volume was examined. The average of data ummation for all batches in 24 hours was recorded as the operational data for one day and this was repeated for four days for each operational HRT after acclimatisation.

Generation of CH_4 from the decoupled process still generate 0.33 $10^3 m^3 CH_4$. kg^{-1} COD removed.

Operation Performances

Table 8 shows the operational performances for the treatment of leachate by AF. By chance, a slightly lower strength leachate was being produced by the HFR, and this strength as calculated in Table 9 would give an OLR of 1.8 $kg.m^{-3}.d^{-1}$for starting up the AF at an HRT of 3 d. This OLR was similar to the last OLR during CSTR operation, which was 1.9 $kg.m^{-3}.d^{-1}$. Such a precaution was taken to avoid shock loading the reactor because the biomass used in the AF was originally from the CSTR. 2.5 L of concentrated biomass from the CSTR were collected and transferred to the AF. Concentrated biomass was obtained by removing the supernatant in the CSTR after 24 hours of sedimentation. pH and alkalinity measurements of the effluent dropped due to changes in operating design. The most probable reason was lacked of dilution for the AF content. Most of the liquor in the reactor was 'crammed' with biomass and substrate. After being digested, it was immediately replaced with new substrate since the reactor was fed almost continuously.

The effluent strength increased with the reduction of COD removal efficiency when *Q* increased. The calculation as presented in Table 9 shows that the anaerobic process for the treatment of OFMSW leachate was able to operate with 90% removal efficiency with an OLR of up to 2.3 $kg.m^{-3}.d^{-1}$, then the efficiency dropped to 60% when the OLR reached 3.4 $kg.m^{-3}.d^{-1}$. The results are therefore in agreement with previous work in which an anaerobic filter (AF) had been reported to achieve 90% of removal efficiency at an OLR of 2.0 $kg.m^{-3}.d^{-1}$for a medium strength carbohydrate based substrate with low content of suspended solids (Mosey, 1977, see Barnes and Fitzgerald, 1987). Nevertheless, the CH_4 yield remained consistent at 0.31 $10^3 m^3 CH_4.kg^{-1}$COD removed in spite of the drop in removal efficiency. At an HRT of 1.5d, when the OLR was at 4.1 $kg.m^{-3}.d^{-1}$, the reactor had completely failed and the effluent pH, alkalinity, and strength were as the same as the influent. At this point, no CH_4 was produced, and the COD and VS removal were zero. The reactor had turned 'soured'. Figure 5 shows the VS removal efficiency of the whole anaerobic operation for leachate treatment was consistently between 80-90 % until the operation failed.

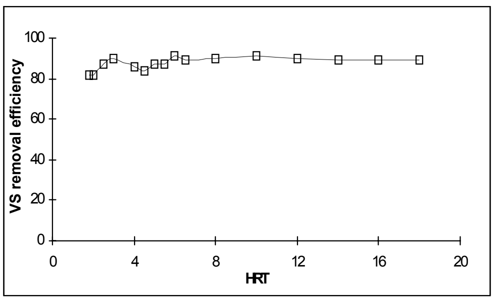

Figure 5 VS removal efficiency for anaerobic treatment of OFMSW leachate

Table 10 VFA analysis in the effluent of each HRTfor AF operation

HRT	VFA analysis
3.0	Total VFA 0
2.5	Total VFA 240 $mg.L^{-1}$ Acetate 200 $mg.L^{-1}$ Propionate 20 $mg.L^{-1}$ Butyrate 20 $mg.L^{-1}$
2.0	Total VFA 300 $mg.L^{-1}$ Acetate 200 $mg.L^{-1}$ Propionate 40 $mg.L^{-1}$ n-butyrate 40 $mg.L^{-1}$ n-valerate 10 $mg.L^{-1}$
1.8	Total VFA 1250 $mg.L^{-1}$ Acetate 500 $mg.L^{-1}$ Propionate 200 $mg.L^{-1}$ n-butyrate 200 $mg.L^{-1}$ iso-valerate 50 $mg.L^{-1}$ n-valerate 200 $mg.L^{-1}$ caproate 100 $mg.L^{-1}$
1.5	Total VFA 1250 $mg.L^{-1}$ Acetate 500 $mg.L^{-1}$ Propionate 200 $mg.L^{-1}$ n-butyrate 200 $mg.L^{-1}$ iso-valerate 50 $mg.L^{-1}$ n-valerate 200 $mg.L^{-1}$ caproate 100 $mg.L^{-1}$

VFA analysis

No VFA was present in the effluent during the fed-batch operation of readily biodegradable wastewater, OFMSW solid-free leachate, and OFMSW leachate. Table 10 shows the profiles and concentration of VFA in the effluent for each operational HRT associated with the anaerobic filter. During the continuous-feeding operation the VFA concentration started to increase in the effluent with the reduction of HRT. There was no change in the VFA concentration profiles in the effluent at HRTs from 1.8 d to 1.5 d. These VFA profiles and concentrations were similar to the influent values, meaning VFA removal efficiency had reduced almost to 0%. The reactor was still producing CH_4 at the HRT of 1.8 d, however, which indicates that methanogenesis was still occurring. A possible explanation is, these VFA's were being produced from the continuation of simultaneous hydrolysis, acidogenesis and acetogenesis of VS content as the VS removal efficiency was not affected. At an HRT of 1.5 d the reactor failed, and the VFA and VS concentration in the effluent were the same as in the influent.

CONCLUSION

Anaerobic process has always being the cleaner option for the stabilisation of OFMSW. Banks and Wang (1999) used the HFR as the anaerobic rapid hydrolyser on the mixed abbatoir wastes showed that it had removed 65% of TS. With the used of AF, the the leachate from such hydrolyser can be further treated up to the loading of 2.3 $kg.m^{-3}.d^{-1}$. This study shows that decoupling the phases in anaerobic process has able to make the treatment process more stable. Without phase separation in the process, imbalance of production of acidic components and its consumption will lead to operational failures as the rate of digestion for both groups of non-methanogen and methanogen is different. Using the decoupled operation, it requires lesser attention on the pH and alkalinity control for the methanogenic process, which has always been associated with failures during reactor shock loading. This study shows that the treatment of leachate requires no additional of pH controlling substances. However, the attempt to control the pH during reactor overloaded was not done to check whether addition of those substances may able to control the effect of disassociation of VFAs. It also can be assumed that the leachate has a balance nutrients composition based on the biomass concentration through out the experimental work. Generation of CH_4 from the leachate treatment still gives 0.3 $10^3m^3CH_4$. kg^{-1} COD removed, even when the removal efficiency has declined. High yield of CH_4 provide a promising solution for the sources of renewable energy.

ACKNOWLEDGEMENTS

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Ultrafiltration Using Gas Sparging Technique For The Treatment Of Natural Rubber Effluent

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ABSTRACT: Physical and chemical properties of natural rubber effluent have been identified to contain large amounts of non-rubber compounds and chemicals which can seriously damage or kill the natural flora and fauna of the waters when the effluent is discharged untreated. This paper presents the application of membrane technology for the treatment of natural rubber processing effluent that involves gas injection technique. During the experiments, permeate was collected and analysed for several characteristics such as total solids (TS), chemical oxygen demand (COD), biochemical oxygen demand (BOD), total nitrogen and ammoniacal nitrogen (NH_3-N). The results show that the use of gas sparging technique was able to enhance total permeate flux in the range 8.3% to 145.3% compared to non-gas sparging technique space like condition. In terms of permeate quality, reductions achieved for total solid (TS), chemical oxygen demand (COD), biochemical oxygen demand (BOD), total nitrogen and ammoniacal nitrogen (NH_3-N) were 95%, 67%, 77%, 51%, 74% respectively. For non-gas sparging technique condition, permeate flux declined sharply with time due to accumulation of foulant on the membrane surface. However both conditions showed increase of total permeate flux with transmembrane pressure and feed flowrate.

Keyword: natural rubber effluent, crossflow ultrafiltration, gas sparging technique

INTRODUCTION

Malaysia is a major producer of agricultural products. Although processing of agricultural products plays an important role in the economic development of Malaysia, it has also been identified as one of the major sources of pollution in this country. One such agricultural products is natural rubber processing effluent which can seriously damage or kill the natural flora and fauna of the waters when this effluent is discharged untreated. Currently most of the natural rubber effluent treatment in Malaysia uses anaerobic/facultative ponding system. This system is popular due to its simplicity in operation and low operating cost. Although this system is effective in removing most of the pollutants from natural rubber effluent, this system needs ample land for its construction and is not suitable for factories in the urban area because it emits offensive smell especially when it rains.

There is an emerging trend towards the use of the other technologies such as membrane technology to enhance treatment process performance. Nowadays, industries avoid use of dead end filtration mode which causes build up of debris on the membrane surface thus effecting a reduction in fluid permeation. Conversely, crossflow filtration employs tangential flow across the membrane surface. There are now four commonly accepted categories or classes of pressure driven membrane filtration processes, defined on the basis of size as shown in Table 1. Recently, the use of membrane filtration that involves gas sparging technique is being studied for the treatment of natural rubber effluent. The aim of this study to investigate the performance of membrane filtration with gas sparging technique to treat natural rubber effluent including to investigate the effects of operating conditions on total permeate fluxes.

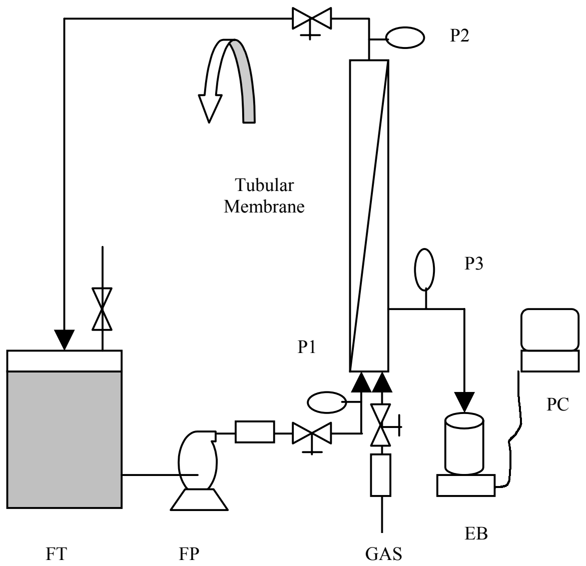
Table 1: Classification of pressure driven membrane filtration processes.

Membrane Process	Pore Size (μm)	Separation Capability	Pressure (bar)
Reverse Osmosis	<0,001	Dissolved salts and low molecular weight substances (up to 100 daltons)	7-70
Nano Filtration	0,0008-0,009	2-valent metal ions, 3-and more valent ions, molecules of low molecular weight (200-300 daltons), viruses	5-15
Ultra Filtration	0,005 - 0,05	Particles size over 1 μm, some viruses, bacterias, dissolved substances with molecular weight between 10 000 - 500 000 daltons	0,5-5
Micro filtration	0,05-5	Colloids, protozoa (Ciptosporidium, Giardia)	0,5-3

MATERIALS AND METHODS

Experimental Setup

The schematic diagram of crossflow ultrafiltration with gas sparging technique system is shown in Figure 1. All experiments were carried out at room temperature. A pilot scale system using a PVDF vertical tubular membrane (MWCO 100,000) has been installed for the experimental setup. It has an internal diameter of 12.5 mm, length 1.2 m, and effective surface area of 0.29 m^2. The natural rubber effluent solution was driven from feed tank by a gear pump and circulated through the membrane module with upward flow. The gas was directly injected to the inlet (bottom) of the membrane through a solenoid valve. Permeate was weighted using an electronic balance where the mass was recorded every five seconds and then recycled back to the feed tank to maintain a constant feed concentration. After each experimental run, the membrane was washed with 1.0% sodium hydroxide immediately and then flushed with distilled water. After cleaning the flux was checked to ensure that the intrinsic membrane resistance had recovered to its original value.



FT: Feed Tank FP: Feed Pump EB: Electronic Balance P1: inlet Pressure P2: Outlet Pressure P3: Permeate Pressure PC: Personal Computer

Figure 1: Schematic of semi pilot scale in upward crossflow ultrafiltration system

Operational Parameters

In order to evaluate the stability and capability of membrane processes, experiments were carried out at different operational condition and parameters. The range of transmembrane pressure (TMP) was varied from 7.5 psig to 13 psig, flowrate gas sparging of 0 -500 ml/min and liquid feed flowrate between of 1000 ml/min to 1600 ml/min.

All experiments were carried out at room temperature. Each experiment was run for 4 hours with interval of 30 minutes for sampling under both gas sparged and non-gas sparged conditions.

Sampling and analytical methods

Skim natural rubber latex serum derived from coagulation of skim latex was obtained from a factory. Due to the milky nature of the skim latex serum, it is necessary to store it overnight before use. Effluent sample and permeate was collected to be analyzed for pH, total solid (TS), chemical oxygen demand (COD), biochemical oxygen demand (BOD), total nitrogen and ammonia nitrogen (NH_3-N). The analyses were performed in accordance with procedures described in the standard methods for examination of water and wastewater.

RESULTS AND DISCUSSIONS

Permeate Quality Achieved

The characteristics of effluent after treatment which involved gas sparging technique and non-gas sparging technique are shown in Table 2 and Table 3.

Table 2: Characteristics of permeate after ultrafiltration under gas sparging condition.

Parameters	Feed	Permeate	%Removal
pH	3.75	4.46	+16
Total Solid (TS)	7100	370	95
COD	3998	1332	67
BOD_5	3642	853	77
Total Nitrogen	596	295	51
NH_4-N	435	115	74

(all values except pH are expressed in mg/l)

Table 3: Characteristics of permeate after ultrafiltration under non-gas sparging condition.

Parameters	Feed	Permeate	%Removal
pH	3.75	4.42	+15
Total Solid (TS)	7100	300	96
COD	3998	1337	67
BOD_5	3642	1012	72
Total Nitrogen	596	240	60
NH_4-N	435	110	75

(all values except pH are expressed in mg/l)

Both tables showed that the characteristics of the permeate quality are not distinctly different, probably due to use of the same material and molecular weight cut off of the membrane. However the total nitrogen content in permeate under gas sparging condition was higher than under non-gas sparging condition. This is probably due to some of the nitrogen gas being soluble in the feed stream during the experimental run. Consequently, the dissolved total nitrogen in permeate under gas sparging was higher than non-gas sparging condition.

Effect Of Gas Sparging On Total Permeate Flux

A typical graph showing permeate flux with time at a constant feed flowrate (1400 ml/min) and different gas sparging flowrate for 240 minutes is given in Figure 2. The effect of flowrate of gas sparging on total permeate flux at different transmembrane pressure for 240 minutes is shown in Figure 3. Both graphs showed that permeate fluxes increased significantly for different flowrate of gas sparging and transmembrane pressure. In Figure 2 it can be seen that permeate flux is found to decrease with time as the retained particles accumulate on the membrane surface and start to show the effect of fouling. Accumulation of cells, cell debris, or other rejected particles on the membrane surface occurs as external fouling or cake formation and is usually reversible. From both figures it is shown that the use of gas sparging technique can enhance permeate flux. Due to gas sparging technique, it will disrupt the cake layer formation on the membrane surface, as a consequence some of cell debris or foulant is swept away from the membrane surface.

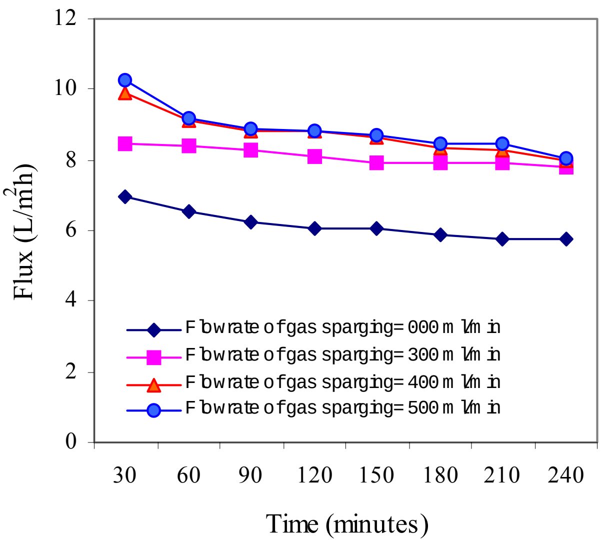


Figure 2: A typical graph showing permeate fluxes with time at different flowrates of gas sparging and a feed flowrate of 1400ml/min and TMP 13 psig.

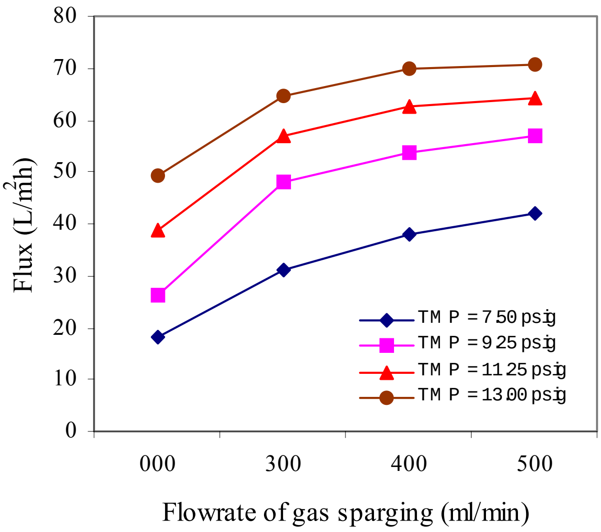


Figure 3: A typical graph showing the effect of gas sparging flowrate on total permeate flux at feed flowrate of 1400ml/min and different transmembrane pressure for 240 minutes.

The use of gas sparging technique also promotes turbulence in the feed stream thus reducing cake layer formation on the membrane surface. Results in permeate flux that are obtained are also higher due to the increase in turbulence in the feed stream. The use of gas sparging technique in upward crossflow when compared with the normal or conventional crossflow under non-gas sparging operation shows total permeate flux increase in the range of 8.3% to 145.3%.

In Figure 3 it can be seen that the highest total permeate flux was obtained at flowrate of gas sparging of 500 ml/min and at transmembrane pressure of 13 psig. In Figure 3 it is also shown that further increase in flowrate of gas sparging did not result in further increase of total permeate flux. It happened due to increase in flowrate of gas sparging at a constant feed flowrate which causes flow pattern changes inside the membrane where voids start to occupy more space than the liquid, thus resulting in total permeate flux decrease.

Effect Of Transmembrane Pressure On Total Permeate Flux

A typical graph that shows the effect of transmembrane pressure (TMP) on total permeate flux with gas sparging technique at a constant feed flowrate is given in Figure 4. The transmembrane pressure is calculated as the averages of the pressure value before and after the membrane module minus pressure of permeate. The applied transmembrane pressure was varied from 7.5 psig to 13 psig.

These results show that the total permeate fluxes increase approximately linearly with increase in transmembrane pressure and then decrease gradually.

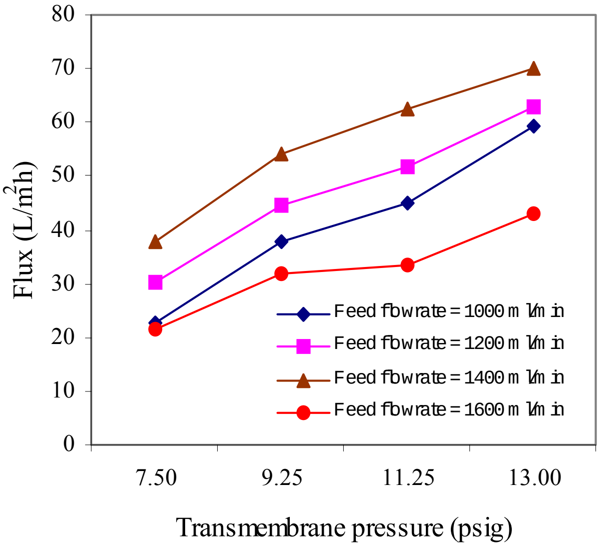


Figure 4: A typical graph showing effect of transmembrane pressure on total permeates flux at feed flowrate of 1400 ml/min for 240 minutes.

Let us take the case of feed flowrate of 1400 ml/min as an example. Initially, from TMP of 7.50 to 9.25 psig, the increase in the total permeate flux obtained is 34.7%. When TMP is increased from 9.25 to 11.25 psig, increase in the total permeate flux is 13.2%. Further increase in TMP from 11.25 to 13.00 psig, resulted in the total permeate flux of 10.1%. This shows that at higher the transmembrane pressure, the higher the total permeate flux and then further increase in transmembrane pressure the total permeate flux drop gradually. Eventually, a limiting permeate flux is reached where any further increase in transmembrane pressure no longer results in further increase in permeate flux. This is probably due to higher transmembrane pressure causing the cake layer or deposited layer on the membrane surface to become more compact resulting in higher resistance towards permeate flow.

Effect Of The Feed Flowrate On Total Permeate Flux

A typical graph showing the effect of feed flowrate at a constant flowrate of gas sparging (500 ml/min) on total permeate flux at different transmembrane pressure for 240 minutes is given in Figure 5. The figure generally showed a linear increase in total permeate flux with an increase in feed flowrate. However there was a sudden sharp decrease at a feed flowrate of 1600 ml/min. Decrease of the total permeate flux at a feed flowrate of 1600 ml/min was probably due to reduction in the driving force acting on permeable solution causing the concentration of rejected solute on the membrane surface being higher than that in the bulk solution. This is the so-called concentration polarization phenomenon, which results in fouling and solute adsorption on the membrane as well as a flux decline. As a consequence, less solution can pass through membrane and the rest remain as retentate. The figure also shows the maximum total permeate flux occured at feed flowrate of 1400 ml/min.

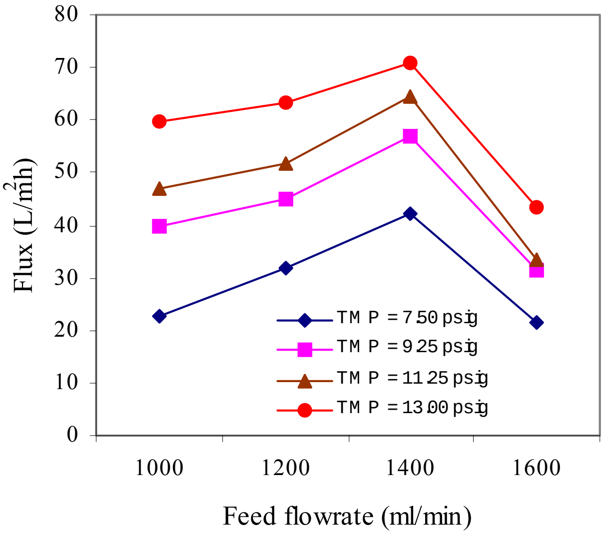


Figure 5: A typical graph showing effect of feed flowrate on total permeate flux at all TMP for 240 minutes under gas sparging condition.

Cake Layer Resistance

A typical graph showing the effect of different flowrate of gas sparging on cake layer resistance at a constant feed flowrate and at transmembrane pressure of 13 psig for 240 minutes is given in Figure 6. It can be seen that, increase in flowrate of gas sparging can reduce cake layer resistance. Reduction of cake layer resistance due to cake layer formation on membrane surface is small. For non-gas sparging condition the cake resistance is high. However when the gas is injected into the feed stream, it disrupts concentration polarization and cause increase turbulence in feed stream thus sweeping away foulant into the retentate. Images of cake layer formation that is taken using scanning electron microscope (SEM) can be seen in Figure 7a and Figure 7b respectively. From the images, cake layer that was formed on membrane surface under non-gas sparging condition was more distinct than under gas sparging condition. Development of cake layer on membrane surface with time increases with cake layer resistance. Cake layer resistance increases with time as the retained particles accumulate on and within in the membrane. Deposition and adsorption of small particles or macromolecules formed as internal fouling usually irreversible. Flux decline in membrane filtration is a result of the increase of the membrane resistance due to the development of these additional resistances.

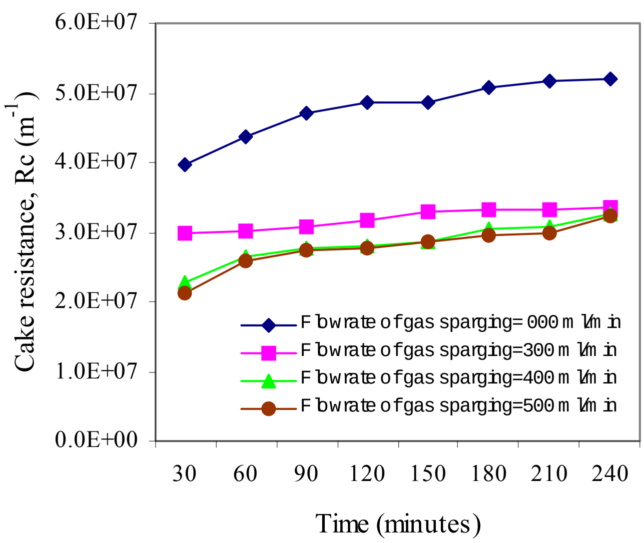


Figure 6: A typical graph showing effect of gas sparging on cake layer resistance at feed flowrate of 1400 ml/min and transmembrane pressure of 13 psig for 240 minutes.

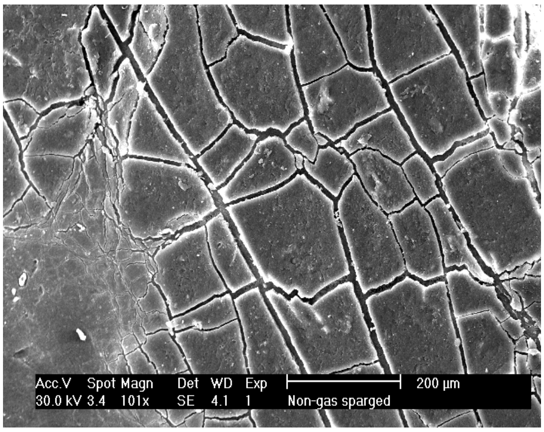


Figure 7a: SEM photograph of PVDF membrane after crossflow ultrafiltration of skim latex serum at feed flowrate of 1400 ml/min and transmembrane of 13 psig under non-gas sparging condition.

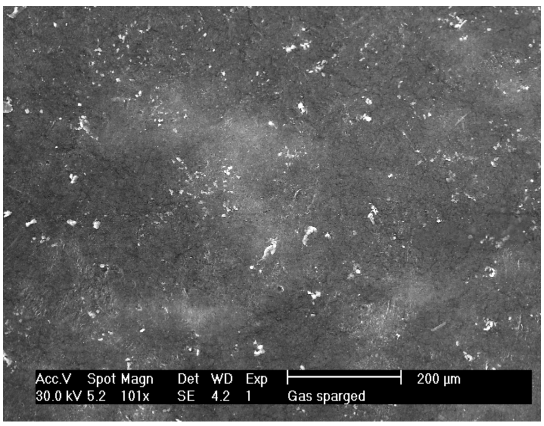


Figure 7b: SEM photograph of PVDF membrane after crossflow ultrafiltration of skim latex serum at feed flowrate of 1400 ml/min and transmembrane of 13 psig under gas sparging condition.

CONCLUSIONS

In this work, the potential of ultrafiltration using gas sparging technique on permeate flux of natural rubber processing effluent was investigated and the following conclusions could be drawn:

1. Reductions achieved for permeate quality with gas injection technique for total solids, COD, BOD, total nitrogen and NH_4-N were 95%, 67%, 77%, 51%, 74% respectively.

2. Reductions achieved for permeate quality non-gas injection technique for total solids, COD, BOD, total nitrogen and NH_4-N were 96%, 67%, 72%, 60%, 75% respectively.

3. Using the gas injection, the homogeneous liquid phase was changed to heterogeneous gas-liquid phase.

4. The technique of gas injection into feed stream was found to effective in enhancing permeate flux.

5. Gas injection technique when compared with non-gas injection technique results in permeates flux increases in range 8.3% and 145.3%.

6. In this work the recommended optimal conditions are gas injection 500 ml/min, feed flowrate 1400 ml/min and transmembrane pressure 13 psig.

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Bioremediation of Maleic Anhydride

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ABSTRACT: This study was conducted to remediate the soil contamination issue identified in a petrochemical plant. Bioremediation was selected as the remedial options based upon a comprehensive Remedial Investigation/Feasibility Study (RI/FS) conducted earlier. This paper will present the findings of the bench scale bioremediation of Maleic Anhydride and its associated products, i.e. Phthalic Anhydride, Maleic Acid, Fumaric Acid and Benzoic Acid. The kinetic constant (K) and half-life of Maleic Anhydride were identified as –6.658 and 0.1 days, respectively. . The K value and the half life of Maleic Anhydride are consistent with the available literature sources. The project was later scaled up for the field implementation successfully.

Keywords: Soil contamination, bioremediation, Maleic Anhydride, kinetic constant, and half life.

INTRODUCTION

Soil contamination occurred due to the improper storage and leakage of waste by-product in a petrochemical plant. This remediation project is part of the remediation efforts that was ultimately aims to clean-up the impacted soil at the facility. The main objectives of this project was to assess the feasibility and treatability of bio-remedial process for the impacted soil. As an immediate response to the contamination, the facility has subsequently conducted an initial investigation in a grid pattern at 1 feet to 4 feet below ground surface (bgs.) at the impacted area. Soil samples were collected and analyzed in the laboratory for Maleic Anhydride and Fumaric Acid.

BACKGROUND

During the project, existing site data were collected, reviewed and compiled primarily for further interpretation. Scope of work performed were to interpret and map the residue concentrations in aerial and vertical extents over several sampling layers to delineate the extent of the contamination and estimate the volume of impacted soil. The largest impacted planar was at 1 feet bgs. with the area of 802 m^2 and the total volume of impacted soil was approximately 607 m^3. Based on the sampling events conducted, the primary Chemicals-of-Concern (COC) were identified based on exceedance of either the Netherlands' Dutch Intervention Values (DIV) or the US-EPA Preliminary Remediation Goals (PRGs) standards. Basically, the COC mainly consists of metals and semi-volatile organic compounds (SVOCs). Due to metals concentrations were generally detected at higher concentrations in background soil sample than samples from impacted area, it was concluded that the metals detected in the impacted soil samples are attributed to the natural occurring minerals in the geologic formation.

There were four types of SVOCs detected at high concentrations in soil at impacted area; one of the highest detected was Maleic Anhydride ($C_4H_4O_4$). The concentration detected was 223,000 mg/kg compared to PRG value of 88,000 mg/kg.

Table 1: Concentration of COCs Compared to PRG

Matrix	Parameter	Lab. Results	Ref. Values	Int. Standards
Soil (mg/kg)	Maleic Anhydride	223,000	88,000	PRG
	Phthalic Anhydride	0.07	100,000	PRG
	Maleic Acid	20,200	NA	NA
	Fumaric Acid	14,700	NA	NA

Notes: NA - Not Available
PRG - Preliminary Remediation Goals

However, Phthalic Anhydride was detected at concentration well below the PRG value. Therefore, it is not considered as one of the COC, but since Phthalic Acid is one of the relevant degradation product of Phthalic Anhydride and it is regulated under PRG, it was added in the monitoring list of this project. Besides that, Benzoic Acid was added in this project as a monitoring parameter due to local authority's request.

Based on the physical and chemical properties of Maleic Anhydride that it's readily biodegradable, bio-treatability studies has been selected as the treatment process for investigation in this study. Tests were designed to allow evaluation of the biodegradation rates under different bench-scale treatment conditions. In favourable conditions, microorganisms is capable of degrading organic compound into carbon dioxcide and water (under aerobic condition) or organic acids and methane (anaerobic). The laboratory scale experiments conducted included:

i) Control soil pile (CP) which soil maxtrix was neutralized with lime;
ii) Treatment pile 1 (TP1) which soil pile was neutralized with lime, and mixed with nutrients.

iii) Treatment pile 2 (TP2) which soil pile was neutralised with lime, mixed with nutrients and equipped with mechanical aeration.

The COCs monitored throughout the treatability study were Maleic Acid, Maleic Anhydride, Phthalic Anhydride, Phthalic Acid and Benzoic Acid. The physical parameters such as pH, moisture content, temperature and oxidation reduction potential (ORP) were also monitored. In addition, the microbial total plate count was also analysed to characterize the microbial activities in the soil pile.

METHODOLOGY AND APPROACHES

Representative composite soil samples were collected using a grid system by drilling equipment. Depth discrete samples were collected at 0.5 m intervals to their respective depth of 3 to 4 m bgs. A total of 300 kg of soil sample were collected. Before soilpile were constructed, the soil sample will first neutralized to pH around 7 by using lime.

The soil samples were divided equally into three portions of 100 kg each:-
a. For the first soil pile, CP, there is no addition of mixing materials; and
b. For the other two soil piles, TP1 and TP2, the neutralized contaminated soil was mixed with nutriens (chicken faeces) at recommended soil void volume (sawdust).
The carbon source and nitrogen source ratio was 1: 30 while the soil void ratio was at 30 percents based on volume basis. Two-inch diameter slotted perforated pipe, mechanical blower and electrical control panel were installed at TP2 for mechanical aeration.

The three soil piles were monitored with a sampling program and samples were sent for laboratory analysis according to testing methods below:-

Table 2: Laboratory Testing Method.

Parameters	Test Method
Total Plate Count	APHA 9215D
Phthalic Anhydride	Finger printing analysis SW 846 8270
Benzoic Acid	Finger printing analysis SW 846 8270
Phthalic Acid	Finger printing analysis SW 846 8270
Maleic Acid	High Performance Liquid Chromatography
Maleic Anhydride	High Performance Liquid Chromatography

Biodegradation kinetic rate (abrreviated as K) for the three experimental piles were evaluated by Michaelis Menten Equation as shown in equation (1). The derivative is a negative number because the concentration of the contaminant, S, was decreasing:

$$\frac{dS}{dt} = -\frac{k_0 SX}{K_M + S} \quad \text{..................................(1)}$$

where:
X = concentration of microbes, mass/volume;
k_m= maximum utilization coefficient, maximum rate of substrate utilization at high substrate concrentration, mass substrate/mass microbes-day;
K_M= half-velocity coefficient, also referred to as the Michaelis-Menten coefficient, mass/volume;
K_0 = the maximum rate constant; and
S = concentration of the rate-limiting substrate, mass/volume.

Microbial growth is defined as microbial specific growth rate, μ derived by using Monod equation govern by equation (2):-

$$\mu = \mu_m \frac{S}{K_S + S} \quad \text{...(2)}$$

where:
μ = specific growth rate, $time^{-1}$
μ_m = maximum specific growth rate, $time^{-1}$
S = concentration of the rate-limiting substrate, mass/volume.
K_S = half-velocity constant, substrate concentration at one-half the maximum growth rate, mass/volume

The Monod model applies to soluble contaminants and heterogeneous system, where kinetic rate is a linear function of the number of active sites on contaminants and non linear with the microbial concentration.

Upon development and combination of Michaelis Menten and Monod understanding, Van Uden expressed that the net specific growth rate is given by equation (3).

$$\mu^{'1} = \mu_m \frac{S}{K_S + S} - k_d \quad \text{.....................................(3)}$$

where:
$\mu^{'1}$= net specific growth rate, $time^{-1}$
k_d = endogenous decay co-efficient, $time^{-1}$

Half-life usually symbolized by $t_{1/2}$, it is the time required for [S] to drop from its initial value $[S]_o$ to $[S]_o/2$. It is simply the time required for half of the amount originally present to react. At the end of one half-life, 50% of the original atoms or molecules remain.

RESULTS AND DISCUSSIONS

The physical parameters monitored compared with the recommended ranges are presented as below:

Table 3: Range of Physical Parameters Recorded for Experimental Soil Piles.

Experimental Piles	Moisture Content (%)	Redox Potential (mV)	Temp. (^{0}C)	pH
CP	9.2-25.8	207-287	28-35	3.80-8.17
TP1	6.6-44	82-203	27-41	4.87-8.46
TP2	3.6-36	92-201	26-38	6.74-8.94
Recommended Range	20-40	-240 - +800	<40, 40-70, >70	6-8

The biodegradation rate for the three experimental piles were evaluated by first-order kinetic. The calculated K values for Maleic Anhydride, Maleic Acid and Benzoic Acid for the three experimental piles are presented below.

Table 4: Biodegradation Rate for Experimental Soil Piles.

Experimental Piles	Biodegradation Rate, K (unitless)		
	Maleic Anhydride	Maleic Acid	Benzoic Acid
CP	-0.592	-0.010	-0.020
TP1	-5.935	**-0.026**	-0.029
TP2	**-6.658**	-0.014	**-0.044**

Notes: Negatives sign of K values indicative of decreacing concentrations over time.

Due to the presence of secondary compounds generated during the degradation process, the lag time for the generation of these secondary compounds (Maleic Acid and Benzoic Acid) were evaluated. The lag time for these two secondary compounds to reach their maximum concentrations are presented as follows:

Table 5: Lag Time for Experimental Soil Piles

Experimental Piles	Lag Time, (day)	
	Maleic Acid	Benzoic Acid
CP	39	20
TP1	37	10
TP2	**30**	**10**

Experimental pile TP2 has the shortest lag time for Maleic Acid (30 days), while both the TP1 and TP2, have the shortest lag time for Benzoic Acid (10 days).

The half-life calculated for Maleic Anhydride, Maleic Acid, and Benzoic Acid for the three experimental piles are:

Table 6: Half Life for Experimental Soil Piles

Experimental Piles	Half Life, $t_{1/2}$ (day)		
	Maleic Anhydride	Maleic Acid	Benzoic Acid
CP	1.1	66.4	32.2
TP1	**0.1**	**24.3**	21.9
TP2	**0.1**	44.5	**14.5**

TP1 and TP2, both exhibited the shortest half-life of 0.1 day for Maleic anhydride. TP1 has the shortest half-life for Maleic acid, and TP2 has the shortest half-life for Benzoic acid.

In general, TP2 is the optimal experimental pile with fastest degradation process for Maleic Anhydride and Benzoic Acid; while TP1 is the optimal experimental pile for Maleic Acid, based on the degradation rate (K), lag time, and half-life obtained from the three experimental piles.

The microbial specific growth rate for the three experimental piles were derived by using Monod equation, whereby the bacteria count (colony forming unit per milli-litre, CFU/ml) were tabulated against time.

Table 7: Bacteria Count (cfu/ml) against Time.

Day	CP	TP1	TP2
1	780	1.20E+09	6.96E+07
3	690	7.92E+08	3.80E+06
5	600	4.20E+07	3.06E+08
10	3.20E+05	8.80E+08	2.34E+08
15	1.05E+08	4.12E+08	1.02E+07
20	4.56E+07	2.37E+08	1.50E+08
25	1.44E+09	2.61E+08	2.88E+08
30	2.56E+08	5.20E+06	1.93E+08
39	3.01E+08	2.95E+06	3.66E+08

The specific growth rate (μ) were derived and presented as follows:

Table 8: Specific Growth Rate for Experimental Soil Piles

Experimental Piles	Specific growth rate, μ (day^{-1})
CP	1.2073
TP1	**0.6085**
TP2	0.4651

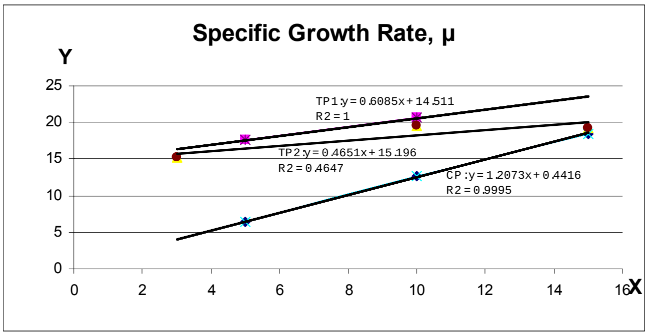

Figure 1: Specific Growth Rate for Experimental Piles Derived by Using Monod Equation.

Based on the calculation, the control pile has the highest value of specific growth rate. However, it should be noted that the microbial population was accelerated only after 20 days of experiment. Comparatively, TP1 has a slightly higher value for the specific growth rate.

The range of microbial count were consistent for TP1 and TP2, that is in the magnitude of 10^6 to 10^9. Control pile has the lowest value of microbial count (in the magnitude of 10^2). This is due to the longer lag phase experienced in the control pile. In general, TP1 supported a better environment for the growth of microbial population compared to TP2 and control.

Table 9: Range of Microbial Count for Experimental Soil Piles

Experimental Piles	Range of Microbial Count, cfu/ml*
CP	$6.00x10^{2} – 1.44x10^{9}$
TP1	$2.95x10^{6} – 1.20x10^{9}$
TP2	$3.80x10^{6} – 3.66x10^{8}$

** Note: colony forming unit per millilitre.*

CONCLUSIONS

Results of treatability study indicated good results were achieved in both biopiles TP1 and TP2. Generally, biopile TP2 has a higher biodegradation rate compared to biopile TP1. However, to set-up biopile TP1 set up was more feasible and applicable option to be implemented onsite; less resources like electricity and start-up capital cost was involved compared to setting up of biopile TP2.

Table 10: Summary of Results.

Results	COCs	TP1	TP2
Biodegradation rate, K value	Maleic Anhydride	-5.935	-6.658
	Maleic Acid	-0.026	-0.014
	Benzoid Acid	-0.029	-0.044
Lag Time (day)	Maleic Acid	37	30
	Benzoid Acid	10	10
Half Life, $t_{1/2}$ (day)	Maleic Anhydride	0.1	0.1
	Maleic Acid	24.3	44.5
	Benzoid Acid	21.9	14.5
Microbial Specific Growth Rate, μ (day^{-1})	-	0.6085	0.4651
Bacteria Count (cfu/ml)	-	2.95×10^{6} - $1.20 x10^{9}$	$3.80x 10^{6}$ - $3.66 x10^{8}$

The project was later scaled up for the field implementation successfully based on methodology and mixing ratio for treatment option TP1.

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Renewable Energy Production Using Biological Process for Municipal Solid Waste Management in Malaysia

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ABSTRACT: Municipal Solid Waste (MSW) management in Malaysia has been highlighted by our government as an important agenda in ensuring a further success of the country. Due to the fast growing urbanization and industrialization of the country, a tremendous increment of solid waste generation is an unavoidable occurrence. In the past years, many countries have relied almost exclusively on landfills for the disposal of the generated MSW. Due to the potential for environmental damage from landfill sites, the scarcity of land near urban centres and growing public opposition, there is a trend towards creating an integrated MSW management system with resource recovery options such as anaerobic digestion, composting and recycling. An innovative system combining methods of anaerobic digestion and aerobic composting are proposed for the recovery of energy and the production of compost for organic fraction of household waste while reducing waste disposal problem. The anaerobic digestion of organic solid waste produces biogas, which is an excellent energy source used as fuel in combined heat and power units. The production of methane via anaerobic digestion would benefit society by providing clean fuel from renewable feedstock. This would replace fossil fuel-derived energy and reduce environmental impacts including global warming and acid rain.

Keywords: Solid waste management, anaerobic digestion, methane, compost

INTRODUCTION

Rapid urbanisation in most developing countries such as Malaysia is one of the emerging challenges of our time. The expansion of cities and the creation of urban conurbation, with growth in their populations, will continue and problems associated with such large urban centres should therefore be expected. The fact that the productive activities tend to be concentrated in urban centres where 60% of the gross domestic product (GDP) is generated is an important point to consider (Bartone and Bernstein, 1993). In some largely urban countries, the urban share of GDP is as high as 80% in the year 2000. According to the World Resources Institute (1990), the percentage of the world's total population in developing regions will have increased from 67% in 1950 to 84% in 2025. Recent studies indicate that the waste generation rate in Malaysia has increased from 0.7 kg/capita/day in 1991 to about 1.0 kg/capita/day in the year 2000, and to further increase steadily at a rate of 2% per annum per capita (Hassan (a), 2000). At present, the capital city Kuala Lumpur alone generated waste approximately 2200 tons/day (Hassan(b), 2000).

The underlying threat of the inability of urban areas to cope with the increasingly large amounts of waste that will be produced and the attendant health problems, is what professionals engaged in waste management will have to contend with. The situation is further compounded and aggravated in the low-income settlements due to additional problems of crowded dwellings, congested traffic, air pollution, and water contamination. For developing countries, these problems present serious challenge to the problem of solid waste management.

SOLID WASTE TREATMENT AND DISPOSAL IN DEVELOPING COUNTRIES

The ineffective management of solid wastes in most developing countries is a fact that has been established among experts in the field. Whereas the shortfalls in service delivery is correctly attributed to inadequate inputs to solid waste management (SWM) services; selection of equipment, methods of collection and transportation of waste, it is the disposal stage which often has the most impact on the environment and health. Current service coverage in most developing countries is inadequate with the poor sections of many urban centres without any proper service. Generally, less than half of the waste generated in most cities of developing countries is collected by municipal authorities whilst uncontrolled dumping in open spaces, access roads and water courses is widespread (Habitat, 1988). The major contributing factors responsible for this problem can be summarised as:

- *Inadequate resource mobilisation*. The municipal income base from which revenue is derived is much smaller in developing countries (5 to 20 %) as compared to developed countries. This is due to the lower average disposable income, inadequate tax collection systems and poor administration.
- *Over-reliance on imported equipment.* This often is not matched by an adequate supply of fully trained

staff and thus prone to operation and maintenance snags.

- *Inappropriate methods of finance*. Many foreign-aid programmes are often tied to the capture of markets for supplying most inappropriate and ineffective machinery and their subsequently needed spare parts.

- *Use of inappropriate technology*.Many authorities have been led to introduce systems that have proved inappropriate and ineffective due to the lack of appreciation of socio-economic and cultural factors, which determine behavioural responses from the public.

- *Inequity in service provision*. Low-income communities in urban areas, where population densities are highest and hygiene most lacking, have the greatest need for the service. Unfortunately, they have traditionally been denied adequate access to waste disposal.

However, the underlying issues behind these factors are mostly related to management and organisation, and not so much on financial (Rushbrook and Finnecy 1988, Cointreau 1982). Therefore, the priority when attempting to tackle solid waste management problem should focus on these rather than pouring money into the system indiscriminately.

With a rapid growth of urban areas, accompanied by increasing population densities and increasing per capita production of solid wastes, the pressure on many cities' already deficient service will increase. One might want to ask that if developing countries were to collect 75 percent of the total solid waste generated, would the existing facilities (landfills) cope with the increased waste volumes? The answer to this is generally left to practitioners in the field.

Presently, the most appropriate cost-effective options for refuse disposal and treatment in developing countries would appear to be sanitary landfilling and/or composting and its variations. However, most landfilling practice in developing countries does not meet the basic requirements of sanitary landfill, which are leachate collection systems, gas control systems and groundwater monitoring systems. Consequently, gross adverse environmental effects occur. Rapid urban growth is also imposing a limit on the cost-effective use of landfilling in most developing countries as they are sited further away from the sources of generation; a problem already encounter in most developed countries. To forestall the problem of inadequate landfill capacities owing to increased volumes of solid wastes, a proper practice is called for.

Recently interest has focused on resource recovery options as possible methods for treatment of solid organic waste. Biological treatment such as composting and anaerobic digestion, although attractive has received limited attention in most developing countries due to lack of appropriate technology and poor product marketability. However, recent innovations in anaerobic digestion and composting technology in Europe and the United States of America has demonstrated the potential viability of this method, if not as an income generating operation, as a treatment method.

EFFECTIVE SOLID WASTE MANAGEMENT

The problems of urban solid waste management in developing countries, while broadly similar to those in the developed countries, have some peculiarities of their own, especially in tropical regions. These peculiarities arise from life styles which themselves are often influenced by tradition, religion, economics, standard of living and climate. There is no universal solution applicable to all cities (Flintoff,1977). Every city has different prevailing characteristics, and thus, the workable waste management plans should consider factors such as; (a) climate and seasonal variations, (b) budget and foreign exchange limitations, (c) economic structure of the region, (c) physical characteristics of the cities, (d) social and religious customs, (f) level of public health knowledge among the general public, (g) quality of management and available technical skills, and (h) setting and enforcement of appropriate environmental standards.

Appropriate technology has become an important concept for urban as well as rural planning. This not only refers to operation and cost of machines imported from developed countries, but also appropriateness of the techniques in a specific setting. Consequently, a waste management plan should best be prepared locally against the background mentioned previously. It may also be the case that an appropriate technology, whilst appropriate to the first inhabitants, may not be appropriate for the following generations who may have changed their way of living which does not fit in with the existing technology. This could happen through changes in the social, educational and economic conditions.

A successful overall strategy should be environmentally and economically sustainable. Environmentally sustainable means that it must reduce as much as possible the environmental impacts of waste management, including energy consumption, pollution of land, air and water and loss of amenity. It must operate at a cost acceptable to the community, which depends on existing local infrastructure, and ideally should be little or no more than existing waste management cost. However, it is very difficult to minimise the variables simultaneously, hence, there will always be a trade-off. Economically and environmentally sustainable solid waste management is likely to be integrated, market-oriented and flexible.

According to White (1995), an integrated system must consider storage, collection, transport, and processing, followed by one or more of the following options which have to be developed such that they are compatible with one another:

- Recovery of secondary materials (recycling)- this will require adequate sorting and access to reprocessing facilities. The potential materials are paper, board, glass, ferrous metal, aluminium cans, non-ferrous metal, plastic and textiles;

- Biological treatments of organic materials- this will produce marketable compost or reduce volume for disposal. Anaerobic digestion produces methane that can be burned to release energy;

- Thermal treatment- this will reduce volume, render residues inert and may recover energy; and

- Landfill- this can increase amenity via land reclamation but will at least minimise pollution and loss of amenity.

In addition to the above, they must be strategically supported by other relevant programmes, which includes factors such as behavioural patterns, economic conditions, public education, public relations and training. According to Rushbrook and Finnecy (1988), there are certain requirements for an effective solid waste management, namely trained and experienced people, equipment, land, money and organisation that involve technical, financial, institutional and social considerations.

PRINCIPLES OF ANAEROBIC DIGESTION TECHNOLOGY

Anaerobic digestion is a biological process in which biodegradable organic matters are broken down by bacteria into biogas, which consists of methane, carbon dioxide, and other trace amount of gases. It is a process responsible for degradation of much carbonaceous matter in natural environments where organic accumulation results in depletion of oxygen for aerobic metabolism. Oxygen-free is the primary requirement of anaerobic digestion to occur, while other important factors such as temperature, moisture, nutrient contents and pH are also critical for the success for the process. Anaerobic digestion can be best occurred at two range of temperatures; mesophilic (30-40^oC) and thermophilic (50-60^oC) with moisture contents in greater than 85% or higher.

A generalised scheme for anaerobic digestion is that the feedstock is coarsely shredded, and placed into a reactor which has an active inoculum of microorganisms required for the methane fermentation. A conventional reactor is mixed, fed once or more per day, heated to a temperature of 35^oC, and operated at hydraulic retention time of 20-30 days and loading rate of 1.7 kg VS (organic matter as ash-free dry weight) m^3 d^{-1}. Under these conditions, about 60% reduction in organic matter is achieved corresponding to a methane yield of 0.24 m^3 per kg VS added. The composition of biogas produced is typically 60% methane and 40% carbon dioxide with traces of hydrogen sulfide and water vapour. Solid residues may be settled and/or dewatered by other means and used as compost. The product gas can be used directly or processed to remove carbon dioxide and hydrogen sulfide.

Biomass and organic wastes may be converted into a variety of energy forms including heat, steam, methane, electricity, hydrogen, methanol, and ethanol. Selection of a product for conversion is dependant upon a number of factors, including need for direct heat or steam, conversion efficiencies, energy transport, economies of scale, environmental impact of conversion process waste streams and product use. Under most circumstances methane is an ideal fuel. Compared to other fossil fuels, methane produces less atmospheric pollutants and generates less carbon dioxide per unit energy. Because methane is comparatively a clean fuel, the trend is toward its increased used for appliances, vehicles, industrial applications, and power generation.

The conventional design of anaerobic digestion is being replaced by more innovative designs influenced primarily by feed suspended solids content. The objectives of most of these advanced designs are to increase solids and microorganism retention, decrease reactor size and reduce process energy requirement.

JUSTIFICATION OF ANAEROBIC DIGESTION AS APPROPRIATE TECHNOLOGY FOR SOLID WASTE MANAGEMENT IN MALAYSIA

Anaerobic digestion of organic wastes is receiving increased attention because biomethanogenesis decomposes organic matter with production of useful energy product and organic fertilisers. With increased levels of waste production, limited area for landfilling, and increased awareness of environmental impact, alternative methods of treatment of solid and agricultural wastes are being sought. Currently these wastes release undesired methane into the atmosphere due to anaerobic conversion in landfills, lagoons, or stock piles.

Methane as renewable energy can be produced from organic wastes by anaerobic digestion or biological gasification. Resource potential estimates for several feedstocks including municipal solid waste and sewage sludge (Table 1) has been reported at 7 EJ (one exajoule=1 quad = 1015 Btu) and 22 EJ for terrestrial biomass (grasses and woods). The potential of marine biomass is huge at greater than 100 EJ per year. However, this optimistic estimate has many uncertainties related primarily to design of off-shore farm. Total estimation indicated that the potential from several feedstock is 29.5 EJ/yr exluding marine biomass.

Anaerobic digestion is suitable for treatment of agricultural wastes, household waste, garden and park waste, sewage sludge and solid waste products from food that will produce beneficial end-products. Selection of appropriate waste treatment greatly depended on various factors. The quantities of solid waste generated by each inhabitant in most developing countries may be less than in the developed world due to lower general prosperity and level of consumption by the population. The amount of refuse produced in Europe and North America may be as high as 2 kg/person/day, while in tropical developing countries it is usually between 0.3 to 1.0 kg/person/day (Cairncross and Feacham, 1983). Waste in developing countries is usually denser than in developed areas, and its composition is an indicator of the socio-economic situation of the population (Holmes, 1984).

Table 1: Energy potential of several biomass and wastes (Chynoweth, 1987)

Resource	EJ/yr
Municipal solid waste	1.5
Sewage sludge	0.8
Biodegradable industrial wastes	0.4
Crop residues	4.1
Logging residues	0.3
Animal waste	0.4
Energy crops:	
a. land-based	22.0
b. marine	> 100
Total (excluding marine)	29.5

Table 2 shows a comparison of typical refuse compositions represented for some developed countries and developing countries. It is difficult to compare solid waste characteristics and composition of different countries due to varying methods of sampling and investigation (Yhdego, 1991). The distinct differences and general trends that can be identified; the vegetables and ash fractions dominate the waste composition in developing countries, which is three to four times greater than in developed countries. The biodegradable portion of waste in hot humid climatic conditions decomposes rapidly, and hence requires an efficient management system.

Table 2: Comparison of waste characteristics and composition (% by weight)

Composition (% weight)	U.S.A. (1)	U.K. (2)	Kuala Lumpur, Malaysia (3)	Jakarta, Indonesia (4)
Organic	22.6	19.0	45.5	60.0
Paper	37.6	29.0	30.0	2.0
Metals	8.3	9.0	5.10	2.0
Glass	6.6	8.0	3.9	2.0
Textiles	3.0	3.0	2.1	na
Plastic/leather/ Rubber	12.3	7.0	11.10	2.0
Wood	6.6	2.0	na	na
Dust/ash/others	3.1	21.0	4.3	33
Refuse density (kg m-3)	100	147	230	200
Per capita (kg day-1)	1.97	0.95	0.76	0.60
Moisture content (%)	20	30 to 35	65	55 to 75

Sources: (1) EPA (U.S.A.), 1994
(2) Dept. of Energy, 1990
(3) Hassan *et al*, 1998
(4) Baldisimo *et. al.*, 1988

Organic matter makes up a large proportion of the waste in developing countries, and most of the valuable items are extracted by people to either be sold or re-used. While Asian nations generate as much as 75% organic wastes. U.S.A. and U.K. generate more paper (about 40%). Most of paper is recycled efficiently by scavengers in the Asian nations, especially in less developed countries like India, Nepal and Pakistan. Plastics, leather and rubber are typically present in low quantities in most Asian countries, but in the developed nations it accounts for about 7% to 12%. Furthermore, the quantity of ash and earth may be higher in developing nations due to the presence of surface drain sludge, silts and the cooking and domestic heating methods that use wood or charcoal. The proportion of roads with engineered surfaces such as asphalt and concrete is generally greater in large cities and consequently the ash and earth content is less. Due to a significant amount of putrescible matter with high moisture content and greater quantity of ash and earth found in the refuse, the density is much higher than that of developed nation. The density of refuse in industrialised countries can be as low as 100 kg/m^3 while in developing countries it could be around 400 kg/m^3.

Because a large organic fraction with high moisture content is present in most developing countries refuse, therefore, biological process can be seen as a viable option for solid waste treatment whilst making incineration relatively unsuitable. Although mechanistic processes are presently prevalent in the developed countries, a system with low demand on capital and maintenance cost is the most ideal technology for lower-income countries.

Cost will always be an important criterion in the choice of waste management methods to ensure satisfactory standards for the protection of health and the environment. Production of renewable energy, improvement on environmental pollution in air and water, reduction of municipal and agricultural wastes, and utilisation of byproducts as organic fertilisers, has increase the attractiveness of anaerobic digestion application.

Energy is the lifeblood of any economy and plays a key role to achieving the nation's vision. For Malaysia, the national quest is to be a developed country by the year 2020. Therefore, the growth and development of Malaysia energy sector will continue towards industrialisation and socio-economic welfare, and therefore Malaysia gives a high priority to ensuring greater security and sustainable of energy supply. Economic growth cannot happen without the increased use of energy. Currently combustion of fossil fuel such as oil , natural gas and coal is still the predominant means to derive energy for Malaysia. However, the increment appetite for energy is suffocating our environment.

In Malaysia, other than hydrocarbon sources, renewable and clean energy resources are available. Organic residues can be obtained from agricultural and food processing, municipal solid waste and animal manure. Renewable energy is now endorsed to be the fifth fuel by the Malaysian government. Efforts are now geared towards the promotion of renewable energy sources. The world consumption of renewable energy sources is projected to grow at 2.3 per year between 1990 to 2010 (Sulaiman, 2000).

The byproduct of anaerobic digestion is compost. The waste in many developing countries is ideal for conversion into organic fertiliser where waste is wet and highly organic, and can be recycled as compost that can replace some commercial fertiliser. Economic forces also favour compost usage where high food production is of great importance, and fertiliser imports are limited by foreign exchange constraints.

Many of the less developed countries are in the tropical or sub-tropical zones where high soil temperatures lead to far faster loss of organic matter; this immediately puts these countries at a disadvantage as their soils need a constant input of organic matter to remain productive. Compost application to agriculture is by far the most responsible technical solution for many developing cities, especially where the climate is arid and the soil is in serious need of organic supplements. In addition, manuring with compost instead of untreated organic waste products gives a more uniform spread of the plant nutrients, and in contrast to raw organic waste, the compost is not phytotoxic, so seedlings and plant roots will not be damaged.

The nutrients such as nitrogen, phosphorus and potassium (N, P, K) which are present in the waste are usually in complex organic forms, difficult to be taken up by the crops. After composting, some of these nutrients would be in inorganic forms such as NO_3^- and PO_4^- that are a more available form for crop uptake. Compost is more like a slow release fertiliser because the bacteria slowly convert the organic nitrogen, which is tied up in the organic material, into an inorganic form, which is then appropriate for uptake by the plants. The application of compost product as fertiliser to land will reduce nutrient loss through leaching because the inorganic nutrients are mainly in the insoluble forms, which are less likely to leach than the soluble forms of the uncomposted wastes. In addition, the soil tilth is improved thereby permitting better root growth and consequently ready accessibility to the nutrients (Golueke, 1982). The application of compost to unproductive soils should eventually improve the soil quality, and the otherwise useless land can be reclaimed.

A range of excreted pathogens which pose a high risk of infection and disease to humans, animals and plants, can be present in untreated solid waste and these are destroyed because of the high temperatures during the process. Temperature and length of the exposure time are the two most important parameters responsible for pathogen die-off during the biological process. Although there are some pathogenic micro-organisms that can survive exposure to temperatures above 100^{o}C, the most dangerous of the pathogens in waste can be eliminated at much lower temperatures.

CONCLUSIONS

Malaysia is still struggling to select the most appropriate method to dispose municipal solid wastes with various available alternatives such as incineration, gasification, composting and landfilling. Biological process such as anaerobic digestion could provide a vital element in an integrated solid waste management system for a community in a developing country while preserving the natural ecosystem within an acceptable cost. Organic waste is a resource that needed to be tapped and not to be wasted into landfills or reduced to ashes and dust in incinerators. The renewable energy and compost produced from anaerobic digestion process can be seen as a good reason to for many community to start recycling our valuable resources.

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TREATMENT OF TRICHLOROETHYLENE CONTAMINATED WASTEWATER USING FENTON'S REAGENT

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ABSTRACT:

Trichloroethylene (TCE) was contaminated in wastewater by its used for solvent in many industries. The treatment of TCE was studied by using the Fenton's reaction with optimized the conditions in laboratory scale. The feasible implementation to the real wastewater treatment system and the economic evaluated were also studies.

The results showed that the optimum (molar concentration) ratio of H_2O_2: Fe^{2+}: TCE = 20:2:1 could treated the TCE over 90% and the recycling of reagent was possible.

Keywords: Fenton, TCE, TiO_2, Treatment Condition, Wastewater

1. INTRODUCTION

The wastewater streams from industrial discharges are the primary release of trichloroethylene (TCE) into the environment[1, 2]. TCE can be treated by many techniques unfortunately, each method has its shortcomings. Granular Activated Carbon (GAC) adsorption and air stripping are commonly used; however, neither technology results in the direct destruction of the organic contaminant. TCE can also be treated using biological degradation, but it takes time and has problem of microbial activity tapering off overtime[3]. In order to solve these problems, Fenton's reagent is a possible solution with reasonable short reaction time and cost. In general, the oxidant has been capable of achieving high treatment efficiencies (e.g.> 90%) with very fast reaction rates[4]. However, because of the sensitivity of Fenton's reagent to the conditions and pollutant in wastewater, it is recommended that the reaction always be characterized through laboratory tests before proceeding to plant scale[5].

Titanium dioxide is usually used as a photocatalytic substance [6-14]. Due to its properties of being able to transfer electrons through its surface, some evidences have shown that TiO_2 surfaces can effectively stabilize radicals and radical ions. The prolonged lifetime results in a greater chance for the occurrence of chemical reaction[7-10, 15].

The objective of this research was optimized the conditions to treat TCE in wastewater by using Fenton's reagent with and without the present of TiO_2 with the intention to determine the optimal ratio of H_2O_2, Fe^{2+}, and TCE. The expectation of this work is possibly use for treatment of hazardous waste, TCE in wastewater to prevent TCE from releasing to the environment.

1.1 Fenton's Reagent

Fenton's reagent is a mixture of hydrogen peroxide (H_2O_2) and ferrous salt. It produces hydroxyl radicals that are strong oxidizers. Fenton's reagent is not stable. Once H_2O_2 and Fe^{2+} are mixed, several reactions take place simultaneously. These reactions produce hydroxyl radicals (HO•), hydroperoxyl radicals (HO_2•), Fe^{3+}, and O_2 (Eqs.1–7).

The chemical mechanisms have been proposed that hydroxyl radicals act as the oxidant species that are generated in the following chemical equation[7, 16].

$$Fe^{2+} + H_2O_2 \longrightarrow Fe^{3+} + OH^- + OH\bullet \quad \text{-----(1)}$$

Hydroxyl radicals may be scavenged by reaction with another Fe^{2+}:

$$Fe^{2+} + OH\bullet \longrightarrow Fe^{3+} + OH^- \quad \text{-----(2)}$$

Fe^{3+} catalytically decomposes H_2O_2 following a radical mechanism that involves hydroxyl and hydroperoxyl radicals.

$$Fe^{3+} + H_2O_2 \rightleftharpoons Fe\text{-}OOH_2^+ + H^+ \quad \text{-----(3)}$$
$$Fe\text{-}OOH_2^+ \longrightarrow Fe^{2+} + HO_2\bullet \quad \text{-----(4)}$$
$$Fe^{2+} + HO_2\bullet \longrightarrow Fe^{3+} + HO_2^- \quad \text{-----(5)}$$
$$Fe^{3+} + HO_2\bullet \longrightarrow Fe^{2+} + H^+ + O_2 \quad \text{-----(6)}$$
$$H_2O_2 + OH\bullet \longrightarrow HO_2\bullet + H_2O \quad \text{-----(7)}$$

Among these oxidants, hydroxyl radicals has much stronger oxidizing power than hydroperoxy radical, then the optimal conditions, which lead to Eq.(1), must be controlled. However, the degree of oxidation depends upon the ratio (R) of H_2O_2, Fe^{2+}, and contaminant.

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There is no report on the exact products from the reaction between hydroxyl radical and TCE. However, Chen *et al.,* found no VOC intermediates or by-products in the oxidation process. He suggested that TCE be most likely mineralized to CO_2, Cl^-, and H^{+1} [(7)].

1.2 Synergic Effect between TiO_2 and Fenton's Reagent

Over the last several years, numerous studies have demonstrated the efficiency of photocatalytic oxidation of organic compounds in aqueous TiO_2 suspensions1[6, 12]. From the procedures of photocatalization by TiO_2, addition of dissolved transition metal has been observed to increase the rate of TiO_2 photocatalytic oxidation[8, 13, 15]. This observed increasing rate has been attributed to electron trapping at the semiconductor surface:

$$M^{n+} + e^- \longrightarrow M^{(n-1)+} \qquad \text{-----(8)}$$

where M^{n+} represents Cu^{2+}, Fe^{3+}, or Mn^{3+}. If operative, reaction (8) prevents electron-hole recombination and results in an increased rate of formation of OH• radical. Moreover, in case of Fe^{3+}, converted Fe^{2+} may act as Fenton's reagent to produce additional OH•. On the other hand, the detrimental effects of high metal concentrations have been attributed to oxidation of reduced metals by OH• radical, or to the reverse of reaction (9).

$$M^{(n-1)+} + h^+ \longrightarrow M^{n+} \qquad \text{-----(9)}$$

In addition, a reaction pathway involving the formation of a ternary complex between the metal, the organic substrate, and H_2O_2 or O_2 may be significant when dissolved metals are present in TiO_2 photocatalytic systems.

Wei *et al*., and Sclafani *et al.* also found that in the system, which contains suspended TiO_2, H_2O_2, and Fe^{2+}, phenol removal rate had been extremely enhanced[13, 15]. Since OH• was produced by Fenton's reaction, TiO_2 can effectively stabilize radicals and radical ions. Thus photogenerated surface-associated redox intermediates may have a longer lifetime than the same intermediates chemically generated in the solution. The prolonged lifetime results in a greater chance for the occurrence of chemical reaction[15].

From these above observations, TiO_2 will be used as a new role to enhance the Fenton's reagent furthermore than a photocatalyst. This will combine the advantage of these two treatment techniques, while reducing amount of costly TiO_2 needed to be used alone in the system with higher efficiency and practicability.

2. Materials and Methods

2.1 Experimental Devices

To ensure the validity of the results of this investigation, all glassware used for this study was of the highest quality. Hydrogen peroxide (35% by weight) from Sigma-Aldrich, Inc. USA, ferrous sulfate crystals ($FeSO_4 \cdot 7H_2O$), trichloroethylene 99.9%, and TiO_2 powder, grain size 325 mesh, 99+% from Fisher Scientific International, USA were used in these works. All chemicals were reagent grade. The experiments were conducted in 165 ml glass vial reactors with sealed aluminum caps to prevent TCE leaking from the reactors. Pure water obtained from Milli-q UV plus ultra-pure water system was used in the study to prepare all solutions.

Junior Orbit Shaker from Lab-Line Instruments, Inc., USA was used at 220 ppm to shake the reactors. To measure pH in the solution, pH meter ORION model 420 A was used. Centrifuger Sorvall RC 28S from E.I. du Pont de Memours and Company, USA was used to separate sludge from treated water.

2.2 Analytical Methods

Analytical methods for TCE measurement was adopted from Standard Methods method 6232 B- liquid-liquid extraction gas chromatographic method for trihalomethanes and chlorinated organic solvents[18]. Column was changed to GC column DB-1701 (length = 30 m., I.D. = 0.53 mm) from J&W Scientific. Dynamic Headspace Concentrator Tekmar model 4000 was used for extract TCE from water sample. In addition, temperature program was set as Table 1

Table 1 GC column temperature program[18]

Level	Rate (° C/min.)	Final Temperature (C)°	Final Time (min.)
1	4.0	70	0.00
2	70.0	150	1.00
3	30.0	240	1.00

Before each analysis, oven, injector, and detector temperatures were set as high as possible (less than the maximum temperature of stationary phase) to completely clean TCE from the system (injector temperature = 200°C, detector temperature = 325°C). Headspace concentrator was set at condition which gave the most consistent data.

2.3 Experimental Methodology

Three sets of samples were studied for each condition. Blank samples were tested for quality control and to ensure that there were no impurities or interferences that would alter the results in some unexpected way.

Wastewater from the cleaning process of the APS Company, furniture and fixtures manufacturer located in Songkhla, Thailand was analyzed for TCE. TCE was found at around 20 ppm. However, the presence of other organic contaminants in the wastewater was taken account. then the initial concentration of TCE in this study was set at the maximum concentration of 100 ppm.

2.3.1 Determination of the Optimal Conditions for Using Fenton's Reagent to Treat TCE in Wastewater

Synthetic wastewater contaminated with 100 ppm TCE was prepared by using ultra pure water and standard TCE. The experiment was adopted from previous researches using Fenton's reagent[14, 17]. First, the TCE solution (synthetic wastewater) was adjusted and controlled the pH closed to 3 before adding of Fe^{2+} stock solution and H_2O_2. Next, simultaneously determined the TCE and H_2O_2 concentration in the solution during the chemical reaction occurred in a period of time to obtain the rates of TCE and H_2O_2 degradation (K_{TCE} and K_{H2O2}). H_2O_2 was analyzed by titration with $KMnO_4$ in acidic condition[19]. Then, Na_2SO_3 solution was added to stop the reaction. The solution then was adjusted pH above 10 with 5 N NaOH to precipitate iron. The comparison of controlled reactors between the TCE/iron and TCE/H_2O_2 were carried out at the same time. Ratio of initial chemical concentration (R_2) at 20:1:1, which close to the optimal R that reported by Weeks[14], was chosen for the first ratio in this study. The other 3 ratios, i.e. R_1 = 10:1:1, R_3 = 20:2:1, and R_4 = 40:2:1, were also studied.

2.3.2 Possibility of Using TiO_2 to Enhance Fenton's Reagent

This work used TiO_2 250-1,000 mg/L for the entire experiment. The TiO_2 was suspended in the systems, i.e. R_1, R_2, R_3, and R_4 as in Butler, Sclafani, and Wei's observation[8, 13, 15]. TiO_2 powder was added into the solution after H_2O_2. All parameters were analyzed as well as those with only Fenton's reagent.

2.3.3 Study of the Recycling Iron and TiO_2

The objective of this study is to recycle iron in treated water back to the next treatment cycle. By doing this, ferrous iron, which is one of the major components of the Fenton's reagent, or TiO_2 could be saved. Thus, only H_2O_2 is needed for the next cycle.

To recycle ferrous iron, pH was increased to above 10 to precipitate iron in the solution. Iron sludge was separated from water by centrifuging. The centrifuger was set at 8,000 rpm for 20 minutes and RCF equals to 9643. And then, iron sludge was transformed into ferrous iron form by digestion with sulfuric acid. The procedure is also shown in Figure 1

Conclusively, four different conditions; A, B, C, and D were studied in this section. Each condition contains different amount of oxidizing agent and catalyst. Ratio of initial substances molar concentration for each condition can be defined as in Table 2.

Table 2 Conditions setting in the study

Type	Conditions and Ratios by Molar
A	R = H_2O_2:TCE
B	R = H_2O_2:Fe^{2+}:TCE
C	R = H_2O_2:TCE and TiO_2 in mg/L
D	R = H_2O_2:Fe^{2+}:TCE and TiO_2 in mg/L

2.4 Economic Study

The economic evaluation was justified base on the most feasible treatment condition for TCE removal, cost of treatment, %TCE removal and reaction time were considered.

3. Results and discussions

3.1 Optimal Conditions of Using Fenton's Reagent to Treat TCE in Wastewater with the Present of Suspended TiO_2

From 2.3.1, the results are shown in Figure 1, TCE from condition B and D removed by 80.60 and 82.61 % respectively, while conditions A and C were removed only 6.12% and 8.96%, respectively. These results agreed with Goi's work that without iron and UV radiation, degradation of organic compounds is quite slow[20].
Figure 2 to 5 shows the comparison of TCE removal and H_2O_2 degradation between conditions B and D for the reactors of R_1-R_4. From the results, condition D always showed higher TCE removal than condition B, and, R_4 was the highest TCE removal. The comparison of all conditions is shown in Figure 6.

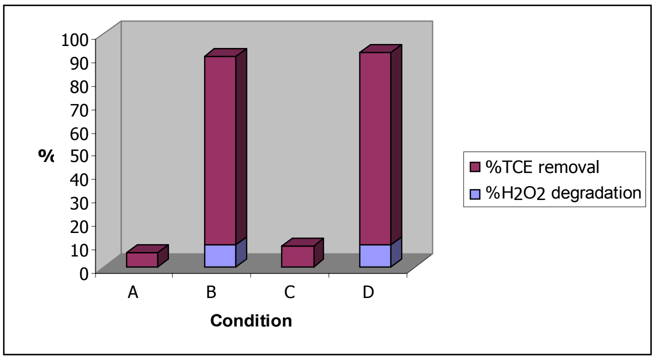

Figure 1 Comparison of TCE removal and H_2O_2 degradation from condition A, B,C and D; Initial TCE concentration = 100 ppm, reaction time = 30 min., condition A: R=20:1, B: R-20:1:1, C: R=20:1 TiO_2 = 500 mg/L, D: R = 20:1:1 TiO_2 = 500 mg/L

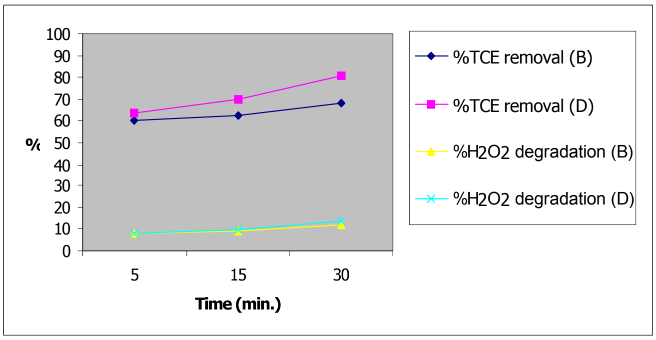

Figure2 TCE removal and H_2O_2 degradation from condition B and D. Condition B; R_1 = 10:1:1, Condition D; R_1 = 10:1:1, TiO_2 = 500 mg/L

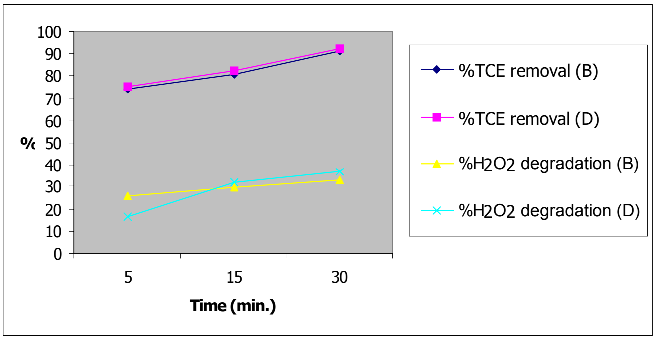

Figure 3 TCE removal and H_2O_2 degradation from condition B and D. Condition B; R_2 = 20:1:1, Condition D; R_2 = 20:1:1, TiO_2 = 500 mg/L

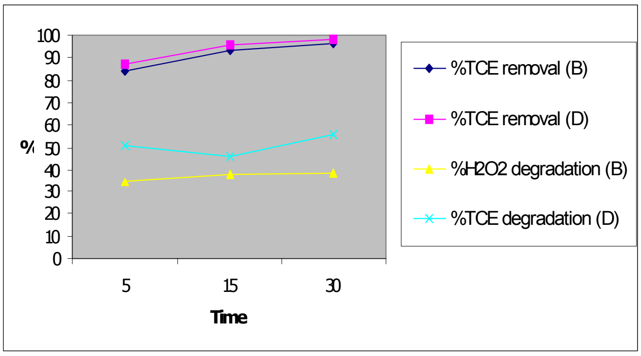

Figure 4 TCE removal and H_2O_2 degradation from condition B and D. Condition B; R_3 = 20:2:1, Condition D; R_3 = 20:2:1, TiO_2 = 1,000 mg/L

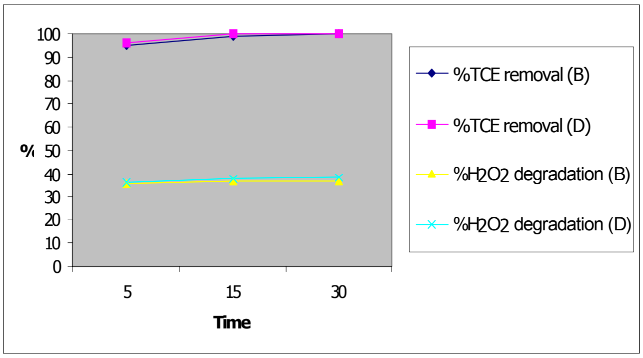

Figure 5 TCE removal and H_2O_2 degradation from condition B and D. Condition B; R_4 = 40:2:1, Condition D; R_4 = 40:2:1, TiO_2 = 250 mg/L

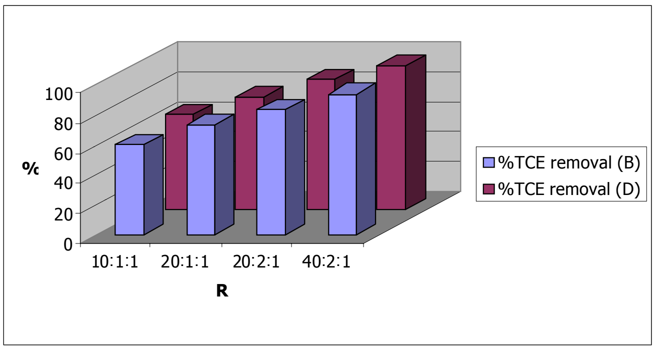

Figure 6 Comparison of TCE removal from different R, reaction time = 5 min.

In this study, TiO_2 was varied without fixing the molar ratio of initial chemicals (R). The results showed that, the smallest amount of TiO_2 (250 mg/L) in R_4 comparing to 1,000 mg/L TiO_2 in R_3, very small difference between conditions B and D. The addition of TiO_2 to speed up the reaction as other reports did not work out for the amount that used in this work. However, to confirm this conclusion, a future studies should be conducted by fixing the ratios and varying amount of TiO_2.

According to the results of this work, R_3 with condition B was chosen to be the optimal ratio for using Fenton's reagent to treat TCE contaminated wastewater. Although TCE removal from R_3 was lower than R_4 and TCE removal from condition B was slightly lower than condition D, H_2O_2 addition was much less and no TiO_2 addition. Moreover, it may needs more Fe^{2+} iron than R_2, which gave lower TCE removal, but Fe^{2+} is rather inexpensive comparing to H_2O_2 and TiO_2.

3.2 Recycling of Reagent Sludge

The comparison of using fresh iron and recycled iron is shown in Figure 7, the results showed that TCE removal from recycled sludge was slightly different from fresh reagent and both R_3 and R_4 were almost similar. However, sludge separation, iron transformation and pH control to recycle iron must take account for the real wastewater treatment. The separation of iron sludge from treated wastewater could be reasonably performed through sludge thickening and dewatering.

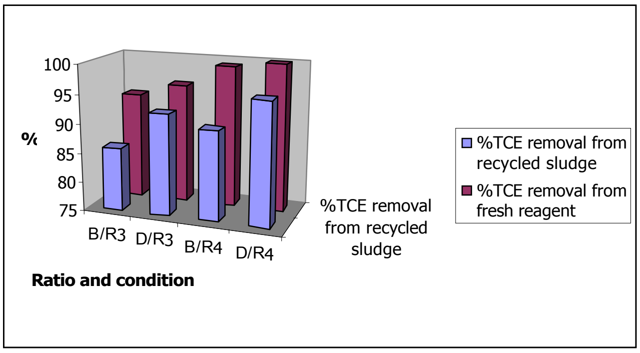

Figure 7 Comparison of %TCE removal between recycled sludge and fresh reagent from R_2 and R_4 respectively

3.3 Economic Study

Base on the result obtained from 2.3.1, treatment cost for 1L of 100 ppm TCE in wastewater using condition B and D and different R (R_1-R_4) was determined. Comparison of treatment cost is shown is Table 3. The prices of chemicals used in this study are referred to the Handbook of Fine Chemical and Laboratory Equipment from Sigma-Aldrich Corporation (2002)[21].

Table3 Comparison of treatment cost for 1L of 100 ppm TCE in wastewater using condition B and D; reaction time 15 min.

R	Condition	TiO_2 (mg/L)	%TCE removal	Cost of Treatment

				($)
R_1	B	-	62.25	0.033
R_1	D	500	71.34	0.046
R_2	B	-	80.60	0.059
R_2	D	500	83.43	0.071
R_3	B	-	93.32	0.065
R_3	D	1,000	93.68	0.088
R_4	B	-	99.15	0.118
R_4	D	250	98.65	0.124

From Table 3, R_3 and R_4 gave reasonably high %TCE removal. However, treatment cost of R_4 was almost double of R_3. Therefore, R_3 was considered to be the optimal ration for this treatment. Next, condition B and D of R_3 was compared in their treatment cost to determine for the optimal condition. Treatment cost for 1L of 100 ppm TCE in wastewater for condition B and D using R_3 are \$0.065 and \$0.088, respectively. Considering 15 min. reaction time, % TCE removal was 93.32% and 95.44% for condition B and D, respectively, however, the treatment cost for condition D is 35.38% higher. Then, condition B should be preferred than condition D.

Indeed, the experiments did not go smoothly in the early stage. The results of using Fenton's reagent to oxidize TCE did not match other researchers' findings. The causes of problem were analyzed by the Root Cause Analysis. Methanol and ethanol, which were used as co-solvent of TCE in the early experiments, were found to be the cause of problem. These alcohols inhibited the Fenton's reaction. After that, synthetic TCE in wastewater was prepared directly from concentrated TCE without using any co-solvent.

The Fenton's reaction inhibition from alcohol could be explained by eqs.(10)-(14). Weeks (2000) reported that the rate constant of reaction 1 is very low (37-76 $M^{-1}s^{-1}$)[14]. Then, the co-solvent; methanol or ethanol, could compete with Fe^{2+} to react with H_2O_2 as shown in eq.10 and 18[22, 23]. Furthermore, reaction between hydroxyl radical and TCE was proposed by Getoff as shown in eq.(12)[24]. Rate constant of this reaction is $3.3*10^9$. In this case, hydroxyl radical could also react with the alcohols as shown in reactions 20-21[24, 25]. Rate constant of reactions (13) and (14) are $8.3*10^8$ and $2.2*10^9$($M^{-1}S^{-1}$) respectively. The further study should be conducted to identify an exact explanation for this incident

$CH_3OH + 3\,H_2O_2 \rightarrow CO_2 + 5\,H_2O$ -----(10)
$C_2H_5OH + 2\,H_2O_2 \rightarrow CH_3COOH + 3H_2O$-(11)
$OH\bullet + TCE \rightarrow CCl_2CHClOH\bullet$-----(12)
$OH\bullet + CH_3OH \rightarrow CH_2OH + H_2O$-----(13)
$OH\bullet + C_2H_5OH \rightarrow C_2H_5O + H_2O$ -----(14)

4. Conclusions

The results obtained from this study show the optimal conditions for using Fenton's reagent for TCE removal in wastewater, the catalytic effect of TiO_2 powder, and the possibility of recycling of iron sludge. These results will be useful to apply to the real wastewater treatment. The interference from alcohol was also investigated.

The results showed that Fenton's reagent alone and Fenton's reagent with the present of TiO_2 (conditions B and D), gave much higher treatment efficiency than the other condition without ferrous iron. TCE removals were more than 90% within 15min. reaction time. The optimal ratio of initial substances (R) was H_2O_2:Fe^{+2}:TCE = 20:2:1. This condition and ratio could be applied for wastewater containing different amount of TCE than 100 ppm. However, to apply Fenton's reagent to wastewater containing much higher TCE concentration i.e., 500 ppm or wastewater containing various kinds of contaminants, further study is recommended. The role of TiO_2 was not clear in this studied since the results from conditions B and D were insignificantly different.

Percentage TCE removal from using recycled iron is closed to %TCE removal from using fresh reagent. However, cost of using recycled sludge, which include sludge separation, iron transformation, pH control, should be compared with using fresh reagent when it is used in the real wastewater treatment. From cost estimation, using of Fenton's reagent without TiO_2 was preferred to other alternatives.

Methanol and ethanol, which were used as co-solvent for TCE, were identified as the inhibitors of Fenton's reaction. This work indicates that wastewater characterization must take in account before using Fenton's reagent to treat the water.

Acknowledgement

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Arsenic Removal From Water Using Activated Seawater-Neutralised Red Mud

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ABSTRACT: In this paper activated seawater-neutralised red mud, herein referred to as activated Bauxsol (AB), is used as a novel adsorbent for removing arsenic (As) from water. The adsorption of As onto AB is studied and adsorption envelopes are prepared for both As(V) (arsenate) and As(III) (arsenite). Within the range tested the optimal pH for the adsorption is 4.5 for arsenate and 8.5 for arsenite, with roughly 100% and 53% removals, respectively. The As adsorption data fits the Langmuir isotherm and its linearized forms well. Moreover, the linearized forms are used to calculate the adsorption capacity for arsenate and arsenite at pH 7.0, which is found to be 39.8 and 7.2 μmol g^{-1} for arsenate and arsenite, respectively. The combined effects of the anions are also tested, and it is found that phosphate and silicate hinder the removal more significantly in the presence of sulphate and bicarbonate, despite the fact that sulphate and bicarbonate are not themselves strong suppressers at the concentrations found in natural waters. This study shows that arsenite needs to be oxidised to arsenate for favourable removal using AB, but AB can be a very efficient unconventional adsorbent for removing arsenate from water in the absence of the competing anions, but in their presence adsorbent dosages must be increased for favourable arsenate removal.

Key words: Red mud, activated Bauxsol, arsenic adsorption, Langmuir isotherm, desorption

INTRODUCTION

Arsenic (As) is a known carcinogen and chronic exposure of As is linked to serious health risks including cancers of the skin and internal organs, and cardiovascular and neurological effects (Tseng, 1977; Mandal *et al.*, 1998). Soluble As can be found in natural waters due to several reasons *e.g.* weathering of arsenic bearing minerals, discharging arsenic waste from petroleum refining, glass melting, and smelting of ores that are mined for their lead, copper, zinc, gold, and silver content. Moreover, using As-containing pesticides and fertilizers may also cause As release to the environment (Bothe and Brown, 1999). High concentrations of As in water and soil have been documented in many countries globally including Taiwan, Mongolia, Mexico, Chile, Argentina, Ghana, the UK, Greece, Spain, and the USA; but the most severe outbreaks of arsenic poisoning have been associated with groundwaters in the Bengal Delta *i.e.* West Bengal, India and Bangladesh (Mandal *et* al., 1998; Chowdhury *et al.*, 2000).

The inorganic form of As is more common, but organic As species can also occur in natural water as a result of in situ biomethylation, and through the application of organoarsenical pesticides. Here, only the inorganic form of As is considered, as organoarsenic compounds do not appear to be particularly important in the overall As cycle (Drever, 1997). As (III) (arsenite) and As (V) (arsenate) are common inorganic As species in natural waters, and among them the arsenate anion is prevalent in aerobic conditions *i.e.* oxygen-rich surface waters. Arsenite is prevalent in reducing environments *i.e.* anoxic groundwater (Hering and Kneebone, 2002). It should be noted that arsenite exists as a monovalent ion in pH values widely encountered in nature due to the fact that the pK_{a1} value of arsenite is 9.2, whereas arsenate exists as arsenate anions. It should also be noted that the toxicity of As depends on the oxidation state, and arsenite is more toxic than arsenate. Ionisation reactions of arsenous acid (H_3AsO_3) and arsenic acid (H_3AsO_4) are given below (after Kartinen and Martin, 1995).

<u>Ionization of As (V)</u>

$H_3AsO_4 \rightarrow H^+ + H_2AsO_4^-$ $pK_{a1} = 2.2$
$H_2AsO_4^- \rightarrow H^+ + HAsO_4^{2-}$ $pK_{a2} = 7.1$
$HAsO_4^{2-} \rightarrow H^+ + AsO_4^{3-}$ $pK_{a3} = 11.5$

<u>Ionization of As (III)</u>

$H_3AsO_3 \rightarrow H^+ + H_2AsO_3^-$ $pK_{a1} = 9.2$
$H_2AsO_3^- \rightarrow H^+ + HAsO_3^{2-}$ $pK_{a2} = 12.3$

Humans are exposed to arsenic in many ways, but the most critical pathway is through drinking water. For example millions of people in the Bengal Delta currently drink arsenic contaminated well water ([As] $\geq$ 0.05 ppm). Due to the serious health problems associated with As exposure, As standards are stringent. Since 1993 the World Health Organization (WHO) has reduced the 0.05 ppm guideline, and recommended a maximum arsenic concentration limit for drinking waters of 0.01 ppm (0.133 μM) (WHO, 1993). Many countries permit higher arsenic concentrations in drinking water, however, mainly due to the high cost of treatment to lower concentrations. Well known arsenic removal technologies usually rely on coagulation with ferric or aluminum salts (*e.g.* Gregor (2001) and Edwards (1994)). These methods are favourable only in large treatment plants, however, and result in the production of large amount of toxic sludge.

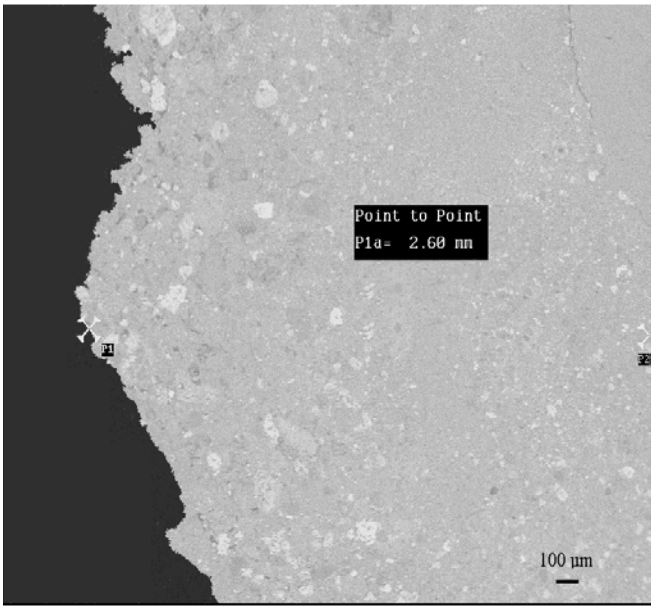

Figure 1 SEM backscatter image of a polished mount representing a portion of a single bauxsol grain.

Alternatively, ion exchange and adsorption systems especially using iron and aluminum oxides are reported to be
very efficient, particularly for arsenate (Wilkie and Hering, 1996). But these oxides need to be prepared in a laboratory, thus there is a need to develop efficient and cheap adsorbents that compete with these pure sorbents.

Red mud is a residue that remains when the Bayer process is used to extract alumina from bauxite. Because individual bauxites may differ in composition, the composition of the residues varies. However, all red muds contain abundant finely divided Fe-, Al- and Ti-oxides and oxyhydroxides, and untreated red mud contains large amounts of sodium hydroxide and sodium carbonate that leaves it highly caustic (the pH is usually >13.0). There are several possible ways to neutralise red mud, including adding acid, hard groundwaters, magnesium and calcium chloride salts, saline brines, or seawater. In recent years the application of cheap and easily available materials *e.g.* red mud, seawater-neutralised red mud (Bauxsol), for removing arsenic from water has been studied (Altundoğan *et al.*, 2000; and Genç *et al.*, 2003). Among them, Altundogan *et al.* (2000) investigated the possibility of using red mud and activated red mud (ARM), as a low-cost adsorbent to remove As from water, and results indicate a moderate removal capacity at pH values that are potable in drinking water. Similarly, Genç *et al.* (2003) use seawater-neutralised red mud (Bauxsol) to remove arsenate from drinking water, and report significantly higher removal capacity than red mud. Later, Genç & Tjell (2003a and 2003b) use a simple dissolution precipitation process (Pratt and Christoverson, 1982) to activate the Bauxsol (AB) and report significantly higher arsenate removal capacity using AB compared to Bauxsol; however they suggest investigating the process characteristics further *i.e.* testing the adsorbent using arsenite.

MATERIALS AND METHODS

Activated Bauxsol (AB)

The red mud used in this study is provided by the Queensland Alumina Ltd. Refinery, Gladstone, Australia. The red mud has been seawater-neutralised, which simply involves adding seawater to the red mud and stirring until an equilibrium pH is achieved (usually at a pH within 8.4 to 8.8). Bauxsol is prepared by suspending red mud in a seawater solution, and stirring it until the equilibrium pH is achieved. The entire process takes about an hour and the fully neutralised Bauxsol has a pH of 8.6 ± 0.2, and is therefore not caustic. The chemical composition and mineralogy (determined by X-ray florescence and X-ray diffraction studies) of the major components in the Bauxsol used in this study is given elsewhere (Genç *et al.*, 2003). Here, only the chemical composition is shown in Table 1, where it can be seen that Bauxsol is primarily composed of Fe- and Al-oxides. In addition, Bauxsol is dominated by very fine particles. The fine particle sizes are evident in Fig. 1, which shows an SEM backscatter image. Here it is seen that coarse particles of Bauxsol are aggregates of much finer, but compositionally similar, particles and that many of these finer particles are themselves aggregates of still finer particles. Most mineral crystals in Bauxsol are finer than 5 µm and most of the coarser particles detected in grain size analyses are in fact incompletely disaggregated masses of finer particles (Genç *et al.* 2003).

Here, AB is prepared using the combined acid and heat treatment method of Pratt and Christoverson (1982), which involves refluxing Bauxsol in HCl, adding ammonia for complete precipitation, filtrating, washing with distilled-deionised water (DIW), and calcining at 500 ^{0}C for two hours. Details of this method along with more data on the characteristics of AB are also given elsewhere (Genç and Tjell, 2003a). Below is the simple scheme for the AB production from red mud.

$$\text{Red mud} \xrightarrow{\text{seawater-neutralisation}} \text{Bauxsol}$$

$$\text{Bauxsol} \xrightarrow{\text{activation}} \text{AB}$$

Table 1 Chemical composition of Bauxsol.

Chemical composition			
Constituent	% (w/w)	Constituent	% (w/w)
Fe_2O_3	34.05	Na_2O	2.74
Al_2O_3	25.45	MgO	1.86
SiO_2	17.06	K_20	0.20
TiO_2	4.90	P_20_5	0.15
CaO	3.69	MnO	0.04

Standard Solutions

Arsenate and arsenite stock solutions were prepared by dissolving $Na_2HAsO_4.7H_2O$ and $NaAsO_2$, respectively in water to 1 g L^{-1} As. Secondary stock solutions of 100 and 10 mg L^{-1} As were prepared every week, and these stock solutions were used to prepare As test solutions with concentrations between 0.05 mg L^{-1} (0.67 μM), and 14.60 mg L^{-1} (194.40 μM). Alternatively, $Na_2SiO_3.5H_2O$, NaH_2PO_4, Na_2SO_4, and $NaHCO_3$ salts were used to prepare the stock silicate, phosphate, sulphate, and bicarbonate solutions, respectively. When effects of the competing anions were investigated, the desired amounts of sodium salts of phosphate, sulphate, or bicarbonate stock solutions were added to the solution.

Sorption And Desorption Experiments

Duplicate batches were examined to prepare adsorption and desorption curves, and to investigate the characteristics of the adsorption process. All chemicals used in this study were reagent-grade or better and were used without additional purification. A matrix electrolyte of 0.01 M NaCl, prepared by dissolving reagent grade NaCl in DIW, was used for all sorption experiments. Fifty mL solutions having different initial As concentrations were added to 100 mL inert plastic bottles (PE), and samples were taken from each bottle to represent the initial As concentrations prior to adding AB at amounts required to obtain the required adsorbent dosages. The pH of AB is 7.0 ± 0.1, and most of the adsorption studies were carried out at this pH. For other tests the pHs of the samples were adjusted through the addition of 2 M HCl or NaOH solutions as required. The flasks were then capped tightly and shaken with a mechanical shaker at room temperature (23 ± 1^{o}C) for 3 h. After 3 h, the pH was measured and reported in this study as the pH of the experiment. Note that the addition of AB to the solution results in minor pH changes within the equilibrium time, thus results are reported to ± 0.1 pH units. Furthermore, desorption of the bound arsenate was studied at pH 4.5. In the desorption tests arsenic loaded AB was leached using DIW, and the pH was adjusted to the desired value by adding 2M HCl or NaOH as required. Glassware and PE were acid- washed for at least 12 h before each experiment using 6% HNO_3, and then washed with distilled water four times and dried.

Arsenic Measurements

After centrifuging batches for 30 min at 4200 rpm, the supernatants were analysed for As using a Perkin-Elmer 5000 hydride generation unit on an atomic absorption spectrophotometer. The system was calibrated using commercially available 1 g L^{-1} standard As solution. For hydride generation 3% $NaBH_4$ (prepared in 1% NaOH) and 1.5% HCl solutions were reacted with the samples. Alternatively, 1% $NaBH_4$ (prepared in 0.1% NaOH) and 0.1% HCl (the pH was kept at 5 to minimise arsenite oxidising to arsenate) solutions were used for the arsenite determinations. After trying various combinations and checking the precision and sensitivity of the measurements, these analytical conditions were found to give the best results for arsenate and arsenite determinations. Furthermore, 99.99% liquid carbonic nitrogen was used as a purge gas for the hydride generation unit, and the glass reaction vessel and quartz cell were continuously purged with nitrogen gas to eliminate the interference from air at 194.3 nm. The detection limit was 2 μg L^{-1}. Moreover, soluble phosphate and silicate concentrations were determined using the ascorbic acid and heteropoly blue methods, respectively. All samples were analysed within two days and analysis of duplicates (or triplicates) indicated a precision better than ± 5%.

RESULTS AND DISCUSSION

Effect Of The Ph

Fine grained AB compounds *e.g.* Fe- and Al-oxides and hydroxides exhibit a pH dependent surface charge. Thus, the pH dependence of the arsenate and arsenite sorption onto AB is investigated with pH values ranging from 4.5 to 12.5 at the fixed solution concentration, adsorbent dosage, and contact time. Adsorption envelopes are presented in Fig. 2, where it can be seen that the process is pH dependant, favouring the sorption at pH below 7.0 for arsenate, and at 8.5 for arsenite. It is suggested that the reason why no further increase on the arsenate adsorption capacity is observed below pH 7.0 for arsenate in Fig. 3 is due to the fact that all arsenate in the solution is already adsorbed, but not all the available adsorption sites are occupied.

Arsenate adsorption on AB suggests a ligand based adsorption *i.e.* a decrease of the anion sorption at higher pHs due to the strong negative charge of the surface, because OH^- is competing for the available adsorption sites. The data obtained in this study is in agreement with the arsenate and arsenite sorption results obtained elsewhere. For example, the adsorption of arsenate on metal oxides and oxyhydroxides is reported to increase at lower pH values and to gradually decrease at higher pH values in Arai *et al.* (2001), and the optimal pH value (*i.e.* where the maximum sorption occurs) for arsenite is reported to be between 7.0 and 8.5 in Altundogan *et al.* (2000) and Manning and Goldberg (1997).

Adsorption Isotherms

Adsorption isotherms relate the amount of a substance (adsorbate) attached to a surface (adsorbent) to its concentration in the solution at a fixed temperature. The experimental data obtained for arsenate and arsenite are applied to the Langmuir isotherm

$$q_e = \frac{(Q_0 b C_e)}{(1 + b C_e)}, \qquad [1]$$

and to its linearized forms

$$\frac{C_e}{q_e} = \frac{1}{(Q_0 b)} + \frac{C_e}{Q_0} \text{ or } \frac{1}{q_e} = \frac{1}{Q_0} + \frac{1}{bQ_0 C_e}. \qquad [2]$$

Here C_e is the equilibrium concentration in µM, q_e is the amount adsorbed at equilibrium in µmol g^{-1}, and b, K and n are isotherm constants. Langmuir isotherms for arsenate and arsenite are given in Fig. 3. The Langmuir isotherms (with high correlation coefficients deduced using linear regression) fits the adsorption data better than the Freundlich isotherm (data not shown). Later the linearized forms are used to calculate the adsorption capacity for arsenate and arsenite at pH 7.0, which is found to be 39.8 and 7.2 µmol g^{-1} for arsenate and arsenite, respectively.

In this study, at pH 7.0 ± 0.1 the calculated removals are 96% to 99%, and 13.4% to 53.1% for arsenate and arsenite, respectively when 5 g L^{-1} AB is applied. Thus it is suggested that arsenate is adsorbed by AB in appreciable quantities, whereas the capacity is significantly lower for arsenite. Similarly, metal adsorption onto red mud using the Langmuir model, in which adsorption is limited by the surface saturation (Langmuir modelling is useful for predicting the experimental saturation capacity of a sorbent), is efficiently applied using monodendate surface complexes despite the heterogeneous nature of the adsorbent (Altundogan *et al.*, 2000; Pradhan *et al.*, 1999; Apak *et al.* 1998). It should be noted that the arsenate adsorption capacity of AB can compete with those of goethite and gibbsite (Manning and Goldberg, 1996), hematite, activated bauxite, and activated alumina.

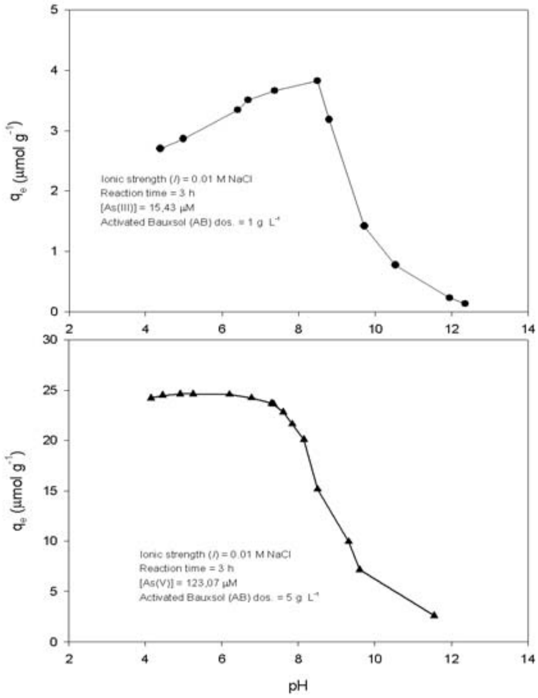

Figure 2. As adsorption envelopes on activated Bauxsol (AB) at room temperature.

Desorption

The reversibility of the arsenic sorption on AB is studied at different pH values, and different solution concentrations. The investigation is carried out using the spent AB and DIW, and following the same experimental procedure that is used for the adsorption experiments. Desorption with changing solution concentration is presented in Fig. 4. A low reversibility of arsenate adsorption using AB may suggests that the mechanism governing the process is not ion exchange, but may be chemisorption, since chemisorption is the result of much stronger forces (comparable to those leading to the formation of chemical compounds). This is under current investigation.

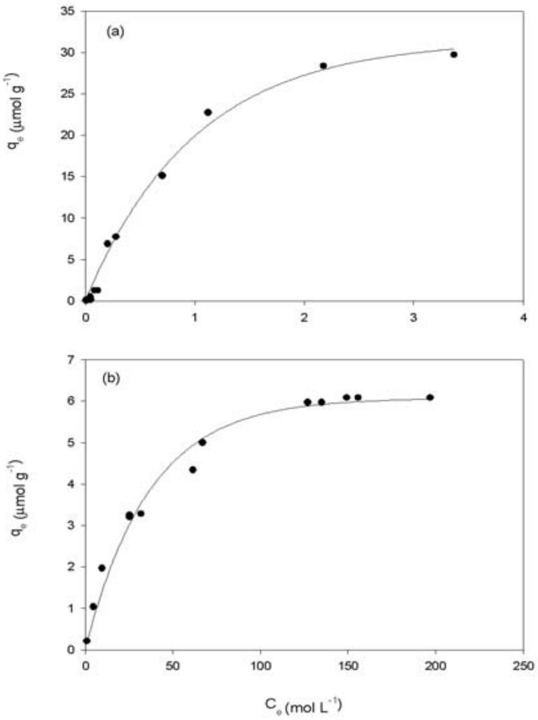

Figure 3. Langmuir isotherms for As(V) adsorption on activated Bauxsol (AB) at room temperature with reaction conditions: pH = 7.0± 0.1, reaction time = 3 h, ionic strength (*I*) = 0.01 M NaCl.

Combined Effect Of Competing Anions

The combined effects of silicate, phosphate, and of silicate, phosphate, bicarbonate and sulphate are studied. The results are depicted in Figs. 5 and 6, where the percentage arsenate removal is plotted versus the arsenate concentration in the solution after the removal. The results show that the percentage arsenate removal decreases by 10% in the presence of phosphate, silicate, sulphate, and bicarbonate compared to the presence of only phosphate and silicate. The calculated results nearly coincide with the system when only phosphate and silicate are present. These results indicate that even though bicarbonate and sulphate do not have a significant effect when present alone, they can have a suppressive effect on the adsorption when present along with phosphate and silicate. It should be noted that the experiments differ slightly in that even though both experiments start with the same pH of 6.9, the end pH is around 7.2 with the phosphate and silicate system, compared to pH 6.9 with the combined anion system in Fig. 6. According to Fig 3, which shows the effect of pH on adsorption, there should not be any effect on the adsorption due to the pH within this range. Therefore it can be asserted that the effect of anions from a single anion system cannot be directly applied to a multi anion system. On the other hand, in Fig. 5 adsorption data is given for arsenate in another multi adsorbent system with pH 8.5. We note that groundwater with such a high pH is not uncommon (*e.g.* in Hungary). Here, the low adsorption can be attributed to the combined effects of pH and the presence of the competing anions. Thus, it is suggested that in this system the pH should be decreased to at least to 7 and / or the adsorbent dosage increased for favourable arsenate removal using AB.

The individual and combined effects of phosphate, silicate, sulphate, and bicarbonate have also been studied elsewhere (Genç and Tjell, 2003c; Wilkie and Hering, 1996; Holm, 2002). For instance, Genç and Tjell (2003) studied the individual presence of these anions on the arsenate removal using AB, and report the suppression in a decreasing order on a molar basis as phosphate > silicate > sulphate > bicarbonate. The reason that dissolved phosphate strongly competes with dissolved arsenate for the available adsorption sites of AB is that phosphate has similar chemical properties (*i.e.* pK_a) as arsenate.

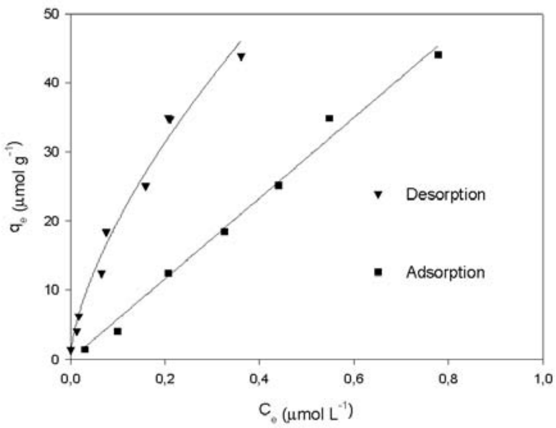

Figure 4. Desorption and adsorption of arsenate using AB with reaction conditions: Ionic strength (*I*) = 0.01 M NaCl, reaction time = 3 h, pH = 4.5 ± 0.1.

Table 2 Water compositions

	Anion concentrations, µM	
Anion	Sample 1	Sample 2
Arsenate	1.5 – 42.4	1.5 – 42.4
Phosphate	38.0	59.9
Silicate	723	685
Sulphate	260	0
Bicarbonate	4098	0

All concentration are given in µM

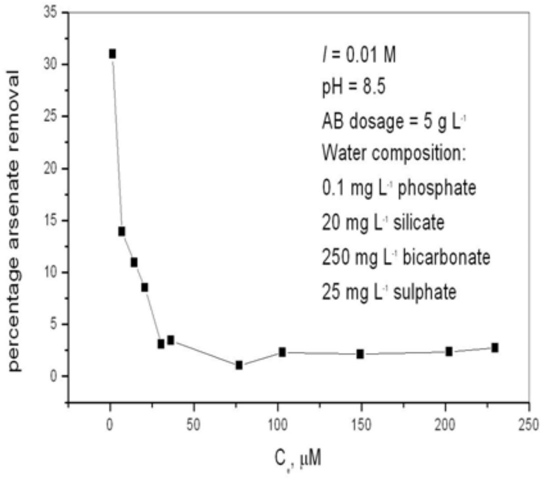

Figure 5. Arsenate adsorption onto activated Bauxsol (AB) in the artificial groundwater sample at room temperature with reaction time of 3h.

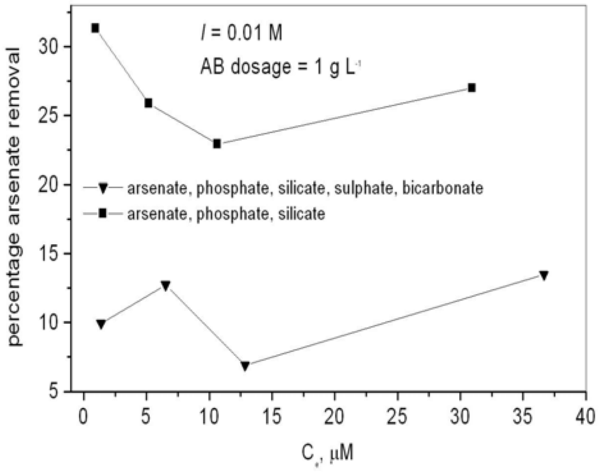

Figure 6. Arsenate adsorption onto activated Bauxsol (AB) in the multi adsorbent systems at room temperature with reaction conditions: Reaction time = 3 h, pH= 70 ± 0.1. The water composition of each sample is given in Table 2.

CONCLUSIONS

Arsenic adsorption onto activated Bauxsol (AB) is evaluated in batch experiments by preparing adsorption envelopes and isotherms. The results demonstrate that within the pH range studied the optimum removal is achieved at pH 4.5 for arsenate (roughly 100% removal) and pH 8.5 for arsenite (53% removal), respectively. Arsenate can also be efficiently removed even at circum neutral pH values, but arsenite needs to be oxidised to arsenate prior to the treatment for optimum removal.

Given the obtained data, it is suggested that the AB used in this study has a promising sorption capacity as an unconventional adsorbent, which is comparable with commonly used pure adsorbents for arsenic removal (*e.g.* Fe- and Al- hydroxides), and it may well be suitable as an unconventional new adsorbent for arsenic removal from water. However, more experimental work is required to elucidate the process characteristics further under batch and continuous flows. Moreover, a detailed cost analysis will also be necessary before reaching further conclusions.

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Influence Of Catalyst Type, Temperature And Grain Size On Contact Precipitation Of Fluoride

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ABSTRACT: High fluoride concentration in drinking water has caused problems of fluorosis among people in several parts of the world, including Thailand. Contact precipitation is a relatively newly described low-cost defluoridation technique where fluoride is precipitated with calcium and phosphate. The influence of catalyst type and temperature was investigated in batch experiments and influence of catalyst grain size was investigated in sequenced columns in this study. The results showed that contact precipitation on bone char was efficient while activated carbon was unable to catalyze contact precipitation and had also a low adsorption capacity. Difference in efficiency by bone char of different origin and preparation was significant in adsorption, but not so significant in contact precipitation. In contrast, temperature and grain size obviously showed their influences in this process. Higher temperature resulted in higher efficiency. Bone char with the smaller grain size had more fluoride removal capacity as a catalyst.

Keyword: Fluoride removal, contact precipitation, defluoridation, bone char, drinking water

INTRODUCTION

Throughout many parts of the world, high concentration of fluoride occurring naturally in groundwater has caused widespread fluorosis - a serious bone disease - among the local population (WHO, 1996). In the northern region of Thailand, where groundwater is one of the most important water resources, the groundwater in several places contains high fluoride concentration exceeding the 1993 WHO guidelines (1-1.5 mg/l) and also the 2000 Thai guidelines for rural area's drinking water (0.7 mg/l) (Chaiupalar, 1998; Ministry of Public Health, 2000; WHO, 1996). Thus, suitable solutions should be investigated.

Among the defluoridation methods previously described, contact precipitation is a relatively new method. It had been tested in field only for a short period in Tanzania (Dahi, 1997) and in lab in Thailand (Albertus et al., 2000). Fluoride is precipitated with calcium and phosphate that are added to the fluoride containing water. Only when the solution comes in contact with bone char or a very similar compound like synthetic hydroxyapatite it precipitates. The chemical processes involved are assumed to be basically a combination of precipitation of calcium fluoride (CaF_2) and fluorapatite ($Ca_{10}(PO_4)_6F_2$) (Bregnhøj, 1998).

Since it requires low operation and maintenance cost, low daily working load, no risky chemicals, but gives high removal efficiency, contact precipitation might be an appropriate defluoridation method for e.g. Thailand and other places where the problem exists.

The previous relevant works had found that factors such as dosage of chemicals, initial fluoride concentration, amount of bone char and type of bone char had influence on process' efficiency and the reaction (Dahi, 1997; Albertus et al., 2000).

The objective of this study was to investigate contact precipitation of fluoride on bone char with particularly focus on the influence of catalyst type, temperature and grain size of bone char.

METHODOLOGY

This study was divided into three (series of) experiments. 1) The "influence of catalyst type" (bone char vs. charcoal) was studied in batch. 2) The "influence of temperature" was studied in batch at 15, 20, 25, 30 and 35 ^{0}C. 3) The "influence of grain size" was investigated in column tests.

Material preparation

Materials used in 1) "influence of catalyst type", consisted of 3 types of bone char : Nakuru (locally produced in Nakuru, Kenya by partly calcination, brown) (Jacobsen and Dahi, 1997), ICOH (produced by the researcher at the Intercountry Center for Oral Health in Thailand by partly calcination, black with some white) and Brimac-216 (commercially produced in Scotland by pyrolysis, black) and 2 types of activated carbon : Thai AC (commercially produced in Thailand) and Scot AC (commercially produced in Scotland). In the second and third study only Nakuru was used.

In experiment 1) and 2) bone char/activated carbon was used in the powder form. To produce powder, grain bone char/activated carbon was manually crushed in a mortar and then sieved to pass through 0.045 mm. Bone char was then saturated, see Methods.

In the third study, "influence of grain size", only Nakuru bone char was used. Three columns containing different bone char sizes, 0.5 – 1.0 mm, 1.0 – 2.0 mm and 2.0 – 4.0 mm, were first saturated by 10 mg/L F^- solution by continuous upflow at 400 mL/H.

Methods

Bone Char Saturation for exp. 1) and 2): Bone char was saturated in 800 mL distilled water with 10 mg/L F^- solution in a water bath, using a chemostat system of Metrohm 691, 614 and 715. The chemostat system kept the fluoride concentration constant at 10 mg/L by controlled addition of 3,000 mg/L F^- solution to the reactor. Stirrer speed was 200 rpm. Saturation was reached when fluoride addition stopped. The bone char sedimented for 24 hours and was then dried at 85 ^{0}C for 24 hours.

Adsorption Capacity: Three types of bone char were tested for adsorption capacity to confirm the results obtained by previous saturation. Two grams of each bone char having grain size 0.5 – 1.0 mm were added in the 1 L glass beaker, containing 1 L of 20 mg/L F^- solution at time zero. Three beakers were stirred using a jar test apparatus, Phipps & Bird multiple-stirrer, at speed of 60 rpm. After 24 hours, samples of the water were taken for fluoride analysis and pH measurement. (Dahi and Bregnhøj, 1995)

Exp. 1) Influence of Catalyst Type: 3 types of saturated bone char and 2 types of activated carbon in powdered form were tested for its ability to catalyse the precipitation of fluoride, phosphate and calcium. The test was carried out in a jar test apparatus, at speed of 100 rpm. Twelve 1 L glass beakers, containing 800 mL of 10 mg/L F^- solution, were reactors for 12 experiments. Phosphate, calcium and catalyst were added at time zero in various amounts, see results. The amount of catalyst powder per reactor was 1 g. Phosphate and calcium were added in molar ratio of F:PO_4:Ca = 1:3:5. Samples were taken for fluoride, calcium and phosphate analysis until 240 minutes.

Exp. 2) Influence of Temperature: This study was conducted in 1 L glass beakers, containing 800 ml of 10 mg/l F^- solution in a water bath. The solution was stirred at 200 rpm. The thermostat bath was adjusted 15, 20, 25, 30 or 35^{0}C. 1.00 g saturated Nakuru bone char powder was added to the beaker and at time zero, phosphate and calcium were added in the molar ratio of F:Ca:P = 1:3:5. Samples were collected for fluoride, phosphate and calcium measurement. pH was measured online. Experimental time was 300 minutes.

Exp. 3) Influence of Grain Size : This study was carried out in three PVC columns containing saturated bone char with different grain size. Each column consisted of four beds (B1, B2, B3 and B4) of bone char with sampling points at the inlet (S_{inlet}), between the beds (S1, S2 and S3) and at the outlet (S_{outlet}) as shown in Figure 1. The beds are connected with 5 mm canals with a side canal for sampling by syringes, ensuring well defined sampling along the column. Each column/bed was 5 cm in inner diameter and (4*5.4) 22 cm total length, thus total volume of bone char in a column was 432 mL. Other properties are listed in Table 1. The continuous upflow system was controlled by gravity. Before the experiment started, all colums were saturated with 10 mg/L F^- solution until effluent reached the influent level. Each column was fed from a 20 L tank that was exchanged whenever empty. The tanks were filled with a solution of 10 mg/L F^- with PO_4 and Ca at a molar ratio of 1: 2.25: 3.88. Before use, the tanks were placed in a 40 ^{0}C thermostat room for about 20 hours with stirring in order to remove the dispersed air. During this preparation pH decreased from 7 to approximately 4.5, and white precipitation occurred. Thus the actual fluoride in the inlet was 0.35 mM ± 0.01, phosphate 0.85 ± 0.01 mM and calcium 1.32 ± 0.03 mM, bringing the average molar ratio to 1 : 2.4 : 3.8. Every day flow was measured and adjusted, and fluoride was measured. Phosphate and calcium were measured two or three times a week.

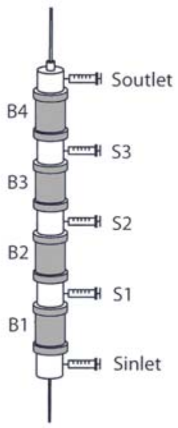

Figure 1: Column

Table 1: Column properties

Physical parameter	Col. 1	Col. 2	Col. 3
Bone char grain size (mm)	0.5 – 1	1 – 2	2 – 4
Amount of bone char (g)	274.5	299.5	299.9
Flow rate (mL/H)	398±36	405±30	404±31

Chemicals

Distilled and deionised water and analytical grade chemicals were used for all solutions. Fluoride solution was made from NaF, calcium solution from $CaCl_2.2H_2O$. Phosphate solution was made from $Na_2HPO_4.2H_2O$ (55%) and $NaH_2PO_4.H_2O$ (45%) by weight. A molar ratio of e.g. F: PO_4: Ca = 1: 3: 5 at 10 mgF^-/L means that fluoride, phosphate and calcium were added at 0.526 mM, 1.579 mM and 2.632 mM respectively.

Fluoride was analysed by the "Ion-Selective Electrode Method", Phosphate by the "Ascorbic Acid Method" and Calcium by the "Direct Air-Acetylene Flame Method" (APHA, 1998). pH was measured by a Metrohm 692 pH meter.

RESULTS

Bone char saturation and adsorption capacity test

The adsorption capacity of bone char obtained from bone char saturation and adsorption capacity test are shown in Table 2 together with the final pH of the solutions.

Table 2 : Results from bone char saturation (Sat.) and adsorption capacity test (Ads. T.)

Type	Nakuru		ICOH		Brimac-216	
Test	Sat.	Ads. T.	Sat.	Ads. T.	Sat.	Ads. T.
Ads. Capacity (mg F^-/ mg BC)	2.94	2.17	4.35	2.79	2.48	1.49
pH	8.60	7.79	8.73	8.26	8.72	9.12

Influence of catalyst type

The results of fluoride, phosphate and calcium precipitated or removed from 12 jar tests are shown in Figure 2.

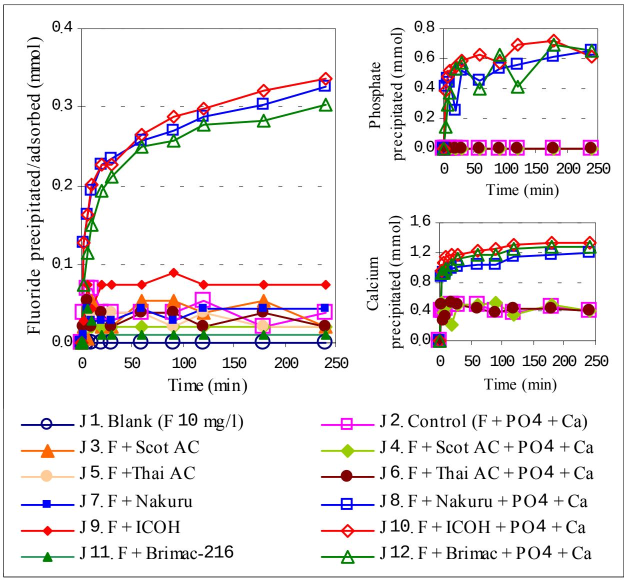

Figure 2 : Effects of catalyst type on fluoride, phosphate and calcium precipitated/removed

Jar test 1 and 2 served as reference experiments. Jar test 3-6 showed whether activated carbon could act as a fluoride adsorbent or as a catalytic surface for contact precipitation. Jar test 7, 9 and 11 showed whether the three bone chars had been properly saturated with fluoride and 8, 10 and 12 compared the bone chars' ability to act as catalytic surface.

For Jar test 8, 10 and 12, the amount of phosphate and calcium precipitated were divided by the amount of fluoride precipitated to demonstrate the precipitation molar ratio. Calculated ratio is shown in Figure 3.

Influence of temperature

Results of fluoride precipitated at different temperatures conducted in jar tests are shown in Figure 4. It reveals that more fluoride was precipitated at higher temperature.

Calcium and phosphate precipitated at 30 and 300 min are shown in Figure 5. Calcium and phosphate precipitated were generally increasing with temperature and time.

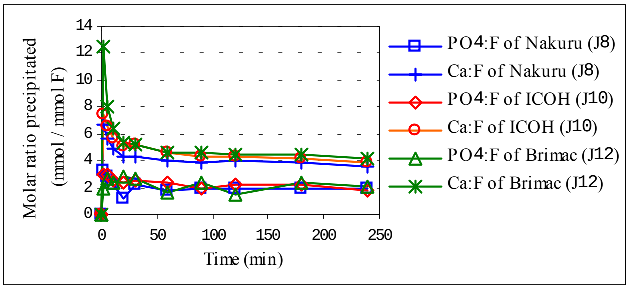

Figure 3 : Molar ratios of PO_4: F and Ca: F precipitated in J8 (Nakuru), J10 (ICOH) and J12 (Brimac-216)

Calculated molar ratio of PO_4: F and Ca: F precipitated are shown in Figure 6. PO_4: F and Ca: F precipitated at 30 minutes and 300 minutes were not so much different in chemostat but in jar test. It did not clearly show the trend of molar ratio changing by temperature.

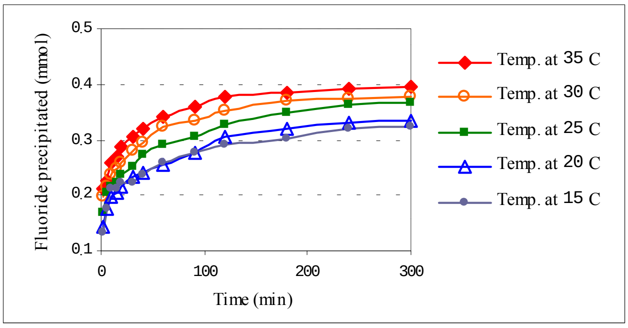

Figure 4 : Effect of temperature on fluoride precipitated

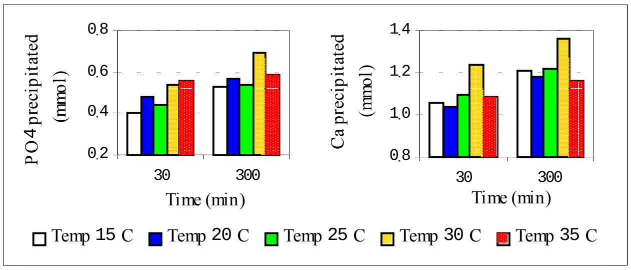

Figure 5 : Effects of temperature on calcium and phosphate precipitated.

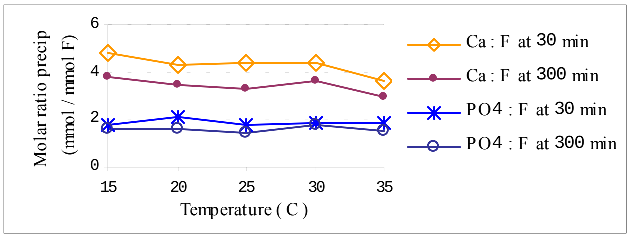

Figure 6 : Effects of temperature on PO_4: F and Ca: F precipitated

Figure 7 demonstrates development of pH in the contact precipitation process. The process(es) lowered pH. At higher temperature, pH decreased faster.

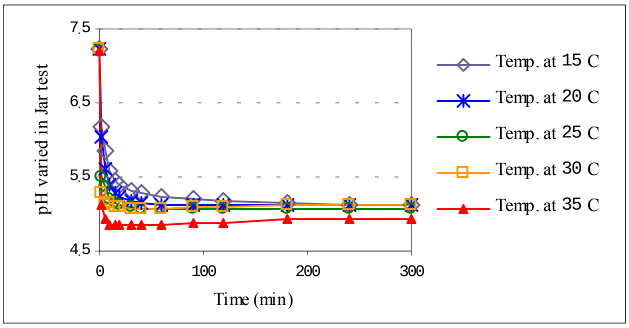

Figure 7 : Effect of time and temperature on pH

Influence of grain size

Fluoride concentrations (for each sampling point) are shown in Figure 8. The flow experiment was operated for 842 hours or 776 BV (column 2 was 431 hours/397 BV). The effluent concentration was still lower than 0.1 mg/L at the end in column 1 and 3 and the results of column 2 tended to be between column 1 and 3. Graphs of three columns showed the same trend. In all sampling points the concentration began at a certain level and then it decreased with time for a while. After some time it began to increase for S1 (and S2 in column 3). In column 3 with bigger grain size the rise in concentration at S1 came before the other columns indicating lower "capacity" at big grain size.

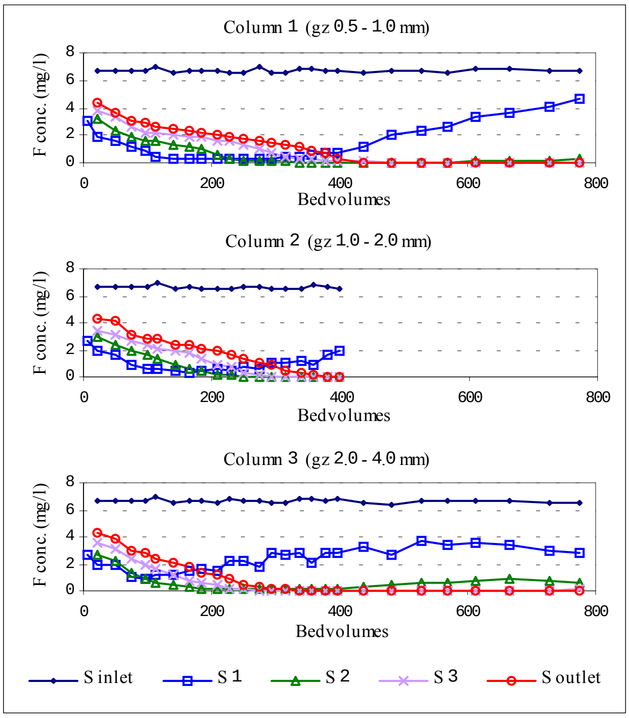

Figure 8 : Effect of grain size on fluoride removal

The profiles of fluoride concentration along the column at different times are shown in Figure 9. Fluoride concentration measured after the first bed (S1 / 5.4 cm) was the lowest and then increased more as it passed through following beds. Later, S1 was rising to be higher than the others, followed by S2. It was assumed that after a while, S3 and Sout would rise up respectively.

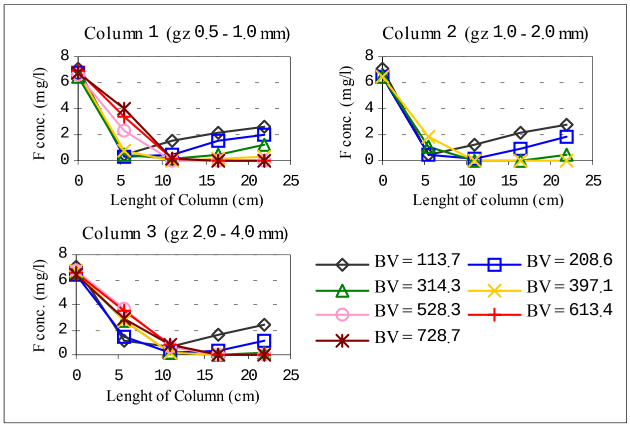

Figure 9 : Profile of Fluoride concentrations in the columns

DISCUSSION

Bone char saturation and adsorption capacity test

ICOH had the highest adsorption capacity, followed by Nakuru and Brimac-216. Furthermore, Brimac-216 caused highest pH to the water, followed by ICOH and Nakuru respectively. The pH development of all pure adsorption experiments showed the same trend; adding bone char caused pH to rise immediately. The pH was then gradually slightly decreased, however, still higher than neutral. The pH increase is a result of the adsorption, which can be partly explained by ion exchange / recrystallisation where fluoride is exchanged with OH^- (Bregnhøj, 1995). The results gained from the two measurements of adsorption capacity (saturation and adsorption capacity test) were in the agreement with each other (table 2). After saturation, ICOH had the highest adsorption capacity, followed by Nakuru and Brimac-216. The adsorption capacity of all bone chars could be considered good quality bone char, which normally is in the range of 1.5 – 3.5 mg F^-/g BC (Dahi, 1999). ICOH had a high capacity compared to others possibly because it was charred at lower temperature than Brimac-216 and by less oxygen than Nakuru. This is supported by the fact, that lower charring temperature and less oxygen result in higher adsorption capacity (Dahi and Bregnhøj, 1995; Albertus et al., 2000). Furthermore, the high pH caused by Brimac-216 in the adsorption capacity test in itself cause a lower adsorption capacity.

Influence of catalyst type

This study confirmed theory and previous works of contact precipitation process. Addition of calcium and phosphate in fluoride solution leads to some precipitation of fluorapatite or calcium fluoride, but not efficient defluoridation. Contact with hydroxyapatite or bone char indubitably furthers precipitation because its surface resembles that of fluorapatite (Bregnhøj, 1995).

In jar 2, 3, 4, 5, 6, 7, 9 and 11, fluoride and calcium removed were actually expected to be zero (no fluoride precipitation), but removes a small fluoride amount. This might due to
(1) Calcium was precipitated as calcium fluoride (CaF_2) since the calculated ionic product was higher than calcium fluoride's solubility constant.
(2) Bone char could adsorb more fluoride although it was previously fluoride-saturated. This was due to the migration process (Christoffersen et al., 1991; Bregnhøj 1995). There was an observation that bone char with higher adsorption capacity might have more migration capacity.

Jar test 3-6 proved that activated carbon was unable to be used as a catalyst and it also had very low fluoride adsorption capacity.

In jar test 8, 10 and 12, fluoride precipitated from solution was still increased until the end of experiment although molar ratio precipitated of PO_4: F and Ca: F were decreased. This situation was also found in other researches (Larsen and Pearce, 1992). The reasons might be
(1) Contact precipitation can takes place in two stages. The second stage allows fluoride precipitated later without calcium and phosphate (Bregnhøj, 1995).

$$10Ca^{2+} + 6PO_4^{3-} + F^- + OH^- \longrightarrow Ca_{10}(PO_4)_6FOH$$

$$Ca_{10}(PO_4)_6FOH + F^- \longrightarrow Ca_{10}(PO_4)_6F_2 + OH^-$$

(2) Fluorapatite precipitation can lead to fluoride adsorption on the newly forming crystals or on the bone char medium (Larsen and Pearce, 1992).

ICOH had the highest contact precipitation capacity (6,41 mg F /g BC), followed by Nakuru (6,19 mg F /g BC) and Brimac-216 (5,77 mg F /g BC). Thereby there is a correlation between contact precipitation capacity and its adsorption capacity as found in this study. These results were not in line with Albertus et al. (2000) indicating that bone char produced by calcinations (the white type) had the best ability to catalyse contact precipitation (but lowest ability in adsorption), while bone char produced by pyrolysis (black type) worked opposite. The experiment of Albertus et al. (2000) was made with unsaturated bone char, subtracting the simultaneous adsorption. Working with saturated bone char is more is a better setup. Differences are however rather small, therefore production of bone char might have no significant effect in contact precipitation. Further investigation is needed with saturated bone char to conclude on the best type for contact precipitation.

Influence of temperature

It was obvious that temperature had a positive effect on contact precipitation, Figure 4. Higher temperature resulted in higher efficiency of fluoride removal, including more phosphate and calcium consumed. Contact precipitation process is therefore thought to be endothermic reaction. Moreover, based on the knowledge that fluorapatite can be precipitated by boiling (MacIntire and Hammond, 1938), higher temperature was able to induce higher fluoride removal.

Processes in contact precipitation

The ratios of F: PO_4: Ca precipitated in two of the experiments; study on influence of catalyst type (figure 3) and influence of temperature (figure 6); were about 1: 2: 4. These ratios indicated that fluorapatite (ratio 1:3:5) was not the only compound precipitated but there must be other compounds. An analysis shows that in this system (where the initial concentrations are fluoride 0.526 mmol, phosphate 1.579 mmol and calcium 2.632 mmol) the following salts can precipitate due to their solubility constants: $Ca_{10}(PO_4)_6F_2$, CaF_2 and $CaHPO_4.2H_2O$.

The jar tests from the temperature influence experiment showed a clear drop in pH when contact precipitation took place, Figure 7. This decrement might due to H^+ creation before fluorapatite formation: $H_2PO_4^-$ or $HPO_4^{2-} \rightarrow PO_4^{3-} + H^+$. At higher temperature, contact precipitation was more stimulated, thus pH was more affected.

Although most part of contact precipitation already took place in 120 minutes, fluoride precipitated was still increased but slowly. In this period, pH was constant or slowly increasing. This might be the result of OH^- released from the intermediate compound ($Ca_{10}(PO_4)_6FOH$) that was changed to be $Ca_{10}(PO_4)_6F_2$ (Bregnhøj, 1995) or that fluoride adsorbed to the newly forming crystals or on the bone char medium (Larsen and Pearce, 1992).

Influence of grain size

The procedure of making feed water resulted in some precipitation in the tank because (1) stirring increased the contact between compounds and the formation of precipitate, and (2) high temperature in thermostat room supported precipitation of fluorapatite. Stirring water before the chemicals are added might prevent this. The decrement of pH might due to the amorphous compounds or the H^+ creation:

$$NaF + Na_2HPO_4.2H_2O + NaH_2PO_4.H_2O + CaCl_2$$
$$\downarrow$$
$$Ca_{10}(PO_4)_6F_2 + CaF_2 + \text{Amorphous compound of calcium and phosphate} + H^+ + NaCl + H_2O$$

The flow experiment revealed that grain size affected contact precipitation in columns as it affected fluoride adsorption (Bregnhøj et al., 1995). Columns were exhausted from the bottom to the top as in theory of adsorption. This experiment was stopped before the total contact precipitation capacity was reached so total precipitation capacity results cannot be obtained from this. The amount of fluoride precipitated at the end of this experiment in the first bed of column 1 (23.67 mg/g) was higher than column 3 (19.88 mg/g). Therefore, the results showed that smaller grain size had higher efficiency and capacity in contact precipitation process. The order of magnitude was similar to earlier findings of Dahi (1997) and Albertus et al. (2000).

The increment of fluoride (S1 < S2 < S3 < Sout) in the first period might due to the desorption of fluoride. After fluoride in feed water had been removed by contact precipitation in the first bed, saturated bone char in the next beds might desorb fluoride into the low-fluoride containing feed water. Thus, outlet from the following bed contained higher amounts of fluoride than the inlet. When the capacity of first bed was reached, higher concentration of fluoride, calcium and phosphate passed through following bed, therefore the defluoridation process started to take place in the next bed. This information may have implication for the practical operation of contact precipitation in columns; it may be better to start adding calcium and phosphate to the columns before saturating them with fluoride adsorption if an intermediary period of high effluent concentrations should be avoided.

CONCLUSION

Influence of catalyst type study confirmed that bone char or a similar compound is needed as a contact precipitation catalyst. Results indicated that contact precipitation capacity of bone char might be correlated with its adsorption capacity rather than production or color. Higher temperature resulted in higher efficiency of fluoride removal.

It was concluded that smaller grain size had higher efficiency and higher capacity in contact precipitation than the larger grain size.

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Nutrients Mineralization from Sludge Amended Acid Soil in Thailand

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ABSTRACT: Agricultural utilization of sewage sludge has been viewed as a first ranked disposal option for a big city such as the Bangkok Metropolitan Region (BMR). An appropriate sludge application depends on the rate of the mineralization process, which will release nutrients to the cropland. This incubation study aimed at investigating the nitrogen and phosphorus mineralization from two selected sludges, septage and sewage, mixed into an agricultural acid soil. The research design was multiple independent variables with two types of sludge, three sludge application rates, two levels of lime addition, and four incubation times under aerobic condition. A non-linear least square regression was used for prediction of mineralization parameters. Within six weeks, only 26% and 17% of nitrogen were mineralized in the soil applied with septage sludge and sewage sludge, respectively. The septage sludge gave higher potentially mineralizable nitrogen (N_0) 247 mg N/kg with mineralization rate constant (*k*) 0.046 week^{-1}. However, the application of septage sludge had a slightly lower phosphorus mineralization rate (48%) than that of the sewage sludge (51%). Total nitrogen and phosphorus mineralization increased with an increasing sludge application rate and incubation time. Other factor that influenced nitrogen mineralization was lime addition, while phosphorus mineralization depended on the sludge type. After six weeks of incubation, the soil had reached neutral pH, with an addition of 3-4% organic matter and contained higher total heavy metals. However, they were under the allowable metals concentrations, and phytotoxic threshold for plant growth.

Keywords: Nitrogen, Phosphorus, Mineralization, Sludge, Acid Soil, Recycling

INTRODUCTION

Utilization of organic waste such as sludge on agricultural lands is now receiving extensive interest. This is due to the high cost of sludge disposal and lack of areas for landfills. Moreover, the sludge contains a substantial amount of nutrients such as N, P, trace elements and organic matter (3), which are essential major and minor nutrients for plant growth. Large amounts of organic matter in sludge can act as a soil conditioner to improve the soil physical properties. This is essential for agricultural soils in Thailand, in which organic materials content is normally low. However, one of the most important determinants of the application rate is the nutrient supplying capacity from the sludge. Information about rate of nutrients release, especially nitrogen mineralization is necessary to predict nitrogen availability during a cropping season.

Earlier studies have reported on the mineralization of nitrogen in sludge. Application of sewage sludge to a sandy soil has beneficial effects on the microbial activity and nutrient mineralization. Inorganic nitrogen and phosphorus contents in the soil increased with the addition of sewage sludge (Wong et al, 1998). Laboratory incubation experiments designed to estimate the nutrient mineralization rate in field have been partially successful in predicting nitrogen availability to crops from sludge amended soil. Stanford and Smith (1972) incubated soil under optimal conditions to determine the nitrogen mineralization potential *(N_0)* and rate constant *(k)* of the soils. The first-order rate constant *(k)* and potential mineralizable nitrogen *(N_0)* was estimated using an iterative statistical method based on a first order rate equation. Others have used the same technique and found similar results (Smith et al, 1977; Cassman and Munns, 1980). Smith et al (1980) improved the method and found that a nonlinear least square equation provided more accurate estimation of *k* and *N_0*. This was confirmed by a study of Magdoff and Amadon (1980) who found that there was 54% organic nitrogen loss in 17 weeks from aerobically digested sludge under laboratory conditions and 55% loss under field conditions.

The objectives of this study were to investigate mineralization of nitrogen and phosphorus from an application of sludge to agricultural soil and to determine factors influencing nutrients' mineralization.

MATERIALS AND METHOD

Sample Collection And Characterization

The plough layer (0-20 cm depth) of Rangsit soil, dewatered septage from Nong Khame septage treatment plants and sewage sludge from Yannawa municipal wastewater treatment plants were sampled and studied. They were air-dried at ambient temperature 25-30°C, crushed by hand and sieved through a 2 mm stainless steel screen. The chemical properties of the sample were determined using the following techniques;

Soil pH values were measured by the electrometric method in a 1:2 soil:$CaCl_2$ mixture. Organic matter was analyzed by the Walkley-Black method. Total organic nitrogen was determined by a semi-micro Kjeldahl method. Inorganic nitrogen was extracted by KCl and measured by a colorimetric method. Total and available forms of phosphorus were analyzed by digestion with conc. H_2SO_4 and extraction with Bray II solution, respectively. P was then measured colorimetrically. Total and available heavy metals were digested with 7 M nitric acid and extracted with DTPA pH 7.3 respectively, and concurrently measured by atomic absorption spectrophotometry (AAS).

Incubation Study

Sludge was thoroughly mixed with the soil at rates corresponding to 10, 20 and 30 ton/ha, respectively. The mixtures were divided into two groups: Some were treated with lime at ratio of 3.12 g CaO /400 g soil and others without lime addition. The samples were incubated for 6 weeks under aerobic condition at 30°C and with 24 hrs. artificial light source. The samples were maintained at 60% moisture. At 0, 2, 4 and 6 weeks of incubation, the samples were analyzed for pH, total nitrogen, ammonium nitrogen, nitrate nitrogen, total phosphorus, available phosphorus and available heavy metals.

Statistical Analysis

Descriptive statistics, mean and percentage, were used to explain soil and sludge characteristics. The kinetic inorganic N data were statistically analyzed using nonlinear regression, as described by Smith et al (1980). Stepwise multiple regressions were used on the following equation to determine factors influencing the sludge mineralization process.

$$\boxed{N_m = N_o(1\text{-}e^{-kt})}$$

where;

N_m is amount of nitrogen mineralized at a specific time (mg/kg),

N_o is potentially mineralizable nitrogen (mg/kg),

k is the first-order rate constant of mineralization ($weeks^{-1}$),

t is time of incubation (weeks).

RESULTS AND DISCUSSION

The general characteristics and metal contents in the sludges and soil are listed in Table 1. The sludges had a suitable pH range and were rich in organic matter and plant nutrients. The soil, on the other hand, had poor characteristics for planting. For heavy metals, however, the sludges also contained higher amount of heavy metals than the soil but they did not exceeded the allowable ranges for application on agricultural land (Follett et al, 1981).

Sludge amendment could improve the NH_4^+-N content of soil, increasing with higher sludge application rate. The NH_4^+-N concentration of all samples increased along the incubation time from week 0 to week 4, after that they decreased till the end of experiment. Nitrate nitrogen (NO_3), increased slowly from week 0 to week 4 of the incubation period and during the weeks 4-6 it increased rapidly. The initial increase in NH_4^+-N content was due to the mineralization of organic nitrogen in the sludge and the soil that release NH_4^+-N as one of the degradation products (Wong JC et al, 1998). It is believed that the decline in NH_4^+-N content at the later period may be due to the decrease in nitrogen mineralization rate as the amount of organic nitrogen decreases, combined with the process of nitrogen volatilization and immobilization, rather than nitrification.

Table 1: Characteristics of sludges and acid soil

Parameters	Septage sludge	Sewage sludge	Acid soil
pH	6.37	6.69	4.42
OM (%)	33.9	13.5	2.86
C/N ratio	4.6	3.3	57.0
Total N (%)	7.35	4.10	0.05
NH_4 (mg/kg)	124	151	46
NO_3 (mg/kg)	1,544	1,408	0
Total P (mg/kg)	10,930	10,737	33
Available P (mg/kg)	3,412	1,034	7
Total heavy metals (mg/kg)			
- Cd	4.36	3.84	1.10
- Cu	477	768	34
- Fe	14,394	38,341	20,882
- Mn	376	2,286	79
- Pb	72	1,938	51
- Zn	2,167	2,317	24
Available heavy metals (mg/kg)			
- Cd	0.08	0.37	0
- Cu	0.63	14.97	2.38
- Fe	203	44	101
- Mn	17.1	91	17.0
- Pb	0.38	1.18	1.73
- Zn	159	233	3.2

Most of the nitrogen mineralization ratios (% released) at the end of operation increased with increasing sludge application rate. Thus the highest mineralization rate was found at sludge application rate 30 ton/ha. The nitrogen mineralization ratios in the experiments with septage sludge were ranged from 21.5% to 31.3%, with a mean value of 26.2%. They were within the range of a study of Qafoku OS et al (2001). Concerning lime addition, the mean value of nitrogen mineralization ratios in the treatments without lime addition was 29.9% while those of treatment with lime addition was 22.5%. When applied with sewage sludge, the nitrogen mineralization rates were ranged from 10.4% to 22.4%, with a mean value of only 17.4%. It agrees with a study of Garau MA et al (1986). A higher nitrogen mineralization rate (21.1%) without lime addition was also obtained than in those treated with lime (13.9%). This might be due to the acidity/alkalinity of the soil having a considerable influence on nutrient availability.

Kinetics Of Nitrogen Mineralization

The curvilinear relationship between cumulative amount of nitrogen mineralization and incubation time indicated that this nitrogen mineralization can approximately be explained by a first-order kinetics. The amount of potentially mineralizable nitrogen (N_o) and the first-order rate constant (k) for the 6 weeks incubation time are derived using a nonlinear regression technique, described by Smith et al (1980). The best estimates are shown in Table 2.

The potentially mineralizable nitrogen (N_o) obtained from the treatment applied with septage sludge and sewage sludge are ranging from 215 to 292 mg/kg soil and 132 to 310 mg/kg soil, respectively. The application of septage sludge could be expected to give higher amount of N_o than the sewage sludge since it contained higher amount of nitrogen. However, they were both within the range (71-394 mg/kg soil) reported by Serna MD et al (1992). In agreement with the higher mineralization ratio of treatment without lime addition, N_o was also higher when no lime was applied. N_o increased with increasing sludge application rate. This result was similar to the study of Garau MA et al (1986) and Parker CF et al (1983).

Although the N_o values varied among the different types of sludge and soil, it is related to the cumulative amounts of nitrogen mineralization (Serna MD et al., 1992). A higher N_o value corresponds to a higher nitrogen mineralization. From such kind of results, the N_o value of sludge treated soil is assumed to be a well-defined quantity that can be useful for estimating nitrogen supplying capacities of soils under specific environmental conditions (Deng SP et al, 2000).

The k values obtained from treatments applied with septage and sewage sludge were ranged from 0.038 to 0.055 week^{-1} and 0.044 to 0.062 week^{-1}, respectively. They were lower than the range of 0.089-0.883 week^{-1}, reported by Serna et al (1992). The increasing sludge application rate could increase k value. Thus the highest k value was found at an application rate 30 ton/ha. A study of Lindermann WC et al (1984) also reported that mean k values were increasing with sludge addition. The application of sewage sludge gave a lower N_o but a higher k value than that of the septage sludge. A study of Deng SP et al (2000) explained that the N_o and k values of soils tested were significantly negatively correlated (r = -0.72). However, Lindermann WC et al (1984) pointed out that the k values were significantly different between soils but the tendencies were not clearly observed for the different types of sludge.

When N_o is multiplied by the first-order kinetic rate constant (k), the product obtained could be used as an index of nitrogen availability. This signifies the amount of nitrogen potentially mineralizable in one week under optimum soil temperature and moisture conditions (Serna MD et al, 1992). From the studied results, the application of septage sludge 30 ton/ha without lime addition had the highest N_ok value (16.1 mg/kg/week) while application of 10 ton/ha with lime addition had the lowest N_ok value (8.2 mg/kg/week). These results supported the suitability of N_ok value as a reliable index of nitrogen availability because is closely related with the cumulative amounts of available nitrogen.

Table 2: Estimated kinetic constants of nitrogen mineralization under different conditions.

Types of Sludge	Lime Addition	App. Rates (ton/ha)	N_0 mg/kg	K week^{-1}	R^2
Septage sludge	0 g	10	265	0.037	0.28
		20	275	0.040	0.29
		30	292	0.055	0.39
	3.12 g	10	206	0.040	0.35
		20	215	0.050	0.42
		30	231	0.053	0.40
Sewage sludge	0 g	10	214	0.044	0.46
		20	206	0.046	0.47
		30	310	0.061	0.50
	3.12 g	10	184	0.046	0.57
		20	132	0.052	0.76
		30	234	0.061	0.69

Notes:

N_0 = Potentially mineralizable N obtained from nonlinear least square regression (mg/kg soil).

K = The first-order rate constant obtained from nonlinear least square regression (week^{-1}).

R^2 = Correlation coefficients as a result of nonlinear least square regression, significant at the 0.05 level of confidence.

Phosphorus Mineralization

Phosphorus mineralization has also been recorded in the sludge application experiments. Total phosphorus in the soil applied with septage sludge and sewage sludge were ranging from 10.91 to 30.64 mg/kg and 8.62 to 64.58 mg/kg, respectively. The change of organic phosphorus forms to inorganic phosphorus forms took mainly place the first four weeks. It was very fast in the first two weeks and thereafter slower. Then the organic phosphorous were increased at week 6, which is caused by the utilization of available phosphorous from the dead cell (Wong JC, 1998). A study of Thompson LM et al (1973) suggested that there is a fraction of the organic phosphorus in soil that soon disappears under cultivation. The remaining organic phosphorus is changed more slowly after this fraction is gone. Thus the lowest concentration of organic phosphorus was found at week 4 of the incubation period. Correspondingly, the available phosphorus concentration was increased during first four weeks and decreased afterwards. The decrease was due to utilization of the newly formed available phosphorus by soil microbes (Thomson Lm, 1973 and Wong JC, 1998). Thus the process of mineralization and immobilization of nitrogen and phosphorus occurs in a similar way and it determines the amount of nutrients available for plant uptake (Metting FB, 1993).

Most of phosphorus mineralization rates increased with increasing sludge application. Ahn PM (1993) indicated that a high organic content and good rate of organic matter mineralization should ensure a rate of release of phosphate ions adequate for crop production. However, the addition of lime could increase the phosphorus mineralization rate up to 8-12%. The mineralization of organic phosphorus is enhanced by pH values that are conducive to general microbial action (Follett et al, 1981). The mean phosphorus mineralization ratio (49.8%) was higher than that of the nitrogen mineralization rate (21.8%). Phosphorus mineralization is partly dependent on the availability of nitrogen and a small amount of nitrogen included in a phosphorus fertilizer makes it more effective (Thomson et al, 1973). The cumulative amount of phosphorus mineralization in soil applied with sewage sludge (51%) was higher than that of the septage sludge (48%), although the difference was small. The C/P ratio is one of the factors, which is important for the phosphorous mineralization rate. Microbiologists agree that a net rate of phosphorus mineralization occurs when C/P ratio in plant residues is less than 200:1 (Follett et al, 1981). In this study the C/P ratio of septage sludge was 31:1 while that of sewage sludge was 13:1. It means that the phosphorus mineralization would also be expected to occur very well in both soil applications.

Factors Influencing Nitrogen Mineralization

There are many factors influencing organic nitrogen mineralization in soil applied with sludge such as soil type, soil pH, temperature, aeration, moisture, rate of sludge, type of sludge and rainfall (Parker CF et al, 1983 and Serna MD et al, 1992). From the analyzed results, factors influencing nitrogen mineralization were (in this order) incubation time, addition of lime and sludge application rate. Increasing the incubation time could clearly increase the cumulative amount of available nitrogen. The incubation time has effect on microbial activities and nutrients transformation. Regarding the addition of lime, it had a negative effect on the nitrogen mineralization rates. A study of Epstein et al (1978) indicated that lime addition generally reduces the level of soluble nitrogen and total nitrogen. Although the treatments without lime addition gave higher nitrogen mineralization rates, however, it cannot surely confirm this explanation. It was a short-term incubation time and there was not enough time for the lime to react with the soil. Generally, lime should be applied 3-6 months ahead of planting the crop especially on very acidic soils (Glendinning, 2000). Concerning sludge application rate, it could increase nitrogen mineralization rates, cumulative amounts of nitrogen mineralization, N_o values and N_ok values. The amounts of ammonium and nitrate nitrogen were highest in the soil applied with 30 ton/ha sludge. It was in agreement with a study of Wong JC et al (1998), who found that increasing sludge amendment rate caused an increasing nitrogen mineralization. In addition, Serna MD et al (1992) reported that increasing sludge application rate could increase cumulative amount of nitrogen mineralization, N_o values and N_ok values.

Factors Influencing Phosphorus Mineralization

The factors influencing phosphorus mineralization are ranged in this order; sludge application rate, type of sludge (sewage/septage sludge) and incubation time. In case of sludge application rate, the sludge application rate 30 ton/ha gave the highest phosphorus mineralization rate and cumulative amount of phosphorus mineralization. Wong JC et al (1998) found that the phosphorus mineralization increased as the sludge amendment increased. Regarding the type of sludge, the sewage sludge gave higher cumulative amount of phosphorus mineralization than that of septage sludge. The lower pH of septage sludge (6.37) might inhibit the soil microbe activities compared to the more neutral pH (6.69) of sewage sludge. Concerning incubation time, the cumulative amount of available phosphorus was increased within a short incubation time (4 weeks) and it was decreased thereafter. The decrease might be due to the utilization of available phosphorus by the bacteria and the decrease in easily mineralizable organic phosphorus. Wong JC et al (1998) also found a similar result. However, incubation time is one factor influencing phosphorus mineralization since longer-term incubation time could increase phosphorus mineralization rates as a whole.

In summary, the main factors influencing both nitrogen and phosphorus mineralization were incubation time and sludge application rate. The longer incubation time and higher sludge application rate could enhance greater nutrient mineralization. However, an increasing sludge application rate could also give higher metals in sludge applied soil as well.

Change Of Sludge Applied Soil Characteristics

The pH of most soil applied with sludges was nearly seven at the end of operation and within the appropriate range for plant growth. It is an important factor affecting microbial growth and the high pH could help decreasing the heavy metals availability in the soil (Chen ZS, 2002 and Alva A. K. et al, 2000). Organic matter (OM) was increased with increasing sludge application rate. The soil applied with septage sludge had higher OM than soil applied with sewage sludge since OM contents in the septage sludge were two times higher than the sewage sludge. The amount of OM at the end of incubation time was higher than that of the first week of experiment. It may be a result of action of soil microorganisms.

The amounts of total heavy metals in the soil applied with sludges were increased compared to the bare soil. However, they were lower than an acceptable range for agricultural utilization as reported in many countries. The sludge applied soil with lime addition had generally lower available heavy metals than those without lime addition. When soil pH is raised by the sludge amendment, most heavy metals were partitioned into sparingly mobile pools (Parkpain P et al, 2000). The amount of available heavy metals was increased with increasing sludge application rate. At the end of operation, however, they were under the phytotoxic threshold concentrations of plant growth (Glendinning JS, 2000).

CONCLUSION

The sewage sludge and septage sludge had large amounts of plant nutrients and appropriate pH range for plant growth. They could be used as soil conditioner since the Rangsit soil had poor characteristics for agricultural purpose.

Application of sludge caused significant increasing of plant nutrients in the soil. The amount of organic nitrogen and phosphorus forms were lowest at week 4 of incubation. And thus opposite, at this time the content of inorganic nitrogen and available phosphorus were the highest. At the end of the experiment (6 weeks), nitrogen mineralization rates in the soil applied with septage sludge and sewage sludge were 26% (21% to 31%) and 17% (10% to 22%), respectively. Phosphorus mineralization rates in the soil applied with septage sludge and sewage sludge were 48% (29% to 63%) and 51% (42% to 65%), respectively.

There was a curvilinear relationship between cumulative amount of nitrogen mineralization and incubation time. It indicated that the nitrogen mineralization can be approximated by a first-order kinetics using a nonlinear regression technique. The amount of nitrogen potentially mineralizable in one week under optimum soil temperature and moisture conditions (N_ok) was estimated. The application of septage sludge gave a potentially mineralizable nitrogen (N_o) 247 mg N/kg soil with mineralization rate constant k = 0.046 week^{-1}. The sewage sludge gave a bit lower potentially mineralizable nitrogen (N_o) 213 mg N/kg soil with mineralization rate constant k = 0.052 week^{-1}. These results can be used as an index of nitrogen availability for sludge application to acidic soil.

The nitrogen and phosphorus mineralization increased with increasing sludge application and incubation time. Another factor influencing nitrogen mineralization was lime addition; without lime addition it gave a higher mineralization. The type of sludge also affected phosphorus mineralization; soil applied with sewage sludge had higher mineralization rate than that of the septage sludge.

After six weeks of incubation, the soil pH became neutral (pH 7) and the organic matter content was around 3-4%. It had a significant increase of both plant nutrients and heavy metals. The available and total heavy metals were under the allowable metal concentrations and phytotoxic threshold for plant growth. It is recommended for agricultural utilization of sludge that the amendment rate should be considered in order to increase the mineralization ability while minimizing the toxic effects of the amendment at the same time.

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Effects Of Fe/As And Ph On Arsenic Removal By Fe(II)/O_2 Process

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ABSTRACT: In batch study, arsenic synthetic wastewater were experimentally treated by Fe(II)/O_2 process at various pH, contact times, iron and arsenic concentration and Fe/As ratio of 50/1 - 2.5/ 1 , 100/1- 5/1 and 200/1- 10/1 in order to investigate arsenic removal efficiency. The results revealed that the best contact time is 60 minutes. The highest As and Fe removal simultaneously was initial Fe/As ratios of 10/1 which initial pH 8 was outstandingly significant and initial iron concentrations of 5.0 ppm.In column study, two media that used as single media including sand and activated carbon were studied at filtration rate of 0.1, 0.2 and 1.0 m/h and bed depth of 10, 20 and 30 cm. The results presented that highest Arsenic removal in term of treated volume was 0.1 m/h-flow rate on AC media. This result can be explained that As-Fe floc was filtrated and adsorbed by AC.

INTRODUCTION

Arsenic's are commercially and industrially used as alloying agent in the manufacture of transistors, lasers and semiconductors. Naturally, it is a mineral that appears in a variety of combined forms. Arsenic is introduced into water through the dissolution of minerals and ores, from industrial effluents. Natural sources, such as the dissolution of arsenic–containing bedrock, often contribute significantly to the arsenic content of drinking water and groundwater.

Inorganic arsenic occurs in water mainly as arsenite [As (III)] and arsenate [As (V)]. In well-oxygenated surface waters, arsenate is generally the most common species present; under reducing conditions, such as groundwater, arsenite is the predominant form.

.Arsenic removal with metal salts has been shown since at least 1934 (Buswell, 1943). The most commonly used metal salts are aluminum salts such as alum, and ferric salts such as ferric chloride or ferric sulfate. Ferrous sulfate has also been used, but is less effective (Jekel, 1994; Hering et al., 1996; Hering et al., 1997). Excellent arsenic removal is possible with either ferric or aluminum salts, with laboratories reporting over 99% removal under optimal conditions, and residual arsenic concentrations of less than 1 µg/L (Cheng et al., 1994). Full-scale plants typically report a somewhat lower efficiency, from 50% to over 90% removal. Alum and ferric salts dissolve upon addition to water, forming amorphous hydrous aluminum and ferric oxides (HAO and HFO, respectively), which are relatively insoluble at circumneutral pH ranges. These metal hydroxides form gelatinous flocs that bind to other flocs and settle out of solution, scavenging many dissolved and particulate materials in the process. Vigorous stirring is usually required to ensure uniform mixing for optimal coagulation. If water is soft and of low alkalinity it may be necessary to add alkalinity to ensure floc formation. Sometimes polymers or colloidal substances such as clays are added to improve flocculation and sedimentation Cheng and others have shown that addition of 2-4 mg/L of cationic polymer allows coagulant dose to be reduced by two-thirds while maintaining good arsenic removal (Cheng et al., 1994). Thus polymers or clays can be used to improve arsenic removal efficiency, and to reduce the volume of sludge generated. Sludge is usually not regenerated, but disposed of directly.

The main object of this study is to find the removal efficiency of As from synthetic contaminated water using batch experiments at various operating conditions of initial arsenic and iron concentrations. In addition, the effects of filtration using two types of single media column, sand and AC were also studied

MATERIALS AND METHOD

Batch experiments were conducted in order to study the removal efficiency of As by Fe (II)/O_2 system. Prepared As (III) and As (V) stock solutions were diluted by RO water to reach the desired arsenic concentrations with a volume of 2 L, then the solution were poured into the reactor. Initial concentration of As was varied from 50 to 1000 ppb. Coprecipitation experiments were conducted by adding desired amount of Fe (II) solution (Fe/As ratio was varied from 1/1 to 200/1) into the reactor. Before aeration, the solution pH was adjusted to the desired value in the range of 2 – 12 by adding HCl or NaOH. The solutions were aerated by controlling the air-diffuser, the aeration time was controlled at 60 minutes.The pH was measured and were collected from the reactor by using pipet for further analysis. The suspensions or colloids were removed by filtration the samples through 0.45 µm pore size Glas Microfiber filter (GFC). The operating conditions of various variables are summarized as shown in Table 1. All the experiments were conducted at ambient temperature.

Table 1. Operating Conditions of batch experiments in this study.

Fe (ppm)	As (ppb)	pH	Contact time (min)
2.5	50	2-12	60
5.0	100		
10.0	250		
	500		
	1000		

RESULT AND DISCUSSION

In arsenic removal by Fe(II)/O_2 process, the precipitation, co-precipitation and adsorption are the main mechanisms. Precipitation refers to the insolubilization of contaminants by exceeding a solubility product, in this case ,the insoluble solid was $FeAsO_4.2H_2O$. Co-precipitation is define as an incorporation of soluble arsenic species into a growing hydroxide phase via inclusion, occlusion, or adsorption. Finally, adsorption refers to formation of surface complexes between soluble arsenic and the solid oxyhydroxide surface site. The possible reactions of arsenate with hydrous iron oxide are shown below where $\equiv FeOH^o$ represents for oxide surface site(Ahmed, 2001).

$$Fe(OH)_3(s) + H_3AsO_4 \rightarrow FeAsO_4.2H_2O + H_2O \quad (1)$$

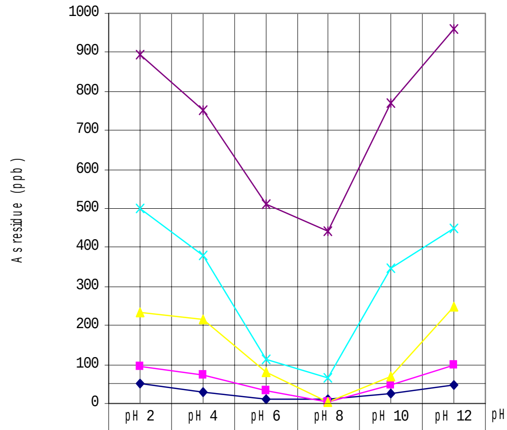
$$\equiv FeOH^o + AsO_4^{3-} + 3H^+ \rightarrow \equiv FeH_2AsO_4 + H_2O \quad (2)$$

$$\equiv FeOH^o + AsO_4^{3-} + 2H^+ \rightarrow \equiv FeHAsO_4 + H_2O \quad (3)$$

Immobilization of arsenic by hydrous iron oxide can be expressed as shown in equation 1 to 3. These mechanisms of arsenic removal require oxidation of arsenic species into As(V) form which will increase the efficiency. The mechanism representation for equation 1 is precipitation. This reaction occurs at low pH because the form of H_3AsO_4 is present at low pH. Equation 2 and 3 represent the adsorption mechanism.

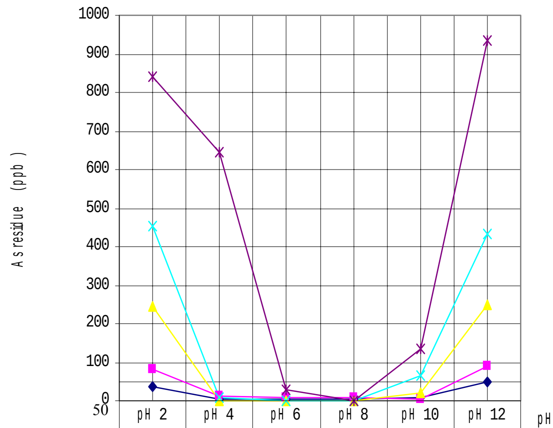
The effect of initial solution pH on As removal due to the natural water source is different. This effect was studied at contact time of 60 minutes, initial pHs of 2, 4, 6, 8, 10, and 12, initial Fe concentrations 2.5, 5.0 and 10.0 ppm, and initial As concentrations 50, 100, 250, 500, and 1000 ppb, respectively. The As concentration at various condition is shown in Figure 1 to 3.

Figure 1, reveals that the best As removal is at initial pH 8 due to the As dominant form as $HAsO_4^{2-}$, which can be adsorbed by iron floc to form $\equiv FeH_2AsO_4$. Thus, the efficiency of arsenic removal at this pH 8 is the maximum value. However, the As residues at initial As concentrations of 500 and 1000 ppb, initial pH 8, initial Fe concentration 2.5 ppm are higher than the drinking water standard due to iron flocs are not enough to entrap As ions.



	pH 2	pH 4	pH 6	pH 8	pH 10	pH 12
As 50 ppb, Fe 2.5 ppm	50	30.04	9.73	9.77	25.83	48.13
As 100 ppb, Fe 2.5 ppm	96.4	73.54	33.06	3.72	46.8	100
As 250 ppb, Fe 2.5 ppm	235.3	214.4	80.35	3.65	69.8	250
As 500 ppb, Fe 2.5 ppm	500	380	112.1	67.1	348	450.3
As 1000 ppb, Fe 2.5 ppm	895.4	750	510.8	441	770.6	960.8

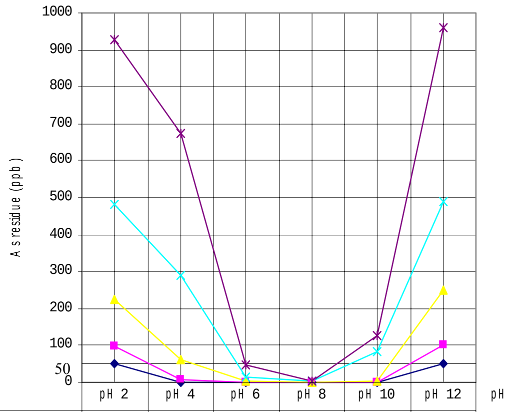
Figure 1. As residue at initial pH 2, 4, 6, 8, 10, and 12, initial Fe concentrations 2.5 ppm and initial As concentrations 50, 100, 250, 500, and 1000 ppb.



	pH 2	pH 4	pH 6	pH 8	pH 10	pH 12
As 50 ppb, Fe 5.0 ppm	38.69	2.95	2.24	3.64	6.63	47
As 100 ppb, Fe 5.0 ppm	82.28	11.3	7.54	7.62	5.84	90.54
As 250 ppb, Fe 5.0 ppm	245.4	0.1	0	0	19.05	247.3
As 500 ppb, Fe 5.0 ppm	451.3	7.1	0	0	64.5	432.7
As 1000 ppb, Fe 5.0 ppm	842.6	643.6	30.6	0	134.4	934.4

Figure 2. As residue at initial pH 2, 4, 6, 8, 10, and 12, initial Fe concentrations 5.0 ppm and initial As concentrations 50, 100, 250, 500, and 1000 ppb.

Figure 2 shows the As residues at initial pH 2, 4, 6, 8, 10, and 12, initial Fe concentrations 5.0 ppm and initial As concentrations 50, 100, 250, 500, and 1000 ppb. In initial As concentration of 50 to 500 ppb-solutions, As removals are effective at widely range of initial pH 4 to pH 10 due to at this rang of pH , $H_2AsO_4^-$ and $HAsO_4^{2-}$ are the main As forms in the solution. These forms of As can be easily adsorbed by iron floc. The reaction between As and Fe is shown in equations 2 and 3. During this type of reaction all negatively charged metal ions are attached to the flocs by electrostatic attachment. As forms which in the range of 4 to 10 are also adsorbed onto the coagulated flocs.



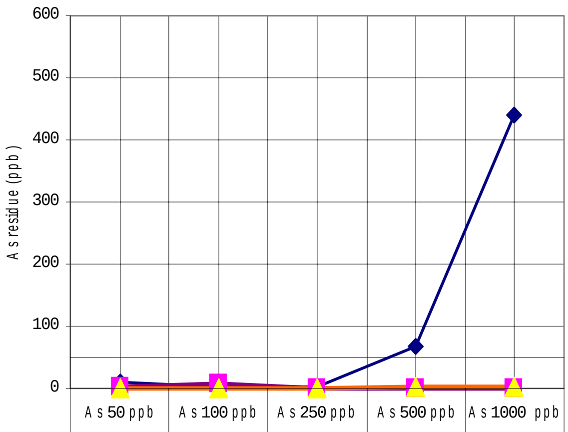
	pH 2	pH 4	pH 6	pH 8	pH 10	pH 12
As 50 ppb, Fe 10.0 ppm	50	0	0	0	0	49.12
As 100 ppb, Fe 10.0 ppm	98.68	8.36	0.04	0.18	1.08	100
As 250 ppb, Fe 10.0 ppm	225.35	60.95	3.3	0.5	4.1	249.95
As 500 ppb, Fe 10.0 ppm	481.7	289.7	15.3	2.1	83.1	489.5
As 1000 ppb, Fe 10.0 ppm	928.4	675.4	47.6	3.6	126.2	959.4

Figure 3.As residue at initial pH 2, 4, 6, 8, 10, and 12, initial Fe concentrations 10.0 ppm and initial As concentrations 50, 100, 250, 500, and 1000 ppb

Figure 3 shows that a large amount of arsenic is removed at initial Fe concentration of 10.0 ppm in the pH range of 4 to 10. The reason for this may be due to the formation of $\equiv FeOH^o$ complex, which can be formed at this pH range. This complex form can introduce the adsorption and co-precipitation of arsenic. The reactions can be explained by equations 2 and 3. The $\equiv FeOH^o$ is required to react with H^+ and AsO_4^- ions. At initial pH of 8, As removal efficiency was highest but Fe residue was over drinking water standard.The reason of this may be due to the Fe oxidation process being incomplete at initial iron concentration of 10.0 ppm. This process takes place in the removal of Fe residue from standard drinking water (Fe 1.0 ppm maximum).
In this section, it can be clearly seen that at pH 8, As can be effectively removed by the Fe(II)/O_2 process in widely range (under all conditions).

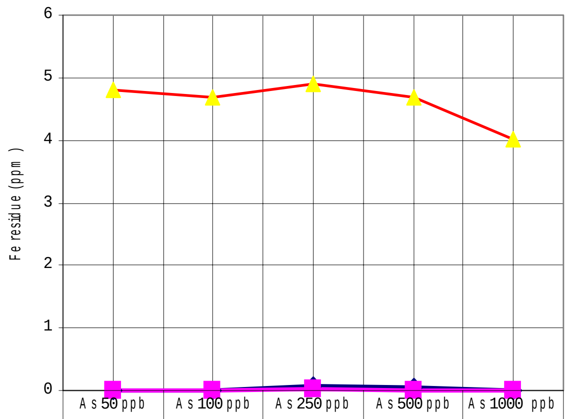
The effect of Fe/As ratio on arsenic removal efficiency was studied and the comparison of these relationships is depicted in figure 4.

Referring to Figure 4 and 5, As removal efficiency is high at high initial Fe concentration. Although Fe residue of initial Fe 2.5 ppm-solution is lower than the drinking water standard at all conditions, As residues from initial As of 500 and 1000 ppm are higher than the drinking water standard. As removal efficiency at initial concentration of 500 and 1000 ppb are low due to an insufficient quantity of iron complex form ($\equiv FeOH^o$). Increasing the iron concentration in the synthetic wastewater would likely enable As removal at initial Fe 5.0 and 10.0 to consistently achieve lower levels of Arsenic. Thus, the most efficient As removal was obtained at initial Fe concentration of 5.0 and 10.0 ppm.



	As 50 ppb	As 100 ppb	As 250 ppb	As 500 ppb	As 1000 ppb
Fe 2.5 ppm	9.77	3.72	3.65	67.1	441
Fe 5.0 ppm	3.64	7.62	0	0	0
Fe 10.0 ppm	0	0.18	0.5	2.1	3.6

Figure 4. As residue at initial pH 8, initial Fe concentrations 2.5, 5.0 and 10.0 ppm and initial As concentrations 50, 100, 250, 500, and 1000 ppb.



	As 50 ppb	As 100 ppb	As 250 ppb	As 500 ppb	As 1000 ppb
Fe 2.5 ppm	0	0	0.06	0.05	0
Fe 5.0 ppm	0	0	0.02	0	0
Fe 10.0 ppm	4.81	4.68	4.91	4.68	4.02

Figure 5. Fe residue at initial pH 8, initial Fe concentrations 2.5, 5.0 and 10.0 ppm and initial As concentrations 50, 100, 250, 500, and 1000 ppb

It can be summarized that a large amount of arsenic is removed at initial Fe concentration of 5.0 and 10.0 ppm. The reason for this may be caused by the $\equiv FeOH^o$ complex, which can be formed at pH 8. This complex form can introduce the adsorption and co-precipitation of arsenic. The reactions of these mechanisms can be explained by equations 2 and 3. The $\equiv FeOH^o$ is required to react with H^+ and AsO_4^- ions. Moreover, arsenic can also precipitate at pH 8. As removal efficiency at initial Fe concentration of 10.0 ppm was high at Fe residue was in the range of 4.02 to 4.91 ppm. The Fe residues are higher than the drinking water standard due to the Fe oxidation process being incomplete at initial iron concentration of 10.0 ppm. This process takes place in the removal of Fe residue from standard drinking water (Fe 1.0 ppm maximum).

In addition, it can be concluded that As removal is highly effective at high initial Fe concentration. As removal is maximized at initial Fe concentration of 5.0 ppm due to residual As and Fe concentrations meet the drinking water standard.

The effects of Fe/As ratios on As removal efficiency using the Fe(II)/O_2 batch experiments were studied due to the Fe/As ratios in each natural water source is different. This effect was studied under a contact time of 60 minutes, initial pH 8, initial Fe concentrations of 2.5 ppm, representing initial Fe/As ratios of 50/1, 20/1, 10/1, 5/1 and 2.5/ 1, respectively, as shown in Figure 6.

The residual As concentrations from initial Fe/As ratio of 5/1 and 2.5/1 are higher than the drinking water standard. The As removal from initial Fe/As ratios of 5/1 and 2.5/1 is ineffective due to an insufficient quantity of iron complex floc to entrap As. The As residues are less than the drinking water standard when initial Fe/As ration are 10/1, 25/1 and 50/1. The maximun Fe/As ratio for As and Fe removal by the Fe(II)/O_2 batch experiments at the sametime is 10/1 due to quantity of Fe per As concentration.

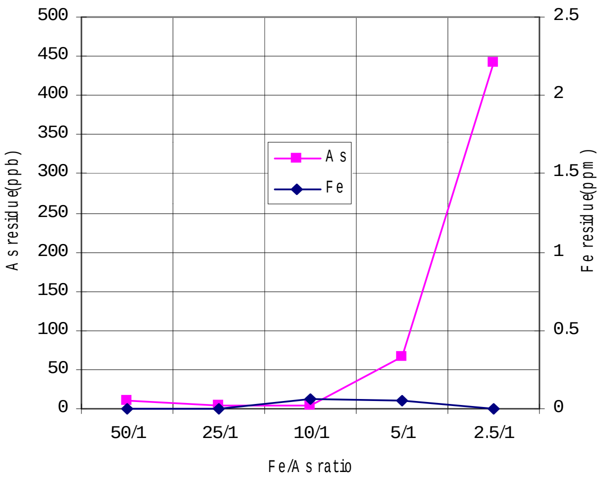


Figure 6. Residual As and Fe concentrations from Fe(II)/ O_2 process in batch experiments at initial Fe concentrations of 2.5 ppm, initial Fe/As ratios of 50/1 to 2.5/ 1 and initial pH 8.

CONCLUSION

Arsenic removal by Fe(II)/O_2 process in batch test showed that this process effectively remove arsenic from the synthetic waste water. Arsenic removal is effective at initial iron concentration of 5.0 ppm and pH of 8. The maximum Fe/As for arsenic removal is 10/1.

ACKNOWLEDGMENT

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Ultrafiltration Of Treated Palm Oil Mill Effluent (POME)

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ABSTRACT: Treatment of palm oil mill effluent (POME) has always been a topic of research in Malaysia. This effluent that is extremely rich in organic content needs to be properly treated to minimize environmental hazards before it is released into watercourses. The common practice for treating POME in Malaysia involves a combination of aerobic and anaerobic methods. The purpose of tertiary treatment is to allow the treated water to be reused in the mill operations for other purposes such as feed water. In this study membrane ultrafiltration is used as the tertiary treatment method. Before the actual membrane operation was conducted, the samples were pre-treated using coagulation. Poly Aluminium Chloride, PAC was used as coagulant and it was found that 15 ml PAC / 1 L effluent to be the optimum dosage. The ultrafiltration of POME was carried out using two different hollow fiber membrane modules (PM 30 and PM 50) each with an effective area of 1.394m^2. The system was conducted based on a semi batch process. It was observed that, PM 30 hollow fiber module operated at TMP of 90 kPa, produced the best-treated sample quality in terms of pollutant contents elimination, namely, 92.2% suspended solids and 97.6% nitrogen removal. This also shows that, permeate and retentate quality meets the selected discharge standard of Environmental Quality Act 1984.

Keywords: Membrane technology, Ultrafiltration, POME

INTRODUCTION

The processing of oil palm fresh fruit bunches (FFB) primarily for palm oil also results in concomitant production of wastes in the forms of palm oil mill effluent (POME), empty fruit bunches, mesocarp fiber and shell. When the industry was at its infancy in 1960's, ignorance compelled us to dispose POME into the waterways or by any other methods to our convenience. The problem of pollution accruing from a mere 92 000 tonnes production by only 10 mills was not apparent then. The environment was able to assimilate

This lackadaisical attitude towards waste discharge did not last long. By the 1970's the growth of the industry was literally exponential, bringing along with it pollution which the waterways could no longer handle. The palm oil processing became synonymous to POME pollution. The oxygen depleting potential of POME is 100 times that of domestic sewage. The industry was faced with a major problem, virtually completely lacking in any proven technology to treat POME.

Committed to overcome the problem, the government and the industry worked together to source for treatment technologies that are environmentally and economically sound. This government-industry synergy towards a common goal - pollution abatement paid off handsomely. Systems for treatment of organic industrial wastes were successfully adapted for POME treatment. The three most commonly used systems were ponding system, open tank digester and extended aeration system, and closed anaerobic digester and land application system.

The year 1978 witnessed the enactment of the Environmental Quality Regulations detailing POME discharge standards. BOD was the key parameter in the standards. From the initial BOD of 25 000 ppm of the untreated POME, the load was reduced to 5 000 ppm in the first generation of discharge standard, down to the present BOD of 100 ppm for Standard B.

Palm oil mills using wet milling process account for the major production of palm oil in Malaysia, Indonesia and Thailand. Besides the main product “crude palm oil”, the mills generate many by-products and liquid wastes that may have significant impact on the environment if they are not dealt with properly. One tonne of fresh fruit bunches (FFB) composed of 230-250 kg of empty fruit bunches (EFB), 130-150 kg of fiber, 60-65 kg of shell and 55-60 kg of kernel and 160-200 kg of crude oil. EFB are bulk solid residues and its use as fuels for boiler is constrained by its high moisture content and low heating value (<10 MJ/kg dry EFB). (*Industrial Processes The Environment Handbook No.3, 1999*)

Palm oil mill effluent (POME) is the mixture of high-polluted effluent (from sterilizer and oil room) and low polluted effluent (steam condensate, cooling water, boiler discharge and sanitary effluent). To minimize overall treatment cost, the different wastewater streams should be collected and treated separately. Oil separated from the wastewater stream by gravity type oil separators is recommended which will contribute to improved production yield and minimize the organic loading for subsequent biological treatment system.

The most appropriate secondary treatment for POME is biological digestion in which the combination of anaerobic and aerobic ponds is used presently. Closed anaerobic system should be used for energy conservation. Some palm oil mills having their plantation nearby have carried out application of biologically treated POME for irrigation. The POME dosage should be based on the fertilizer requirement of plants. Spillage of POME into ground water or into surface water must be avoided.

A possible technological solution to produce higher quality effluent is through the use of membrane technology at the tertiary treatment stage. Membrane treatment is capable of providing a highly efficient treatment, requires minimal energy, and does not introduce any additives to the waste stream.

There are many membrane process applications on water and wastewater treatment that has proven to be efficient. Membrane technology covers a large spectrum of separation techniques, ranging from reverse osmosis to microfiltration. Among the various membrane processing technologies, ultrafiltration offers an attractive option for wastewater treatment. It is a low pressure-driven membrane process retaining most effectively macromolecules sized within 0.001 – 0.02 μm. Although the biologically treated POME is already low in biodegradable organic contents, it still possesses significant amount of persistent cellulosic materials and oily residues that usually occurs in the form of macromolecules. With membrane ultrafiltration, these molecules could be separated from the waste stream thus producing a higher quality effluent.

In this research project, a study has been carried out to examine the feasibility of using membrane ultrafiltration for the final treatment of POME extracted from the aerobic treatment pond. The objectives are to:

- Evaluate the effectiveness of different concentration of *Poly Aluminium Chloride* (PAC) as a coagulant agent for pre-treatment prior to membrane ultrafiltration. Studies had already been carried out on the effectiveness of *Ferrous Sulphate* and *Ferric Sulphate* (Pui Wah, 2002). As the final discharge of POME is still high in solid contents, the possibility of membrane fouling is high. Therefore, pre-treatment is normally required to improve the quality of feed, as it is a convenient way to reduce fouling.
- Investigate the effect of MWCO on ultrafiltration permeate and retentate quality of pre-treated samples.
- Study the overall efficiency of ultrafiltration with different MWCO.
- To compare the permeate flux of the sample and deionized water in order to understand the fouling conditions.
- To determine the possibility of recycling the final discharge effluent as feed water for daily applications in the mill.

Current Status Of POME Treatment Using Membrane Technology In Malaysia

Due to intensive activities of palm oil milling process in Malaysia, a great amount of waste is generated daily. The current treatment available is not sufficient in the long run; therefore research has been carried out to provide a better treatment.

One of the studies was reported by, **Ahmad et.al.,** on integrated of membrane separation with pretreatment process for palm oil mill effluent disposal. From the studies, it was observed that, the pre-treatment process has two stages of separation, first stage is the removal of suspended solids using coagulation and settling and the second stage is removal of oil and grease using solvent extraction. Both treatments are important to reduce membrane fouling at the later stage. Effect of pH, coagulant concentration, mixing time and solvent to oil ratio were studied to find the optimum condition for the pretreatment process. Preliminary studies show that 65 % oil and grease in POME can be removed using solvent extraction. Data also shows that alum as a coagulant at 4, 000 ppm and pH 4.41 can remove up to 80% of suspended solids in POME with flocculation process. The pre-treated effluent is passed to the membrane separation unit containing a cross flow ultrafiltration membrane module. The flux data were obtained under different operating conditions. The residual oil present in pre-treated effluent was also removed by membrane, however the flux values dropped due to oil fouling.

Apart from the above study, **Wong P.W. (2002)** also made a study on membrane ultrafiltration of treated palm oil mill effluent. From her research work, it is observed that, centrifugation and coagulation each gave a different pre-treatment quality that was better than the filtration method of pre-treatment. Coagulation was able to reduce total nitrogen, suspended solids, turbidity and colour as much as an average of 68%. Centrifugation, on the other hand, recorded an average of 68.3% reduction of those parameters. Filtration, however, only achieved an average elimination of 10.1%.

Nevertheless, the overall treatment quality provided a totally different picture. Combination of filtration-ultrafiltration treatment gave the best overall treatment efficiency, with an overall reduction of 93.4% for total nitrogen, suspended solids, turbidity and colour content. For the treatment combination of centrifugation-ultrafiltration, the average removal efficiency was only 86.4% while coagulation-ultrafiltration treatment only managed to achieve an average of 67.1% removal.

The effect of transmembrane pressure on solute rejection was such that solute rejection tends to decrease with increasing transmembrane pressure. By applying larger transmembrane pressure on the membrane, pores are opened up thus providing wider paths for the solute to pass through. This is an advantage for membrane application in actual industry as lower transmembrane pressure gives better efficiency and at the same time requires less energy consumption.

Influence of pH on solute retention was also significant. The original pH of sample (pH 8) provided the best rejection environment compared with pH 2.2, which represented the lower pH range. Thus, treated POME can be fed directly to the membrane treatment plant after adequate cooling without any need of additives or adjustments on the chemical properties of the treated POME.

From both studies, it shows that ultrafiltration treatment of treated POME proved to have good potential in order to comply with regulations that gets more stringent with time. A follow up of this study is essential to realize the achievement of higher quality treated wastewater using membrane treatment as an alternative measure in palm oil mill effluent management.

EXPERIMENTAL METHODOLOGY

Sample Collection

A large quantity of sample [100L] was collected from ***palm oil mill***. The samples were placed in an airtight container and kept in a cold room where the temperature was maintained at 4^{o}C.

Pre-Treatment Of Samples

The raw sample was pre-treated using coagulation technique. Different concentration of PAC as coagulant was tested and the optimum dosage of the coagulant was determined. The large amount of raw sample was mixed with the optimum dosage accordingly. The well-mixed sample was left overnight for better settlement. Finally, the supernatant liquid effluent was collected and preserved as mentioned earlier. A portion of it, was used for membrane feed characterization.

Experimental Setup

The supernatant liquid effluent was ultrafiltered using a pilot-scale hollow fiber ultrafiltration unit as shown in *Figure 1*. Permeate and retentate were collected at different MWCO in order to carry out characterization analysis. The units were then cleaned with 0.1M NaOH and deionized water.

In order to evaluate the efficiency of membrane ultrafiltration, selected parameters were chosen to characterize the various samples (raw, pre-treated and permeate). These parameters are of great importance for effluent characterization and the values need to meet the level of statutory discharge limits in the Environmental Quality Act (Prevailing Effluent Discharge Standards for Crude Palm Oil Mills, 1984) before being released into watercourses. The parameters are TKN, ammoniacal nitrogen, suspended solids, colour and turbidity.

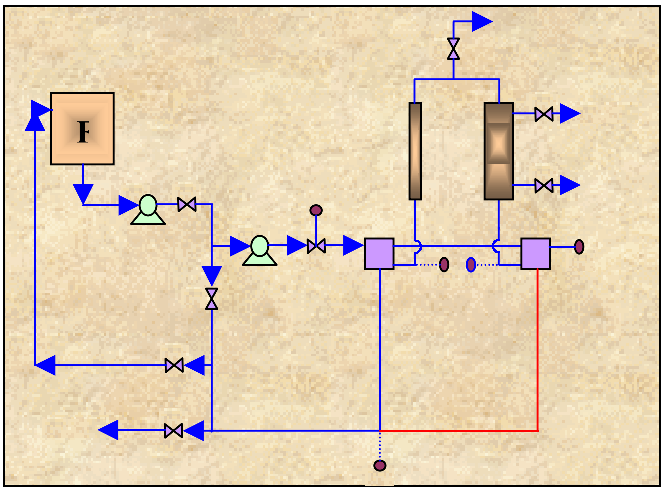

Figure 1 Flow Diagram of Ultrafiltration Pilot Scale Unit
Characteristic Analysis of Sample

RESULTS & DISCUSSION

Effluent Characterization

A series of tests was carried out on samples prior to determination of coagulant optimum dosage and ultrafiltration for characterization purposes. These samples were taken from the final discharge pond of the palm oil mill. The treated effluent in this pond is utilized for land use application of coconut and oil palm plantation in the nearby area. Results of the characteristic test are compared with the *Prevailing Discharge Standards for Crude Palm Oil Mills 1984* ***[Environmental Quality Act]*** as tabulated in *Table 1.*

Table 1 shows that the samples collected had a high content of COD amount, though no limit is given in the discharge standard. Ammoniacal Nitrogen, Total Kjeldahl Nitrogen and Suspended Solids were each 101%, 60% and 475% respectively above the concentrations allowed. A reasonable level of pH (7.76) was observed, which is within the discharge limits. However, the sample exhibited high intensity in colour content, reaching 25 800 unit PtCo. This was quite expected, as colour has always remained a problem in most POME treatment.

Comparing the findings with the discharge standards, measurements of **AN, TKN** and **SS** in sample exceeded the discharge limit, while the **pH** level was within the acceptable range. As the main purpose of this characterization test is to act as reference for the following series of treatment, the non-compliance problem will not be discussed further in this study.

Determination Of The Optimum Dosage Of Coagulant

15 ml of 10% (w/w) PAC (1478 ppm) gave the best overall treated sample quality compared to the other concentrations of PAC. From the original turbidity level of **3200 FTU**, 1478 ppm of PAC was able to reduce the turbidity to the lowest measurement, i.e. **700 FTU** although higher concentration of PAC gave better results. This dosage was

considered optimum because the amount of flocs produced was minimal compared to the others. Apart from that, higher concentration of PAC may give better feed water quality, but this in turn increases the concentration of coagulant in the effluent, that would need an additional treatment to remove it from the wastewater.

Table 1: Comparisons of Selected Parameters between Discharge Standard and Sample for Treated POME

Parameters	Limit of Discharge [Environmental Quality Act 1984]	Average Result [3 samples]
1. COD, mg/l	-	13 000
2. Ammoniacal Nitrogen, mg/l	150	301
3. Total Kjeldahl Nitrogen, mg/l	200	319
4. Suspended Solid, mg/l	400	2 300
5. Colour, PtCo	-	25 800
6. Turbidity, FTU	-	3 200
7. pH	5 – 9	7.76

Pre-Treatment Of Samples

All the samples were treated with the optimum dosage and the results were mainly focused on the effectiveness of the coagulation process. This was done by comparing the characteristic of the sample before and after the experiment was carried out.

As shown in *Table 2*, PAC coagulation was most effective in removing suspended solids, and least effective in treating total nitrogen based on Kjeldahl method, experiencing only a **10.6%** reduction in quantity. Concentration of suspended solids dropped from the original **2 300 mg/l** to **300 mg/l**, which was a **87.0%** elimination. Percentage reductions of turbidity and colour were also high, ranging between **78.1%** and **77.5%**. The removal of turbidity and colour was high because both the parameters is also related with suspended solids concentration. This means that, the higher the removal of suspended solids in the sample, the colour and turbidity of the sample also decreases. COD showed a decrease of **30.8%** from **13 000 mg/l** to **9 000 mg/l**.

Overall Treatment Efficiencies

A graph comparing the overall treatment efficiencies of every treatment system is depicted in *Figure 2*. From the horizontal bars, the usage of PM 30 membrane module recorded the highest reduction measurement in ammoniacal nitrogen compared to PM 50 membrane module. Turbidity, colour, suspended solids and total nitrogen exceeded **90%** reduction for both the modules.

The overall treatment results once again showed correlation among colour, turbidity and suspended solids. Thus, it could be concluded that colour in the POME is apparent and caused by suspended matters. It could be treated more easily than true colour, as once the suspended solids are removed, the colour will disappear as well.

The low reduction of ammoniacal nitrogen implies that it is caused by fine soluble particles, with molecular weight below 30 000.

Table 2: Concentrations of Parameters Before and After Coagulation with Respective Percentage Reduction

Characteristics	Discharge Limit	Raw Sample	Pre-Treated Membrane Feed	Pre-Treatment Efficiency, %
COD, mg/l	-	13000.00	9000.00	30.77
AN, mg/l	150	301.00	244.00	18.94
TKN, mg/l	200	318.75	285.00	10.59
SS, mg/l	400	2300.00	300.00	86.96
Colour, PtCo	-	25800.00	5800.00	77.52
Turbidity, FTU	-	3200.00	700.00	78.13

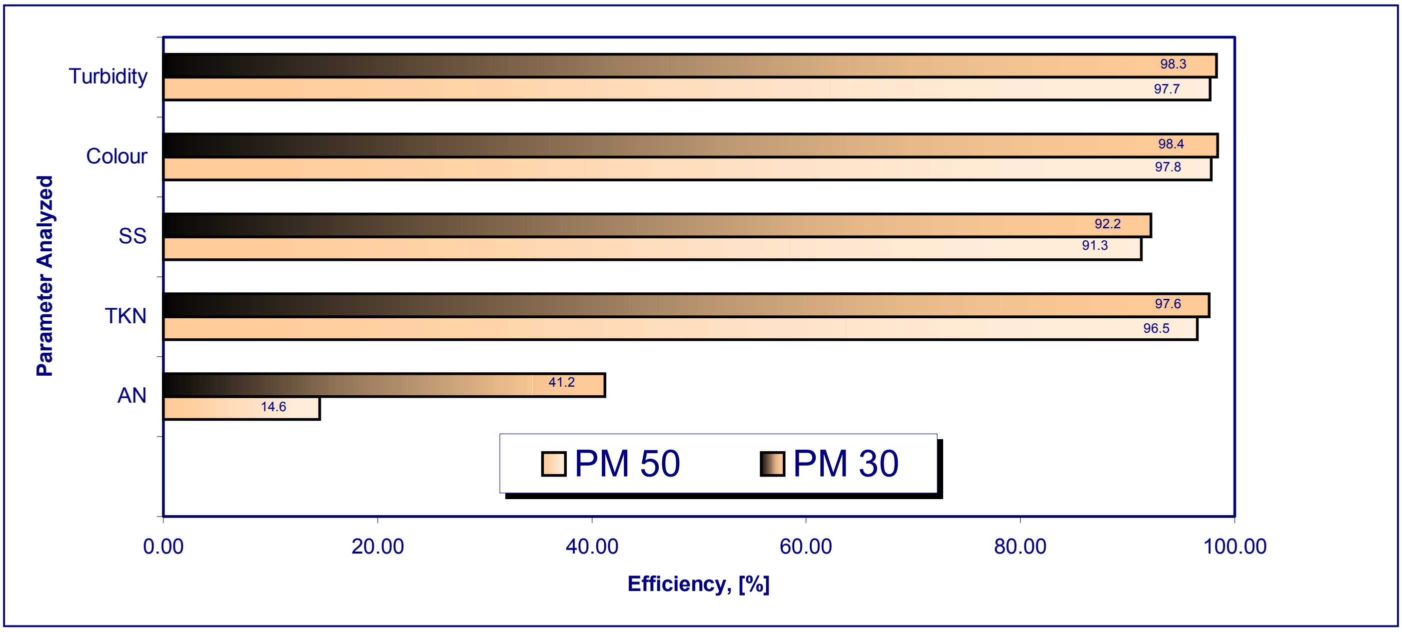

Figure 2: Overall Treatment Efficiency of Ultrafiltration with Different MWCO

CONCLUSION

From the results obtained from the experimental studies, treating the final discharge with different concentration of PAC itself reduces the level of concentration to a great extent. With the usage of this coagulant a dense amount of suspended solid were removed, giving a better feed water quality to the membrane unit. Therefore the fouling partical of the membrane has been reduced. Although higher concentration of PAC produced good result in the water quality, 15 ml of PAC for every liter of effluent was chosen to be the optimum dosage because the amount of flocs produced was the least.

The membrane ultrafiltration was carried out with two different types of MWCO, which were PM 50 and PM 30. The TMP was controlled at the maximum by the control valve for the suction and feed pump where it remained fully open. TMP was maintained at 75 kPa for PM 50 and 90 kPa for PM 30. It is observed that, PM 30 produced the best permeate quality with removal of ammoniacal nitrogen (41.2%), total nitrogen (97.6%), suspended solids (92.2%), colour (98.4%) and turbidity (98.3%).

Apart from that, the permeate flux of the sample is always below the permeate flux of deionized water. This shows that, the membranes had already been fouled. Although a proper cleaning has been carried out, the flux remains the same. The permeate flux produced by PM 30 is greater than from PM 50. This is because, as the MWCO decreases, the TMP increases and this causes the flux to increase. With that, the critical particle size below which smaller particles are transported to the membrane also increases. In other words, particles of larger size are predicted to deposit on membranes as permeation rate increases.

The colour in POME is apparent due the suspended matters and it is has been a problem of removal in the industries. This colour could be removed thoroughly if activated carbon is used after the membrane ultrafiltration process. Activated carbon also helps remove the odour produced in POME but at the same time, a large amount of used activated carbon is produced and need further treatment.

To conclude, ultrafiltration treatment of treated POME proved to have good potential in treated POME treatment in order to comply with regulations that gets more stringent with time. A follow up of this study is essential to realize the achievement of higher quality of treated wastewater using membrane treatment as an alternative measure in palm oil mill effluent management.

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Strength Development of Cement-Stabilized Heavy Metal Contaminated Soil

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ABSTRACT: Cement-based stabilization techniques have been utilized extensively in developed countries for the past twenty years for treatment of metal wastes. The strength development of ordinary portland cement (OPC) treated heavy metal-contaminated soil was investigated in this study. Heavy-metal contaminated soil was collected from a scrap metal yard within the outskirts of Kuala Lumpur, Malaysia. The soil was classified as gravelly sand by using the British Soil Classification System (BS 5930: 1981). The contaminated soil was treated with OPC using cement-to-dry soil (C/S_d) ratios of 0.5, 1, 2, 4 and 8. Strength development of the OPC treated soil was evaluated by conducting the unconfined compressive strength (UCS) test (BS 1881: Part 116, 1983). It was determined that increasing the C/S_d ratio improved the UCS. The C/S_d ratio of 2 was adequate to achieve the minimum United Kingdom UCS mortar limit of 20 N/mm^2 which indicate potential reuse of treated soil for construction material applications.

Keywords:

Ordinary portland cement (OPC), chemical stabilization, contaminated soil, heavy metal, cement-to-dry soil ratio (C/S_d), unconfined compressive strength (UCS), solidified waste acceptance criteria.

INTRODUCTION

The presence of derelict and contaminated land, or 'brownfields' is an issue of concern in many industrialized countries, particularly in the United States (Conner, 1990) and European Union (Ferber and Grimski, 2002). Past industrial activities ranging from petroleum refineries to metal plating have left hectares of land contaminated with detrimental chemicals that render the land unusable for future development.

As these developed nations begin to experience the shortage of uncontaminated sites or 'greenfields' available for development, they must initiate reclamation plans for contaminated land to enable sustainable industrial developments. Contaminated land issues in these countries were critically addressed only after damaging circumstances that affect the public and the environment had arisen, as evident in the infamous Love Canal incident in the US. This incident had prompted the US government to enact the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) in 1980 which was amended in 1986 by the Superfund Amendments and Reauthorization Act (SARA). These enactments imposed stringent regulations that obligate responsible parties to bear the costs of cleaning up contaminated sites (LaGrega *et al.*, 2001).

Even though Malaysia can learn from past environmental disasters caused by contaminated land in developed nations by taking the necessary precautions to prevent these disasters from happening in the country, it is regrettable to say that this has not been the case. Contaminated land issues in Malaysia have so far, attracted scant attention from both the authorities and the public. To date, only a particular national conference on contaminated land supported by the United States-Asia Environmental and Development (US-AEP) and Danish Cooperation for Environmental and Development (DANCED) was organized in 2001 to address this growing concern among environmental professionals.

As specific legislations governing contaminated land are virtually non-existent in Malaysia, manufacturing-based companies are not obligated to clean-up contaminated sites located within their facilities. In 2001, more than 50,000 tonnes of Scheduled Wastes generated by various industries in Malaysia were stored on-site at waste generators' premises (DOE, 2001). Stockpiled wastes, ranging from metal plating sludges to spent fluid catalysts frequently caused soil contamination within their manufacturing premises due to improper wastes handling and illegal burying of chemical wastes. Lenient fines imposed on errant manufacturing organizations that caused land contamination had seriously undermined enforcement efforts.

Chemical stabilization is generically defined as a chemical alteration technique of reducing the mobility as well as solubility of contaminants present in waste or soil in order to convert that particular waste or soil into chemically inert form. Chemical stabilization of contaminated soil may produce an end product of high strength which can be reused as construction-base materials. Unconfined compressive strength tests are usually conducted on stabilized contaminated soil to determine the strength required to sustain any overburden pressure when the treated product is either disposed within a sanitary landfill or applied as construction materials.

The objective of this study was to evaluate the strength development of OPC treated heavy metal-contaminated soil which was subjected to Malaysian weather.

MATERIALS AND METHODS

Site And Soil Sample Description

An operational scrap metal yard located within the outskirts of Kuala Lumpur was selected as the study area (Plate 1). The scrap metal yard has been in operation for more than ten years and manages a variety of scrap metals ranging from construction steel bars to metal components of household appliances.

Contaminated soil samples were collected at depths of 20 cm from the surface by using a stainless steel shovel and stored in cylindrical plastic containers. Based on visual inspection, the soil was dark in colour and contained fragmented metal pieces. All labware and sampling apparatus were pre-soaked in 5 % nitric acid solution followed by distilled water for a day prior to sampling. Large plant debris and metal pieces were manually discarded from the contaminated soil samples before subjected to screening by using a 2-mm sieve.

Plate 1: Scrap Metal Yard

Characterization Of Contaminated Soil

The soil sample was characterized by various standard methods and method previously utilized by other researchers. Physical characteristics that include moisture content, soil particle density (specific gravity), soil pH, loss-on-ignition and particle size distribution were determined by using the *British Standard Methods for test for Soils for Civil Engineering Purposes* (BS 1377, 1990). The soil was acid digested by using *Method 3050B: Acid Digestion of Sediments, Sludges and Soils* (EPA, 1996) prior to chemical analysis by using the 3100 Perkin-Elmer Flame Atomic Absorption Spectrometer.

Production Of Solidified Samples

Type 1 OPC obtained from Associated Pan Malaysian Cement was used throughout the study. OPC was added to the contaminated soil at C/S_d ratios of 0.5, 1, 2, 4, and 8. Mixing of these materials was done in a 25-L SPAR type mixer. The sieved contaminated soil and cement were added into the mixer and homogenized for 15 minutes before the addition of ASTM Type II deionized water. The mixture was then cast into 50 mm × 50 mm × 50 mm cubic steel moulds in three layers, with each layer compacted by using a vibrating table. Solidified cubic samples were prepared in triplicates. After the initial mixing, one day was allowed for setting before the solidified samples were demoulded. A further 28 days were allowed for dry curing of the solidified samples in a cabinet at a controlled condition (temperature = 25^0C, humidity > 80%). The 50 mm × 50 mm × 50 mm solidified cubic samples were subjected to the unconfined compressive strength (UCS) test (BS 1881: Part 116, 1983) after 1, 3, 7, 21 and 28 days of dry curing.

RESULTS AND DISCUSSION

Characterization Of Contaminated Soil

Results of contaminated soil physical characterization are shown in Table 1. The contaminated soil was comprised of 22.68 wt % of gravel, 72.91wt % of sand and 4.41 wt % of silt and clay prior to sieving. The soil was classified as "gravelly sand" based on the British Soil Classification System (BS 5930: 1981). The soil moisture content and particle density were 14.48 % and 2.616 respectively while pH of the soil was determined to be slightly alkaline at 7.11. The soil consisted of 7.63 % of organic content as determined by the loss-on-ignition (LOI) test.

Table 1: Soil Physical Characterization

Characteristic	Value
Particle Size Distribution (%)	Gravel = 22.68
	Sand = 72.91
	Silt & Clay = 4.41
Moisture Content (%)	14.48
Soil Particle Density	2.616
Soil pH	7.11
Loss-on-ignition (%)	7.63

Metal composition analysis by using the Flame Atomic Absorption Spectrometer indicated that the predominant heavy metals present in the soil were iron, lead, zinc in excess of 1000 milligrams of each type of metal per kilogram soil.

Strength Development Of Solidified Samples

Figure 1 shows the UCS of solidified samples throughout 28 days of dry curing. All solidified samples exhibited UCS above the minimum requirement for United Kingdom landfill disposal limit of 0.34 N/mm^2 even after only one day of curing. This suggests that the amount of OPC required to solidify the soil and achieve this strength limit could be substantially reduced. The result indicates that by doubling a C/S_d ratio, the UCS of solidified samples had averagely increased by approximately 6 N/mm^2 from the preceding ratio at day-28 of curing. It was observed that the high concentrations of heavy metals as well as organic content in the soil did not have a significant retardation effect on the hydration and initial strength development of the treated material, as indicated by the rapid strength development during the first three days of curing. A minimum C/S_d ratio of 2 is required to achieve the minimum United Kingdom UCS mortar limit of 20 N/mm^2 after 28 days of curing, in which solidified contaminated soils have tremendous potential in construction material applications such as engineering fills, pavement blocks, bricks etc.

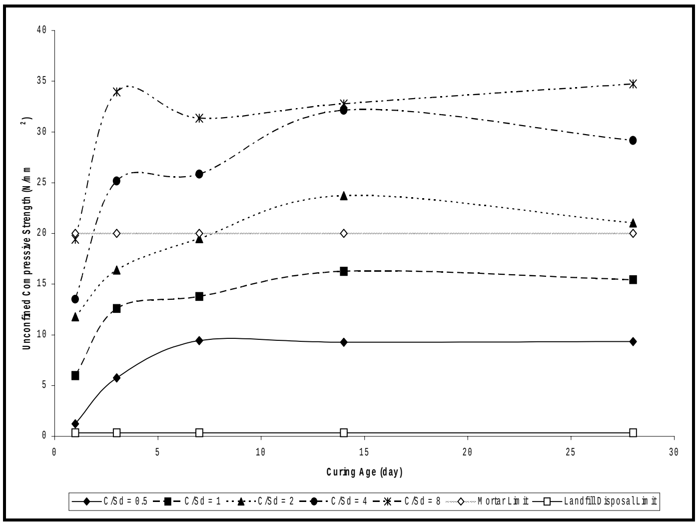
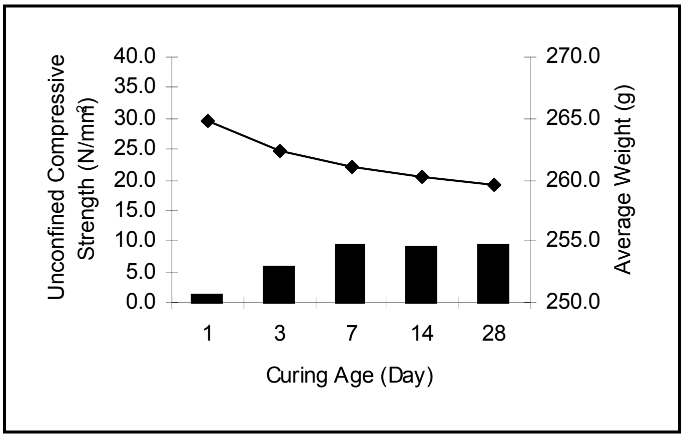
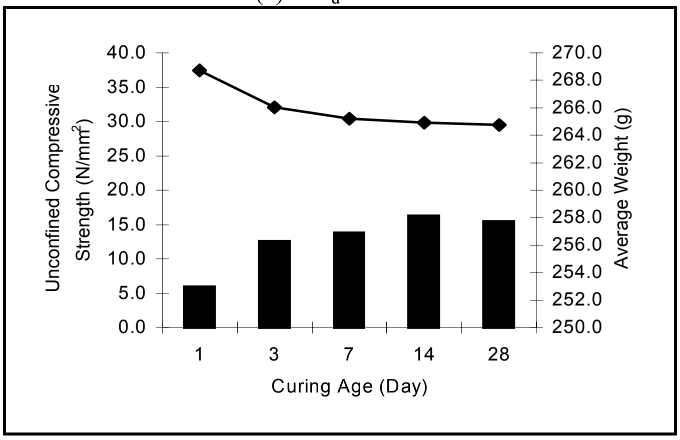


Figure 1: Unconfined Compressive Strength of Solidified Samples throughout 28 Days

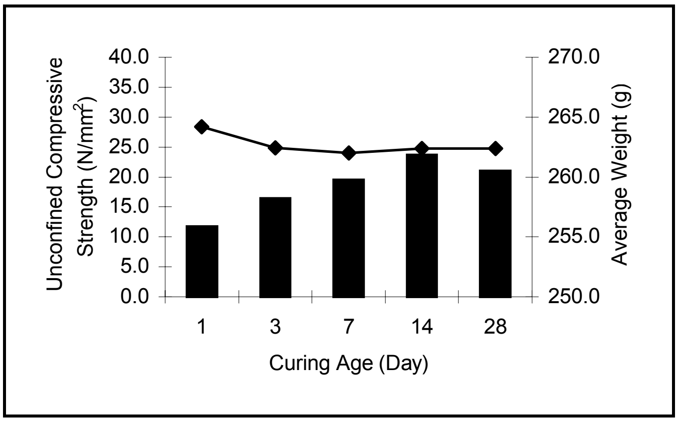
The process of cement hydration necessitates adequate amount of moisture to facilitate the strength development of solidified samples (Neville, 1996). Figure 2 illustrates the average weight of solidified samples in relation to the samples' corresponding curing age and UCS values. For C/S_d ratios of 0.5,1 and 2, it was observed that the average sample weights are inversely proportionate to UCS throughout 28 days of curing. This result was consistent with the established fact that UCS generally increases with the increase of moisture loss within curing samples as water pores are gradually replaced by calcium silicate hydrates. Sample weight losses for C/S_d ratios of 4 and 8 were more apparent that previous ratios during the first three curing days and it was noticed that average sample weights increased from this point onwards. From this observation, it was postulated that at C/S_d ratios higher than 2, there was a surplus amount of cement which was left unhydrated and therefore, the hydration process was completed before day-7 of curing.



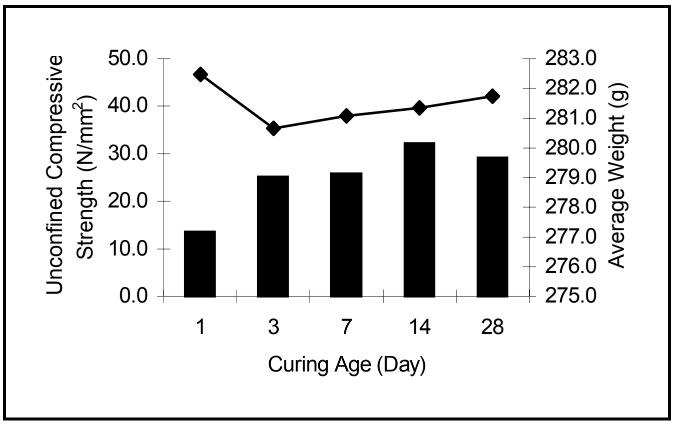
(a) $C/S_d = 0.5$



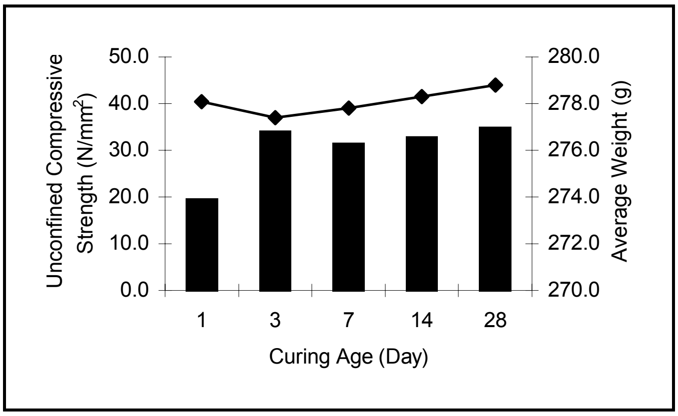
(b) $C/S_d = 1$



(c) $C/S_d = 2$



(d) $C/S_d = 4$



(e) $C/S_d = 8$

Legend:
Average Weight
Unconfined Compressive Strength

Figure 2 (a-e): Average Weight of Solidified Samples throughout 28 Days

CONCLUSIONS

The strength development of the OPC treated contaminated soil had been evaluated and the following conclusions can be drawn:

(1) Increasing the C/S_d ratio increased the strength of treated soils.
(2) All solidified samples exhibited UCS above the minimum requirement for United Kingdom landfill disposal limit of 0.34 N/mm^2 even after only one day of curing.
(3) A minimum C/S_d ratio of 2 is required to achieve the minimum United Kingdom UCS mortar limit of 20 N/mm^2 subsequent to 28 days of dry curing.
(4) The hydration processes for C/S_d ratios of 4 and 8 were completed before day-7 of curing.

ACKNOWLEDGEMENT

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Stabilization of Rubber Sludge Using High Temperature Melting Process

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ABSTRACT: Rubber industries are continuously faced with environmental problems, both in the odour emission and effluent discharge. There is increasing concern with the disposal of rubber sludge, which has been costly to manage and are being classified as "Scheduled waste". The conventional method of disposing into secured landfill may not be economical and other options of stabilization may need to be studied. An alternative process using stabilization of sludge at high temperature and converting it into a stable product appears to be environmentally acceptable. This paper presents the stabilization process of rubber sludge using a high temperature melting system. The sludge sample was melted at 1450°C and subsequently cooled with a cooling rate of 5°C/min until room temperature. Rubber sludge was converted to a crystalline stone at the end of the processes. The chemical characteristic of the final product was studied. US EPA leaching test was also conducted on the produced stone. Results revealed that metals were not leached from the final product after melting process. In general, results from this study indicated that melting technology could convert the rubber sludge into a product that can be either reused or landfilled without any adverse environmental impact.

Keywords: Rubber sludge, thermal treatment, melting process

INTRODUCTION

Malaysia is well known as being a major natural rubber producer. Malaysia leads the world in the dipped goods rubber industry both in volume and quality (Table 1). It is the world largest supplier of medical gloves, catheters and latex threads. There are over 300 companies in Malaysia making a wide range of rubber products, which are exported to over 60 countries (Malaysian rubber board, 2002). Amongst natural rubber producing countries, Malaysia has been the successful in converting almost half of its rubber output into value added products. At the same time Malaysia has planned ahead in increasing the production and export of compounds and masterbatches.

With the increasing of rubber production, disposal of wastes, is one of the main environmental concerns to local authorities. Therefore, attempts to stabilize the rubber sludge into a stable product, which is environmentally acceptable, has received considerable attention.

The aim of this study is to stabilize the rubber sludge waste by a high temperature melting process and also to quantify the potential hazardous associated with the slag produced.

Table 1: Rubber Production in Malaysia (Malaysian rubber board, 2002)

Years	Estates	Smallholdings	Total
1990	396,612	894,364	1,290,976
1991	366,249	889,429	1,255,678
1992	332,249	837,922	1,170,893
1993	296,298	778,039	1,074,337
1994	271,307	829,304	1,100,611
1995	242,314	847,057	1,089,371
1996	237,937	844,533	1,082,470
1997	215,890	755,192	971,082
1998	198,871	686,826	885,697
1999	182,900	585,972	768,872
2000	128,134	487,088	615,222
2001	99,530	447,489	547,019

MATERIAL AND METHODS

Sampling

Samples for this study was taken from a factory operated by Lembaga Getah Malaysia (LGM). The factory is located at Sungai Buluh, Selangor, Malaysia. Sample of rubber sludge from glove production was collected from sand bed, after one week of discharging the sludge to the bed, the sample weighted 25 kg. The parameters of pH and temperature were tested at the site. Sample then was preserved and brought back to the lab.

Melting Process

The dewatered sludge was placed in porcelain crucibles for incineration process in the electrical furnace (Model Carbolite CWF 1200) at a temperature of 900º C, for 3 hours. The produced ash was used as a raw material for subsequent high temperature melting process. The ash was grounded and placed in porcelain crucibles in furnace (Vecstar , Model 808P). The experimental procedure for melting was set according to the values shown in Table 2.

Table 2: Experimental procedure for high temperature melting process

Melting Process	Values
Heating temperature	1450°C
Holding time	45 min
Cooling rate	5°C/min
Gas type	air

Leaching Test

Leaching tests was carried out according to extraction procedure (EP) toxicity test with some modification (USEPA, 1982). Tests were conducted at different pH values; 3, 5 and 9. The pH was adjusted using 0.5 N acetic acid and sodium hydroxide. The ratio of 1:16 (solid:liquid) was used for the test. The mixture was agitated for 24 h. After agitation a quantity of distilled water was added and the mixture was filtered with 0.45 µm membrane filters. The final solid to liquid ratio was 1:20. the metal concentrations in leachate were determined by Atomic absorption-flame emission (Shimadzu AA 680).

Characteristic Of Melted Rubber Sludge

The total metal concentrations were analysed according to USEPA method (Chelsea and Smoley, 1992). About 1.00 g of samples were digested in 10mL of HCl (1:4) and 4 mL of HNO_3 (1:1), followed by heating at 85°C for 30 min. The extracts were filtered using a filter paper (Whatman No.41) and made up to 100 mL volume. The metal concentrations in all extraction solutions were determined by Atomic absorption-flame emission (Shimadzu AA 680).

RESULTS AND DISCUSSION

Sludge Weight Reduction

The weight reduction of rubber sludge
As shown in Table 3 drying process of rubber sludge reduced the weight 22.6%. Incineration process of rubber sludge converted this sludge into a yellow ash. Incineration process reduced the weight of sludge 52.3%. Melting process reduced the weight of rubber sludge to 93.4%.

Table 3: Weight Reduction of rubber sludge during different thermal treatment

Process	Drying	Incineration	Melting
Weight reduction (%)	22.6	52.3	93.4

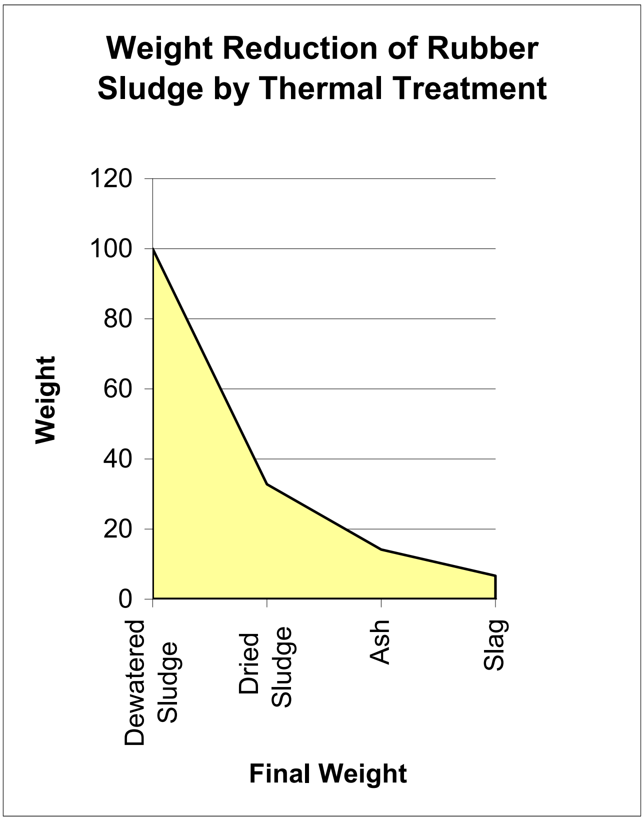

Figure 1: Weight reduction of rubber sludge by thermal treatment

Characteristics Of The Melted Rubber Sludge

The melted slag produced after melting process is shown in Figure 2. The major metals in the rubber sludge samples were identified as Fe, Hg, Sn and Zn (Table 4). As shown in the Table 4, metal contents of the rubber sludge have been reduced significantly after melting process. For As, Cr, Cu and Ni, even the metal concentrations were dropped to zero after melting process. The concentrations of Hg, Pb, Sn and Zn were decreased 4, 2, 1.4 and 47 times in the rubber sludge after melting process, respectively.

Figure 2: Melted slag produced by melting of rubber sludge

Table 4: Metal concentrations in rubber sludge before and after melting process

	Status	
Metal (mg/l)	Before melting	After Melting
As	0.35 ± 0.02	0
Cd	0	0
Cr	0.05 ± 0.010	0
Cu	0.20 ± 0.015	0
Ni	0.01 ± 0.01	0
Pb	0.92 ± 0.035	0.37 ± 0.067
Sn	16.13 ± 2.87	11.25 ± 1.58
Zn	37.91 ± 5.26	0.80 ± 0.062

Leaching Test

The results in Table 5 showed metal concentrations found in leachate from rubber sludge before and after melting process, tested according to the EPA EP toxicity test. Among metals As, Cr, Cu and Ni were not detected in the leachate from the rubber sludge molten slag. As shown in Table 5 all metal concentrations in the leachate from rubber sludge were significantly lower than the concentration of the metals in leachate from the raw rubber sludge. Therefore, it can be accepted that melting of sludge had resulted in great reduction of metals leachability.

Table 5: Leaching of metals from rubber sludge before and after melting process

Metal mg/l	Before melting	After Melting	US EPA limits (mg/l)[a]
As	0.52 ± 0.02	0	5
Cd	0.02 ± 0.01	0.01 ± 0.01	1
Cr	0	0	5
Cu	0	0	100
Ni	0	0	100
Pb	0.47 ± 0.05	0.23 ± 0.01	5

[a] US EPA maximum limits for disposal of waste to landfill (US EPA, 1980).

CONCLUSION

High temperature melting treatment of rubber sludge produced stabilized product, which is proven to be non-hazardous. This can be explained by US EPA leaching test, which verified that metals stabilized in slag were not leached beyond the standard, therefore concluding that the produced melted slag can be classified as non-hazardous product.

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Solar Energy Technologies: Trends And Prospects

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ABSTRACT: Solar energy technologies energy usage play an important role toward achieving sustainability. The paper will address all the applications of these technologies and conclude that every country in this world must invest heavily in these technologies and live in comfort and prosperity for many generations to come. It is important that most nations who implement the use of solar energy whether through educational programme or in real, build up their industries to cover all the applications. The paper not only gives up to date information about these various applications but also addresses the issue of climate change. Finally, solar energy can also be used to produce hydrogen as energy carriers. Thus establishing a long lasting, sustainable, environment friendly renewable energy resources to fulfill the energy needs for mankind.

INTRODUCTION

Energy is an important component for sustainable development and is required in almost all aspect of every day life including agricultural, drinking water, lighting health care, telecommunication, and industrial activities. Presently, the demand of energy is met by fossil fuels (i.e. coal petroleum and natural gas). It is a well know fact that 8 countries have 81% of all world crude oil reserves, 6 countries have 70% of all natural gas reserves and 8 countries have 89% of all cost reserves (IEA, 2003). More than half of Asia, Africa and Latin America import over half of all their commercial energy. This problem is worsened by the fact that demand on power generation is continuously increasing in these countries. In addition, at the current rate of production the world production of liquid fossil fuel (petroleum and natural gas) will decline by the year 2012.

The emission of greenhouse gases arising from human activities, especially those related to the use of fossil fuel, agricultural practices and land-use management have many side effects. Their combustion products produce pollution, acid rain and global warming. In fact the last two decades have been the warmest on record with 1998 being the warmest even with the cold La Nina conditions that dominate the year 1999 (Obasi, 2000). To overcome these global effects, sustainable, clean and safe energy policies that would satisfy the energy demand of the twenty first century have to be implemented. Renewable energy resources particularly solar should therefore be key energy sources for the future (Jefferson, 1998). This paper will discuss the current status on the global application direct solar energy technologies (thermal and photovoltaic technologies), the current global status, trends and its potential in achieving sustainability.

SOLAR ENERGY RESOURCES

Solar energy is the world 's most abundant permanent source of energy and environmentally compatible source of renewable energy. The amount of solar energy intercepted by the planet Earth is 170 trillion kW. Of this amount, 30 % is reflected to space, 47% is converted to low temperature heat and reradiated to space, and 23 % powers the evaporation/precipitation cycle of the biosphere. Less than 0.5 % is presented in the kinetic energy of the wind and waves and in photosynthesis storage in plants.

Figure 1 shows the classifications of energy resources. Solar energy is divided into three namely (a) direct solar energy (b) indirect solar energy and (c) stored solar energy. The direct solar energy can be utilized by solar thermal and photovoltaic technology. Hydropower, wind and OTEC (Ocean Thermal Energy Conversion) are classified as the indirect solar energy. In addition, renewable hydrocarbon (biomass) and non-renewable hydrocarbon (petroleum, natural gas , coal and shale) are classified as stored solar energy.

Figure 2 shows the annual worldwide average daily solar radiation availability. The level of the solar radiation is function of length of path through the atmosphere absorption and scattering. Monthly amount of solar energy varies depending on season and location and annual amount of solar energy varies depending on location. Solar radiation in the tropics is very unique since it is mainly characterized by the diffused nature of the solar radiation. This is due to the cloud formation in the equatorial region and heavy rain. Therefore, the usages of concentrating technologies are not practical since these technologies utilized the direct component of the global solar radiation (Othman et al, 1993).

SOLAR ENERGY APPLICATIONS

Solar energy applications are oriented toward the applications of solar energy for domestic hot water systems, solar distillation of sea and brackish water, water pumping, drying of agricultural produce, solar industrial process heat, photovoltaic for remote applications, space heating and cooling (passive and active design), building integrated photovoltaic systems and products, daylighting, solar thermal electricity generation, and solar refrigeration (Truly, 2000; Eliasson, 2000 and Ebenhack, 1995).

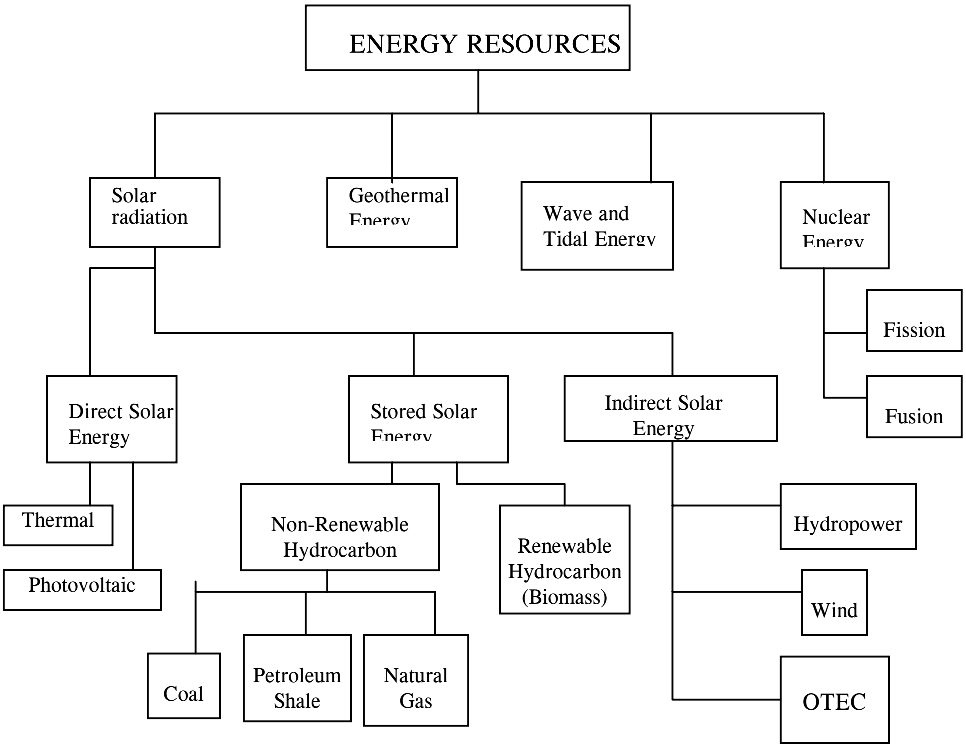

Figure 1 Energy Resources Classifications

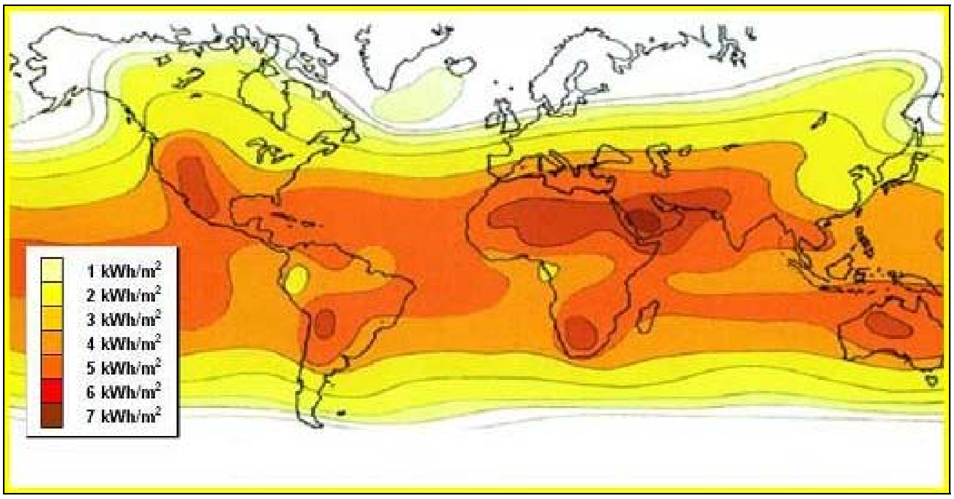

Figure 2 Worldwide Average Annual Daily Global Solar Radiation Levels

Solar Thermal Technologies

Heat and power from thermal conversion were used as early as 1948 (Duffie and Beckman, 1991). Recently almost all countries with some industrial base are building solar water heaters. Israel saves about 4% in their oil importation by using solar water heaters in almost all their buildings. Denmark produces a quarter of a million systems a year and Egypt legislated since 1990 that all newly built buildings must have solar water heaters as an integral part of the building. The main goal in the United States is to achieve $0.04 per kWh for solar water heating systems primarily through the utilization of polymer materials and innovative new designs. This will translate to a homeowner being able to buy a solar water heater for about $1,000, or having the cost include in a mortgage resulting in a monthly incremental payment which is less than the monthly energy savings generated by the system. A typical system will reduce the need for conventional water heating by about two-thirds. Medium-temperature solar water heaters can provide energy-efficient hot water and hot water heat for large commercial and industrial facilities. There are huge potential for the use solar hot water heating in hotels where 24.62% of the total energy consumption is for water heating. Other promising application is the use of solar industrial process heat in textile factories large commercial, industrial facilities and other manufacturing facilities (Sopian *et al*, 2000). However, their cost remains too high to compete effectively with low priced energy except in limited areas of the world. Further cost reductions are needed if the technology is to become a widespread economic option and a common addition to buildings.

Traditionally all the agricultural crops were dried in the sun. The present status of post harvest drying technology for selected tropical agricultural produce is shown in Table 1 (Sopian *et al*, 2000). Consequently, harnessing of solar energy using the appropriate technology for the drying process could be achieved without much difficulty. There are many innovative ways of using solar assisted drying systems for agricultural produce and it depends of many factors including the drying temperature and duration of time to achieve the required quality of produce (Sopian *et al*, 2002). The technical development of solar drying systems can proceed in two directions. Firstly, simple, low power, short life, and comparatively low efficiency-drying system. Secondly, high efficiency, high power, long life expensive drying system. The latter is characterized not only by an integrated structure but also integrating in an energy system involving process other than drying such as hot water when the drying system is not in use. In addition, air based solar collectors are not the only available systems. Water based collectors can also be used. A water to air heat exchanger can be used. The hot air that will be used to dry the product can be forced to flow in the water to air heat exchanger. In addition, the hot water tanks of the farm can be used as heat storage of the solar drying system.

As for the electricity generation, desalination and processed heat, many applications exist in United States, Middle East, India and Africa. Concentrating solar power technologies use reflective materials such as mirrors to concentrate the sun's energy. This concentrated heat energy is then converted into electricity. Since the 1970's, several stand-alone solar systems have been built and perfected, starting with the Algerian paraboloid concentrator-solar furnace of 25 kW thermal manufactured in 1954 and used for the ceramic industry, to the Francia 50 kW_e, central receiver in Atlanta; the Trombe 85 kW_e central receiver in Toulouse; the 100 kW_e MBB-Kuwait 55-dish used for desalination and electricity power generation in the remote areas of Kuwait to the 10 kW_e of Barstow central receiver plant in California which was commissioned in 1981. In the tropics, however, due to the predominantly diffuse nature of the solar radiation and the presence of clouds, the system can be considered not practical for producing sustainable steam required for electricity generation (Brenner *et al*, 2002).

LUZ International has completed a 354 kW_e for the Southern California Edison Company. The LUZ system consists of tracking line focusing parabolic concentrators in loops. All loops are connected by flexible hoses. Each absorber is selectively coated and encased in an evacuated glass tube to reduce losses. A synthetic oil is used for the working fluid in the collector loops at a temperature of 735^0C while a heat exchanger is used which transfers this energy to water loops which generate superheated steam. The steam then operates a Rankine cycle steam electric generating system. A back-up oil burner is an integral part of the system (Duffie and Beckman, 1999).

Photolvoltaic Technology

Efficiency improvement, cost reduction and high reliability have contributed to the expansion of photovoltaic (PV) globally. The world production of photovoltaic cell and module production increase to 390.54 MW in 2001 (see Table 2). This 103 MW increase on the 2000 output - of over 287.65 MW - represents a 36% rise. Japanese PV cell and module production increased 31% to 171.22 MW in 2001. European production increased by 42% to 86.4 MW, while production in the United States increased 34% to 100.32 MW. Production in the rest of the world (ROW) increased 39% to 32.62 MW (PV News, 2002).

Based on an extensive survey, we estimate that the grid-connected residential/commercial sector grew from 120 MW in 2000 to nearly 200 MW in 2001. Over 90 MW of the growth occurred in Japan and Germany. Japanese installations in the calendar year 2001 increased to 110 MW and German installations were about 75 MW. Other growth was in the United States (4-5 MW) and Europe (4-5 MW). Table 3 summarizes the data from 1990 to 2001 by principal market sector. Telecommunication applications range from remote repeaters and amplifiers for all modes of communication including fibre optics, satellite links, and cable links to small data link stations via phone, TV, and secure communications throughout the country. Remote photovoltaic power systems serve as sensor power sources and data communication power for a broad range of applications, including weather, storm warning, seismic/radiation monitors, pollution monitors, security phones on highways and parking lots, and traffic monitors. Remote lighting and signals are proliferating, with applications ranging from bus stops, remote shelters, parking lot lights, billboards, highway information/construction signs (replacing small engine generators), inter-coastal navigation aides and lighting for 'green' corporate headquarters. Owing to the dramatic increase in the German market in 2000-2001 (over 200%), prices for single and polycrystalline silicon held in the range of $3.50-4.00 per Watt, while amorphous silicon modules were sold at prices of $2.00-3.00 per Watt. Nearly 2 MW of amorphous silicon modules were purchased by the Sacramento Municipal Utility District (SMUD) in California, US. Europe's solar PV giant, the largest PV system in Europe, was completed at Serre in Italy. The system is rate 3.3 MW peak, grid connected. It is producing 4.5 million kWh per year at a cost of 60 cents/kWh.

Table 1: The present status of post harvest drying technology for tropical agricultural produces

Produce	Present Drying System	Energy Source	Drying Time
Paddy	(a) Open drying	Sun	5 – 6 hours
	(b) Fixed bed dryer	Diesel	4 –5 hours
	(c) Moisture extraction unit	Diesel/Electric	2 –3 hours
Cocoa	(a) Sundry on cement/tray	Sun	6 days
	(b) Kerosene drying	Kerosene	35 – 40 hours
	(c) Burner blower	Kerosene/Diesel	36 hours
	(d) Rotary drying	Diesel	45 –48 hours
Coffee	Sundry	Sun	14 days
Pepper	Sundry	Sun	7 days(black pepper) 3 days (white pepper)
Tobacco	Conventional curing	Rubber wood	100 hours
		LNG	100 hours
Tea	Drying chamber	Diesel	25 min at 95°C
Banana	Sundry	Sun and wood for smoking	1 day
Anchovies	(a) Sundry	Sun	7 days
	(b) Fixed bed dryer	Diesel	5 – 7 hours
Rubber	(a) Sundry	Sun and wood for smoking	1 day

Around the world there are many projects utilising PV in such divers climates, culture and economies as Germany, with 2000 homes, to the US Department of Energy sponsoring a rural electrification project in Brazil for 500,000 homes. There are 100,000 families in rural developing countries of Dominican Republic, Kenya, Sri Lanka and Zimbabwe, all using PV power for lighting, radio and television. A self-styled "eco-resort" is being built in the Caribbean. It consists of eight guest houses. The energy for each will be provided by a roof mounted 1100 Watt PV array mounted with storage batteries, back-up power will be supplied by 1.5 kW horizontal-axis windmill. Solar water heaters will be used to supply hot water and make ice. Cooking is achieved in outdoor ovens. Each house is passively designed to sane energy and uses recycled building material. Water is supplied to the houses from collected rainfall.

Since 1988, Indonesia has led the way among the developing countries in the installation of PV. The country has tens of thousands of villages scattered throughout the thousands of islands with no electricity service. During 1992, 8000 PV systems were installed in remote areas. Applications include street lighting, public television, radio telecommunications, cathodic protection, security lighting, vaccine refrigerators, waterway lighting and individual home lighting. It is estimated that more than 100,000 people are served by the system already. The government increases PV usage nationwide to 60MW in 1993, installing about one million PV systems in 27 provinces.

Some of the encouraging signs that PV is a reality and its progress has been appreciable, whether judged by efficiency or reliability, can be seen in the following two cases. The University of New South Wales – Centre for PV Devices and systems has produced the first 20% efficiency module. This was verified recently by Sandia National Laboratories.

The second case is that of the Solarex Company which has raised the warranty on its modules from 10 to 20 years in honour of its 20th anniversary. The new warranty guarantees 80% of rated power for a period of 20 years. Product improvement and testing led than to announce that their poly-crystalline silicon modules will survive for more than 30 years. The improvement of new MX83 module that uses rectangular cells 11.4 x 15.2 cm, made Solarex announce a new, low-cost, high power module. The module has a power of 83 Watt at 12V charging voltage.

Table 2 World cell/module production, consumer and commercial (MWe)

Countries	1994	1995	1997	1998	1999	2000	2001
Japan	16.5	16.4	21.2	35.0	80.0	128.6	171.22
US	25.64	34.75	38.85	51.0	60.8	74.97	100.32
Europe	21.7	20.1	18.8	30.4	40.0	60.66	86.38
Rest of the World	5.6	6.35	9.75	9.4	20.5	23.42	32.62
Total	69.44	77.6	88.6	125.8	201.3	287.65	390.54

Table 3. World PV market by application area (MW)

Application Area	1990	1993	1996	1997	1998	1999	2000	2001
Consumer products	16	18	22	26	30	35	40	45
US off-grid residential	3	5	8	9	10	13	15	19
World off-grid rural	6	8	15	19	24	31	38	45
Communications and signal	14	16	23	28	31	35	40	46
PV-diesel, commercial	7	10	12	16	20	25	30	36
Grid-connected residential/commercial	1	2	7	27	36	60	120	199
Central > 100 kW	1	2	2	2	2	2	5	5
Total (MW/year)								

In 1970 the cost of one watt from PV was $100 while in 2000, it is $3 and expected to drop to $2. The goal of $1 per peak Watt is likely to be achieved in the next 10-15 years with a-Si is the forerunner at the present (Barua and Das, 2002). The world PV market for cells and modules has grown rapidly since 1994, due principally to heavily subsidized programs for PV use in Japan and Germany. Continued near-term growth is heavily dependent on retention of these subsidies. United States manufacturers have shared in the rapidly expanding world markets, with United States cell and module shipments rising from 26 MW in 1994 to 61 MW in 1999. Much of the increase in United States shipments has gone to export markets, principally Japan and Germany. However, the United States share of world PV cell and module shipments has decreased from 45 percent in 1995 to 30 percent in 1999. This has been caused by Japanese-based PV manufacturing firms, who have increased local manufacturing capacity in response to heavy government support for the integration of PVs into buildings. Future United States success in manufacturing cells and modules for export lies in the availability of a highly skilled manufacturing work force, high-quality materials, and a willingness to send highly trained technicians to work with end users. Near-term growth in United States. cell and module production for export is highly dependent on foreign governments retaining their PV end-user support programs. United States Federal support for PV use is relatively modest, and most near-term domestic growth is expected to occur in unsubsidized niche markets or in response to State and local programs. Even in these areas, continued cost reductions will be necessary to sustain 15-25 percent annual growth in U United States PV cell and module production for the next several years.

SOLAR HYDROGEN PRODUCTION SYSTEM

Scientists have dreamed of the ultimate source of energy that will power the world forever. This ultimate source is hydrogen. Hydrogen can be produced by the electrolysis of water and when burned in oxygen produces only energy and water, without any of the green house gases. However, when hydrogen is burnt in air oxides of nitrogen, the old green house gases will be produced also. A cleaner way to get energy from hydrogen is through the fuel cell. The fuel cell is an electrochemical cell, which produces electricity directly from hydrogen and air, without the production of green house gases. Research and development on the fuel cell is intensively carried out in the United States, Europe and Japan. Some have claimed to be able to produce fuel cells of 25 kW capacity at the cost of less than US$300 per kilowatt. This price is much reduced from those used in the space shuttle, which was US$500,000 per kilowatt.

Hydrogen is produced from sources such as natural gas, coal, gasoline, methanol, or biomass through the application of heat; from bacteria or algae through photosynthesis; or by using electricity or sunlight to split water into hydrogen and oxygen. The use of hydrogen as a fuel and energy carrier will require an infrastructure for safe and cost-effective hydrogen transport and storage. Hydrogen has an excellent safety record, and is as safe for transport, storage and use as many other fuels. Nevertheless, safety remains a top priority in all aspects of hydrogen energy. The hydrogen community addresses safety through stringent design and testing of storage and transport concepts, and by developing codes and standards for all types of hydrogen-related equipment.

The vision of building an energy infrastructure that uses hydrogen as an energy carrier — a concept called the "hydrogen economy" — is considered the most likely path toward a full commercial application of hydrogen energy technologies. Hydrogen is produced from available energy sources and used in every application where fossil fuel are being used in transportation, residential, commercial and industrial sectors and for electricity generation. The United States, Japan and many European countries have formulated strategies for long term usage of hydrogen as energy carriers. Such concept has been proposed for many developing countries including Malaysia (Sopian *et al*, 1995) as shown in Figure 3. A large scale solar hydrogen production in the Libyan desert and export hydrogen to Europe was also proposed (ElJrushi and Sharif, 1990). The German-Saudi Arabian project HYSOLAR demonstrates the feasibility of this concept and provides useful information for the design and operation of solar hydrogen plant for the future (Winter and Fuchs, 1991). A solar hydrogen production system have been proposed for Saudi Arabia as shown in Figure 4. With this system the Saudi will be exporting hydrogen instead of the depleting petroleum resources. Iceland has a plan of producing hydrogen for domestic use from renewable energy and will convert to full hydrogen economy by the year 2020 The first large scale hydrogen project in Iceland , the Ecological City Transport System was announced in 2001 that 4% of the city's public transport will be run hydrogen fuel cell buses. In addition, filling stations infrastructure and also electrolyzer facilities producing hydrogen from renewables. Already 70 % of the primary energy sources in Iceland are from renewable mainly hydropower and geothermal (Maack and Skulason, 2002).

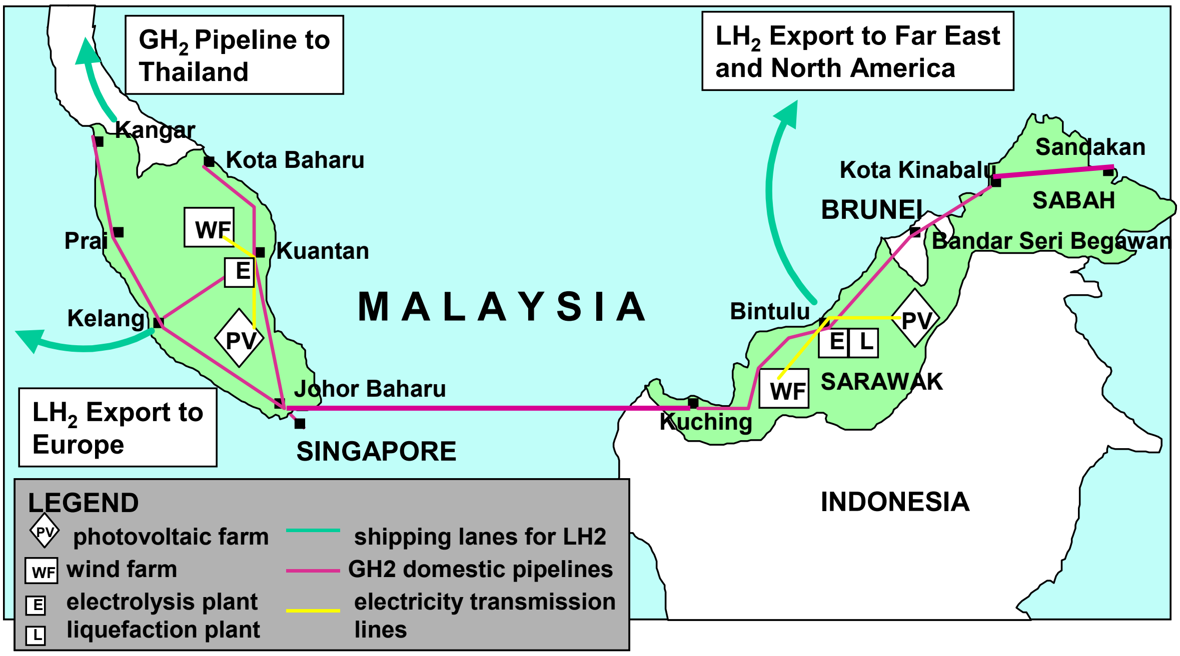

Figure 3 Solar Hydrogen Production and Delivery System for Malaysia

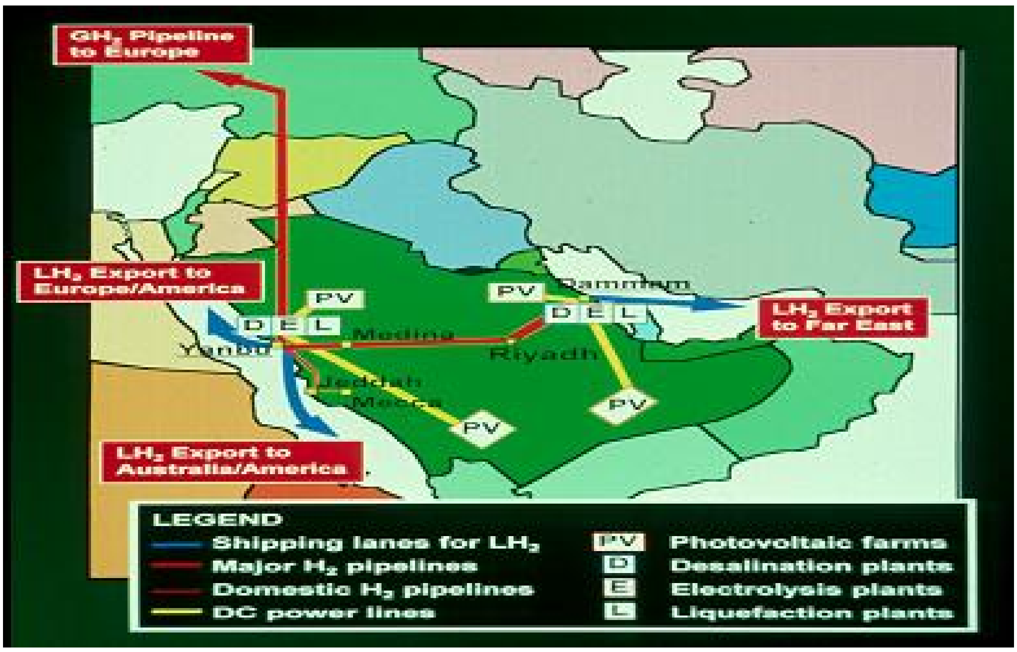

Figure 4 Solar Hydrogen Production and Delivery System for Saudi Arabia

CONCLUSIONS

Solar energy is a commodity just like any other from of energy. It has a major role to play in meeting the needs of global energy demand and combating the danger of global warming. The CO_2 emission in an uncontrolled way must be stopped or at least controlled so that this emission will not exceed 1990 level. Legislation must be introduced at national level as well as an international level. Switching from coal to natural gas will reduce CO_2 emission in the atmosphere. Energy conversation and energy efficiency are both very importation in reducing CO_2 emission. Solar energy thermal and photovoltaic systems are all necessities to reduce CO_2 emission.

Regional and local issues in developing countries may take priority over sustainable energy, sanitation, fuel wood shortages and local air pollution which will bring technological change. We need to be realistic about these changes over the next 30 years, which is why we must start now. Educating the public as well as introducing good legislation coupled with support and incentives in order to speed up the use of renewable energy whether in private or public sectors is important.

The vision of using hydrogen as an energy carrier and will lead mankind for a sustainable future with the concept of the hydrogen economy. Electrolysis can be carried out in scattered places close to the place of usage. It is also matched with hydropower, and other renewable resources such as geothermal, wind, waves, and photovoltaics. Instead of burning fossil fuels for electricity generation, and polluting the environment, the depleting fossil fuels can be kept forever in the ground or only used as chemical feedstock. Hence, establishing long lasting, sustainable, environment friendly renewable energy resources to fulfill the ever-growing energy needs for mankind.

The time has come to unite all our efforts, including the UN, World Bank, rich countries such as OECD countries and other international organizations, to produce a plan for the increased usage of renewable energy on a global scale and to educate individuals and countries in the importance of energy efficiency and conservation.

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Sequencing Batch Reactor (SBR) For Treatability Evaluation Of Solid Waste Leachate

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ABSTRACT: The treatment effectiveness of solid waste leachate utilizing a sequencing batch reactor (SBR) was evaluated in this study. Simulated leachate samples with initial biochemical oxygen demand (BOD_5) and chemical oxygen demand (COD) concentrations of 200 mg/L and 600 mg/L respectively were collected from a laboratory lysimeter. Treatment of the leachate samples was conducted in a 13-L laboratory-scale rectangular SBR at mixed liquor suspended solid (MLSS) concentrations of 3000 mg/L, 3500 mg/L, 4000 mg/L, 4500 mg/L and 5000 mg/L for a hydraulic retention time (HRT) of six hours. The performance of the reactor was monitored on a daily basis. Changes in pH, BOD and COD values were predicted in each of the Fill, React and Settle cycle. It was determined that the loading rate of 0.43 mg COD/ mg MLSS-d gave the highest removal rates for BOD and COD at 76 % and 73.6 % respectively. The treated COD concentration (158.4 mg/L) was found to exceed the limit of Standard B (100 mg/L) of the Environmental Quality (Sewage and Industrial Effluents) Regulations 1979, Amended 1997 (Malaysia).

Keywords: Sequencing Batch Reactor (SBR), leachate, lysimeter, solid waste, mixed liquor suspended solid (MLSS), hydraulic retention time (HRT)

INTRODUCTION

Landfill leachate is produced through vertical percolation of rainwater or liquid from other sources through a solid waste landfill. This type of leachate typically contains high concentrations of soluble organic materials and inorganic ions that cause serious groundwater and streams pollution which can be detrimental to public health (Sapari, 1987).

Treatment of landfill leachate can be carried out by means of physical, chemical and biological methods or by combination of these methods. In this respect, sequencing batch reactors (SBRs) have been proven as cost-effective and energy-efficient biological systems in removing hazardous organic compound in contaminated leachate and industrial wastewater (Nalasco *et al*., 1998., Lahlou & Matthews., 2003). SBRs are basically fill-and-draw activated-sludge treatment systems, which have been successfully used to treat both industrial and municipal wastewaters. The reactor systems are appropriate for wastewater treatment applications characterized by low or intermittent flow conditions (USEPA, 1999). SBRs are also regarded as a suitable method in treating industrial and domestic wastewaters containing high nitrogen and phosphorous concentrations (Chang *et al*., 2000).

The SBR was selected as the treatment method for landfill leachate in this study due to its flexibility in operation, ability to treat both low and high strength wastewater and efficient removal of organic compounds. The objective of this study was to study the treatability performance of solid waste leachate by using a laboratory-scale SBR and to determine the optimum design parameter for the SBR.

MATERIALS AND METHODS

Preparation of Leachate Samples

Leachate samples were preliminarily prepared by inoculation of microorganism seeding into wastewater simulated from a constructed laboratory lysimeter. The microorganism seeding was sourced from sludges obtained from an Indah Water Konsortium sewage treatment plant in Taman Tun Dr. Ismail. The seeding sludges were temporarily kept in a freezer at 4^oC prior to the inoculation process. Leachate used in this study was produced from the lysimeter as oppose to collection of leachate from an existing landfill to facilitate experimental works under controlled conditions.

Reactor Design

The reactor used in this study was a rectangular reactor made of Plexiglas with a working volume of 13 litres and consists of eight valves outlets as shown in Figure 1. It was equipped with an air diffuser located at its base for the provision of intermittent aeration.

Theory

The food-and-microorganism F/M ratio is defined as the rate of substrate per unit mass of biomass in the aeration tank per unit time. It is a common parameter used in the continuous flow system as shown in Equation 2.1 (Metcalf and Eddy, 1991) however in the present study it is not directly applicable for the SBR system.

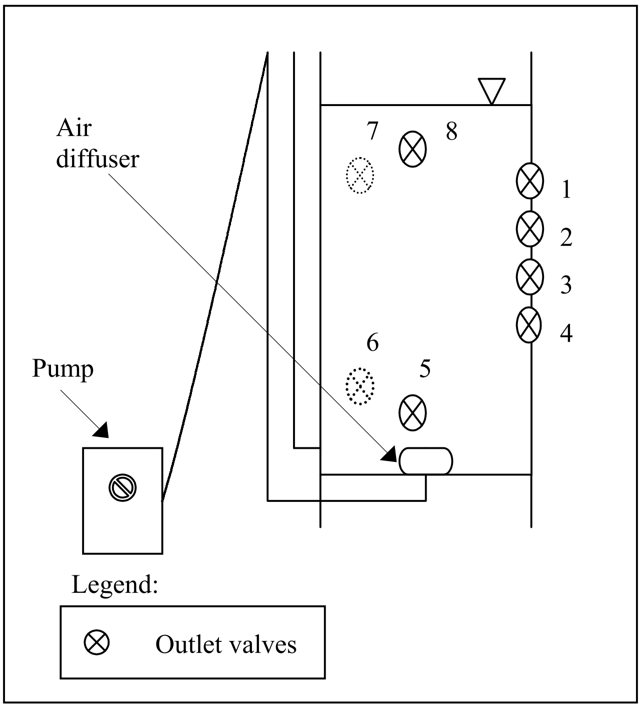

Figure 1: Schematic of the SBR system

$$F/M\ (\mathrm{mg\ mg^{-1}d^{-1}}) = QS_0/\ VX \qquad \text{Eq. 2.1}$$

Where,

F/M = food to microorganism ratio (d^{-1})
Q = volumetric flow rate (L/d)
S_0 = influent substrate concentration (mg/L)
V = volume of reactor (L)
X = mean MLSS in the reactor (mg/L)

A modified loading rate for the SBR has been proposed by Shroeder (1982). The equation is:

$$Li\ (\mathrm{mg\ mg^{-1}d^{-1}}) = V_f\ S_0 24/\ (VXT) \qquad \text{Eq. 2.2}$$

Where,

Li = loading rate (d^{-1})
V_f = volume of feed per cycle (L)
T = react time or aeration time (h)

Imposed loading parameter was varied by varying the MLSS within the SBR whilst other factors remain unchanged.

Experimental Operations

Prepared leachate samples were analyzed for pH, BOD, COD and total suspended solids (TSS) by using the *Standard Methods for Examination of Water and Wastewater by the American Public Health Association (APHA)* prior to addition into the reactor. The samples were added into reactor and reacted with the present sludge at a fixed temperature of 25^0C in six hours of hydraulic retention time (HRT) at mixed liquor suspended solid (MLSS) concentrations of 3000 mg/L, 3500 mg/L, 4000 mg/L, 4500 mg/L and 5000 mg/L. The Fill, React, Settle and Decant cycle were maintained at 0.5, 6, and 1 and 0.5 hours respectively, which the Fill and Decant cycle was operated manually. Aeration was carried out during the React cycle. Throughout the experiment, 350 mg/L of glucose were added as a source of carbon to stimulate microbial growth.

Subsequent to completion of reaction, the sludge was settled and the treated supernatant was removed. The reactor system performance was monitored on a daily basis. In each cycle, effluent samples were taken at two outlet valves with different levels at outlet 4 (107 mm height from water surface) and outlet 5 (150 mm height from water surface). The samples were then analyzed to determine the COD and BOD concentrations. In addition, pH and dissolved oxygen (DO) were measured using pH and DO meter. Loading rates for each simulation was investigated using Equation (2.2) as described previously. Leachate and effluent SBR characterization was carried out according to the methods listed in Table 1.

Table 1: Analytical Methods

No	Parameters	Analytical Methods
1	BOD_5^{20}	APHA SMEWW 18th Method 5220
2	COD	APHA SMEWW 18th Method 5210
3	TSS	APHA SMEWW 18th Method 2540
4	DO	DO probe
5	pH	pH probe

RESULTS AND DISCUSSION

Characterization of Leachate

Table 2 shows the characteristics of raw leachate sample compared with Standard A and Standard B of EQA 1974 and Environmental Quality (Sewage and Industrial Effluents) Regulation 1979.

Table 2: Characterization of Raw Leachate

Parameter	Raw Leachate	EQA 1974	
		Standard A	Standard B
Temperature (^oC)	23.8	40	40
pH	7.29	6.0- 9.0	5.5-9.0
COD (mg/L)	522	50	100
BOD_5 (mg/L)	158	20	50
TSS (mg/L)	345	50	100

From the analysis of raw leachate sample, it was observed that BOD, COD and TSS concentrations were higher than the limit required in the Standard A and Standard B of EQA 1974 for industrial effluents. This showed simulated leachate can be characterized as a high strength wastewater.

Overall Performance

Table 3 summaries the effluent quality during simulation in the SBR. COD and BOD concentration at MLSS of 5000 mg/L, give good effluent quality, 158.4 mg/L and 48 mg/L respectively. The results showed that variation in mixed liquor suspended solid (MLSS) can acffect the study elsewhere concentration profiles of treated effluent. Pervious showed that variation of MLSS has the effects on the concentration of the BOD, ammonium-nitrogen and nitrate-nitrogen (Poonyachat, 2001)

Table 3: Summary of Effluent Quality when MLSS were varied in SBR process.

MLSS (mg/L)	COD Effluent (mg/L)	BOD_5 Effluent (mg/L)	COD Removal (%)	BOD_5 Removal (%)	Loading rate (d^{-1})
3000	356.4	108	40.6	46	0.71
3500	289	87.6	51.8	56.2	0.6
4000	198	60	67	70	0.53
4500	237.6	72	60.4	64	0.47
5000	158.4	48	73.6	76	0.43

Figure 2 illustrates pH profiles in SBR system during react time at different levels. Increasing in pH values was observed during the Feed period at both levels. pH values were increased during Feed stage especially at level 4 due to the stripping of carbon dioxide out of the system. The pH-increasing rate at level 4 was high compared with level 5 during React time due to oxidation of organic matter by microorganisms. Decreasing of pH at level 5 was observed at the end of the cycle. The accumulations of carbon dioxide trapped within settled sludge tend to lower the pH.

Dissolved oxygen (DO) is significant factor to predict whether the biological changes are carried out by aerobic or by anaerobic organisms. Figure 3 shows the DO profile measured by membrane electrodes at different points. DO at level 4 shows greater increase due to effective productivity of organism with more oxygen dissolves at this level compared with level 5 (nearly bottom of reactor). It was observed, DO profile for React time of 6 hours is usually below 1 mg/L for the first hour and then increasing gradually until reaching 5.9 mg/L at the end of react time. This high DO was maintained to promote aerobic condition that produce energy for growth of organism in the reactor.

As can be seen in Figures 4 and 5, variation in mixed liquor suspended solid concentration influence the removal efficiency of COD and BOD concentration throughout entire period of cycle. Average effluent showed increases in COD and BOD concentration beginning of Fill cycle. During this stage organisms showed ability to utilize substrate and growth of new cells with the availability of nutrient. The population of organisms remained stationary whereas BOD and COD concentrations are fairly constant all through reaction time. This is due to the lack of nutrients. Finally, BOD and COD concentration decreased at the end of cycle caused by settlement of settled sludge during settling time. BOD and COD concentration were found to vary with MLSS from 3500 mg/L to 5000 mg/L with removal efficiency exceeding 50 %.

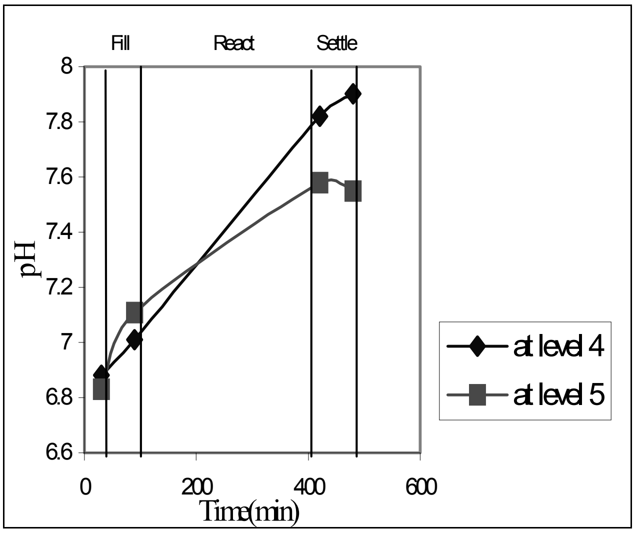

Figure 2: pH Profiles during SBR cycle

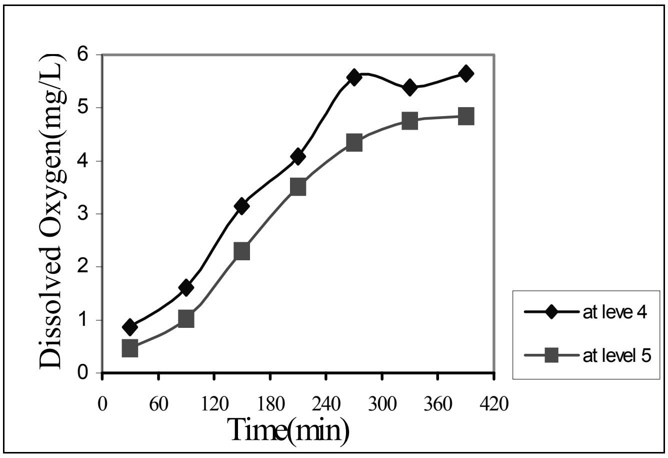

Figure 3: Dissolved Oxygen Profiles during React Time

CONCLUSIONS

The following conclusions can be drawn from the previous sections:

1. Variation of mixed liquor suspended solid (MLSS) can be used as a control parameter for treating leachate using Sequencing Batch Reactor (SBR).
2. Varying the MLSS has direct influence on the concentration BOD and COD.
3. Loading rate of 0.43 d^{-1} with MLSS concentration 5000 mg/L was obtained as the

best condition for effluent BOD_5 and COD concentration, 48 mg/L and 158.4 mg/L respectively.
4. Hydraulic retention time (HRT) 6 hours was insufficient at 3000 mg/L MLSS to remove organics compound.
5. Sequencing Batch Reactor (SBR) with suitable operation flexibility is capable to treat high strength wastewater such as leachate.

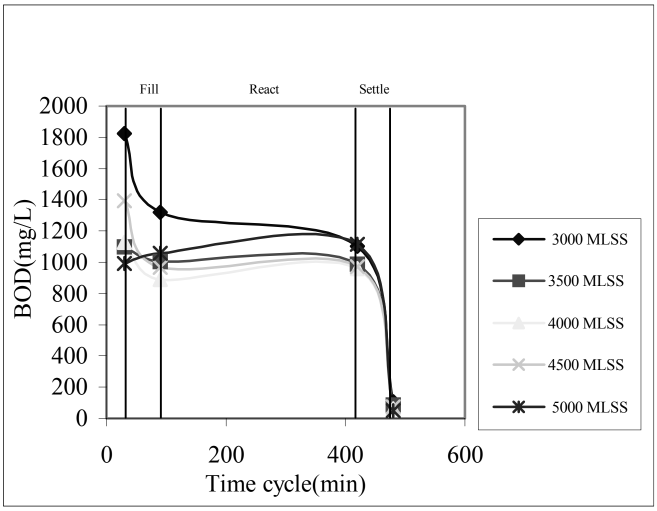

Figure 4: BOD_5 profiles when MLSS were varied during SBR cycle

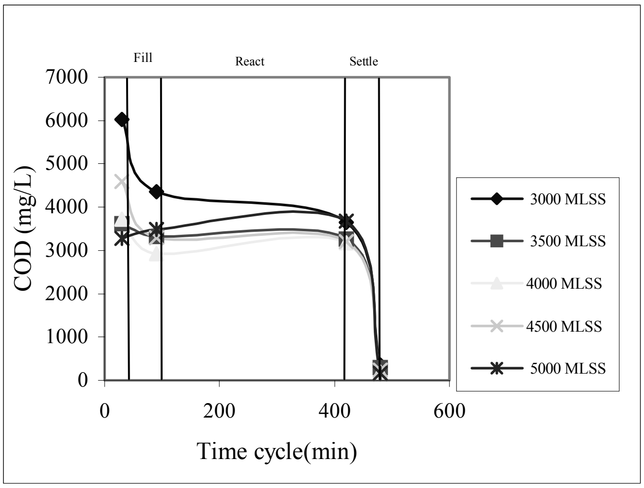

Figure 5: COD profiles when MLSS were varied during SBR cycle

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Removal Of Ash In Palm-Shell-Based Activated Carbon Using Acid Leaching

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ABSTRACT: A series of experiments have been conducted to study the effect of using several acids on removal of ash in palm shell-based activated carbon. The ash content was determined using ASTM standard. The results show that approximately 10 % of ash can be removed using HCl, 25 % using HNO_3 and 90 % using HF.

Keywords: Activated carbon, palm shell, ash, leaching

INTRODUCTION

Over the last 4 decades, the palm oil industry has grown to become a very important agricultural-based industry in Malaysia and currently, the country has become the world leading producer and exporter of palm oil. In this industry, palm oil is the major product and there are a variety of wastes created from it, such as palm shell. In 2000 alone, the amount of palm shell generated was approximately 3.1 million tonnes [1] and it created huge disposal problem. The possible use of palm shell as activated carbon precursor was highlighted by Chan et al [2]. Reupke et al [3] reviewed the possibility of using palm shell for producing activated carbon production and concluded the product from this material could be technically inferior than the product produced from coconut shell in many applications. One of the drawbacks of palm shell-based activated carbon is the amount of ash present in it. The amount of ash in palm-shell-based activated carbon varies from 3 to 5 % and it is relatively high if compared to coconut-shell-based activated carbon that is around 0.3 %. The presence of ash in activated carbon limits its applications. This ash can dissolve, depending on the solvent used and will contaminate the solvent. Besides, the dissolved ash can alter the pH of a solution. In food and pharmaceutical industries, if the ash is not completely removed it dissolved into the product this can lead to contamination of food and medicine. Besides, activated carbon is also widely used as decolorization agent in sugar industry. The leachable ash is undisirable since it can cause uneven distribution of heat in the boiler during sugar crystallization. One of the methods used to remove the ash is through acid leaching process [4]. In this work, three types of acids HNO_3, HCl and HF of different concentrations were used as leaching agents.

EXPERIMENTAL

Raw Material

The palm-shell-based activated carbon sample was obtained from a local company. The samples were washed using distilled water and dried in oven for 24 hours. After that the samples were sieved to particle size 150 to 500 μm.

Leaching Method

The samples have been leached by three types of acids, HNO_3, HCI and HF of different molarity ranging from 0.5 M to 5 M. For a typical operation 100 ml HCI of 0.5 M and 5 g of sample were charged into 250 ml flask and stirred using a magnetic strirrer for 120 minutes. After that the sample was filtered out using filter paper and washed to eliminate CI^- ions. The sample then dried in oven for overnight. Similar procedures were repeated for other concenterations and other types of acids. For HF, the experiments were performed in a Teflon stirred beaker.

Ash Content Determination

The ash contents were determined based on ASTM D 2867-95

Calculations

$$\text{Percentage of ash content} = \frac{(\text{mass of ash}) \times 100}{(\text{mass of dry sample})}$$

$$\text{Percentage of ash removal} = \frac{(\text{ash before treatment} - \text{ash after treatment}) \times 100}{(\text{ash before treatment})}$$

RESULTS AND DISCUSSION

Table 1 shows the ash contents in activated carbon of different particle sizes. It indicates that the particle size does not affect the ash content. The slight variation could be attributed to the uneven distribution of ash present in the particle.

Table 1: Ash content in raw activated carbon

Particle size, μm	Ash content %
< 150	3.53
150-300	3.36
300-500	3.77

500-1000	3.49

The choice of acid used depands on the composition of the ash. Table 2 shows the composition of the ash. It composes of both mineral and non mineral species. The HCI and HNO_3 are effective in removing the mineral species whereas HF is more effective in dissolving silicates which is present in large quantity.

Table 2: Percentage of ash composition

Ash composition	Percentage
Iron	1
Sulfur	0
Phosphate	1 to 2
Potassium	0 to 3
Calcium	0 to 1
Sodium	3
Chlorides	0 to 0.5
Copper	0 to 20 ppm
Silica	25 or higher

Table 3 shows the amount of ash extracted for three types of acids at different concentrations. The results indicate that HCI can extract approximately 10 % of the ash and HNO_3 can remove approximately 25 % of the ash. The results also show that HNO_3 can extract twice the amount of inorganic species than HCI. For this two acids, it seems that changing the acid concentration does not affect the amount of ash removed. For the HF treatment, the results show that the acid can remove the ash up to 93 %.and when the concentration was decreased to 0.5 M, the amount of ash removed also dereased to 72.81 %. The huge increase in the amount of removed using HF could be attributed to its ability to dissolve silicate and its compounds such as alumiminosilicates that is present in a large quantity in the ash. This result was expected according to the well-known capability of HF to extract aluminosilicates from coal [5].

Table 3: The percentage of ash removed (particle size < 150 µm)

Acid concentration, M	Ash removal (%)		
	HCI	HNO_3	HF
5	14.70	27.38	93.47
3	7.10	23.97	94.54
1.5	8.05	26.20	86.58
0.5	9.44	24.53	72.81

Table 4: The percentage of ash removed (particle size 150-300µm and acid molarity 1.5)

Acid	Ash removed (%)
HCI	14.20
HNO_3	24.46
HF	72.14

Table 4 show the amount of ash removed in the samples of particle size range of size 150-300µm at concentration of 1.5 M. The change in particle size does not have a remarkable effect on the amount of ash leached.

CONCLUSION

The possibility of removing ash in palm-shell-based activated carbon has been evaluated using separately three types of acids namely, HCI, $HNO_3$and HF. The results show that approximately 10 % of ash can be removed using HCI, 25 % using HNO_3 and 90 % using HF. Further study is needed on the possibility of using acid blend of different proportions and concentrations.

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Modelling Of Chlorine Decay In Water Distribution System

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ABSTRACT: Drinking water undergoing conventional treatment is chlorinated with excess chlorine in order to prevent bacterial growth inside distribution pipes. Underground pipelines make the detection and monitoring of water quality in the distribution system difficult. The purpose of this study was to investigate the fate of residual chlorine in the distribution system. A network simulation model will be developed using EPANET 2.0 software to assess the behaviour of residual chlorine in the distribution system. A study area at Bukit Tunku, Kuala Lumpur was chosen based on consumer water quality complaints data provided by PUAS Berhad. Thirty samples were taken from the treated water exit at Bukit Nanas Water Treatment Plant and the residual chlorine was tested daily. The decay constants were determined from the best fit of the theoretical first order kinetic of the experimental data.

Keywords: Modelling, chlorine decay, disinfection, chlorine concentration, water quality, water distribution system, EPANET 2.0

INTRODUCTION

Water distribution systems are primarily designed and optimised based mainly on hydraulic performance. However, water quality deterioration on reaching the consumer's taps has resulted in loss of trust on our water supply system. Recently, numerous complaints were received by PUAS Berhad regarding the deterioration of water quality at Bukit Tunku, Kuala Lumpur. As such, the concern when delivering water capacity has shifted to water quality changes when managing a water distribution system.

Chlorination was the most widespread disinfection used in drinking water treatment for inactivation of microbial pathogen. Chlorine demanding compounds may exert a demand inside the distribution pipeline. Therefore, sufficient amount of residual chlorine was the main concern of the water industry to protect the microbial regrowth during the transfer of water to consumers. There are five factors which influence the consumption of chlorine in the distribution network:

1. Initial chlorine concentration (Hallam, 2002)
2. Pipe material and diameter (Hallam, 2002)
3. Reaction with organic and inorganic substances (USEPA, 2001)
4. Reaction with biofilm on the pipe wall (USEPA, 2001)
5. Consumption by the corrosion process (USEPA, 2001)

Chlorine kinetics

Frequently, the residual chlorine along the distribution network was simulated according to the first order reaction kinetics in the bulk water with respect to chlorine as defined by the following equation (Maier, 2000; Walski, 2001, Richter, 2001):

$$C_i = C_0 e^{-kt}$$

Where, C_i: concentration of chlorine at time t
C_0: initial concentration of chlorine
k: Decay coefficient
t: Time of the reaction

The above equation usually fits chlorine decay data well but fails to represent the observable significantly faster decay during the first hours in most chlorine kinetics experiments (Hua, 1999). However, this shortcoming can be neglected by taking consideration of steady state modelling.

Network Simulation

As a result of SDWA and SDWAA in the United State, the interest in water quality in water distribution system have increased and numerous computer software have been developed to solve the network simulation equation. Water quality simulation uses mathematical approximating technique to track the behaviour of real water distribution system. By assuming that water flow through the network satisfies the law of conservation of mass (Mays, 2001; HDR Eng., 2001), the fate of chemicals along the pipelines can be determined.

A water quality model presented here is used to track the concentration of free chlorine throughout the distribution network at Bukit Nanas. Under a known set of hydraulic conditions for a "hydraulic time step", the mass conservation equation in a single pipe is represented:

$$\frac{\partial C_i}{\partial t} = -u_i \frac{\partial C_i}{\partial x} - K_i C_i = 0$$

where C_i is the chlorine concentration in pipe or link *i* at a distance *x* along the pipe at time *t*, u_i is the flow velocity in pipe or link i and K_i is an overall decay constant. (Rossman,2000)

EPANET 2.0

One of the more reliable and widely used network analysis program was EPANET 2.0 which was used in this study to solve the chlorine transport equation at steady state, using a constant average flow rate. The equations governing EPANET 2.0 are based on the principles of conservation of mass coupled with reaction kinetics is presented as follows (Rossman, 2000; HDR Eng., 2001):

1. Advective Transport in Pipes
2. Mixing at Pipe Junction
3. Mixing in Storage Facilities
4. Bulk Flow Reactions
5. Pipe Wall Reactions
6. System of Equations

MATERIALS AND METHODS

This study has been carried on the distribution system at Bukit Tunku, Kuala Lumpur with the help of PUAS Berhad in field sampling data collection. This distribution system is fed by the treated water from Bukit Nanas and Batu Estate reservoir which is sourced from Selangor River. Two treated flow exit from the treatment plant are mixed at Maxwell Booster Station and finally transferred to Bukit Tunku area.

The water network was digitised in EPANET 2.0. Input data, such as initial quality (residual chlorine) variations were monitored at 4 locations and used as input and calibration data in the model. Figure 1 shows the Bukit Tunku Distribution System. The hydraulic time step used was 1 hour The network consists of about 57 nodes and 57 pipes with total pipe length of around 10km.

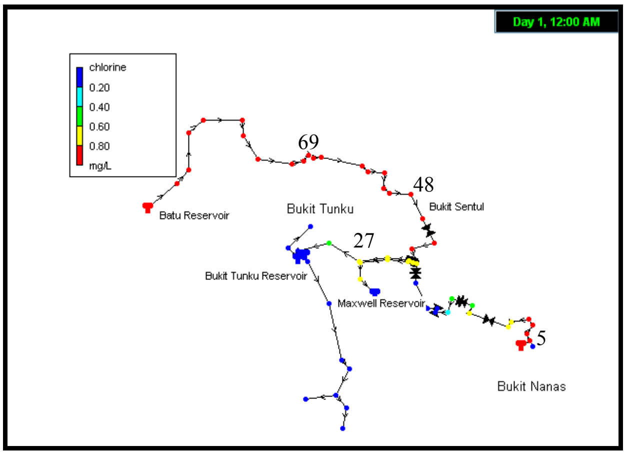

Figure 1: Schematic Distribution Map of Bukit Tunku

The rate constant for chlorine decay in the bulk flow had been estimated by performing a bottle test (HDR, 2001; Walski, 2001; Hua, 1999; Powell, 1999; Hart, 1992) in the laboratory of University of Malaya. 30 Samples were collected in dark bottles from the outlet of Bukit Nanas Water Treatment Plant and the initial water quality and chlorine concentration was measured immediately as initial time zero. The remaining 28 samples were then stored at ambient temperarute (28.5 ± 0.5ºC) in an incubator kept at a constant temperature. The free chlorine concentration were measured on duplicate sub-samples by adding the N,N-diethyl-p-henylnediamine (DPD) tablets and measured using the DPD colorimetric meter until it became undetectable.

RESULTS AND DISCUSSION

The average water quality produced by Bukit Nanas water treatment plant is observed to be better than the WHO International Standards for Drinking Water. In can be said to be world class standard comparable to those of developed countries (Subramaniam, 2003). Table 1 below gives the comparison of WHO standards and the actual quality data collected during the study.

Table 1: Average water quality at Bukit Nanas water treatment plant

Parameters	Actual Quality	WHO Standards
Turbidity, NTU	0.36	<5
Colour, TCU	<5	<15
pH	7.21	6.5-9.0
Chlorine, mg/L	1.78	0.2

Chlorine decay constant

The results of the laboratory investigation of the chlorine decay rate constant is shown in Figure 2 are the average of duplicate measurements. The profile showed that for most of the time, chlorine was decaying according to the first-order equation.

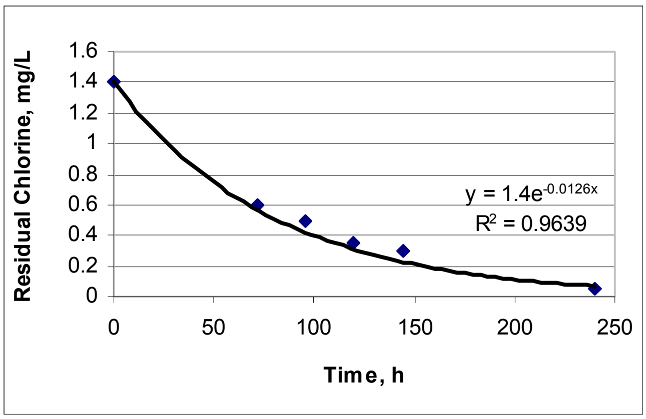

Figure 2: Profile of chlorine Decay for Bukit Nanas Water Treatment Plant

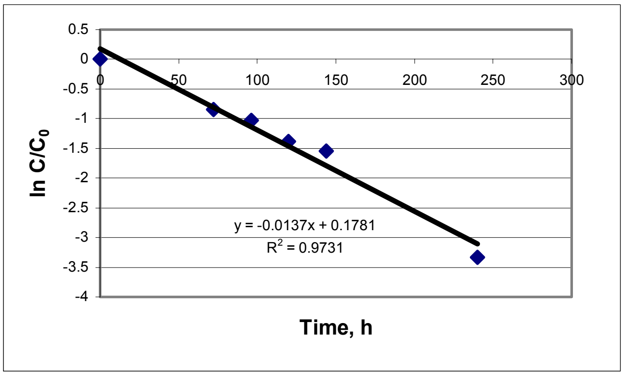

Figure 3: Graph ln C/C_0 versus time

Since the chlorine decay was shown to be well approximated to first-order reaction (Figure 2), the reaction rate coefficient was found by using linear regression techniques. A best-fit straight line is drawn through the data collected from bottles test, with concentration plotted on a ln axis as illustrated in Figure 3. The estimated first-order bulk decay coefficient from the slope of linearised plot for Bukit Nanas Water Treatment Plant were 0.013/h and reach a residual chlorine concentration of 0.1mg/L which correspond to 10 days.

Model verification

The accuracy of the model developed was verified by comparing the model results with the field sampling data. Table 2 shows the calibration statistics for chlorine, it could be noticed that good agreement was obtained between the observed and computed chlorine concentration with the correlation between means at 0.951.

Table 2: Calibration Statistics for Chlorine

Location	Observed Mean (mg/L)	Computed Mean (mg/L)	Mean Error	RMS Error
5	1.40	1.48	0.084	0.084
27	0.87	0.74	0.126	0.126
48	1.07	0.90	0.170	0.170
69	1.16	0.95	0.213	0.213

Network water age

The model was also used to predict the age of water throughout the distribution system and is presented in Figure 4. The average water age of this network was found to be 12.9 hours. By using the decay coefficient of 0.013/h, this retention time would account for 16.7% chlorine loss. Based on this number of age distribution pattern, it was observed that portion of the chlorine decay was due to the storage times in the network.

However, the balance of 83.3% of the chlorine loss was most probably due to the chlorine demanding materials rather that the excessive retention time. This aspect of chlorine loss determinants will form future experimental investigation. One of the most important chlorine demanding materials was natural organic matter (NOM) precursors which react with chlorine to form Disinfection By-Product (DBPs). No reaction mechanism has been found to completely explain the behavior of DBPs (Sekhar, 2001) and several types of these DBPs was found to have adverse health effects.

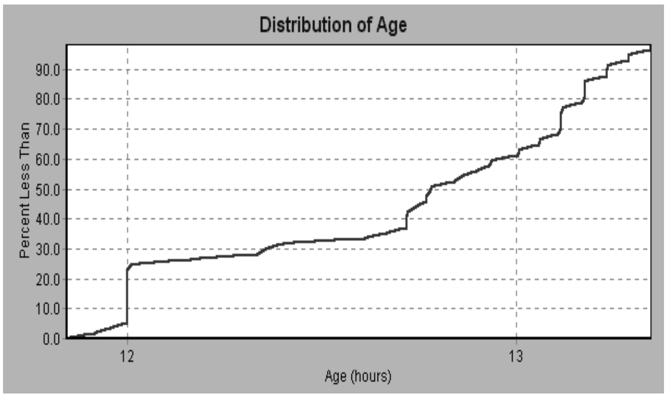

Figure 4: Distribution of Age

Distribution of chlorine

Figure 5 shows the contour profile of the bulk average chlorine concentration in the Bukit Tunku distribution systems. The chlorine concentration decreased gradually from the water treatment plant until it reaches a level ≤0.2mg/L at some place of Bukit Tunku area.

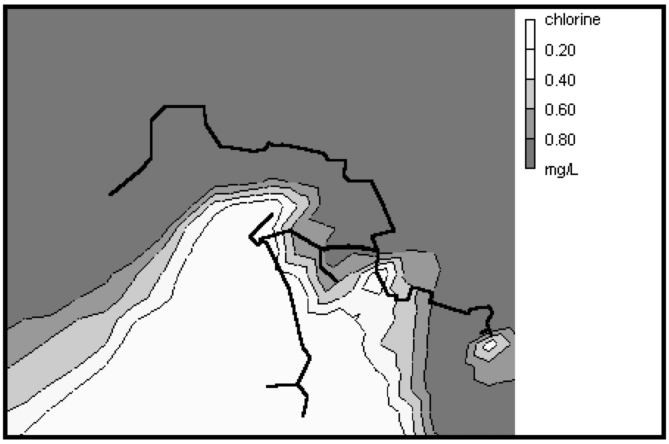

Figure 5: Contour profile of chlorine distribution

Distribution curve of chlorine with the initial concentration of 1.78 mg/L at the water treatment plant was simulated. A plot of chlorine concentration versus percent of network with chlorine is then used to describe the chlorine residual distribution pattern of the network.

As can be seen from Figure 6, more than 80% of the distribution was shown to have higher or equal to 0.2 mg/L of chlorine residual in the network which complied with the WHO standards. On the other hand, there were 20% of the network which has chlorine residual lower than 0.2 mg/L.

Throughout this 20%, the level of chlorine was still in detectable level. This observation indicated that the degree of chlorine distribution and the disinfectant level of water within the distribution pipelines were maintained.

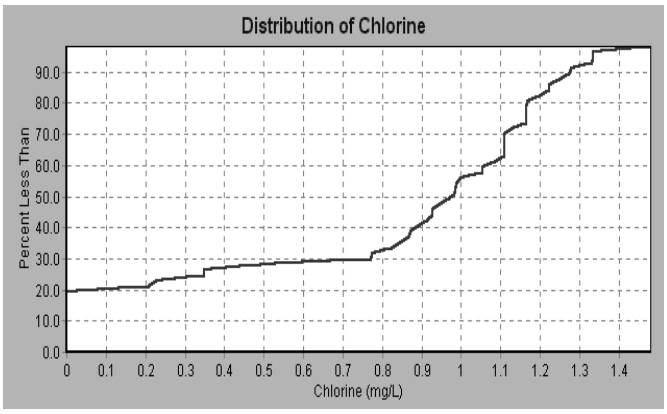

Figure 6: Chlorine distribution curve

It should be clearly pointed out that the level of residual chlorine within the network, especially if an emergency event occurs must be continuously assessed. The standard requires a residual of 0.2 mg/L at consumer's taps, hence this dictate the chlorine dose at the water treatment plant to be careful monitored and operated at all time.

In order to maintain an appropriate level of chlorine within the network, increasing of the chlorine dosage at water treatment alone was not necessarily appropriate. Moreover, it may pose a risk of DBPs formation. Therefore, operation and maintenance of the pipeline was utmost important in preventing the deterioration of water quality along the network. It was reported by Subramaniam (2003) about 40% of this distribution pipeline was actually beyond their serviceable life. Corrosion that took place in the old pipe may increase the chlorine decay rate and provide host for bacterial growth.

CONCLUSIONS

The model was very useful to predict the behaviour of a typical water treatment plant treated water exit through the distribution pipeline in ensuring the desired water quality at consumer taps.

Results of this study are summarised as follows:

- The water quality of treated water from treatment plant was in accordance with the WHO International Standards for Drinking Water.
- Chlorine distribution curve showed that this network was operated well and maintain a good degree of disinfecting capability at most part of the study area.
- Laboratory evaluation of treated water from Bukit Nanas water treatment plant showed that it has a very low chlorine decay.
- Water age evaluation of this work showed that low chlorine residual within the network was not caused by the excessive water retention time.
- Losses of chlorine residuals in the distribution pipeline are assumed to be caused by the pipe material or other chlorine demanding matter.
- Calibration of network chlorine models can be based on the first-order kinetics model for bulk reaction and good agreement were obtained.

With this simulation model study, a number of operating and maintenance adjustment scenarios are possible for the water distribution system. The model developed here could be used for further plans such as evaluation of storage tank impacts, biofilm growth, and modification to pipeline rehabilitation and use of chlorine injector along the network.

ABBREVIATIONS AND SYMBOLS

PUAS: Perbadanan Urus Air Selangor
SDWA: Safe Drinking Water Act
SDWAA: Safe Drinking Water Act Amendment

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Kinetic Studies Of Simulated Leachate By Granular Activated Carbon Process

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ABSTRACT: Leachate contains high concentrations of refractory organic compounds and heavy metals. This may result in long-term environmental problem in terms of accumulation of organic compounds in organisms. Adsorption onto activated carbon is the process that has been shown to be efficient in regard to removal of refractory organic compounds from leachate. Researchers in United States of America extensively studied carbon adsorption of leachate and there have not been any studies to treat landfill leachate in Malaysia. Analysis of characteristic of landfill leachate was carried out and the results showed high concentration of COD, BOD and Total Suspended Solid (TSS). From the analysis, the COD, BOD and TSS were 3005, 385 and 475mg/L respectively. It was also observed that the concentration of several heavy metals was high. The concentration of iron, tin and arsenic were 6.06, 3.91 and 1.65mg/L respectively. From the result, landfill leachate can be characterized as a high strength wastewater. Consequently, neither conventional biological treatment nor chemical treatment processes separately achieve high removal of leachate. Hence, treatment of leachate using Granular Activated Carbon (GAC) has been initiated. GAC was tested for the treatment of leachate simulated from the laboratory lysimeter. Batch adsorption studies were performed for COD concentration. Results of batch studies conducted to determine the effect of time on the kinetics of adsorption of leachates were reported. The adsorption of leachate onto the GAC was studied in terms of two simple kinetic models, pseudo-first and pseudo-second order. The kinetic models were developed to predict the rate constant of adsorption. Adsorption capacity of GAC to treat COD in leachate was expressed by Langmuir and Freundlich isotherm model. Langmuir constants (Q_0 and K_L) were found to be 16.18 mg/g and 0.104 L/mg, respectively. Freundlich constants (n and K_f) were 2.99 and 3.137 mg/g, respectively.

Keywords: GAC, adsorption, leachate, COD, heavy metal, batch study, kinetics, pseudo-first order, pseudo-second order, Langmuir isotherm, Freundlich isotherm.

INTRODUCTION

Landfill leachate is a complex and highly polluted wastewater from breakdown of solid waste. Leachate contains a wide variety of potential carcinogens and potentially toxic chemicals that represent a threat to public health. In addition, leachate will also contain high concentrations of toxic organic, chlorides, sulphates, heavy metals and high alkalinity (Horan *et. al.*, 1997). It was known that small amounts of leachate can pollute large amounts of groundwater and will render it unsuitable for use as domestic water supply. This will also be a threat to public health and the environment.

A wide range of treatment options has been utilized for treating leachate. Biological processes as activated sludge or aerated lagoons plants are the most common leachate treatment to remove biodegradable organic fraction. Ammonium ion concentration can be reduced by microbiological treatment (the nitrification and denitrification processes) (Welander *et. al.*, 1998). However, the removal of COD during these processes is fairly low. Hence, treatment of leachate using GAC adsorption is often applied. Activated carbon adsorption is one of the most widely used methods in water and wastewater treatments (Cheremisinoff & Ellerbusch, 1980). GAC is considered one of the most effective adsorbents,

especially for substances containing refractory organic compounds that resist biodegradation and persist in the environment (Abu-Zeid *et. al.*, 1995). In the adsorption process, GAC has good adsorbing capacity, due to the high surface area, resulting from the high porosity.

The aim of this research is to study the efficiency of GAC adsorption to remove significant contaminants in the sample of leachate. The adsorption kinetics and equilibria of COD and several heavy metals on the GAC were investigated. Two simple kinetic models, that is, pseudo-first- and pseudo-second order, were developed to predict the rate constant of adsorption. Adsorption isotherms were determined according to the Langmuir and Freundlich equations.

MATERIALS AND METHODS

Adsorbents

GAC was used as the adsorbent in the present study. The adsorbent was grounded and sieved to produce particle size of 300-600μm. The sieved adsorbent was then washed thoroughly with distilled water to remove all the foreign matter, impurities and unwanted moisture. Subsequently, the washed adsorbent was dried in an oven at 103°C for 24 hours, cooled at room temperature and finally stored in a desiccator until use.

Leachate samples

Raw leachate sample was collected from transfer station of Jinjang Landfill site at Taman Beringin, Kuala Lumpur. Samples were collected in clean acid-washed polyethylene bottle. Analysis of the characteristic of the leachate was carried out immediately after the leachate collection. Leachate simulated from the laboratory lysimeter was used as an adsorbate during the batch adsorption study due to its availability and ease for leachate controlling.

Kinetic of adsorption

The kinetic experiment was carried out by batch technique using a series of Erlenmeyer flasks of 250 mL capacity. A control sample was taken to determine the exact concentration of adsorbate before contact with GAC. 2g of GAC were added to each flask containing 80 mL of leachate sample. The flasks were then capped with Parafilm and placed on an orbital shaker and agitated for specified time of 15, 60, 90, 120, 180, 240 and 300 minutes at a speed of 150 rpm. At the end of each contact time, carbon is removed by filtration. The concentration of COD remaining in solution was measured according to APHA 18th Standard Method 5220. Heavy metals were quantified by Inductively Coupled Plasma-Atomic Emission Spectroscopy (ICP-AES). The experiments were performed at 25°C and the working pH was that of the solution and was not controlled. The adsorbate uptake q (mg adsorbate/g GAC) was determined as below:

$$q = (C_0 - C_t) \times V/M$$

where C_0 and C_t are initial and final adsorbate concentrations (mg/L), respectively, V is the volume of solution (mL) and M is the mass of GAC (g).

Adsorption Isotherm

The experiment was carried out in the batch technique for the measurement of adsorption capacities. A series of Erlenmeyer flasks of 250 mL capacity was used and containing 80 mL of leachate sample. Eight dosages of GAC (0.25, 0.35, 0.50, 0.75, 1.00, 1.50, 2.00 and 2.50 g) were mixed with leachate sample for 2 hours time experimentally determined by kinetic studies of adsorption process. The GAC was then filtered off and the concentration of metals and COD remaining in the solution was measured. The experiment was performed at 25°C and the working pH was that of the solution and was not controlled. Control experiment was also carried out.

RESULTS AND DISCUSSION

Characterization of Leachate

Table 1 shows the characteristic of raw leachate sample from Jinjang Landfill. From the analysis, it was observed that the sample contains high concentration of COD, BOD, Total Suspended Solid (TSS) and several heavy metals. However, the concentration of heavy metals is generally low due to the removal by ion exchange reactions as leachate travels through the soil (Tchobanoglous & Vigil, 1993). The age of landfill, limitation of solid generation and thus the degree of solid waste stabilization have a significant effect on the composition of leachate. The leachate sample was dark brown in colour and the pH was 5.28.

Table 1: Characteristic of Raw Leachate (Jinjang Landfill)

Parameter	Result
Temperature (°C)	28.1
pH	5.28
COD (mg/L)	3005
BOD (mg/L)	385
Color (Hazen)	35-40
Acidity (mg/L as $CaCO_3$)	580
Turbidity (NTU)	153
Chloride (mg/L)	224
Free chlorine	0.1
TSS (mg/L)	475
Manganese (mg/L)	0.039
Copper (mg/L)	ND
Cadmium (mg/L)	ND
Iron (mg/L)	6.06
Arsenic (mg/L)	1.65
Lead (mg/L)	ND
Nickel (mg/L)	ND
Tin (mg/L)	3.91
Zinc (mg/L)	0.564
Chromium (mg/L)	ND

In comparison, typical composition of untreated domestic wastewater is shown in Table 2. It was concluded that leachate could be categorized as a high strength wastewater.

Table 2: Typical composition of untreated domestic wastewater (Metcalf & Eddy, 1991).

Contaminants	Concentration (mg/L)		
	Weak	Medium	Strong
COD	250	500	1000
BOD	110	220	400
TSS	100	220	350

Effect of contact time

Figure 1 shows the kinetics of COD adsorption onto the GAC obtained by batch contact time studies. The plots represent the amount of COD adsorbed, q_t onto the GAC versus time. The kinetic shows that strong increase of the capacity of COD removal during the first 15 minutes of contact time. This is follow up by a slow increase until a state of equilibrium is reached. Equilibrium adsorption was reached within 1 to 2 hours of contact time. According to this result, the shaking time was fixed at 2 h for the rest of the batch experiments to make sure that equilibrium state was reached.

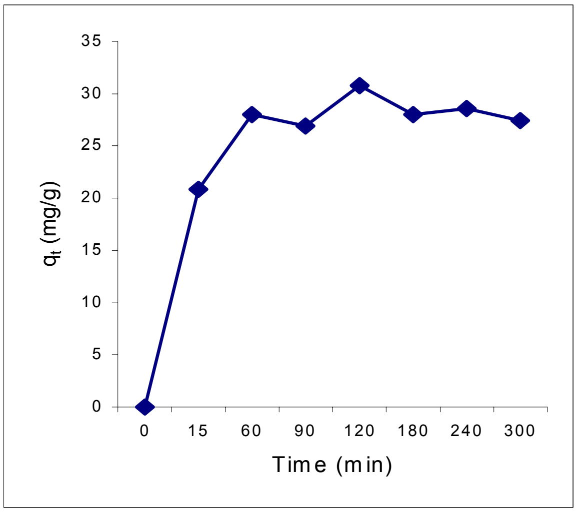

Figure 1: Kinetics of COD adsorption onto GAC

Adsorption Rate Constant

The rate constant for adsorption of COD can be determined by using pseudo-first order Lagergren equation (Lagergren, 1898) and pseudo-second order (Ho, 1999) as below (Eqs. 1 & 2), respectively.

$$\log (q_1 - q_t) = \log (q_1) - k_1 t/2.303 \quad (1)$$

where q_1 and q_t (both in mg/g) are the amounts of adsorbed COD at equilibrium and at time t (min), respectively, and k_1 (min^{-1}) is the rate constant for adsorption. In order to obtain the rate constant, the linear plots of log ($q_1 - q_t$) vs. t were analyzed and shown in Figure 2. The values of k_1 and regression coefficients, r_1^2 calculated from the plot were found to be 2.99×10^{-3} min^{-1} and 0.344 respectively.

$$t/q_t = 1/k_2 q_e^2 + t/q_e \quad (2)$$

where q_e (mg/g) is the amount of adsorbed COD at equilibrium and k_2 (g $mg^{-1}min^{-1}$) is the equilibrium rate constant of pseudo-second order. The linear plot of t/ q_t vs. t was tested to obtain rate constant (Figure 3). The values of k_2 , q_e and regression coefficient, r_2^2 calculated from the plot were found to be 0.3641 g $mg^{-1}min^{-1}$, 28.01 mg/g and 0.9973 respectively.

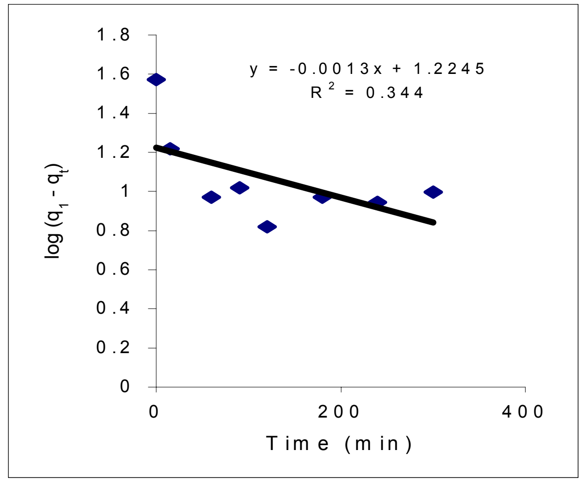

Figure 2: Pseudo-first order Lagergren plot for the adsorption rate of COD removal onto GAC.

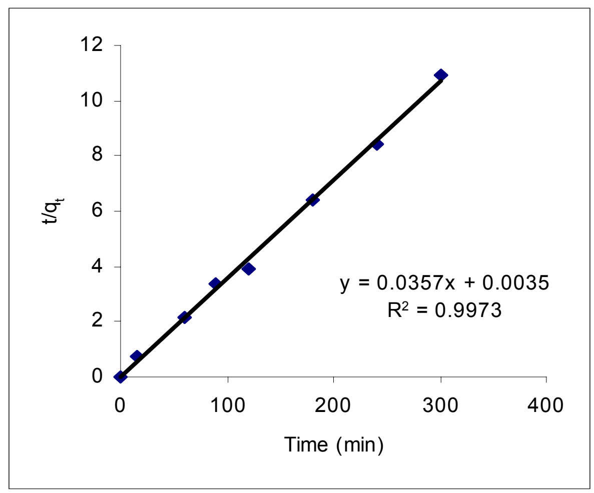

Figure 3: Pseudo-second order plot for the adsorption rate of COD removal onto GAC

Many literature reviews have shown that the majority of adsorption studies can be represented as a pseudo-first order rate mechanism where the sorption of adsorbate is diffusion controlled (Ho, 1999). However, it was clearly found that the pseudo-second order model is better described the kinetics of COD adsorption onto GAC with high regression coefficient (r_2^2 = 0.9973). Pseudo-second order model was based on the assumption that the rate-limiting step will be chemical adsorption or chemisorption involving valency forces through sharing or exchange of electrons between adsorbent and adsorbate (Ho, 1999).

Effect of Adsorbent Dose

Figure 4 shows the sorption of COD as a function of GAC dosage. The percentage of COD sorption increases with GAC dosages (0.25-2.5 g). This can be explained by the fact that as the mass of adsorbent increases, more contact surface becomes available for the sorption to take place.

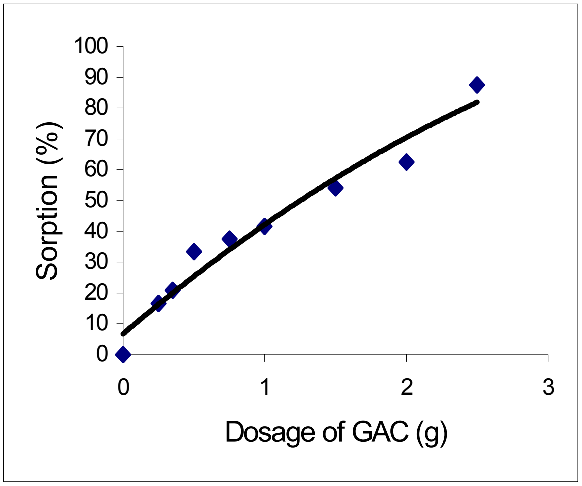

Figure 4: Sorption of COD at different dosage of GAC

Adsorption Isotherm

The results obtained on the adsorption of COD were analyzed in accordance with the Langmuir (Langmuir, 1918) and Freundlich (Freundlich, 1906) sorption isotherm. The Langmuir isotherm has found successful application to many other real sorption processes. The model assumes uniform energies of adsorption on to the surface and no transmigration of adsorbate in the plane of surface. It is assume that once an adsorbate molecule occupied a site, no further adsorption can take place at that site. Therefore, a saturation value is reached beyond which no further sorption can take place (Allen *et. al.*, 1988). The linear form of this expression is given by the following equation:

$$C_e/q_e = 1/Q_0K_L + (C_e/Q_0)$$

Where q_e (mg/g) is the amount adsorbed at equilibrium, C_e (mg/L) is the equilibrium concentration, and Q_0 and K_L are Langmuir constants related to the adsorption capacity and energy of adsorption, respectively. Figure 5 shows the linear plots of C_e/q_e vs. C_e . Langmuir constant, Q_0 and K_L were determined from the slope and intercept of the plot and were found to be 16.18 mg/g and 0.104 L/mg, respectively. The regression coefficient was 0.3737. The characteristics of Langmuir isotherm can be expressed in terms of dimensionless equilibrium parameter, R_L as below:

$$R_L = 1/(1 + K_L C_0)$$

Where C_0 is the initial concentration of COD in the sample and K_L is the Langmuir constant. The value of R_L indicates the shape of isotherm shown as below (Table 3):

Table 3: Correlation of R_L value and type of isotherm.

R_L value	Type of isotherm
$R_L > 1$	Unfavorable
$R_L = 1$	Linear
$0<R_L < 1$	Favorable
$R_L = 0$	Irreversible

The R_L value was found to be 0.0179 and this value was between 0 and 1 indicates favorable adsorption.

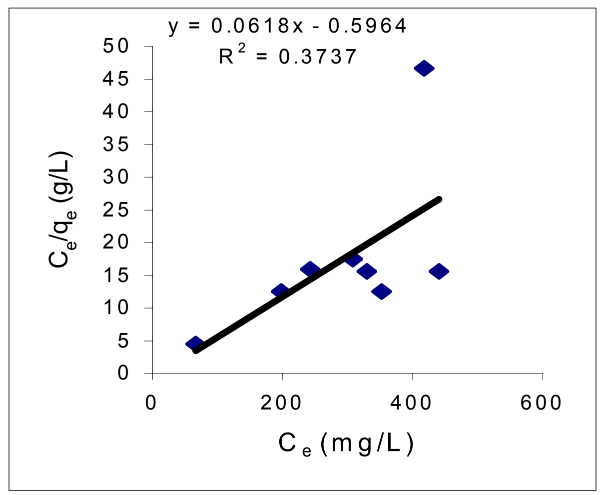

Figure 5: Langmuir plots for adsorption of COD from leachate.

The Freundlich isotherm is expressed by the following equation:

$$q_e = K_f C_e^{1/n}$$

$$\text{loq } q_e = \log K_f + 1/n \log C_e$$

where q_e (mg/g) is the amount adsorbed, C_e (mg/L) is the equilibrium concentration, and n and K_f are constants incorporating factors that affecting the adsorption process that is intensity and adsorption capacity, respectively. n and K_f values were calculated from the slope and intercept of the loq q_e vs. log C_e plots (Figure 6). From the plots it was found that values of n and K_f were 2.99 and 3.137 mg/g, respectively. It has been shown that n values between 1 and 10 represent beneficial adsorption (Kadirvelu and Namasivayam, 2000). The regression coefficient was 0.5595.

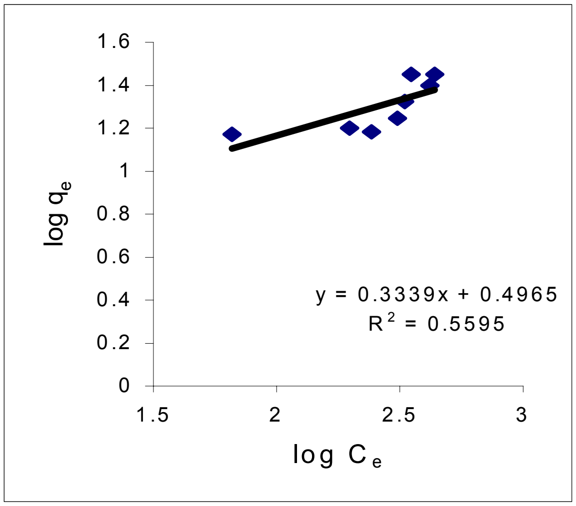

Figure 6: Freundlich plots for adsorption of COD from leachate.

CONCLUSIONS

The following conclusions can be drawn from the previous discussion:

1. From the characterization study, it can be concluded that leachate is a high strength wastewater.
2. The linearity of the plot t/ q_t vs. t confirmed that the process followed a pseudo-second order kinetics model.
3. The percentage of COD of leachate sample sorption increases with GAC dosages.
4. Langmuir constants (Q_0 and K_L) were found to be 16.18 mg/g and 0.104 L/mg, respectively. Freundlich constants (n and K_f) were 2.99 and 3.137 mg/g, respectively.

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Hazardous Air Pollutants (HAPs) Removed by Vapor Recovery System at Bulk Gasoline Terminals

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Abstract

The studies carried on December 2002 to February 2003, the gasoline emission samples were daily collected at both inlet (uncontrolled) and outlet (controlled) of Vapour Recovery Unit (VRU) from two Bulk Gasoline Terminal. All the samples were analysed for major HAPs i.e. benzene (B), toluene (T), ethyl benzene (EZ), xylene (X) and methyl tert-butyl ether (MTBE) by gas chromatography - mass spectrometry (GC/MS) at the optimum conditions. The general informations i.e. gasoline loaded quantity and temperature were also recorded at the sampling site.

The results shown that at the inlet of VRU the HAPs (B, T,EB, MTBE and X) were 644-36,872, 0-13,704, 0-3,624 and 0-1,909 µg/l respectively while the outlet were 0-73.7, na-102.8, 0-0, 0-139 and 0-63 µg/l. From this studies shown that the VRU could removed the HAPs varies from 97% to 100%. The order of HAPs control efficiency were ethylbenzene > MTBE > o-xylene > benzene > toluene > m-xylene, 100%, 99.82%, 99.69%, 98.75%, 98.21% and 97.93%, respectively. These studies indicated that the carbon adsorption units could used for control HAPs.

Keywords

Vapor Recovery Unit / Hazardous Air Pollutant / VOC Control Effectiveness

1. Introduction

Gasoline vapor is categorized into volatile organic compounds that consist of various hazardous air pollutants especially aromatic group such as Benzene, Toluene and Xylene. These vapors are considered toxic at high concentrations with major effects on nervous and metabolic system, and could caused cancer. Once these volatile organic compound or hydrocarbon vapors released they could also react with the oxides of nitrogen from tailpipe emissions and in the presence of sunlight caused photochemical oxidants such as ozone, which reduced the lung capacity, irritate eyes, damage respiratory system and aggravate asthma. (U.S.EPA, 2001)

Gasoline transport from fuel depots to gasoline stations and refueling to cars are major causes of hydrocarbons in the air. It was found that consumption of gasoline in the year 2000 in Thailand was about 6,761 million liters. That could produce a large amount of gasoline vapor in the atmosphere (Automotive Emission Organization, Pollution Control Department [PCD], June 2001) of the Bangkok metropolitan area where the gasoline station consumed about 2 billion liters per year and emitted of 5,560 tons per year. Wongwises (1995) reported that approximately 21,000 ton of gasoline evaporated annually in Thailand from petroleum storage and transfer operations. The report stated that the largest source of emissions was the evaporative lost from gasoline distribution which included gasoline loading to storage tanks (21%), the transfer from storage tanks to tank trucks (28%), the transfer from tank trucks to underground storage tanks at the service stations (24%) and the refueling loss (22%).

There are increasing concerns worldwide about the environmental and health effects of volatile organic compounds (VOCs) emissions, which have led to legislation in a number of countries. The control of emissions from gasoline distribution and marketing has also been addressed in many countries including Thailand. In the final report of "Vapor Emission from Gasoline Transport, Storage and Refueling in Bangkok" by Panich, *et.al.* That submitted to National Energy Policy Office in 1995, they recommended that the Energy Policy Office should impose regulations on Vapor Emission Stage I, to control vapor emissions generated during gasoline loading to underground storage tanks in all municipal areas nation wide. In addition, the Stage II to control vapor emissions during refueling should be imposed for Bangkok Metropolitan Region in the first phase and expanded to all municipalities in 5 years.

Although the control of emissions from gasoline distribution and marketing has been addressed in many countries, especially developed countries, it is very new for Thailand to implement and there was also no information on the efficiency of vapor recovery units being used. The vapor

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recovery units are an example of western technology which is applied in countries with different conditions, i.e. climate and composition of gasoline. Thailand also has no regulations that specifically regulate hazardous air pollutants at gasoline terminals. Since the law has been promulgated, there have been no follows up studies on either the VRU efficiency or cost-effectiveness. In this research the efficiency of vapor recovery units will be described both for total volatile organic compound and major hazardous air pollutants.

2. Characteristic of Vapor Recovery Unit in the studying : Carbon Vacuum Adsorbent (CVA)

The vapor recovery unit (VRU) in this study was carbon adsorption. The unit was supplied by Cool Sorption (Thailand) Limited. The VRU have been placed at Fuel Pipeline Transportation Limited (FPT) and The Shell Thailand.

Vapor from the loading point pass through the vapor header to the recovery unit. Prior to the vapor entering the CVA it will pass through a knock-out vessel to ensure that no gasoline enters the carbon bed.

The CVA consists of 2 activated carbon beds, one being connected to the vapor line "adsorption mode"- while the other undergoes regeneration by means of vacuum. Activated carbon has an extremely high surface area in relation to volume and the hydrocarbons were adsorbed in a very thin layer on the activated carbon surface. The activated carbon only adsorbed a given amount before it approaches saturation. If this occurred throughout the bed, then the vapor will pass through untreated. Consequently, the activated carbon will be regenerated in order to restore its capacity, so that it can effectively adsorb hydrocarbons in the following cycle.

The regeneration takes place in two stages. First the bed was evacuated until the pressure reached the level at which the hydrocarbons begin to desorb from the activated carbon. The bulk of the hydrocarbons are removed in this stage. In order to remove the remainder, it is necessary to introduce a small amount of purge air, to complete the regeneration. From the separator, the vapor which is now very rich in hydrocarbons, passes into the absorber column where the bulk of the hydrocarbon is absorbed in a counter flow of gasoline. The small amount of air present, particularly during the purge stage, passed out of the top of the absorber column and result in a small carry over of hydrocarbons, and was returned to the activated carbon bed which is in adsorption mode.

Specification of the activated carbon in VRU

Palletized thermal activated mineral coal based

Density (Vibrated)	: 380-420 kg/m^3
Specific surface	: >1500 m^2/gram
Ash content	: <8%
Grain size	: 95% > 3.15 mm
Hardness	: >96
Water content	: < 8%
Auto ignition temperature	: > 450 C

Pore size distribution :

Microspores r < 1 mm : 0.38 ml of pores per gram activated carbon equal to 16% of carbon volume

Mesopore r = 1-25 mm: 0.26 ml of pores per gram activated carbon equal to 11% of carbon volume

Macrospore r > 25 mm : 0.36 ml of pores per gram activated carbon equal to 15% of carbon volume

Summarized the pore volume is 42% of activated carbon volume.

3. Materials and Methods

3.1 Sampling

The samples were taken during all oil loading operated by simultaneously inlet and outlet samplings. The samples were taken for 2 periods, normal period and peak loading period with 1 hour on each period.

Sample collection apparatus

The 40 liter, Tedlar bag (SKC, USA) was encased in another black polythene bag to prevent any photochemical reaction occurring in the sample. The bags were washed by zero air and then checked for residues before used and re-used. Portable air sampling pump: Escort Elf® Sampling Pump, MSA, USA An low flow adjustable (Gemini Twin-Port Sampler, MSA, USA) and a rigid box. The sampling inlet (probe) made of Teflon® tube length depending on the work. The adsorbent tube (Charcoal tubes : SKC No. 226-09: 8 mm OD x 110 mm length) packed with two sections of activated carbon (400/200mg), SKC, USA. A temperature detector, Zero air and Bubble Flow Calibrator, Gilian®, USA.

Sampling method was followed the EPA method 18; Measurement of gaseous organic compound emissions by gas chromatography.

Due to the real situation, the limited area of outlet sampling point it was impossible to place all sampling equipment's then, a stainless pipe was connected from the vent point down to earth. The outlet sampling line and inlet sampling point are shown as figure 1 and 2, respectively.

Figure 1: Outlet Sampling Line

Figure 2: Inlet Sampling Point

The vapor samples collected by Tedlar bag and operated as follows:

Assemble the sample train as shown in Figure 2, leak check both the bag and the container. Then, connected the vacuum line from the needle valve to the Teflon sample line and place the end of the Teflon probe at the centroid of the sampling point and start the personnel pump to obtain a flow 0.5 liter/minute. After allowing sufficient time to purge the line several times, connect the vacuum line to the bag. When the pump was operating, a vacuum is created in the box. Then, the gas flowed into the bag immediately by the vacuum force. The sampling rate was maintained at 0.5 liter per minute for one hour. At the end of the sampling period, shut off the pump and disconnect the vacuum line from the container bag. Recorded the temperature, ambient temperature and initial and final sampling time.

Then, drawn the gas samples from sampling Tedlar bag into adsorbent tube at-site as follows:

Both the inlet and outlet sample bags were drawn through coconut based charcoal tube using a portable air-sampling pump with adjustable low flow holder. The sampling rate was maintained at 0.05 liter per minute for inlet sample for 2 minutes. The sampling rate was maintained at 0.1 liter per minute for outlet for 10 minutes. Then the charcoal tubes were sealed by parafilm, recorded number and date of sampling and then kept at temperature under - 4 °C before analysis.

3.2 Analytical procedures

Total VOCs analysis

Apparatus

A flame ionization detector (FID) of PIERBURG, FID PM-2000 Standard, Germany. Stainless three way, Swecklog, USA, Teflon tube, Purified Nitrogen gas (99.99%) , Thai Industiral Gas (TIG) Thailand and propane (C_3H_8 +Air) as standard gas with range between 10-16,500 ppmC_3 , Thai Industiral Gas (TIG) Thailand.

The amount of total VOCs of both inlet and outlet samples were analysed by a flame ionization detector (FID) of PIERBURG, FID PM-2000 Standard.

Since the detector is sensitive only to carbon atoms, a real concentration measurement (displayed in part per million (ppm)) can only be carried out if the gas composition is known; for identical volume concentration levels of methane and propane the detector shows almost three times the concentration for propane. As a result this method is particularly suited to determining the mass of carbons in a gas per volume unit that is bound in hydrocarbons.

The use of propane or methane as a comparison gas leads to a display of the measuring values in the unit ppm C3. (Pierburg Operating Manual Analyzer FID PM-2000, 1997) In the case of an exceedingly high concentration of inlet samples to measure by FID analyzer, purified Nitrogen gas (99.99%) was adopted with dynamic dilution technique to dilute the samples. Stainless three ways was assembled with teflon line. One was connected to Nitrogen gas bag while the another was connected to sample bag as shown in Figure 3 The dilution ratio of sample to N2 gas is 1:53 approximately.

Figure 3 : Dynamic dilution with purified Nitrogen gas

Hazardous Air Pollutant (BTEX, MTBE) analysis

After sampling, the charcoal tubes were sent to laboratory and the activated carbon was extracted in 4 ml of carbon disulfide (CS2). The extraction was shaken and left to stand for 30 minutes.

The collected BTEX and MTBE were analysed using gas chromatography with flame ionization detector (GC/FID) Hewlett Packard HP 6890 series gas chromatograph with optimum conditions as:

- A capillary column (0.32 mm i.d. x 60 m , 1.0 µm film thickness) 1% Methyl Siloxane (HP-1)
- Helium carrier gas at optimum flow rate, 2 ml/min
- Injector, detector temperature 280 °C Column temperature programmed as initial temp 40 °C held for 1 minute ramped at 5 °C/min to 100 °C and held for 1 minute. then ramped at 10 °C/min. to final temperature at 180 °C and held for 3 minutes.

The concentration of all analytes were quantitated using FID measurements and peaks identified on the basis of a comparison of retention times with those in working standard. Five levels calibration were performed utilizing selected in range of about 50 ppmv to 2300 ppmv standards for all compounds. The calculation of regression parameters yielded $r^2 > 0.999$

4. Results and Discussions

The total of sixty-eight samples from both sites (inlet and outlet) was analysed for total VOCs and HAPs (benzene, toluene, ethylbenzene, m-xylene, o-xylene and methyl tert-butyl ether (MTBE). The results from these studies, VOCs and the HAPs concentration from the Shell of Thailand and FPT are shown in Table 1 and 2 respectively.

The summaries of control efficiencies of the unit for individual HAPs and total VOCs were presented in Table 3. The results showed the control efficiency of the total VOCs was over 99.9% while the individual HAP that varied from 97% to 100% for both sites. Average control efficiency for VOCs and HAPs was shown in Figure 4.

Table 1 : The concentration of total VOCs and HAPs at sampling sites of VRU (The Shell of Thailand)

Date	Sampling Time	MTBE (ug/l)		Benzene (ug/l)		Toluene (ug/l)		Ethylbenzene (ug/l)	
		inlet	outlet	inlet	outlet	inlet	outlet	inlet	outlet
Sunday	11.28-12.28 AM	39,851.04	103.82	5,900.92	73.68	na	na	3,624.40	0
1/12/02	12.45-1.15 PM	75,969.16	82.12	1,547.32	65.12	na	na	0.00	0
Monday	10.58-11.58 PM	428.56	0	767.44	14.66	1,626.84	31.23	0	0
2/12/02	00.05-1.05 AM	1,062.00	23.60	1,356.08	7.64	2,072.00	0	0	0
Thuesday	10.48-11.48 AM	18,443.60	0	3,877.92	48.22	na	na	0	0
3/12/02	11.59-00.59 AM	21,297.60	0	900.28	63.41	na	na	0	0
Thursday	11.03-00.03 AM	95,636.00	0	36,872.16	7.57	13,704.40	27.67	0	0
5/12/02	00.17-1.17 AM	2,381.24	0	5,098.32	3.12	6,832.80	0	0	0
Sunday	9.25-10.25 AM	32,607.20	46.78	1,440.20	64.45	na	na	0	0
8/12/02	10.55-11.55 AM	66,981.40	0	7,021.76	35.45	na	na	0	0
Thursday	10.20-11.20 PM	4,663.60	139.26	664.12	46.86	1,863.00	102.78	204.92	0
12/12/02	11.40PM-00.40 AM	1,255.16	0	1,156.16	24.32	1,940.52	54.74	0	0
Thursday	10.20-11.20 PM	16,998.80	12.43	3,139.96	56.58	2,551.64	37.21	58.28	0
13/2/03	11.30PM-00.30AM	69,604.00	14.07	7,942.80	64.43	6,139.60	50.79	126.48	0
Friday	10.50-11.50 PM	2,624.20	14.14	884.00	64.60	405.28	52.11	0	0
14/2/03	00.00-1.00 AM	9,114.40	0	1,914.68	61.65	1,057.32	38.22	0	0
Sunday	9.40-10.40 AM	104,736.00	0	11,283.16	9.05	9,144.00	60.08	277.52	0
16/2/03	11.00-12.00 AM	38,172.80	17.48	3,597.16	16.59	3,425.80	76.63	129.96	0

Table 1 : The concentration of total VOCs and HAPs at sampling sites of VRU (The Shell of Thailand) (con't)

Date	Sampling Time	m-xylene (ug/l)		o-xylene (ug/l)		Total VOC (ppmv)		Total VOC (mg/l)	
		inlet	outlet	inlet	outlet	inlet	outlet	inlet	outlet
Sunday	11.28-12.28 AM	1,909.24	37.93	0	0	411,101.90	76.39	739.82	0.14
1/12/02	12.45-1.15 PM	0	0	80.04	0	499,450.20	27.97	898.81	0.05
Monday	10.58-11.58 PM	0	0	0	0	208,068.40	80.00	374.44	0.14
2/12/02	00.05-1.05 AM	261.08	0	0	0	448,464.73	61.43	807.05	0.11
Thuesday	10.48-11.48 AM	0	0	0	0	240,719.69	94.10	433.20	0.17
3/12/02	11.59-00.59 AM	0	0	0	0	460,150.31	76.18	828.08	0.14
Thursday	11.03-00.03 AM	180.48	0	0	0	889,177.50	298.72	1,600.16	0.54
5/12/02	00.17-1.17 AM	345.76	0	0	0	707,467.50	256.24	1,273.15	0.46
Sunday	9.25-10.25 AM	0	0	0	0	654,179.66	112.73	1,177.26	0.20
8/12/02	10.55-11.55 AM	0	0	0	0	684,487.95	154.74	1,231.80	0.28
Thursday	10.20-11.20 PM	0	0	0	0	274,445.78	131.90	493.89	0.24
12/12/02	11.40PM-00.40 AM	0	0	0	0	584,335.88	273.64	1,051.57	0.49
Thursday	10.20-11.20 PM	209.20	8.83	0	0	225,977.44	220.80	406.67	0.40
13/2/03	11.30PM-00.30AM	378.16	10.01	88.28	0	749,102.50	301.50	1,348.08	0.54
Friday	10.50-11.50 PM	0	5.57	0	0	114,081.91	264.50	205.30	0.48
14/2/03	00.00-1.00 AM	57.28	6.62	0	0	453,808.33		816.67	-
Sunday	9.40-10.40 AM	729.48	14.00	184.64	0	553,683.75	50.97	996.40	0.09
16/2/03	11.00-12.00 AM	381.36	15.56	90.40	0	286,047.38	66.72	514.77	0.12

Table 2 : Total VOCs and HAPs concentration at VRU, Fuel Pipipeline Transportation

Date	Sampling Time	MTBE (ug/l)		Benzene (ug/l)		Toluene (ug/l)		Ethylbenzene (ug/l)	
		inlet	outlet	inlet	outlet	inlet	outlet	inlet	outlet
Tuesday	11.10-12.10 AM	8,810.80	0	1,405.60	0	2,776.20	31.64	280.04	0
21/1/03	12.30-1.30 PM	27,485.60	0	2,874.56	0	905.60	24.372	0	0
Wednesday	11.00-12.00 AM	21,008.00	0	4,432.12	4.06	5,592.80	31.48	131.72	0
22/1/03	1.00-2.00 PM	17,246.80	0	4,588.12	0	8,311.20	21.00	231.44	0
Thursday	10.50-11.50 AM	17,051.60	0	2,005.88	0	2,425.80	66.86	0	0
23/1/03	1.00-2.00 PM	26,985.20	0	2,966.28	1.06	2,826.64	45.54	0	0
Friday	10.45-11.45 AM	20,190.00	0	2,485.88	0	2,748.00	0	0	0
24/1/03	12.10-1.10 PM	31,877.20	0	3,377.64	0	1,885.32	24.33	0	0
Saturday	10.30-11.30 AM	19,620.40	0	2,082.48	5.80	1,093.76	17.03	0	0
25/1/03	11.50-12.50 AM	9,905.20	0	2,738.80	5.58	2,763.20	22.01	0	0
Sunday	10.40-11.40 AM	24,659.20	0	4,386.12	0	6,453.20	0	204.92	0
26/1/03	12.00-1.00 PM	60,881.04	0	6,757.08	0	5,568.40	0	0	0
Monday	11.20-12.20 AM	43,424.00	0	5,498.52	2.38	0	0	141.60	0
27/1/03	12.40-1.40 PM	18,420.40	0	4,793.32	0	0	0	141.00	0
Sunday	11.15-12.15 AM	113.68	0	0	0	334.48	0	0	0
2/2/03	12.30-1.30 PM	12.24	0	0	0	337.04	0	0	0

Table 2 : Total VOCs and HAPs concentration at VRU, Fuel Pipeline Transportation (con't)

Date	Sampling Time	MTBE (ug/l)		Benzene (ug/l)		Toluene (ug/l)		Ethylbenzene (ug/l)	
		inlet	outlet	inlet	outlet	inlet	outlet	inlet	outlet
Tuesday	11.10-12.10 AM	8,810.80	0	1,405.60	0	2,776.20	31.64	280.04	0
21/1/03	12.30-1.30 PM	27,485.60	0	2,874.56	0	905.60	24.372	0	0
Wednesday	11.00-12.00 AM	21,008.00	0	4,432.12	4.06	5,592.80	31.48	131.72	0
22/1/03	1.00-2.00 PM	17,246.80	0	4,588.12	0	8,311.20	21.00	231.44	0
Thursday	10.50-11.50 AM	17,051.60	0	2,005.88	0	2,425.80	66.86	0	0
23/1/03	1.00-2.00 PM	26,985.20	0	2,966.28	1.06	2,826.64	45.54	0	0
Friday	10.45-11.45 AM	20,190.00	0	2,485.88	0	2,748.00	0	0	0
24/1/03	12.10-1.10 PM	31,877.20	0	3,377.64	0	1,885.32	24.33	0	0
Saturday	10.30-11.30 AM	19,620.40	0	2,082.48	5.80	1,093.76	17.03	0	0
25/1/03	11.50-12.50 AM	9,905.20	0	2,738.80	5.58	2,763.20	22.01	0	0
Sunday	10.40-11.40 AM	24,659.20	0	4,386.12	0	6,453.20	0	204.92	0
26/1/03	12.00-1.00 PM	60,881.04	0	6,757.08	0	5,568.40	0	0	0
Monday	11.20-12.20 AM	43,424.00	0	5,498.52	2.38	0	0	141.60	0
27/1/03	12.40-1.40 PM	18,420.40	0	4,793.32	0	0	0	141.00	0
Sunday	11.15-12.15 AM	113.68	0	0	0	334.48	0	0	0
2/2/03	12.30-1.30 PM	12.24	0	0	0	337.04	0	0	0

The results showed that at the inlet of VRU the HAPs (B, T,EB, MTBE and X) were 644-36,872, 0-13,704, 0-3,624 428.56-104,736 and 0-1,909 µg/l respectively while the outlet were 0-64.6, 0-102.8, 0-0, 0-139 and 0-37.93 µg/l.

Table 3 The control efficiencies for VOCs and HAPs of Carbon Vacuum Adsorption Unit (CVA) at bulk gasoline terminals

HAP Compound	Shell			FPT		
	Average CE%	Min CE%	Max CE%	Average CE%	Min CE%	Max CE%
MTBE	99.64	97.01	99.98	100.00	100.00	100.00
Benzene	97.55	92.69	99.94	99.95	99.72	100.00
Toluene	97.32	87.14	99.80	99.10	97.24	100.00
Ethybenzene	100.00	100.00	100.00	100.00	100.00	100.00
o-Xylene	100.00	100.00	100.00	99.38	95.02	100.00
m-Xylene	97.07	88.84	98.08	98.79	89.3	100.00
Total HAP	98.60	94.28	99.63	99.54	96.88	100.00
Total VOC	99.955	99.77	99.994	99.982	99.948	99.999

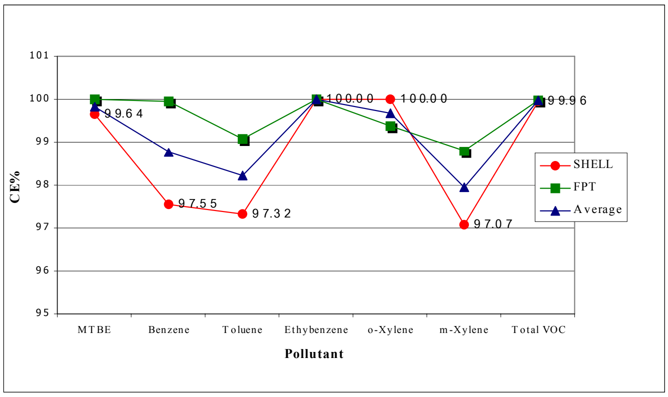

Figure 4 VOCs and HAPs control efficiency of CVA

From these studies, the VOCs and HAPs removal efficiencies of two units were almost the same rate which an average efficiency of 99.97% and 99.01% respectively. However, the control efficiency for individual HAP was insignificantly difference and has the similar trended for individual HAP removal efficiencies of two units. The order of HAPs control efficiency were ethylbenzene > MTBE > o-xylene > benzene > toluene > m-xylene, 100%, 99.82%, 99.69%, 98.75%, 98.21% and 97.93%, respectively. These studies indicated that the Carbon Adsorption Units tend to control HAP emission independent of the control efficiency for VOCs and also shown that HAPs control efficiency was slightly lower than VOCs control efficiency, that was around 1%.

The study of hazardous air pollutant emissions from gasoline loading operations at bulk gasoline terminals performed by the American Petroleum Institute (API) (Table 4) in 1998 found that the order of HAPs control efficiency were benzene > toluene > hexane > ethylbenzene > MTBE > o-xylene > isooctane > m,p-xylene, 99.97%, 99.93%, 99.88%, 99.66%, 99.65%, 99.62%, 99.61%, 99.55%, respectively. The API reported the average HAP removal efficiencies by Carbon Adsorption Unit was 99.73% and often greater than VOCs removal efficiencies averaged 97.3%.

Table 4 HAP control efficiencies (CE) for vapor control units at gasoline loading racks

HAP Compound	Carbon Adsorbers		
	Average (CE%)	Min (CE%)	Max (CE%)
MTBE	99.65	98.49	100.0
Benzene	99.97	99.86	100.0
Toluene	99.93	99.62	98.54
Ethylbenzene	99.66	98.54	100.0
‘m,p-Xylene	99.55	97.98	100.0
o-Xylene	99.61	97.69	100.0
Hexane	99.88	99.00	100.0
Isooctane	99.62	97.51	100.0
Total HAP	99.74	98.77	100.0
Total VOC	97.30	87.44	99.94

Source: American Petroleum Institute 1998

The difference of the order of HAPs control efficiency and the VOCs control efficiency in this study and the study of API might be from the different properties of activated carbon contained in the unit such as the pore size distribution, specific surface, density etc. However, these studies indicated that the Carbon Adsorption Units tend to control HAP emission independent of the control efficiency for VOCs and the carbon adsorption units could used for control HAPs efficiently.

5. Conclusion

The VOCs and HAPs removal efficiencies of two units were almost the same rate which an average efficiency of 99.97% and 99.01% respectively. The average VOCs emitted at the Shell of Thailand and FPT were 0.24 mg/l and 0.11 mg/l, respectively. The results showed that at the inlet of VRU the HAPs (B, T,EB, MTBE and X) were 644-36,872, 0-13,704, 0-3,624 428.56-104,736 and 0-1,909 µg/l respectively while the outlet were 0-64.6, 0-102.8, 0-0, 0-139 and 0-37.93 µg/l.

The control efficiency for individual HAP was insignificantly difference and has the similar trended for individual HAP removal efficiencies of two units. The order of HAPs control efficiency were ethylbenzene > MTBE > o-xylene > benzene > toluene > m-xylene, 100%, 99.82%, 99.69%, 98.75%, 98.21% and 97.93%, respectively. These studies indicated that the carbon adsorption units tend to control HAP emission independent of the control efficiency for VOCs and also shown that HAPs control efficiency was lower than VOCs control efficiency. These studies indicated that the carbon adsorption units could used for control HAPs.

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GAC Adsorption Of Dyes Used By Terengganu's Batik Industry: Isotherm Studies

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ABSTRACT: Three colours of remazol reactive dyes, namely, Red 3BS, Yellow FG, and Blue R were used in the adsorption study using granular activated carbon (GAC). Dye solution was shook with the activated carbon for 5 days for equilibrium to achieve. The Langmuir adsorption isotherm was found to fit the experimental data better than the Freundlich adsorption isotherm. This was due to the relatively high ambient temperature that allowed only monolayer adsorption to occur. The van der Waals force that forms multilayer adsorption was overcome by the adsorbate due to the high ambient temperature. Blue R dye was found to have the highest adsorption capacity, 80.65 mg/g, followed by Yellow FG dye, 70.92 mg/g, and Red 3BS dye, 4.30 mg/g. The high adsorption capacity for Blue R dye was due to the large quantity of functional group on the activated carbon surface. In addition, Blue R dye was found to have the largest molecular size among the dyes that were studied.

INTRODUCTION

Industrial wastewater contains various chemical either organic or inorganic compound., The main chemical constituent from the discharge of the batik industry is dye, used in the manufacturing process. Dye is an organic compound used in the manufacturing process that will introduced colour to water. Colour in water is not only esthetically displeasing but might pose a threat to the human health and the environment. Therefore, wastewater from any industries that introduces colour to water must be treated prior to discharging it into open water bodies.

Suspended material in wastewater can be removed by using sand filter. However, dyes dissolve in water, and one of the ways to remove dissolved materials from water is by adsorption. Adsorption in general, is the process of collecting soluble substances that are in solution on a suitable interface (Tchobanoglous and Burton, 1991). In adsorption process, foreign matter is extracted from one phase and concentrated at the surface of a second (not into the lattice structure), and this process is properly termed as a surface phenomenon. The material that is adsorbed is called the adsorbate, while the phase that adsorbs the adsorbate is called the adsorbent.

The most popular adsorbent that is used to remove organic matter from wastewater is activated carbon. The effectiveness of activated carbon to remove organic contaminant had been proven due to the broad range of contaminants it can remove from water or wastewater (Droste, 1997). In addition, the internal surface area that develops during activated process increases the adsorption capacity.

The objective of this study was to determine whether activated carbon can be used to remove dye from water. If the outcome of the study is favourable, therefore it can be used as an alternative to treat dye wastewater from batik and other textile industries. The significant of this study is that, activated carbon has been used widely in many attempts to remove organic substances from water. Dye is also an organic substance, and therefore it could be removed by activated carbon. In this study, the batch test was conducted to investigate the adsorption capacity of remazol reactive dye onto the granular activated carbon. The Freundlich and the Langmuir adsorption isoterms were used in the study.

THEORY

The Freundlich adsorption isotherm is an empirical equation and is expressed as

$$q_e = k_f C_e^{1/n} \tag{1}$$

k_f and n are empirical constants that depend on temperature, the adsorbent, and the substance to be adsorbed. The Freundlich adsorption isotherm can be expressed in the linear form as

$$\log q_e = \log k_f + \frac{1}{n}\log C_e \tag{2}$$

Therefore, a linear graph will be obtained by plotting log q_e versus log C_e and the interception at the y-axis is log k_f while the slope of the graph is represented by $1/n$.

The Langmuir adsorption isotherm is derived based on the assumption that only monolayer adsorption occurs. The Langmuir adsorption isotherm is expressed as

$$q_e = \frac{abC_e}{1 + bC_e} \tag{3}$$

The Langmuir adsorption isotherm can be expressed in the linear form as

$$\frac{1}{q_e} = \frac{1}{ab} \cdot \frac{1}{C_e} + \frac{1}{a} \tag{4}$$

A linear graph should be obtained by plotting $1/q_e$ versus $1/C_e$ where the slope of the graph is represented by $1/ab$ and the interception at the y-axis is $1/a$.

MATERIALS AND METHOD

The materials that were used in this study were granular activated carbon (GAC) and dye. The GAC was used supplied by Kekwa Indah Sdn Bhd in Nilai, Negeri Sembilan, a local manufacturer of GAC. The raw material used to manufacture GAC was made from coconut shells. Dyes used in this study were remazol reactive dye. There were three colours of the remazol dye, which were red (Red 3BS), yellow (Yellow FG), and blue (Blue R) that were used in the study.

The GAC was washed thoroughly with deionized water to remove impurities such as dust and ash (Meshko et al., 2001). Washed GAC was dried in an oven at 110 °C for 24 hour (Chern and Wu, 2001). The GAC used in this study was crushed into powder form. This was to reduce the time needed to achieve equilibrium. The crushed GAC was stored in a dessicator until it was required.

The apparatus used in the study were washed with deionized water to remove impurities. Presence of impurities can cause some adsorbate in the liquid phase to adsorb onto the impurities surface instead. Thus, the presence of impurities may affect the accuracy of the experimental result.

A sample of dye was scanned through a range of wave length between 350 – 900 ηm by using a UV Spectrophotometer, model Cary 50 series, in order to determine the dominant wave length. The dominant wave lengths obtained for Red 3BS, Yellow FG, and Blue R dye were 540 ηm, 415.1 ηm, and 589.9 ηm respectively.

The dye solution was prepared by diluting an amount of dye to a concentration of 70 mg/L with deionized water. The initial concentration of the dye was determined by measuring the absorbance of the dye at the dominant wave length using the UV spectrophotometer. From the absorbance, the concentration of the dye sample was determined from the calibration curve that had been determined earlier.

The batch test was conducted to determine the adsorption capacity by using adsorption isotherm of each dye onto GAC. The batch test was conducted by mixing an amount of processed GAC with 250 ml of dye solution in a beaker and shook at 150 rpm until equilibrium is reached. Preliminary experiment that was conducted showed that equilibrium was achieved after 5 days. This test was conducted at room temperature. This test was conducted using various dosages of GAC, between 0.05 and 6.50 g. After the equilibrium was achieved, the dye solution was filtered through a 0.45 µm filter paper to remove the activated carbon. Then, the dye solution was analysed to determine its equilibrium concentration using the UV spectrophotometer. The amount of adsorbate adsorbed onto the GAC was determined using the following formula (Wu et al., 2001).

$$q_e = \frac{(C_O - C_e)V}{W} \tag{5}$$

RESULTS AND DISCUSSION

Data obtained from the experiment were fitted into the Freundlich and Langmuir adsorption isotherms. A graph log q_e versus log C_e was plotted to determine the constant k_f and n in the Freundlich adsorption equation. While to determine the constant a and b in the Langmuir adsorption equation, a graph $1/q_e$ versus $1/C_e$ was plotted. The graphs log q_e versus log C_e, for each dye, are shown in figures 1 to 3.

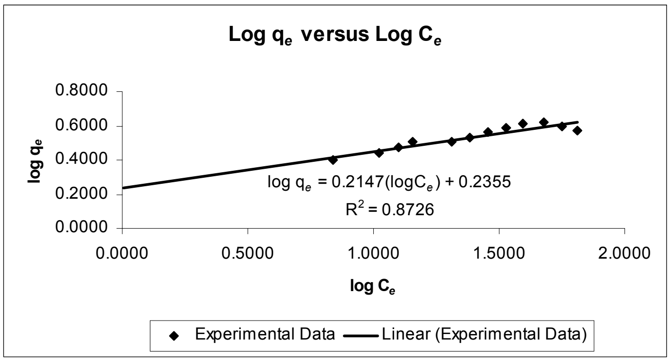

Figure 1: Plot of log q_e vs. log C_e for Red 3BS dye.

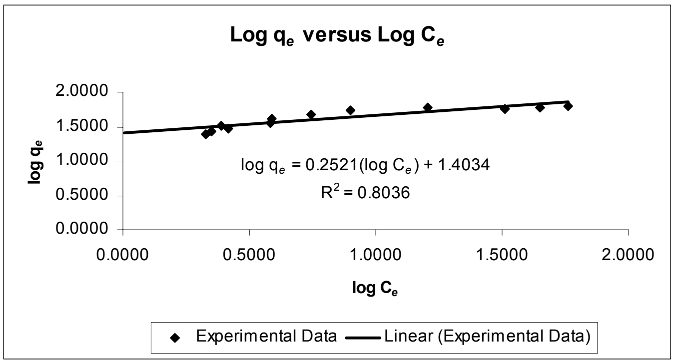

Figure 2: Plot of log q_e vs. log C_e for Yellow FG dye.

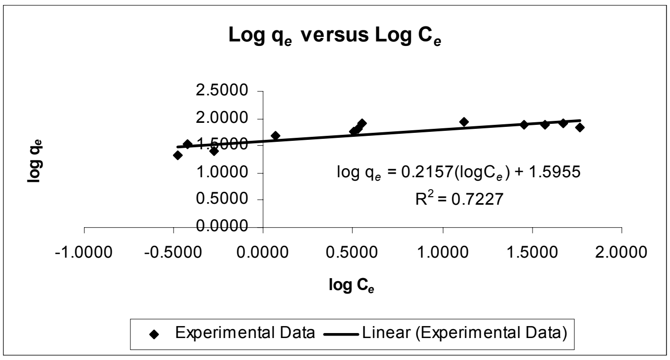

Figure 3: Plot of log q_e vs. log C_e for Blue R dye.

The graphs $1/q_e$ versus $1/C_e$ that were plotted for each dye in order to determine the Langmuir constant are shown in figures 4 to 6.

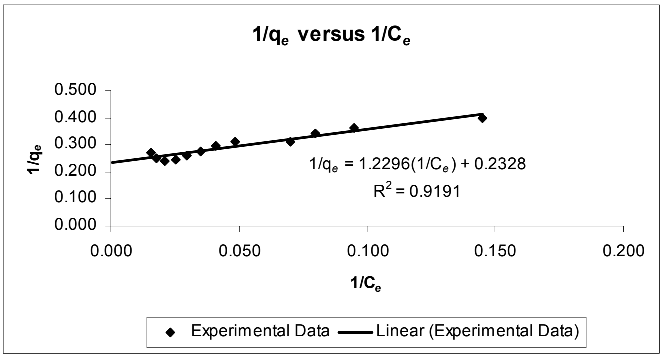

Figure 4: Plot of $1/q_e$ vs. $1/C_e$ for Red 3BS dye.

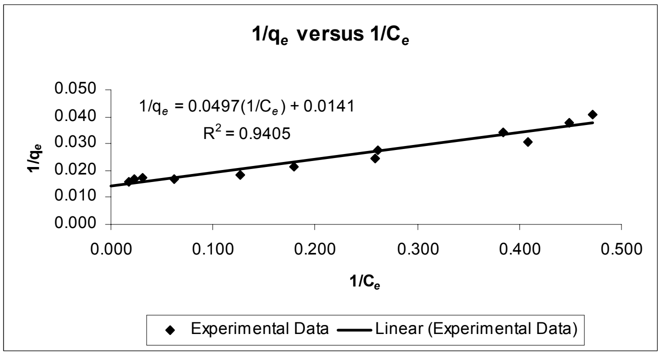

Figure 5: Plot of $1/q_e$ vs. $1/C_e$ for Yellow FG dye.

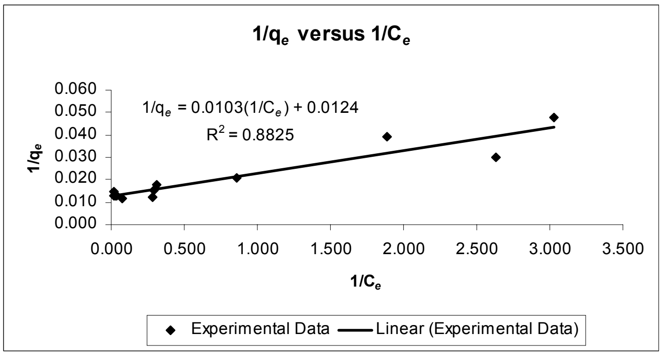

Figure 6: Plot of $1/q_e$ vs. $1/C_e$ for Blue R dye.

From the linearization of both equations onto the experimental data, it was found that the Langmuir adsorption isotherm fitted the experimental data better than the Freundlich adsorption isotherm. The correlation coefficient, (R^2) obtained for the Langmuir equation was more than 0.88 while the correlation coefficient obtained for the Freundlich equation was between 0.72 – 0.87. The nearer the value of correlation coefficient to one, the better the equation fits the experimental data. The Freundlich and Langmuir adsorption isotherm were fitted into the experimental data for each dye are shown in figures 7 to 9. The data obtained from the batch test is summarized in tables 1 and 2.

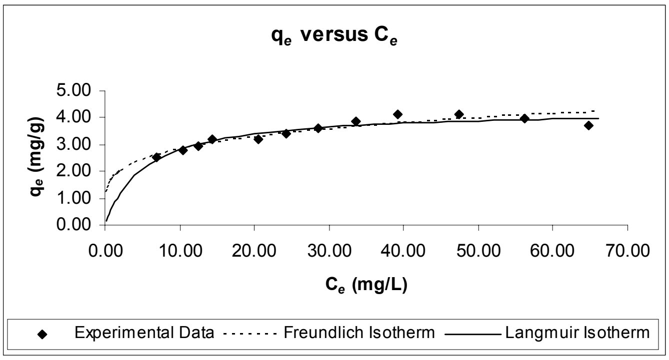

Figure 7: Fitting of Freundlich and Langmuir isotherm into experimental data for Red 3BS dye.

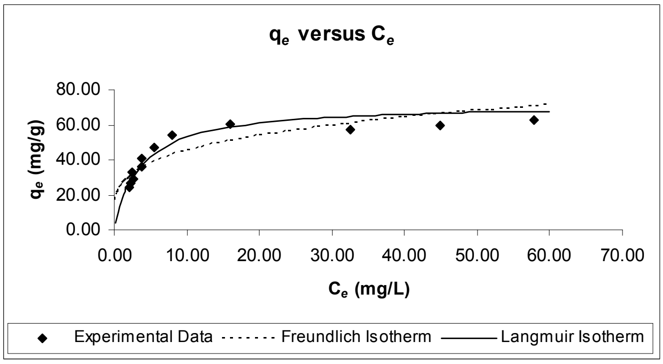

Figure 8: Fitting of Freundlich and Langmuir isotherm into experimental data for Yellow FG dye.

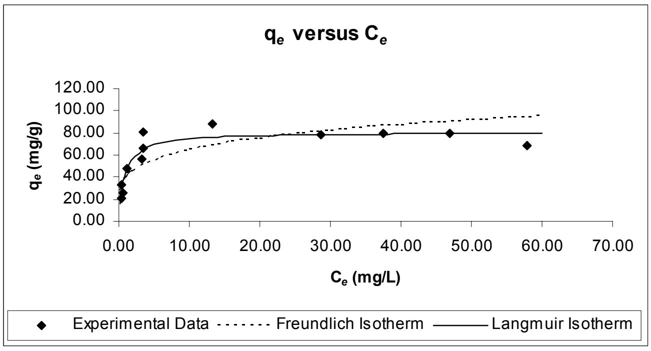

Figure 9: Fitting of Freundlich and Langmuir isotherm into experimental data for Blue R dye.

Table 1: Freundlich adsorption equation for dyes

Dyes	Freundlich Equation	Freundlich Constant	R^2
Red 3BS	$q_e = 1.72\ C_e^{0.2147}$	$k_f = 1.72$ $1/n = 0.2147$	0.8726
Yellow FG	$q_e = 25.32\ C_e^{0.2521}$	$k_f = 25.32$ $1/n = 0.2521$	0.8036
Blue R	$q_e = 39.40\ C_e^{0.2157}$	$k_f = 39.40$ $1/n = 0.2157$	0.7227

Table 2: Langmuir adsorption equation for dye

Dyes	Langmuir Equation	Langmuir Constant	R^2
Red 3BS	$q_e = \dfrac{0.812C_e}{1+0.189C_e}$	a = 4.30 mg/g b = 0.189 L/mg	0.9191
Yellow FG	$q_e = \dfrac{20.14C_e}{1+0.284C_e}$	a = 70.92 mg/g b = 0.284 L/mg	0.9405
Blue R	$q_e = \dfrac{97.10C_e}{1+1.204C_e}$	a = 80.65 mg/g b = 1.204 L/mg	0.8825

The adsorption capacity of the GAC with respect to the adsorption the Langmuir adsorption isotherm (due to the fitness of this equation with the experimental data) is discussed. The constant *a* in the Langmuir adsorption equation is the adsorption capacity of dye adsorbed onto the activated carbon to form a monolayer. The Blue R dye has the highest adsorption capacity which was 80.65 mg/g, followed by Yellow FG and Red 3BS, which were 70.92 mg/g and 4.30 mg/g respectively.

The experimental data obtained from the batch test fitted well with the Langmuir adsorption equation, which means that chemisorption had occurred between these dyes and GAC. The adsorbate was expected to interact with only a specific functional group on the GAC surface. Batch test that was carried out by Wu et al., (2001) at 30 °C on dyes also showed similar results where the Langmuir adsorption equation fitted with the experimental data and the correlation coefficients were greater than 0.972.

There was a large difference between the adsorption capacity of Red 3BS dye, Yellow FG and Blue R dye. The adsorption capacity for Red 3BS dye was 4.30 mg/g while for Yellow FG and Blue R dye were 70.92 mg/g and 80.65 mg/g respectively. The empirical constant *b* obtained from the batch test for Red 3BS, Yellow FG, and Blue R dye were 0.189 L/mg, 0.284 L/mg, and 1.204 L/mg. According to Eckenfelder (1989), the empirical constant *b* is an indicator for molecular size of adsorbate. Higher values of *b* show that bigger molecular size is present. Therefore, Blue R dye has the highest molecular size followed by Yellow FG and Red 3BS. The molecular size of Blue R dye was found to be the largest among the dyes used in this study. Therefore, the adsorption capacity for Red 3BS dye was not due to molecular sieve effect. Molecular sieve effect is the result of the size of adsorbate that is larger than the macropores, thus reduces the available surface area for adsorption (DeSilva, 2000). Thus, the possibility that may have limited the amount of Red 3BS dye being adsorbed onto the GAC, was the surface functional group that had interacted with the dye.

The higher the amount of functional group that an activated carbon has, the higher is the adsorption capacity, for a particular adsorbate. This means, the GAC used in this study had more functional groups that can be chemically bonded with the Blue R dye compared to Red 3BS and Yellow FG dye.

Larger molecular weight or molecular size could also contribute to adsorption (DeSilva, 2000). Dye is a hydrocarbon molecule. The increase of hydrocarbon amount in the dye molecule reduces the degree of solubility. Therefore, it will be pushed towards the solid liquid interface to be adsorbed. It was found that the Blue R dye has the highest adsorption capacity and also molecular size compared to Red 3BS and Yellow FG dyes. The molecular size factor could have contributed to the adsorption.

The functional group of an activated carbon is dependant upon the manufacturing temperature and the raw material (Tchobanoglous and Burton, 1991). Wu et al., (2001) also found that the adsorption capacity of activated carbon, using dyes, varied with different manufacturing temperature, citing the same reason for the change in the functional group.

The Freundlich adsorption isotherm did not fit the experimental data so well compared to Langmuir adsorption isotherm but the correlation coefficient obtained were between 0.72 – 0.87. This means that the adsorption occurred between the dye and activated carbon was not solely chemisorption but also physisorption. Physisorption is caused by the bonding of van der Waals force between the adsorbate and the adsorbent. Physisorption can also occur between adsorbate and adsorbate. If physisorption occurs between the adsorbate adsorbed onto the activated carbon and the adsorbate in the liquid phase, the adsorption capacity will keep on increasing as shown in the Freundlich adsorption equation.

Chemisorption was, however, more dominant than physisorption because the temperature at which the adsorption process occurred was relatively high, at about 30 °C, the room temperature. For a chemical reaction to occur there is an energy barrier needed to be overcome before two materials can be chemically bonded. Relatively high temperature provides sufficient energy to overcome the energy barrier so that the chemical bond between the dye molecule can be established. At high temperature desorption will also occur for the physically bonded adsorbate on activated carbon by the van der Waals force. Adsorbates which are physically adsorbed onto the activated carbon receive enough energy from the relatively high temperature to overcome the van der Waals force. Thus, the Freundlich adsorption equation did not fit well compared to the Langmuir adsorption equation.

The experiment carried out by Mollah and Robinson (1996) on pentachlorophenol shows that the amount of pentachlorophenol adsorbed onto activated carbon at equilibrium decreased with increased temperature. A similar behaviour was also observed with organic solutes adsorption (Radke and Prausnitz, 1972). The Freundlich adsorption equation was a better fit than the Langmuir adsorption equation for the experimental data obtained by Sotelo et al., (2002), on adsorption of chlorinated organics at a 25 °C.

The low temperature did not provide enough energy for the adsorbate to overcome the van der Waals force. Thus, the Freundlich adsorption equation fitted the experimental data better.

CONCLUSION

In the batch test, the Langmuir adsorption equation was found to fit the experimental data better than the Freundlich adsorption equation. This was due to the relatively high ambient adsorption temperature that breaks the physical bonding between the adsorbate and the adsorbent. In addition, Blue R dye was found to have the highest adsorption capacity, compared to other dyes that were studied. The high adsorption capacity for Blue R dye was due to the presence of large amount of functional groups on the activated carbon surface that interacts with the Blue R dye. Besides that, Blue R dye has the largest molecular size among the dyes that were studied. The large molecular size is also a factor that had helped in the adsorption process.

NOTATION

R^2	Correlation coefficient
q_e	Amount of dye adsorbed per gram of activated carbon
C_e	Equilibrium concentration
k_f	Adsorption capacity for Freundlich adsorption isotherm
n	Freundlich empirical constant
a	Adsorption capacity for Langmuir adsorption isotherm
b	Langmuir constant
W	Weight of activated carbon
V	Volume
C_O	Initial concentration

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Elimination Of Heavy Metals From Wastewater Using Agricultural Wastes As Adsorbents: A Review

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ABSTRACT: The adsorption process is the most versatile technique for the removal of heavy metals from waste streams and the activated carbon has been widely used as an adsorbent. Despite its extensive use in the water and wastewater treatment industries, activated carbon remains an expensive material. In recent years, the need for safe and economical methods for the elimination of heavy metals from contaminated waters has necessitated research interest towards the production of low cost alternatives to commercially available activated carbon. Therefore there is an urgent need that all possible sources of agro-based inexpensive adsorbents should be explored and their feasibility for the removal of heavy metals should be studied in detail. The objective of this study is to contribute in the search for less expensive adsorbents and their utilization possibilities for various agricultural waste by-products such as sugarcane bagasse, rice husk, oil palm shell, coconut shell, coconut husk etc. for the elimination of heavy metals from wastewater.

Keywords: adsorption, adsorbents, agricultural wastes, heavy metals, wastewater, activated carbon

INTRODUCTION

Excessive release of heavy metals into the environment due to industrialization and urbanization has posed a great problem worldwide. Unlike organic pollutants, the majority of which are susceptible to biological degradation, heavy metal ions do not degrade into harmless end products (Gupta et al., 2001). The presence of heavy metal ions is a major concern due to their toxicity to many life forms. Heavy metal contamination exists in aqueous wastes of many industries, such as metal plating, mining operations, tanneries, chloralkali, radiator manufacturing, smelting, alloy industries and storage batteries industries etc. (Kadirvelu, 2001). Treatment processes for heavy metal removal from wastewater include precipitation, membrane filtration, ion exchange, adsorption, and co-precipitation/adsorption. Studies on the treatment of effluent bearing heavy metal have revealed adsorption to be highly effective technique for the removal of heavy metal from waste stream and the activated carbon has been widely used as an adsorbent (Chand et al., 1994). Despite its extensive use in the water and wastewater treatment industries, activated carbon remains an expensive material. In recent years, the need for safe and economical methods for the elimination of heavy metals from contaminated waters has necessitated research interest towards the production of low cost alternatives to commercially available activated carbon.

The low cost agricultural waste by-products such as sugarcane bagasse (Chand et al., 1994, Mohan and Singh, 2002, Khan et al., 2001), rice husk (Srinivasan et al., 1998; Munaf and Zein, 1997; Ajmal et al., 2003; Suemitsu et al., 1986), sawdust (Ajmal et al., 1996; Kadirvelu et al., 2003; Selvi et al., 2001), coconut husk (Chand et al., 1994; Tan et al., 1993) etc., for the elimination of heavy metals from wastewater have been investigated by various researchers. Due to their low cost, after these materials have been expended, they can be disposed of without expensive regeneration. Cost is an important parameter for comparing the sorbent materials. However, cost information is seldom reported, and the expense of individual sorbents varies depending on the degree of processing required and local availability. In general, an adsorbent can be termed as a low cost adsorbent if it requires little processing, is abundant in nature, or is a by-product or waste material from another industry. Of course improved sorption capacity may compensate the cost of additional processing (Bailey et al., 1999). Therefore there is an urgent need that all possible sources of agro-based inexpensive adsorbents should be explored and their feasibility for the removal of heavy metals should be studied in detail. The objective of this study is to contribute in the search for less expensive adsorbents and their utilization possibilities for various agricultural waste by-products, which are in many cases also pollution sources.

RELEVANT LITERATURE

Reviews of some agricultural adsorbents for the removal of heavy metals from wastewater are presented as follows.

Rice husk

Rice husk is an agricultural waste material generated in rice producing countries, especially in Asia. The annual world rice production is approximately 500 million tons, of which 10 – 20% is rice husk. Dry rice husk contains 70 – 85% of organic matter (lignin, cellulose, sugars, etc) and remainder consists of silica, which is present in the cellular membrane (Vempati et al., 1995). In recent years, attention has been focused on the utilization of unmodified or modified rice husk as an adsorbent for the removal of pollutants. Wong *et* *al.* (2003) using tartaric acid modified rice husk as adsorbent have carried out batch studies for the removal of lead and cuprum and reported the effects of various parameters such as pH, initial concentration of adsorbate, particle size, temperature etc. It was reported modified rice husk to be potentially useful material for removal of Cu and Pb from aqueous solutions. The rapid uptake and high adsorption capacity make it a very attractive alternative adsorption material. It was also shown that the uptake of Cu and Pb was maximum when pH was increased from 2 to 3, thereafter remained relatively constant. Adsorption behaviour of Ni (II), Zn (II), Cd (II), and Cr (VI) on untreated and phosphate treated rice husk (PRH) by Ajmal *et al*. (2003) showed that adsorption of Ni (II) and Cd (II) was greater when PRH was used as adsorbent. Adsorption of Cd (II) was dependent on contact time, concentration, temperature, adsorbent doses and pH of the solution. It was also reported that the maximum adsorption (> 90%) was obtained at a pH value of 12. Srinivasan et al., (1988) studied on chromium removal by rice husk carbon. The activated carbon prepared by carbonization of rice husk with sulphuric acid followed by CO_2 activation showed 88% removal of total chromium and greater than 99% removal of hexavelent chromium. Column studies showed capacity of 8.9 mg/g and 6.3 mg/g for rice husk and commercial carbons respectively, for Cr (VI) removal.

Suemitsu et al. (1986) studied on the use of dyestuff-treated rice husk for removal of heavy metal from waste water. Rice hulls, when coated with the reactive dye of Procion Red or Procion Yellow, was found to be highly effective for removal of many metal ions from aqueous solutions both in batch and column method. The high removals for red dyestuff-treated husk are on lead (II) and cadmium (II) at 99.8% and 99.2% respectively, for yellow dyestuff-treated husk are on lead (II) and mercury (II) at 100% and 93.3% respectively. Munaf and Zein, (1997) studied on the use of rice husk for removal of toxic metals from wastewater. They have reported, at optimal conditions, the chromium, zinc, copper and cadmium ion removal from aqueous solution and stated as 79%, 85%, 80% and 85% respectively. Roy et al. (1993) studied on adsorption of heavy metals by green algae and ground rice hulls. They have concluded that, metal adsorption by algal and rice hull biomass, from the aqueous test systems, was greater than 90% for all the metals tested, (Sr, Cd, Ni, Pb, Zn, Co, Cr, As) except Ni, for which removal was nearly 80%. Guo et al. (2002) studied on adsorption of Cr(VI) an micro- and mesoporous rice husk-based active carbon. They have concluded that the rice husk carbon is a good sorbent for the removal of Cr(VI) from aqueous solution range from 5 to 60 mg/l with adsorbent dose of 0.8 g/l at pH < 5 under the minimum equilibration time of 2 hours. There is a sharp decrease in adsorption above pH 5.0 and the adsorption in the higher pH range would be negligible. Maximum reported adsorption is > 95% removal of Cr(VI). A study on utilization of agro-residues (rice husk) in small waste water treatment plans was done by Daifullah et al. (2003). They have characterized and evaluated two types of sorbents made from rice husk. The efficiency of both sorbents in the removal of the complex matrix containing six heavy metal was nearly 100%. These metals are Fe, Mn, Zn, Cu, Cd, and Pb, which are found in the drain containing the agricultural and sewage wastewater.

Sugarcane Bagasse

Bagasse pitch is a waste product from sugar refining industry. It is the name given to the residual cane pulp remaining after sugar has been extracted. Bagasse pitch is composed largely of cellulose, pentosan, and lignin (Mohan and Singh, 2002). Peternele et al. (1999) studied on adsorption of Cd (II) and Pb(II) onto functionalized formic lignin from sugar cane bagasse. They have stated that the Pb (II) adsorption process obeys Langmuir's model and Cd (II) presents adsorption in multiplayer, especially when the temperature is higher than 30 ºC. When ionic strength increases, the maximum adsorption capacity diminishes. The carboxymethylated lignin from sugar cane bagasse can adsorb Pb(II) selectively rather than Cd(II) under special conditions (pH 6.0, 30ºC, and ionic strength of 0.1 mol/dm^3), when both ions are present in mixture. Factorial analysis of Pb(II) adsorption suggests that temperature is the most important factor in single system, adsorption increases with increasing temperature. Mohan and Singh (2002) carried out a research on single- and multi-component adsorption of cadmium and zinc using activated carbon derived from bagasse – an agricultural waste. They have reported that the removal of Cd(II) and Zn(II) is found to increase as pH increases beyond 2 and at pH > 8.0 the uptake is 100%. It is also evident that the sorption affinity of the derived activated carbon towards Cd(II) and Zn(II) is comparable or more to other available adsorbents. Therefore cost wise the activated carbon prepared would be cheaper than the commercially available ones. Khan et al., (2001) reported that at an adsorbent dose of 0.8 g / 50 ml is sufficient to remove 80 – 100% Cr(VI) from aqueous solution having an initial metal concentration of 20mg/l at a pH value of 1 but the efficiency reduced sharply to 15% at pH 3. Chand et al. (1994) have studied on removal of hexavalent chromium from wastewater by adsorption. Removal of chromium (VI) from aqueous waste was investigated using adsorption based on bagasse and coconut jute. The effect of solution pH, Cr(VI) concentration, adsorbent dosage and contact time were studied in a batch experiment. The removal was in general most effective at low pH ([2) values and low chromium (VI) concentration. Activated coconut jute carbon was the most active among the four adsorbent studied. It was fairly stable even at higher pH. This was followed by activated bagasse carbon, raw bagasse and bagasse ash respectively. The maximum removal obtained was around 99.8 percent at pH 2. The data for all the adsorbents fit well to the Freundlich isotherm.

Sawdust

Studies on removal and recovery of Cr(VI) from electroplating waste were carried out by Ajmal et al. (1996). Phosphate treated sawdust (PSD) shows remarkable increase in sorption capacity of Cr (VI) as compared to untreated sawdust. Adsorption of Cr (VI) on PSD is highly pH dependent. The maximum adsorption of Cr (VI) is observed at pH 2. The adsorption of Cr (VI) remains maximum (100%) even at a pH less than 2. The adsorption densities in general decrease as the adsorbent dose is increased from 0.2 to 3g. 100% removal of Cr (VI) from synthetic wastewater as well as from actual electroplating waste containing 50 mg/l Cr (VI) was achieved by batch as well as by column process. The adsorbed chromium can be recovered by using 0.01 M NaOH solution. Selvi et al. (2001) studied the removal of Cr(VI) from aqueous solution by adsorption onto activated carbon. Activated carbon prepared from coconut tree sawdust was used as an adsorbent for the removal of Cr (VI) from aqueous solution. Batch mode adsorption studies were carried out by varying agitation time, initial Cr (VI) concentration, carbon concentration and pH. Langmuir and Freundlich adsorption isotherms were applied to model the adsorption data. Adsorption capacity was calculated from the Langmuir isotherm and was 3.46 mg/g at initial pH of 3.0 for the particle size 125-250 μm. The adsorption of Cr(VI) was pH dependent and maximum removal was observed in the acidic pH range.

Soybean hulls, cottonseed hulls, rice bran and straw

Marshall et al. (1999) done a research on enhanced metal adsorption by soybean hulls modified with citric acid. A method was developed to enhance metal ion adsorption of soybean hulls for wastewater treatment using copper ion (Cu^{2+}) as a typical metal ion. Hulls, extracted with 0.1 N NaOH, were modified with different citric acid (CA) concentration (0.1 – 1.2 M) at 120ºC for 90 min. CA-modified hulls had adsorption capacities for Cu^{2+} from 0.68 to 2.44 mmoles/g, which was much higher than for unmodified hulls (0.39 mmoles/g). They have also concluded that, soybean hulls treated with sodium hydroxide and modified with citric acid, especially at concentration of 0.6 M and above removed over 1.7 mmoles of copper ion from solution per g of hulls. This is due to the increase in carboxyl group imparted onto the hulls by reaction with citric acid. Marshall and Champagne (1995) stated that soybean hulls contains (mg/g dry weight basis) protein, lipid ash, lignin, cellulose, hemicelluloses and silica which are 109, 10.0, 36.4, 49.1, 676, 137, and < 10 respectively They studied on agricultural byproducts as adsorbents for metal ions in laboratory prepared solutions and in manufacturing wastewaster. Byproduct of soybean and cottonseed hulls, rice straw and sugarcane bagasse were evaluated as metal ion adsorbents in aqueous solutions. Adsorption capacities were determined by adsorption isotherms using the Langmuir model. Their adsorption capacities for Zn (II) were: soybean hulls > cottonseed hulls > rice straw > sugarcane bagasse. Capacities varied from 0.52 to 0.06 meq/g dry weight of byproduct. Marshall and Johns (1996) done a study on agricultural by-products as metal adsorbents to find the sorption properties and resistance to mechanical abrasion. Defatted rice bran, soybean and cottonseed hulls were evaluated for their sorption properties and resistance to mechanical abrasion in consideration of their potential use as commercial metal adsorbents. These by-product were evaluated using both laboratory prepared solution and metal plating wastewater for their ability to adsorb Zn (II) and/or Cu (II) and Ni (II). Extrusion stabilized, pilot plant-prepared brans had greater adsorption capacities and adsorption efficiencies than expander stabilized, commercially available bran. NaOH- and HCl-washed soybean and cottonseed hulls had generally higher adsorption efficiencies than water-washed (control) hulls, but had higher or lower adsorption capacities, respectively, than water-washed hulls. Heat treated cottonseed and soybean hulls had lower adsorption properties than water-washed hulls. Reuse of hulls after one adsorption/desorption cycle resulted in a large decrease in adsorption capacity which classified hulls as single-use adsorbents when desorbed with HCl. In another study

Wheat straw and sago waste

Kumar et al. (2000) used wheat straw in their study in alkali-treated straw and insoluble straw xanthate as low cost adsorbents for heavy metal removal – preparation, characterization and application. Heavy metal removal using alkali-treated straw (ATS) and insoluble straw xanthate (ISX) is reported. Insoluble straw xanthate consisting of 4.1 % total sulfur is also applied for the removal of various metal ions simultaneously. Potentiometric data of alkali-treated straw and xanthate straw indicated polyfuntionality of these materials. Removal of Cr^{3+} from aqueous solution using ATS and ISX followed the Langmuir adsorption model and both the materials have shown significant chromium removal efficiency (>80%). An approximate removal efficiency of 91% was found wit h1.0 g ISX in a contact period of 1 hour. It was also reported that the ISX have shown an order of removal efficiency in the case of synthetic waste is: Pb(II) > Fe(II) > Cu(II) > Cr(III) > Zn (II) > Ni (II) > Mn(II), and in case of tannery was it is: Cr(II) > Fe(II) > Cu(II) > Zn(II) > Mn(II) > Pb(II) > Ni(II). The sago waste chemical composition suggest that they could have some potential as a biosorbent, stated by Quek et al. (1998) in their study on the use of sago waste for the sorption of lead an copper. Sago processing waste, which both a waste and a pollutant, was used to adsorb lead copper ions from solution. The sorption process was exammed in terms of its equilibria and its kinetics. The most effective pH range was found to be 4 to 5.5 for both metals. The equilibria data for both metals fitted both the Langmuir and the Freundlich models and based on the Langmuir constants, the sago waste had a greater sorption capacity for lead (46.6 mg/g) than copper (12.4 mg/g). the kinetic studies showed that the sorption rates could be described better by a second-order expression than by the more commonly applied Lagergren equation.

Other agricultural waste by-products

Kadirvelu et al. (2003) studied on utilization of various agricultural wastes for activated carbon preparation and application for the removal of dyes and metal ions from aqueous solution. Mercury (II) and nickel (II) were used in the study for various adsorbents. Activated carbon were prepared from the agricultural solid wastes, silk cotton hulls, coconut tree sawdust, sago waste, maize cob, and banana pitch and used to eliminate heavy metals and dyes from aqueous solution. Adsorption of all dyes and metal ions required a very short time and gave quantitative removal. Experimental results show all carbons were effective for the removal of pollutants from water. Since all agricultural solid wastes used in this investigation are freely, abundantly, and locally available, the resulting carbons are expected to be economical viable for wastewater treatment. Tan et al. (1993) studied on removal of chromium (VI) from solution by coconut husk and palm pressed fibres and it was investigated using batch and column techniques. The optimum range for >70% Cr(VI) removal is between 1.5 and 5 and 1.5 to 3.0 for coconut husk fibre and palm pressed fibre respectively. For both substrates, the optimum pH for maximum removal is at 2.0 which corresponds to > 80% removal. Kadirvelu et al. (2002) studied on activated carbon prepared from biomass as adsorbent: elimination of Ni (II) from aqueous solution. Activated carbon carbon prepared from waste Parthenium was used to eliminate Ni (II) from aqueous solution by adsorption. Batch mode adsorption experiments are carried out, by varying contact time, metal ion concentration, carbon concentration, pH and desorption to assess kinetic and equilibrium parameters. They allowed initial coefficient, adsorption rate constant and maximum adsorption capacities to be computed. The adsorption data were modelled by using both Langmuir and Freundlich classical isotherm. The adsorption capacity (Q_o) calculated from the Langmuir isotherm was 54.35 mg Ni (II) /g of AC at initial pH of 5.0 and 20ºC, for the particle size 250 – 500 µm. Increase in pH from 2 to 10 increase percent of removal of metal ion.

Martin-Dupont et al. (2002) have studied on heavy metal adsorption by crude coniferous barks: a modelling study. This paper reports an extensive study on the biosorption abilities of coniferous barks. At considered granulometry, a chemical pretreatment of the barks caused a decrease in their metal binding capacities. The mechanism of the metal biosorption by barks was approached by the means of the Langmuir adsorption model and seems quite complex. The selective affinity of barks for the metals tested, in the physico-chemical condition defined by their study, is: $Pb^{2+} > Cr^{3+} > Ni^{2+} > Zn^{2+} > Cu^{2+}$. Ranganathan, K. (2000) studied on chromium removal by activated carbons prepared from *Casurina equisetifolia* leaves. *Casurina equisetifolia* leaves were carbonised and activated after treatment with sulphuric acid (1:1), phosphate salt (10%) or zinc chloride (25%) at different temperatures. Prepared activated carbons were used to remove Cr (VI) from wastewater and the conditions optimised for most effective carbons. The equilibrium data fitted well with the Freundlich adsorption isotherm. Desorption studies shows that 65 – 80% of adsorbed chromium could be desorbed by alkali followed by acid treatment. Recycling of the carbons could be carried out without change in the adsorption efficiency. The carbons were also tested for the removal of chromium (VI) and total chromium from plating effluent. Halim et al. (2003) studied on removal of lead ions from industrial wastewater by different types of natural materials. From the research done it was reported that at lead concentration of 4 mg/l and pH 6 the adsorption capacity is maximum for Nile rose plant powder at 80% removal and at the same concentration and pH it was also reported that bone powder removed 98.8 % of lead.

Wafwoyo et al. (1999) carried out studies on the utilization of peanut shells as adsorbents for selected metals. The results showed that for single metal ion solutions, treatment with phosphoric or citric acid increased the amount of metal ions adsorbed by peanut shells for the metals (Cd (II), Cu (II), Ni (II), Pb (II) and Zn (II)) studied. Base wash increased the effectiveness of citric acid-treated samples in single metal ion solutions while it had no effect on phosphoric acid-treated or untreated samples. Overall, phosphoric acid treatment resulted in higher metal ion adsorption than citric acid treatment. For multiple metal ion solutions, the metal uptake from solution by adsorbents dependent strongly on the presence and type of other competing metal ions. The acid-treated samples exhibited a high selectivity for Cu(II) ions; 42% for citric acid-treated and 28% phosphoric acid-treated. Citric acid-treated samples were significantly more effective than the phosphoric acid-treated samples as well as commercial resin Amberlite, in removal of Cu(II) ions from multiple ion solution. Peanut shells show promise for use as metal adsorbents from aqueous solutions. Adsorption capacities of various agricultural by-products are given in Table 1.

Table 1: Adsorption capacities of various agricultural by-products wastes as adsorbents

Reference	Adsorbent	Adsorbate (Heavy Metal) removal (%)							
		Cr(III)	Cr(VI)	Ni(II)	Cu(II)	Zn(II)	Cd(II)	Hg(II)	Pb(II)
Wong et al. (2003)	Tartaric acid modified rice husk	-	-	-	> 80 pH 2-3	-	-	-	> 95 pH 2-3
Suemitsu et al. (1986)	Dyestuff-treated rice hulls (red)	-	39.7	61.6	78.8	75.1	99.2	92.7	99.8
	Dyestuff-treated rice hulls (yellow)	-	39.1	60.8	70.0	61.3	83.3	93.3	100.0
Roy et al. (1993)	Rice hull biomass	-	98.93	-	-	-	97.96	-	99.43
Ajmal et al. (2003)	Phosphate-treated rice husk	-	-	-	-	-	> 90 pH12	-	5 -
Munaf and Zein (1997)	Rice husk (water and HCl washed)	-	79	-	80	85	85	-	-

(*Continued*)

Table 1 (*Continued*)

Reference	Adsorbent	Adsorbate (Heavy Metal) removal (%)							
		Cr(III)	Cr(VI)	Ni(II)	Cu(II)	Zn(II)	Cd(II)	Hg(II)	Pb(II)
Srinivasan et al. (1988)	Rice husk carbon	-	> 99	-	-	-	-	-	-
Daifullah et al. (2003)	Rice husk carbon	-	-	-	≈ 100	≈ 100	≈ 100	-	≈ 100
Tan et al. (1993)	Coconut husk	-	> 80	-	-	-	-	-	-
	Palm pressed fibre	-	> 80	-	-	-	-	-	-
Chand et al. (1994)	Bagasse ash	-	53.4	-	-	-	-	-	-
	Activated bagasse carbon	-	99.97	-	-	-	-	-	-
	Raw bagasse	-	93.5	-	-	-	-	-	-
	Activated coconut jute carbon	-	99.7	-	-	-	-	-	-
Mohan and Singh (2002)	Sugarcane bagasse activated carbon	-	-	-	-	100 pH > 8	100 pH > 8	-	-
Khan et al. (2001)	Raw sugarcane bagasse	-	80 - 100 pH 1	-	-	-	-	-	-
Marshall and Champagne (1995)	Soybean hulls	98.1	-	95.6	99.7	96.4	-	-	-
	Cottonseed hulls	97.6	-	96.7	98.8	96.6	-	-	-
Ajmal et al. (1996)	Phosphate treated tree sawdust	-	100 pH 2	83 pH7	86 pH 7	86 pH 7	-	-	-
	Untreated tree sawdust	-	-	91 pH 7	86 pH 7	75.7 pH 7	-	-	-
Selvi et al. (2001)	Coconut tree saw dust carbon	-	98.84 [Cr^{6+}] 5mg/l	-	-	-	-	-	-
Kadirvelu et al. (2003)	Silk cotton carbon	-	-	64	-	-	-	100	-
	Coconut tree sawdust carbon	-	-	84.3	-	-	-	100	-
	Sago waste carbon	-	-	100	-	-	-	100	-
	Maize cob carbon	-	-	100	-	-	-	100	-
	Banana pitch carbon	-	-	96.40	-	-	-	100	-
Kumar et al. (2000)	Alkali treated straw	87	-	-	-	-	-	-	-
	Insoluble straw xanthate	99	-	-	-	-	-	-	-
Marshall and Johns (1996)	Soybean hulls								
	*water washed	-	-	53.0	83.3	51.6	-	-	-
	*NaOH washed	-	-	55.8	61.0	71.4	-	-	-
	*HCl washed	-	-	69.8	89.6	90.3	-	-	-
	*90˚C – heat treated	-	-	52.5	80.0	59.8	-	-	-
	*145˚C – heat treated	-	-	31.7	71.0	33.3	-	-	-
	Cottonseed hulls								
	*water washed	-	-	47.6	58.8	59.5	-	-	-
	*NaOH washed	-	-	72.8	37.4	69.5	-	-	-
	*HCl washed	-	-	51.6	81.5	70.3	-	-	-
	*90˚C – heat treated	-	-	46.5	54.9	56.1	-	-	-
	*145˚C – heat treated	-	-	44.1	52.6	50.3	-	-	-
	Defatted rice brans (pH 5.0)								
	*Non stabilized, defatted at Southern Regional Research Center (SRRC)	-	-	29.2	71.5	38.4	-	-	-
	*extrusion stabilized, defatted at SRRC	-	-	36.6	83.2	75.0	-	-	-
	*extrusion stabilized, defatted at Riceland Foods Inc. (RF)	-	-	38.3	75.6	96.8	-	-	-
	*expander stabilized, defatted at Riceland Foods Inc. (RF)	-	-	20.4	64.7	20.5	-	-	-
Quek et al. (1998)	Sago waste	-	-	-	> 75 pH 4.5 to 5..5	-	-	-	> 95 pH 4.5 to 5..5

CONCLUSION

A review of various agricultural adsorbents presented herein shows a great potential for the elimination of heavy metals from wastewater. The sorption capacity is dependent on the type of the adsorbent investigated and the nature of the wastewater treated. The use of commercially available activated carbon for the removal of the heavy metals can be replaced by the utilization of inexpensive, effective, readily available agricultural by-products as adsorbents. More studies should be carried out to better understand the process of low-cost adsorption and to demonstrate the technology effectively.

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Effect Of Magnetic Fields On Suspended Particles In Sewage

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ABSTRACT: The capabilities of sewage treatment to achieve the allowable limit standards are well known to be a universal problem. All kinds of technology treatment methods are used but is still difficult to reach the minimum standard requirements. Magnetic technology is a physical treatment technique, which is commonly used in water processing industry. This situation attracts treatment research to use the magnetic technology to further increase the sewage treatment capabilities. This research is mainly focused on the capability of the technology to increase the sedimentation of suspended particles rate through two processing methods which are static and flowing methods which will be conducted using the settling tube test. According to each designed system correspond with certain value of the parameters, the efficiency to dissolve the concentrations of SS, BOD, NH_3-N and COD tests are conducted. The settling of the suspended particles test, which was done, applied to the behaviour of the first kinetic model and the settling time, found out to be most suitable after 80 minutes. The results of the test conclude that the capability of suspended particles removal can be further increased using the flowing method with different magnetic strength and flow rate. The study reveal that higher magnetic strength and lower flow rate will enhance the settling of suspended particles and the concentrations of BOD, NH_3-N, COD in sewage. Experimental design with a magnetic strength of 0.55 Tesla, a flow rate of 1.84 mL/s, 6 paired of non-parallel magnets, with pH less than 7 shows that the concentrations of BOD, NH_3-N, COD and SS were decreased up to three times using the settling test compared to typical treatment. The percentage of SS removal is 85.40 compared to 29.92 without magnet, so as BOD is 41.54 compared to 17.54, COD is 43.43 compared to 25.26 and NH_3-N is 60.99 compared to 27.15 without magnet. This study concluded that magnetic technology has the potential to be used to further increase the efficiency of domestic sewage treatment by increasing the removal of suspended particles.

Keywords: Magnetic fields, sewage, suspended particles

INTRODUCTION

Waste treatment is concerned with environmental protection and with the reduction of pollutant discharges into the environment. In the light of growing concern about the environmental impact of wastewater discharges it is likely that tightening regulatory requirements will inevitably lead to increasing wastewater disposal costs. Therefore wastewater treatment is important for long-term environmental protection and conservation. Usage of magnetic treatment as an alternative form of water and wastewater treatments are stills remain anecdotal and limited due to lack of credible and proven mechanisms.

Magnetic water treatment has been shown in the past to be a promising treatment process that can be used to avoid scale formation in the water pipe lines especially boiler system. Currently, the application of magnetic treatment has been used in industrial water treatment (Hibben, 1973); removal of phosphate from water (Bogatin *et al.,* 1999) and reducing the formation of wax and paraffin in the oil rigs (Partidas, 1995).

Presence technical papers pertinent to magnetic treatment claim that it has the ability to alter the physicochemical properties of water, suppressed nucleation of CaCO3, (Beruto and Giordani, 1995), enhancing the crystallization process (Donaldson and Grimes, 1988), intensify the coagulation and precipitation of colloidal particles (Tsouris and Scott, 1995) and inhibit scaling (Florenstano et al., 1996).

Currently applications of magnetite slurry, magnetite particles and magnetic powder in treating wastewater have been becoming the main interest of many researchers. A pre-treated finely sized magnetic particles that are known as 'magnetite slurry' had been used as a coagulant for colloidal material such as clays, humic acids, bacteria, viruses and algae (Anderson *et al,.* 1982). Research organization (CSIRO) had reported on the successful application of magnetic particles on treating wastewater with respect to adsorption and coagulation process (Bolto, 1990). This study was made on number wastewater applications such as sewage sludge, metal recovery from electroplating and hydrometallurgical effluents.

Magnetic particles or magnetic seeding and a magnetic field have been applied in most of the research conducted by researchers. Sakai *et al.* (1991) added magnetic Ferro oxide powder to activated sludge to improve the efficiency of the sedimentation. Ozaki *et al.* (1991) applied a magnetic particle and magnetic field for phenol biodegradation. Another researcher van Valsen (1990) had managed to develop an effective magnetic technique for treating sewage effluents. Magnetite that acts as carrier materials had been applied to remove phosphate concentration off the sewage's effluents.

On the similar approach Sakai (1994) has studied the submerged filter system consisting of magnetically anistropic tubular support media for the sewage treatment with a biofilm system. Activated sludge was supplemented with ferromagnetic powder for the preparation of the biofilm. The biofilm was formed within 15 min on magnetic support media by magnetic attraction. The magnetic support media were able to treat sewage containing 0.2g/L COD and remove 72%-94% COD with a retention time of 8h.

However these technologies have some disadvantages, such as the use of magnetic particles and the necessity of recovering them considering the environmental viewpoint, practical cost problems and may be too complicated for practical application. Others have reported the sedimentation enhancement of activated sludge with an external magnetic field without addition of magnetite into the sludge, using a cultivated activated sludge that was acclimated with a synthetic sewage, that accompanied the enlargement of the flock size. The flock size and sedimentation were improved by the addition of $FeCl_3$ to the activated sludge. However the mechanism of sedimentation enhancement effects is still unclear.

Previously most studies regarding to magnetically treated wastewater were only concentrating on the usage of magnetite (magnetic particle and slurry). However, there are still lacks of studies that have been published regarding to the specific consumption of magnetic field (non-invasive) effect on the sewage properties. Therefore it is the purpose of this study to investigate the feasibility of magnetic technology in enhancing the sedimentation of sewage's suspended particles as well as to look its effect on the sewage properties (i.e. turbidity and pH). In this report, the mechanism of enhancement of sedimentation of suspended particles in wastewater by magnetic field, the effects of a magnetic field on the sedimentation rate due to magnetic field strength and flow rate were investigated using design laboratory magnetic devices.

MATERIAL AND METHODOLOGY

The experimental set up was employed magnetic field that is orientated orthogonal to the direction of sewage flow. Three permanent magnets with different strengths were used in this experiment, namely NdFeB of 0.55T, SmCo of 0.16T and AlNiCo of 0.08T. All magnets are cubic-shape rare earth permanent magnet size (50mm x 50mm x 20mm). The experiments carried out in this work are classified into two categories namely static system and flowing system.

Static system: The fluid was kept in a cylindrical glass cell. Two cubic-shaped permanent magnets were centered on the outside of the bottle faces, of the sample container with opposite magnetic poles facing each other. They rested on the glass surface vertically, by their magnetic attraction. The distance between the two poles is the diameter of the bottle, i.e. 20mm. The sample is filtered by using filter paper after exposed to the magnetic field for every 10 minutes of interval time. Each filtered sample was dried in an oven for 1 hour before weighted. The second test was carried out by changing the magnetic field strength. Each series consisted of control runs with no applied magnetic field, followed by otherwise identically conducted magnetic runs. During each 1-hour run, the turbidity of both magnetically treated sample and control sample were all carefully monitored. The time dependence of turbidity was then used to make inferences about the precipitation process.

Flowing system: A schematic of the flowing system rig is shown in Figure 1. This rig consists of a 1-liter reservoir for filling and a treatment loop, which permits continuous flows of fluid through a magnetic treatment device, contains 20 units of permanent magnets under controlled laboratory conditions. All pipe work is made of flexible PVC tube or teflon with a nominal internal diameter of 19.05mm (3/4 in). Other plastic materials are employ wherever possible. Where metal components are required, nonferrous materials such as brass or copper was utilized. The variable speed pumps allow adjustment of the flow rate from zero to 100mL/s. The fluid is continuously flowed at between 0.1mL/s – 10mL/s. The flow was kept as a laminar flow. The fluid flow is design to flow orthogonal to the magnetic field direction. 4 similar rigs will be set-up and run simultaneously, each with different magnetic strength and one loop without magnet as a control system. The treated sewage was collected at the end of the tube and then was placed in a settling column of 45cm high and 7cm in diameter. This will consume about 275mL of treated sewage. Sampling was taken periodically every 10 minutes intended for turbidity analysis.

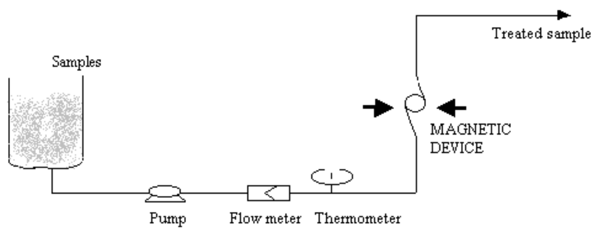

Figure 1: Schematic layout of the Flowing System

Settling column: The settling column is made of a cylinder of glass tubing with a 7cm internal diameter and 1m high. Samples were collected from the column at 10cm from the top of the column using 10 mL pipette. Samples were collected at 10, 20, 30, 40 minutes and 1, 2 and 3 hours. Analysis of the samples collected throughout the experiment allowed the change in concentration against time to be determined.

RESULTS AND DISCUSSION

Effect of Magnetic Field Strength

The effect of the magnetic field strength on the precipitation of colloidal particles is experimentally studied by varying the magnetic field strength between 0 - 0.55T. The magnetic field enhances the removal efficiency of colloidal particles from approximately 8% without magnetic field to 20% with magnetic field of 0.08T at 80 minutes settling time under static system, while removed about 21% without magnet to 40% with magnet when using flowing system.

As shown in Figure 2, the rate of concentration difference after and before treatment that magnetized sewage treatment is seen to have higher removal of suspended particles compared to control. The percentage of removal seems to be increasing with the settling time but the rate of removal is declined as settling time increases. As the magnetic field is increased further, the particles removal efficiency increases by about 50% – 60% with magnetic field strength of 0.55T. It is found that the removal efficiency increases rapidly until the magnetic field strength becomes approximately 0.2T. Above this field strength, the removal efficiency increases slowly because the concentration of particles in the solution decreases.

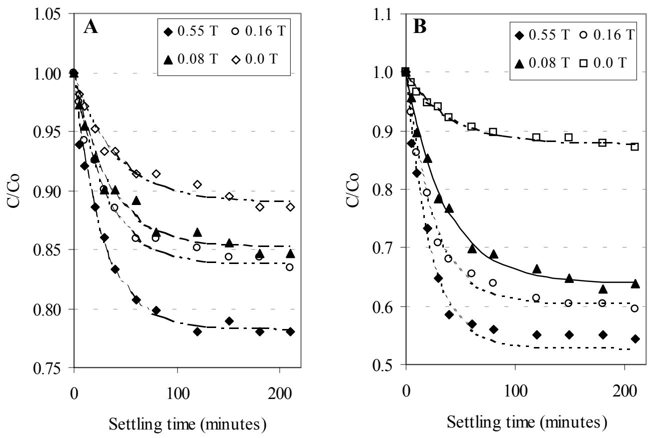

Figure 2 : Effect of different magnetic field strengths on the rate of suspended particles removal under static (**A**) and flowing system (**B**)

The reason for this behaviour is that the magnetic force enhances the settling velocity of the suspended particles. This settling velocity is increased when more suspended particles are agglomerate and cloaked together. Exposed to magnetic field would electrically contribute to a greater ionic charge. This energy will make the charged particles to vibrate excessively. Thus more particles are colliding among themselves. This reaction contributes to additional number of ions (positive and negative charge), which consequently creates a natural magnetic attraction between the opposite charged particles. Particles are then attracted and agglomerated. This phenomenon intensifies coagulation that enables them to flocculate and precipitate. Another reason that could cause a limitation in the removal efficiency in the experiments is due to the heterogeneous flocculation rate of suspended colloidal particles.

Effect of Flow Rate

The effect of flow rate on the removal efficiency is experimentally shown in Figure 3, where magnetic treatment experiments of colloidal particles were conducted by varying the flow rate from 0.92mL/s - 5.52mL/s. It is shown that the removal efficiency decreases as the flow rate is increased. Increased flow rate results in increased drag force; therefore colloidal particles are not easily aggregated or accumulated under high flow velocities.

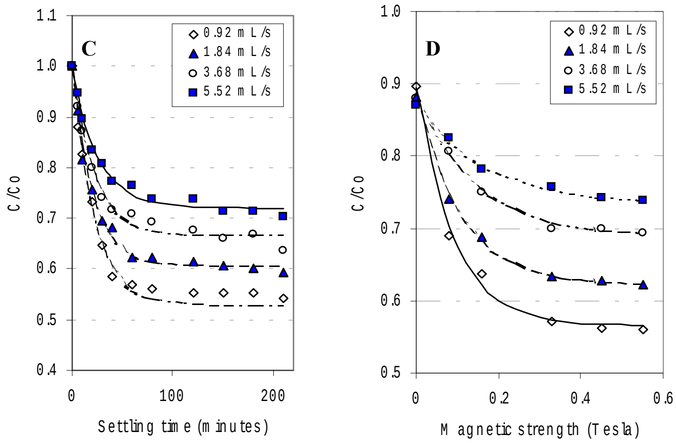

Figure 3 : Effect of flow rate on the rate of suspended solids removal under flowing system based on settling time (**C**) and magnetic strength (**D**)

The reason is that the magnetization effect starts to wear off as the particles' magnetic memory depleted. Flow rate that is applied in the treatment process reflects to the exposure time and quantity of magnetic fields that are absorbed by the suspended particles. Lower flow rate means more exposure time and magnetic field quantity given to the sewage's particles thus increasing the magnetic memory and magnetization effect on the sewage.

Effect to the Selected Parameters

The effect of the magnetic-field intensity on the BOD, COD, SS and NH_3-N removal of sewage is experimentally studied by applying magnetic field of 0.55T, flow rate of 1.84 mL/s with desined magnetic devised comprises of 6 paired magnet. The pH of the samples was maintained below 7. As shown in Figure 4, magnetized sewage treatment reduced the concentrations of BOD, COD, SS and NH_3-N in the sewage. The concentrations of each parameter are reduced due to the reduction of suspended particles in the sewage due to the aggregation effect by the magnetic fields. This phenomenon again support the theory that magnetic field can speed up the settlement of suspended particles. As more suspended particles settle down the sewage becomes more clarified and consequently leads to the reduction of early mentioned parameters in the sewage.

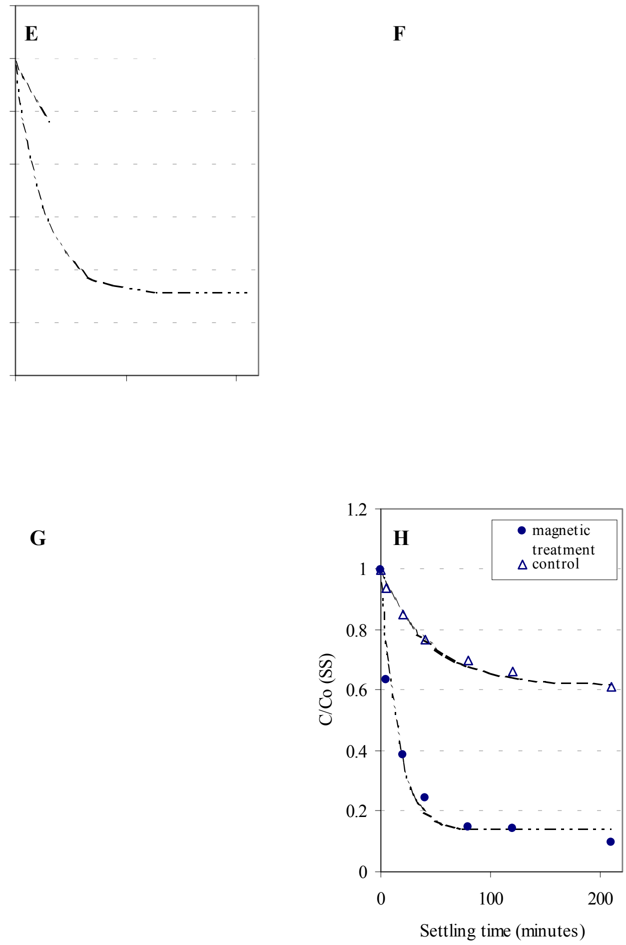

Figure 4 : Effect of magnetic treatment on various parameter in sewage i.e. BOD (**E**), COD (**F**), NH3-N (**G**) and SS (**H**) under flowing system with magnetic strength of 0.55T and flow rate of 1.84 mL/s.

As shown above, the optimum reduction in concentration of each parameter is about 80 minutes of settling time. The concentrations of BOD, NH_3-N, COD and SS were found decreased up to three times using the settling test compared to typical treatment. The percentage of SS removal is 85.40 compared to 29.92 without magnet, so as BOD is 41.54 compared to 17.54, COD is 43.43 compared to 25.26 and NH_3-N is 60.99 compared to 27.15 without magnet. Reduction of the concentration of each parameters mentioned is due to the removal of suspended particles in the sewage.

Surface Chemistry and Flocculation

The effect of magnetic fields on the suspended particles in the sewage can be explained based on the colloidal aggregation due to magnetohydrodynamic. Colloidal suspended particles carry a surface charge, and this charge is affected by the imposed magnetic fields. The surface charge on the particles is compensated by attraction of counter ions to the surface in the form of a diffuse layer, resulting from thermal motions of ions in the solution. The electric state of the surface is known as an electric double layer. A fixed charge is attached to the solid surface and another layer of charge is diffused or distributed in the liquid in contact with the surface (Satapah, 1989). The concentration of ions not balanced by the counter ions decreases exponentially away from the fixed layer, resulting in an electric potential that decreases away from the particle surface.

In aqueous colloids, suspended charges particles experience double layer repulsion and attraction due to van der Waal's forces. The magnitude of van der Waal's forces, which originates from the charge fluctuations in atoms, does not depend on colloidal chemistry. Fluctuations in charge lead to mutually induced dipoles in interacting particles, which result in an attraction between the particles.

CONCLUSIONS

Magnetic technology is potential to be a promising treatment process that can enhance the separation of suspended particles from the sewage. Increased percentages of suspended particles removal have been observed for both static and flowing systems in the presence of an orthogonal applied magnetic field. The study has also concluded that the magnetic treatment has the ability to enhance the sewage treatment plant performance by reducing the concentration of BOD, COD, NH_3-N and SS in the sewage. It is suggested that a magnetic field may enhance the collision rate and efficiency among those colloidal particles and therefore easier to flocculate into bigger aggregates. Expose to magnetic field would electrically contribute to a greater ionic charge (extra energy) that helps the charged particles to vibrate and collide excessively. As a result particles can move closer as the electrostatic repulsive forces have less effect on them. Thus more particles are flocculated and precipitated together. This effect is best explained as a magnetohydrodynamic effects (Johan, 2003). Increased in aggregation was also observed under the magnetically non-flowing system (static condition). Expose to magnetic field would enhance the effect of Brownian flocculation as the magnetic field has become the dominant force that drives particles (electrically induced particles) to collide and flocculate together.

Study carried out shows that magnetic field enhances the suspended particles removal by accelerating the settling of aggregated particles as well as increasing the particles density due to coagulation process. Hence this technology is definitely beneficial in reducing the volume of sedimentation tank as well as increasing the treatment plant efficiency.

ACKNOWLEDMENTS

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Effect of Coagulation on Arsenic Removal Efficiency Using Microfiltration

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ABSTRACT: The removal of arsenic from water by microfiltration-coagulation process was investigated. Arsenic removal experiments included variation of dosage of coagulant. In general, arsenic removal increased with decreasing in specific flux and was enhanced in the presence of coagulant. Arsenic was removed 83% and 72% from water containing 243-255 μg/l arsenic, resulting in arsenic concentrations of 40 μg/L and 68 μg/L, using microfiltration-coagulation and microfiltration only, respectively.

Keywords: arsenic removal; water treatment; membrane treatment; microfiltration

INTRODUCTION

Arsenic is a ubiquitous element in the environment. Arsenic exists in water in a variety of forms including the trivalent (As(III)) and pentavalent (As(V))oxidation states, and soluble, particulate and organic-bounded. Effective treatment must target all of these forms, either directly or after conversion to a more readily removed form.

Several studies have addressed the issue of arsenic removal from natural and synthetic waters. Research includes studies using ion-exchange resins (Vaaramaa and Lehto, 2003), iron oxide adsorbent (Zhand et al., 2003), permeable reactive materials (Joo et al., 2003), chitosan derivatives (Dambies and Guibal, 2002) and advanced oxidation process (Zaw and Emett, 2002).

Pressure driven membrane separation processes have also been identified as promising technologies for the arsenic removal in small water treatment systems. In general these processes are divided into four categories: reverse osmosis (RO), nanofiltration (NF), ultrafiltration (UF) and microfiltartion (MF). Previous studies evaluated the ability of specific membrane systems to remove arsenic in natural and synthetic waters (Brandhube and Amy, 1998, Vroenhoek and Waypa, 2000, Brandhube and Amy, 2001; Ning, 2002; Sato et al., 2002).

Important characteristics of naturally occurring arsenic include, the presence of colloidal/particulate arsenic in the raw water, the speciation of arsenic in the raw water and the "coagulability" of arsenic by metal hydroxides. Hence, by carefully matching membrane characteristics and pretreatment methods with the source water to be treated, a wide range of membranes may be effective in arsenic removal.

Coagulation process still plays an important role in the removal of arsenic. However, still little information has been provided concerning the effectiveness of conventional coagulation process on arsenic removal by membrane process.

Therefore, this study presents the efficiency of the integration of microfiltration and coagulation techniques for arsenic removal in water sample from pool.

MATERIALS AND METHODS

Sample collection

Water samples were collected from an ex-tin mining pool (now known as Mines Wonderland, a recreational water body), which is located at Selangor, Malaysia. Samples were collected at the depth of about 1.5 m from the water surface. The water contains naturally occurring arsenic 220 – 240 μg/l. The main characteristics of the samples are presented in Table 1.

Table 1. Characteristics of the water sample

Parameter	Value
pH	7.61 – 7.72
Turbidity (NTU)	2.95 – 4.21
BOD_5 (mg/l)	3.2 – 4.38
DO (mg/l)	3.24 – 3.42
TSS (mg/l)	0.243 – 0.255
Total arsenic (μg/l)	220 – 240

Type of MF membrane

This study was intended to elucidate the efficacy and mechanisms pertaining to the separation of arsenic by MF membrane. Therefore, a hollow fibre polyethylene membrane module with a total surface area of 0.014 m^2 were used in this study.

The dimensions of the hollow fibre membrane are presented in the Table 2.

Table 2. Dimensions of hollow fibre membrane (Megat Johari et al., 2002)

Hollow fibre	Dimension
Outer diameter (mm)	0.37
Inner diameter (mm)	0.25
Inner surface pore size (µm)	0.3-1.0
Outer surface pore size (µm)	0.1-0.9

Rig Set up

The experimental rig was set up as shown in Figure 1. The pool water sample was mixed continuously, in the feed tank, using a multi-rotational speed stirrer. The coagulant was added into the feed tank with the certain dosage determined from the jar test. A submersible pump was placed on the bottom of the tank to feed the pool water sample to a header-tank fixed at the top of the feed tank. The samples were fed, by gravity, from the header tank to the filtration rig via a float valve.

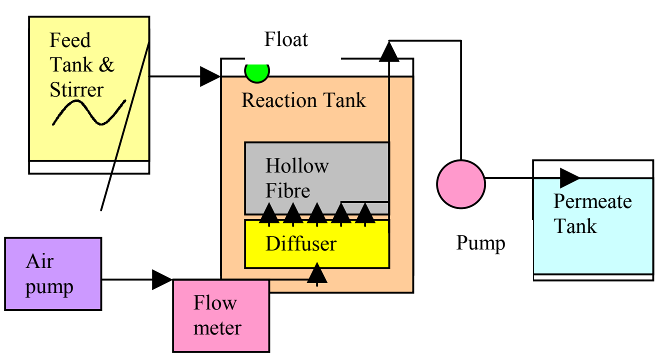

Figure 1. The schematic diagram of the experiment set up

Analytical methods

Graphite Furnace Atomic Absorption Spectrometry (GF-AAS) instrument (Hitachi, Japan) was used to determine the concentration of the total arsenic in the samples. pH, total suspended solid (TSS), biochemical oxygen demand (BOD), and dissolved oxygen (DO) of the sample were measured using standard methods for water and wastewater samples (APHA, 2000). Turbidity was measured by turbidity meter (HACH, model 2100AN).

Statistical analysis

Statistical Package, (SPSS, version 11.5 program) was used for all statistical analysis. All statistical significance was considered when $p<0.05$.

RESULTS AND DISCUSSION

Arsenic removal as a function of coagulant dosage

The purpose of this experiment was to show microfiltration, coupled with alum pretreatment, as a practical method for arsenic removal in drinking water. These tests determined the amount of arsenic that could pass through a microfiltration membrane following coagulation with alum. The results of this experiment are presented in figures 2 and 3.

As shown in the figure 2, using microfiltration about 59% arsenic removal was achieved at the beginning of the experiment. The arsenic removal was increased rapidly up to 66% after 2 days and continued to about 72% until the end of the experiment.

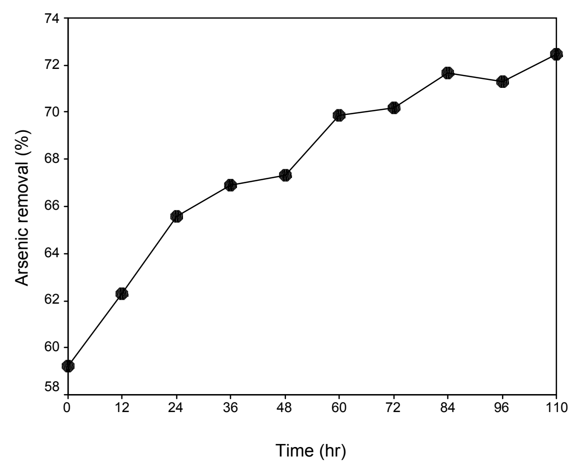

Figure 2. Arsenic removal using microfiltration

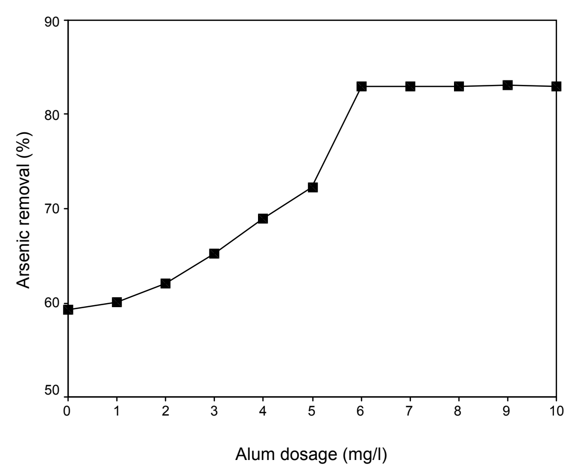

Figure 3. Arsenic removal using microfiltration coupled with coagulation

Arsenic removal using microfiltration coupled with coagulation is presented in the figure 3. As can be seen adding alum was enhanced the arsenic removal efficiency. Arsenic removal increased with increasing coagulant dose, although an incremental increase of coagulant dose above 6 mg/l was much less effective in the removal of arsenic than below a 6 mg/l dose.

Comparison between figures 2 and 3, showed that arsenic was removed 83% and 72% from water containing 243-255 μg/l arsenic, using microfiltration-coagulation and microfiltration only, respectively.

Arsenic concentrations in pool water samples using microfiltration-coagulation were dropped to 0.04 mg/l, which is less than the maximum allowable concentrations, 0.05 mg/l (USEPA, 2000).

In general, the percentage of arsenic removal using microfiltration – coagulation obtained in this study were found to be in the same range of percentage reported by others using tighter membranes (Table 3). Although for some cases the results was found to be higher than previous studies.

Table 3. Arsenic removal (%) using other membrane system

Element	Removal	Membrane	Reference
As(V)	88-99	RO	Ning, 2002
As(III)	46-84	RO	Ning, 2002
As	87-94	RO	Brandhuber &Amy, 1998
As	62-89	UF	Brandhuber and Amy, 1998
As	34-72	NF	Brandhuber and Amy, 1998
As(V)	95	NF	Sato et al., 2002
As(III)	75	NF	Sato et al., 2002

CONCLUSION

In this study, effectiveness of microfiltration coupled with coagulation for arsenic removal were investigated. Generally, coupling the system with coagulation was found to be effective in arsenic removal. Arsenic was removed 83% from water containing 243-255 μg/l arsenic, using microfiltration-coagulation, while microfiltration was able to achieve 72% removal only.

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Coagulation Of Turbid Waters Using Extraction Of Long Bean

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ABSTRACT: Coagulation is an important process in water treatment. The common chemical coagulant used in the water treatment is alum. However, since the publicity of *Moringa oleifera* seed as natural coagulant, researchers have tried to exploit the possible usage of natural coagulants as well as developing new natural coagulants from other plants. The potential of a locally available vegetable, long bean, to act as natural coagulant was studied using jar test. Turbid water used was prepared by adding kaolin to distilled water. It was discovered that long bean alone could not remove the turbidity. However, the coagulation activity was remarkable only when bivalence cation such as Ca^{2+} and Mn^{2+} were added. In this study, the active component of long bean was extracted using NaCl salt solution. The long bean extract achieved an average turbidity removal efficiency of 80 %.

Keywords:

Coagulation, turbidity, NaCl extraction, jar test, *long bean*

INTRODUCTION

The tap water that we use everyday is treated using coagulation, flocculation, sedimentation, filtration and disinfection processes before it reaches our water tap. Since the quality of tap water affects our health either direct or indirectly, the water treatment process becomes a very worthy subject for research, and coagulation is one of it. The main concern in the study of coagulation process is the coagulants. Alum (aluminium sulphate) is by far the most widely used coagulant in water and wastewater treatment. However, alum in water treatment can cause Alzheimer's disease. Its residual in water triggers such health related problems (Ndabigengesere and Narasiah, 1998). The coagulation effect of *Moringa Oleifera* seeds receives a great deal of attention. Among others were on coagulation active agents, mechanism of coagulation (Ndabigengesere *et al.*, 1995; Okuda *et al.*, 2001), and improve method to extract coagulation active component (Okuda *et al.*, 1999 and Bhole, 1995).

Cowpea, often call *long bean* in eastern countries, is a potential natural coagulant. *Long bean* has a shape of smooth pale green pods. It is frequently used in oriental cooking. *Long bean* can grow up to 40 cm. Some varieties such as *yard-long beans* can even grow longer. It is a cheaply priced vegetable that grows in Malaysia and ready to harvest in just around 50~60 days.

The purpose of this study is hence to examine the quality of the turbid water treated by coagulation process using *long bean* to explore its potentiality and compare it with that of the alum treated water.

MATERIALS AND METHODS

Model Turbid Water

For the purpose of this study, a synthetic turbid water was prepared by adding kaolin of laboratory grade into distilled water. Coagulation study was conducted based on this turbid water. Two grams of kaolin were added into a beaker containing 800 ml of distilled water. The suspension was stirred at 100 rpm for 30 minutes using jar test apparatus for uniform dispersion of the particles. The suspension was then allowed to stand for at least 20 hrs to allow for complete hydration of the kaolin. This was used as the stock solution for the preparation of water samples for the coagulation tests. From the stock solution, turbidity of 100 NTU was prepared by serial dilution of the stock solution. Turbidity was measured using a Hach turbidimeter Model 2100N. Four types of bivalence cationic salts i.e. $FeSO_4.7H_20$, $MnSO_4.H_2O$, $CaCl_2.2H_2O$ and $Ca(OH)_2$ were also added into the diluted turbid water accordingly.

Preparation Of *Long Bean* Suspension

Long bean used for this study was procured from local market. First, it was sun-dried for two weeks, and heated for half an hour in an oven at 55°C before ground into powder using ordinary food blender. Active coagulation component of *long bean* was extracted using 1 mol/L sodium chloride (NaCl) solution. One gram ground *long bean* and 5.85 g NaCl salt were added into 100 ml distilled water and stirred at 100 rpm for 30 minutes using jar test apparatus to extract the active ingredient. Then the residual was filtered using a Whatman filter paper. The filtered green coloured stock solution was used as coagulant. The stock solution was prepared fresh for use and when needed since deterioration sets after extended period of storage.

Preparation Of Alum

Alum [$Al_2(SO_4)_3.18H_2O$] was used to compare the performance of the *long bean* as a potential coagulant. The alum solution used for the comparison test was prepared by adding 10 gram of alum into 1 litre distilled water.

Coagulation Test

Coagulation tests were conducted using jar test apparatus of Phipps & Bird using 400 ml capacity jars.

First, a rapid mix at 100 rpm for 2 minutes at which during this time, the required coagulant dosage was quickly added into all beakers using pipette. Then followed by a slow mix of 30 minutes at 40 rpm. After that, followed by 30 minutes of sedimentation.

Comparative coagulation tests were run under the same conditions as described above but using alum solution instead of *long bean*.

RESULTS AND DISCUSSION

Moringa Oleifera seed 1 mol/L can dissolve in distilled water as well as in NaCl solution contained 1 mol/L NaCl. The NaCl extracted *Moringa Oleifera* coagulant showed a remarkable coagulation activity when the turbid water contained strong bivalence cation such as Mg^{2+}, Ca^{2+}, or Ba^{2+}. These bivalence cations might electrically be absorbed to the negatively charged *Moringa Oleifera* active component to form insoluble net-like structure to capture the suspended kaolin particle. On the other hand, the univalent cation cannot form nets because one valence cannot connect to two active components together. A mechanism called "enmeshment" mechanism has therefore been suggested. (Ndabigengesere *et al.*, 1995; Okuda *et al.*, 2001).

Earlier study on *long bean* indicated that it did not dissolve completely in water and hence did not contain water soluble coagulation active component. When 1 mol/L NaCl extracted *long bean* suspension was used, it showed coagulating characteristics when the model turbid water contain sufficient dosage of $CaCl_2$ salt. This can be seen in Fig. 1 below.

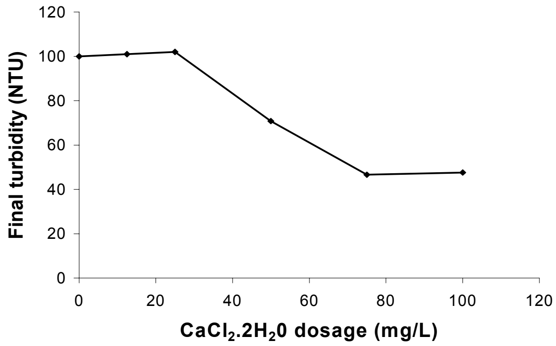

Figure 1: Effect of $CaCl_2.2H_2O$ with 40 mg/L *long bean* suspensions on model turbid water with initial turbidity of 100 NTU.

The calcium chloride used in the study was calcium dihydrate [$CaCl_2.2H_2O$]. Fig. 1 shows that the optimum dosage of $CaCl_2.2H_2O$ was found to be at 75mg/L. A minimum dosage around 25~50 mg/L of $CaCl_2.2H_2O$ was needed for coagulation. This is equivalent to 0.23~0.45 mmol/L $CaCl_2.2H_2O$. This finding was comparable with results obtained by Okuda *et al.* (2001) that at least 0.2 mmol/L Ca^{2+} was necessary for coagulation using salt extracted *Moringa Oleifera* coagulant.

Bivalence cation, such as Ca^{2+} by itself can react as coagulant agent at a sufficient dosage because it can destabilize negatively charged colloid. However, the possibility of that, flocs formed due to $CaCl_2$ instead of *long bean* was not true. Jar test was conducted using $CaCl_2.2H_2O$ as coagulant without *long bean* to justify this hypothesis. The results have shown that at least 125 mg/L $CaCl_2.2H_2O$ was needed to form the flocs.

However, in this study of using *long bean*, it showed that 75 mg/L $CaCl_2.2H_2O$ was enough for coagulation purposes. Thus, *long bean* has coagulation effect up to a certain degree. *Long bean* was then further studied by varying its dosage at 75mg/L of $CaCl_2.2H_2O$ to obtain its optimum coagulation condition as shown in Fig.2.

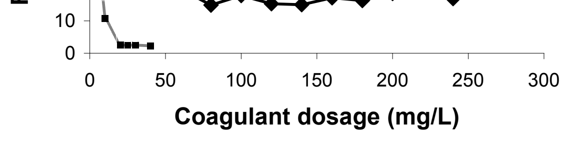

Figure 2: Coagulating activity of (a) *long bean* with 75mg/L calcium chloride [$CaCl_2.2H_2O$], and (b) alum with 10mg/L hydrated lime [$Ca(OH)_2$].

Unfortunately, the turbidity removal efficiency of *long bean* was far behind of that compared to alum. At optimum dosage, *long bean* achieved an average turbidity removal efficiency of 80% whereas alum achieved a higher percentage of 97.2%.

Observation has showed that the flocs formed faster as the *long bean* dosage was increased. However, the trend line of *long bean* suggested that the optimum *long bean* dosage was around 100 mg/L. There was no significance improvement with the increase of *long bean* dosages after this. This was mainly because of the coagulation activity

depended on both *long bean* dosages and $CaCl_2.2H_2O$ dosages. For *long bean* dosages of 100 mg/L or above, the 75 mg/L $CaCl_2.2H_2O$ was fully utilized to achieve final turbidity of around 16 NTU. Similarly, at $CaCl_2.2H_2O$ dosage of 80 mg/L or above, the 40 mg/L *long bean* was fully utilized to achieve final turbidity of 46.6 NTU (Figure 1). Hence, the turbidity removal efficiency using *long bean* as shown in Figure 2 will be improved by increasing the calcium chloride dosages. On the other hand, the turbidity removal efficiency will be improved as well by increasing the *long bean* dosages (as shown in figure 1).
It must be noted that the flocs formation using *long bean* do not settled completely within 30 minutes. The complete sedimentation process took approximately 1 ½ hours. It was not due to the flocs size because the flocs size were comparable to those at optimum alum dosage. It may be possible that the flocs using long bean is lighter in weight as compared those using alum.

The study of *long bean* was repeated using hydrated lime [$Ca(OH)_2$] to replace $CaCl_2$. Interesting result was obtained as shown in Fig. 3. Although lime is not a true coagulant, it is known as coagulant aid and has certain turbidity removal ability. However, in spite of coagulation effect of lime, it showed a similar turbidity removal trend line when compared with $CaCl_2$ at the same molar dosage as can be seen in Fig. 3. Its difference only became significant when $Ca(OH)_2$ dosage was above 0.5 mmol/L. This suggested that *long bean* depended on bivalence cation Ca^{2+} to form the flocs but not anion Cl^- or OH^-. It was very similar to the criteria suggested by Okuda et al. (2001) for their "enmeshment" coagulation mechanism for *Moringa Oleifera* seed coagulation. Thus, it suggested that long bean may have the same "enmeshment" mechanism.

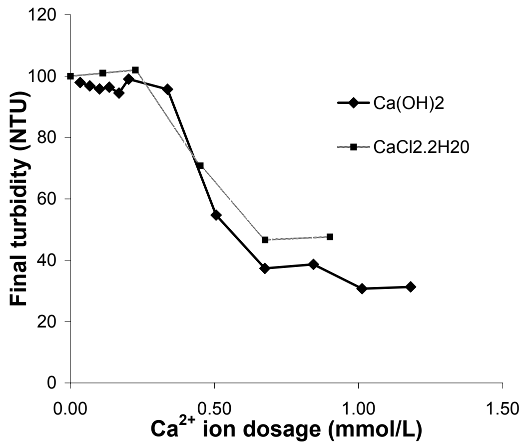

Figure 3: Comparison of the turbidity removal by 40 mg/L *long bean* coagulant, with Ca^{2+} ion from two different salts: (a) hydrated lime [$Ca(OH)_2$] and (b) calcium chloride [$CaCl_2.2H_2O$].

Besides Ca^{2+}, Ba^{2+} and Mg^{2+}also showed a remarkable coagulating activity. For this study, attention was mainly paid to bivalence cations that contained in raw water. If there are suitable bivalence cations existing in raw water, this means that *long bean* can be used in raw water treatment directly, without necessity to add extra bivalence cations into the raw water. The bivalence cations that matched this purpose were Ca^{2+}, Mg^{2+}, Fe^{2+} and Mn^{2}. However, ferrous and manganese are two major parameters need to be removed from raw water for the purpose of water treatment. Their presence in raw water is often significant. For Ca^{2+} and Mg^{2+}, WHO Water Quality Standard stated that the maximum allowable concentration of calcium ion is 200mg/L and magnesium ion is 150mg/L (Nik Fuaad, 1990). According to Ndabigengesere and Narasiah (1998), Sherbrooke tap water contained 48.0mg/L Ca^{2+} and 21.0mg/L Mg^{2+}. This concentration may not true for Malaysia scenario but it is true that raw water contained Ca^{2+} and Mg^{2+} (Brian, 1979). Even if the concentration of these ions is low in Malaysian raw water, the total concentration of these four ions might be still sufficient for coagulation using *long bean*. Since Okuda *et al.* (2001) already justified that Ca^{2+} and Mg^{2+} can caused remarkable coagulation activity, the study will also examined on other bivalence cations such as Fe^{2+} and Mn^{2+}. Ferrous sulphate [$FeSO_4.7H_2O$] and manganese (II) sulphate [$MnSO_4.H_2O$] were chosen in this study. This was because these two salts are easily dissolved in water. Study showed that *long bean* formed flocs with Mn^{2+} but not Fe^{2+} as seen in Fig.4.

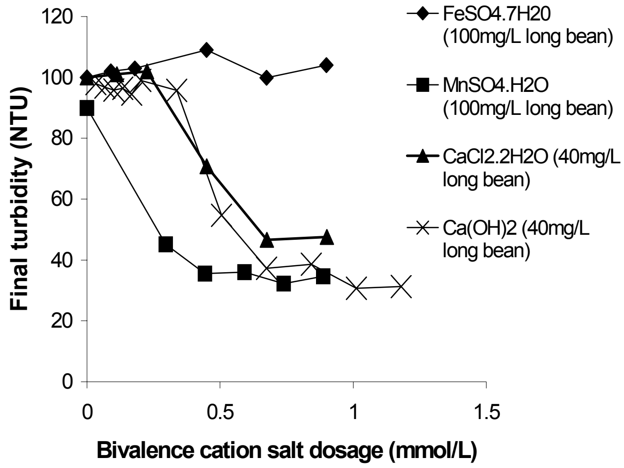

Figure 4: The effect of different bivalence cation salts on turbidity removal using *long bean*: (a) ferrous sulphate [$FeSO_4.7H_2O$] with 100 mg/L *long bean*, (b) manganese (II) sulphate [$MnSO_4.H_2O$] with 100 mg/L *long bean*, (c) calcium chloride [$CaCl_2.2H_2O$] with 40 mg/L *long bean*, and (d) hydrated lime [$Ca(OH)_2$] with 40 mg/L *long bean*.

Overall Fig. 4 shows that manganese (II) sulphate [$MnSO_4.H_2O$] has surprisingly the coagulation effect when used with *long bean*. On the other hand, ferrous sulphate [$FeSO_4.7H_2O$], a well-known chemical coagulant other than alum, showed low coagulation effect. Small flocs were formed at the dosage of 0.67mmol/L $FeSO_4.7H_2O$. Ferrous salt performed the charge neutralization coagulation mechanism. This mechanism needs alkalinity in the water. So it was possible that the coagulation activity was low because there was insufficient alkalinity. At this stage, it was deduced that ferrous salt will not help coagulation using *long bean*, whereas manganese (II) ion and calcium ion tested were being able to formed flocs when *long bean* was used. These two cations may be in low concentration than expected in Malaysian raw water, or they may not be in free cation conditions (may be in complex structure) that can react with *long bean*.

Fig. 4 also shows that the coagulation using *long bean* does not depend on pH. It is clear in this study that flocs were formed when calcium chloride, manganese sulphate or hydrated lime was added. Turbid water was acidic when Cl^- or SO_4^{2-} is added, but it became alkaline when OH^- was added. Since flocs formed in both acidic and alkaline cases, it indicated that coagulation using *long bean* did not depend on pH. Also, final pH of treated water was in the range of 6.88~7.01. It suggested that coagulation using *long bean* do not significantly affect the pH value.

Effect of NaCl

The *long bean* active component was extracted using NaCl, and Na^+ is a univalent cation. Thus, NaCl would have certain coagulating effect. In fact, in the study of colloid science, the coagulation power of NaCl is been tested long ago (Jirgensons and Straumanis, 1962). It showed that univalent cation such as NaCl has coagulation power 20~80 times weaker than bivalence cation salt such as $CaCl_2$. However, the coagulation effect of cations mixture was additive (Jirgensons and Straumanis, 1962). It means that if NaCl has coagulation power of 0.1 unit, and $CaCl_2$ has coagulation power of 1.0 unit, the mixture of NaCl and $CaCl_2$ will have total coagulation power of 1.1 unit. Hence the NaCl contained in *long bean* will enhance the charge neutralization coagulation effect of Ca^{2+}. However, the coagulating power of NaCl was not high. It would not enhance the coagulation power of $CaCl_2$ to a significance degree. Hence, if mixture of NaCl and $CaCl_2$ were to cause the charge neutralization mechanism in the study, it would not be dominant mechanism in the coagulation process. The dominant mechanism still was the reaction between *long bean* and $CaCl_2$.

Although NaCl did not help much in coagulation, it can extract the active coagulation agent in *long bean*. The NaCl increases the affinity of the distilled water, causing it possible to extract the ionic active coagulation component contained in *long bean*.

Conclusions

NaCl extracted *long bean* coagulant is proved to have coagulation effect when bivalence cation Ca^{2+} or Mn^{2+} is contained in turbid water. Since raw water contains these bivalence ions, it is an advantage to utilize these ions, other than to remove it. These ions will settle together with the flocs. Besides that, *long bean* coagulation does not depend on pH. *Long bean* also has advantage as non-toxic coagulant. Unlike chemical coagulant such as alum, *long bean* is an organic material.

However, *long bean* turbidity removal efficiency is lower than alum. The second disadvantage is that complete sedimentation of flocs using *long bean* takes more than 30 minutes. Third disadvantage is that it NaCl salt is required to extract the active coagulation component.

Turbidity removal efficiency depends on both *long bean* dosage and total concentration of bivalence cations contained in raw water. The coagulation efficiency dropped when either one is insufficient. Raw water does not have a constant turbidity and bivalence cations concentration.

In short,

1. One mol/L NaCl salt solution is used to extract active component of *long bean* in this study.
2. *Long bean* only removes turbidity when sufficient bivalence cations contained in turbid water such as Ca^{2+} and Mn^{2+} cations. The coagulation activity does not depend on anions such as Cl^-, OH^-, and SO_4^{2-}.
3. *Long bean* coagulant is not pH dependent.
4. At the tested dosage range, optimal dosage found for *long bean* is 100 mg/L, with addition of 75 mg/L calcium chloride [$CaCl_2.2H_20$]. It removes 80% of turbidity and hence *long bean* turbidity removal efficiency is lower as compared to alum.

At this moment, *long bean* still has many weaknesses and further research is still needed.

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Automatic Control Of Dissolved Oxygen Concentration For Activated Sludge Process In A Sequencing Batch Reactor

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ABSTRACT: This paper presents the automatic control of dissolved oxygen (DO) concentration for activated sludge process in a sequencing batch reactor (SBR). Dissolved oxygen (DO) concentration is regarded as the most important control parameter in the biological nitrogen removal processes. Too high dissolved oxygen concentration will lead to unnecessary power consumption due to high aeration and can affect the anoxic process. A DO concentration that is too low inhibits bacterial growth. Therefore, the optimum condition of SBR processes can be achieved by adjusting the dissolved oxygen set point according to the effluent of chemical oxygen demand (COD) and ammonia concentration. In this work, automatic control of dissolved oxygen (DO) concentration for activated sludge process in a sequencing batch reactor (using Artificial Neural Network) has been developed. The development encompassed neutral network controller with the basic scheme. Neural Network controller was developed with DO as the control variable. The method proposed utilizes feed forward network in the direct inverse neural network control method. The control strategy was developed after the by simulation study of the dynamic behavior of the system. The results showed that the controller that depends merely on the neural network model is able to provide reliable control performance but it cannot control smoothly when disturbances enter the process.

INTRODUCTION

Along with development of automatic instruments and computers, various types of automatic control technology for wastewater treatment have been developed. Many studies have reported significant improvements of the effluent quality and the reduction of operating cost due to the application of automatic control.

The dissolved oxygen (DO) concentration of the activated sludge process has been recognized as an important variable to be controlled both for economical and process efficiency purposes. Proper control of DO could achieve improved process performances and there is an economic incentive to minimize excess oxygenation by supplying only necessary air to meet the time-varying oxygen demand of mixed liquors. Despite the relatively simple dynamics of the DO mass balance, the control may be difficult because of time-varying influent wastewater conditions, non-linearity, time delay, sensor noise and slow sensor dynamics. Due to their impressive capability in dealing with severe nonlinearity and uncertainty of a system, the application of neural network method for the design of controllers is flourishing (Hussain, 1999).

To overcome these problems, several adaptive control strategies have been suggested recently for the control of DO concentration in the aeration basin (Lindberg and Carlsson, 1996; Lindberg, 1997; Yoo et al., 1999). Although the afore mentioned conventional control strategies worked reasonably well for the continuous activated sludge process for carbon removal, they can not be applied directly for modern biological nutrient removal (BNR) activated sludge process, in part due to the low food/microbial ratios of the latter. Consequently, Zhao et al. (1994) introduced a model-based predictive control strategy to reduce the effluent ammonia, nitrate and nitrite (SNOx) by adjusting the cycle length of a sequencing batch reactor (SBR) scheme. Using the same SBR process, Isaacs et al. (1995) formulated an adaptive control scheme by introducing an external carbon source, in order to achieve a similar end.

In this paper, modeling and control strategies for biological nitrogen removal process in a sequencing batch reactor using artificial neural network will be introduced. Simulation data from the mathematical model of a sequencing batch reactor was used to train and test various neural network topologies. The control method proposed utilizes feed forward neural networks in the direct inverse neural network control method. The proper control strategy is developed after being preceded by simulation study of the dynamic behavior of the system.

MODEL DEVELOPMENT

In the Sequencing Batch Reactor (*SBR*) system, all treatment steps take place in a single reactor with different phases separated in time. The cycle in a typical SBR is divided into five discrete time period: Fill, React, Settle, Draw, and Idle period. Different biological reactions, including carbonaceous *COD* removal, nitrification, denitrification and uptake, can be readily realized to the desired extent with proper sequence.

The models used in the simulation studies are based on the Activated Sludge Model No1, or ASM (Henze *et al*., 1987)., as below;

Mass balance for the readily biodegradable substrate:

$$\frac{dS_s}{dt} = \frac{F}{V}(S_{s,f} - S_s) - \frac{1}{Y_H} r_{H,G} + r_h \quad (1)$$

Mass balance for the slowly biodegradable substrate:

$$\frac{dX_s}{dt} = \frac{F}{V}\left(X_{s,f} - X_s\right) + (1 - f_p)(r_{H,d} + r_{A,d}) - r_h \quad (2)$$

Mass balance for the nitrate and nitrite:

$$\frac{dS_{NO}}{dt} = \frac{F}{V}(S_{NO,f} - S_{NO}) + \frac{1}{Y_A} r_{A,G} - \frac{1 - Y_H}{2.86 Y_H} r_{H,G}^{anoxic} \quad (3)$$

Mass balance for the ammonium:

$$\frac{dS_{NH}}{dt} = \frac{F}{V}(S_{NH,f} - S_{NH}) - \left(i_{XB} + \frac{1}{Y_A}\right) r_{A,G} + r_{NH} - i_{XB} r_{H,G} \quad (4)$$

Mass balance for the soluble organic nitrogen:

$$\frac{dS_{ND}}{dt} = \frac{F}{V}(S_{ND,f} - S_{ND}) + r_h \left(\frac{X_{ND}}{X_s}\right) - r_{NH} \quad (5)$$

where:

$$r_{A,G} = \mu_A \left(\frac{S_{NH}}{K_{NH} + S_{NH}}\right)\left(\frac{S_o}{K_{OA} + S_o}\right) X_{BA}$$

$$r_{H,G} = r_{H,G}^{aerobic} + r_{H,G}^{anoxic}$$

$$r_{H,G}^{aerobic} = \mu_H X_{BH} \left(\frac{S_s}{K_s + S_s}\right)\left(\frac{S_o}{K_{OH} + S_o}\right)$$

$$r_{H,G}^{anoxic} = \mu_H X_{BH} \left(\frac{S_s}{K_s + S_s}\right) \eta_g \left(\frac{K_{OH}}{K_{OH} + S_o}\right)\left(\frac{S_{NO}}{K_{NO} + S_{NO}}\right)$$

$$r_{NH} = k_a S_{ND} X_{BH} \left[\left(\frac{S_o}{K_{OH} + S_o}\right) + \eta_g \left(\frac{K_{OH}}{K_{OH} + S_o}\right)\left(\frac{S_{NO}}{K_{NO} + S_{NO}}\right)\right]$$

$$r_h = k_h \frac{X_s / X_{BH}}{K_X + (X_s / X_{BH})} X_{BH} \left[\left(\frac{S_o}{K_{OH} + S_o}\right) + \eta_h \left(\frac{K_{OH}}{K_{OH} + S_o}\right)\left(\frac{S_{NO}}{K_{NO} + S_{NO}}\right)\right]$$

The dynamics of S_o is described by the nonlinear differential equation (Olsson and Newel, 1999). Accordingly, the mass balance for dissolved oxygen in the reactor is:

$$\frac{dS_o}{dt} = \frac{F}{V_f}(S_{o,f} - S_o) - \frac{1 - Y_H}{Y_H} r_{H,G}^{aerobic} - \frac{4.57 - Y_A}{Y_A} r_{A,G} + k_L a(Q_{air}(t))(S_{o,sat} - S_o(t)) \quad (6)$$

The function $k_L a(Q_{air}(t))$ describes the oxygen transfer and it is in general nonlinear and depends on aeration actuating system and sludge conditions. It is assumed linear (Olsson and Newell, 1999) and given by the following equation:

$$k_L a(Q_{air}(t)) = a\left(1 - e^{-\frac{qA(t)}{b}}\right) \quad (7)$$

The system characteristics, kinetic parameter, influent and initial conditions employed for the process is shown in Table 1.

Table 1: System characteristics, kinetic and stoichiometric parameters

Parameter	Value	Parameter	Value	Parameter	Value
Y_H	0.67	S_{Osat}	10	*DOf*	6.8
μ_H	6	a	166	*XbHf*	0.001
K_S	20	b	16	*XbAf*	0.001
K_{OH}	0.2	k_a	0.08	*SNof*	35
Y_A	0.24	f_p	0.08	*SNDf*	50
μ_A	0.8	i_{xb}	0.086	*XNDf*	10
K_{OA}	0.4	i_{xp}	0.06	*XbHo*	2240
b_H	0.62	t_r	2.5	*XbAo*	560
K_{NO}	0.5	V_f	10000	*Sso*	12
K_{NH}	0.3	t_f	0.5	*SNHo*	0.6
K_{NH}	0.3	V_o	2400	*DOo*	0
b_A	0.15	V_t	12400	*Xso*	20
k_h	3.0	F	20000	*SNoo*	0.01
η_g	0.8	*Xsf*	250	*SNDo*	0.4
η_h	0.4	*Ssf*	513	*XNDo*	3
K_x	0.03	*SNHf*	20	*OURo*	250

Data from Lau et al., 1984; Dold & Marais, 1986; Henze, et al 1987

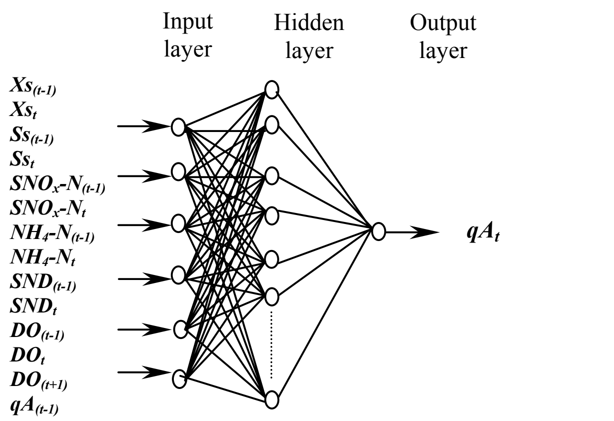

Figure 1: Typical Neural Network Control for SBR

DESIGN OF NEURAL NETWORK INVERSE MODEL

In this scheme, inverse model is used directly as elements within the feedback loop. The network inverse model is utilized in the control strategy by simply cascading it with the controlled system or plant. The plant inverse neural model represents the inverse dynamics of the plant; it computes directly the estimated value of the control variable that drives the plant to the desired output (Figure 1). In this case, the neural network acting as the controller has to learn to supply its output, the appropriate control parameters, u for the desired targets and y_{sp} as input. The quality of the model relies strongly on how well the learning algorithm is able to extract the essence of the data in order to best represent the dynamic behavior of the process.

The neural networks used in this study is the multi-layer-perceptron (MLP) and Levenberg-Morquardt method is adopted for training the neural network. For the hidden layer, tansig transfer function is used while purelin transfer function is used for the output layer. The training cycle was repeated with all input/output pair patterns in data set, and the iteration was continued until the error function was minimized. The input and output of a hidden neuron can be represented as follows:

$$S = \sum_{i=1}^{nh} (b + w_i I_i) \quad (8)$$

$$O = \frac{1}{1 + \exp(-S)} \quad (9)$$

where b is a bias, I_i is the ith input to the hidden neuron, w_i is the weight associated with I_i, and O is the hidden neuron output. Eq.(9) is known as the sigmoidal neuron activation function and its output is in the range (0,1). For process modeling applications, output layers usually use the linear activation function since it can give a wide range of outputs.

The network weights are trained till such a time that the sum of squared network prediction errors is minimized. The prediction results are evaluated by root mean square error that is defined as

$$RSME = \sqrt{\left(\frac{1}{N}\sum_{t=1}^{N} (y(t) - \bar{y}(t))^2\right)} \quad (10)$$

where *RMSE* is the number of training data points, $\bar{y}$ is the network prediction, y in the target value, and t is an index of the training data.

Training Data Generation

Data for training the neural network in the simulation study are obtained by solving the ordinary differential equation (ode23s). Firstly, a set of simulation data from the mathematical model of a sequencing batch reactor was used to train and test various neural network topologies. In this study, to obtain the training data sets, the airflow rate was changed to get the value of dissolved oxygen (DO) for set-point control. In order to train the neural network model, four sets of plant data were collected. The models were chosen in an effort to identify the one that best represent the system. That data were divided into three training sets and a validation data set, and preprocessed before training the ANN using back propagation algorithm and scaled down between 0 and 1 by normalizing them with their respective maximum values.

Training of the neural network models was carried out using the Neural Network Toolbox, MATLAB 6.5.

Forward Modeling

The procedure of training a neural network to represent the dynamics of the system is referred to as forward modeling. The inputs to the forward model consist of the present and past values and can be expressed mathematically as shown below:

$$DO_{(t+1)} = f(Xs_{(t-1)}, Xs_t, Ss_{(t-1)}, Ss_t, SNo_{(t-1)}, SNo_t, NH_{4(t-1)}, NH_{4t}, SND_{(t-1)}, SND_t, DO_{(t-1)}, DO_t, qA_{(t-1)}, qA_t). \quad (11)$$

The model is made of 14 input nodes; 24 hidden nodes and one output node. The validation result for the forward model is shown in Figure 2. The results show that the neural network model has been properly trained to predict the forward dynamics of the system.

Figure 2: Forward model validation result

Inverse Modeling

Inverse modeling is referred to the training of neural network to predict the control action by changing the connection weightings in order to minimize the error between the current control action and predicted control action. In determining the inverse model to use as the controller, the network architecture and activation functions that were chosen are similar to the forward model. The inverse model architecture is shown in Figure 1 and mathematically, the inverse model is expressed as a function of inputs to the model as shown below:

$$qA_t = f(Xs_{(t-1)}, Xs_t, Ss_{(t-1)}, Ss_t, SNo_{(t-1)}, SNo_t, NH_{4(t-1)}, NH_{4t}, SND_{(t-1)}, SND_t, DO_{(t-1)}, DO_t, DO_{(t+1)}, qA_{(t-1)}) . \quad (12)$$

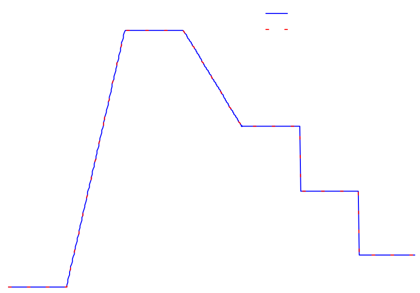

Figure 3: Inverse model validation result

The validation result for the inverse model is shown in Figure 4. The network was trained until the RSME reached the value of $1.023e^{-007}$.

CONTROLLER PERFORMANCE

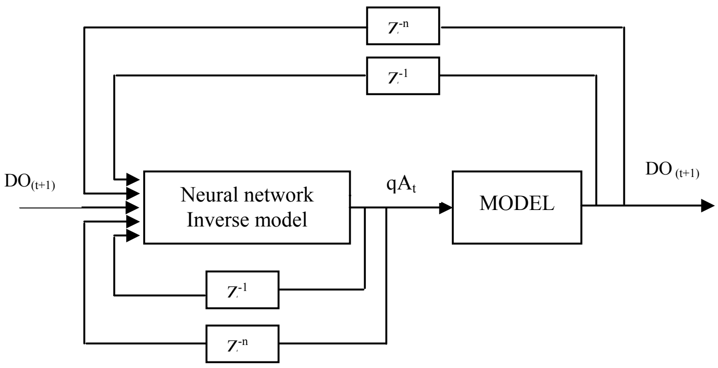

Figure 5: Basic block diagram for model control strategy

Figure 5 shows the basic application of neural network direct inverse control strategy. It is seen that the inverse model acts as the controller and provides the current control action with respect to certain current and past values of the process variables. In this case, dissolved oxygen (DO) was chosen as the control variable and airflow rate as the manipulated variable. This parameter serves as the controlled variable whose nominal operating set point is shows Table 2.

The model is considered to consist of fourteen input nodes, the output of the model is the one-step-ahead difference value of airflow rate. Mathematically, this input-output relationship is expressed by Equation (11). $DO_{(t+1)}$ in Eq. 11 serves either as the output of the process or the controller setpoint in the control operation.

The actual controller output, i.e. the manipulated airflow rate is then obtained by the following equation:

$qA = qA_t$

(13)

$e_t = (DO_{sp} - DO_t)$ *(14)*

The performance of the controller was assessed based on its response characteristics that were observed under nominal and varying operating conditions. The disturbances considered in this study was generated through the changes growth rate for nitrifiers (μ_A), which represent internal disturbance. The nominal and varying values of the set point and disturbances are listed in Table 2.

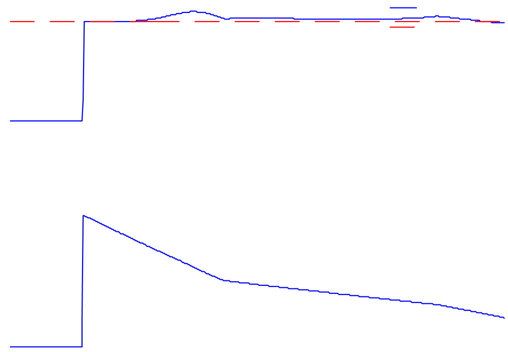

Figure 6: Process and controller response of basic neural network controller for nominal operating condition study.

From the Figure 6, it can be seen that aggressive control actions are observed during t=0.5 h until t=3.5 h. The controller is able to bring the process to follow the given set point changes and is successful in rejecting the disturbances. But, in the period around t = 1h to t = 1.5h, the controller over acts and caused the process response to deviate from the set point

Table2: Variation in the process disturbance and set-point

No	Periods	Set-point, (DO)	Disturbance, (μ_A)
1	0.5-1.0 h	0.006	0.88
2	1.0-1.5 h	0.005	0.72
3	1.5-2.0 h	0.006	0.88
4	2.0-2.5 h	0.005	0.72
5	2.5-3.0 h	0.006	0.88
6	3.0-3.5 h	0.005	0.72

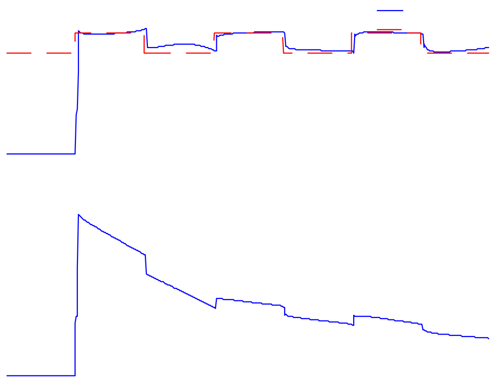

Figure 7: Process and controller response of basic neural network controller for set point tracking study.

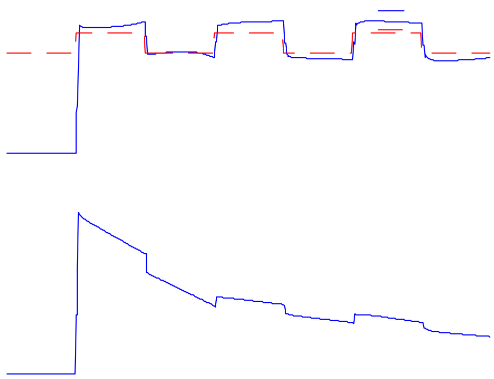

Figure 8: Process and controller response of basic neural network controller for disturbance rejecting condition study.

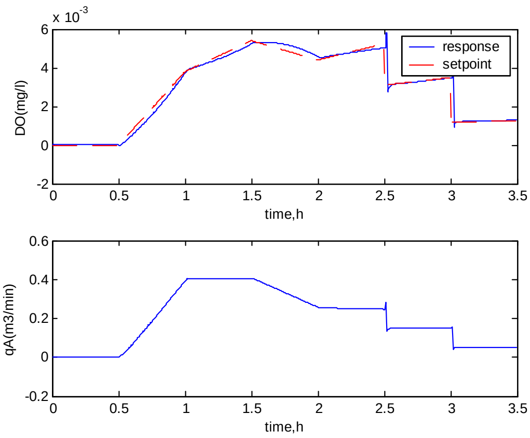

Figure 9: Process and controller response for optimizing supply oxygen at nominal operating condition study.

Figure 9 shows the performance of the controller in maintaining the nominal operating condition in dealing with the variation of set point. The controller is able to bring the process to follow the given set point changes and is successful in rejecting the disturbances. But, in the period around t = 1.5 h to t = 2 h, the controller over acts and caused the process response to deviate from the set point

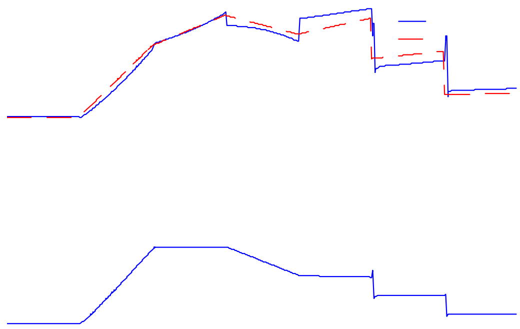

Figure 10: Process and controller response for optimizing supply oxygen at mixed disturbance rejection study

Figure 10 shows the process and controller response of basic neural network controller for mixed disturbance rejection study. It can be seen that the controller performs reasonably when responding to deviation at t = 0.5 h till 1.5 h. But, it becomes sluggish when responding to large deviations in the process response as noticed in figure at t = 1.5 h to 3.5 h. The disturbances considered in this study were generated through the changes in K_La exponent coefficient (b), oxygen haft saturation (K_{OH}), and growth rate for nitrifiers (μ_A). The values of the set point and disturbances are listed in Table 3.

From the results shown above, it can be seen that, since only small oscillations and offset are observed in the process response in Figure 9, the controller is capable of following the time-varying characteristic of the process. The controller seems capable of dealing with the process nonlinearity as indicated by its ability in tracking set point changes.

Table3: Variation in the process disturbance and set-point for optimization supply oxygen

No	Periods	Set-point, (DO)	Disturbance, (μ_A; K_{OH}; b)
1	0.5-1.0 h	$0.076t - 0.0038$	(0.96; 0.24; 19.2)
2	1.0-1.5 h	$0.032t - 0.0006$	(0.64; 0.16; 12.8)
3	1.5-2.0 h	$-0.002t + 0.0084$	(0.96; 0.24; 19.2)
4	2.0-2.5 h	$0.0017t + 0.0010$	(0.64; 0.16; 12.8)
5	2.5-3.0 h	$0.0008t + 0.0011$	(0.96; 0.24; 19.2)
6	3.0-3.5 h	$0.0001t + 0.0009$	(0.64; 0.16; 12.8)

CONCLUSION

In this work, development of a neural network controller for biological nitrogen removal process in a sequencing batch reactor has been studied. The controller performance was evaluated through process and controller response of the basic neural network controller for nominal operating condition and disturbance rejection study. From the results shown above, it is clear that the controller that depends merely on the neural network model is able to provide reliable control performance but it cannot control smoothly when disturbances enter the process.

NOMENCLATURE

a= K_La value at infinite airflow rate (l/d)

b= K_La exponent coefficient (m^3/min)

f_P =Fraction of biomass leading to particulate products

Y_A = Yield for autotrophic biomass (g. N oxidized)$^{-1}$

Y_H = Yield for heterotrophic biomass (g. COD oxidized)$^{-1}$

K_{NH} = Ammonia half-saturation coefficient for autotrophic biomass (g. NH_3-N m^{-3})

k_a = Ammonification rate (m^3 COD (g. day)$^{-1}$)

b_A = Decay coefficient for autotrophic biomass

b_H = Decay coefficient for heterotrophic biomass (day^{-1})

K_S = Half-saturation coefficient for heterotrophic biomass (g. COD m^{-3})

K_X = Half-saturation coefficient for hydrolysis of slowly biodegr. Substrate (g. COD (g. cell COD)$^{-1}$)

i_{XB} = Mass of nitrogen per mass of COD in biomass (g. N (g. COD)$^{-1}$)

i_{XP} = Mass of nitrogen per mass of COD in products from biomass (g. N (g. COD)$^{-1}$)

k_h = Maximum specific hydrolysis rate (g. COD (g. cell COD)$^{-1}$)

K_{NO} = Nitrate half-saturation coefficient for denitrifying heterotrophic biomass (g. NO_3-N m^{-3})

$K_{O,A}$ = Oxygen half-saturation coefficient for autotrophic biomass (g. O_2 m^{-3})

K_{OH} = Oxygen half-saturation coefficient for heterotrophic biomass (g. O_2 m^{-3})

$S_{O,sat}$ = Saturated oxygen concentration (mg/l) Greek Symbols

η_g = Correction factor for μ_H under anoxic conditions

η_h = Correction factor for hydrolysis under anoxic conditions

μ_H = Maximum specific growth rate for heterotrophic biomass(day^{-1})

$_A$ = Maximum specific growth rate for autotrophic biomass (day^{-1})

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Adsorption Of Lead And Copper With Single And Binary Components In Wastewater By Macadamia Shell Granular Activated Carbon

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ABSTRACT: The objective of this study are to determine the optimum conditions of macadamia shell activated carbon synthesis, to study some physical properties of activated carbon and the adsorption capacity of activated carbon on lead and copper, and to predict the binary components adsorption. The maximum conditions for the activation of macadamia shell were carbonization temperature 400°C for 1 hour $ZnCl_2$ 2.93 molar activation temperature 950°C for 3 hours. The carbon demonstrated iodine number 615.58 mg/g and BET surface area 689.70 m^2/g. The studies of lead and copper adsorption capacity by F-300 and Macadamia shell activated carbon were carried out in batch. The effects of adsorption were lead and copper concentration range 2-10 mg/l, pH range 3-9, carbon dose, carbon types and adsorption capacity. The studies were carried out in both single component adsorption and binary components adsorption. From the single component adsorption study, The effects of lead and copper concentration by both adsorbents have a low influence on equilibrium contact times of 240 minutes, successful pH of adsorption was pH 5, the more carbon dose decrease equilibrium contact times, The increasing of pH by both adsorbents increased maximum adsorption capacity, The lead and copper adsorption data of both adsorbents were well fit by Freundlich isotherm than Langmuir isotherm. The comparison of binary components adsorption study, model prediction and experiment, were considered from MSC. Finally, The lead and copper predicted data by F-300 activated carbon were well predicted by Langmuir isotherm than Freundlich isotherm. However, The lead and copper predicted data of Macadamia shell activated carbon by Freundlich isotherm was not similar as experiment.

INTRODUCTION

In present, Thailand has been developing quickly, Economic, Social, Culture and Industrial. Spending a lot of natural resource without pollution management made pollutant in environment for example wastewater, solid waste, air pollution. All of pollution needs to be treated in order to reduce a distribution of these hazard.

Heavy metals are such a kind of hazardous waste such as As, Cu, Hg, Zn, Pb, Cd, Ni, Cr etc. If human or animals are dosed some heavy metal, It can harm consciousness until enzyme system.

Contaminated wastewater can be treated by different processes such as physical process, chemical process, biological process and physical-chemical process, adsorption and reverse osmosis. Both methods conduct high efficiency. The advantage of adsorption are: It is not only remove organic matter but also adsorb heavy metal ions.

So far, Thailand imported expensive activated carbon each year meanwhile there was lot of agricultural waste that is valuable material which can be developed as activated carbon So, in this study macadamia shell was selected to perform chemical activation by $ZnCl_2$ for removing lead and copper in waste water and to be data base for industrial.

MATERIAL

The aim of this study is to investigate the adsorption capacity between macadamia shell activated carbon and F-300 activated carbon and investigate adsorption of lead and copper with single and binary components. A batch adsorption studies were done by using 30 ml of solution. The condition are metal varying concentration range 2-10 mg/l, pH range 3-9 and amount of adsorbent. The system were agitated 200 rpm at room temperature. All solutions were made with distilled water. 0.1 molar of H_2SO_4 or NaOH were used for pH adjustment.

EXPERIMENTAL

Activation study

Macadamia shell was dehydrated at 105°C. Afterward it was performed carbonization at 400-600°C for 1-3 hr respectively. After cooling, The carbonization material was treated with $ZnCl_2$ 2.93 and 7.33 molar at 750-950°C for 1-3 hr respectively. The ratio of $ZnCl_2$ and carbonized material is 2:1 w/w. The $ZnCl_2$ –washed sample were leached by hot distillated water for 2 days. The samples of each conditions were tested Iodine Number in order to analyze the relationship of each factor by statistic software and get optimum condition activated carbon synthesis.

Single component adsorption study

For equilibrium contact time, The total volume 30 ml contained heavy metal concentration range 2-10 mg/l, 0.025 g. of adsorbent and pH range from 3 up to 9. The equilibrium isotherm were conduct by varying heavy metal concentration range 2-10 mg/l, 0.025-0.3 g. of adsorbent. After equilibrium contact time, The mixture was filtrated through Whatman No.1 filter paper and the filtrated was analyzed residual heavy metal by atomic absorption spectrophotometer (GBC Atvanta Model GF3000).

Binary components adsorption study

The concentration ratio of the first: second metal were 1:1, 2.5:1 and 5:1 respectively. The condition of equilibrium contact time was as same as Single component system but the equilibrium isotherm contain 15 ml of each. The data were evaluated using Langmuir isotherm and Freundlich isotherm.

Predictions of binary adsorption isotherm study

In this work Extended-Langmuir isotherm and Extended-Freundlich isotherm were used to described the equilibrium data (Al-Asheh *et al*., 2000). These models were shown in equation 1 and 2 respectively

Extended- Langmuir

$$(X/M)_i = \frac{a_i b_i C_{ei}}{1 + \sum_{j=1}^{m} b_j C_{ej}} \quad (1)$$

X_i = The uptake of component *i* (mg).

M = Weight of adsorbent (g).

a_i, b_i = Langmuir constants which derive from single solution system.

C_{ei} = The equilibrium concentration of component *i.*

C_{ej} = The equilibrium concentration of component *j.*

m = Number of component in system.

Extended- Freundlich

$$(X/M)_i = \frac{n(K_i/n_i)^{1/n_i} C_{ei}}{((K_i/n_i)^{1/n_i} C_{ei} + (K_j/n_j)^{1/n_j} C_{ej})^{1-n}} + \Delta F_2 \quad 2$$

$$\Delta F_2 = \frac{(n_i - n_j)((K_i/n_i)^{1/n_i} C_{ei})((K_j/n_j)^{1/n_j} C_{ej})}{((K_i/n_i)^{1/n_i} C_{ei} + (K_j/n_j)^{1/n_j} C_{ej})^{2-n}}$$

$$\times \ln(((K_i/n_i)^{1/n_i} C_{ei})((K_j/n_j)^{1/n_j} C_{ej}))$$

$$n = \frac{n_i (K_i/n_i)^{1/n_i} C_{ei} + n_j (K_j/n_j)^{1/n_j} C_{ej}}{(K_i/n_i)^{1/n_i} C_{ei} + (K_j/n_j)^{1/n_j} C_{ej}}$$

X_i = The uptake of component *i* (mg)

M = Weight of adsorbent (g)

K_i, n_i = Freundlich constants which derive from single solution system.

C_{ei} = The equilibrium concentration of component *i.*

C_{ej} = The equilibrium concentration of component *j.*

The comparison between the experimental data and those predicted by the two models was expressed by the model selection criteria (MSC) which shown in equation 3 (Al-Asheh *et al*., 2000).

$$MSC = \ln\left[\frac{\sum_{i=1}^{n} (X/M_{exp,i} - \overline{X/M}_{exp})^2}{\sum_{i=1}^{n} (X/M_{exp,i} - X/M_{cal})^2}\right] - \frac{2P}{M}$$

Equation 3

$X/M_{exp,i}$ = The experimentally measured uptake of component *i* (mg/g)

$\overline{X/M}_{exp}$ = The mean of the total measured uptake of experiment (mg/g)

X/M_{cal} = The predicted uptake by the model (mg/g)

P = The number of parameters in the models.

M = The number of experimental data points.

According to this criterion the most appropriate model is the one with largest MSC. The experimental measured uptake was calculated by using equation 4.

$X/M = [(C_o - C_e) \times V]/m$

Equation 4

X/M = The uptake phase (mg/g)
C_o = The initial equilibrium concentration (mg/l)
C_e = The final equilibrium concentration (mg/l)
V = The solution volume(ml)
m = The mass of adsorbent(g)

RESULT AND DISCUSSION

The activated carbon 32 conditions prepared by chemical process were studied Iodine number (mg/g) and analyzed by Minitab Version 13. The optimum condition of activation are: Carbonization temperature 400°C for 1 hour, $ZnCl_2$ 2.93 molar and activation temperature 950°C for 3 hours. The sampling carbon demonstrated iodine number 615.58 mg/g and BET surface area 689.70 m^2/g.

The physical properties of adsorbent in this study were given in table 1. The scanning electron microscope (SEM) of the surface appearance of macadamia shell activated carbon 750x and 2000x were illustrated in figures 1 and 2 respectively.

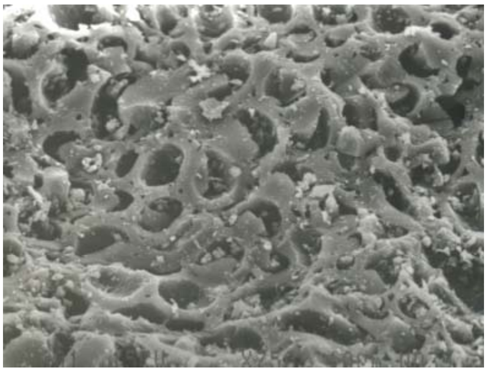

Figure 1 Scanning electron microscope 750X of macadamia shell activated carbon

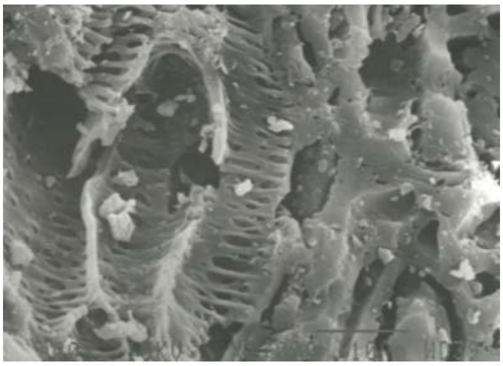

Figure 2 Scanning electron microscope 2000X of macadamia shell activated carbon

The activated carbon were brought in contact with distillated water at pH range 3-9 by using 0.3 g. of adsorbent and 30 ml of solution. The result of released amounts of different ion were given in table 2.

Mohan and Chander 2001 investigated the releasing ion of adsorbents at pH 4. The result were: The wood base activated carbon Nuchar SN, Nuchar SA, Nuchar WV-B mainly released sodium and phosphate meanwhile coal base activated carbon released sodium and calcium the coconut base activated carbon UU released sodium and potassium.

Table 1 Comparison properties of some selected activated carbons

Type Properties	Macadamia shell without activation	Macada mia shell activated carbon	F-300 activated carbon
BET Surface Area(m/g.)	-	689.70[A]	900-1000[B]
Iodine Number (mg/g.)	177.32	615.83	900-950[B]
Particle Size (Mesh)	-	12 X 14	12 X 14
Average Pore Size (A°)	-	14.54[A]	-
Toal Ash(%)	-	2.96	5.76
Moisture(%)	-	3.36	7.83

A Department of chemical engineering Chulalongkorn University, Micromeritics Model ASAP 2000.
B Calgon Carbon Corporation Pennsylvania U.S.A.

Table 2 Releasing of various ions from adsorbents

pH	F-300 activated carbon				Macadamia shell activated carbon			
	Released amount of ions (mg/l)				Released amount of ions (mg/l)			
	Sodium	Potassium	Calcium	Phosphate	Sodium	Potassium	Calcium	Phosphate
3	0.902	1.013	ND	0.010	0.457	0.232	0.377	0.040
5	0.930	0.445	0.194	0.090	0.350	0.143	0.339	0.030
7	0.612	0.026	0.319	0.030	0.597	0.119	0.227	ND
9	2.490	0.077	0.152	0.105	2.380	0.105	0.116	0.010

ND: Non detect

Heavy metals precipitation was studied at concentration 2-10 mg/l in different pH 3-9. The precipitated matter was filled through what man filter paper No.1. The result were shown in table 3.

Table 3 The precipitation of lead and copper at different pH

Element	Initial concentration (mg/l)	Residual concentration(mg/l)			
		pH 3	pH 5	pH 7	pH 9
Lead	2.078	1.354	0.518	0.176	0.019
	5.329	5.029	3.180	0.050	0.002
	10.373	10.373	8.002	0.353	0.019
Copper	2.317	2.317	0.932	0.013	0.000
	5.466	5.466	3.039	0.005	0.000
	11.171	11.171	10.091	0.280	0.021

Corapcioglu and Huang (1987) expressed that metal hydroxo surface species are a function of pH. From their result, It was seen that at each pH there may be several species of metal. Particularly, at alkaline pH, the hydrolysis of metal cations occurs by the replacement of metal ligand in the inner coordination sphere with hydroxyl groups.

Single component adsorption

The results of concentration and carbon dose against contact time, It was found that the contact time results of both activated carbon have the same trend. Lead and copper adsorption at pH 5 were found that the equilibrium contact time for the complete adsorption was 240 min. At first 15 min, The uptake rate of both metals was high because a concentration of heavy in solution are higher when compare to the porous surface area of adsorbents. The uptake amount of metal increasing with an increase in the amount of adsorbent as shown in figure 3.

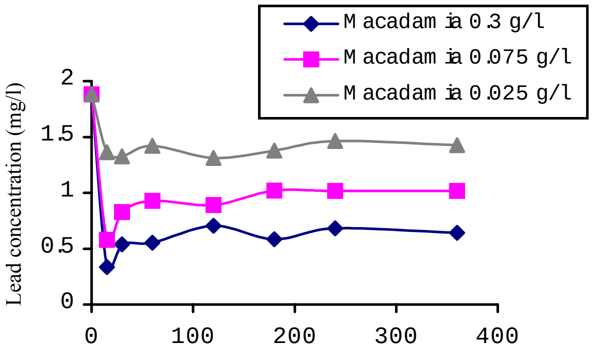

Figure 3 Lead concentration versus contact time at pH 5 by Macadamia shell activated carbon

The result of pH against contact time, the contact time results of both activated carbons have the same trend. According to the lead and copper species at pH 3, Lead and copper species were Pb^{2+} and Cu^{2+} respectively, so adsorption and desorption on adsorbent surface occur continually. At pH 5 the amount of lead hydroxide $Pb(OH)^+$ and copper hydroxide $Cu(OH)^+$ were increased as solution pH was increased. The equilibrium contact time was 240 min. At pH 7-9, there were more aqueous species in the solution when pH is high. The equilibrium contact time was 120 min. as shown in figure 4.

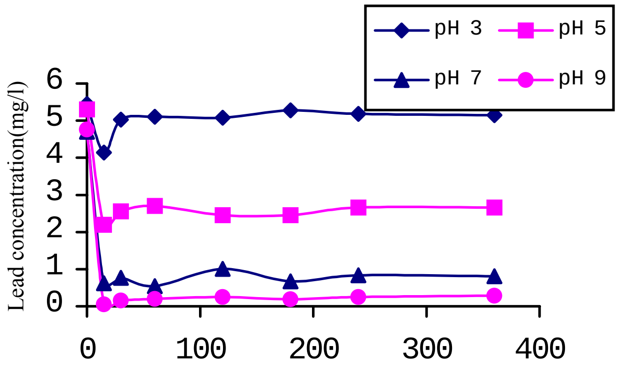

Figure 4 Lead concentration versus contact time by Macadamia shell activated car bon 0.025 g.

The effect of pH against adsorption capacity, the result was seen that effect of pH versus adsorption capacity of both adsorbents was same. The adsorption capacity of metals increase obviously with increasing solution pH. From regression coefficients, the data were better fitted by Freundlich isotherm than Langmuir isotherm. The figures 5 and 6 showed the relationship between log (X / M) and log C_e by using heavy metals concentration 2, 5 and 10 mg/l.

Table 4 summarized the Freundlich parameter k, n and maximum adsorption capacity at different pH.

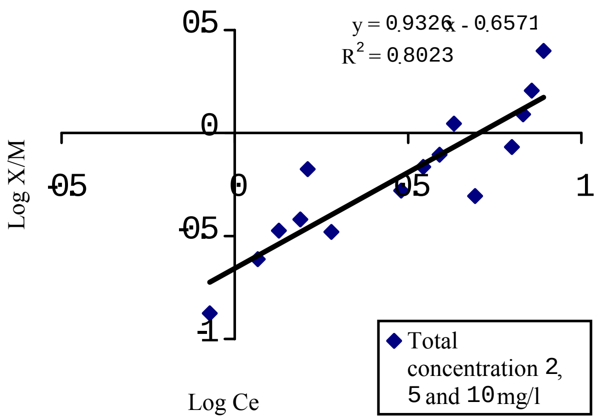

Figure 5 Freundlich plot for adsorption of lead, concentration 2, 5 and 10 mg/l. pH 3 by macadamia shell activated carbon.

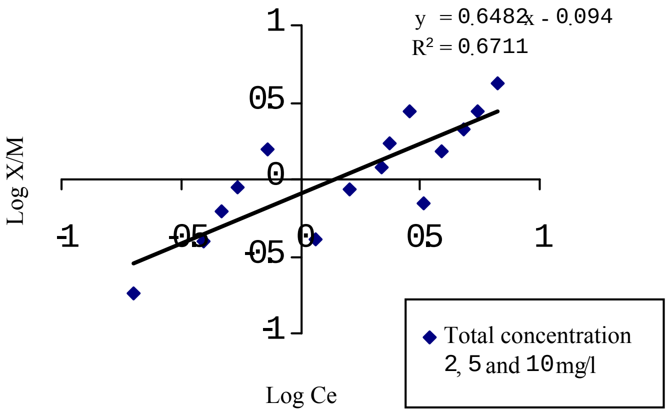

Figure 6 Freundlich plot for adsorption of lead, concentration 2, 5 and 10 mg/l. pH 5 by macadamia shell activated carbon.

Table 4 Parameters constant and adsorption capacity of Freundlich adsorption isotherm for Lead total concentration 2-10 mg/l pH 3-5.

Heavy metal	Lead			
Adsorbent	F-300		Macadamia	
PH	Constant	Adsorption capacity (mg/g)	Constant	Adsorption capacity (mg/g)
3	K=0.745(mg/g) n=5.917	1.097	K=0.220(mg/g) n=1.072	1.863
5	K=6.547(mg/g) n=1.915	21.957	K=0.805(mg/g) n=1.542	3.617

Huang *et al.* (1978) explained the adsorption that a surface charge of adsorbent depends on pH. The points of pH at zero electrophoretic mobility is $pH_{zpc.}$ For example, the pH_{zpc} of F-400 is 7.1. Less than 7.1, the protonation of the functional group gives a proton charge to the adsorbent surface. On the other hand, Increasing the pH more than 7.1 reduces the electrostatic repulsion but exposing more ligans carrying negative charges. However, Metal species depend on pH range as well. The highest Driving force of adsorption will generate when there was a little electrostatic repulsion between adsorbent surface and metal species.

Li *et al.* (2002) studied lead adsorption by CTNs (carbon nanotubes) at concentration 10 mg/l pH 3, 5, and 7. From the experimental data, the constant can be approximated by Freundlich isotherm. At pH 3, Freundlich constants k, n and R^2 are : 0.3184, 1.8 and 0.9945 respectively. At pH 5, Freundlich constants k, n and R^2 are : 5.9918, 1.91 and 0.9877 respectively. At pH 7, Freundlich constants k, n and R^2 are : 7.7179, 1.09 and 0.9974 respectively. Li explained that at pH 3 adsorption effect is very weak due to competition of H^+ with Pb^{2+} on the adsorption site. The increasing pH 5 and 7, the adsorption capacity is higher because of the cooperating role of adsorption and precipitation.

Binary adsorption

The result of concentration, It has seen that the changing of lead and copper concentration has low influence to an equilibrium by both adsorbents but binary components system reach an equilibrium phase faster than single component system. Because of the competition of two metals and reduced ratio of total concentration in system.

The result of pH against contact time, The pH influence of lead and copper adsorption is as same as single component adsorption but Binary system reach an equilibrium faster.

The effect of concentration against adsorption capacity, Increasing metals concentration increase adsorption capacity by both adsorbents. Table 5 shows Freundlich constant, adsorption capacity and Q^{mix}/Q^0 ratio of lead adsorption at different concentration. A detail analysis of regression coefficients shows that the data are well fitted by Freundlich isotherm for binary components system. The Q^{mix}/Q^0 ratio at all lead and copper concentration less than one. It means lead adsorption was suppressed by copper ion. The result for copper is same.

Mohan and Singh (2002) explained that the effect of ionic interaction on adsorption was represented by the ratio of the adsorption capacity constant for one metal in the present of the other metal ions to adsorption capacity constant for the same metal when it present alone in solution.

$Q^{mix}/Q^0 > 1$ means the adsorption is promoted by the presence of other metal.
$Q^{mix}/Q^0 = 1$ means there is no interaction among ion.
$Q^{mix}/Q^0 < 1$ means the adsorption is suppressed by the presence of other metal ions.

Mohan and Singh (2002) compared the single components and binary component system of cadmium adsorption by using Freundlich isotherm constant and Q^{mix}/Q^0. The system were obtain at pH 4.5. A 1:1 ratio was used to find the effect of other metal ions on the cadmium adsorption. It was found that in single cadmium system, the constant k, 1/n and R^2 were 5.78, 0.28 and 0.976 respectively. In cadmium and copper system, the constant k, 1/n, R^2 and Q^{mix}/Q^0 were 4.30, 0.29, 0.9706 and 0.74 respectively. In cadmium and zinc system, the constant k, 1/n, R^2 and Q^{mix}/Q^0 were 1.74, 0.02, 0.9864 and 0.3 respectively.

The result of pH against adsorption capacity of lead and copper, the effect of pH against adsorption capacity of lead and copper of both adsorbents were same. The adsorption capacity of metal increased with increasing pH. Table 5 Shows constant, adsorption capacity and Q^{mix}/Q^0 ratio of lead adsorption by Freundlich isotherm at different pH. From regression coefficient, the data were better fitted by Freundlich isotherm. The Q^{mix}/Q^0 ratio at all lead and copper concentration is less than one. It means lead adsorption was suppressed by copper ion. The result for copper is same.

Table 5 Parameters constant adsorption capacity and Q^{mix}/Q^0 of Freundlich adsorption isotherm for lead total concentration 2-10 mg/l in mixing with copper concentration 2 mg/l pH 3-5.

Heavy metal		Lead					
Adsorbent		F-300			Macadamia		
Innitial Concentration (mg/l)	pH	Constant	Adsorption capacity (mg/g)	Q^{mix}/Q^0	Constant	Adsorption capacity (mg/g)	Q^{mix}/Q^0
2	3	K=0.617(mg/l) n=6.094	0.695	0.899	K=0.146(mg/l) n=0.498	0.627	0.798
	5	K=3.677(mg/l) n=2.327	5.024	0.786	K=2.100(mg/l) n=0.994	4.360	0.911
5	3	K=0.563(mg/l) n=13.774	0.629	0.943	K=0.121(mg/l) n=0.894	0.662	0.953
	5	K=4.995(mg/l) n=2.210	9.910	0.959	K=0.296(mg/l) n=0.537	4.954	0.970
10	3	K=1.058(mg/l) n=8.467	1.391	0.987	K=0.0015(mg/l) n=0.299	3.473	0.750
	5	K=7.666(mg/l) n=3.068	16.297	0.931	K=0.037(mg/l) n=0.455	6.010	0.740

Model prediction of binary adsorption isotherm for lead and copper adsorption.

From previous lead and copper adsorption experiments by both adsorption. It was found that at pH 3 adsorption capacity was rather low. In order to avoid metal precipitation at pH 7, Model prediction experiments were conducted only pH 5.

The table 6 shows statistical parameter model selection criteria (MSC) which obtained from F-300. The predicted results expressed that Langmuir isotherm are better predicted than Freundlich isotherm at all lead and copper ratio. Figure 7 represented the two-dimensional graph of lead adsorption by F-300.

Table 6 Statistical parameter(MSC) of lead and copper prediction by F-300.

System		Lead in mixing with copper	Copper in mixing with lead
Concentration (mg/l)	Isotherm	MSC	MSC
2 : 2	Freundlich	-2.185	-2.486
	Langmuir	-1.779	-0.406
5 : 2	Freundlich	-3.488	-8.719
	Langmuir	-1.902	-0.366
10 : 2	Freundlich	-4.438	-15.064
	Langmuir	-1.647	-0.364

Table 7 shows statistical parameter model selection criteria (MSC) which obtained from macadamia shell activated carbon. From the two-dimensional graph and MSC, The predicted results of lead and copper by macadamia shell activated carbon was not as fit as experiments.

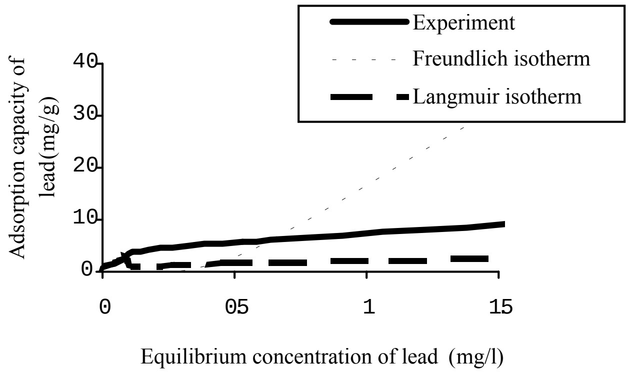

Figure 7 Adsorption capacity of lead 10 mg/l in mixing with copper 2 mg/l by F-300.

Table 7 Statistical parameter(MSC) of lead and copper prediction from macadamia shell activated carbon

System		Lead in mixing with copper	Copper in mixing with lead
Concentration (mg/l)	Isotherm	MSC	MSC
2 : 2	Freundlich	-2.244	-3.165
5 : 2	Freundlich	-2.379	-3.157
10 : 2	Freundlich	-3.127	-3.139

CONCLUSION

Adsorption of lead and copper with single components, the changing of heavy metals concentration has low impact to an equilibrium contact time. Both adsorbent have the same equilibrium contact time 240 min. The increasing carbon doses decreased an equilibrium contact time of lead and copper adsorption by both adsorbents.

The solution pH 3-9 was important parameter that affecting to the adsorption. By both adsorbents, the minimum equilibrium contact time required for complete adsorption of pH range 3-5 was 240 min but for pH range 7-9 was 120 min. The increasing of pH, OH^- in solution increase gradually and make adsorption capacity increase significantly for both adsorbents.

The adsorption data of single component system was better fitted by Freundlich isotherm for both adsorbents. At pH 3, Lead adsorption capacity by F-300 was lower than macadamia activated carbon but at pH 5 adsorption capacity by F-300 was higher. From previous lead and copper adsorption experiments, It is seem that macadamia activated carbon has some potential to remove heavy metals from waste water.

The equilibrium contact time of binary components system was shorter than single component system. In binary component system at pH 3, Lead adsorption capacity by F-300 was quite lower than macadamia activated carbon but at pH 5 adsorption capacity by F-300 was higher at all concentration.
The lead and copper adsorption in binary component system. These metals inhibit the uptake capacity of each other. The lead and copper adsorption by F-300 was better predicted by Langmuir isotherm than Freundlich isotherm. However, The predicted adsorption of macadamia activated carbon by Freundlich isotherm was not appropriate enough.

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3 Environmental Monitoring & Assessment

Trichloromethane Contamination In Water

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Abstract : The residue of trihalomethane in water was analyzed by Headspace-Gas Chromatography with electron capture detector (HS-GC/ECD). All HS parameters and GC conditions were investigated and optimized for high sensitivity, low detection limit, and high precision. These were found to be: equilibrate time 15 minutes, equilibrate temperature 60°C, and phase ratio 2.06. The GC column was 1.7ft*1/8 i.d. glass column, 0.1 % SP1000 on Carbopack C 80/100 mesh at the optimum flow rate 30 ml/min. The column, injector, and detector temperatures were 70, 70 and 250 °C, respectively. The method, at optimum conditions, provided the linearity of 1-100 ppb, limit of detection of 0.3 ppb and relative standard deviation (%RSD) of 3.6. Sample of drinking and tap water were analyzed and trihalomethane residue in drinking water was found to be in the range of N.D. - 5.3 ppb. The concentration of trichloromethane in tap water from Hat Yai City was in the range of 34.72-90.05 ppb and Prince of Songkla University was in the range of 2.1-37.21 ppb.

Keywords: headspace-gas chromatography, electron capture detector (ECD), trichloromethane

INTRODUCTION

In water treatment process, chlorine is the most used disinfectant. It can also react with organic matter to form disinfection by-product (DBPs). The major class of chlorinated disinfection by product in water is the trihalomethanes (THMS), which was also the first category of disinfection by-product that occur from the reaction between chlorine residual
and organic compounds such as humic acid. Trichloromethane is one of the THMS and occurred from the chlorine residue through the following reactions

$$Cl_2 + H_2O \longrightarrow HOCl + H^+ + Cl^-$$
$$C_6H_6O_2 + 7Cl_2 + 4H_2O \longrightarrow CHCl_3 + CO_2 + 10HCl + \text{cis- } HOOCCCl{=}CHCOOH$$

Trichloromethane evaporates very quickly when exposed to air. It is also easily dissolved in water, but does not absorb to the soil very well. This means that it can travel down through soil to groundwater where it can enter a water supply. It can also last for a long time in both air and groundwater (ASTDR, 1997).

It has been estimated that the amount of trichloromethane exposed to human from drinking water ranges from 4 to 88 µg/day. (ASTDR, 1997). However, the amounts of trichloromethane that could be exposed by food and water could not be estimated.

Trichloromethane affects the central nervous system (brain), liver and kidneys after expose by breathing air or drinking liquid that contain large amount of trichloromethane. There were some reports showing a possible link between the trichloromethane in chlorinated water and the occurrence of cancer of the colon and urinary bladder (ASTDR, 1997). The maximum contaminant level for total THMs concentration set by US Environmental Protection Agency was 100 ppb (US EPA, 1988). For trihalomethane, the World Health Organization (WHO) has set the maximum concentration level (MCL) at 30 ppb (World Health Organization, 1984) and the US EPA has also set a maximum concentration level goal (MCLG) at 0 ppb in drinking water.

Removal of trichloromethane from aqueous sample could be performed in several ways such as direct aqueous injection (DAI), liquid-liquid extraction (LLE) and purge and trap. These techniques have a drawback e.g. high cost, take a long time and use a lot of solvent. So in this work, a headspace (HS) technique was selected since it is suitable for the determination of volatile organic compounds. (Afghan, 1980)

HS-GC analysis consists of two steps. First, the liquid sample was placed in a close vial, which was heated at a constant

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temperature until was reached the equilibrium of gas and liquid phases. After equilibrium an aliquot of the gas phase was introduced into the carrier gas stream that carried it into the column (Bruno *et al*., 1997), as shown in Figure 1

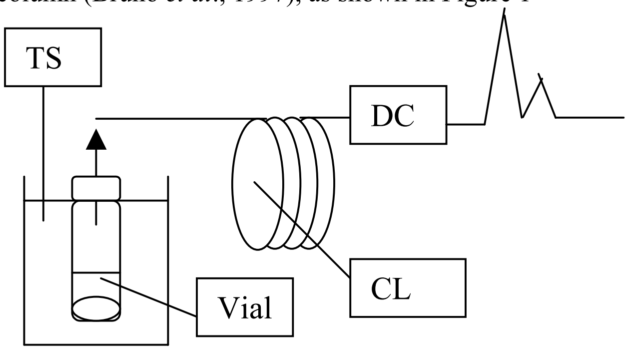

Figure 1 static headspace-gas chromatography; TS: thermostate, DC: detector, CL: column

Kuivinen and Johnsson, (1999) reported the detection limit of trihalomethanes at 0.1 μgl^{-1} and a linear range of 0.1-75 μgl^{-1} using capillary column.

Anastasia *et al*., also studied volatile organic compounds in drinking water by four techniques, i.e. LLE-GC-ECD, LLE-GC-MS, purge and trap - GC-MS and headspace-GC-MS. They found that headspace – GC-MS give a good response for trihalomethanes but it had high detection limit. In this work, the analysis method using HS-GC with ECD, which is more specific to chlorinated compounds, was investigated.

EXPERIMENTAL

Chemicals

Stock solutions of trichloromethane (1,000 μgl^{-1}) was prepared in 10-ml volumetric flasks using 6.8 µl of trichloromethane (BDH Laboratory Supplies, England) and adjusted to volume with methanol. Intermediate standard solutions, 100μgl^{-1}, was prepared by 1 ml. of stock solution into 10-ml. volumetric flask and adjust to volume with methanol.

Intermediate standard solutions were used to prepare the working standard, known volumes of intermediate standard solution were pipetted into deionized water in order to obtain working standard solution with concentrations ranging from 1-1000 μgl^{-1}.

Instrumentation

A gas chromatography (GC-14B, Shimadzu) coupled with ^{63}Ni electron capture detector (ECD) was used. In this study, nitrogen is a carrier gas. The glass column used in this study was a 1.7ft*1/8" packed with 0.1% SP-1000 coated on 80/100 mesh Carbopack C. The analytical conditions of the gas chromatograph are presented in Table 1.The cleanliness of the syringe was confirmed by injecting the empty syringe at the beginning of the day and after injections of high concentrations of standards or samples. At the beginning a blank, series of standards and samples were injected. Check standards and blanks were also injected randomly in between the samples.

The concentrations of the analytes were automatically calculated by the obtainable calibration curves, where the peak areas were plotted against the concentrations.

All glassware used during analysis were washed with detergent, rinse with tap water, deionized water and placed in and oven at 120°C for 2 hours.

Optimization of the HS-GC-ECD conditions

The following parameters for HS-GC-ECD were studied: flow rate of carrier gas (N_2), column, injector and detector temperatures. In the part of headspace, the study parameters consisted of equilibrated temperature, equilibrate time and phase ratio. The relative standard deviations that obtained were less than 4%.

The optimum of flow rate was studied by varying the flow rate of nitrogen i.e. 10-40 ml/min. (five replications of the analysis were performed). The retention time and response, which were determined from the chromatogram, were used to calculate the plate number and high equivalent to a theoretical plate (HETP) respectively. From a Van Deemter plot, the optimum flow rate was obtained at the lowest HETP. The injector, column and detector temperature were varied as 60-90 °C, 60-90 °C and 225-300°C respectively.

Phase ratio, equilibrated temperature and times were studied to obtain the high sensitivity in the headspace technique.

Linear dynamics range was studied by plotting the obtained response versus the concentration. The linearity of the response was obtained by considering the correlation coefficient of the curve.

The determination of a limit of detection was performed by blank measurements, X_b, and a finite small number of blank was normally taken, e.g. n_B = 20 or greater and then calculate for S_B (IUPAC, 1983).

RESULTS AND DISCUSSION

Optimization of Gas Chromatography

All GC parameters e.g. flow rate, column temperature, injection and detector temperature were optimized. The optimum flow rate was 30 ml/min. The column temperature, injector temperature and detector temperature were 70°C, 70°C and 250°C respectively. The GC optimum condition was shown in Table 1. The chromatogram obtained from the optimum conditions that gave the clear and symmetric peak shown in Figure 2.

Table 1 Optimum temperature of HS-GC-parameters

Optimum conditions	Range of study	Optimum condition
Flow rate (ml/min)	10-40	30
Column temperature (°C)	60-90	70
Injector temperature(°C)	60-90	70
Detector temperature(°C)	225-300	250
Equilibrate temperature(°C)	10-25	15
Equilibrate time (min)	50-90	60
Phase ratio	1.17-12	2.06

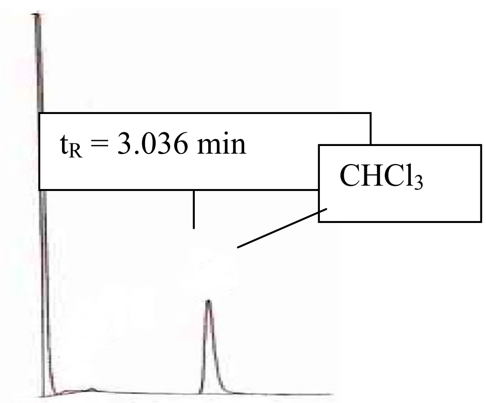

Figure 2 Chromatogram of trichloromethane

Optimization of headspace parameters

All headspace parameters e.g. equilibrate temperature, equilibrate time and phase ratio were studied to obtain high efficiency of analytical performance. Equilibrate temperature was studied in the range 50-90°C. Equilibrate time was studied in the range 10-25 min. The phase ratio of the headspace was also studied since the change in the ratio of the volume between the gas and the liquid phase would affect the transfer of the volatile compound from the liquid to the gas phase. This could affect the sensitivity. Therefore, the phase ratio of headspace was studied by varying the volume of sample from 2 to 20 ml in a 27-ml vial. All of the parameters obtained provided high precision with relative standard deviations (RSD) of less than 4% for five replications.

The optimum conditions were used to study the linear range and the limit of detection. The linear dynamic range obtained was in the range of 1-100 μgl^{-1} (Figure 3) and the limit of detection was 0.27 μgl^{-1}.

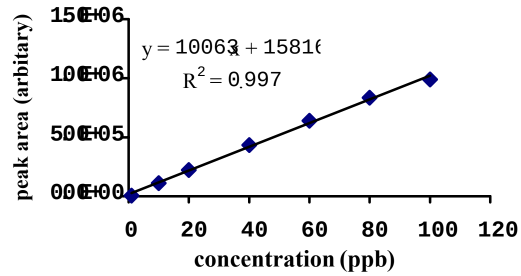

Figure 3 Linear dynamic range

The limit of detection was lower than the lowest concentration of linear dynamic range because the limit of detection calculated by the IUPAC equation, i.e.

$$LOD = kS_B/m$$

Where k is the constant at the confidence levels 99.86%, S_B the standard deviation from injection blank 20 times, and m the slope of the relative graph between concentration and response.

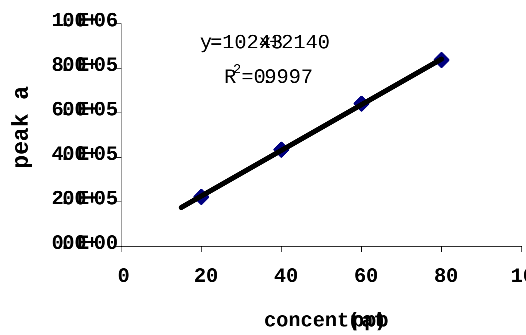

Figure 4 Standard curve for trichloromethane

Analysis of water

The HS-GC-ECD was used for qualifying and quantifying of trace trichloromethane in tap water and drinking water. The optimum conditions were set as Table 1. Tap water samples were collected from 5 sites in Haitian municipal and 5 sites at Prince of Single University. Drinking water samples were purchased from the local stores. All water samples were analyzed at optimum conditions.

The results showed that dichloromethane in tap water in Hat Yak municipal was in the range of 34.7-90.0 μgl^{-1} and at Prince of Songkla University was in the range of 2.1-37.2 μgl^{-1}. Trichloromethane in drinking water was in the range of N.D.-5.3 μgl^{-1}. The average trichloromethane levels in tap water and drinking water were much less than the recommended limits of US EPA and WHO

The recommendation for using this water is to boil it in open system to eliminate trihalomethane. This method can remove between 61% - 82% of trihalomethane in water. In addition, filtering the water through activated carbon can also help to reduce trichloromethane. (Kuo *et al*., 1997)

CONCLUSIONS

Trace analysis of trichloromethane residue in water by headspace-gas chromatography with electron capture detector has advantage over other methods. The headspace technique was simple and inexpensive, no need of sample preparation, and suitable for analysis volatile organic compounds. Moreover, this method with halide-specific detector (ECD) provided a very low detection limit. The total concentration of trichloromethane, obtained from the analysis of drinking water, is less than standard US EPA and WHO (World Health Organization, 1984).

ACKNOWLEDGEMENTS

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Arsenic Concentration in Hair As An Indicator of Exposure

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ABSTRACT: Elevated concentrations of the extremely toxic Arsenic in ground water occur in many parts of the world with largest population being exposed in the entire Bengal delta. Exposure to Arsenic can occur through food, water, and air. One of the biological indicators of exposure to Arsenic is its accumulation in hair. The Arsenic concentrations in hair in this study indicate that the exposure decreased in the following order: West Bengal (India) > Thailand > Malaysia (Kuala Lumpur) > Denmark > Malaysia (Rural); however only in India, Thailand and Kuala Lumpur is there an indication of chronic Arsenic exposure. Our findings also indicate difficulty in distinguishing between external exposure and exposure due to intake of water and food. Hair is a promising indicator of Arsenic exposure, but there is a need for further research to exactly define how Arsenic accumulates in hair and whether the ingested form (organic and inorganic) of Arsenic has an effect on the accumulation rate in hair.

Keywords: Arsenic, Hair, Water, Food

INTRODUCTION

Since the discovery of mass scale Arsenic poisoning in the Bengal Delta Plain (Bangladesh and West Bengal India) a decade ago with an estimated population of 40 million people at risk of drinking Arsenic contaminated water above 10 μg/l, Arsenic in drinking water has caught the attention of both researchers and policy makers (Smedley and Kinniburgh 2002). WHO changed the Maximum Contaminant Level (MCL) of Arsenic in drinking water from 50 μg/l to a provisional guideline value of 10 μg/l in 1993 (WHO, 1996), but it is only recently many industrial countries have adopted the new lowered guideline value. Arsenic is a documented human carcinogen and there are reported incidences of arsenic poisoning through elevated concentrations in air (mostly due to burning of coal containing elevated concentrations of Arsenic) (Liu et al. 2002) and drinking water (mostly groundwater with elevated concentrations of Arsenic)(Karim 2000, Tseng et al. 1968, Chatterjee et al. 1993), whereas limited data is available on arsenic toxicity through food.

According to WHO, 1996 the estimated mean daily intake of arsenic from food is approximately 40 μg, about 10 μg of which is inorganic arsenic, and from drinking water it is generally less than 10 μg in areas without natural sources of arsenic and with arsenic concentration of less than 5 μg/l in drinking water. The estimated intake from air is generally less than 1 μg/l. The toxicity of Arsenic depends on the species with inorganic Arsenic being more toxic than organic arsenic.

Exposure to Arsenic through drinking water can only be determined by measuring the Arsenic content in water since Arsenic is colourless and odourless. The same holds good in case of exposure through food and air. Samples of urine, blood, Hair and Nails can also be used to assess the human exposure to Arsenic, since exposure to Arsenic results in elevated concentrations of Arsenic in these biological samples. Acute and sub-acute Arsenic exposures can easily be determined by measuring Arsenic in the urine, and an arsenic concentration in excess of 50 μg/l (or 100 μg in 24-hour urine) in the absence of any sea food or fish ingestion indicates the symptoms of acute or sub-acute toxicity (Rahman et al. 2001). However hair and finger/toe nails gives more qualified results for chronic exposure to Arsenic and according to WHO a hair As concentration below 1 mg/kg indicates a normal value for individuals exposed to accepted dietary levels. According to the literature survey made by Matschulla 2000, the natural Arsenic concentration in hair, finger/toe nails, blood and urine are 0.02-3.7 mg/kg, 0.2-3 mg/kg, 1.7-10 μg/l, 2-8 μg/l respectively, whereas according to the literature review by Peach and Lane (1998) the reported world average Arsenic concentration in human hair is in the range of 0.01-0.4 mg/kg.

The relationship between hair As and drinking water As concentrations differ between studies. The literature review by Yang et al. (2002), cites a study which reports that an As concentration of 400 μg/l in drinking water gives rise to hair Arsenic of approximately 3 mg/kg, while the same literature review sites other studies where a concentration of 100 μg/l As in drinking water corresponds to 0.26 mg/kg As in hair in California and Nevada: 0.09 mg/kg in Taiwan; 0.94 mg/kg in Bangladesh; 1 mg/kg in Finland. The results obtained by Yang et al. 2002 for 100 μg/l As in drinking water correspond to approximately 1 mg/kg As in hair, while 400 μg/l corresponds with approximately 3 mg/g hair, thus agreeing with the results of one of the studies in their literature review. The results obtained by Kurttio et al.

(1998) indicates that an increase in the arsenic concentration in drinking water of 10 μg/l and an increase in the daily dose of 10-20 μg/d from drinking water correspond to a 0.1 mg/kg increase in the hair arsenic. The above literature review indicates that except for Taiwan and US (California and Nevada) drinking 100 μg/l arsenic contaminated water results in approximately 1 mg/kg arsenic concentration in hair. According to Pazirandeh et al. 1998 the average Arsenic concentration in men was higher than in women. Furthermore the average Arsenic concentration in men/boys in the age group below 20 years was higher compared to other age groups. This may be due to the greater physical activity leading toa higher consumption of water.

Limited data is available in the literature on correlation between Arsenic concentration in food and elevated Arsenic concentrations in hair.

Toxicology studies have shown that inorganic arsenic is absorbed far more rapidly when inhaled than when entering via the gastrointestinal tract or following deposition on intact skin (de Peyster & Silvers 1995). The authors found the following Arsenic concentrations in hair: in the highest exposure potential area (15 μg/m3) 0.042 mg/kg, in the administrative controls 0.033 mg/g, in the slightly exposed 0.034 mg/kg, and the lowest exposure 0.044 mg/kg. The Arsenic concentration in heavy smokers with 1-2 pack cigarettes per day was 0.076-0.106 mg/kg. According to Shraim et al. 2003, the Arsenic concentration in the hair of population exposed to Arsenic in a province of inner Mongolia due to burning of Arsenic rich coal with an arsenic content of 2166.7 mg/kg was 3.08 mg/kg where as in the controlled population with coal Arsenic content of 2.5 mg/kg the Arsenic content in hair was 0.97 mg/kg. The overall estimated mean daily intake of Arsenic per person was 31 mg in the polluted city and only 1.34 mg in the control one. There was no significant difference between concentration of Arsenic in the hair of men and women.

The presence of other ions, such as selenium in the diet can have an effect on Arsenic concentration in hair. According to Yang et al. 2002, with a supplementation of Se the Arsenic concentration in hair decreased from 2.57 +/- 0.16 to 0.68+/- 0.06 mg/kg, where as in controlled population with a placebo tablet the Arsenic concentration decreased to 1.25+-0.16 mg/kg.

How arsenic enters the hair from the blood is still unknown, and different hair samples from different persons adsorb arsenic differently (Mahata et al. 2003). According to the literature review by Hindmarsh (2002) one study reports that the arsenic in the hair of guinea pigs injected with sodium arsenite reached well beyond where it could reach by growth alone and the same was found by another study which detected high levels of Arsenic 4 cm from the scalp hair even though the hair growth was only 3.5 mm since the onset digestion. The study also investigated whether washing could move the hair Arsenic by capillary action and found that although there was some spreading by washing most of the applied Arsenic remained at the point of deposition on the hair even after washing with various solutions. The explanation from both the studies was that injected arsenic is secreted in the sweat and/or sebaceous secretions and becomes deposited on the surface of the hair where it remains firmly attached for the life of the hair. Hair can concentrate arsenic from the solution in which it is suspended. A human hair placed in a solution of sodium arsenite for 10 days (10 mg/mL) increased its arsenic content from 1 to 50 mg/g. 60% of this arsenic remained after 15 days soaking in distilled water. Even though washing techniques eventually removed Arsenic from hair, the study could not distinguish between external and internal contamination. Hair levels of 12 mg/g have been reported in corpses buried in arsenic contaminated soils. Neither can location of arsenic in a cross-section of hair determine whether arsenic is ingested or derived from external contamination.

The literature review by Hindmarsh (2002) also cites a study with 31 persons in Alaska who drank bottled water but were washed their hair with arsenic contaminated well-water (>= 100 μg/l) who had mean arsenic level of 5.74 mg/kg in hair, another person who drank and washed in water with Arsenic content less than 100 μg/l had a mean level of 0.46 mg/kg. Another study from Japan also showed similar results of elevated Arsenic concentration in hair from washing with contaminated water. The results obtained by Hindmarsh 2002 show that two of the worst cases had hair arsenic concentrations of 47 and 4.2 mg/kg even though both of them lived in the same house indicating the extreme variability of hair arsenic level at similar level of exposure.

Hair washing procedure for analysis may have an effect on the measured Arsenic concentration in hair. By washing some of the external contamination is removed and a study reported a difference of 3 mg/g between washed and unwashed hair (unwashed 5.99 mg/kg and washed 3.08 mg/kg) (An et al. 1992).

From the above literature review it is evident that the amount of Arsenic in hair varies for each individual and depends on the type of exposure, but it is for certain that exposure to Arsenic results in elevated Arsenic concentrations. The aim of the present study is to assess the human exposure to Arsenic in Denmark, Malaysia, West Bengal India and Thailand and to investigate whether there is any indication of chronic toxicity of Arsenic in the studied areas based on the arsenic concentrations in the hair.

Table 1: Arsenic concentration in different parts of the world.

Place	As concentration in hair (μg/g)				Arsenic concentration in water (mg/L)	Reference
	Type	Median	Mean	Range		
Bangladesh	All	2.49	4.05			Samantha et al., 1999
Bangladesh	All			1.1-19.84	0.01-9	Cited by Anawar et al. 2002
Bangladesh	All	6.4	8.57	0.26-79.49		Rahman et al. 2001
Chile; Antofagasta	All			4-83.4		Cited by Karim 2000
Egypt	M		0.303			Saad and Hassanien 2001.
	F		0.292			
	C		0.353			
	A		0.233			
	NS		0.294			
	PS(I)		0.376			
	PS(O)		0.141			
	AS		0.36			
	Cigar		0.209			
	M. T.		0.459			
Finland		0.96		0.06-12.5	0.017-0.51	Kurttito et al.1998
Finland		0.05		B.D.-0.18	0.004-0.044	
Iceland		0.04		≤0.0037-0.2		Raie 1996
India, (WB)				1.81-31.05		Karim 2000
India, (WB)		1.32	1.48	0.18-20.34		Samantha et al., 1999
Inner Mongolia	M			≤ 1-9.5	≤0.1-0.8	Yang et al. 2002
Iran			0.073	≤0.0155-0.427		Raie 1996
Iran, Najaf Ajad village	All	0.2+-0.07			0.05	Pazirandeh, Brati, and Marageh 1998
	M	0.281				
	F	0.119				
	All	4.9+-0.5			0.55	
	M	5.53				
	F	4.19				
	All	5.6			0.74	
	M	7.18				
	F	2.89				
UK, Cornwall	All		2.51	0.89-14.56		Peach and Lane 1998
	M		2.54	0.92-12.69		
	F		2.49	0.89-14.56		
UK, Glasgow			0.65	≤0.2-8.17		Raie 1996
UK Oxfordshire & Wiltshire	All		0.7	≤ 0.70-9.03		Peach and Lane 1998
	M		0.37	≤ 0.7-1.56		
	F		1.07	≤ 1.72-9.03		
US Lassen county, CA		0.01-2				Cited by Karim 2000
US, Millard county UT		0.1-4.7				Cited by Karim 2000
US AL Fairbanks		1				Cited by Karim 2000

METHODS

Collection, Preparation and Analysis of Hair samples

Hair samples from Thailand, Denmark, and West Bengal (India): hair samples from these areas were collected from individuals with no attempt to control the location from where hair was extracted. In all cases a sample of the person's hair was cut and stored in either individual plastic bottles or polyethylene bags and sealed to avoid any further contamination. Since there exists no standard procedure for the preparation of samples of Arsenic all the samples were washed in 0.1% Triton-x and rinsed with running distilled water for eventual removal of surface contamination. The samples were dried at 100 °C. The washed and dried hair was cut into 2-5 mm lengths for digestion. The digestion was carried out using HNO3-HClO4 method, where 2 ml of HNO3 and 0.2 ml of HClO4 was added to 0.2 g of hair and the samples were gently heated until a clear solution appeared. The samples were analysed with a continuous Hydride Generation method on an Atomic Absorption spectrometer (Perkin Elmer 5000 AAS). The detection limit of the method was 1 μg/l.

Hair samples from Malaysia: hair samples were collected from donors by single cutting from the occipital region with a pair of clean stainless steel scissors in accordance with the IAEA protocols. During collection of the hair samples, each individual was asked to complete a questionnaire detailing name, sex, age, occupation and dietary habits. The hair samples were cut to lengths of about 2-5 mm. The hair samples were then washed according to the standard procedure recommended by the IAEA: wash hair in acetone, Three times in water and once more in acetone. The samples were then dried overnight in an oven at 60˚C.

The standards were prepared by pipetting about 1μl of known concentration standard chemical solution of methylmercury onto ashless filter paper and packed in polyethylene envelopes after careful drying.

Samples, standard and blank were irradiated in the TRIGA reactor of the Malaysian Institute for Nuclear Technology and Research for 6 hours in a neutron flux of 2.3.1012 n.cm-2.s-1. The irradiated samples were then cooled for 2 days prior to counting. After cooling, the samples, standards and blanks were counted for 1000s using HPGe detector. For calculation of As concentrations, the 559.1 kev peak of 76As (t1/2= 26.44 h) was used. Gamma ray energy calibration was made with standard sources prior to every set of experiments. The nuclides were quantified by comparing net photopeak area with those of standards.

Collection, Preparation and Analysis of water samples

Water samples were collected in 20 ml plastic bottles and later on preserved using HCl. The samples were analysed with a continuous Hydride Generation method on an Atomic Absorption spectrometer (Perkin Elmer 5000 AAS). The detection limit of the method was 1 μg/l.

RESULTS & DISCUSSION

The obtained Arsenic concentrations from Denmark, Malaysia, Thailand and West Bengal, India are shown in Table 2. The hair Arsenic concentrations from these different areas decreased in the following order: West Bengal (India) > Thailand > Malaysia (Kuala Lumpur) > Denmark > Malaysia (Rural). Based on the available information it is also expected that the highest hair Arsenic concentration is to be found in West Bengal, India, since people are exposed to Arsenic both through food and drinking water.

Table 2: Arsenic concentrations in hair of subjects from different countries.

Country	Median mg/kg	Average mg/kg	Range mg/kg	No. of samples
Denmark	0.3	0.4	0.2 -0.9	14
Thailand	1.1	1.8	0.4 -5.8	14
Malaysia (Kuala Lumpur)	0.7	0.8	0.2 -1.8	25
Malaysia (Rural)	0.3	0.3	0.1-0.6	66
West Bengal, India	2.4	4.2	0.5 -14.4	43

Figure 1 shows the arsenic concentrations in hair and the corresponding Arsenic concentrations in water from West Bengal, India. The figure also shows the expected Arsenic concentrations in hair with corresponding Arsenic concentrations in drinking water (straight-line with square points) based on the literature values of Arsenic concentration in water and the resulting Arsenic concentration in hair. Only few results were in accordance with the literature values, whereas more than half of the samples lie far above the expected values. There could be many reasons for this; one of which could be that the amount of water consumption could be higher in the present case due to hot climate compared to the literature value. In the literature the water consumption was around 2 L. A second reason could be that the persons in the present case also used the Arsenic and Iron contaminated water for washing hair and hence may have higher Arsenic concentrations in hair due to precipitation or adsorption of Arsenic compounds compared to the literature value. A third reason could be that person's smoking habits have an effect on the arsenic concentration in hair, especially if tobacco is grown locally on contaminated soils. A fourth reason could be a high dietary intake from food items originating from the same contaminated soils.

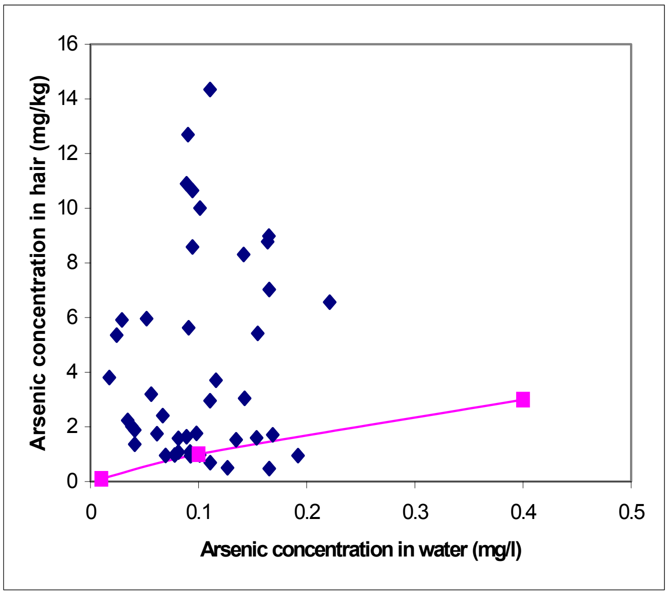

Figure 1: Arsenic concentrations in hair and the corresponding Arsenic concentrations in water from West Bengal, India. The line with square points shows the expected Arsenic concentrations in hair corresponding Arsenic concentrations in water (taken from the literature Yang et al. 2002, and Kurttito et al. 1998).

An attempt was made to investigate whether there is any difference between in hair Arsenic concentration between men and women but no such difference was found and it was also found that people from the same family have different hair Arsenic concentrations. This could be despite persons being from the same family they may not consume the same water depending on their occupation. For example, children and youngsters are away from home most of the time and hence may consume water from different sources than the elderly people who usually remain at home. This could also be one of the reasons why the measured arsenic concentrations do not coincide with the literature values for dose-response values.

The second highest hair Arsenic concentrations were found in Thailand, and the samples were taken from the Ronphiboon Area where there are reported cases of Arsenicosis. Water samples from this area were not collected, but according to Williams et al. 1996, the average Arsenic concentration in the groundwater (both shallow and deep) is approximately 350 µg/l. The average and median hair Arsenic concentration found in Thailand was above 1 mg/kg and according to WHO's definition of chronic toxicity the studied persons are exposed to chronic Arsenic poisoning.

In Denmark and Malaysia there are no reported incidence of elevated concentrations of Arsenic in drinking water, and hence the major route of exposure would be through food. The Arsenic concentrations from the rural areas of Malaysia are comparable with the Arsenic concentrations from Denmark and most of the samples are within the normal range of the normal Arsenic concentration range of 0.01-0.4 mg/kg, whereas the Arsenic concentrations from Kuala Lumpur city are higher than from Denmark and rural areas of Malaysia, with the highest concentration being 1.73 mg/kg. If 1 mg/kg is taken as an indicator for chronic Arsenic poisoning the highest value from Kuala Lumpur city indicates that some of the persons may be suffering from Chronic Arsenic toxicity.

The highest value found in Denmark is 0.86 mg/kg and the person reported using a shampoo for the treatment of dandruff and a high consumption of seafood. The second highest was 0.64 mg/kg in a person who smokes 20-25 cigarettes per day. The Arsenic concentration in water is assumed to be less than 1 µg/l, and the air arsenic concentrations are also very low.

The above results indicate that higher Arsenic concentrations in hair are a result of exposure to Arsenic, but it is difficult to comment whether the elevated Arsenic concentrations in hair are due to direct intake or external exposure as the highest Arsenic concentration in a person in Denmark.

According to a Japanese study the daily intake of Arsenic is 182 µg, which is very high, compared to the estimation of 53 µg /d by US Food and Drug administration based on a market basket survey (Pontius et al., 1994). The higher Arsenic consumption in the Japanese study is largely attributed to the consumption of seafood. As fish is one of the main sources of protein for the general population in Malaysia, one of the possible explanations for higher Arsenic concentrations in the Kuala Lumpur city compared to the rural areas in Malaysia could be that the city people consume more fish compared to the villagers as the city dwellers have a higher income compared to the villagers. But only 5% of Arsenic in the fish is found as inorganic arsenic. So far it is not clear which form of Arsenic is accumulated in hair. Although the rural population in West Bengal, India does not consume high amounts of fish according to a study conducted in West Bengal, India (Roychowdhury et al. 2000) the average intake of Arsenic through food it is 172 mg/d, which is almost equal to the Japanese study. This would also contribute to the hair Arsenic concentration, and hence higher Arsenic concentrations in hair could be expected compared to the dose response curve for ingested Arsenic through drinking water alone.

CONCLUSIONS

- The Arsenic concentrations in hair indicate that people in Denmark, Thailand, Malaysia and West Bengal, India are exposed to Arsenic and the exposure decreases in the following order: West Bengal (India) > Thailand > Malaysia (Kuala Lumpur) > Denmark > Malaysia (Rural).
- The results from Denmark and rural areas in Malaysia indicates that chronic exposure to Arsenic rarely occur due to dietary exposure to Arsenic since the measured concentrations were far below the value suggested by WHO as an indicator of chronic exposure.

- Based on the present knowledge it is difficult to conclude whether the higher Arsenic concentrations in the Kuala Lumpur compared to rural areas of Malaysia are due to higher consumption of fish in the city population compared to the villagers.
- The results also indicate that exposure to Arsenic can be investigated by measuring hair Arsenic concentrations but the results do not indicate whether the exposure is external or due to direct intake.
- High individual hair concentrations found may be attributed to a combination of high intake with water and food, smoking and even external contamination from washing in Arsenic rich water.
- Although chronic exposure to Arsenic can be determined by measuring Arsenic concentration in hair and it is one of the easiest ways of determining chronic exposure more research is needed to exactly define how Arsenic accumulates in hair and whether the ingested form of Arsenic has an effect on the accumulation.

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Cadmium Risk Assessment In Recycling Waste To Agriculture In Thai Societies

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ABSTRACT: The heavy metal, cadmium is a toxic compound to all living organisms, and requires therefore special attention in risk assessment studies. As cadmium is a rather mobile ionic species under acidic soil conditions, which are dominating in e.g. Thailand's agricultural lowland, one could expect it to be readily available to agricultural crops. Consequently it poses a potential risk of entering human food products. Research conducted over the last decades has found that rice being the main staple food item is the main contributor to human intake of cadmium in Asian countries. The objective of this study is to determine the flow of cadmium in waste in representative Thai societies and assess the change in risk of using treated biodegradable waste products as a substitute for chemical fertilisers in the agriculture. The chemical analyses showed that the highest flow of cadmium in organic waste is with municipal wastewater sludge and biodegradable kitchen waste, whereas human excreta only carry small amounts of cadmium. Thailand does not presently have any regulation on this potential element of risk, so consequently international standards may be used for comparison. Recycling the urban waste to agricultural land would potentially not exceed the American and European Union's threshold limit for waste application to agricultural soils. However a few European countries (e.g. Denmark) have stricter threshold limits, due to specific soil and groundwater conditions, and these would potentially be exceeded if some of the urban Thai wastes were applied to the soils. It is concluded that recycling of urban waste to Thai agriculture poses only a small potential risk for food contamination.

Keywords: Recycling waste; Cadmium; Risk assessment; Thailand; Songkla Lake Basin

INTRODUCTION

Plant nutrients and organic material in soils are essential prerequisites for healthy plant growth and thereby food supplies. Depletion of plant nutrients (macro nutrients and micro nutrients) or organic material in soils may lead to severe agricultural as well as environmental problems, such as insufficient crop yield, economic recession, famine, soil erosion and desertification (Campbell, 1998; Gardner, 1997). Recycling of plant nutrients in biodegradable kitchen waste (from harvested crops and animal products) and in human waste back to agricultural areas has long way back in history been the basic method for keeping the agricultural soils fertile (Fig. 1, Esrey, 2001). However, during the last century the extensive urbanisation, and consequently practical constraints in connection with the mentioned recycling, has led to a decreasing use of this ancient and natural method (Gardner 1997). Plant nutrients tend to enter a "one-way flow" direction out of rural areas and into urban waste, where inadequate handling methods often results in local accumulation of nutrients as well as unhygienic and polluting living conditions for the urban population (Fig. 2, Diaz et al., 1996; Esrey, 2001). Reversing this adverse development back to a sustainable development in relation to agriculture and urban sanitation[1] requires a fundamental rethinking of the possibilities for modern societies to handle the flow of nutrients from urban back to rural areas (Fig. 1).

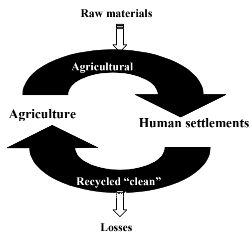

Figure 1: Closing the nutrient cycle

However there are several potential constraints to recycling of waste to agriculture, of which the threat to human health by recycling of pathogens and toxic chemical compounds are the most important.

[1]Sanitation of solid waste, human excreta and sullage (wastewater from kitchen and bathroom).

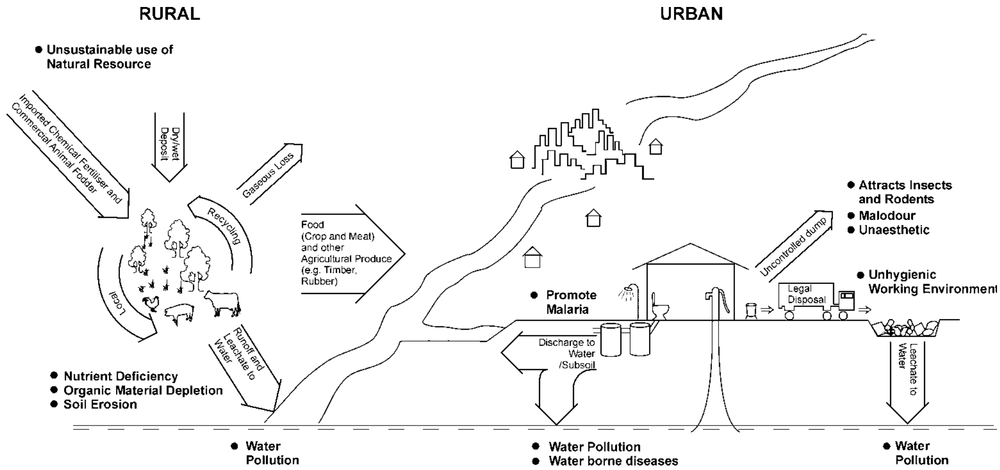

Figure 2: Illustration of one way nutrient flow in typical Asian communities (text in arrows indicate transport means) and environmental problems caused (bold font).

This paper studies the heavy metal contents of waste, and focuses on cadmium, as this is a very toxic metal accumulating especially in kidneys of humans impairing the function. It may also be toxic at elevated concentrations to other animals and plants. The human intakes of cadmium with food in the Southern Thailand have been assessed by Schouw et al. in 2002b, estimating the intakes to between 20 and 40 µg per person and day. Cadmium intakes of this order approximates half of the recommended provisional allowable intake. The intake is at the same level as found in the European countries, where strict measures are introduced in order to curb further increase due to environmental pollution. It is well known that nearly all human cadmium intakes originate from agricultural soils as the metal is mobile in the soil-plant system. Thus the cadmium mass balance for the soils also determines the future changes in the human intake. The purpose of this paper is to assess the changes in the load of cadmium to agricultural land, and thereby the human intake, if a substantial part of the present recyclable organic waste is brought back from urban areas for use in agriculture, i.e. as feed for domestic animals or as composted material replacing chemical fertilisers. In most cases the nutrients, and associated toxic compounds will eventually end up in the soil as manure or compost used as fertilising materials. The flow of cadmium in available waste is examined in three case study areas in Southern Thailand, and the risk of using the waste products in local agriculture directly or indirectly as a substitute for chemical fertilisers is assessed.

METHODOLOGY

The sites

It was chosen to focus this study on the Songkhla Lake Basin, as the mentioned pollution problems from inappropriate waste handling are particularly severe in this area. Additionally this area is being used for extensive agriculture, supplying both the local population with food, and the export industry with produce (e.g. rubber, fruits and rice). An intensification of the agriculture over the last decades has led to an increased nutrients demand partly met by purchases of chemical fertilisers.

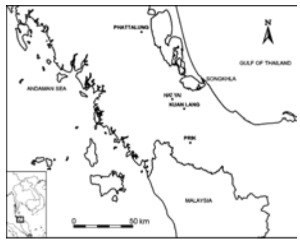

Figure 3: Southern Thailand: three case study areas.

Muang Phattalung, TAO Kuan Lang and Muang Prik were selected as specific case study areas (Figure 3) as they represent the Southern part of Thailand (Table 1). Thereby the findings of this study should be partly applicable to most other communities of Southern Thailand.

Table 1: Characteristics of the three study areas (Schouw et al., 2002abcd)

	Phattalung	Kuan Lang	Prik
Province	Phattalung	Songkhla	Songkhla
Area size, km^2	13.3	66.7	4.8
Population size	37,777	26,266	5,926
No. of household	10,978	3,422	925
Administrative level	Municipality	TAO[2]	Municipality

[2] Tambon (~ village) Administrative Organisation

Community level	Urban	Peri Urban	Rural
Income, Baht/cap/yr	18,874	23,463	19,996

Sampling
To study the flow of cadmium in the human settlements representative samples of solid biodegradable waste and wastewater were collected at the waste generating sources (industry, fresh food market, restaurants) as well as biodegradable kitchen waste, grey wastewater and human excreta from households. For detailed information on sampling methods and selection criteria for the representative waste generating sources confer to Schouw et al., 2002a,b.

Analysis
The waste samples were *inter alia* analysed for cadmium. The wet waste samples were dried at 75ºC for 3-5 days, until constant weight. All dried solid waste samples (0.2 g dry matter) and wastewater samples (25 ml) were digested in 15 ml acidic reagent (1,250 ml conc. HNO_3 and 250 ml conc. $HClO_4$ and 0.06 g NH_4VO_3) during a stepwise temperature increase from 80ºC to 190ºC. The volume of the digested solution was finally adjusted to 50 ml. All human excreta samples were dried in an oven at 70ºC for 4 days, and then digested using 2 g TS in 60 ml conc. HNO_3 and 1ml $HClO_4$ (60%) in conical flasks on a hot plate. After heating for 3 – 4 days the remaining volume was adjusted to 50 ml by addition of de-ionised water. The atomic absorption spectrophotometer with graphite furnace (Perkin Elmer AAnalyst 600) was used to analyse cadmium using standard conditions. Problems with respect to upper or lower detection limits were avoided by diluting or increasing the quantity of sample being analysed. Blank samples were included in each analysis series. An internal reference sample, homogenised grass pills, was further included in each analysis series (SRM 1571).

RESULTS

The flows of cadmium in potentially recyclable biodegradable waste (solid biodegradable waste, grey wastewater and human excreta) from three typical representative human settlements in Southern Thailand are illustrated in figures 4-6.

Phattalung cadmium balance
In Phattalung the main cadmium source in waste is grey wastewater from households (Figure 4). Grey wastewater from households, restaurants, canteens, markets, and industry are discharged via gutters and a river into the Songkhla Lakes. The toilet septic tanks are connected to conventional drainage pits, which infiltrates the liquid phase of the human excreta to the subsoil and groundwater. About 1/3 of the biodegradable kitchen waste from households and most food waste from the fresh food markets are collected by pig farmers around Phattalung and reused as animal fodder. The rest is disposed at a landfill site.

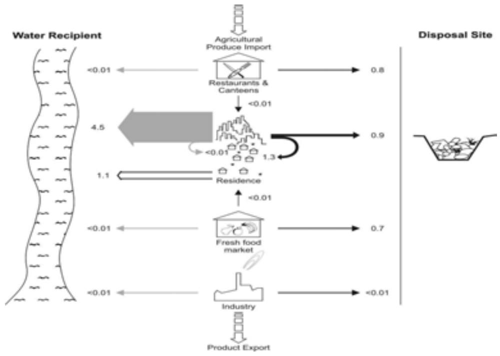

Figure 4: Cadmium flow in Phattalung, indicated by arrow sizes (quantity of cadmium), numbers at arrows (kg Cd per year) and arrow shading (grey: wastewater; white: human excreta; black: solid waste).

Kuan Lang Cadmium Balance
Most cadmium is being generated via the waste from grey wastewater and industry (rubber glove factory) in Kuan Lang (Figure 3). Kuan Lang also uses the conventional Thai septic tank toilet system, but around 30% of the householders empty their own tanks and recycle the septic sludge in private gardens (Schouw et al., 2002d). Sullage is discharged to stagnant water pools in ditches from where it slowly penetrates into the sub soil. Around 35% of the householders recycle sullage by watering their garden crops (Schouw et al., 2002d). Solid household waste is mainly dumped or buried in the private gardens as the conditions of the roads do not allow municipal trucks to collect the waste (Schouw et al., 2002a). The industrial wastewater is discharged to the river via a treatment plant reducing the organic content.

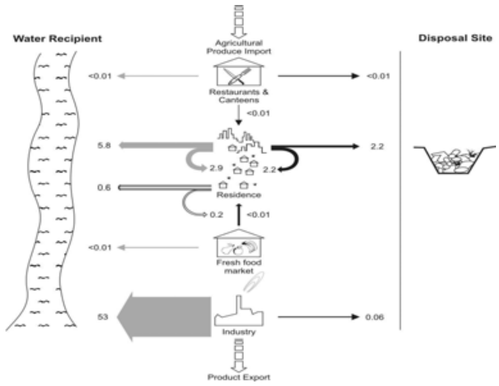

Figure 5: Cadmium flow in Kuan Lang

Prik cadmium balance
The sawdust from the timber factory and the grey wastewater are the dominant cadmium sources in waste in Prik (Figure 6). The industrial sawdust is deposited together with the main fraction of the solid household waste at a landfill site outside Prik. The human excreta are handled in similar ways as in Kuan Lang and Phattalung, only with a minor fraction (6%) being reused for fertilising fruit trees in

private gardens (Schouw et al., 2002d). Sullage is recycled as irrigation water by 30% of the householders in Prik, and the remaining fraction is infiltrating the soil or discharged via ditches to rivers (Schouw et al., 2002d).

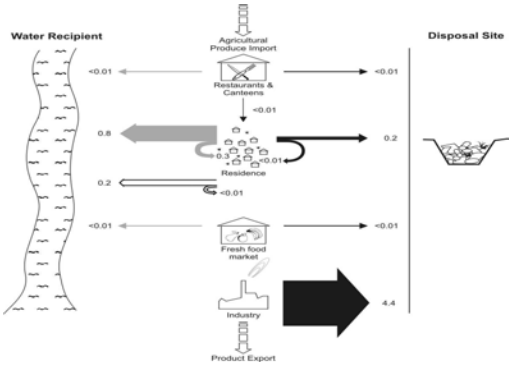

Figure 6: Nutrient flow in Prik

Cadmium Concentrations in Potentially Recyclable Waste Materials and in Fertilisers

The quality of organic waste materials, which potentially may be recycled to agriculture from the three settlements is found in Table 2. The total concentrations of cadmium and phosphorus are shown, and the ratios between the toxic cadmium and the plant nutrient Phosphorus are calculated.

Table 2: Cadmium content in various potentially recyclable waste fractions of Thai societies

Item	mg Cd/kgDM	mg Cd/kg P	Reference
Kitchen waste	0.65	539	Schouw et al., 2002a
Grey wastewater	0.002	85	Schouw et al., 2002a
Human excreta	0.26	15	Schouw et al., 2002b
Sewage sludges	1.22	1060	Parkpain et al., 2000
Sewage sludges, Bangkok	2.5-3.8[3]	200-350[3]	Namatra & Manmee 2002
Rubber industrial wastewater	0.034	1800	Schouw et al., 2002a
Rubber industrial solids waste	14.76	36900	Schouw et al., 2002a
Fresh food market solid waste	1.72	400	Schouw et al., 2002a
Saw dust	0.6	1500	Schouw et al., 2002a
Canteen waste	1.32	600	Schouw et al., 2002a
Chemical fertilisers sampled	-	0-400[3]	Schouw et al., 2002a
Chemical fertilisers used in SLC	-	1.4-30 (8.6)[3]	Sae-Eong, 2002
Cultivated soils in SLC	0.001-0.09	250	&
Non-cultivated soils in SLC, range	0.001-0.002[3]	50	Sereewatthanachai 2002
Fertiliser limit, DK	-	100	MST 2000
Sludge use, guideline, EU	10	250	EC 2000
Compost use, guideline, EU	0.7-5[3]	-	EC 2001
Organic waste, guideline, DK	0.8	200	MST 2000

Table 3: Recently reported results for the inputs of phosphorus and cadmium to the Songkla Lake Basin. Results are recalculated as inputs per person and year[4]

Waste	Generation kg P/p.y	Generation mg Cd/p,y	Average Cd/P	Cd in DM	Reference
Kitchen waste	0.06	22	350	0.65	Schouw 2002a
Grey wastewater	0.9	75	70	-	Schouw 2002a
Human excreta	0.6	9	15	0.26	Schouw 2002a
Fertiliser use in SLB	1.3	11	8.6	n.a.	Sereewatthanachai 2002; Sae-Eong 2002
Fertiliser, max.	1.3	130	100	n.a	See table 2

[3] Concentration range (average in bracket)

[4] Assumptions: average population density on available agricultural land is 700 persons/km^2; all human excreta are brought back to land; other organic waste with a Cd/P ratio less than 200, or having a maximum Cd concentration of e.g. 1 mg/g DM from this population may be brought back to that land; the shown value for the aerial input is derived from experience in Europe.

Aerial input, min.	~0.020	50	~2500	-	Sereewatthanachai 2002

Cadmium and Phosphorus Flows with Fertiliser into Agriculture

There have only been few attempts to quantify the phosphorus and cadmium inflow to the region. In table 3 is shown some recently reported results for the most likely inputs of phosphorus and cadmium to agricultural land in the Songkla Lake Basin in the Southern Thailand. It is evident that the cleanest fertilising material is the fertiliser in use, followed by the human excreta. The grey wastewater can provide fair amounts of phosphorus, still with a reasonable quality. Kitchen waste is low in fertiliser potential and somewhat contaminated. The fertiliser quality is unusually high (Imported from Russia, Kola Peninsula), and this may change if suppliers change.

DISCUSSION

The cadmium concentrations in the organic waste from the settlements in the Songkla Lake Basin vary considerably depending on the origin and the possibilities of getting polluted. Apart from industrial waste the grey waste water and human excreta are the major carrier of nutrients out of the households, while they hold only minor concentrations of cadmium. The concentration in the excreta reflects closely the human ingestion of the metal. The other organic wastes have higher concentrations of cadmium in the dry matter. The few sewage sludges (not from the SLB) examined appear not to be excessively contaminated with cadmium, but do not either have high concentrations of nutrients, i.e. phosphorus.

Generally the mass flow studies in the Songkla Lake Basin show that the majority of cadmium in urban waste is generated in the industrial waste and the grey household wastewater, which apart from the recycled waste mostly ends up in water bodies. Cadmium flow in human excreta is quite low and is mainly discharged to deep drainage pits via the septic tank systems.

If waste is considered as a useful fertilising material, the inorganic toxicological quality of waste should be examined. The ratio Cd/P is in use in the European countries and may be considered as one of the future quality parameters in Thailand. The ratio is one of several useful parameters when assessing alternative fertilising material, i.e. the origin of chemical fertiliser, or the management of waste materials, which might be useful in agriculture as fertiliser or feed for animals. Apparently there are no specific guidelines in Thailand regulating the use of waste materials for agricultural use. Most industrialised countries have introduced rules and regulations for the activity. When comparing the existing regulation for the EU and Denmark, only the use of contaminated industrial waste and kitchen waste seem problematic.

The flow of cadmium in agriculture in the Songkhla Lake Basin undertaken by Sereewatthanachai 2002, and Sae-Eong 2002 may be used in assessing the impact of using organic waste as supplement/substitute for chemical fertilisers. This is attempted in table 2. They also found that the soils of the Songkhla Lake Basin are very acid, ranging in pH 3.8-4.0 for uncultivated soils and 3.6-5.7 for cultivated soils. At low pH the mobility of cadmium in the soils is high and rather quickly the inputs (precipitation, fertiliser and manure) equals the outputs (cropped plants and leaching). This means that the average and quasi-stationary cadmium concentrations in the acid soils are low and thus the average retention time in the soil is equally low. It also means that an increase in cadmium inputs in a few years will lead to a proportional sized increase in plant concentrations, if other conditions are kept constant. Likewise a decrease in input to soils may lead to cleaner plants in a few years. So it is fairly important to ensure that the annual input of cadmium will not be excessive.

CONCLUSION

From our results it is safe to say that the fertiliser in use in the SLB is unusually clean, and that the possible alternative fertilising materials (human excreta and grey waste water) in quality are well above the acceptable according to European guidelines for use in agriculture.

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Environmental Chemistry Of Panchang Bedena Landfill, Selangor

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ABSTRACT: The environmental chemistry of Panchang Bedena landfill, which is located in Selangor state was studied. In this study, leachate, landfill soil (0-30cm depth) and some common plants were analyzed for their chemical characteristics, including the heavy metal content (Cr, Cu, Fe, Mg, Ni, Pb, Zn), using Inductively Coupled Plasma (ICP). Plants selected were *Ipomoea aquatica* (Kangkung), *Amaranthus sp* (Bayam), *Eleusine indica* (common weed), and *Eustachys tenera* (common weed). Panchang Bedena landfill is basically a rural type of landfill and received mainly household, institutional and agro-wastes. The leachate from the landfill contained high amounts of organic content, as shown by their COD (1506mg/L-4425mg/L), BOD (420mg/L-860mg/L), and TOC (180mg/L-410mg/L). Generally, the leachate quality exceeded the Standard A and B, except for some heavy metals, like Cu, Cr, and Ni, which were below the Standard A, Environmental Quality Act (1974). Majority of the elements were found abundant in old cell surface soil (0-15cm). Within the soil profile, Cu, Pb, and Zn were found concentrated in the surface horizons. Plant samples show different degree of selectivity in metal uptake. Generally, K is the element with the highest concentration (min. 720mg/g to 4247 mg/g) among all the plants tested. While Mg and Zn (ranging from 1.66mg/g to 3.46mg/g) tend to accumulate in the plant tissues.

Keywords: Landfill, leachate, waste management, environmental chemistry

INTRODUCTION

Waste and their disposal are the cause of a great deal of environmental pollution. Presently, more than 95% of the municipal solid waste (MSW) is disposed into the landfills in Malaysia. There are 168 landfills, 50% of them are open dumps, while only six landfills are equipped with leachate collection and treatment systems (MHLG, 2002). Landfills for industrial and municipal solid wastes contain a complex mixture of both organic and inorganic matter and are potential sources for the spreading of toxic compounds. A variety of wastes contain heavy metals and these are not separated before disposed into landfill. When waste is deposited into the ground, metal particles frequently bind to the soil and do not easily dissolve or migrate with water.

In the landfill environment, microorganisms in the soil can degrade organic components within the waste. While metals are not self-degraded, they are mobilized within the landfill environment, primarily via leachate, depending on the reaction conditions and metal speciation behavior. The potential release of metals from solid waste is primarily affected by the changes of pH and redox conditions (Fôrstner, 1993; Bozkurt *et al*, 1999; Beccaloni *et al*., 2000) In acidic conditions, metals such as cadmium, copper, iron, manganese and lead can dissolve and migrate with leachate.

Vegetation is usually the first interceptor of heavy metals deposited into an ecosystem. If an ecosystem is sparsely vegetated, soils may be the first interceptor of heavy metal deposition (Friedland, 1990). Different patterns of metal uptake could be related to different mechanisms of metal tolerance at the whole plant level (Wu, 1990; Baker and Walker, 1990; Macnair, 1997; Verkleij and Schat, 1990). It is evident that different plant species may possess varying degree of metal tolerance, and may be tolerant at different levels in terms of genetic variability and of innate plasticity (Macnair, 1997; Wu, 1990; Bradshaw, 1984). The knowledge on the fate of contaminants in the ecosystems is important, in order to determine to what extent the contaminants will affect the nature. In this study, leachate, landfill soil and some common plants were analysed for their chemical and physical characteristics, including the heavy metal content. The results would enlighten the pollution intensity of these landfills on the environment.

METHOD AND MATERIALS

In this study, the leachate, landfill soil and some common plants were collected to analyze for their chemical and physical characteristics, including the heavy metal content (Cr, Cu, Fe, Mg, Ni, Pb, Zn). The samples were collected over a three-month period. The leachate quality parameters analysed were pH, conductivity, turbidity, total suspended solids (TSS), total dissolved solids (TDS), BOD, COD, TOC, Kjeldahl Nitrogen, total phosphate, alkalinity, total hardness, chloride, sulphite, and metal concentrations. Concentrations of metals were determined after digesting with nitric acid -hydrochloric acid digestion method and analyzed with Inductivity Coupled Plasma Atomic Emission Spectroscopy (ICP-AES) Model

Baired 2000. All the analysis methods used were referred to the standard methods for the examination of water and wastewater (APHA., 1998).

Plants selected for analysis of metal uptake were *Ipomoea aquatica* (Kangkung), *Amaranthus sp* (Bayam), *Eleusine indica* (common weed), and *Eustachys tenera* (common weed), as they were common in landfill areas. *Ipomoea sp.* and *Amaranthus sp.* are leafy plants, while *Eustachys sp*. and *Eleusine sp*. are common weeds found in open area. Only matured plants were collected in order to reduce age effect on the metal uptake behaviour. The whole plants (all parts) were harvested and each kept in plastic bags to prevent further contamination.

RESULTS AND DISCUSSIONS

Panchang Bedena Landfill

Panchang Bedena landfill is located in Sabak Bernam district, Selangor, which is typically a rural landfill receiving MSW from the major townships in Sabak Bernam. The total area of this landfill is 4 ha, and is about 2 km away from the town of Sungai Besar. This landfill site commenced operation in 1993 and had been operated for 10 years now. There was only a layer of clay underneath the landfill, and the leachate was drained and collected in the leachate pond. The leachate was not treated properly and seeped out from the pond and underground into the surface water. The waste generated was mainly kitchen waste (58%), which is putrecible, organic and compostable. High percentage of organic waste was contributed from the residential areas, and commercial areas, like the wet market, chicken-processing factory, agro-waste from coconut estate, etc. The moisture content ranged from 39% to 86% of the total weight. High moisture content in the waste will bring higher production of leachate.

Table 1: Leachate Characteristics (Mean & standard deviation)

Parameter	Leachate	Standard A*	Standard B*
BOD	**626 ± 190**	20	50
COD	**3220 ± 1359**	50	100
pH	8.04 ± 0.19	6.0-9.0	5.5-9.0
Conductivity (μS)	15.4 ± 11.5	50	100
Turbidity (FAS)	367 ± 120	-	-
Total Solid	2681 ± 345	-	-
Alkalinity	636 ± 564	-	-
Hardness	236 ± 72	-	-
Chloride	872 ±605	-	-
Sulphite	39 ±17	-	-
Kjeldahl-N (%N)	0.33 ± 0.01	-	-
Total-P	145 ± 53	-	-
TOC	274 ± 93	-	-
Na	1197 ±368	-	-
K	248 ± 78	-	-
Ca	95 ± 16	0.2	1.0
Mg	**88.4 ± 22.6**	1	5
Fe	**6.8 ± 3.0**	0.2	1.0
Zn	0.50 ± 0.42	0.2	1.0
Mn	0.52 ± 0.26	0.01	0.50
Pb	0.05 ± 0.02	-	-
Ag	0.11 ± 0.07	-	-
Ba	0.08 ± 0.03	0.2	1.0
Cu	0.02 ± 0.01	0.2	1.0
Cr	0.18 ± 0.20	0.2	1.0
Ni	0.06 ± 0.03		

All unit in mg/L except otherwise stated.; * Environmental Quality Act (1974) (Parameters exceeded Standard B were bolded)

Leachate Characteristics

The characteristics of leachate generated from landfill are shown in Table 1.0. COD and BOD values of 3220 and 630 mg/L, respectively, are typical for landfill 10 to 20 years old (Farquhar, 1989). A low COD/BOD ratio (below 0.20), showed that the landfill is under "moderately stable" stage (SWANA, 1997). Other parameters like pH, showed that the leachate was slightly basic, which exhibited a shift towards methanogenic activity in the landfill. The inorganic content of the leachate was relatively low, as shown by the degree of alkalinity and hardness, with average values of 636 mg/L and 236mg/L, respectively. This would lead to weak complexation capacity of heavy metal, due to lower carbonate levels. Generally, the leachate quality parameters exceeded the standard A and B, except for Cu, Cr and Ni, which still complied with standard A.

Soil and Plant Contamination

The moisture content of landfill soil ranged from 14.3% to 25.7%, while the organic matter ranged from 15.42% to 34.4%. Generally, cover soil contained 2 to 4 times lower concentration of metals compared to landfill soil, except for Mg, which was found to be higher in cover soil. The highest concentrations of metal in soil at 0-15cm depth was Al, ranging from 100mg/g to 1344 mg/g, followed by Fe (138-588mg/g) and Ca (1.78- 42.2 mg/g). Ni, Pb and Cr were found in trace quantity in the soil. Most of the metals, like Cu, Pb and Zn are found concentrated at surface horizons as a result of cycling through vegetation, atmospheric deposition and adsorption by the soil organic matter (Alloway, 1995). The concentrations of Cr, Mg, Pb, Cu and Zn in landfill soil of different depths is shown in Figure 1.0.

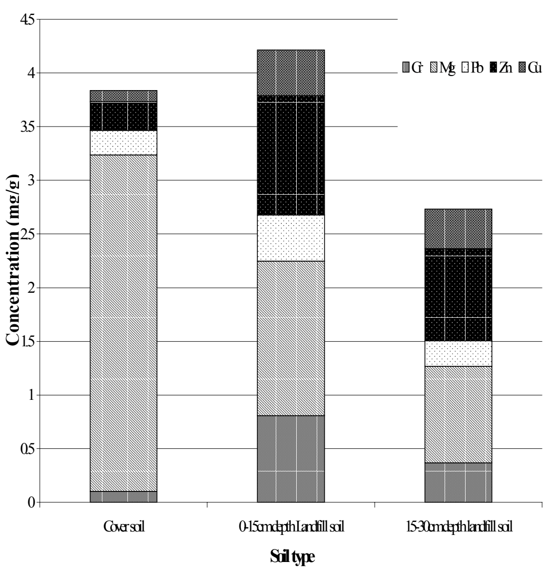

Figure 1: Concentrations of Cr, Mg, Pb, Zn and Cu in Different Soil Sample

Generally, K is the element with the highest concentration (min.720mg/g to 4247 mg/g) in all the plants tested, followed by Ca (177mg/g to 974 mg/g). This is maybe due to their high amounts in the soil. Mg and Zn tend to accumulate in the plant tissues, which exceeded 100% of the concentration found in soil. Pb, Cr, and Cu appeared to be significantly lower, ranging from 0.01 to 0.03 mg/g of plant tissues, compared to 0.10 to 2.58 mg/g in soils. This can be explained by their immobile characteristics in soil and are not apparently available to plant (McGrath, 1995; Murphy *et al.* 2000).

The concentration of metal in plant samples did not reflect any direct relation with the concentration in landfill soil. The uptake of metal by plant depends on external and internal factors, which differ from species to individual, and also the characteristics of the ion studied (Baker and Walker, 1990; Macnair, 1997). The concentrations of Cu, Ni, Pb and Zn are shown in Figure 2.0. Comparison between plant samples from landfill and from market (as reference) were carried out and results showed 3 to 4 times higher concentrations of Ni, Pb and Zn in landfill samples, except for Ca, Mg, Cr and Fe, which were 20-35% more in samples from market. This is probably due to the application of fertiliser and pesticide at the source of the sample from market. Among the species, leafy plants like kangkung and bayam contained relatively higher concentrations of metal ions when compared to the weeds.

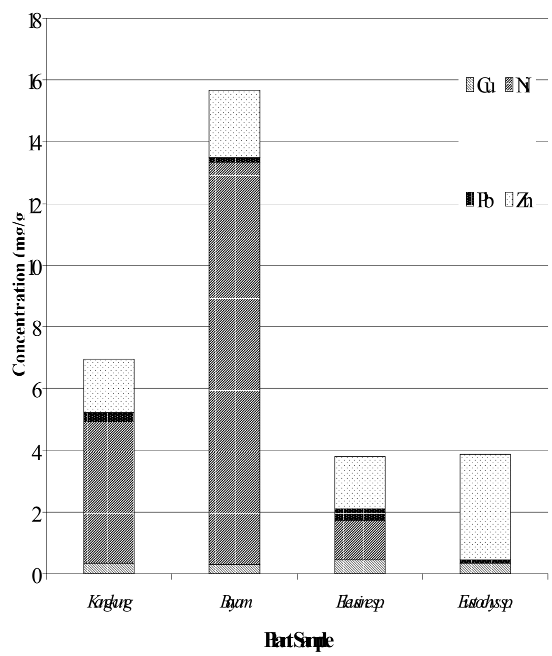

Figure 2: Concentrations of Cu, Ni, Pb and Zn in Plant Samples

CONCLUSION

Landfill is a highly heterogeneous environment and the reactions and mechanisms, which take place in landfill environment is complex and somehow remains unknown for some extent. Leachate is the source of all contaminant in landfill area. The metals concentration in Panchang Bedena landfill still within normal range, but at a higher intensity at surface areas. Plant has different metal uptake patterns, differing from species to species and in this study leafy plant contained relatively high amounts of metal in the plant tissues compared to weeds.

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Studies Of Gas Migration On A Selected Landfill In Malaysia

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ABSTRACT: Global warming issues have been seriously discussed widely that various approaches have been suggested to reduce the impact. One of the most important aspects, which was discussed in the World Summit in Rio, was the reduction of green house gas emission, including, carbon dioxide and methane. Methane emission can originate from various activities, such as from municipal solid waste landfill. As much as 100-150 m^3 of biogas/tonne of waste could be generated. Landfill gas emissions has become one of the crucial problems in municipal solid waste management throughout the region. Incidents such as landfill explosion due to uncontrolled emissions of methane have been reported. This study was conducted to analyze the rate of methane oxidation in landfill soil cover to determine the appropriate parameters, which can accelerate the process at an optimal rate. The study indicated that at temperatures of 27°C and 35°C, oxidation of methane occurred at a higher rate, and reached its completion within 48 hours and 28 hours, respectively. At 4°C to 15°C, as during winter, methane oxidation process was very slow. The results also indicated that the rate of methane oxidation within the soil cover depended on the temperature of the soil and the environment. It was also found that soil covering an active waste cell tend to undergo higher rate of methane oxidation compared to soil covering 8 months or 1 year old waste cells. Methane oxidation in soil from an active landfill reached its completion within 13 days, compared to soils covering older waste cells that required more than 30 days. When appropriate factors are prevailing, the rate of methane oxidation could be expedited to a more rapid level and this will reduce methane gas concentration within an area and prevent landfill explosions.

Keywords: Landfill, methane oxidation, soil cover, municipal solid waste

INTRODUCTION

The disposal of organic waste into landfills causes the generation of gases mainly carbon dioxide (35%) and methane (55%), and these are released into the atmosphere. The main source of methane emission comes from landfills, which contribute as much as 38% of the total anthropogenic sources (Popov and Power, 1999).

Landfill gas is generated through the anaerobic decomposition of organic components in solid waste by bacteria, fungus and actinomycetes. The components in landfill gas (LFG) mainly consist of approximately 55% methane, carbon dioxide and less than 10% of other non-methane organic gases (NMOG) (Agamuthu, 2001). NMOG are from wastes that do not undergo decomposition, such as paints, solvents, pesticides and adhesives, which contain several organic components (EPA, 1999).

The organic compounds in the waste components are extracted by microbial activities forming methane and carbon dioxide which not only caused odor problems and hindered the ground level ozone formation, but is also a potential fire hazard due to methane migrations (Kjeldsen, 1996).

It has been reported that various kinds of organic components are degraded during the process of methane oxidation, particularly, components with halogenated combinations (Scheutz & Kjeldsen, 2001).

Landfill gas emission requires more attention than any other stationary gas emission sources, as the landfill gas emission continues even after the landfill is out of operation. The generation of landfill gases is affected by soil characteristics, including the pressure and the permeability of the gas, and the microbial activities in the soil (Christophersen *et al.*, 2001).

The need to control landfill gas migration had caused many countries to impose a more stringent regulation such as "Interim Internal Technical Guidance for Best Practice Flaring of Landfill Gas" in United Kingdom (Baker *et.al.,* 2000; EA, 1999).

The control of landfill gas emission requires an effective gas collection system and controlling devices. A variety of technologies are available for controlling landfill gas accumulation and migration, mainly to extract gas from landfill and controlling the migration.

Landfill gas can be collected using a network of vertical gas extraction wells with adequate operating system (Cheung, 2000). Insufficient extraction of the gas is caused by air infiltration into the landfill through its surface. Methane concentrations should be less than 500 ppm above background levels to avoid fire hazards.

The landfill gasses, particularly methane can be recovered up to 82% for domestic utilization (Rodriguez *et al.,* 1999) that more studies have been conducted to benefit from the 'cheap source' of energy. However, due to the pressure to comply with the environmental requirement, landfill gas harvesting operation cost had been reported to increase considerably (Moulden, 2000).

This study was carried out to analyse the landfill gas concentrations in the covering material and the rate of methane oxidation at a landfill in Selangor, Malaysia. Studies were conducted at different temperature with different depth of soil cover, to determine the optimal parameters that encouraged the oxidation of methane.

MATERIALS AND METHODS

Soil materials used for this analysis were obtained from a landfill in Kuala Selangor, Selangor, Malaysia. The samples were taken from a current active cell, an 8 months old cell, and a 1 year old cell at different depth i.e. 10 cm, 20cm and 30 cm deep.

The analysis was set up in air tight bottles, with approximately 20 g of each soil samples, in triplicates. The air-tight bottles were then sealed with a rubber stopper and fixed steel lid. Approximately a volume of 30 ml of air were sucked out from the bottles with an air-tight syringe. A volume of 20 ml of oxygen and 10 ml of methane were then injected into the samples in the bottles to encourage oxidation process in the soil samples.

The bottles were then labelled and marked accordingly for analysis using a micro gas chromatogram (GC) at the appropriate period of time to determine the degradation of methane and the rate of carbon dioxide formations.

Soil samples were exposed to various temperatures to establish the optimum temperature conducive for methane oxidation. The temperature applied ranged from 4 °C to 35 °C. The data were processed with Maestro Program and the results were in terms of gas concentrations.

The analysis of five soil samples which were obtained from a landfill in Malaysia at different depths and locations were conducted. Further trials were carried out by altering the parameters for incubation including temperature.

Results obtained were presented in term of line graphs indicating the rate of methane oxidation for each particular soil samples.

RESULTS AND DISCUSSION

The results indicate that each soil sample has different methane oxidation rate even when exposed to a similar environment. The covering materials of the cell of 1year old waste showed the slowest rate of methane oxidation, particularly from the mid layer and bottom layer soil. This indicates the possibility that the degrading microorganisms, are lower in number that the concentration of methane gas continued to remain at a higher level.

The level of oxygen started to reduce as soon as the analysis began, particularly in the sample from the active cell as indicated in Figure 1.

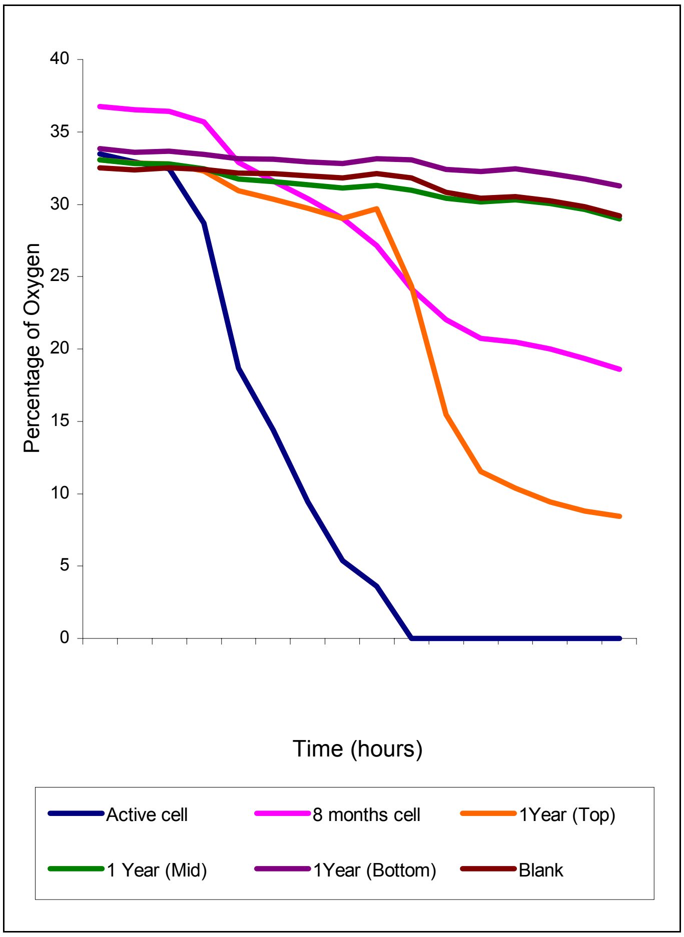

Figure 1: Percentage of oxygen in the soil samples throughout the analysis.

The top layer soil showed the ability of methane oxidation at the faster rate starting from the beginning. The concentration of methane gas decreased rapidly after approximately 8 days and oxidation was complete after the third week. However, soil from the mid layer and bottom layer indicated a very minimal reduction in the concentration of the landfill gases.

Figure 2 shows that the soil covering 8 months old waste contains a much higher percentage of methane-oxidizing microorganism due to the rapid decrement of methane gas since the analysis started. After approximately 3 weeks all methane gas were converted to carbon dioxide and moisture.

A similar trend was indicated by the soil from the active cell, which actually showed a more rapid decrement of methane gas even after the second day of analysis and methane oxidation was complete after the ninth day. This showed the possibility that the soil contained more microorganisms that actively oxidized methane gas into carbon dioxide and moisture.

The higher the temperature, the faster the rate of methane oxidation. Also, it indicated that at lower temperature the methane oxidation was very low due to the lack of microbial activities. This is so as the activities of cell tissues decrease when the temperature drop due to the inactivation of enzymes in the cell tissues.

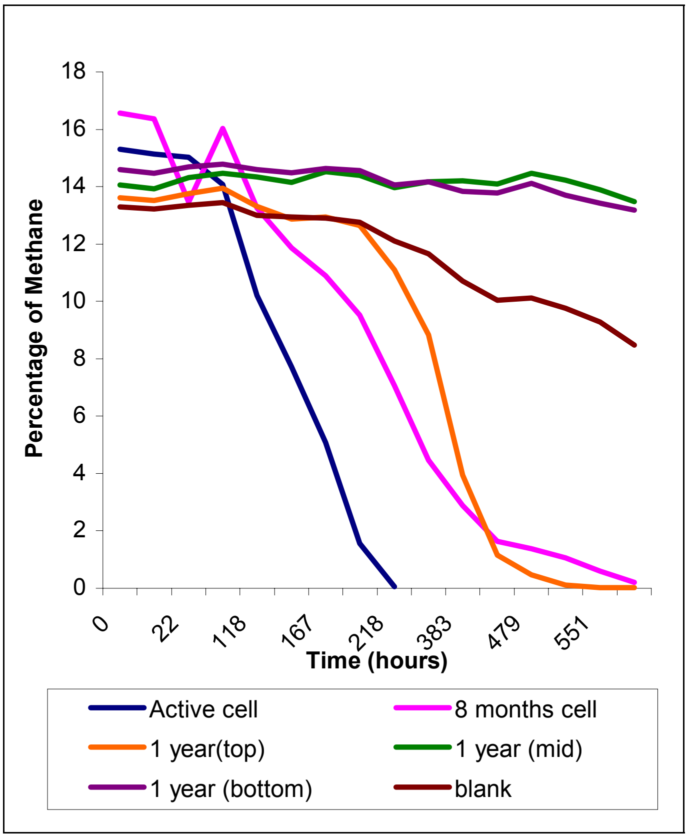

Figure 2: Percentage of methane gas in the samples bottles throughout the analysis.

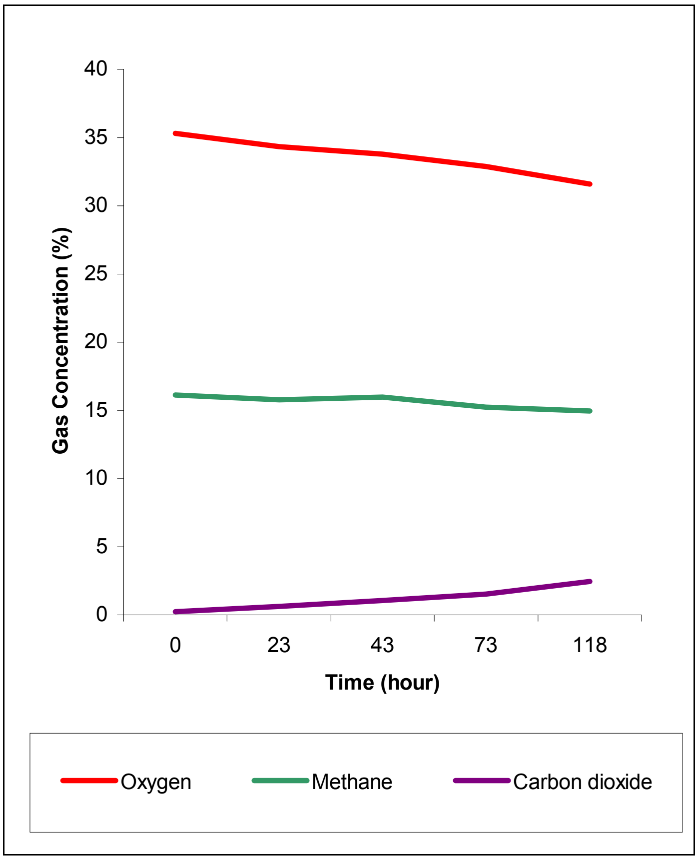

Figure 3: Percentage of O_2, CH_4 and CO_2 throughout the analysis at 15°C.

At 4 °C to 15°C, the activities of most microorganism were inhibited and methane oxidation was low (Figure 3). However, at higher temperatures of 27 °C and 35 °C, methane oxidation can been seen to occur at a very rapid rate as indicated in Figure 4.

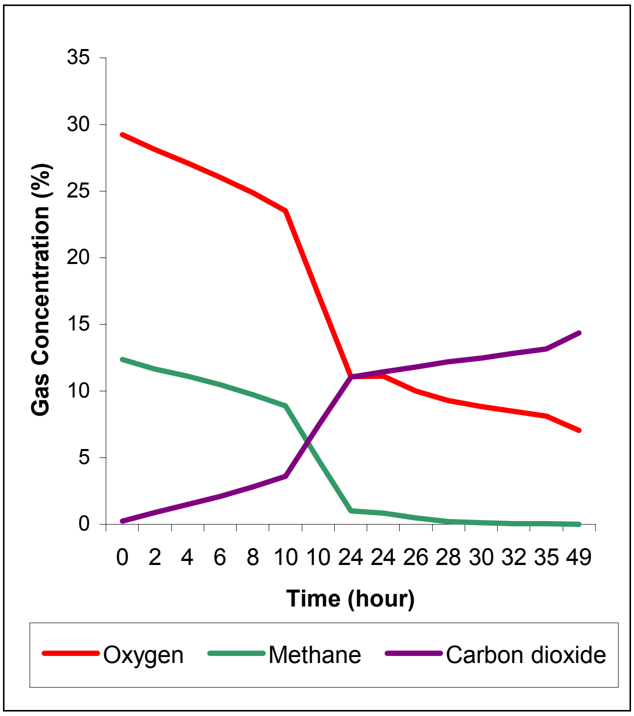

Figure 4: Percentage of O_2, CH_4 and CO_2 throughout the analysis at 35°C.

At 27 °C, methane gas was completely oxidized after the third day while at 35 °C, methane oxidation came to completion within 28 hours. It is established that the rate of methane oxidation in landfill covering soil increased as the temperature increased (Fauziah and Agamuthu, 2002).

CONCLUSIONS

Rates of methane oxidation depend on different parameters and the conditions of the samples. Soil from active cell reached completion in methane oxidation the fastest and the rate can be accelerated at temperature within the range of 27 °C and 35 °C. The results from the study indicated that rate of methane oxidation accelerated as temperature increased and methane was the most actively oxidized in the top layer soil of active cells as compared to other depths and cell age.

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Distribution Of Lead From A Disused Tin Mine Into The Pattani River In Southern Thailand

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ABSTRACT: The lead (Pb) contamination situation in the Pattani River at Yala and Pattani provinces in the Southern Thailand has been assessed. The main source for contaminating lead is Galena (PbS) in waste piles at abandoned tin mines. Sample, both water and sediments collected from 8 locations, along a distance of 120 km for two occasions March (rainy season) and June (dry season) 2002, were analyzed. Grain-size distribution highlighted the presence of two distinct particle populations in the upper Pattani River (coarser particles) and in the lower Pattani River (finer particles). The sediments are severely contaminated with Pb, especially in the vicinity of the mining pollution sources, where the metal concentrations are several orders of magnitude above background levels. Lead in sediments (particle size < 53 μm) in streams nearby Tum Ta Lu tin mines was found at high concentrations up to 28,000 ppm. Concentration of Lead in the Pattani River sediments was found to decrease with distance from the mine in both samplings. Lead in sediments after Pattani dam, around 80 km down stream from the old tin mining area, was found at elevated concentrations around 250 ppm. The dissolved lead in the Pattani River water was mostly below 20 ppb. These reported values clearly demonstrate the spreading of lead in the river system. This study can form a basis for future reference, when introduced remediation measures take effect.

Keywords: Lead, sediment, disused tin mine, waste, distribution and Thailand

INTRODUCTION

Pattani River basin (Figure 1) covering an area of around 74 square kilometres begins in the Sungalakeeree Mountain, where numerous abandoned smaller tin mines are located. The river, about 120 km in length, runs through Yala and Pattani provinces and ends in the Thai gulf at Pattani bay. One of the most important pollution problems of the Pattani River Basin, is the contamination with lead from weathering galena (PbS) from mine waste piles at disused tin mines. This has gone on for more than a century, and even after the closure 50 years ago the effluent still carries considerable amounts of suspended and dissolved heavy metals away.

In 1987, the metal contamination in Pattani bay was reported for the first time by the Everaarts and Swennen (1987). They investigated the heavy metals copper, zinc, cadmium and lead in benthos fauna and surface sediments from 3 areas: Pattani bay, Ban Don bay up the coast, and Jeram coast in Malaysia. The highest concentration of lead at 242 ppm was found in sediment samples from Pattani River mouth, while the concentrations of lead in sediments at the two other locations were 40 and 48 ppm, respectively. The authors characterised the Pattani bay as being grossly contaminated especially with lead. Later Everaarts *et al.* (1994) studied copper, zinc, cadmium and lead concentrations in sediments and some organisms at different levels in the food web *i.e.* polychaete, mudskippers and birds, collected from Pattani bay in October 1992. The concentrations for lead in the sediments were in the range of 80-100 ppm. Viriyanon *et al.* (1998) also studied copper, zinc, cadmium and lead in sediments in the Pattani bay. Some samples taken at the Pattani river mouth were found to be highly contaminated with several metals, especially lead. However in 2002, Cheewasedtham identified the shipyard at the river mouth as the major contributor of PbO, used for wood protection, to the immediate marine surroundings, and thus this point source is probably responsible for the earlier high findings.

Arrykul and Kooptarnon (1993) studied the concentration of lead in water, suspended solids and stream sediments mainly from smaller tributaries to the Pattani River. They found lead in water and stream sediments at 0.25-20 ppb and 170-3,800 ppm, respectively. They proposed that the lead could come from tin mining waste at the Pin-Yoh and Tum Ta Lu sub-districts, in the Yala province. They also determined the main components of mine waste to be tin oxide (SnO_2), galena (PbS), arsenopyrite (FeAsS), chalcopyrite ($CuFeS_2$), sphalerite (ZnS) and pyrite (FeS_2).

In the Sungalakeeree Mountain large scale mining operations have had a widespread impact on the downsteam regional watershed caused by the acid mine drainage from weathering of the tailings. Large quantities of mine waste, with toxic metals such as lead and arsenic, have been left over. Especially lead was left there in high quantities estimated at 120,000 m^3 highly contaminated waste (Department of Mineral Resources, 2000). During 1992-1995, Thailand's Department of Mineral Resources has monitored the contamination level of lead and arsenic at this disused tin mines area, at the upper part of Pattani River basin. The monitoring of water quality in 45 natural streams water samples, 6 shallow well water samples, 7 mountain piped water samples and 10 ground water samples were investigated *in total*. Some natural water resources were found contaminated with lead and arsenic at higher concentration than the standard setting for drinking water. Especially, acid water samples, in streams around Tum Ta Lu sub-district, lead and arsenic were found at 0.47 and 0.24 ppm, respectively. Lead and arsenic in the mine wastes were found at concentrations of 240-630 and 0.14-0.59 ppm, respectively.

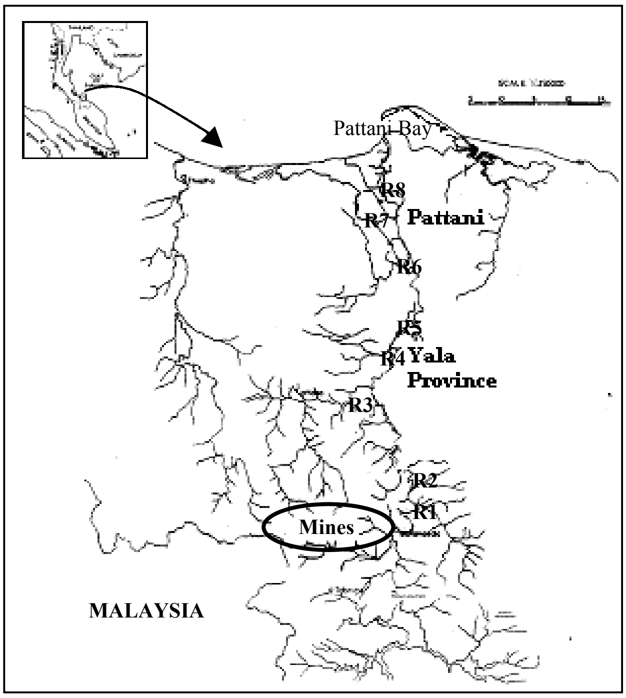

Figure 1: Map of Pattani River Basin area and sampling sites

The Pollution Control Department, Thailand, therefore proposed to study distribution, the ecological risk assessment and the strategy plan for controlling the problem for the river in the future. The project was run by the Department of Science, Faculty of Science and Technology, Prince of Songkla University, Pattani campus. This paper reports on the distribution of lead contamination of the Pattani River.

Aims Of The Study:

- To study the lead distribution in the Pattani River
- To evaluate sources for the elevated lead concentrations found in the river sediments
- To assess methods for following the lead contamination over time when changes are expected after remediation at the mining site is introduced in the period 2000 to 2003

MATERIALS AND METHODS

The 8 sampling sites (Table 1) on the river down from the disused tin-mining area Ban Nang Sta District, Yala Province to the mouth of the river are shown in Figure 1. The sediments were grab sampled down to 20 cm depth. The sediments were dried and sieved into several size ranges.

Table 1: Pattani River Sampling Stations

Station Numbers	Station Name, Province (Position)	Distance* (km)
R1	Yee Ra Pan Bridge, Yala (6^{o} 16' N, 101^{o} 17' E)	15
R2	Klong Pi Nang Bridge, Yala (6^{o} 24' N, 101^{o} 16' E)	38
R3	Ta Sab Bridge, Yala (6^{o} 33' N, 101^{o} 15' E)	61
R4	Yala Tap Water Plant, Yala (6^{o} 33' N, 101^{o} 16' E)	66
R5	Pattani Dam, Yala	80
R6	Pattani Crossing Bridge, Pattani (6^{o} 42' N, 101^{o} 17' E)	89
R7	Aa Noh Pu Loh Bridge, Pattani (6^{o} 46' N, 101^{o} 16' E)	96
R8	Ta Lu Bo Bridge, Pattani	107

*River distance from Tum Ta Lu disused tin mines at Ban Nang Sta district, Yala Province

The water samples were immediately filtered (0.45 µm) and acidified for storage.

Samplings of water and river sediment samples were done on two occasions, the 19th March (rainy season) and 18th June 2002 (end of dry season).

The lead was determined in the sieved sediment samples after extraction with HNO_3 6 M (Tjell and Hovmand, 1987). The determination was done with flame-AAS for the high concentration, and HGA-AAS for the low concentrations in water samples.

RESULTS AND DISCUSSION

The water concentrations of lead measured in the Pattani River are shown in Figure 2 where the results for the dry season and the rainy season are given.

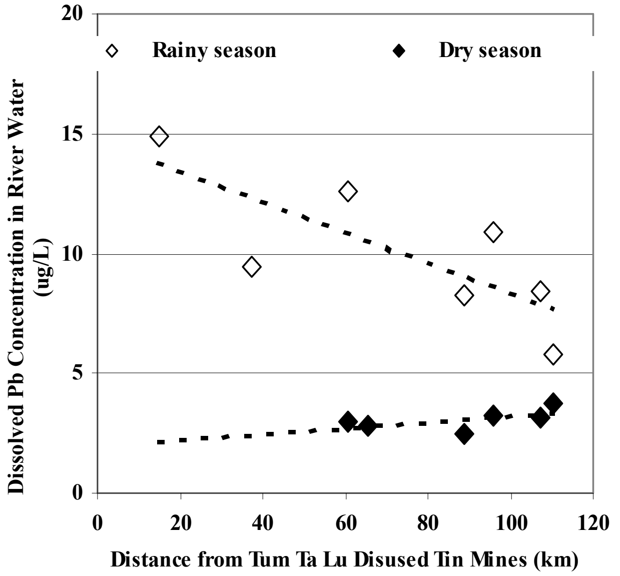

Figure 2: The water concentrations of lead measured in the Pattani River

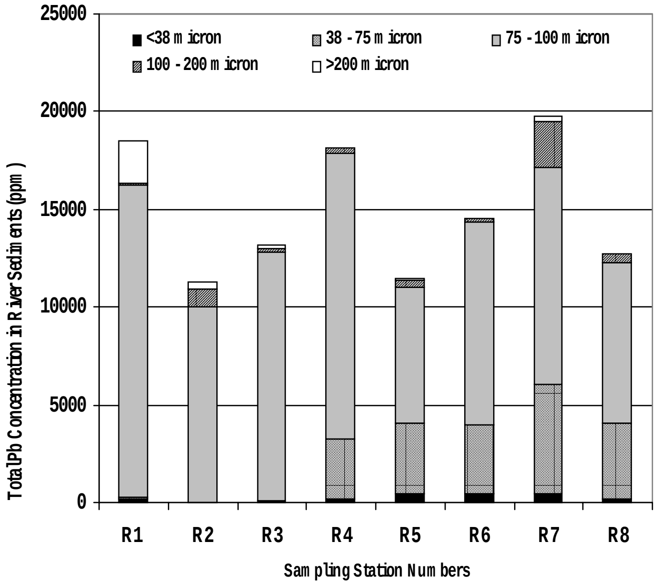

Figure 3: The sediment grain size distribution along the Pattani river

There are only recorded high concentrations in the small creeks and dams at the mining site where pH is low. In the dry season there is no indication that the Pattani River downstream from the mining area is receiving lead in dissolved form from point sources in the upper section. This is probably due to the limiting solubility of lead carbonates which are readily formed in the neutral waters (pH 6.5-7.5 and carbonate concentrations 1-2 mM) running through the calcareous hills. This means that dissolved water concentrations of lead are independent of the suspended particle concentrations or the stream sediments. The measured dissolved concentrations in the dry season are between 1-5 ppb.

The dissolved lead concentrations in the rainy season are generally higher than in the dry, around 15 ppb. The reason for this may be lower carbonate concentrations, although not measured here. There is a distinct downward trend along the river in the rainy season indicating either that lead precipitation is taking place on the plains, or that the river is receiving "clean" water from the tributaries.

Apart from the study of lead distribution in Pattani River, the contamination level of lead in sediments in small streams around the Tum Ta Lu disused tin mines area was also investigated. The lead concentration in stream surface sediments (particle size < 53 µm) was found in the ranges of 390 - 28679 ppm.

In Figure 3 is shown the sediment grain size distribution along the river. It is quite evident that the river current at the sampling points no. 1-3 in the hills is strong, only allowing the larger grains to settle.

The grains below 75 µm are virtually none existing, while grains larger than 100 µm are plentiful. Below the hills on the plain the small grains are dominant, while the largest are absent. These distinct differences means that total concentrations of lead in the sediments are not likely to reveal the influence of the mine in the hills as lead is bound to the finer particles.The total concentrations measured in the river sediments are shown in Figure 4, giving as expected no indication of the eventual point sources for lead along the river.

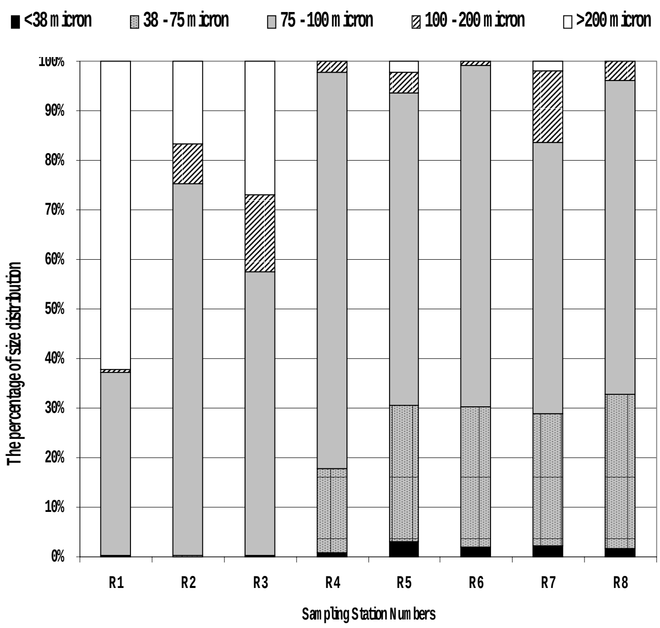

Figure 4: Total Pb concentrations measured in the Pattani river sediments

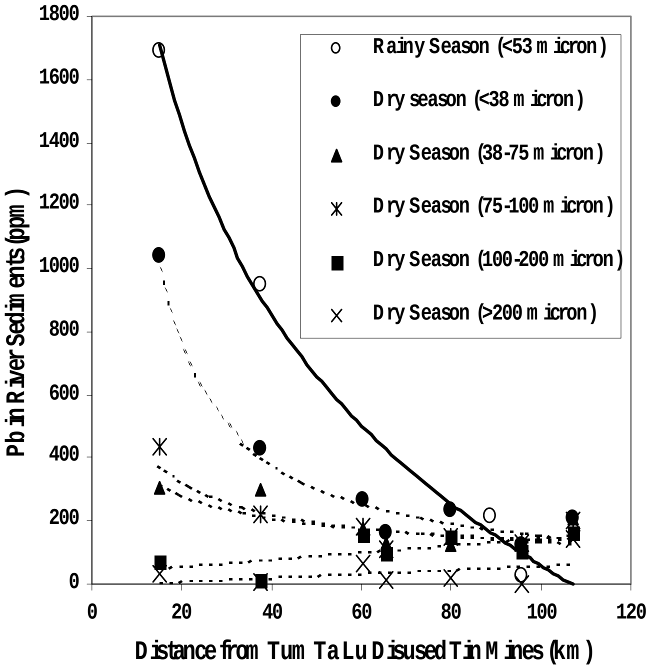

Figure 5: The lead concentrations in the different grain sizes of Pattani River sediments

Contrary to this it can be seen from Figure 5, that the finer grains have strongly elevated lead concentrations. Here the lead concentrations in the different grain sizes are shown for the sampling points. The far left column indicates the range in lead concentrations found in the finest fraction in the small creeks leading away from the mining site itself. The grains in the river sediments below 38 µm show the highest concentrations, over 1000 ppm near the outlet from the mining area, and down to 200 ppm near the bay. The larger particles have much less concentrations. The strongest indicator for the point source is therefore quite expectedly the finest grains. However it is also evident that the finest grains are “diluted” with “clean” fine grains from side streams especially within the hill tracts. At sampling station no. 4 on the plains the lead concentration in the finest fraction is down to near the average concentration downstream from this point. Apparently the Pattani River down on the plains may not be receiving significant amounts of the finest grains from smaller tributaries as the concentration in these particles is not diminishing on the plains, but remains consistently high all the way to the bay.

CONCLUSION

The lead contamination of the Pattani River show strong point source contamination originating from an abandoned tin mine in the hills near the origin of the river. The concentration of leadin the water during the rainy season was elevated, while in the dry season they are not affected and remain below 5 ppb.

The total lead concentration in the river sediments do not reveal the influence from the mine. However, the fine grained material (< 38 µm) shows strong influence from the outflow from the mining area. Analysis of the fine grains should be used as basis for monitoring effects of remediation of the mining site as was done in 2002/3.

ACKNOWLEADGEMENTS

We thank Assoc. Prof. Proespichaya Kanatharana, the group leader of the chemical assessment of the environment group at Prince of Songkla University, Thailand for the initiation of this joint research. Thanks are also due to the pollution control department of Thailand and TUCED-DUCED for the research funding.

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An Automated On-Line Solvent Extraction And Flame Atomic Absorption Spectrometric Determination Of Heavy Metals In Soil Samples

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ABSTRACT: An automated on-line solvent extraction system for flame-AAS determination of some metals in soil samples has been developed. The system employs solvent extraction of aqueous trace metals as diethyl-dithiocarbamate complexes into methy-isobutyl ketone fed directly to flame-AAS. It was found that quantitative extraction of the metals of interest: Cu, Pb, Cd, Ni and Zn was possible under an acidic condition. Thus metal contents can be determined after a sample being digested. However pH adjustment was required for Cd and Zn determination. The procedure is especially suitable for the analysis of samples with high salt and Fe contents, which usually need extensive sample preparation The method is rapid and reproducible, so it minimises tedious sample preparation and contamination. The method was validated by using soil reference materials.

Keywords: Solvent extraction, automation, diethyl-dithiocarbamate, heavy metal, flame-atomic absorption spectrometry, soil

INTRODUCTION

There are various methods to determine heavy metal in soil samples (Goossens et al., 1995; Bettinelli et al., 2000; Capitelli et al., 2002 and Tuzen, 2003). Solvent extraction is quite often used in sample treatment prior to measurement by atomic absorption spectrometry (AAS) either in order to remove the metal ions from interfering matrix components or in order to preconcentrate them (Tinsley and Iddon, 1974; Magnusson and Westerlund, 1981; Nord and Kalberg, 1983; Bengtsson et al., 1984; Ramesh Babu and Naidu, 1991; Bortoli et al. 1996; Bermejo-Barrera et al., 2002 and Ndung'u et al., 2003). The solvent extraction solves important problems related to selectivity and sensitivity in a large number of determinations. The extraction procedure may become very time consuming. The automation of the system would be useful (Wang and Hansen, 2002 and Hans et al.). Therefore an automated on-line solvent extraction and flame-atomic absorption spectrometry (FAAS) determination of heavy metals in soil samples was developed.

The system employed solvent extraction of aqueous trace metals as diethyl-dithiocarbamate (DDC) complexes into methy-isobutyl ketone (MIBK) fed directly to FAAS.

EXPERIMENTAL

The system comprises of an automated on-line solvent extraction unit, which connected with FAAS. The set up is shown in Figure 1.

Procedure

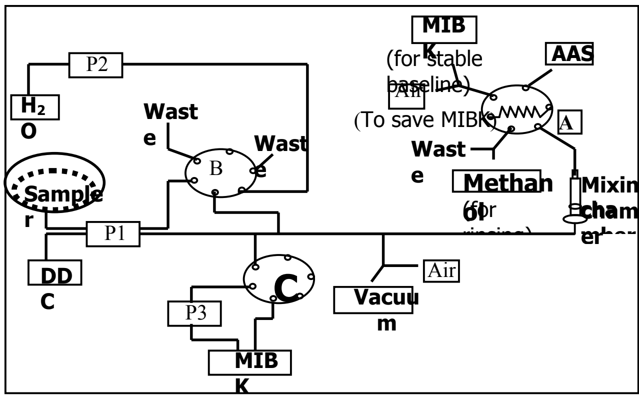

Figure 1: The set up of the automated on-line solvent extraction system for FAAS; P1 = peristaltic pump1, P2 = peristaltic pump2, P3 = HPLC pump3, A, B and C = 6-port injection valves, W = waste, AAS = atomic absorption spectrophotometer

The set-up of the system is shown in Figure 1. All components were controlled via a software program. Sample and DDC were delivered to the system by a peristaltic pump (P1). The sample was aspirated to waste first via a 6-port injection valve (B). Then the valve B was switched to pass the sample into a mixing chamber made from a 3 ml-plastic syringe. For MIBK, it was aspirated into the system by a HPLC pump (P3). It was turned on all the time during determination. MIBK was aspirated through a 6-port injection valve(C) and sent back to the same bottle when it was not involved in the procedure. All the reagents and sample related to the extraction were transferred to the mixing chamber. In order to mix all reagents well and efficient, a small magnetic bar was used. After reagents and sample were mixed in the mixing chamber and then metal-complexes were extracted into an organic phase. After leaving for a while, organic and aqueous phases were separated from each other. The organic phase, lower density than water, the upper layer was flowed to fill the sample loop of 6-port injection valve (A) by transferring water to the chamber with another peristaltic pump (P2). Then the valve (A) was switched and metal-complexes in organic phase was transferred into the carrier stream of MIBK, which passed throughout the valve (A) by nebuliser of FAAS, then fed directly to FAAS. After that methanol was sucked to clean the system by a vacuum. The rinsing procedure is necessary to avoid a carry over effect.

RESULTS AND DISCUSSION

Effect of injection volume

The effect of injection volume was investigated. The standard solutions of Cu(II) in the range of 10-1000 ug l^{-1} in 0.1 M HNO_3 were prepared. The results are illustrated in Figure 2.

It was found that higher injection volume produced higher sensitivity (better slope of a calibration graph). The sensitivity slightly decreased when an injection volume larger than 150 ul. That means, an injection volume larger than 150 ul should not be considered. The injection volume of 150 ul was the most suitable, however peak shape was well defined and precision was the best when using injection volume of 100 ul. Smaller injection volume was preferred because less organic phase was used and more convenient to fill sample loop up. Hence an injection volume of 100 ul was selected.

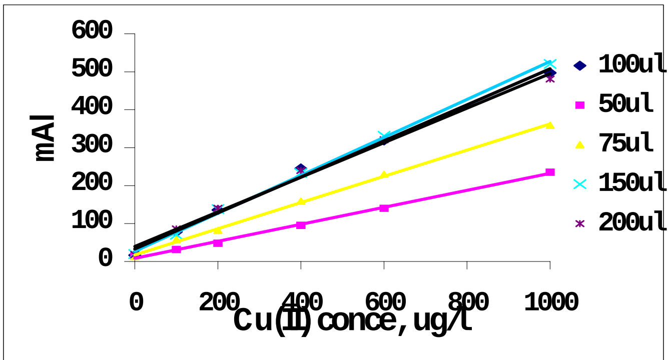

Figure 2: Effect of injection volume on calibration graph

Effect of pH

Efficiency of extraction is affected by pH. To investigate this effect, 1.0 mg l^{-1} standard solutions of each metal solution were prepared. Acetate buffer was used to control pH. The pH was varied in the range of 0-4 by adding (conc.) HCl. The results are shown in Figure 3A and Figure 3B.

It is indicated that there is no significant difference of signal at different pH for Cu, Pb and Ni determination. Therefore, it's possible to determine these metals in a digest solution without any pH adjustment. Anyway pH has affected to Cd and Zn determination obviously. Both of Cd and Zn could not be extracted efficiently at pH approximately lower than 1.0. It is necessary to adjust pH before determination.

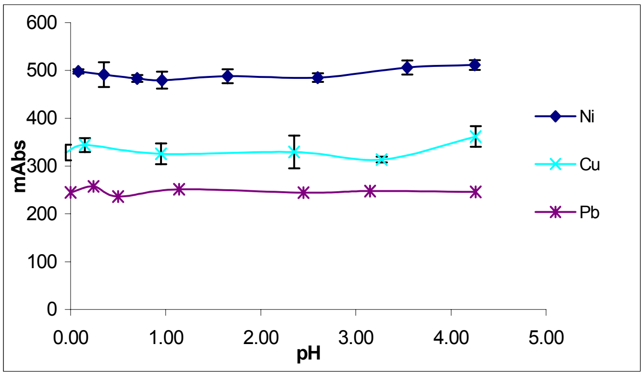

Figure 3A: The effect of pH on signal for Cu, Pb and Ni determination

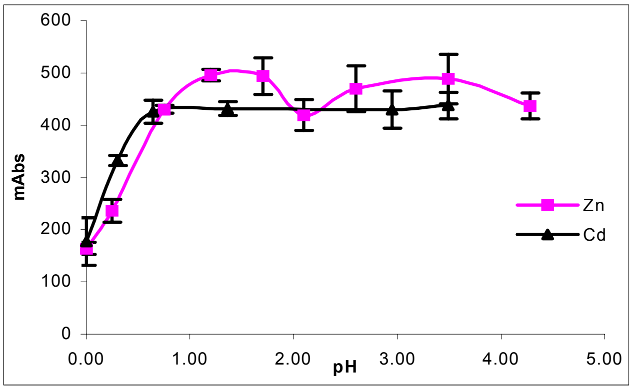

Figure 3B: The effect of pH on signal for Cd and Zn Determination

Application

The proposed system was applied to soil reference materials. The results are shown in Table 1.

It was found that the results by the proposed method were corresponding to those obtained from certified values for soil reference materials.

Table 1: Application of the proposed method for heavy metals determination in soil reference materials

Heavy Metals (mg kg^{-1})	Soil-5, n=2		DS-259, n=2	
	Developed method	Certified Value[a]	Developed method	Certified Value
Cu	72.0	72.0	15.0	14.0
Pb	144.6	146.0	28.5	22.0
Ni	7.5	7.3	7.6	7.6
Cd	1.13	0.92	0.19	0.17
Zn	390	360	47	55

*n= replication, Soil-5 and DS-259 = reference materials, [a]= certified value of soil reference material from IAEA

CONCLUSION

The automated on-line preconcentration flame atomic absorption spectrometric method fulfills the demand for detection limit imposed by for example Danish threshold limits-avoiding costly and laborious graphite oven or ICP method.

The authors are grateful to the Thailand University Consortium for Environment and Development-Industry and Urban Areas (TUCED-I&UA) and the Development and Promotion of Science and Technology Talent Project (DPST) for providing scholarship and the Postgraduate Education and Research Program in Chemistry (PERCH) for partial support.

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Sample Preparation Techniques For Polycyclic Aromatic Hydrocarbons (PAHs) Analysis In Various Samples

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ABSTRACT: The sample preparation techniques were studied for trace PAHs (7 PAHs in group 2B) analysis. Various sample preparation techniques, *i.e.* Solid Phase Extraction (SPE), Accelerated Solvent Extraction (ASE), Soxhlet Extraction (SE), Membrane Extraction (ME), and Gel Permeation Chromatography (GPC) were studied for water and fried chicken samples. The analysis were carried out by Gas Chromatography equipped with Flame Ionization Detector (GC-FID) and spectrofluorometry at the optimum conditions, *i.e.* Gas Chromatography carrier gas (He) flow rate :1.5 mL/min, column programmed temperature was operated as initial temperature: 130°C, then ramped the temperature with rate of 15°C/min to 220°C and hold for 1 min. The temperature was ramped to final temperature: 290°C with rate 3°C/min, hold the temperature at this for 2 min. The injector and detector temperature were 280 and 300°C respectively. Spectrofluorometry excitation (λ_{ex}) and emission (λ_{em}) wavelength were 286 and 389 nm respectively. These sample preparation techniques required less organic solvent and provided high recovery (60 – 100%) and acceptable precision (% RSD < 10).

Keywords: PAHs, water analysis, food contaminated

INTRODUCTION

Humans are at risk from contact and expose to pollutants from contaminated air, soil, water and/or food. Polycyclic Aromatic Hydrocarbons (PAHs) were reported as carcinogenic and mutagenic substance by many organizations concerned with human health and environmental pollutants. US EPA classified seven PAHs as group B2, indicating the evidence to possible carcinogens in human. These are Benzo(a)anthracene,B(a)an;Chrysene,Chry;Benzo(b)fluorathene, B(b)fl; Benzo(k)fluorathene, B(k)fl; Benzo(a)pyrene, B(a)p; Indeno(1,2,3-cd)pyrene, I(123-cd)p; and Dibenzo(a,h) anthracene, D(a,h)an. PAHs are ubiquitous pollutant since they are originating from a wide variety of natural and anthropogenic sources. PAHs are generally formed during incomplete combustion or pyrolysis of organic matter (Popp *et al.*, 2000). The main natural sources of PAHs emissions are forest fire and volcanic eruption, and the anthropogenic sources are industrial emission, domestic or municipal effluent, engine consumption of fuel, crude oils spillage, and coal tar etc. PAHs have two or more fused benzenoid rings and no elements other than carbon and hydrogen. According to their chemical structure the solubility decreases when molecular weight increases (Marce and Borrull, 2000).

PAHs present in water may originate from fall out including wet and dry particulate matter and vapor transported through the air. Atmospheric deposition is considered to be important input of PAHs to surface waters. It has been estimated that 10 – 80% of PAHs input to the world's oceans is from atmospheric sources (Manoli and Samara, 1999). In fact, PAHs are widely distributed throughout the water on the earth where they can enter the food chain. Most of the higher PAHs are slowly degraded, and thus represent a long-term potential health hazard to man and animal (Li *et al*., 2000).

Different laws on water for public consumption passed by the EU, US EPA, and WHO include control over PAHs. The recent European Community Directive 80/778/EEC states a maximum level for PAHs in drinking water of 0.2 μg/l with Fluoranthene, fl; B(a)p; B(b)fl; B(k)fl; Benzo(ghi)perylene, B(ghi)pe and limits to 0.01 μg /l for B(a)p. Maximum levels for the sum of PAHs in surface water can reach 1 μg/l depending on the surface water treatment process. The US EPA legislation includes B(a)p and limits it to a concentration of 0.2 μg/l. WHO in its lastest "Guidelines for drinking water quality", considers only B(a)p with a reference level of 0.7 μg/l (Urbe and Ruana, 1997, Manoli and Samara, 1999).

PAHs have spread nearly everywhere and reach some of our food through the air and the soil. But the food was not only contaminated by pollution from burning fuel. Some preparation methods used in the food industry during oil refining and processes such as smoking, roasting, frying, and grilling can leave food contaminated with PAHs. The main source of human PAH intake is by the consumption of cereal product, edible oils and fats (Europa, 2003). There is no

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directive of European Union (EU) establishing legal limits for these compounds in oils and fats. For instance, Germany, Austria and Switzerland have adopted a legal limit of 1 ng g^{-1} for B(a)p content in smoked foodstuff, and recently Spain has set a limit of 2 ng g^{-1} in olive residue oils for some of these compounds. This lack of a legal limit in edible oils and fats has led some organizations to set their own recommended limits. For example, Germany Society for Fat Science has established the following limits: 25 ng g^{-1} for total PAHs and 5 ng g^{-1} for heavy fraction. Taking these facts into account, there is a need to design analytical methods which reach these limits of detection (Barranco *et al*., 2003).

PAHs are usually determined by chromatographic techniques because of the wide range of different compounds with similar characteristics, and individual concentration. These include High Performance Liquid Chromatography (HPLC), Gas Chromatography (GC), Supercritical Fluid Chromatography (SFC), and Capillary Electrophoresis (CE) etc., with various detectors such as Ultraviolet Detector (UVD), Fluorometric Detector (FLD), Mass Spectrometry Detector (MSD), or Flame Ionization Detector (FID) (Manoli and Samara, 1999).

Due to the complexity of the matrix, PAHs determination in environmental samples is often a difficult task, even after fractionation of sample extracts, therefore good chromatographic selectivity, both in separation and in detection are required during environmental analysis. Moreover, since their concentration in water sample is extreamly low due to their low solubility, the determination of PAHs is rather difficult (Bruzzoniti *et al*, 2000). In general, most organic pollutants of interest in aqueous and food samples have to be extracted and enriched before the instrumental determination. This isolation from a sample matrix is often achieved by sampling and extraction steps separate from the instrumental analysis. In the past, sample preparation was dominated by the conventional liquid – liquid extraction (LLE). Today many sampling and extraction methods are still based on classical technique, such as the common Soxhlet extraction method (Eisert and Levsen, 1996). Liquid – liquid extraction has been largely replaced in the past few years by SPE using a variety of different sorbents. An optimized selectivity could be achieved by using analyte–specific sorbent for different compound classes.

In this study, we emphasized on the sample preparation techniques for the seven PAHs in various matrices, *i.e.* water sample and fried chicken. These techniques: Solid Phase Extraction (SPE), Accelerated Solvent Extraction (ASE), Soxhlet Extraction (SE), Membrane Extraction (ME) and Gel Permeation Chromatography (GPC) were used in the cleaning up step for concentrated sample. Two analysis method were used *i.e.* Gas Chromatography-Flame Ionization detector (GC-FID) and spectrofluorometry.

EXPERIMENTAL

Reagents

Certified seven PAHs, group B2, standard solution, with 99% purity, were purchased from Restek, USA. Solvents used in the study i.e. dichloromethane, methanol, acetone, ethyl acetate, 2-propanol, and isooctane, are all AR grade from Lab-scan, Thailand.
All gases, nitrogen (OFN grade), hydrogen and helium (high purity grade), and air (zero grade) used in experiment from TIG, Thailand.

Solid Phase Extraction

A 100-ml water sample was added with 0.5% (v/v) of 2-propanol as organic modifier, then kept it overnight in dark or foil-wrapped at 4°C.

ENVI^{TM}-18 (Reverse phase octadecyl silica-bonded) DSK 47 mm Solid Phase Extraction Vacuum Disks (Supelco, USA) was used in this work. The disk was cleaned by rinsing with 10.0 mL of dichloromethane follow with 5.0 mL ethyl acetate. These solvents were passed through the disk under vacuum. The conditioning solvents were 10.0 mL methanol followed by 10.0 mL water. After the disk was cleaned and preconditioned, water sample was loaded into the apparatus reservoir and vacuumed through the disk. The disk was left to dry for 3 minutes, then PAHs were eluted from the disk with 5.0 mL acetone. Ten mL of acetronitrile, was then passed through the disk. Finally, two portions of 3.0-ml ethyl acetate were used as the last elution solvent. The solvent extract was dried by evaporating rotator until dry. A 0.3-ml dichloromethane was then added and this was analyzed by GC-FID (HP 6890 Seires, Hewlette Packard, USA).

Membrane Extraction – flow fluorescence

Benzo(a)anthracene was selected to represent PAHs in water. The flow fluorescence system include a peristaltic pump (Gilson Miniplus3, France), Viton tube (i.d. = 1.5875 mm), a lab-built dialyser and a Spectrofluorometer (model FP 777) as detector. Water was used as carrier and the eluting solvent was isooctane. The sample carrier and eluting solvent were pumped at flow rate 0.5 ml/min through the system to a reaction coil via the Viton tube. At the reaction coil, water sample and organic solvent were mixed and analyte from the aqueous phase was partitioned in to the organic phase. The separation was ongoing at the lab-built dialyser which consisted of a hydrophobic membrane. Analyte and organic solvent passed through the membrane while the carrier was drained through waste-line. The analyte was collected on the other side of the membrane and was analyzed by Spectrofluorometer with an excitation wavelength of 286 nm and an emission wavelength of 389 nm.

Soxhlet Extraction

The ground fried chicken sample was added into cellulose thimble, and assembled to the soxhlet apparatus. The sample was extracted with dichloromethane for 8 hrs. The extractant was filtered with 0.45 μm Nylon filter and concentrated by evaporating rotator. Then, the analyte was determined by spectrofluorometer at excitation and emission wavelengths at 305 and 412 nm respectively.

Accelerated Solvent Extraction

The ground fried chicken sample was mixed with sodium sulphate and added into extraction cell. The accelerated solvent extractor conditions were set as static time 5 min, % flush 60 sec, purge 60 sec, cycle 1, pressure 1500 psi, and temperature 125°C.

The supernatant was centrifuged for 20 min and filtered by 0.45 µm Nylon filter and concentrated by evaporating rotator. The analyte was then determined by spectrofluorometer at excitation and emission wavelengths at 305 and 412 nm respectively.

Gel Permeation Chromatography

The extractant from fried chicken sample was used to study the clean up step of PAHs in matrix. The analyte was injected to 300 mm × 19 mm i.d. reverse phase Environ gel (Polystyrene divinylbenzene) column equipped with UV-visible spectroscopy detector, using dichloromethane as the mobile phase. The analyte was pumped through the system with a flow rate at 2.00 ml/min. The fraction was collected at 24.28 – 32.60 min and the analyte was concentrated by rotating evaporator. A 1-µl of analyte was analyzed by GC-FID.

Gas Chromatography-Flame Ionization Detector

The water sample extracted by SPE and the fried chicken cleaned up by GPC were analyzed by GC-FID using the following optimum conditions: carrier gas (He) flow rate: 1.5 ml/min, column programmed temperature was operated as initial temperature 130°C, then ramped the temperature with rate of 15°C/min to 220°C and hold for 1 min. The temperatures was ramped to final temperature 290°C with rate 3°C/min, hold the temperature at this for 2 min. The injector and detector temperature were 280 and 300°C respectively.

RESULTS AND DISCUSSION

Sample preparation by SPE

SPE method development was based on the optimization of elution solvent, solvent volume, drying time, and percentage of organic modifier.

Figure 1 shows the effect of the percentage of 2-propanol to the recovery of PAHs from SPE method. The extraction was run under the optimum conditions as mentioned the in the experimental section.

The results showed good recovery and good precision (% RSD < 10). The recovery of seven B2 PAHs was summarized in Table 1.

The advantages of SPE are the selectivity of C_{18} sorbent to PAHs without breakthrough problem. The method was also environmental friendly because minimal solvent was required (less than 6 mL).

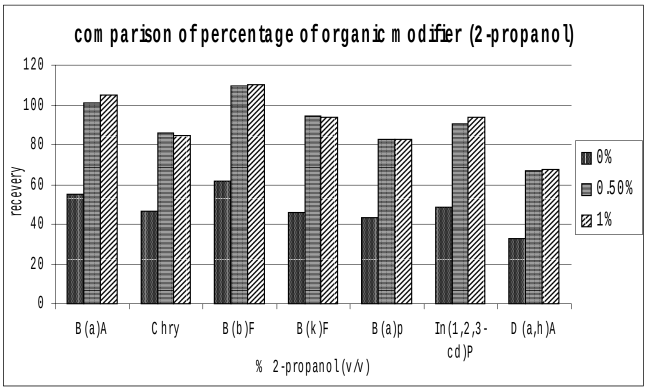

Figure 1 comparison of percentage of 2-propanol

Table 1 Recovery of seven PAHs from SPE method

PAHs	Recovery (%)
Benzo(a)anthracene	100.7
Chrysene	85.9
Benzo(b)fluoranthene	109.3
Benzo(k)fluoranthene	94.2
Benzo(a)pyrene	82.8
Indeno(1,2,3-cd)pyrene	90.4
Dibenzo(a,h)anthracene	67.0

Membrane Extraction

The proposed ME, hydrophobic membrane, was used in our work to decrease the amount of solvent used in sample preparation of PAHs. The sample was simulated by adding B (a) an into ultra pure water then passed the water through the system as described in the experimental section. The result showed linearity in the range of 10 – 300 ppb, and the analysis time was 50 min. The proposed ME system has a possibility to be developed into an on-line sample preparation systems.

Comparison of Soxhlet extraction and ASE

From this study, ASE had advantages over SE, i.e. better recovery, time, and precision. The recoveries from ASE were over 100 % while SE was less than 30 %. The sample preparation time was only 20 minutes for ASE compared to 8 hours by SE. The ASE gave a better precision than SE *i.e.* % RSD < 5 and < 10 respectively.

Cleaning up by GPC

Samples of fried chickens cleaned up by GPC were compared to these without the cleaned up. GC chromatograms indicated that the cleaned up sample was clean and had lower interference. The cleaning up also provided good recovery for the collecting of the fraction i.e. 80.0%.

CONCLUSIONS

The difficulty in the management of sample for analysis of trace pollutant in any matrix is from their complexity. PAHs are ubiquitous pollutant which is found in many samples. Extraction technique is usually employed for compounds which could not be analyzed efficiently by purge and trap, because the analyte is not volatile enough to be purged in a reasonable time. This work provided several alternative for sample preparation of PAHs which can be applied to various profiles of matrix, either solid (fried chicken sample) or liquid (water sample).

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Numerical Analysis Of TCE In Porous Media

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ABSTRACT : The study of nonaqueous phase liquids (NAPL) for volatile organic compounds (VOC), requires a solution of multiphase fluid flow, heat flow and pollutant transport in a deforming porous media. A numerical model has been developed that describes the phenomena which govern a fully coupled multiphase fluid flow, heat flow and pollutant transport through soil in a deforming porous media for subsurface systems. In this study, the liquid phase is assumed to be pore water and NAPL containing dissolved dry air, whilst, the gas phase is composed of two continuous subphases; vapour phase and 'dry' air phase (i.e., air), where the dry air is the air that does not contain water vapour. The nonlinear saturation and relative permeability functions are incorporated into Galerkin finite element model, which is subsequently used to simulate multiphase immiscible fluid flow under unsaturated conditions in porous media. The governing partial differential equations, in terms of soil displacements, fluid pressures, concentrations and temperature, which are coupled and non-linear, are solved by the finite element method. The weighted residual finite element approach is employed to achieve spatial discretization of the problem while temporal discretization is achieved by a fully implicit scheme. Numerical implementation of the formulation is discussed and examples of the problems of TCE in one-dimensional analysis are presented to demonstrate the model capability for geoenvironmental applications.

KEYWORDS: Groundwater, unsaturated zone, finite element, TCE, multiphase flow, heat and volatilisation.

INTRODUCTION

The occurrence of groundwater contamination and the quality of groundwater have become major issues since the discovery of numerous hazardous waste site in the late seventies. The migration of contaminant, process of dissolution, factors of influence, effects and the techniques for remediation of groundwater contamination are the main components to understand and look after, to ensure these resources could be used in the long term. Due to these reasons, some alternatives are needed in order to simulate the behaviour of groundwater contamination.

An understanding of the mechanisms of pollutant transport through soil is very important in predicting VOC volatilisation from the soil system. In contaminant aspect, there are several important mechanisms of pollutant transport involved such as diffusion through the vapour and aqueous phases, flow of water-soluble pollutants to the surface due to capillary action and evaporation of water from the soil surface. Factors that affect volatilisation include contaminant vapour pressure, contaminant concentration, Henry's law constant, chemical adsorption reaction, contaminant solubility in soil water and soil organic matter, soil temperature, water content, organic content, porosity, bulk density, humidity and adsorption to soil. However, the major contaminant property effecting volatilisation is its vapour pressure and the factors effecting contaminant mobility such as various air or water partition coefficients, which is present within the soil system.

Numerical model is one of the techniques that have been developed as an effort to quantify some of the phenomena of groundwater contamination. Laboratory works and field studies have been carried out in order to understand the processes of contamination and to get data required in model verification. All the experiments and models were developed to assess the impact of contaminant concentration on the subsurface systems, especially for petroleum product. Therefore, these types of contaminants had been recognized for a long time compared to other types of chemical contaminants.

CONTAMINANT IN THE UNSATURATED ZONE

Many highly toxic contaminants commonly found in the subsurface occur as slightly soluble and highly volatile fluids and immiscible with water. Despite of their low solubility, these compounds post a widespread potential threat to our groundwater resources. The important characteristics of the contaminant that should be considered includes vapour pressure, aqueous solubility, Henry's law constant, diffusion coefficient and the ability of contaminants to degrade. Therefore, the organic compounds have a potential to degrade biologically and chemically. Thus, contaminants with high vapour pressure will volatilised quickly compared with the contaminants, which have lower vapour pressures such as pesticide.

In unsaturated soil, organic compounds may dissolve into the water phase, as well as volatilise into the gas phase. The indicator parameter that measures the ability of the organic compound to dissolved in water is called the water solubility. After dissolving into the aqueous phase, the solute is transported to the saturated zone. In reality, transport in the unsaturated zone is much more complex than in the saturated zone mainly because there are numerous phases of interest: soil, water, air and contaminant. Chemicals exist in the unsaturated zone in four phases: dissolved in soil moisture, sorbed to the soil particles, as nonaqueous phase liquids (NAPL) and as an enveloped of organic vapours. These organic vapours have been identified as one of the more ubiquitous groups of hazardous chemicals present in contaminated soils and groundwater. They can migrate much faster than the liquid phase. Moreover, the vapour flow velocities and direction are not controlled by groundwater gradients.

PHYSICAL MODEL PROPERTIES AND CONSIDERATION

The physical model for multiphase flow within an unsaturated flow regime can be described as follows:

a) The phase saturation value sum to unity, i.e.:
b)

$$S_n + S_w + S_g = 1$$

where S_n is the NAPL saturation, S_w is the water saturation and S_g is the gas saturation.

c) Capillary pressure and temperature are function of saturation, i.e.;

$$S_\alpha = f(P_{cgw}, P_{cnw}, T)$$

where, $P_{cgw} = P_g - P_w$ and $P_{cnw} = P_n - P_w$. These equations are function of two capillary pressure values (gas, water, NAPL and temperature). The nonisothermal case refers to conditions where temperature is not a constant.

d) Relative permeability is a function of saturation, i.e;

$$K_{rw} = K_{rw}(S_w)$$
$$K_{rn} = K_{rn}(S_w, S_g)$$
$$K_{rg} = K_{rg}(S_g)$$

e) The pressures are function of density and viscosity.

The distribution of the zones as a function of capillary pressure and the relative permeabilities for the water, $k_{rw,}$ and gas, k_{rg} phases are calculated form capillary pressure values using the Brooke & Corey (1964) equations and relative permeability for NAPL, k_{rn} based on Lujan (1985) as below:

$$k_{rg} = S_{we}^{\frac{(2+3\lambda)}{\lambda}} \tag{1}$$

$$k_{rg} = (1 - S_{te})^2 (1 - S_{te}^{\frac{(2+\lambda)}{\lambda}}) \tag{2}$$

$$k_{rn} = (S_{te} - S_{we})^2 (S_{te}^{\frac{(2+\lambda)}{\lambda}} - S_{we}^{\frac{(2+\lambda)}{\lambda}}) \tag{3}$$

which,

$$S_{we} = \left(\frac{S_w - S_{rw}}{S_{\max}} \right)$$

$$S_{te} = \left(\frac{1 - S_g - S_{rw} - S_{rn}}{S_{\max}} \right) \tag{4}$$

Where S_{we} is the effective water saturation and S_{te} is the total effective liquid saturation. In the fluid density function, for a non-isothermal case, the thermal effects on the rate of fluid accumulation in the mass conservation equation are also considered. The solid density ρ_s and the pore liquid density ρ_α are assumed to be pressure, temperature and contaminant concentration dependent (Norhan Abd. Rahman and Lewis, 1997) as below:

$$\rho_w = \rho_w(P_w, T, C_w),$$
$$\rho_g = \rho_g(P_g, T, C_g),$$
$$\rho_n = \rho_n(P, T),$$
$$\rho_s = \rho_s(P, T) \tag{5}$$

The fluid density is taken to be linear function of pressure, temperature and contaminant concentration. For flow solubility the organic contaminants also requires a consideration of the interphase mass transfer. Dissolution and volatilization of the NAPL phase are responsible for the input of the pollutant into the groundwater and soil gas, and gas water partitioning can significantly affect transport within these phases (Dorgaten and Tsang, 1992). The dissolution rate is controlled by C_{wm} which is the equilibrium concentration of the organic matter in the water phase and controlled by a rate coefficient κ_{nw} where:

$$\frac{\partial C_g}{\partial t} = \kappa_{ng}\left(C_{gm} - C_w\right) \quad \text{and}$$

$$\frac{\partial C_g}{\partial t} = \kappa_{wg}\left(HC_w - C_g\right) \tag{6}$$

where C_{gm} is the equilibrium concentration in the vapour phase, C_g is the concentration of organic constituent in the gas phase, and κ_{ng} is the mass transfer coefficient for volatilization of organic compounds in the vapour phase. Interphase mass transfer by dissolution and volatilization will generally be the dominating phase exchange in regions where a significant amount of the NAPL phase is present. Gas-water partitioning is mainly controlled by Henry's law with a constant value of H that express the relation between C_g and C_w at equilibrium, where $H = \frac{C_{gm}}{C_{wm}}$, and κ_{wg} is the mass transfer coefficient for gas-liquid partitioning between the water and gas phases.

THEORETICAL FORMULATION

The molar concentration of the air is given by c_{gj} and could be derived from Dalton's law. Hence, by assuming that dry air and water vapour behave as ideal gases:

$$P_g = P_j + P_v + P_i \tag{7}$$

where P_j, P_v and P_i represent the partial pressures of air, water vapour and the contaminant gas respectively. Introducing the ideal gas assumption and simplifying yields the molar concentration of dry air (Thomas and Ferguson, 1998):

$$c_{gj} = \frac{P_g}{RT} - \frac{\rho_v R_v}{R} - c_{gi} \qquad (\text{mol/m}^3) \tag{8}$$

where ρ_v is vapour density and R_v is specific gas constant for water vapour. The sum of the molar concentrations, c_g, which relates to the gas phase pressure P_g (Pa) and its absolute temperature T (°K) by the ideal gas law, now becomes:

$$\sum c_i = c_g = c_{gj} + c_{gi} = \frac{P_g}{RT} - \frac{\rho_v R_v}{R} (\text{mol/m}^3) \tag{9}$$

The equation for mass density,

$$\rho_g = \frac{M_{gj}}{1000R}\left(\frac{P_g}{T} - \rho_v R_v\right) + \frac{M_{gi} - M_{gj}}{M_{gj}} c_{gi} \tag{10}$$

Finally, the density of the gas phase becomes,

$$\left(\frac{d\rho_g}{dT}\right)_P = \frac{M_{gj} P_g}{1000RT^2}$$

$$\left(\frac{d\rho_g}{dP_g}\right)_T = \frac{M_{gj}}{1000RT} \tag{11}$$

$$\left(\frac{d\rho_g}{dC_{gi}}\right) = \frac{M_{gi} - M_{gj}}{M_{gi}} = \beta_{cg} \tag{13}$$

The gas and water phase tortuosity is taken from the Millington and Quirk model as :

$$\tau = \phi^{1/3} S^{7/3} \tag{14}$$

by assuming that local chemical equilibrium exists between the liquid or organic phase, gas phase and water phase. Partitioning between water and gas is common and is described by Henry's law where the Henry constant of low solubility can be calculated by a formulation governs by Jury et. al (1983) as follow:

$$H = \frac{C_i}{C_w} \tag{15}$$

where C_w is the solubility of the organic in water , H is Henry's constant for the organic material and the parameter for h can be represent as, $h = \frac{1}{H}$.

Governing Equation

The governing equations that might be used in this VOC model are such as soil equation, multiphase equation and energy equation, which were derived from the previous model (Norhan Abd. Rahman, 1998). Meanwhile, in a multiphase flow equation especially in gas phases, which consists of vapour flow and dry air equation, the equation used is referred to the equation of contaminant from Thomas and Ferguson (1998).

Multiphase Flow Equation

In the multiphase phase flow equation, the fluid phase behaviour of immisible and incompressible fluids flowing in a deforming porous media can be obtained by combining Darcy's linear flow with the mass conservation balance for each of the flowing phases. Lewis and Schrefler (1987) have previously studied this behaviour of contaminant then continued by Norhan Abd. Rahman (1998) with additional processes of interphase mass transfer. The Darcy's velocity can be expressed as:

$$V = -\frac{1}{\mu} K \nabla (P + \rho g h) \tag{16}$$

where, K represents the absolute permeability matrix of the medium *(L^2)*, μ is the dynamic viscosity of the fluid *(M/LT)*, g is the gravitational constant *(L/T^2)* and h is the head above a given datum.

General form of the continuity equation for each of the phase may be expressed as:

$$\begin{aligned} & -\nabla^T \left[\frac{Kk_{r\alpha}\rho_\alpha}{\mu_\alpha B_\alpha} \nabla (P_\alpha + \rho_\alpha g h) \right] + \\ & \rho_\alpha \frac{S_\alpha}{B_\alpha} \left[\left(m^T - \frac{m^T D_T}{3K_s} \right) \frac{\partial \varepsilon}{\partial t} + \frac{m^T D_T C}{3K_s} + \left(\frac{(1-\phi)}{K_s} - \frac{m^T D_T m}{(3K_s)^2} \right) \frac{\partial \bar{p}}{\partial t} + \right. \\ & \left. \left(-(1-\phi)\beta_s + \frac{m^T D_T m}{3K_s} \frac{\beta_s}{3} \right) \frac{\partial T}{\partial t} \right] + \\ & \phi \frac{\partial}{\partial t}\left(\frac{\rho_\alpha S_\alpha}{B_\alpha} \right) + \rho_\alpha Q_\alpha + \Gamma_\alpha = 0 \end{aligned} \tag{17}$$

where,

$$\phi \frac{\partial}{\partial t}\left(\frac{\rho_\alpha S_\alpha}{B_\alpha}\right) = \phi \frac{\rho_\alpha}{B_\alpha}\frac{\partial S_\alpha}{\partial t} + \phi \frac{S_\alpha}{B_\alpha}\frac{\partial \rho_\alpha}{\partial t} + \phi \rho_\alpha S_\alpha \frac{\partial}{\partial t}\left(\frac{1}{B_\alpha}\right)$$

$$\Gamma_w = -\phi S_w \kappa_{nw}\left(C_{wm} - C_w\right) + \phi S_g \kappa_{wg}\left(HC_w - C_g\right)$$

$$\Gamma_g = -\phi S_g \kappa_{ng}\left(C_{gm} - C_g\right) + \phi S_g \kappa_{wg}\left(HC_w - C_g\right)$$

where ϕ, Γ and Q are the porosity of the medium, internal sinks or sources due to interphase mass transfer and internal sinks or sources. Equation (17) is called a multiphase incompressible fluid flow with interphase mass transfer for an isotropic soil in deforming porous medium. Additionally, this equation is strongly coupled and nonlinear, due to dependence of the saturations on the capillary pressures and represents the general governing equation for multiphase incompressible fluid flow with interface mass transfer for an isotropic soil. The mobility terms in this equation also are strongly dependent on the unknowns. Furthermore, the fluid flow is coupled with the transport, due to the dependence of the densities on the concentration and due to interphase mass transfer.

Vapour Flow Equation

The development of the equilibrium of vapour equation is based on the theoretical approach from Thomas and Ferguson (1998). The governing principle of vapour flow is as stated below:

$$\frac{\partial(P_w\theta_v)}{\partial t} = -\nabla.(\rho_w V_v) - \nabla.(\rho_v V_g) \qquad (18)$$

and;

$$\theta_v = \frac{\phi S_g \rho_v}{\rho_w}$$

where θ_v, ρ_v, V_v and V_g are the volumetric vapour content, water vapour density, vapour velocity and gas velocity, respectively. This equation assumes that the liquid water and the water vapour are in equilibrium at every instance. The value of S_g denotes the gas saturation and it is a function of temperature.

Dry Air Equation

At the constant temperature, the weight of gas that dissolves in a given volume of liquid is directly proportional to the pressure of the gas with which it is in contact. By invoking the principle of conservation of mass to the dry air phase yields (Thomas and Ferguson, 1998):

$$\frac{\partial}{\partial t}\left[\phi C_{gj}\left(S_g + H_{air}S_w\right)\right] = -\nabla\left[C_{gj}\left(V_g + H_{air}V_w\right)\right] \qquad (19)$$

where H_{air} is Henry's coefficient for air, C_{gj} is the molar concentration of the contaminant gas, V_g and V_w are the gas velocity and water velocity and S_g, S_w is the saturation of gas and saturation of water, respectively.

Gas Migration Equation

The contaminant gas migration is based on the principle of mass conservation and assumed that gas and liquid velocities of the contaminant gas are equal to those of the gas mixture gives (Thomas and Ferguson, 1989):

$$\frac{\partial}{\partial t}\left(\phi S_g C_{gi} + \phi H_i S_w C_{gi}\right) = \nabla\left(\left[D_g + H_i D_w\right]\nabla C_{gi}\right) - \nabla\left[\left(V_g + H_i V_w\right)C_{gi}\right] \qquad (20)$$

where, D_g, D_l and H_i are the effective diffussion coefficient, the hydrodynamic coefficientand Henry's law coefficient for the contaminant gas, respectively.

Energy Transport Equation

Referring to Norhan Abd Rahman (1998), the energy conservation equation for nonisothermal simulation within a porous medium, is expressed as:

$$\begin{aligned}&\frac{\partial}{\partial t}[(1-\phi)\rho_s C_{ps} + \phi\rho_w S_w c_{pw} + \phi\rho_g S_g c_{pg} + \phi\rho_n S_n c_{pn}]T \\ &+ \rho_w S_w c_{pw} V_w.\nabla T + \rho_g S_g c_{pg} V_g.\nabla T + \rho_n S_n c_{pn} V_n.\nabla T = \nabla.(\lambda_T \nabla T) \\ &+ (1-\phi)\rho_s Q_s + \phi\rho_w S_w Q_w + \phi\rho_g S_g Q_g + \phi\rho_n S_n Q_n]\end{aligned} \qquad (21)$$

Where;

$$\begin{aligned}&\frac{\partial}{\partial t}[(1-\phi)\rho_s C_{ps} + \phi\rho_w S_w c_{pw} + \phi\rho_g S_g c_{pg} + \phi\rho_n S_n c_{pn}]T = \\ &\left[(1-\phi)\rho_s C_{ps} + \phi\rho_w S_w c_{pw} + \phi\rho_g S_g c_{pg} + \phi\rho_n S_n c_{pn}\right]\frac{\partial T}{\partial t} + \\ &T(1-\phi)\rho_s\frac{\partial\rho_s}{\partial t} + T\phi\rho_w c_{pw}\frac{\partial S_w}{\partial t} + T\phi S_w c_{pw}\frac{\partial\rho_w}{\partial t} + T\phi\rho_g c_{pg}\frac{\partial S_g}{\partial t} + \\ &T\phi S_g c_{pg}\frac{\partial\rho_g}{\partial t} + T\phi\rho_n c_{pn}\frac{\partial S_n}{\partial t} + T\phi S_n c_{pn}\frac{\partial\rho_n}{\partial t}\end{aligned}$$

where $\rho c_{p\alpha}$ is the heat capacity of the liquid or soil phase, T is temperature, V is apparent velocity of the fluid and λ_T is the thermal conductivity matrix of the soil.

Initial and Boundary Condition

The initial and boundary condition for the nonisothermal problem must be complemented by an appropriate condition for heat flow. Thus, the initial conditions within porous media are specified as:

$$u_i = u_i^{\,o} \qquad P_\alpha = P_\alpha^{\,o} \qquad C_\theta = C_\theta^{\,o} \qquad T = T^o$$

Table 1: Boundary and Initial Condition

Initial condition	**Value**
Water Saturation, S_w	0.445
Gas pressure, P_g	101325 N/m^2
Water pressure, P_w	-420 x 10^4 N/m^2
Temperature, T	293.15 K
Boundary condition	
Lateral Surface:	$\mu_h = 0, q_w = 0, q_g = 0$
Top surface:	
• P_w	-280 x 10^4 N/m^2
• P_g	101325 N/m^2
• T	323.15K
Bottom surface:	$\mu_v = 0, q_w = 0, q_g = 0$

The boundary conditions are specified as either prescribed values,

$$u_i = \bar{u}_i \text{ on } \Gamma_u \quad \text{and} \quad \sigma_{ij}n_i = t_j \text{ on } T_t$$

where $\Gamma_u U \Gamma_t = \Gamma$

and, $P_\alpha = P_\alpha^{\,b} \qquad C_\theta = C_\theta^{\,b} \qquad T = T^b$

or flux : $q_\alpha = -\dfrac{Kk_\alpha\rho_\alpha}{\mu_\alpha}\nabla\left(P_\alpha + \rho_\alpha g h\right)n$

where b_i is the body force, t_j is the imposed traction, $\overline{u_i}$ is the external displacement, q_x is the flux, o represents the initial conditions and n is the vector normal to the boundary.

DISCRETIZATION AND SOLUTION PROCEDURE

In this solution procedure, the governing equations are carried out of finite element in space and finite difference in time. In the space discretization, the unknowns are associated with 'nodes' or 'nodal points', which are distributed in a logical manner around the perimeter of the element. A weak formulation of the governing equations could be obtained by applying Galerkin's procedure of weighted residuals. The Gauss theorem is used to transform the second spatial derivatives.

The primary unknown such as displacements, fluid pressures, temperature and concentrations then will be performed as a fully coupled nonsymmetrical and highly nonlinear system of ordinary differential equation in time. In this method, an implicit scheme will be used, since all the non-linear coefficient are dependent on the unknowns. The iterative procedures are usually performed within each time step to obtain the final solution.

NUMERICAL ANALYSIS

This analysis will show the migration TCE in unsaturated zone. One-dimensional simulation of TCE will be performed with the same surface temperature with an initial water saturation of 0.445. The domain of soil column used is 1 meter in height and the initial and boundary condition used in the simulation is given in Table 1. The value of vapour pressure, molecular weight and Henry's law constant for TCE are 0.076 atm, 131.4 g/mol and 0.26, respectively.

This simulation was conducted with intrinsic permeability of soil, K =1.0 x 10^{-13} m^2 and 1.0 mg/L of concentration introduced at the top surface of soil column without initial value of concentration. The physical properties used for analysis are as follows,

Elastic modulus	E = 10.0 x 10^6 N/m^2
Poisson ration	$\nu = 0.3$
Porosity	$\phi = 0.5$
Gas viscosity	$\mu_n = 1.81 \times 10^{-5}$ Pa. S
Bulk modulus	$K_s = 6.1 \times 10^8$ N/m^2
Gas Diffusion	$D_g = 1.0 \times 10^{-5}$ m^2/s
Liquid water diffusion	$D_w = 1.0 \times 10^{-10}$ m^2/s
Density for Carbon Tetrachloride	$\rho_n = 1584.0 kg/m^3$
Density for Trichloroethylene	$\rho_n = 1460.0 kg/m^3$
P_{dgw}	225.0 x 10^3 N/m^2
k_{rg}	S_g^3
S_w	0.10
Initial NAPL saturation	S_n=0.25
Initial gas saturation	S_g = 0.60
λ	3.0
NDF	U, P_w, P_g, T, C_{gi}

Figure 1 shows the profile of TCE mass fraction distribution along time with a different depth of consideration. From the simulation, it shows that the maximum value of TCE mass fraction occurred at the elevation of 0.3m of soil column with the value of 5.0 x 10^{-9} . Value of 3.25 x 10^{-9} and 1.05 x10^{-9} was simulated at a depth of 0.5m and 0.3m. These results indicate the maximum value of TCE mass fraction occurred at around every 10 hours for each depth of 0.7m, 0.5m and 0.3m after the simulation process. However after 10 hours, shows the mass fraction of TCE decreases slightly during the time.

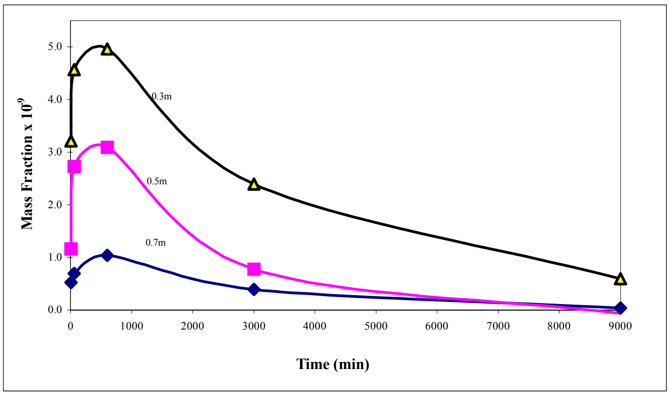

Figure 1: TCE concentration distribution in soil (K=1.0x10^{-13} m^2)

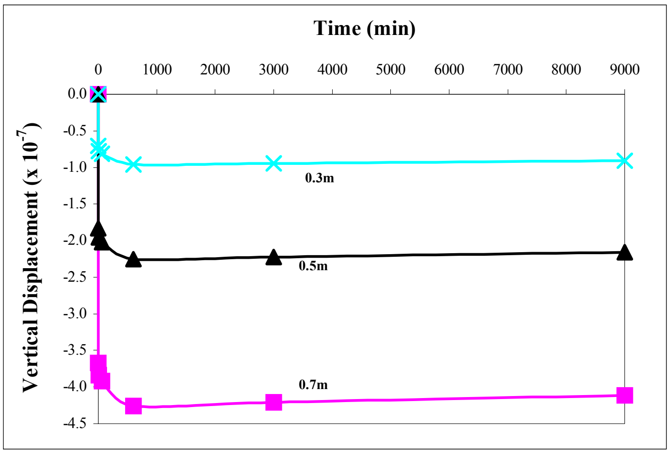

Figure 2: Vertical displacement versus time (K=1.0x10^{-13} m^2)

In addition, the resulting profile of vertical displacement has been shown in Figure 2. The results have been presented for a difference depth of 0.7m, 0.5m and 0.3m. For each depth of consideration, the results indicate a small vertical displacement. Only after 10 hours, the displacement increases slowly until it reaches 150 hours. Gas pressure versus time profile at different depths is plotted in Figure 3.

After 50 hours, the gas pressure was changed from the initial value of 101.325 kN/m to 101.3256089 kN/m at 0.5m. At depth of 0.7m and 0.3m, a similar trend of gas pressure was observed. These results show that changes in gas pressure along time is very small and can be negligible.

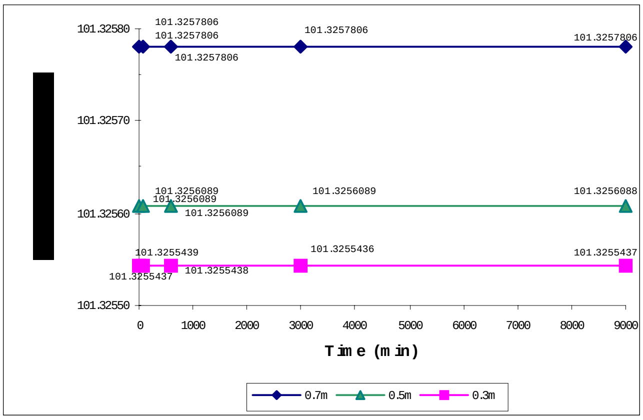

Figure 3: Gas pressure distribution versus time at different depths

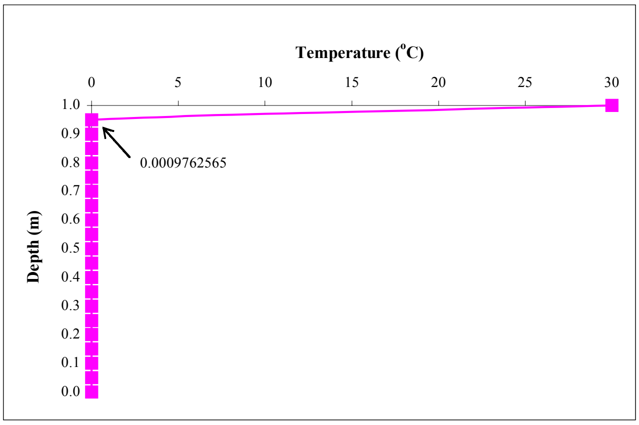

Figure 4a: Profile of temperature for TCE at 1 hour

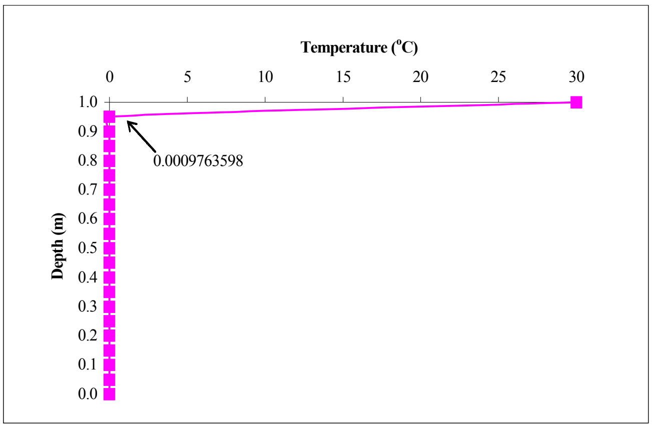

Figure 4b: Profile of temperature for TCE at 150 hours

Figure 4a and Figure 4d show a profile of temperature throughout soil column at the same condition. The results indicate that the effect of temperature is very small. Instead of 1 hour and 150 hours after simulation, the temperature represents a very steep temperature gradient. Therefore, the model imposes heat only at the top surface of soil column. That is why even after 150 hours of simulation, the variation is still very small.

CONCLUSION

From the results, it can be concluded that a numerical model, describing the migration of contaminant gas (VOC model) through soil in a deforming porous medium under nonisothermal condition has been discussed. Examples of the problem of TCE in one-dimensional analysis have been performed to demonstrate the model capability for geoenvironmental applications.

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Trace Analysis Of Hormone Disruption Contaminants In Ground Water Near Wastewater Treatment Pond And Landfill

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ABSTRACT: Trace hormone disruption contaminants (PCBs and Dioxins) in water were analysed by Gas Chromatography-Mass Spectrometry technique in selected ion monitoring (SIM) mode at optimum conditions. For trace PCBs, the detection limit was in the range of 0.05-0.10 μg/L and the linearity was in the range of 60 ng/L – 1 mg/L (r^2> 0.99). Sample preparation was carried out by using a lab built filtration unit coupled with solid phase extraction (SPE), C_{18} Empore disk. The extraction process provided the recovery of 83-112%. For trace Dioxins, the detection limit was 16.9 ng/L and linearity (r^2 > 0.99), 0.5-100 μg/L. The preconcentration step for Dioxins in water was done by using Amberlite XAD-2 resin coupled with ultrasonic extraction technique. The recovery was higher than 93%. These methods were implemented to analyse real samples near wastewater treatment pond and landfill of Songkhla municipal, Thailand. Both hormone disruption contaminants were found at 0.11-0.67 ng/L (PCBs) and N.D-16.2 ng/L (Dioxins) respectively. The techniques have the advantages over other methods i.e. less organic solvent and time consuming, high accuracy and precision with %RSD less than 4.

Keywords: PCBs, Dioxins, SPE, XAD-2, Gas chromatography-Mass spectrometry, water, wastewater treatment pond, Landfill

INTRODUCTION

Trace of Polychlorinated biphenyls (PCBs) and Dioxins, can be expressed as hormone disruption contaminants [1]. They are either directly or indirectly introduced into the environment. The contamination of these compounds in water is one of the most concerned toxicity and persistence environmental issue.

PCBs are mostly used in dielectric fluids in capacitors, heat transformer fluids, hydraulic fluid, lubricating and cutting oil and many more [1]. Trace residue in water could be from the run off from agicultural areas, industrial sites or transported from the atmosphere into surface water which is the source for drinking water.

Spills, improper handling or disposal also lead to contamination and are often resulted in relative high, localized concentrations. In Thailand, the division of food, Department of Medical Science reported that 861 out of 1,503 samples of the consumable import-export products tested during 1994-1996 were contaminated by chlorinated compounds including PCBs [2].

In the case of Dioxins, these compounds are not intentaionally produced, but a variety of industrial diposable and combustion have been identified as the sources. The Bangkok Post, June 10, 1999 reported that high contamination of dioxins had been found in the imported meat, eggs and dairy products from Belgium. Thus, Thai government imposed a ban and a strict inspection on animal feed and meat from there and its neighbours until the situation improves [3], since the presence of dioxins in these key products can have an impact on human health and the environment.

The toxic nature of PCBs and Dioxins at extremely low concentration (ppq - ppt) poses a very difficult problem for scientists and regulator to address. Therefore, the sample preparation is very important for qualitative and quantitative analysis of PCBs and Dioxins residues in water. Moreover, many powerful chromatographic separation methods such as capillary gas chromatography (GC) or high performance liquid chromatography (HPLC) are indispensable for analytical determination of both PCBs and Dioxins due to their superior efficiency and sensitivity [4-5]. A complete set of retention time data for a capillary column in gas chromatography technique can be available for all congeners of PCBs and Dioxins [6-9]. For a detector, mass selective detector (MSD) established a prominent advantage over conventional detectors such as an electron capture or flame ionization detector with its sensitive mode for quantitative measurements and a further confirmation is done by a mode called selected ion monitoring (SIM) [10]. This mode is capable of detecting PCBs and Dioxins in a complex matrix

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among various halogenated compounds which can give response with retention time in their windows [11].

This work emphasized on the trace analysis of three congeners of PCBs (PCB138, PCB153 and PCB180) and one congener of Dioxin (2,3,7,8-Tetrachlorinated dibenzo-p-dioxin, TCDD) contaminated in water by the hyphenated method, Gas Chromatography - Mass Spectrometry by focusing on the development of a method that minimized the hazardous solvent waste.

Songkhla is a province in Sounthern Thailand where communities are expanding at a high rate and the industries are growing rapidly and continually. All town and municipalities are, therefore, facing the risk of exposure to pollutants from several major sources, i.e. industrial, agricultural, and human activities, accidental spill, and waste discharges to water resources.

In the present work the quality and quantity of trace level of PCBs and Dioxins contaminated in well water near the wastewater treatment pond and landfill in Songkhla province were investigated.

EXPERIMENTAL

Chemicals And Materials

Standard of 2,2´,3,4,4´,5´- hexachlorobiphenyl (IUPAC No.138), 2,2´,4,4´,5,5´- hexachlorobiphenyl (IUPAC No.153) and 2,2´,3,4,4´,5,5´ - heptachlorobiphenyl (IUPAC No.180), 35 mg/L each, (Certified solution with purity 99-100%) were obtained from Accustandards Inc., USA. Standard of 2,3,7,8-Tetrachlorinated dibenzo-p-dioxin in toluene, 10 µg/mL, Supelco, USA. General Solvents and Chemicals were all Analytical Grade: Toluene, Isooctane, n-hexane, dichloromethane, ethyl acetate and acetronitrile from LAB-SCAN, Thailand; Acetone from Carlo Erba, USA; Methanol (GR Grade) from Merck, USA; Amberlite XAD-2 resin, Supelco, USA.; Perfluorotributylamine(PFTBA, MS.grade) from Hewlette Packard, USA; and 1:1v/v Sulfuric/water solution (A.C.S.Reagent) from J.T.Baker, USA. Ultra pure water was prepared in the laboratory (Maxima, ELGA, England). Solid Phase Extraction Disks (ENVI^{TM}-18 DISK 47 mm) were obtained from Supelco, USA, Filter Aid 400 fromd 3M, USA, and Glass fiber filter (47 mm) from Whatman, USA.

Samples

Water samples were taken from wells near Songkhla municipal Wastewater Treatment Pond and Landfill in Songkhla.

Instruments And Apparatus

Gas Chromatography – Mass spectrometry System (GC-MS): model 6890 Series with capillary column, 30 m. x 0.25 mm. ID. x 0.25 µm film thickness of 5% diphenyl and 95% dimethylpolysiloxane, HP-5MS coupled with an auto-sampler injction model 7683 Series and Mass Selesctive Detector (MSD) model 5973 (Agilent Technologies, USA). Other apparatus used in the experiments include: 10 µL syring; 2 mL amber vial with polypropylene screw cap and red rubber septa; 2 mL vial with Silver aluminum cap; 11-mm Crimper (Agilent Technologies,USA); 50 mL and 250 mL round bottom flash (Pyrex, USA); 100 mL test tube (Pyrex, USA); 200 µL and 1000 µL micropipettes (Gilson, France); evaporating rotator (EYELA; Japan); a vacuum pump (Sargent-welch, USA.) capable of maintaining a vacumm of approximately 22 inches of mercury (150 mL/min); Multi meter model Check-mate 90 (Mettler-Toledo Ltd., USA); 50 cm Buchner funnel; and standard Filter apparatus (Wheaton, USA): 47 mm ID., consisting of a sample reservoir, clamper disk and filtration head with drip tube with 60 mL, glass collection tube (Pyrex, USA) and 500 mL, Glass filter flask (Pyrex, USA).

METHODS

Preparation Of Pcbs And Dioxins Working Standard Solutions

The working standard solutions of PCBs (three congeners: PCB138, 153 and 180) in the range of 1.0 µg/L-1.0 mg/L were prepared by diluting 35 mg/L, PCBs standard stock solution, with isooctane. The 2,3,7,8-TCDD was prepared at 100 µg/L in toluene. All standard solutions were kept in amber glass bottles with PTFE-lined screw caps and stored at 4 ^{0}C as recommended by the manufacture and to protect them from light [12-17].

Optimization Of The GC-MS System

The GC-MS conditions, *i.e.* carrier gas flow rate, column temperature programing, inlet and interface temperature were optimized for best analysis of PCBs and Dioxins. PCB153 congener or 2, 2´, 4, 4´, 5, 5´- Hexachlorobiphenyl congener was a PCBs representation for the the optimization of all the parameters throughout this experiment because of its highest abundance (Figure1) while 2,3,7,8-TCDD was a Dioxins representative. Throughout this investigation 1-µL, 100 µg/L of the working standard was used to inject into the GC-MS system via splitless mode. The MS mass was scanned from m/z 45 to 450 amu by the scan mode (full range) to obtain the qualitative information. The carrier gas flow rate was investigated by varying the flow rate of helium gas in the range of 0.5 - 1.5 mL/min and the optimum flow rate was then obtained by a van Deemter plot.

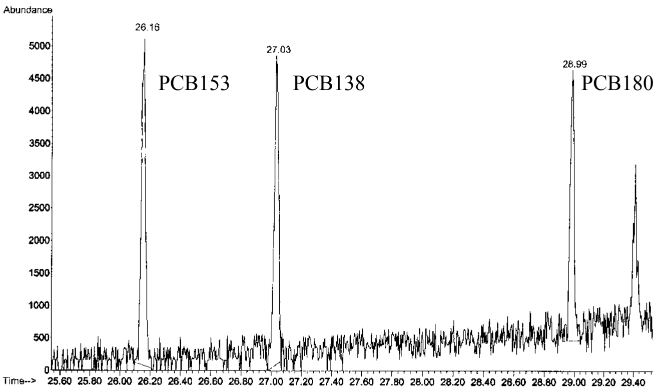

Figure 1: Total ion current chromatogram after auto injection of 1 µL, 100 µg/L of the PCBs working solution into the GC-MS with condition 70°C (2min), 25°C/min, 150°C (0 min), 3°C/min, 200°C (0 min), 8°C/min, 280°C (10 min)

The column temperature programming was investigated by varying the initial temperature, hold time, ramp rate, each stage temperature and final temperature including final hold time. The abundance and resolutions obtained from the different temperature programing were compared to find out the optimum programing. The inlet and interface temperature were also optimized by considering from abundance and resolution.

Linearity And Detection Limit

The linearity was investigated using a series of 50.0 ng/L-100.0 µg/L of working solution and 1-µL of each standard solution was injected into the GC-MS system at the optimum conditions. The linearity of the response was determined by ploting a calibration curve and considering the correlation coefficient ($r^2 > 0.99$).

The lowest concentration or amount of analyte that mass selective detector could detect and has a signal was taken from the total ion chromatogram using the SIM data acquisition. The Signal to Noise ration (S/N) was calculated automatically by the Chemstation Operating Software.

Sample Preparation and Analysis

Trace PCBs

Four liters of each water samples were collected from the wells near Songkhla Municipal Landfill and Water Treatment Pond and placed in amber glass bottles. The samples were preserved by storing in ice and transported to the research laboratory. All physical and chemical parameters were measured at the sampling sites with a multi-meter (Checkmate 90, USA.). The water samples were prefiltered through a lab-built prefiltration unit and 500 mL of each water samples were extracted by 47 mm ENVI™-C_{18} Empore extraction disk (Figure 2). Then eluted by 2 x 5.0 mL of dichloromethane and concentrated the extractant to a final volume of 1.0 ml and analyzed by GC-MS at the optimum conditions.

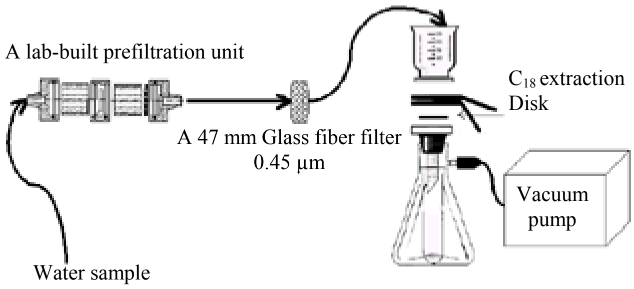

Figure 2 Scheme of sample preparation for trace PCBs.

Trace Dioxins

Amberlite XAD-2 polymeric adsorbent is a hydrophobic crosslinked polystyrene copolymer resin. The extreamly hydrophobic nature of resin attacts other hydrophobic organic compounds such as dioxins [18] and is used as one of the alternative sampling methods for concentrating dioxins from large volume of water. A 25 g. of Amberlite XAD-2 resin was conditioned by methanol then packed into glass column, 30.5 cm x 1.8 cm ID plugged with glass wool at the bottom end. The resin was allowed to settle before sample loading (Figure3). Trace of 2,3,7,8-TCDD in water sample was then extracted from the resin by ultrasonic extraction technique. The high efficiency of extraction was studied by optimizing the sequencing of conditioning solvent series, extraction solvent, extraction time, volume of extraction solvent, number of extraction and volume of spiked water loading.

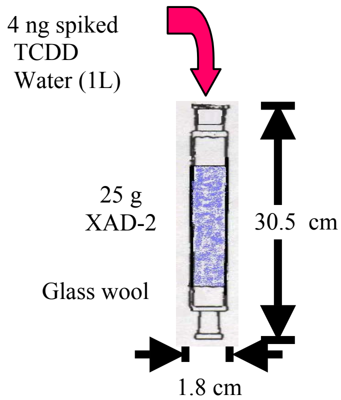

Figure 3: Scheme of sample preparation for trace Dioxins.

RESULTS AND DISCUSSION

Trace PCBs In Water Sample

Optimization of GC-MS system

In the optimization process, the carrier gas flow rate of 0.8 mL/min was obtained by calculating the height equivalent to a theoretical plate (HETP) using Golay equation [11]. This flow rate provided the best resolution for multiresidue analysis i.e. PCB138, 153 and 180 congeners. The optimum temperature programing was optimized by considering its relative response, retention time, and abundance of the three PCBs congeners at variuos parameters. The best results were obtained at 130°C (hold 2 min), ramped to 250°C with 40°C/min, immediately ramped to 300°C with 25°C/min and hold at 300°C for 10 min. The optimum of injector and interface was 230°C and 290°C respectively.

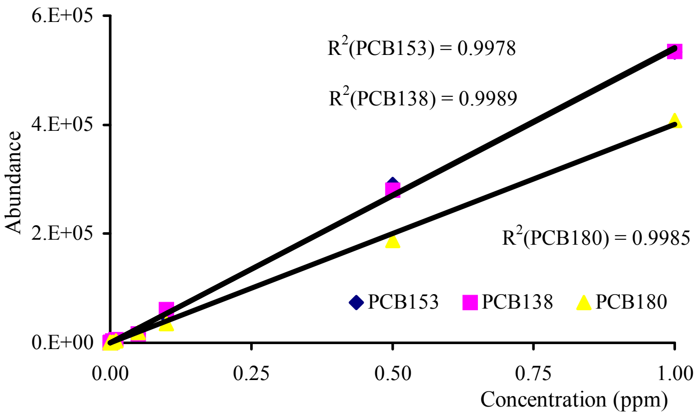

Figure 4: Linearity of three PCBs congeners (PCB138, 153 and 180)

These optimum conditions could provide an analysis time of 13 minutes, limit of detection in the range of 60-70 ng/L and linearity in the range of 60 ng/L to 1 mg/L with R^2 of higher than 0.99 (Figure 4). However, at these limit of detections, the system could not be used to analyze the trace amount of PCBs residue in water due to the normally low concentration (ppq to sub-ppt). Therefore, sample prepration, extraction and preconcentration, of the PCBs before injecting into GC-MS system was needed.

Sample preparation and analysis

Solid phase extraction technique, using ENVI^{TM}-C_{18} Empore extraction disk, was used for the enrichment of very diluted PCBs residue in water where required large sample volume was processed, to yield concentrations of the analyte sufficient for detection. The water sample was loaded into the extraction reservior and vacuumed, passing through the ENVI^{TM}-C_{18} Empore extraction disk. Analytes were adsorbed on the media and then eluted by organic solvent. Five organic solvents i.e. hexane, ethyl acetate, dichloromethane, hexane:ethyl acetate (1:1) and dichloromethane:ethyl acetate (1:1) were investigated for an appropriate solvent for extracting trace PCBs in water. Dichloromethane was chosen since it provided high recovery (83-112%) with high precision, relative standard deviation less than 3%.

Some interferrence, which could affect the analysis were also studied, phthalate, from plastic container, was found to be a major interference that produced a large error in the cleaned up process of these compounds before the extractant was analyzed by the GC-MS system. Another interference, was the large amount of suspended particle matter content in the water sample. These could affect the extraction efficiency of the ENVI^{TM}-C_{18} Empore extraction disk since they would clog the media if a large volume of water sample was used. Therefore, a lab-built pre-filtration unit was used to minimize the suspended particle content before loaded the sample to the disk. The pre-filtraiton unit provided the advantages of reducing the quantity of suspended particle matters with particle size larger than 40 micrometer and also minimizing the time of pre-filtration by 30% compared to conventional method.

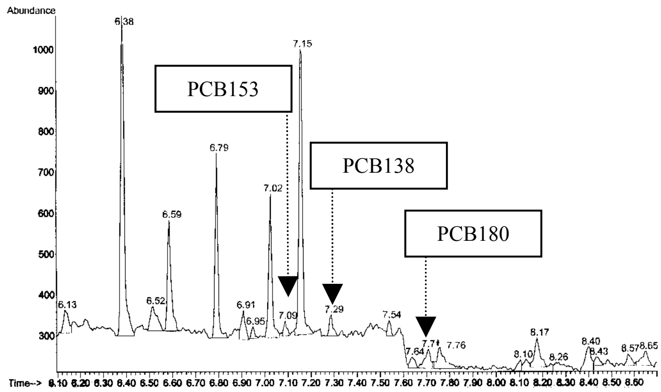

Figure 5: Total ion current chromatogram of the three PCBs congeners detected in well water sample near the wastewater treatment pond and landfill of Songkhla municipal.

When the real samples from wells near the wastewater treatment pond and landfill of Songkhla Municipal were analyzed, it was found that water in all areas has been contaminated with the three PCBs congeners (Table 1, Figure 5). Some congeners were closed to the contaminant level set by EPA 0.79 ng/L (ppt), which is the maximum level specified for PCBs in ambient water. These results were reliable since they were analyzed by following a quality assurance criteria set for such a system (gas chromatography coupled to mass selective detector with electron impact ionization was used in selected ion monitoring , SIM mode). In addition, the GC-MS under full scan condition was also used for spectrum identification and PCBs confirmation.

Table 1: PCBs contaminated in well water near Songkhla Municipal Wastewater treatment Pond (WWT) and Landfill

Sampling site	Date (Feb, 2002)	PCB138	PCB153	PCB138
WWT	5, 16	0.13-0.14	0.16-0.59	0.20-0.25
Landfill	11, 16	0.11-0.14	0.58-0.67	0.20-0.44

5 replication, %RSD < 4

Trace Dioxins In Water Sample

Optimization of GC-MS system

The optimum conditions of GC-MS system for the analysis of 2,3,7,8-TCDD were as follow: carrier gas flow rate 1.0 mL/min, injector and interface temperature at 260°C and

300°C respectively, The column temperature was programmed at the initial temperature of 100°C, held for 3 mins, ramped up to 220°C at the rate of 30°C/min held for 2 mins, then ramped up to 240°C at a rate of 5oC/min held for 5 mins before ramped up to 300°C at a rate of 20°C/min and finally held for 5 mins. This programming could be used to analyze Dioxins with high precision (%RSD less than 4). The results showed a linearity in range of 0.5-100.0 μg /L with the correlation coefficiency of 0.9977 (Figure 6). The detection limit was 16.9 ng/L.

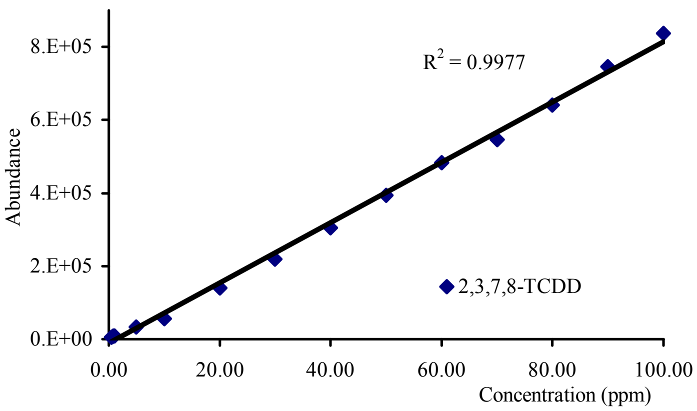

Figure 6: Linearity of 2,3,7,8 -TCDD

Sample preparation and analysis

Normally, Dioxins residue concentration in water was very low, pre-concetration was necessary. Traditional extraction of dioxins is very expensive and time-consuming. To overcome these disadvantages, Amberlite XAD-2 resin was used to pre-concentrate dioxins in water sample. Ultrasonic extraction was used to minimize manual labor and time. The water samples were prepared using the optimum conditions (Table 3), then analyzed by GC-MS at optimum condition as mentioned in 4.2.1. The toluene-acetone mixture (1:1 v/v) was the best extraction solvent and the optimum extraction time was 20 minutes. A 60 mL of the solvent was sufficient for double extraction (2x30 mL) which provided the highest extraction efficiency (93%) with a good relative standard deviation of less than 4%.

Table 3: Optimum parameters for sample preparation of Dioxins

Parameters	Optimum conditions
Series of sequencing solvent for condition Amberlite XAD-2 resin	Methanol-water
Extraction solvent	Toluene-acetone (1:1)
Extraction time (min)	20
Volume of solvent (mL)	60
Number of extraction	2
Volume of spiked water (mL)	100

The concentrations of the contaminant in the water sample were calculated from the chromatogram. Identification of dioxin was based on the retention time and ratio of the response at the M^+ and $[M+2]^+$ values on the SIM chromatograms. Initially, the analytes were undetectable because their concentrations were less than the detection limit of 16.9 ng/L. Therefore, further analysis was then carried out by standard addition method with the same samples. The results of the analysis for 2,3,7,8 - TCDD residue of the two water samples from Songkhla Municipal Landfill are shown in Table 4.

Table 4: 2,3,7,8-TCDD concentration of the samples determined by standard addition method

Sample No.	Concentration (ng/L)
1	Not detectable
2	16.2
3	2.3

According to the US EPA water quality criteria, the presence of dioxins in water should be less than 1.3 x 10^{-2} pg/L [19]. Therefore, the results showed that in all areas dioxins contamination was much higher than the recommended value.

CONCLUSIONS

Qualitative and quantitative analysis of trace hormone disruption contaminants (PCBs and Dioxins) in water were achieved using the hyphenated method, GC-MS (gas chromatograph equipped with a HP-5MS capillary column and a mass selective detector). The sample preparation by Solid phase extraction, Ultrasonic extraction coupled with pre-concentration using Amberlite XAD-2 resin provided many advantages i.e. more economical, minimization of manual labor, faster extraction and reduction of time and less solvent consuming, included providing high extraction efficiency.

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Studies On Organochlorine Residue From Mother's Milk In Malaysia

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ABSTRACT: Milk samples from 71 mothers were collected from Kuala Lumpur and Cameron Highlands and analysed for the organochlorine residues. Thirty –three samples were collected from Orang Asli whilst the 38 control samples from Kuala Lumpur comprise of 20 Malay, 7 Chinese and 11 Indian mothers. A social survey was also conducted during sampling where mothers were required to give information about their age, frequency of giving birth, diet, smoking habit as the environment where they were residing. The organochlorine residues were extracted from the milk by procedures reported by earlier workers, the fat analysed . The extract was then analysed using gas chromatography Results show that the Orang Asli have lower levels of DDT (1.27 μg/g) compared to the control group in Kuala Lumpur (1.67 μg/g). The data for Malaysia is much lower than those of Thailand (6.89 μg/g) and China (3.55 μg/g) but higher than data from Europe. In this study diet show a great importance to the retention of organochlorine in the Malaysian population.

INTRODUCTION

Organochlorine pesticides are organic carbon containing chemical compounds that, to a varying degree, resist photochemical, biological and chemical degradation (UNEP 2003). OCPs are often characterised by low water solubility and high lipid solubility, leading, together with their persistence, to bioaccumulation in fatty tissues (Connell 1997), and thus may pose a risks to human health (Rogan 1996).

In human milk, the presence of OCPs results from mobilization of body fat during the synthesis of milk, and consequently the breast milk can be a source of contamination for infants (Jensen 1995).

A number of studies have been conducted on organochlorine pesticide contamination of groundwater, soil and sediments in Malaysia but the amount of pesticides accumulated in human tissues and in human milk is unknown as no investigation has previously been conducted (Zakaria 1998) . The OCPs investigated are alpha-, beta-, gamma- and delta–BHC, DDT,DDD, DDE, aldrin, Endosulfan I , heptachlor and heptachlor epoxide of human milk is investigated in this study: These OCPs were selected based on previous and current use (both legal and illegal) in Malaysia. DDT is highly relevant to include because it has until recently been applied by the Health Ministry in Malaysia for vector control. Furthermore all of these OCPs are on UNDP's list over OCPs of high concern (UNDP 2003).

Some of the pesticides are degraded in human tissue or in the environment, thus the most relevant degradation products are included in this present study. Aldrin will be transformed to dieldrin in human tissues, DDT will be degraded to DDE and DDD, and heptachlor will be degraded to heptachlor epoxide (Tomlin 1995).

The present study collected human milk samples from breast-feeding mothers in two different areas in Malaysia. The areas were selected based on concerns in Malaysia of the health of the people living in areas with heavy agriculture and thereby heavy usage of pesticides. Milk samples were collected from women living nearby Cameron Highlands, a high pesticide usage area, and compared to milk samples from Kuala Lumpur, a low pesticide usage area.

Kuala Lumpur is selected to be the control area in this investigation as there is no direct use of the selected pesticides .The main exposure source to the selected pesticides for the general population in KL is assumed to be through ingestion of contaminated food

The objectives for this investigation are to:

1. Determine contamination levels in human milk in Orang Asli mothers living in Cameron Highland and compare with the contamination levels found in the human milk from mothers living in Kuala Lumpur.
2. Identify possible factors influencing the contamination of OCPs in human milk in Malaysia.
3. Compare human milk OCP residue contamination levels found in Malaysia with results from similar investigations in other countries.

METHODOLOGY

Sampling

Organochlorine Pesticides (OCPs) residue analysis was performed in Malaysia on human milk obtained from 33 healthy lactating Orang Asli women living in Cameron Highlands, a high pesticide usage area, and from 38 lactating women living in Kuala Lumpur, a low pesticide usage area. The women from Kuala Lumpur resemble the control group and were all occupational unexposed healthy mothers.

All participating mothers were interviewed, using a questionnaire, to obtain information on personal characteristics such as; *age, body mass, parity, lactation, dietary habits, former place of residence and occupation history.*

Analytical Method

Depending on the donors' milk production 5-20 mL milk was hand-expressed into test tubes. The tubes were put on ice and frozen as soon as possible. Both the fat extraction and the clean-up procedure are based on the method described in (Campoy et al. 2001).

A measured volume of human milk of 2,5 mL is liquid-liquid extracted with hexane/diethylether. The hexane extract is isolated, dried and the fat concentration in the milk is measured. The fat is hydrolysed by sulphuric acid, and the clean up is performed using solid phase extraction, SPE. Chromatographic conditions are applied that permit the separation and measurement of the analytes in the extract by capillary column/GC with an electron capture detector.

The applied quality control include; *Calibration curves, recovery calculations, MDL, internal standard, daily calibration checks, and blank samples.*

The chromatograph apparatus used is a Shimadzu GC 17A with a Shimadzu AOC-20i auto-injector, with a ZB 5 column, 30 m x 0,32 mm, and electron capture detector (^{63}Ni). The software used is Class-GC10. A 2-µL aliquot of the extract is injected (splitless) at a flow rate of 1,5 mL/min. The injector and detector temperatures were 275 and 325^{o}C, respectively. The temperature column was programmed from 100^{o}C to 300^{o}C at 10^{o}C/min.

RESULTS AND DISCUSSION

Social factors

The age of the mothers ranges from 18-46 years. The average age both in the investigation group and for the control group is 30 years.

The Body mass index (BMI) ranges from 14.7 to 45.3 with an average of 21.5 ± 3,7 for the Orang Asli mothers and 25.8 ± 6,9 for the control group. There is a higher percentage of the Orang Asli that is under weighted compared to the control group. Furthermore is a higher percentage of the control group over weighted and even found to be obese compared to the Orang Asli. The higher BMI for the control group is assumed to be a result of better living standards and high consumption of food combined with little physical activity.

The majority of the Orang Asli mothers had given birth more than 20 days before the milk donation, hence mature milk is collected. Most of the mothers in the control group had given birth 1-3 days before donating milk resulting in mostly colostrum milk in the control group.

The number of children of the participating mothers range from 1-10 with an average for the Orang Asli of 3.4 children and for the control group 3 children.

It can be seen that there are clear differences concerning lactation patterns between the different ethnic groups. It can be seen that the Orang Asli and Malay mothers approximately breast-feed each child 1-2 years per child. However, are there exceptions in these two groups, were children are breast-fed 4-5 years. The Chinese are obviously not in favour of breast-feeding their children and if they breast-feed it is not longer than approximately 1 month. The Indians breast-feed around 4-5 months, which makes their lactation period longer than the Chinese but shorter than most of the Malay and Orang Asli.

External factors

Diet

The table below presents the results from the interviews concerning diet. The data is separated in the four ethnic groups to identify differences in the diet between the groups. The data is based on the average number of times per week the mothers answered that they eat the different products (Figure 1).

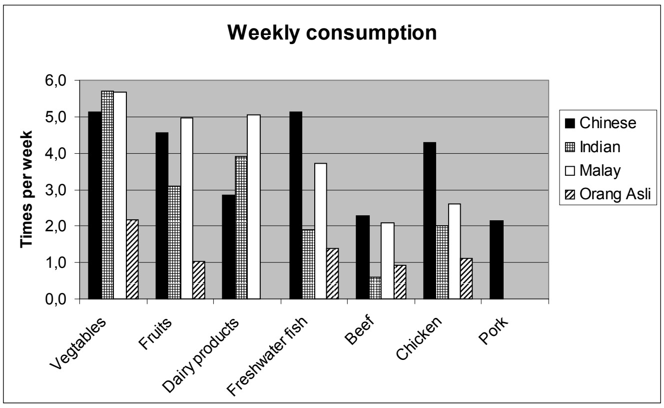

Figure 1. Weekly consumption of sampling population

Based on discussions with the Orang Asli mothers it appeared that they nearly only eat rice with chili for every meal. The Orang Asli eat freshwater fish, beef, and chicken approximately once a week. It is assumed that the consumed amount of fish and meat is much smaller than for the mothers in Kuala Lumpur as a result of poverty among the Orang Asli.

It is further assumed that the vegetables and fruit that the Orang Asli consume are from their own garden or from the jungle hence these products are assumed to be sprayed with less pesticides, if sprayed at all, compared to commercial food products.

The Malay women in this investigation claim that they only eat beef and chicken 2-3 times a week despite the fact that many of the regularly eaten Malay dished contains lots of beef and chicken. The consumption of dairy products, fruits and vegetables (5-6 times per week) is relatively high.

Indians are often vegetarian and even the non-vegetarians seldom eat meat and it can be seen that Indian eat vegetables at least five times per week. Furthermore is it generally assumed that Indians eat lots of chicken, although the participating Indian mothers say they only eat chicken twice per week.

It is characteristic for Chinese to eat a lot of freshwater fish. The participating Chinese mothers eat freshwater fish more than 5 times a week, which is much more frequent than the rest of the mothers do. Additionally they also eat pork, which none of the other mothers do, and they also eat more beef and chicken compared to the other mothers.

Place of residence and occupation

Most of the Orang Asli mothers are housewives and take care of their children and the elder generations in the family. As mentioned it is usual that unmarried Orang Asli women work in plantations and five of the participating Orang Asli mothers have worked at plantations.

The control group consists of mothers living in KL or in the sub-areas, where they have lived nearly all of their life. The mothers are housewives or involved with business and none of them have an occupational background that involves pesticides.

Fat concentrations

The mean fat concentration is 3.0%±2.3% for colostrum milk and 4.8%±3,2% for mature milk, which represent the fat concentrations in the control group and in the Orang Asli respectively[1]. This is in agreement with literature, which has determined the fat content in colostrums milk to be 2.9% and 4% in mature milk (Needham and Wang 2002).

OCP concentrations

All OCPs *(DDT, DDE, DDD, α-BHC, β-BHC, γ-BHC, Δ-BHC, Heptachlor, Heptachlor epoxide, aldrin, endosulfan 1*) were detected in the milk samples in the range 70 to 100% in the Orang Asli samples and 90 to 100% in the control group samples. The mean recovery of the OCP's are in the region of 44-100%.

The detected OCP concentrations (except for DDT and its isomers) in the human milk from Kuala Lumpur were significantly higher than the concentrations found in the human milk from the Orang Asli. Mean total-DDT concentrations were 1.27 µg/g milk fat and 1.67 µg/g milk fat for the Orang Asli and the control group respectively. Detected mean concentrations in the Orang Asli was: *total-BHC 0.10 µg/g milk fat, heptachlor 0.062 µg/g milk fat, heptachlor epoxide 0.024 µg/g milk fat, aldrin 0.015 µg/g milk fat* compared to *0.60 µg/g milk fat heptachlor, 0.13 µg/g milk fat heptachlor epoxide, and 0.14 µg/g milk fat* aldrin in the control group (Table 1).

The lifestyles (occupation, diet, residence) of the women in the control group are quite similar, but differ dramatically from the Orang Asli. The figures below illustrate the general contamination trend of OCPs among the races (Figure 2 and 3).

As it can be seen figure 1 above total-DDT does not vary significantly between the two groups. The Orang Asli have relatively high levels of total-DDT, which is inconsistent with the other OCP levels This can probably be explained by the fact that DDT has been applied in vector control in the Orang Asli villages until year 1999. The combination of previous use of DDT and its high persistency may contribute to the elevated levels of DDE in Orang Asli.

When evaluating the different races total-DDT concentration is highest among the Chinese women (2.21 µg/g fat), followed by the Malay (1.79 µg/g fat), and the Orang Asli actually have higher total-DDT concentrations than the Indian women (1.21 µg/g fat and 1.00 µg/g fat respectively). Compared to total-DDT levels, which do not vary significantly, the other OCP levels are significantly higher among the control group than the Orang Asli. The Malay women have the highest average OCP levels, followed closely by the Chinese and Indian women and the Orang Asli have the lowest concentrations.

In all the races DDE, DDT's major metabolite, is significantly higher than DDT and DDD. The relative proportion of DDT and DDE detected can be an indicator of the length of time since exposure. In areas where DDT exposure is recent, the DDE/DDT ratio is low, whereas in areas where substantial time has passed since use, the DDE/DDT value is higher (Solomon 2002). The DDE/DDT ratio both in the Orang Asli (5.2) and in the control group (6.3) indicates that the exposure is not recent. This may reflect the fact that DDT was banned from agricultural use in the early 90's and as vector control in 1999 /Pesticide Board 2003/.

Common for all races is that β-BHC concentrations are significant higher than the α-, γ-and Δ-isomers (Figure 27), which reflects the high persistency and bioaccumulation of the β-isomer. β-BHC is the most persistent BHC- isomer and is generally the major isomer found in human milk.

Heptachlor concentrations are also found to be significant higher than the other OCPs in all the groups. Heptachlor is usually metabolised to heptachlor epoxide in humans (Tomlin 1995) thus both compounds are expected to be found in milk. Since heptachlor epoxide is the major metabolite of heptachlor, it should occur at higher concentrations than the parent compound, if exposure to heptachlor has ceased (Jensen 1983). The present study showed a mean ratio (heptachlorepoxide/heptachlor) of 0,40 for the Orang Asli and 0,21 for the control group, which may suggest a continuing exposure to heptachlor. Heptachlor and chlordane were banned in Malaysia in year 2000, but remaining stocks and illegal use can be responsible for the findings of heptachlor in all the milk samples.

Table 1. OCP concentration milk from Orang Asli and Kuala Lumpur mothers.

OCP	Orang Asli				Control group			
	Mean (µg/g fat) ± STDV	Median (µg/g fat)	Max. (µg/g fat)	Pos. N Total n= 33	Mean (µg/g fat) ± STDV	Median (µg/g fat)	Max. (µg/g fat)	Pos. N Total n= 38
α-BHC	0,011±	0,0073	0,030	25	0,091± 0,12	0,061	0,64	35
β-BHC	0,010	0,045	0,20	29	0,27 ± 0,32	0,11	1,15	38
γ-BHC	0,062±	0,0062	0,030	23	0,057±	0,041	0,35	38
Δ-BHC	0,052	0,018	0,060	26	0,086	0,045	0,51	38
Heptachlor	0,010±	0,050	0,19	31	0,10 ± 0,14	0,16	7,91	38
H.epoxide	0,010	0,017	0,070	33	0,60 ± 1,35	0,053	0,69	37
Aldrin	0,021±	0,012	0,040	32	0,13 ± 0,17	0,037	1,48	38
Endosulfan 1	0,016	0,0065	0,030	31	0,14 ± 0,31	0,027	1,33	36
DDD	0,062±	0,010	0,070	32	0,14 ± 0,30	0,042	1,69	34
DDE	0,046	0,71	7,40	33	0,16 ± 0,35	0,66	4,49	38
DDT	0,024±	0,08	0,72	33	1,26 ± 1,32	0,072	1,66	38
Total-DDT	0,018				0,25 ± 0,41			
	0,015±				1,67			
	0,012							
	0,011±							
	0,010							
	0,014±							
	0,014							
	1,10 ± 1,24							
	0,16 ± 0,23							
	1,27							

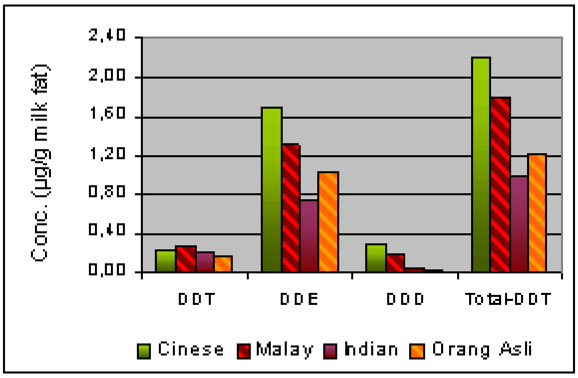

Figure 2. Differences in DDT, DDE, DDD, DDT concentrations (µg/g milk fat) among the races

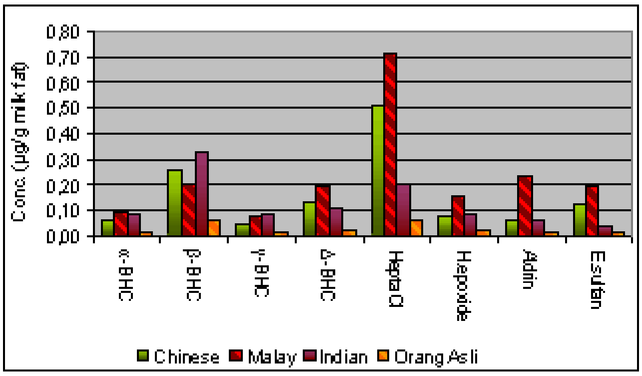

Figure 3. OCP concentrations (µg/g milk fat) in total - Chinese, Malay, Indian and Orang Asli women.

Aldrin concentrations should be seen in relation to dieldrin concentrations because aldrin is easily degraded to dieldrin both in the nature and in the body. Dieldrin is degraded in the analytical method, hence it is difficult to determine if aldrin concentrations was actually higher in the milk sample, than what is detected in the GC.

DISCUSSION

Occupation

Only five of the women in the present study have had occupational contact with OCPs, all Orang Asli that have worked at plantations. The women who have worked at plantations have 160% higher levels of total-DDT in their breast milk, where DDE is the main contributor with 188 % higher levels compared to those women who have not worked at plantations

The woman with the highest concentration (7,9 µg total-DDT/g milk fat) has worked at a plantation for 5 years and been in direct contact with pesticides. Three of the five women are not sure if they have had any direct contact with pesticides, and they have lower total-DDT levels than the two women who claim to have been in direct contact with pesticides. When comparing with the control group, the Orang Asli women with no direct OCP contact still have relatively high total-DDT concentrations even when the 5 women who have worked at plantations are excluded from the comparison. Again this is assumed to reflect the previous use of DDT in vector control in the Orang Asli villages.

Based on above-mentioned facts it is assumed that the mothers' occupational background will influence the OCP concentration in the milk if the work included contact with pesticeds.

Diet

When analysing the results, diet is the one parameter that dramatically separates the two groups, and there is a significant difference between Orang Asli and the control group. Whereas the Orang Asli has a monotonous and relatively low fat diet, the control group eat a fat rich diet, in addition to vegetables that are cultivated in areas where OCPs are assumed to be or have been used. Because the Orang Asli mostly eat rice and chilli they are not assumed to be exposed through the diet.

The women in the control group consume considerable amounts of meat, fruits and vegetables, and are assumed exposed to OCPs through these food products. However, the women mostly eat chicken, which is relatively lean and appears not to increase lipophile OCP levels in the milk. Malaysia also imports food from other countries /Pesticide Board 2003/ and these food products may be contaminated with OCPs. This is an exposure source that may contribute to the contamination levels found in the milk from the women in the control group.

The effect of these products' influence on OCP concentrations in human milk is illustrated by comparing the OCP levels in Orang Asli, who seldom eat meat or vegetables, with the OCP levels in the control group. The fact that the Orang Asli have lower levels of all OCPs, except DDE combined with poor diet, indicates that diet influences the OCP levels in milk.

The results are further analysed with regard to fish and dairy consumption. The Orang Asli are excluded from the following comparisons as they seldom eat fish and dairy products, and it is already stated that they have generally lower OCP concentrations than the control group.

Freshwater-fish consumption

As fish is stated to be one of the main contributors, among food products, to OCP contamination in human milk (Harris et al. 2001, Jensen 1995), the women are separated into freshwater-fish consumers and non-fish consumers to determine if the women that consume freshwater-fish have higher OCP levels than the ones who do not eat fish do.

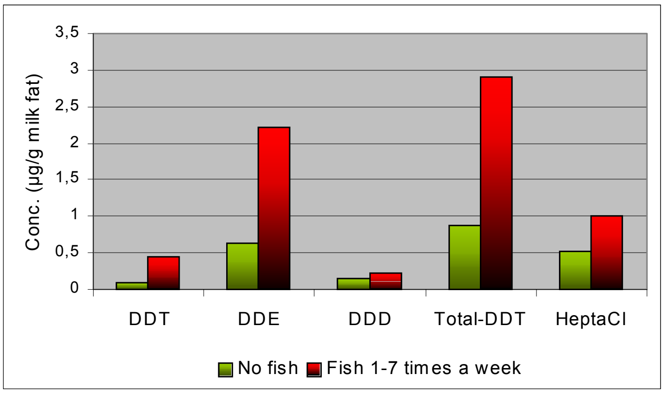

Figure 4: Illustration of DDT, DDE, DDD, total-DDT, and heptachlor concentrations in fish consumers and women who do not eat fish among the control group.

In agreement with other investigations (Harris et al. 2001) a significant difference between fish consumers and concentrations of DDT and DDE is noted ($p<0,01$). DDT is remarkably 368 % higher in women who eat freshwater-fish, and DDE is 254% higher in women who eat fish. No significant correlation is noted with regard to DDD concentrations.

Consumption of contaminated fish is proven to be one of the major exposure sources to heptachlor /IARC 2003/, and a significant difference ($p<0,05$) for heptachlor is noted; heptachlor is 91% higher in fish consumers than in women who do not eat fish. Fish consumption is also weakly positively related to β-BHC, but the correlation is not significant ($p>0,05$).

Total-DDT concentration is 233% higher in fish consumers. The total-DDT value for fish consumers is relatively high compared to the mean value for the control group, and this may be because of two Chinese women who eat fish have high DDE values (2,7 and 3,6 µg/g milk fat). Even if these two women are removed from the comparison, the fish consumers have significantly higher total-DDT concentrations than the non-consumers.

When the fish consumers are divided into women who eat fish 1-3 times a week and 4-7 times per week, no evidence is found that the women who eat fish 4-7 times per week have higher OCP values. Hence, the difference in fish consumption and OCP concentrations are best illustrated by comparing fish consumers with no fish consumers.

As mentioned the women who eat fish are younger and thinner than the women who do not eat fish. Additionally they have lactated for a longer period of time, and may have secreted higher levels of OCPs than the non-consumers.

Because of fish's correlation with meat, vegetables and fruits these products may contribute to higher OCPs levels found in fish consumers.

Even though the women say that they often eat fish, no information on amounts (kg) of consumed fish was obtained in the questionnaires, which complicates the comparison. It would have been appropriate to divide the women according to amount of consumed fish and not only how often fish was consumed, as this would probably better reflect the correlation fish consumption/OCP contamination in human milk. This may also be an explanation to why no significant difference is seen between women who consume fish 1-3 and 4-7 times a week.

Dairy products

There is a clear difference between the OCP concentration in human milk from women who regularly consume dairy products and those who do not consume dairy products (Figure 5).

DDT and DDE levels are significantly higher, 452% and 144% respectively in dairy products consumers than in non-consumers. No significant difference is seen in DDD levels, but a weak correlation with dairy consumption is observed. Total-DDT levels are 196 % higher in dairy consumers than in non-consumers. Heptachlor is 393% higher in dairy product consumers.

The period of lactation's influence on OCP concentrations is addressed in this study, and it is assumed that the longer the mother has previously breast-fed, the lower OCP concentrations are detected in human milk. Thus, the risk for especially the Malay and Orang Asli infants decrease with the number of children the mother has previously given birth to and breast-fed.

Even though the Chinese women exceed the ADI for heptachlor and aldrin, the average lactation time per child is only 0,75 months and the risk for health effects on the infant is thus minimal. The fact that these mothers do not transfer the OCPs to the infants during lactation may mean that the OCPs remain in the body and may induce harmful health effects on the mothers.

The risk for the Indian, Malay and Orang Asli infants may be greater than the two other groups because these women breast-feed longer (average 7, 20 and 26 months per child). However, the Orang Asli mothers only exceed the ADI for heptachlor, and the risk for the infants is assumed to be minimal with regard to health effects.

WHO and the The Danish Veterinary and Food Administration claim that temporary exposure to the OCPs is not considered a public health concern, but no information is found that defines 'temporary'. The Malay and Orang Asli averagely breast-feed the children for two years, and it is complicated to determine if the exposure is considered temporary or not.

Comparison with other countries

The results from the present study are compared to other countries' contamination levels for total-DDT and total-BHC (Table 2) as only information concerning these compounds' concentrations in other countries are found. Again, it has to be remembered that differences in analytical method and fat determination may affect the OCP levels and makes the comparison complicated and uncertain. Furthermore, no specific donor information was found and the results are presented as 'concentrations in the general population'.

Table 2. Results from the present study compared to other countries' contamination levels for total-DDT and total-BHC

Country			Total-DDT	Total-BHC*	(µg/g milk fat)
	Year	N	Mean	Mean	Reference
Malaysia (Orang Asli)	**2003**	**33**	**1,27**	**0,10**	**Present Study**
Malaysia (Control group)	**2003**	**38**	**1,67**	**0,52**	**Present Study**
North Thailand	2002	30	6,89		Zimmermann and Pedersen 2003
North Thailand	1998	25	14,96		Stuetz et al. 2001
China	2000	54	3,55		Wong et al. 2002
Hong Kong	1999	132	2,87		Wong et al. 2002
Jordan	1997	411	9,7	0,89	Nasir et al. 1998
Nigeria	1981/82	35	1,51	0,52	Hayes and Laws 1991
Uganda	1992/93	143	3,24	0,61**	Ejobi et al. 1996
UK	1997/98	156	0,47		Harris et al. 1999
Sweden	1997	40	0,14		Norén and Meironyté 2000
North Germany	1995/97	246	0,24		Schade and Heinzow 1998
New Zealand	1988		1,18	0,02**	Bates et al. 2001
New Zealand	1998	36	0,57	0,02**	Bates et al. 2001
Denmark	1982	57	1,15	0,08	Hayes and Laws 1991
France	1975	13	1,04	0,05	Hayes and Laws 1991
Finland	1988	165	0,66	0,20	Mussalo-Rauhamaa et al. 1988
Irland	1971/72		0,13	0,00	Hayes and Laws 1991

Some of the detected values are dramatically higher than the others, indicating that the investigated population may have been drawn from a highly exposed group, and may not be representative for the general population.

Concerning total-BHC no information on levels in Asian countries was available, but compared to the other countries, the control group have relatively high total-BHC values. Total-BHC among the Orang Asli is relatively low, and does not differ significantly from the other listed values.

Compared to the above listed Asian countries the women in the control group and the Orang Asli have relatively low total-DDT values. Both the Orang Asli and the control group have higher total-DDT values when comparing to the industrialized countries, but many of the investigations from these countries are relative old.

The studies from Denmark and France were compiled 20-30 years ago, and the high total-DDT levels resulted in initiatives to reduce the use of OCPs. The more recent studies from industrialized countries demonstrate that these initiatives have clearly reduced OCP contamination, and the total-DDT levels are considerable lower than in the 70's and 80's. In this period of time DDT was banned from these countries, and as DDT was only banned in 1999 in Malaysia the found concentrations are reasonable and it may be expected that the same decline in total-DDT levels will be seen in Malaysia in the future.

CONCLUSION

The study confirmed that dietary intake, especially fish and dairy products, are important determinants of OCPs levels in human milk. Fish and dairy consumption are observed to increase DDT, DDE and heptachlor concentrations in human milk. A reduced consumption of fat from fish and dairy products will likewise lead to a decreased intake of OCPs. Increased lactation was observed to decrease OCP levels in the human milk. In cases where the women had worked at plantations where pesticides had been used, increased levels of total-DDT were detected.

The detected concentrations of OCP in human milk were compared with similar data obtained from other countries. This study has indicated that the average total-DDT-levels In Malaysia are of the same order of magnitude as levels detected in Scandinavia about 20 years ago. This is assumed to be a result of recent (within the last 3 years) restrictions of DDT in Malaysia. However, the detected total-DDT concentrations are lower compared to contamination levels reported from other Asian countries.

Mean levels for heptachlor exceed the ADI in all races in the range 280% to 2690%, and mean levels for aldrin (except Orang Asli) exceed the ADI with 120% to 800% in all races, which is considered unacceptable. Only the Malay women exceed the ADI for heptachlor epoxide (16%). Even though the period of breast-feeding is short in relation to lifetime, the OCPs persist in the body and enter the infant at a sensitive phase of its development. There should be a constant awareness of this source of potentially toxic substance for the breast-fed infants. Since there is no evidence that the levels of OCP residues detected in breast milk in this study have serious harmful effects on the health of the breast-fed infants, breast-feeding should be, as recommended by WHO, encouraged and promoted because of its nutritive and immunological advantages.

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4 Environmental Education

The Art Of Doing Field Research With In Environment And Development & The Creation Of (New) Knowledge

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ABSTRACT: The International literature on Industry, Environment and Development is a relatively young field of investigation. Being a 'new' field it is not surprising that the field can be characterised by limited knowledge in some areas and that researchers often argue in favour of collecting new information through fieldwork. The International Industry, Environment and Development literature only provide limited examples of systematic application of theoretical frameworks. Concerning SMEs, Environment and Development literature the contributions have tended to be pre-occupied with policy orientation and have been quite slack on fulfilling scientific requirements concerning formulation of research designs, collection of data and analysis. The authors PhD-project, which has included 2 longer periods of fieldwork in South Africa and 3 shorter trips, is used as an example of how a match between research questions, methodology and theory can be obtained. The author discusses the general implications of this 'fieldwork' premises and exemplify how the application of a Critical Realist Perspective can make up for a part of this caveat in the social science field of Industry, Environment and Development. Finally, the author discusses the lessons learnt[i].

KEYWORDS: Fieldwork, methodology, scientific coherence, Critical Realism

INTRODUCTION

Research often has the ambition of coming up with new knowledge, and conducting empirical investigations aimed at obtaining primary data is a well-known method to acquire such information. The International literature on Industry, Environment and Development is of recent origin and many researchers there fore (with some rights) argue that they are investigating new and/or unexplored areas. While e.g. the level of experience regarding doing fieldwork in a different context of our own raises a number of challenges, the situation concerning amount of knowledge available, our ambitions and the projected outcome of our project raises related, but distinct academic or scientific issues. One could ask how and to what extent the amount of knowledge in a particular field impacts on the types of research, which can be conducted and the implications for the fieldwork conducted?

Research projects sometimes not only seek to describe and explain certain issues, the projects also want to end with recommendations about how to change the present situation and maybe even engage in implementing change. Fulfilling these aims can be a question about resources available, but it also depends on the knowledge generated in the field. If, few investigations have been conducted, if the existing data are of a certain character (e.g. only based on quantitative methods or mainly anecdotic), oR if the data are old and outdated, the project needs to reflect these circumstances and the kind of methodologies, which will be relevant to use (theoretically as well as empirically).

Different viewpoints have been articulated on this matter. Some have argued that research with in a relatively new field has to move through various phases from explorative studies, to descriptive, explanatory, analytic to prescriptive studies. Others argue that such sequence in the knowledge creation is not necessary. An explanatory research project can be conducted in a new field, if the study is well defined, focused on selected aspects of a phenomenon etc. Such project(s) can be complemented with other projects, which further expands the knowledge on the subject, deepen the complexity of our understanding and the dynamics involved and add to the knowledge creation.

Further more, we seldom encounter totally unknown phenomenon. A certain amount of knowledge exists, and/or theories, frameworks and research designs have been developed, which are relevant for the project, we are undertaking. A literature review is one way of scrutinising the existing contributions and gain insights to the present 'state of art' in a field, older or younger. However, doing fieldwork also entails considerations on e.g. the relevance of a certain theory, formulating hypotheses and employing coherent research designs in the quest of answering the research questions.

Being a new of investigation to a certain extent explains that the Industry, Environment and Development field is characterised by limited knowledge such as lack of knowledge on causes and effort of greening, on driving forces and barriers as well as analytical frameworks, which impacts on what kind of aims that can be fulfilled and what kind of knowledge that can be generated. However it doesn't explain or justify that the Industry, Environment and Development field has also been marked by lack of scientific rigour (Gladwin 1993) as coherent scientific approaches obviously should be applied.

From a Critical Realist Perspective, the author proposes an approach to make a fit between the amount of knowledge in a field and a coherent methodological set-up.

KNOWLEDGE ON INDUSTRY, ENVIRONMENT AND DEVELOPMENT

Project proposal on 'Environmental Management in manufacturing SMEs in South Africa' took its point of departure in the situation that little research has been conducted on greening of SMEs in 3rd world countries. Research question was formulated as an investigation of the driving forces of greening in small manufacturing firms in the South African industry. The emphasis of the project was thought to be on the problem analysis, with some descriptive and explanatory elements as well as some recommendations at the policy level. It also had the ambitions of providing a scientifically coherent approach to this issue. These elements are no different from many other research applications and project formulation, but the aims of my PhD-project addressing these different audiences later stood out as being rather different to achieve. The fulfilment of the objectives would require a body of knowledge, which however did not exist.

Among the objectives of in the research process was to embark on a literature review of the Industry, Environment and Development area. Apart from confirming the limited amount of knowledge, the review also indicated that the knowledge concerning environmental practices of SMEs was limited too. Further, the review revealed that the majority of the contributions had a normative perspective and were focussed prescription.

Seen from a Critical Realist position different related issues make up for the problem(s) with in the SMEs, Environment and Development area. One element is the emphasis on empirical investigations, which however in some cases lack of thorough methodological considerations, a coherent theoretical framework and use types of explanation, especially generalisation, which are problematic due to the lack of methodological and theoretical considerations.

A major area of investigation has been achievement of sustainable development and a key approach was to employ a 'win-win' perception that pursuing and improving environmental performance (always) goes hand in hand with improvements of economic performance. Instead of taking the point of departure in a theoretical framework, which conceptualised the possible relationship between environmental and economic performance, the contributions assumed that e.g. implementation of an Environmental Management System (EMS) automatically leads to a 'win-win' situation. Few studies provided more open framework and outlined, which factors potential impact towards the environmental practices of SMEs and how the context matters (e.g. Whalley, 2000 and Scott, 2000).

One section of contributions assessed drivers and barriers of greening, but applied frameworks which entailed 'factors' picked more or less at random and with out being connected to a theoretical understanding on causes and effort of why SMEs green. In spite of limited knowledge e.g. on what kind of the environmental practices that the SMEs conducted, on why SME green or not green, the contributions took for granted that SMEs across sectors had a serious environmental impact and prescribed how to mitigate this. A number of contributions took their departure in the perception that 'SMEs are lacking resources and capabilities to perform environmental management' (see e.g. Hillary, 1995 and Petts, 2000). Not surprisingly, these kinds of contributions ended up concluding that particular barriers to environmental performance are related to the size of the firms – a tautological (or circle type of) argument.

The empirical foundations of the contributions were often flawed, e.g. using a sample of arbitrarily selected SMEs with out specifying the selection criteria or interviewing randomly picked stakeholders (consultants, government officials, NGO's) with few or none considerations concerning how and whether the data collection methods supported the aim and type of investigation. Wide of generalisation took place, e.g. arguing that findings on SMEs in the UK could be extended to SMEs in South Africa or that if 40% of SMEs say that environmental regulation is of little concern to them, then environmental regulation is an unimportant driver of environmental management in SME. Yet others used quantitative data from e.g. a survey to generalise about drivers and barriers, though limited knowledge on causes and effects exists (Gerrans and Hutchinson, 2000).

In practical terms, this seemed related to the policy orientation of many investigations and an obligation to provide policy makers with information on this 'new phenomenon' of SMEs and the environment. While the policy orientation is quite legitimate, the scientific outcome is problematic, as the contributions show a lack of scientific rigour and produce dubious accounts of SMEs and their environmental management.

The main problem rests with the incongruence that we on the one hand have little knowledge concerning SMEs and their environmental impact and on the other hand can argue that the activities of SMEs are a major environmental problem. If environmental management of SMEs has been rudimentarily dealt with, how can we then state that SMEs constitute an environmental problem? A crucial issue seems to be the position that we take as researchers concerning how we can establish explanations of phenomena relating to SMEs, Environment and Development.

With many contributions drawing on rational, positivist perspectives, which were compromised for the reasons outlined above, what would then be an alternative? The critique came from among others so-called the Critical Realist perspective (CRP).[i]

THE CRITICAL REALIST PERSPECTIVE

Ontologically, the basic understanding of Critical Realism (CR) is that reality exists and that it is possible to conceptualise it and make theories in order to describe it. Simultaneously, the CR position doesn't make claims of totally comprehensive understanding of a certain problem or establishing a 'grand perspective'. Furthermore, the CRP or CR perspective regards all knowledge as fallible, in the sense that a scientific account of a phenomenon is a partial account of certain aspects, deliberately chosen and due to change.

A central point of the CR ontology is the division of reality into different domains with specific propensities. At the domain of the empirical we can make observations of 'experiences', meaning the visible observations of the phenomenon, we study. These experiences constitute parts of the 'events', which we can identify at the domain of the actual, which in turn is the outcome of 'mechanisms' at the domain of the real.

Epistemologically, the aim of CR is to explain the relationship between the experiences and events and the mechanisms. Hence, the perspective emphasises questions of 'how and why' a particular phenomenon came into being, got its specific character and so on. The emphasis is on the explanation of the constitution of empirical phenomenon and not to give predictions.

In order to make analysis of the various domains of reality and identify the relationship between experiences, events and mechanisms, we need to use different kinds of reasoning, inductive, deductive, abductive and even retroductive (Danermark et al, 1997, p. 123-172).

Investigating conditions with in social science is according to the CRP based on premises and characteristics like 'openness' (closure does not exists), double-hermeneutic relations between the researcher and the object (both make interpretations when they engage), our understanding and analysis is theory-laden and concept-dependent (the theories and concepts that we use impact on our study, but they don't determinate the outcome), and the context (time and space) influences the phenomenon we study.

Sayer's work (Sayer 1992) is a contribution to the development of Critical Realism, called a '(Critical) Realist Approach' (hereafter CRA). Sayer underlines the focus on scientific/methodological coherence and emphasises the relevance of different methods of data collection for different types of projects.

Sayer advances 4 types of research, intensive or concrete, abstract, generalisation and synthesis. The intensive/concrete involves theoretical and empirical analysis, the abstract only theoretical, the generalisation only empirical, while the synthesis is interdisciplinary analysis coverings different perspectives and fields (Sayer op.cit. 1992, p. 237 ff).

Sayer outlines 2 different kinds of research designs, which are relevant when doing fieldwork. The intensive and the extensive research designs (Sayer op.cit 1992 p. 242ff) can be employed in relation to research, which seeks to link the theoretical (or 'abstract' in a Critical Realist terminology) and the empirical (or 'concrete' in the Critical Realist terminology).

The 'intensive research design' is used in research, where we want to obtain in-depth knowledge of specific phenomena, like how and why a firm mobilise resources and capabilities for environmental practices. While the extensive research design is appropriate, e.g. when we want to establish an overview of the environmental practices in manufacturing SMEs in South Africa (Sayer op.cit 1992, p. 242). Intensive research mainly applies qualitative methods and analysis, while extensive research typically uses more quantitative methods and analysis (Sayer op.cit 1992, p. 244).

Sayer bases the outline of the research designs on the assumption that we as researchers are studying fields that have been thoroughly investigated by other researchers earlier. He argues that a concrete research type is the preferable one. As this precisely not is the case concerning Industry, Environment and Development, Sayers intensive and extensive designs have to be supplemented by a third design, the explorative design (Jeppesen, 2003, p. 85). The explorative design is aimed at investigating the field where we need to establish a basis understanding of the area investigated, the perceptions of the phenomenon under scrutiny and what constitutes 'issues or problems in the field' according to involved parties (e.g. government employees, researchers, industry associations, firms, consultants and NGOs). The explorative study could involve a literature review, investigations of the history, political, economic and social conditions, environmental regulation and knowledge on Industry, Environment and Development and interviews with key persons. [ii]

A CRITICAL REALIST APPROACH FOR STUDIES OF SMES AND ENVIRONMENTAL PRACTICES

Lack of knowledge on SMEs, Environment and Development had consequences with regard to the research strategy and especially research design, the aims of the project had to be adjusted by lowering the original level of the ambitions. The first outcome of these reflections was the decision on focusing on one type of project.

One way of characterising project types is by dividing them into 5 'ideal types', the explorative, the descriptive, the explanatory, the predictive and the action orientated (Andersen & Gamdrup, 1990, p. 41). The explorative type of research aims at presenting information on a phenomenon and how it is constituted. The descriptive type seeks to explain how it has developed, the character of the phenomenon and relations to a specific context. The explanatory analysis has the ambition of answering why the phenomenon has developed in a certain way, identifying hidden causes of this development and addressing the main reasons, which should be addressed. The predictive type aims at coming up with suggestions, proposals, recommendations concerning how the phenomenon can be changed, improved and the implications of these suggestions. Finally, the action orientated type seeks to implement the changes in collaboration with the target group or problem owners.

Andersen argues that a research project should clarify the research type at an early stage. The advice is to concentrate on ‘one type’, though all projects often entail descriptive elements, in addition to the focus on explanation, problem solving and maybe intervention too (Andersen 1999, p. 23-29 and p. 55). But the decision concerning the focus should also depend on the amount of knowledge that we have on a particular phenomenon. The newer the field and the less knowledge, the more it points to a descriptive and/or explanatory type of project. The more established and well researched area, the better foundation for a problem analysis type and maybe even problem solving.

The conclusion was the project type should be the explanatory, and more specifically a concrete or intensive research type in Sayers terminology.

The second and related outcome was the importance of addressing the issue of ‘scientific coherence’, which is an obvious requirement with in social as well as others sciences. Andersen argues that a key priority is to secure a tight relationship between 4 elements, the ‘problem type’, the research question(s), the methodological approach and the theory used/applied. However, this approach has to be supplemented with considerations anchored in a research strategy and a research design, which reflect coherence between the philosophy of science, a social ontology and the social theory level. Securing a fit between these 3 methodological elements is a bigger task compared to securing a fit between the 4 elements, but to my opinion needed in order to establish a foundation, which can provide us with new knowledge. Here additional methodological considerations are necessary.

Thirdly, in relation to my fieldwork, my assessment of the international literature gave little foundation of a possible theoretical framework and predominantly contained case studies from a First World context. Further more, as few investigations had taken place in the South African context, limited knowledge existed in the field as well as specifically on South Africa. I needed to collect empirical information, which not only were non-existing in South Africa, but also to a certain extent absent internationally in order to establish the empirical foundation for the analyses in my project.

In relation to my fieldwork, I included all 3 designs in my PhD project in order to illustrate the arguments by Sayer (and other Critical Realists) concerning the importance of establishing a coherent scientific framework, applying it and reach to the explanations, which the project type is aimed at. One important first aim of the PhD-project was then to gather primary data in order to fill the knowledge gap and investigate how SMEs conducted environmental management. The information should provide me with the overview of the kind of environmental practices that the SMEs were carrying out as a means to go into depth with the issue of the driving forces of greening in the small firms.

LESSONS LEARNT

Taking a Critical Realist approach when conducting research within the field of Industry, Environment and Development is not the only possible way of securing a coherent scientific framework, which helps the process of knowledge production. Still, I think that a CRA is useful and helps avoiding a number of the pitfalls, which normative, rational, positivist contributions have. Applying a CRA means addressing a number of important elements in the research process and establishes the relations between the data that we want to generate during our fieldwork, the theories used and the answering of our research questions.

The argument presented is that what can be accomplished with a research project depends on the amount of knowledge that exists in the particular field, which the research is situated in. This implies that we as researchers need to make an assessment of the way that our particular field is constituted and how we view our contributions. Conducting research with in the field of Industry, Environment and Development from a social science position is presently based on the condition that limited knowledge exists. But, the conclusion is not that we should advocate a ‘puritanical view’ on research methodology, arguing that the knowledge creation only can take place through a step-by-step approach moving from exploration, description, and explanation to understanding, analysis and prescription. We don’t need to confine ourselves to historical, explanatory research and hence limit the potential use of the results. Different types of research, e.g. action research, and the application of research in practice are important (see e.g. Wad 1998 for a discussion of this issue).

An important condition is the limited resources and priorities that are given to environmental issues in the countries and contexts that we research. One implication seems to be that we need to reflect thoroughly on our ambitions with the research and an aim itself should be to make a contribution, which is useful to future research in the context, whether it might be internationally or locally funded research. It is also important that the work is useful, can be applied and has relevance for policy formulation. But, I will argue that it is very important that the processes of conducting the research and e.g. making input and suggestions for policy interventions are separate. The research has to be conducted in its own right, with the particular set of conditions attached to it. The practice orientation is another process, where relevant parts of the research findings are translated into suggestions concerned possible policy interventions. However, the inputs should be presented as e.g. scenarios of what could happen under certain circumstances and not as closed recommendations.

My contributions to the issues of driving forces of greening in small firms in South Africa have mainly been at the methodological and analytical levels. Still, the empirical investigations also provided a bulk of new knowledge in this particular area. E.g. my findings concerning the environmental practices of the SMEs in South Africa related to the ambitions of upgrading these practices from the Department of Trade and Industry and the Department of Environmental Affairs and Tourism. First of all, one point would be that the environmental practices differ substantially between Micro, Small and Medium-sized firms and between the manufacturing sectors. So, the issue is not just to say that SMEs lack resources and capabilities to carry out environmental management and hence reproduce the myths in the international literature, but instead to suggest that the policies target the SMEs according to the level of environmental practices that the firms carry out.

While the PhD-project mainly has academic interest, it contained amble information, which could be of relevance to companies, government and trade associations and with out reproducing the prejudices on the lack of resources and capabilities for environmental management among small firms, which the international literature carries. The point is that the 'translation' of the scientific work should take place as a separate phase, in a dialogue with policy makers.

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ENDNOTES

[i] Roy Bhaskar and Rom Harré are among the founders of 'Critical' Realism. They launched a critique of the 'rational' and 'positivist' scientific requirements entailed in the natural sciences as well as major parts of social science (see Archer et al 1998 for an introduction and discussion of Critical Realism). The aim was to construe a new ontology and a new realist philosophy of science (Bhaskar and Lawson 1998, p. 3) as an alternative to the positive, rational as well as social-constructionist perspectives.[i] The work has concentrated on the philosophy of science level and ontological, epistemological and methodological issues. Less emphasis has been placed on how actually to link the abstract and concrete levels in the research process. Authors like Sayer (op.cit, 1992 and 2000) and Danermark et al (1997) have focused on this aspect of Critical Realism.
[ii] For an elaborate assessment of this issue, see Jeppesen 2003 (chapters 3-5).

Bias, Intimacy and Power in Qualitative Fieldwork Strategies

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ABSTRACT: The paper discusses how bias, presuppositions and power relations affect and form part of qualitative approaches to fieldwork in local communities. Specifically, the paper critically reviews the notion that we may shed our roles as pre-disposed outsiders by entering the field with an "open mind", and by developing close relationships with community members. It is argued that these approaches, while effective in many ways, contain and are constrained by a number of biases, and that they therefore need to be complemented by explicit reflexivity.

TWO ASSERTIONS

Recent years have seen an increasing emphasis on the role of local communities and their livelihood patterns in relation to environmental planning and natural resource management. This has prompted studies seeking to understand the social dynamics of these issues through a social science or inter-disciplinary context. One of the main challenges for such approaches is the difficult question of how we as field researchers cope with the role as outsiders in the local (community) context. How do we *access* the "foreign" empirical world that we are trying to study, how do we secure the best possible insight despite our status as outsiders?

This is, of course, not a problem particular to environmentally related studies. Ethnography, for instance, has long attempted to address the issue (eg. Fettermann 1998), while in broader terms there is an increasing focus on the issue as part of the increasing popularity of qualitative approaches within the social sciences (eg. Denzin & Lincoln 1998). However, let me a bit more specific and refer to a recent course I attended. The course addressed methodological aspects of fieldwork in Asia, and I took special note of two assertions made during the lectures and subsequent discussions:

The *first* assertion was that, in order to avoid ethnocentric biases in our fieldwork we need to retain an "open mind" when entering the field, thereby allowing the local context to influence our thinking. The *second* assertion was that, by developing a close and personal relationship with the agents being studied, we are able to gain a clear insight into the sensitive, unspoken issues of community life (the "best guarded secrets" as the instructor called them).

These are plausible and sympathetic notions that form core elements in ethnographic research, and would probably be widely accepted by many field researchers in general. Indeed, they are ideals to which I have striven myself during current fieldwork in Southern Thailand, and during past fieldwork elsewhere.

The question, however, is whether and to what extent these two principles really do allow for such easy access to the "closely guarded secrets" as is sometimes claimed? In the following, I shall seek to problematize and seek out the limits of these assertions, arguing that it is highly problematic to take them for granted without making explicit their underlying conditions and inherent biases.

THE FIELD AS A CONSTRUCTION

The notion of the "open mind" takes a variety of forms, but one of the purest can be found in empiricist approaches such as Grounded Theory. Here, the idea of *tabula rasa* suggests that we can and should commence fieldwork with a "clean slate", free of prior experience and theoretically informed constructions of the world (Glaser & Strauss 1968).

Such a notion, however, ignores the degree to which we are socialized and institutionalised into given ways of structuring and labelling the empirical context we explore. Consider, for instance, the field of environment and development, within which my own research takes place: We talk of *sustainable* resource management practices and *unsustainable* ones, thereby implicitly establishing categories of *people* who live sustainably and unsustainably. And we inscribe ourselves into storylines such as that of *biodiversity conservation*, which come to form the basis of entire research agendas and development interventions, and help shape our basic ontological frames of reference (Escobar 1998, Leach & Mearns 1996, Long & van der Ploeg 1989).

This *framing* of the world through our pre-conceived ontologies often takes place through dichotomies: When addressing development problems, we frequently approach the world as divided into the poor and the wealthy, the rural and the urban, the community and the state, the traditional and modern, the natural and the degraded. Although we may attempt to overcome some such dualisms, they are powerful notions that to a large extent provide our only means of negotiating the world.

We may think, of course, that this implicit construction of the empirical world can be avoided simply by taking one step back and making this process of labelling – and the power behind it - a research object in itself. In my own current fieldwork for instance, I have taken a largely sociological perspective on a participatory coastal zone management project, seeing it as a social process loaded with power and interest. However, while such a power perspective may sharpen attention to some of the processes of labelling taking place, it immediately establishes others:

In seeking to identify community members to interview, I divided them first into "participants" and "non-participants", subsequently developing and applying additional categories such as "fishermen" and "non-fishermen" and "Buddhist" and "Muslim" households. Not to mention the application of the terms "community" and "household" in the first place. This structuring of my fieldwork area rested on a more deeply embedded perception of communities as essentially heterogeneous, stratified entities, steeped in struggles over access to and control over natural resources. This underlying conflict perspective constitutes an implicit yet distinct way of thinking, into which I have been socialized through many years of interaction with teachers and peers at University.

We cannot, then, escape the pre-disposed construction of the field that we undertake prior to and during fieldwork. This is also recognized in (newer) Ethnography, another approach which has long advocated the "Open Mind". As Fetterman (1998) puts it, the ethnographer "enters the field with an open mind, not an empty head" (see also Massey 1998). What ethnography and most other approaches rarely acknowledge, however, are the underlying ethnocentric conditions of the fieldwork process *as such*. I turn now to this more fundamental aspect of fieldwork, focusing particularly on the Asian context.

THE WESTERN BIAS

Shamsul (2003a, 2001) describes how the present patterns of knowledge production in most of Asia today reflect a mode of thought originating in the West, introduced during colonial times as a means of rationalizing, naturalizing and thereby legitimising the science-state-capital complex that provided the basis for colonial resource extraction and domination.

In this way, "Western science" came to structure and to some extent even re-create Asian societies, through processes such as classification (eg naming ethnic groups) and spatial categorization (eg through mapping). Even *time* was laid out and defined through a Western epistemology, establishing for instance "traditional" resource management as opposed to "modern" resource management, thus contributing to the "Invention of Tradition" discussed elsewhere (Hobsbawm & Ranger 1992). As Shamsul has pointed out, such a notion is applicable also in Thailand, which despite its lack of a distinct colonial history has *de facto* appropriated the same Western modes of knowledge production as the rest of Southeast Asia (Shamsul 2003b).

It is, of course, possible to dismiss Shamsul's point as part of a wide-spread "blame-colonialism" discourse that seeks the roots of all evil in this time, but such an argument faces problems in the light of Shamsul's further argument that the reproduction of Western knowledge production systems *continues* in Asia today through the national Universities themselves, and through, for instance, the Banks and the Aid complex (Escobar 1995 makes the same point on a more general scale).

This has important implications for the argument made here: Firstly, it suggests that it is not only I, as a foreign researcher, who may have problems encountering the field with an "open mind": My Asian colleagues may well be part of the same presuppositions and frames of reference as myself. Secondly, and more fundamentally, it poses considerable constraints on just how "open-minded" we can hope to get in the first place: If the field is *already* structured by Western rationality and labelling when we arrive, how are we to even *see* the implicit categorizations we make, and how are we to avoid reproducing them?

Consider, for instance, anthropology. There is no doubt that anthropology (using, of course, ethnographic methods) has helped to greatly enhance our understanding of the way significant features and concepts are defined locally (including, for instance, crucial concepts such as "nature" and "the environment"). And yet anthropology itself is, if anything, a primarily Western science: Here is a science that, perhaps more than any other, imbues the "local" and the "traditional" (concepts with distinctly Western overtones) with *meanings* and *categories.* Is such a process not in fact just a more subtle version of the traditional Western labelling and categorization that Shamsul refers to?

I hasten to add that I am myself a believer in ethnographic methods. I am by no means out to deride any particular approach, but to point out the substantial barriers that confront the ideal of the "open mind". In the following I will address one last such constraint, which may well be the most fundamental of all.

THE ACADEMIC BIAS

Like much other research on the relationship between the environment and a given group of actors, part of my own fieldwork is focused on seeking to understand people's motives and strategies. Here, of course, the "open mind" is more important than ever. Most people will probably agree that understanding other humans fully is impossible, and that different cultural backgrounds imposes further constraints on this. However, the French sociologist Pierre Bourdieu adds a further dimension to this by drawing attention to the particular constraints inherent in the academic point of view.

Space does not allow me to elaborate here on Bourdieu's conceptual framework, but for the purposes of this discussion, his basic claim is that we as academics apply a distinct view of the world that is always different from that of the agents under study (Bourdieu & Wacquant 1989, 1992). Like any other social space, says Bourdieu, the Academic Field has it's own particular schemes of perception, it's own associated values and norms. Through training and systems of reward we are socialized into these schemes of perception, which become a deeply ingrained part of us, whatever our specific position in the scientific debates (Bourdieu 1984). We come, in other words, to possess a particular *academic bias*, based, for example, on features such as abstract thinking, theorizing, conceptualisation, analytical categorization, and scientific "rigour".

These features influence both our construction of the empirical field, and our understanding of what takes place within it. Through interpretation and analysis we become cognitively *remote* from the practical world we are studying. This inevitably distances us from the practical everyday worlds (with their own associated values and schemes of perception) of the agents that we seek to understand. Hence within the social sciences at least, the very same values and systems of perception that define "good science" also come to provide a major constraint in undertaking it. This suggests that *as academics* we can never simply "learn another culture like we learn a language" as one participant claimed at the course referred to above. Only if we were to shed our academic agendas fully and become involved in the field as practical individuals might we hope to do so – but then we are by definition no longer researchers.

It is important here to point out that Bourdieu's argument does not in any way imply that the academic field is somehow superior to other social fields – it is just *different*. Nor is there an assertion here that the "open mind" should not be striven for - only that our academic point of view constrains it. Indeed, Bourdieu suggests that when seeking to understand the social practices of others, we may often gain important insights by referring more to our own *non*-academic experiences (the *other* fields that we inhabit) than the academic ones (Bourdieu & Wacquant 1992).

In extension of this, let me emphasize that the point of the above discussion has not been to suggest that we could or should do away with the notion of the "open mind" altogether. Rather, the argument is that we need to be explicitly aware of its limitations, including the larger processes and structures into which we are inscribed as field researchers.

INTIMACY AND POWER

I turn now to the second assertion made at the PhD course referred to above: That the best overall strategy for securing in-depth, qualitative knowledge about local societies is to develop good relationships with the agents under study. In order to elaborate on the logic behind this notion, let me quote at some length from the reading material provided for the course (Lindberg 2003, p.1):

"The main tactic a fieldworker has to develop is to play the game as an outsider making friendly visits, learning about the local ways and thoughts without criticising these. […] Showing respect, socializing, developing friendship and keeping it, is not just a tactic, but it is also necessary in order to get accurate information, which most often comes out of relaxed casual conversations, off the record, so to say. The hospitality, friendliness and natural socialising ability of South Asians means that the fieldworker needs to play on these strings to create rapport."

Although rarely stated in such (jarringly) explicit terms, this quote does capture much of the inherent logic in much qualitative field research within the social sciences today. In this respect, the Norwegian psychologist Steinar Kvale has begun to question what it actually is that we *do* when we pursue qualitative information from individuals (Kvale 2003). He arrives at the conclusion that much qualitative interviewing works through a postulated *intimacy*, which legitimises our quest for data in the field.

Within ethnography, this strategy of intimacy (though never termed as such) has long formed a core strategy for accessing information (eg the anthropological principle that fieldwork should be initiated with an extended period of time allocated solely to becoming accepted and known within the community under study). However, in recent decades, the strategy has also become widely embedded in qualitative social sciences more broadly.

Consider, for instance, my own past and current fieldwork approach: Much effort is spent on developing a good relationship with the communities where I work, and on creating a relaxed context before and during the interviews themselves. I try also to disassociate myself from any threatening perceptions that the respondents have of me, seeking a friendly and good-humoured dialogue. Indeed, *dialogue* is a key word: The implicit intension is always to establish a sense of open dialogue between two good-natured beings.

What actually takes place, however, is essentially an extraction of intimate details about the person or persons under study, designed first and foremost to generate "good" information for my research purposes. We may, of course, seek to apply two-way information-flows or apply participatory methodologies. Yet even within such approaches, the researcher ultimately remains in charge, and ultimately pursues a given (usually hidden) research agenda, however veiled this process may be (Kothari 2001, Christoplos 1995). Hence we are reminded again of Shamsul's linking of Western knowledge production to colonial exploitation and labelling, although here of course the labelling is more sophisticated, and the exploitation is not about material resources: it is about knowledge – the knowledge of people's lives, no less.

Behind the strategy of intimacy, says Kvale, lies a subtle and unspoken relationship of power: It is only through power that we are able to pursue intimacy as a data collection strategy. This was particularly explicit in my own recent fieldwork in Southern Thailand: The project I studied is funded by the Danish Government, through the very same agency that funds my PhD research, and for whom I have worked as a consultant on several occasions. To this was added my status as an Academic (if only a lowly one!), a position that holds not inconsiderable respect in Thai culture. Although I actively attempted to disassociate myself with these roles during fieldwork in the communities, they *de facto* constituted a major element in legitimising my right to be there in the first place - to access certain information, to ask questions about people's lives, to pursue intimacy.

THE PITFALLS OF INTIMACY

The role of intimacy and power in qualitative fieldwork raises significant moral questions, of course, but also – more cynically - illuminates the analytical pitfalls involved.

Firstly, we risk becoming unknowingly trapped within our limited world of intimate relations: Our view becomes limited to those agents with which we are able (or willing) to become intimate. Secondly, and more seriously, the strategy of intimacy rests on core assumptions that are dangerous to take for granted: As Atkinson & Silverman (1997) have pointed out, qualitative interviews have come to form a keystone in what they term the "interview society" – a society resting on the assumption that the agent's *themselves* are the best sources of data. This is often taken to imply that such data is somehow "deeper" and more "detailed" than other types of data. Depending on the situation, this *may* be so, but it may also include substantial distortions, and is certainly never more "real" than other types of data.

A third potential pitfall in the strategy of intimacy is the ease with which we may come to believe that we *control* the data generation process: The combination of intimacy and power is alluring, and may lead to a false sense of having gained the complete confidence of people, and of being able to "see through" their attempts at manipulating data.

A related aspect of this is the tendency among some to suggest that techniques such as triangulation (the checking of data or methods against other data or methods) can serve as some sort of technical fix to data distortion (Fetterman 1998). Such methods may certainly help us along the way, but un-reflected faith in them is dangerous – partly because they are not always as compatible with qualitative methods as we like to think (Massey 1999, Richardson 1994), and partly because the field researcher rarely finds himself in the objective position that a fully unbiased triangulation would require.

To elaborate on this, we need to appreciate another side of the power-intimacy relationship, not mentioned by Kvale: Through intimacy, we automatically become enrolled in local power relations. There are two aspects of this: For one thing, we need to appreciate that we as field researchers inevitably form part of the power plays related to the issues we study. We do so through our overall role as knowledge producers, and – in some instances at least - as social agents ourselves. For instance, by studying the activities of a participatory environmental project, I was developing data that could potentially be used by others (eg the donor agency) to pass judgement on the project and the actors within it. Likewise, it is quite possible – even likely - that my presence as an observer at community meetings affected the meetings to some extent (ie we are *always* "participant observers").

However, exactly because we constitute players within the field under study, we may also become the subject of strategic manipulation by the local agents themselves. Although we may possess the power to pursue intimacy, this does not mean that the agents we study have no means of "manipulating back". In my own case, I was clearly considered a strategic asset by some of the agents I interacted with, who saw me either as a potential instrument for securing further funding to the project, or as an asset in the power plays surrounding the community project activities.

We are, then, always enrolled in the field in one way or another, and this in itself makes it highly problematic to assume that the strategy of intimacy (or techniques such as triangulation) allows us to somehow pass directly by manipulation and get at the "best guarded secrets", as was claimed by one lecturer at the methodological course referred to earlier.

THE NEED FOR REFLEXIVITY

I have in the above outlined a range of potential biases and problems associated with the notions of the "open mind" and intimacy as strategies for exploring the local as an outsider. I have done so from a mainly qualitative, social science perspective, with a certain emphasis on ethnographically inspired methods. Clearly, there are elements herein that are specific to such approaches, and yet I would claim that some of the issues touched upon are relevant beyond the typical, relatively long-term ethnographic study.

Hence, from a more overall perspective we may see the spreading of participatory approaches to project planning and Social and Environmental Impact Assessments as expressions of similar notions. Here, the attempted intimacy may take place at a larger scale (in focus group interviews, public hearings etc), but much of the logic is the same: The allusions to an unbiased, open-minded planning approach and the pursuit of intimacy between the external and "the local" (Nicro 2000). In this process, we as academics often play a significant role as knowledge producers and masters of the instruments (the methods) of intimacy - as seen, for example, in the widespread use of academics as consultants and facilitators within such processes in Thailand.

Again I should emphasize that my aim here is not to suggest that open-mindedness and intimacy is in any way a "bad" approach as such. What I do object against is the assumption that these approaches will somehow do away with bias, power and manipulation in the data generation process. These features are always there in some form or other, irrespective of the approach.

What is needed, then, is to couple these approaches with an ongoing *reflection* over their limitations. The actual means of ensuring such reflection has been approached differently by different schools of thought. Attempts at within anthropology have included careful registration of the field researcher's daily interactions and emotions during fieldwork. Such efforts at self-understanding may be important enough for the researcher herself, but risks a situation where narcissistic self-revelation comes to prevail over the actual research process (what some have dubbed the "diary disease").

Others have focused less on the researcher's own lived experience, and more on the epistemologies into which he is inscribed. Hence in a distinctly postmodern vein, Alvesson & Sköldberg (1999) argue for a reflexivity resting on the notion that whichever perspective we may take on the empirical world, it is just that: a perspective. We must therefore incorporate in our (field-) research a critical reflection over what other epistemologies and approaches might have brought us in terms of findings and conclusion.

My own understanding of reflexivity is in line with the "Participant Objectivation" of Bourdieu (2000). This suggests an emphasis not so much on the individual trajectories of the field researcher herself, nor *only* on the epistemologies into which she is inscribed, but also more broadly on the power relations and schemes of perception into which she and her methodologies are embedded. By reflecting explicitly on such issues, we come to see better our own predispositions and biases, and may thereby appreciate better their impact on our work.

Clearly, though, such a process has limitations. As we have seen, some biases and pre-suppositions may be sufficiently implicit to avoid tracing by ourselves. But it is exactly here that open-mindedness and intimacy comes back into play: If we acknowledge clearly that we come loaded with pre-suppositions and a distinct agenda of collecting data for our research project, we have the basis for a more open process of reflexivity: By making clear who we are, we open for the inclusion of inputs from others on the biases and misconceptions they see in our work. In such a process there would be no hiding of the fact that we *are* outsiders: Indeed, it would be exactly this otherness that would help us see our biases: Only by drawing in those who stand at some distance to us, can we begin to see ourselves fully.

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Preparations For The First Field Study: The Impact Of Working In Mixed-Culture Groups

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ABSTRACT: Preparations for a semester-long field study in a distant country has to deal with both the scientific contents of the project and the differences in cultural setting from the home country. In this paper it is investigated what Danish students at the Technical University of Denmark (DTU) learn from working in mixed-culture groups as part of the preparations and how a positive outcome can be supported. The students mainly learn from foreigners' attitudes, get a broader view on the subjects and learn to work with foreigners in mixed-culture group work. But learning the subject matter is made difficult because of particularly international students' poor skills in problem-based learning and lack of time for group discussions. Teachers can improve this by giving room for creating a good atmosphere for selection and work in the groups. The students generally find it rewarding to work in a mixed-culture group and it is believed that it is a good preparation for field studies.

Keywords: Field studies, Mixed-culture groups, group work, preparations for field work

INTRODUCTION

Danish students that choose to spend a semester to do field studies in a distant country find themselves in deep water in several ways. They are suddenly far away from several of their well-known environments and have to relate to new situations everywhere. Ribeiro et al. (2002) highlight three environments: 1) The overall socio-cultural environment that every tourist experience, but for students that stay for a long time the same place this is presumably more intense; 2) the context of e.g. low-income societies, NGO's and types of institutions that are often central to the investigation, but the students may not be used to work with the same type of institutions in Denmark and 3) the professional society at the university they attach to, where other traditions of supervision often exist. It is itself a challenge to handle these differences, and then the students are on top of this expected to do an investigation of high quality related to their own professional field.

Perhaps because of these constraints, for many students the field studies end up being perhaps the most important learning experience during their studies. This is both in terms of the scientific gain from performing a long and concentrated project and the exploration of another culture. For some the challenge of overcoming a great number of difficulties stands as an important learning experience in itself. And yet some - fortunately very few - end up with a poor product and/or a poor experience.

Appropriate preparations for such field studies will certainly improve the chances of success in all fields.

Environment & Resources at the Technical University of Denmark, E&R DTU, have sent around 10-20 students per year on field studies in developing countries since 1989. The students are either on their 7-9th semester or doing the M.Sc. thesis work on 10th semester. All students are sent out for 3-5 months. Typically the M.Sc. project students work alone and the younger students work in groups of 2-4 persons.

Until 1997 all students went to Tanzania, most years within the frames of the same research collaboration project on drinking water treatment. In those years the students went out in a group that also lived together. From 1998 the students have been sent out to different countries without a common theme, under the broad umbrella of environmental studies and development.

The content of the field study for E&R students is a small research project or an investigation/assessment/evaluation having a substantial research component. Sometimes the students have a local supervisor in the country of the field study, e.g. at a local university, but at the end the project report is always evaluated (and most often finished after return) at DTU.

Students need to follow certain prerequisite course to be qualified to do field studies. First and foremost they should have followed relevant technical courses, e.g. "wastewater treatment" if the project is related to wastewater management. Furthermore the students follow 2-3 courses (25-45% of a full years study) specifically about working with technology, management and development. Finally, before going abroad the students prepare their field study in an intensive three weeks full time individual project. This preparatory study is finalized with a report that documents that the students are well prepared to go to field.

This paper looks into what is "good preparations" for doing a field study for the first time - or rather for students that are inexperienced with travelling in distant countries in the south.

Preparations at E&R DTU

Figure 1. Field work in Thailand

It is impossible to prepare for any situation that may arise during a field study. A main purpose of preparations is to get an understanding of the working conditions in the new environment and which approaches to problem solving can be used in that environment. Taking the three new "environments" from Ribeiro et al. (2002) and the fact that the students should do a high level scientific project in their own field, some of the issues that should be addressed in the preparations are:

- The scientific methods to be applied in their project. For engineering students they are often related to sampling, measuring, testing environmental technology etc. It is obvious that the students should have necessary theoretical and practical skills to work with the technical aspects of the project. This is in practise done through selection an overall topic in which the students have followed courses and through intensive specific preparations for the particular project in lab and in the library.
- But the projects mostly tend to have additional aspects to the technical that the students have been trained in using. It is e.g. often interesting for engineering students to work with institutional aspects and collect data via interviews or other participatory work with authorities, NGO's etc. These kind of "project" aspects are dealt with in three development courses at DTU, which most field students follow as preparations and through the individual intensive preparations.
- Working with supervision of people from the visited country with other traditions for supervision. Supervisors in many countries are often more authoritative than in Denmark and expect that students comply with their directions without much discussion. On the other hand the Danish students have often surprised the local supervisors positively with their rather good and independent working methods. It is dealt with through discussion of experiences from former field students.
- Working in a society with other norms, like clothing standards, precision in time can often cause stress situations, but seldom be changed. It is mentioned in many student evaluations that this aspect has been particular difficult (but also interesting and a learning experience). It is dealt with through practical group work with people from other cultures in the development courses.

The last point of preparations through group work on a development topic with people from other cultures is thought to be important and it is the main topic for this investigation.

Learning approaches in different cultures

Cultures are not simple to define because every individual are affected by different cultures at a given time. Every person belongs to macrocultures (Europeans) and smaller scale cultures like Danish or "Copenhageners" depending on the situation. On top of the geographically defined cultures comes the professional cultures (the engineers, the students) that may glue people together across boarders on some points. A pragmatic definition and overview of the subject is given by Gullestrup (2001).

Biggs (1999) reviews a number of studies of how non-English speaking countries experience and are perceived in universities in mainly England, Australia and USA. There are a number of prejudices regarding students from e.g. East Asia; from their home countries they are used to rote learning and lack critical thinking skills, they are passive, do not participate in discussions, they tend to stick together and see the teachers as definite authorities. Biggs argues and shows, referring to a number of investigations, that most of these prejudices are wrong. Most misperceptions are based on some foreign students lack of language skills and other social attitudes, but not a different way of learning.

Group work

A comprehensive and easy readable overview of group work and supervision of same is given in Christensen (2001). In a good group work the synergy between members means that the sum of the group performs better than the sum of the single members and that every member learns more than (s)he would by working alone. The good group work cannot be defined explicitly, but consists of many factors.

One is the working approach. In working life the purpose group/team-work is to create a good product. But at university the purpose is rather the process of acquiring knowledge and competence through the group work (Christensen 2001). This goal is more difficult to describe and for the single student it may seem rather diffuse. By experience we know that for some students the end product (report, presentation) seems to be the main goal, while others can live with knowing that they learn by going through the different phases and learning by the process. In a situation of different goals it is important for the success of a group work that the group members can build up a certain amount of responsibility for the group (Christensen 2001).

Another factor is the composition of group members; often a group works best if it consists of different personalities - e.g. optimised by the roles described by Belbin (2002), e.g. the Co-ordinator, the Implementer, the Teamworker and the Specialist. At least the members of the group should contain these qualities to a certain degree to have a successful collaboration and product.

The social side of group work may be important. Group members automatically build up internal social relations like being popular, accepted, bearable and outsider. And social positions like leader, helper or passive. It is an asset for the supervisor to have an idea of these relations in order to approach the group members the right way (Christensen 2001).

The social side can be more complicated if the group is a mixed culture group. Culturally some people are brought up in and are used to a very hierarchical structure while others are used to a more flat structure. Some are used to criticize and speak out very directly, while others find it annoying and rude and use to say things indirectly to keep good spirit and avoid loosing face.

Mixed culture group work

Volet and Ang (1998) have investigated aspects of group work between Asian students and the local students at a university in Australia. The general picture is that students tend to form a group with students from their own culture/country. The reasons mentioned were cultural-emotional connectedness, language, difference in time allocated for studies and negative stereotypes. Even though positive experiences came out of forcing students into mixed culture groups, both local and international students preferred "uni-cultural" groups again next time. They concluded that both local and international students need to be prepared and motivated for inter-cultural work, otherwise it will not work or happen.

METHODS

In this investigation 10 process reports have been reviewed from the course 12242 Environmental Management in the Tropics in the years 2001 and 2002. In the course students work in mixed culture groups and write a process report to document their working methods and problems experienced with the group work as part of their final deliveries. In 2001 the number of foreigners were low, so the groups had typically one foreigner and 4 Danes (6 groups in total). In 2002 the number of foreigners were far exceeding the Danes and the groups typically consisted of 5 different nationalities from all continents (8 groups in total). Both years the groups were forced to form mixed culture groups (but they voluntarily chose their group mates) because the course deals with international work and it is regarded as a purpose to learn to work together. In 2002 group formation was based on a game where each group had to be as mixed as much as possible with regards to ethnicity, sex and personality.

Eight Danish students that had followed the course were then interviewed using a questionnaire with ten open-ended questions (names are anonymized). The questions were concerned with what the students learned from working in a mixed-culture group, what differences they observed in working methods between cultures and how the teacher could support a successful learning result. Six of the eight students had after the course carried out a field study.

RESULTS AND DISCUSSION

From year 2001 practically the groups mentioned no cultural problems. Presumably the single foreigner was just outnumbered and followed the Danes' working methods. The quotes mentioned in the following text (Group X) are either from the process reports of 2002 or from the interviews conducted in this investigation unless other sources are mentioned.

It is important to realise that the interviewees were all Danes because of the purpose of the investigation. This is obviously giving ethnocentric answers.

On selecting group mates from your own culture

All the interviewees (who had participated in mixed-culture group work) had some kind of interest in learning about other cultures and practicing their English skills (Mikkel). More interesting was perhaps their reasons for still in most cases choosing Danish group mates - this is the same trend as was seen in Australia (Volet and Ang 1998). It is obvious that you identify students that you work well with and choose them again. A reason is thus to get better marks

> " you often learn more by working with foreigners, but get higher marks by working with Danes" (Birgitte)

Another important reason is to keep your social and study network since group work is the place you have close working relations.

> "(I) chose in general to work with Danes, simply because you can establish a longer term relationship with them" (Annika)
>
> " group work is also social relations and we would like to keep our relations to our Danish co-students rather than starting relations to those who leave Denmark soon." (Gurli and Bodil)

Today when the foreigners are actually more than the Danes on the environmental studies it can almost be like a defence mechanism

> " ... as a Dane you can sometimes feel like being outside!" (Gurli and Bodil)

Cultural differences

In 12242 one group has used a cultural group management tool to analyse the different cultures represented in the group (Group 7). They used the analysis to acknowledge that there were several potential problem areas in collaboration and thus set up some strict rules (mainly based on Danish group work behavior) for how to work in the group. Apart from shyness of some members they did not face any substantial intercultural problems.

Figure 2. Practical mixed-culture group work in a preparatory DTU course

Others have used the Belbin group analysis tool to identify roles of the single members in the group work.

Among the cultural problems identified are difficulties in discussing in equal terms. Some people find it difficult to participate in discussions because they "think" different from the rest, while others find it interesting to explore the different ways of looking at things (Group 3). Or put another way:

> " some people don't participate much in discussions or has a different way to participate in a discussion compared to Scandinavian style. (Annika)

Two groups (5 and 7) mentioned specifically the problem of shy or "high context" Thai people as a barrier to discussions in the group. "Culturally the biggest hurdle was the shyness of the two Thai members" (Group 5)

Punctuality at meetings is in some cases confirmed by the cultural prejudices:

> " Bad experiences of foreigners not attending meetings at agreed times are annoying." (Gurli and Bodil)

But the picture is not totally clear, the reasons may be many as for example:

> "Foreigners often take too many courses, which means that they don't spend the necessary time on group work."

Volet and Ang (1998) mention the opposite, that the local students are always busy with their family and friends while the foreigners have a lot of time for work. Although the interviewees do not mention it, this aspect also applies to Danish student.

For most groups the cultural barriers in 12242 were actually small if you consider the process reports. Two groups mentioned specifically:

> "As for this group the issues of culture should not be dealt with in this report, as they do not really constitute the problem of this report" (Group 1)
> "Globally, the relative importance of the cultural differences is small comparing to our own personality. (Group 2)

In the interviews with the Danes, a bit more clear views are given. One mention the difference in ways of expression, which is to some extent culturally determined:

> "His shouting and wild gestures was not everyone's cup of tea and actually deeply scarred our Thai colleague" (Morten)

Like in the Australian study (Volet and Ang 1998) some stereotypes are mentioned:

> " Asians (Thais and Pakistanis) as having difficulties in taking the initiative/action and Africans as being uncritical with data." (Birgitte)

It is presumably more relevant to be aware that more variation is found in an international group than to know exactly when a difference is culturally or personally determined.

Working methods
From the 12243 process reports the students saw only small differences:

> "No fundamental differences of working method were found between us" (Group 2)
> "Some of the group members have never made a problem formulation and it was quite hard to define our own problem formulation." (Group 8)

When interviewing the Danish students they could point at more differences. All students mention the foreigners' disabilities in working problem oriented, e.g.:

> " Most foreigners (excl. North Europeans and French) lack totally experience in problem oriented work." (Birgitte)

The Danish style direct expressions versus the more consensus seeking cultures are often mentioned, e.g.

> " Thais learn and discuss things in a very different manner than other people" (Mikkel)

In some cultures it is not usual to discuss with the teacher and he is often defining the problem to be worked with. This can cause frustrations among the Danes:

> "Some of my fellow students felt most comfortable when trying to follow the teachers directions very literally and was not used to trying to find their own way to the goal of a given assignment." (Morten)
> " Very authority believing cultures might be skeptical when another suggests to contact the local government themselves without involving the teacher and they can be

scared of a suggestion like this: I don't know if it is correct to do it like this, but let's try." (Morten)

Different educational backgrounds
In the process reports some are mentioning the different educational backgrounds the students have. This is because foreigners can be accepted on the international master programmes with a wide range of backgrounds, while almost all of the Danish students ar uniform because they have started from B.Sc. studies in DTU.

"The most important difference within the group comes from the background of each member. Some have a scientific (technical) background, while some ar more concerned by management" (Group 1)

It is mainly an advantage in a broad course like 12242:

" The very different backgrounds has been an advantage to us as we have been able to share many different experiences and opinions" (Group 6)

Language
Language is a problem from two sides; native English speakers can tend to speak too fast for others, while people from some other countries can be difficult to understand because of their accents (Group 5)

"the language skills are, from far, the most important aspects of working in a multiethnic group" (group 2)

Poor English skills of some students are causing extra work for the better ones, and the poorer ones are loosing sometimes e.g.

"(The Danes)... would also have to double as the ones reading the report through, looking for mistakes. And also quite often have to repeat whatever they just said many times....which can be quite frustrating." (Mikkel)
" the most serious problem of working with poor English-speakers that they are not included in some of the discussions because it is too time consuming." (Birgitte)

Some English problems are also culturally determined:

"We had big problems with understanding each other as the same words meant something different in each persons mind." (Group 3)
" A simple example is the question: You did not kill your sister yesterday? I would answer: "No" while the Thai would answer: "Yes" though we both meant the same: we did not kill anyone yesterday." (Morten)

Learning from the others
Despite many troubles all interviewees express that they learn something from working in mixed culture groups. Although difficult to expess, on the personal level a lot can be assimilated regarding ways of looking at things and understanding of other peoples thinking and views:

Figure 3. Field work in Malaysia

"I learned a lot from a Chinese, a Palestinian and a Pakistani, but not as much from Europeans and Americans, as the culture difference are smaller." (Annika)

Some examples are:

" more mixed ideas and focus areas....sometimes the ways thing are understood is different adding a more wide perspective." (Mikkel)
" During the course I've learned a lot of patience and a lot about negotiating in a foreign language across different cultures." (Morten)
" And Patience is really important, it is sometimes necessary to go out and scream..." (Mikkel)

Even the difficulties with carrying out the group work can result in better and particularly deeper learning. Because the foreigners lack project work experience

"...(the Dane) is forced to argue and be critical a lot about the working methods. In this way the Dane learn more than working with other Danes" (Birgitte)

And at the bottom-line it is perhaps worth it for a simple reason:

" Besides, lets face it, it can be a LOT of fun" (Mikkel)

How can a mixed culture group work be supported?
It is the experience from Australia (Volet and Ang 1998), which is supported from several interviews here, that the mixed-culture group work provide both satisfaction and good learning experiences, but also negative in a way that seems to scare some students from repeating the experience. E.g. expressed in:

"To put in a nutshell, working in a multicultural group is a great opportunity to overcome our prejudice and to learn how close we are to each other. Nevertheless, it can be extremely time consuming due to lack of understanding" (Group 2)

It is thus important to look into how the group work can be supported by the teacher, resulting in an overall good experience and positive synergy in the learning. These conclusions apply mostly to the situations where foreigners outnumber the Danes.

The formation of groups will not result in mixed-culture groups if it is left to the students themselves. This may in some cases be all right, but if the wish is to have the international touch for the students, some actions may support a positive outcome.

Figure 4. Field work in South Africa

It seems important to establish a positive atmosphere around the group formation and let the students get a chance to know their group mates before they have to choose.

> " For project work it is important to get a chance to get to know your group mates before choosing them. Social activities are always good." (Gurli and Bodil)
> " A good group process is supported by a dynamic group forming process, where the students get to know each other." (Birgitte)

A small social game where the students get to talk to many of the others have been successfull in this in courses 12242 and 12210. Every week a new group for discussing subjects in the beginning of the course (as in 12333 and 12240) is also positive. Social activities like a course party or visits to the basement bar after classes are also mentioned as positive in getting to know each other and overcome cultural barriers. This will make the quiet persons speaking more out in group work.

More generally teachers could try to include more "light" and funny issues in the group sessions as it may improve the "serious" part as well:

> " Having fun always makes the group better at the serious and therefore it is always preferably if there is some initiatives from the teachers to use the short time it takes to make the groups having fun!" (Morten)

The busy schedules of all students makes it often difficult for students to find time for group work outside classes. It supports the group work if time is allocated within the teaching hours.

It seems like there is a need for introducing international students to problem-oriented work in a more deductive way, since it is considered such a nuisance by the Danish students. It may perhaps most rationally be done case-based in the introduction of the course, as part of the "normal" teaching. It could also be a special program for all foreign students in the week before semester start.

Although the students interviewed did not put much emphasis on this, it is the authors experience that writing process reports can induce a focus in the mixed-culture groups on the functioning of the group and each members role in attaining a good result. More experience in how to use this type of report can presumably be gained from e.g. Aalborg University, where it is an important tool in learning.

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Learning By Knowledge Networking Across Cultures - The Experience Of Joint Courses In Environmental Studies For Malaysian And Danish Engineering And Science Students

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ABSTRACT: Engineers and planners working in trans-national production and aid project interventions in Third World countries must be able to 're-invent' technological systems across cultures and plan and build capacities of their counterparts. A series of joint courses on cleaner production (CP) and environmental impact assessment (EIA) in Malaysia 1998-2003 has sought to address these needs for new competences. Differences in educational background and work culture of the participants have presented difficulties during these courses, in particular in terms of achieving a mixed team building to turn some of the obstacles into resources for knowledge sharing. However, students have stressed their positive experience of cross-cultural communication. While a joint course of three-week duration by itself may involve only limited cross-cultural learning, serving primarily as an introduction to a long-term field study, the course efficiently initiates the 'embedding' of the students into and their interaction with the socio-political and cultural context of the host country. Thus, learning across cultures requires a longer term process whereby mixed teams leave the class room, collect data together in the field, negotiate and agree on the analysis, and sustain the exchange of knowledge, possibly through virtual peer-to-peer networking.

Keywords: Global learning, cross-cultural, environmental studies

INTRODUCTION

As part of the Danish University Consortium for Environment and Development, Industry & Urban Areas (DUCED, I&UA) Project, a series of joint courses on cleaner production (CP) and environmental impact assessment (EIA) has been conducted in Malaysia 1998-2003 in cooperation with the Malaysian University Consortium for Environment & Development, Industry & Urban Areas (MUCED, I&UA). Both consortia projects have received financial support from The Danish Co-operation for Environment and Development, Ministry of Environment and Energy (DANCED), which have sponsored similar university consortia in Thailand and South Africa. In December 2001, DANCED was absorbed into the Danish International Development Assistance, Ministry of Foreign Affairs (DANIDA) due to a change of government.

The overall objective of the initial Danish university consortium project was to increase the capacity and competence in the Danish education and research resource base for the Danish Environmental Assistance in DANCED target cooperation countries. Its main components are a) curriculum development in environmental studies at Master's level, including development of new course modules and upgrading of existing modules; b) staff exchange, including joint development of case studies for course materials and co-teaching c) student exchange, including joint courses; and d) the formation of cross-consortia research networks on environmental problems of mutual interest. Key priorities are the promotion of inter-disciplinary perspectives in environmental studies and problem-based learning.

'SCAN GLOBALLY - REINVENT LOCALLY'

Since colonial times, Danish engineers have worked overseas in infrastructure development, construction, and production. The building of railways in Siam was one of the early efforts. In Dutch East India, Danish engineers were extensively involved in construction and sugar refining. The technology of producing cement has been transferred to numerous facilities. Also the development of telecommunication e.g., in China and Japan, came about with the assistance of Danish engineers. During the post-war period, Danish consultancies and suppliers obtained major contracts with government funded technical cooperation projects in the newly independent, developing countries.

Reviewing the experience of early technology transfer, a recent UNDP report (Fukuda Parr et al. 2002) has summarized the adverse impact of development pursued through displacement. It advocates an alternative paradigm giving the central role to capacity development in the host country at three levels by:

- enabling individuals to embark on a continuous process of learning - building on existing knowledge and skills;
- seeking out existing institutions, however nascent, and encouraging these to grow - building on their current capacities;
- strengthening capacities in the society as a whole, e.g. by creating opportunities to enable trained people to use and expand their skills in stead of joining the brain-drain.

Rather than providing a foreign blueprint, this paradigm implies that knowledge acquisition and institutional innovations for capacity building are initiated as a process of development as pursued by transformation. The commitment and ownership of the agency in the host country is in focus, as available knowledge and technologies are sought, selected, analysed, modified, disassembled and recombined to fit local needs: 'Scan globally - reinvent locally'!

Targeting middle-income countries, DANCED gave emphasis to capacity building rather than supply of equipment. The concept of capacity building was initially defined simply as a departure from conventional training schemes for human resource development. In a more elaborate version (DANCED 2000), the agency draws a distinction between organisational and institutional capacity. In adopting these concepts of capacity building, project planners and project staff in a DANCED project are challenged to implement an extensive participatory approach, which can produce a thorough and precise analysis of the key stakeholders.

COMPETENCES IN CAPACITY DEVELOPMENT

In 1996, DANCED commissioned an analysis of the Danish resource base of the advisory component for its environmental aid projects (Danmarks Teknologiske Institut 1996). The report identified three areas of competences:

1. Technical-professional qualifications, including relevant education with a sufficiently broad scope to address environmental problems;
2. 'Soft' competences, including team-building and management, process-oriented, inter-sector working methods, intercultural communication and understanding, and popular participation;
3. Knowledge about language and culture of the host country.

The report concludes that 'soft' competences needs to be given a much higher priority in the educational development of the Danish resource base, while the technical-professional competences should not be downgraded but more precisely targeted. The then Director of DANCED, Mr. Mogens Dyhr Nielsen, further specified the requirements for key expatriate personnel in DANCED projects during a DANIDA/DANCED workshop on Capacity Development in Environment (CDE) in 1998 (Dyhr-Nielsen 1998). A shortage of personnel with a “softer” skills profile pointed to the need of expanding the Danish resource base. This need formed a basic rationale for supporting Danish university consortia to upgrade their Master programmes in environmental studies.

THE CONCEPT OF JOINT COURSES

The joint courses were developed as a new core component available to Master students of the DUCED universities. Initially, they were inspired by the experience of field stations established by natural science departments, and accordingly termed 'field courses'. Bringing Danish student to the working context of expatriate facilitators, the courses would respond to the need for 'soft' competences of Danish resource base.

This objective remains. However, the joint courses held in Thailand, Malaysia, South Africa and Botswana, with fifty-fifty participation of host and visiting students, have additional aims. Apart from being a mechanism for introducing an intercultural dimension in education for both students/tutors of the consortia, the courses are envisaged as a means to introduce improved teaching techniques, inter-disciplinary and problem/oriented approaches. Today, students within various disciplines from Denmark (this includes students from various nationalities studying in Denmark) work together with students from Thailand, Malaysia, South Africa, or Botswana. They are open for Master students who are aiming at a Certificate as Intensively Trained Master in Environmental Studies. For DUCED students, this involves a field study of minimum three months duration (DUCED, I&UA 2003). Subsequently, further objectives have been specified:

- Joint courses should be integrated into the DUCED Certificate Program as well as into the Master programs of the partner consortia in order to support the curriculum development in all consortia.
- The partner consortia should be able to conduct joint courses as a long term, sustainable activity after the project period.
- In terms of content, the course topics should focus on those environmental issues, which are given priority in the DANCED country programs. The aim is to position them as a third 'column' of capacity next to the government and the private sector, and followed by non-governmental organizations (NGOs). The consortia research networks are the main resource in this effort.
- As joint courses become part of the Master programs of the partner consortia, they can also be offered as specialized, continued education for professionals in industry, the private sector, government, NGOs and DANCED supported projects.

The DANCED/DANIDA funding of the university consortia will come to an end in 2003. However, alternative funding currently is being sourced for the joint courses and the scholarships for long-term field studies.

PLANNING FOR CROSS-CULTURAL LEARNING

The topic of the most recent joint course conducted in Malaysia in January 2003 was 'Environmental Impact Assessment (EIA) and Public Participation'. During the planning, the following course objectives were defined:

- To develop an understanding of conditions, methods, processes and outcome of stakeholders' involvement in planning and policy-making related to the Environment Impact Assess of a particular development project
- To study case illustrations of recent EIA studies conducted in Malaysia, in particular with regard to the methodologies adopted
- To exchange experiences on environmental regulation and environmental awareness in relation to the policy cultures of Malaysia, Denmark and other countries

- To provide a forum of inter-cultural dialogue between Malaysian and Danish Master students exploring, among other things, approaches to study, life on campus and improvement of the environment.

The theme of the course provides an illustrative example on perspectives and problems in utilising European experiences in an Asian context. Denmark has a long tradition with public participation in the environmental policy and a decade of experience with public participation in EIA, whereas the experiences with public participation in environmental policy and EIA in the Malaysian context are rather limited (Stærdahl et al. 2003). Thus, focusing on public participation EIA in Malaysia provides an opportunity to consider whether more public participation would be beneficial in the Malaysian context, and how it could be integrated into the and existing institutions taking the Malaysian cultural and political tradition and present situation into account. For the Malaysian students it provides a good case for considering whether foreign experiences are useful – and how. For the European students it provides a good case for reinventing European experiences in the Malaysian context.

The course consists of two parts: a one week lecture program in class – interrupted by a few field excursions - and a two week study in the field by mixed MUCED-DUCED groups, each focusing on one selected case study. The course is concluded by a full day evaluation seminar, as the written report of each group is presented and discussed during a one hour session. Planning the lecture program is done through e-mail exchanges between the Danish and Malaysian organizers. From the Danish point of view, one key problem is to secure relevance and coherence, as Malaysian guest lectures are scheduled in the program. Their inclusion is made by recommendation, and seldom based on a previous, joint experience. The preparation of case studies for the group work – the key component in facilitating Problem-Based-Learning (PBL) – has met several challenges, as the organizers have struggled to clarify problem focus, availability of documents, and supervision arrangements through e-mail exchanges.

During the first week of the course, team building exercises and the group formation are initiated. Those DUCED participants, for whom the joint course is the first phase in a long term field study, have already formed groups. However, during the course they are expected to split and join the mixed groups. These groups may express doubts about the benefit of splitting up and pursuing case study topics, which do not directly contribute to their long term field project. This scepticism and hesitation about their 'counterparts' tends to wear off, as they start to mingle and participate in the intercultural games during the first week, which concludes with a joint social excursion.

THE STUDENTS EVALUATION OF THE COURSE

Evaluations were conducted twice during the course. Upon completion of the plenary programme after the first week the students were asked to rate around 20 different aspects of the course ranging from relevance of the objectives of the course programme to quality of quality of food and accommodation. On a scale from 1 to 5 the average score was 3.4 (between 'satisfactory' and 'very satisfactory'). One of the highest scores was on relevance of the objectives scoring 4 ('very satisfactory') and the lowest was the rating of the accommodation scoring 2.4 (between 'fairly satisfactory' and 'satisfactory'). Overall the MUCED students were slightly more satisfied than the DUCED students (a difference on 0.4). At end of the course the students were asked once again to evaluate the course. They were asked to rate some aspects of the outcome of the course (table 1) and in a number of open questions asked about how the course could be improved and what had been especially beneficial for them.

Table 1: *Course participants' rating of the three weeks joint course*

	All	*MUCED*	*DUCED*
1. Has the course given you a better understanding of community participation in environmental policy in Malaysia?	4,0	4,0	4,0
2. Have you learned new concepts and methods?	3,3	3,8	2,9
3). Overall, did the course meet your expectations?	3,5	3,7	3,3
4) Do you think you have become better in communicating across cultures?	3,7	3,8	3,6

The scale is from 1 to five (5 is 'Yes, very much' and 1 is 'No, not at all'). N is 27, 13 MUCED students and 14 DUCED students.

Table 1 shows that the in terms of improving the students understanding of public participation and EIA in Malaysia the course scores quite high with 4 ('Yes, quite a lot'). When it comes to learning new methods and concepts (question 2)) the MUCED participants score higher that the DUCED students, whereas both groups find that they have become better in communication across cultures (question 4).

The students were also asked open-ended questions about the course. One of the questions were "Please indicate what have been the most positive elements or benefits from the course?" 26 statements were given as response to this question. The statements have been categorised after content in three categories: 'cross-cultural experience', 'public participation, EIA and environment' and finally 'others'. Some of the statements contains several elements, thus altogether 31 categorisations were made. 15 elements were categorised as related to cross cultural experience. For example one of the MUCED students answered "Meet new people, new experience. Get to know Danish kind of work" and one of the DUCED students answered "Learn about the Malaysian culture and work with people from another culture". 8 elements were categorised as related to public participation, EIA and environment, for example one of the MUCED students answered "Exposure to public participation in EIA report", and 8 elements answers were in relation to other issues for example “encouragement to speak more in English and to voice out openly”.

The most striking thing about the evaluations is the importance the students ascribe to the cross-cultural experience. The students find the objectives of the course relevant, and they find that the objectives have been reached. But when they are asked to formulate in their own words what has been most beneficial for them, a huge number of the students emphasise the experience of working in a cross-cultural setting.

THE SUCCESS AND LIMITATIONS OF JOINT COURSES

In 1996, Walker, Bridges and Chan reported on their experiment to introduce PBL at the Chinese University of Hong Kong that the first tension they met was the notion among Chinese students that the teacher is the “wise person”, or the giver of wisdom. PBL is the antithesis: learning must be discovered by the participants. The social values in group work interaction presented another challenge. Conflict avoidance, reliance on high status third parties to resolve conflicts, culturally sanctioned deference to group members with high status, inhibited the discussions on definition of the focal problem. There was a feeling of “being lost at sea”. Nonetheless, the group work process was completed and at the time of presentation the groups all appeared confident and proud of their achievement. Walker and his colleagues asked the question: Would PBL produce a similar learning process and outcome in a non-Western culture as reported in the West? Their study did not offer a full answer.

The experiences from the group work during MUCED-DUCED joint courses are in many ways similar to those achieved at the Chinese University of Hong Kong. We cannot claim a more definite result. However, we will try to elaborate Walker’s question and offer some suggestions for developing cross-cultural learning programs.

The statements of the long term DUCED students during the course evaluation give positive emphasis to the quick overview to Malaysian economy, culture and politics and the effective introduction to useful contacts. They feel that the intercultural experience and the logistic support have saved time and trouble and given them a push forward in the field work. Looking at the combined feedback, there is no doubt that participants and organizers have gained valuable experiences in cross-cultural communication.

Also, the DUCED students have experienced that attitudes toward and procedures in relation to environmental problems can be rather different from those they were familiar with from their home country. The MUCED students on their part have become acquainted with theories, methods and practices attached to critical environmental research, which beside the introduction to specific planning tools might have raised their environmental consciousness.

Assessing the joint course experience, we need a concept of learning, which differs from a functionalist view of simple acquisition of knowledge transmitted by others. While this notion may apply to the collecting of factual information prior to going to the field, it is definitely inadequate in capturing the learning process as a new context and its problems are encountered and being interpreted.

Rather, a dialectical view of learning as the combined assimilation and transformation (Rasmussen 1998), by which new learning is built on existing knowledge, is relevant. In a layer between the known and unknown, new knowledge is related to something, with which the students are already familiar. They differentiate, generalize, use analogies, and break away from what they already know, in the effort to come to terms with a new environment of experiences. Working in the field, the exposure induces learning, which goes beyond what most of the formal lecture program is able to convey.
The concept of situated learning by Lave and Wenger (applied by Ribeiro et al. in their discussion on field work) gives emphasis to the context dependency of learning. The learner moves from legitimate peripheral to full participation in a community of practitioners. Crossing cultures in this process adds to the complexity and challenge. "Culture shock" refers to the phenomenon of loosing orientation, as a person's scheme of interpretation becomes obsolete in a foreign environment.

For some DUCED students, it was a shock to discover that Malaysian civil servants deliberately try to hide facts and critical issues. The students may be used to reluctant or non-informative answers from public authorities. However, the outright cover up of what they felt should be transparent as a matter of public interest definitely did shake them. In this example, the DUCED students may have acquired extensive knowledge about Malaysian economy, society and culture. However, only the encounter with a particular practice triggered their reflections about the implications of a different socio-political regime.

The DUCED students have to interact simultaneously with a range of different contexts including:
- The national cultures of everyday life
- Stakeholder representatives in public authorities, the private sector, and in community-based organizations, each having different objectives, interests and resources
- The university institution and its staff and students (adapted from Ribeiro et al.)

In each of these encounters they are challenged to rethink their original perceptions. To what extent does this process develop into inter-cultural learning, whereby original notions are transcended, the initial amazement is substituted by a penetration of the new context, and schemes of interpretation are re-invented? In our opinion, this depends upon the guidance and clues, which the MUCED students and staff can provide.

Another example illustrates this point. Towards the end of the latest joint course, DUCED staff raised the question: Are the ways we are handling the problems in the West the only and the most efficient way in a Malaysian context. In Denmark, students traditionally develop a critical confronting environmental attitude discussing environment and technological innovations. The MUCED students most often are proud of the technological innovations of their country, and consider that environmental problems should be solved via co-operation between the actors in the field. They do not see the confronting attitude as the most efficient. It does not fit in to the traditional conflict solving culture; hence it can counteract positive dialogue. On the other hand, Danish experiences tells that environmental planning is an issue embedded in contrasting interests, and prioritizing between the environment and economy is not only a technical issue but also a highly political one.

To move beyond this contradiction, extensive dialoguing between MUCED and DUCED staff and students is needed. The DUCED "side" tends to interpret the non-confrontational approach as a lack of understanding of underlying conflicting interests. MUCED on its part may be taken aback by the lack of sensitivity and rudeness displayed by their DUCED counterparts.

The students interact extensively as they live together on campus and work in the mixed groups. Does this involve a process of enculturation facilitating inter-cultural learning beyond the initial "shock", whereby concepts and theoretical framework are being shared? At this point, our claim is that the exposure facilitates an inter-cultural training experience which initiates the 'embedding' of DUCED students into the socio-political and cultural context. As such, it serves as an introduction to their long-term field study.

MUCED staff has repeatedly requested that joint courses should be conducted in Denmark - as an alternative to the conventional consortia student exchange program. They argue that MUCED students will benefit from exposure to the Danish atmosphere and work ethics, i.e. if a structured study program has been prepared, the objective of which is more than just learning a new technique. Thus, there is a shared interest of both parties to take further steps towards inter-cultural learning.

We feel that the bonding among the mixed group of students, their social involvement in the issues being studied, and the reunion activities - which they organised on their own initiative after the conclusion of the joint course, provide a key driving force, from which the dynamics in a vision of inter-cultural knowledge networking may be drawn.

INTER-CULTURAL KNOWLEDGE NETWORKING

So far, the definition of course topic, the lecture programming and the focusing the case studies are being prepared by the staff at the initiative of DUCED. The first step in a vision for inter-cultural learning program would be an early formulation of the key problems to be addressed in the case studies for group work. This should be developed as a truly joint effort, which reflects current concerns and issues in both countries, allowing comparative perspectives to be included. A second step would be a particular effort trying to 'synchronize' the problem areas addressed in the longer term projects being planned or conducted by the participating students from both MUCED and DUCED. The third step would be the joint course itself, now giving emphasis to bringing the students on par in terms of theoretical framework and methodological approach, as contributions from MUCED and DUCED are presented and discussed. The shared problem areas and exchange of analytical procedures could allow a fourth step: a continuation of joint field work after the conclusion of the joint course, as MUCED and DUCED students engage in long term projects in mixed groups. Obviously, a number of practicalities has to be overcome in terms of timing, resources and credit transfer.

To strengthen the component of peer-to-peer learning in the students' interaction, which runs through the whole process, we suggest to develop a continued, decentralized networking facility. This would serve as the basic and transparent format for student and staff activities from initial contact, throughout the planning and implementation stages, to the resulting knowledge networking. The networking in face-to–face relations and in a virtual format must be fully integrated to support each other.

CONCLUSION

We have presented the origin and experiences of a series of joint courses. It has been the aim of these courses to depart from the traditional conception of knowledge transfer implying that developed countries shall 'teach' the developing countries how to do things in the right way. Of course, Denmark has a long-standing experience with environmental problems and planning which is relevant to hand over to new industrialised countries such as Malaysia, which within a few years will face serious environmental problems unless a proactive environmental planning concept is implemented. However, knowledge sharing is the overall objective of the joint courses. If a common understanding should be constructed, and the Danish participants should not return with the prejudice that 'the Malaysian must learn to do it in the right way', it is of decisive importance the opportunities to develop courses of long duration both for Danish students in Malaysia and Malaysian students in Denmark are maintained. In this way, the valuable experiences gained will not be lost but further developed.

We have asked the question: Are East and West learning from each other or are we only learning to communicate with each other? The first answer is that we might have missed much if we hadn't tried. The second answer is: While a joint course of three week duration by itself may involve only limited cross-cultural learning, serving primarily as an introduction to a long-term field study, the course efficiently initiates the 'embedding' of the students into and their interaction with the socio-political and cultural context of the host country. Thus, learning across cultures requires a longer term process whereby mixed teams leave the class room, collect data together in the field, negotiate and agree on the analysis, and sustain the exchange of knowledge, possibly through virtual peer-to-peer networking. And the third and final answer is that these critical self-reflections need to be carried forward in a long-term, sustained co-operation between supervisors from the different countries exploring the options for technology enhanced, peer-to-peer learning networks so that conventional course delivery can be effectively replaced.

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The Experiences In Joint Course Development For An Inter-University Environmental Programme

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ABSTRACT: This paper describes the experiences and approaches undertaken in attempting to include project-based and problem oriented learning within the courses of several existing environmental engineering graduate programmes found at four universities in Malaysia. The details in implementing one such course in respect to co-teaching, and its evaluation by the students are discussed.

Keywords: Environmental education, environmental geotechniques, programme and course development

INTRODUCTION

The environmental impact of engineering work needs to be given more emphasis than it currently receives. The effect of rapid development on the physical environment can mean irretrievable damage, which the country may later come to regret bitterly. Under the pressures of economic survival and growth, developing countries in general are less caring for their environmental heritage – e.g. their forests, fauna, marine life, clean air and unpolluted waters and soil - than the developed countries have become. It can be found that in most graduate courses, much more attention is given to the analyses of engineering problems rather than to synthesis. What is really needed is to develop the students' ability to think clearly, to express unfamiliar problems in their essential elements and to encourage their powers of synthesis and imagination. It is only too easy to tell the students, to pump information into them and not so easy to bring them out, to encourage them to contribute to the educational process. Real engineering, however, contains at least as much practice as theory, and success in it also depends on the art of dealing with and getting on with people, and on an understanding of the socio-economic and environmental factors that are hardly touched on in most engineering or applied science courses (Yong et al, 1986). In short, how students are taught appears to be more important than what they are taught**.**

Given the foregoing discussion, a brave attempt is made in Malaysia to point to new directions in the environmental education of the professions at the graduate level. MUCED-I&UA* was formally operational in August 2000 although work to initiate a collaborative project in the field of environment had started in the mid-nineties. The project to formulate a common programme and courses at postgraduate level between four participating Malaysian universities i.e. UPM, UTM, UM and UKM, was proposed. The project is geared towards the improvement and integration of education and research in environmental management and technology in urban areas and industry. Key priorities are the promotion of multidisciplinary approaches and in environmental studies and problem/project based learning (PBL).

The formal structure adopted is a first collaborative effort amongst the four participating Malaysian universities in the consortium. In such an endeavour, MUCED-I&UA is aided by the wealth of experience to be found within their Danish counterparts in DUCED-I&UA.

PROGRAMME DEVELOPMENT

Malaysian universities are offering programmes in all fields relevant to sustainable environmental management. Each of the participating university has a postgraduate programme anchored to different disciplines; from engineering and technology to economics. However, the teaching found in these programmmes is by discipline whereas sustainable development requires multidisciplinary skills and interdisciplinary approaches. Given that existing programmes are already in place, it was decided that twelve selected courses be either developed or enhanced and incorporated into the existing master programmes in the four universities. The involvement of other stakeholders from industry and NGOs, such as Alam Flora, IWK and WWF, were emphasised. Their input ensured that the courses developed take cognizance of the current needs of the industry and society. Further inputs from their Danish counterparts were solicited through visits of course developers to Danish universities to study the content and conduct of related courses. Members went to respective host universities, such as AAU, DTU and RUC to study the Danish PBL model. The PBL approach in Denmark varies between universities such that RUC's approach is very much a student driven menu, the AAU model is the in-between and DTU is the other extreme, i.e. more theoretical than PBL. The observations were disseminated through workshops as the course modules were being developed.

* A list of acronyms used in this paper is presented in Appendix A.

The twelve courses selected are:

1. Environmental Management
2. Water pollution Control
3. Environmental Monitoring and Assessment
4. Solid and Hazardous Waste Management
5. Air Pollution
6. Cleaner Technology
7. Environmental Economics
8. Environmental Geotechniques
9. Environmental Health and Safety
10. Environmental Impact Assessment
11. Environmental Modeling
12. Environmental Technology and Design

Credit transfer mechanism allows students registered at a particular university to undertake some courses at the other participating universities and carry the credit for graduation. As such there would be cross-fertilisation and also the sharing of resources among consortium members. Instead of being competitors the consortium acts as a single unified body that provides the opportunity for students to obtain their environmental education at its optimum condition and for the realisation of the multidisciplinary approach. This is possible since the consortium comprises expertise of various disciplines ranging from the arts and social sciences to engineering. As for the engineering programmes, the incorporation of non-engineering courses enhances the overall skills and competencies of its graduates as in reality problem solving do involve non-engineering solutions. Further details on the various aspects of the programme development have been elucidated by Azlan et al (2003).

COURSE DEVELOPMENT AND IMPLEMENTATION IN ENVIRONMENTAL GEOTECHNIQUES

Course developers for the Environmental Geotechniques Group consist of two members from UM, two from UPM, and one from UTM. The group members have a background in Geotechnical, Geoenvironmental and Groundwater Engineering, and Engineering Geology. The topics covered in this course range from the mineralogical and geological aspects right up to the fate of contaminants and methods employed for containment and remediation in the ground. As the deadline approaches, the contents of the syllabus were often altered from its initial form to take into account overlaps and shortcomings. Within the time constraint of a 15-week semester, it was decided that the course would be regarded as a primer and thus would cover breadth rather than depth of the agreed topics. On this basis, the final contents of the course module is as shown in Appendix B. For guidance to the instructors, an outline of each main topic is provided. A typical topic outline as found at the beginning of each topic in the module is shown in Figure 1.

In the March Semester of 2003, the course was conducted at UM for the first time. The March Semester occurs over the long vacation break between the normal semesters found in an academic year. Unlike the normal semesters, the course duration is 7 instead of 15 weeks. It was conducted wholly by the main author who hails from UPM. The co-teaching of the course allowed for further networking and the sharing of resources amongst consortium members. Due to the short duration and taking into account the intense workload subjected upon the students (they normally carry two other 3 credit courses), it was decided that a qualitative rather than quantitative approach should be emphasized. In addition, at UM the course is opened to all engineering students and is pegged at an advanced standing undergraduate elective. However, graduate students can gain credit from it for graduation. The total enrolment was 18 undergraduate students, 14 having a background in Civil Engineering, 2 in Engineering Science, and 1 each from Manufacturing and Computer Engineering.

Chapter 3: Groundwater Flow and Contaminant Transport (12 hours)

Objective:	Lecture Topics:
To introduce the basic principles involved in governing ground water flow and solute transport, and examine the models available for prediction and analysis, including an introduction to computer models. Learning assessment: Assignments and a final examination on topics covered in this chapter.	3.1 Introduction 3.2 Groundwater motion 3.3 Groundwater flow modeling 3.4 Groundwater quality

Notes: Chapter 3: pp. 47-111
Slides: No. 3.1-3.40

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Figure 1: A typical topic outline of a chapter in the environmental geotechniques course module (Azlan et al, 2003).

In the conduct of the course, much use is made of the course module that has been developed. The slides were used during the instruction class. Due to the syllabus requirements at UM, the topics covered during the course varied from the content of Appendix B by about 30%. At the end of each topic, quantitative exercises utilizing as much as is possible real data are included to strengthen student's comprehension. The two local and one international case studies developed, one of which include socio-economic aspects, were presented during and towards the end of the course. Here, questions for discussion are posed and participation from the students is required. Accordingly, their contribution results in marks apportioned individually.

Other forms of assessment include the typical final examinations (which at UM the norm is 60% of the total marks) and a term-paper due on the last day of the course. The term paper required the students to choose a topic title related to the course. The student is required to explore in depth a topic of special concern. In addition, a detailed account of one or more actual case studies dealing with a particular problem is to be included in the term paper. A tentative topic title and one paragraph abstract are required for approval one week before the final submission. On the day of submission, the students are required to do a short presentation of their work and copies of their term papers are provided to the rest of the class for review. Additionally, in the course of the presentation, the students are impressed upon that the solution to environmentally related problems require a multidisciplinary approach. The most economical and/or the most advanced technology may not necessarily be the 'best' solution when considering the different aspects of the problem. 20% of the total marks are attributed to the term paper.

The conduct of the course over at UM provided the opportunity for the course and the teaching methods employed to be assessed. Only 16 students responded in the questionnaire distributed for student's feedback on the last day of the course. One student however responded in a manner that rendered the analysis of the questionnaire futile. Appendix C shows the format of the questionnaire. For the purpose of this paper, only sections II and III, which have direct relevance, will be discussed in detail. The students were asked to rate on some aspects of the course and teaching methods in the respective sections. The scale employed range from 1 ('disagree completely') to 5 ('agree completely'). Table 1 shows the average values of all respondents to the statements posed in section II and III.

Table 1 indicates that in terms of the teaching methods employed, the course scores quite high. The students appear to benefit from fewer straight lectures and more two-way activity; like the discussion classes, and the assignments in which the students had to find out things for themselves, and/or having strong links throughout with the life of the community and its engineering problems. However, similar rating cannot be found with respect to the assessment of the course, although overall, the respondents agreed that the course is good. They found that the course is not that easy to follow (statement 6 scoring an average scale of 3.2) and that reference material to be inadequate (statement 7 scoring an average scale of 3.3). This could be due the breadth and multi-disciplinary approach of the topics covered in the course. The students were sometimes required to find unfamiliar reference material as compared to their other engineering courses.

One student consistently responded in the negative to the statements posed in section II and III i.e. either scale 1 or 2. On reviewing the personal details of the student in section I, he is found to repeat the course, having taken a similar course and failed previously in the normal semesters. The conduct of the course appears not to stimulate his interest nor make him want to pursue it further. Open-ended questions in Section V soliciting comments remained unanswered. The responses from this student although included towards the average values of the scale in Table 1 were considered an outlier. Perhaps, for the student, this being his final semester, only want to graduate.

The analysis of the above questionnaire can only be regarded as preliminary. At the present time, the approach to teaching is conceived as more of project-oriented instruction rather than truly problem based. The course is at various stages of operations or academic approval at UPM and UTM. With full implementation, more data of students' response will be made available for analysis and for further improvement to be made on the course.

Table 1 : Students' rating of the course and teaching methods

Statement No.	Average Values Of Scale[a]
II. Course Assessment	
5	3.5
6	3.2
7	3.3
8	3.9
III. Teaching Assessment	
9	3.7
10	4.4
11	4.2
12	4.2
13	3.7
14	4.3
15	4.3
16	4.5

[a] Scale: 1 (disagree completely), 2 (disagree), 3 (disagree slightly), 4 (agree), 5 (agree completely)

CONCLUDING REMARKS

The MUCED-I&UA Environmental Engineering programme as currently envisaged is somewhat similar to that found at DTU. The courses are not organized under themes as in AAU and RUC. There is flexibility in the programme through transfer credit mechanism between participating universities. The developed and/or enhanced courses are organized as a separate entity although continuity, multi and inter disciplinary approaches to problem solving are considered. These courses are assessed separately. As seen in the implementation of one such course, the PBL approach is expected from the individual mini-projects assigned. Students are expected to draw the knowledge from the attended course or seek additional knowledge separately to solve the problem. Assessments made by the students indicate the good response on the PBL approach. More data is required to make further improvements on the scope of the course content.

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APPENDIX A: LIST OF ACRONYMS

The following are the main acronyms used in the paper:

AAU	Aalborg University
DANCED	Danish Cooperation for Environment and Development
DTU	Technical University of Denmark
DUCED-I&UA	Danish University Consortium for Environment and Development - Industry and Urban Areas
IWK	Indah Water Konsortium
MUCED-I&UA	Malaysian University Consortium for Environment and Development – Industry and Urban Areas
NGO	Non Governmental Organisations
PBL	Problem/project Based Learning
RUC	Roskilde University
UM	Universiti Malaya
UPM	Universiti Putra Malaysia
UTM	Universiti Teknologi Malaysia
UKM	Universiti Kebangsaan Malaysia
WWF	World Wildlife Fund

APPENDIX B: CONTENTS OF THE ENVIRONMENTAL GEOTECHNIQUES COURSE MODULE

Chapter 1 Geoenvironmental Problems and Regulations
Lecture: 2 hours

Lecture Topics

1.1 Geoenvironmental and contaminated land
1.2 Soil contamination
1.3 The problem and its investigation
1.4 Geoenvironmental and contamination problems in Malaysia
1.5 Risk assessment and management
1.6 Remediation standards and regulation

Slides

Chapter 2 Environmental Geology
Lecture: 6 hours

Lecture Topics

2.1 Brief review of geological fundamentals
2.2 Rock and soil classification in engineering geology and geotechnics
2.3 Mapping, site investigation and logging
2.4 Environmental geohazards
2.5 Environmental geochemistry

References
Slides

Chapter 3 Groundwater Flow and Contaminant Transport
Lecture: 12 hours

Lecture Topics

3.1 Introduction
3.2 Groundwater motion
3.3 Groundwater flow modeling
3.4 Groundwater quality
Slides

Chapter 4 Waste Containment Systems and Development of Landfill Sites
Lecture: 11 Hours

Lecture Topics
4.1 Characterization of urban wastes and its engineering properties
4.2 Review on engineering properties of soil
4.3 Soil-waste interactions
4.4 Waste containment systems (sanitary landfills)
4.5 Engineering problems associated with landfill

Slides

Chapter 5 Remediation of Contaminated Land
Lecture: 8 Hours

Lecture Topics
5.1 Introduction
5.2 Site characterization
5.3 Geostatistics
5.4 Contaminants release mechanisms
5.5 Identification of hazardous wastes
5.6 Exposure assessment
5.7 Estimation of clean-up levels
5.8 Treatment approaches
5.9 Pump and treat
5.10 Soil flushing
5.11 Volatilization and air-pressurization
5.12 Vitrification
5.13 Reactive wells
5.14 Solidification and stabilization
5.15 Chemical treatment
5.16 Monitored natural attenuation
5.17 Phytoremediation
5.18 Bioreclamation

Slides

Chapter 6 Case Studies
Lecture: 6 Hours

Lecture Topics
Case Study I – Contaminant Transport Modeling in subsurface Systems
Case Study II – Planning for NAPL's Contaminated Soil-Groundwater Remediation
Slides

APPENDIX C: STUDENT QUESTIONNAIRE – ASSESSMENT OF COURSE AND TEACHING

SOAL SELIDIK PELAJAR: PENILAIAN KURSUS DAN PENGAJARAN
(STUDENT QUESTIONNAIRE – ASSESSMENT OF COURSE AND TEACHING)

Sila hitamkan pada kotak yang berkenaan. Pen (selain daripada merah) boleh digunakan untuk menanda. Gunakan cecair pemadam untuk memadam.

Sesi: Kod Kursus: Semester:

I. Butir Peribadi
(Personal details)

1. Dalam program pengajian anda, kursus ini merupakan:
(In your study programme, this course is)
   a. Kursus Teras Wajib Fakulti
   (Compulsory Faculty Core Course)
   b. Kursus Teras Pilihan Fakulti
   (Elective Faculty Core Course)
   c. Kursus Teras Pilihan Jabatan
   (Department Elective Core Course)
   d. Kursus Elektif Fakulti
   (Faculty Elective Course)
   e. Kursus Elektif Luar
   (Outside Elective Course)

2. Secara purata, berapa jam seminggu anda gunakan untuk mengulangkaji kursus ini?
(On average how many hours a week do you revise this course?)
   a. Kurang dari 1 jam
   (Less than 1 hour)
   b. 1 hingga 2 jam
   (1-2 hours)
   c. 2 hingga 3 jam
   (2-3 hours)
   d. 3 hingga 4 jam
   (3-4 hours)
   e. lebih dari 4 jam
   (More than 4 hours)

3. Adakah kursus ini menimbulkan minat anda untuk lebih mendalami bidang ini? *(Does the course interest you and make you want to pursue it further?)*
Ya *(Yes)* Tidak *(No)*

4. Adakah anda mengulang kursus ini?
(Are you repeating the course)
Ya *(Yes)* Tidak *(no)*

Untuk bahagian II, III dan IV sila gunakan skala berikut: (For sections II, III and IV use the following scale:)	
Sangat tidak setuju *(Disagree completely)*	(1)
Tidak setuju *(Disagree)*	(2)
Kurang setuju *(Disagree slightly)*	(3)
Setuju *(Agree)*	(4)
Sangat setuju *(Agree completely)*	(5)

II. Penilaian Kursus lni

(Assessment of course)

Beri pendapat anda tentang kenyataan berikut:
(Comment on the following statements:)

5. Skop kandungan kursus adalah sesuai. …
(Scope of course content suitable.)

6. Kursus ini mudah diikuti. …
(Course is easy to follow.)

7. Bahan rujukan adalah mencukupi. …
(Reference material is adequate.)

8. Pada keseluruhannya kursus ini adalah baik. …
(Course, on a whole is good.)

Ill. Penilaian Pengajaran
(Assessment of teaching)

Beri pendapat anda tentang kenyataan berikut:
(Comment on the following statements:)

9. Perancangan dan penyediaan kursus ini adalah baik. …
(Course planning and preparation is good.)

10. Pensyarah berpengetahuan tentang subjek. …
(Lecturer is knowledgeable in the topic.)

11. Pensyarah menyampaikan subjek dengan jelas. …
(Lecturer presents the subject matter clearly.)

12. Pensyarah menggunakan contoh-contoh yang relevan. …
(Lecturer uses relevant examples.)

13. Pensyarah merangsangkan minat anda dalam subjek berkenaan. …
(Lecturer stimulates your interest in the subject.)

14. Pensyarah berinteraksi dengan pelajar. …
(Lecturer interacts with the student.)

15. Pensyarah mengamalkan ketepatan waktu. …
(Lecturer keeps good time.)

16. Pada keseluruhannya pensyarah telah menjalankan kursus ini dengan baik. …
(On the whole lecturer has conducted the course well.)

IV. Penilaian Kemudahan Pembelajaran

(Assessment of facilities)

Beri pendapat anda tentang kenyataan berikut:
(Comment on the following statements:)

17. Kelengkapan dan peralatan pengaiaran kursus ini mencukupi. …
(Teaching aids and equipment for course is adequate.)

18. Kemudahan dan kelengkapan makmallbengkel/kerja lapangan bagi kursus ini mencukupi. …
(Lab./seminar /field study facilities for the course is adequate.)

V. Komen-komen lain

(Other comments)

………………………………………………………………
………………………………………………………………
………………………………………………………………

5 Solid Waste Management

Estimating The Benefits Of Improved Household Solid Waste Management Services In Malaysia

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ABSTRACT: This study estimated the economic values of household preferences for improved solid waste management (SWM) service attributes in Malaysia. The Choice Model (CM) was employed on 859 randomly selected urban households in Kajang and Seremban areas. The study found that households were willing to pay a premium for improvements in SWM system. More specifically, the study ascertains that households on average are willing to pay a charge of RM1.57 per month for a change in collection frequency - from 3 times irregular to either 3 times every alternate day or 4 times per week, *ceteris paribus;* RM3.32 if waste disposal method was improved from control tipping to sanitary landfill, *ceteris paribus;* and RM2.48 if transportation mode was improved from a mix of compactor and open trucks to either compactor or a mix of compactor and covered trucks, *ceteris paribus*. The CM has also shown that households derive positive utility from the provisions of recycling facilities and compulsory kerbside recycling with an implicit price (willingness to pay) of about RM3.51 monthly. Results from the study can be used by service providers to identify any mismatch between what the public actually wants and are willing to pay for and the affordability of supply on the part of service providers.

Keywords: Environmental valuation, choice modelling, economics of solid waste management

INTRODUCTION

Background and Problem Statement

Managing SW has become a major problem for local governments in Malaysia. In 1995, per capita generation rates averaged 0.77 kg/day. These rates are expected to increase steadily as the economy grows. Per capita SW generation for 2000 was estimated at 1 kg daily.

In Malaysia, the local government authorities have been responsible for solid waste management services. However, over the years, lack of infrastructure, weak institutional setup, weaknesses in financial and technical resources, have led to inefficiency in management. These contrast to the increasing waste generation rates and environmental awareness among the general public. To reduce the burden facing local governments, the privatization process was initiated in 1996 with the aim of attaining an integrated and efficient management system to enhance environmental quality through resource re-use and waste minimization.

Before the privatization program, the most common waste collection method was through communal bins and the wastes disposed in open dumps, normally without ground cover or control for leaching. It was reported that in 1990 (Mourato, 1998), there were 230 official dumping sites with less than 2 years of operating life. About half of these sites were open dumps. It was also reported that there were 3 times more unofficial dumping sites (Agamuthu, 2000).

Control tipping has become an increasingly popular method of waste disposal. It is regarded as the lowest quality method amongst the class of sanitary landfills.

The Malaysian government has of late increased its campaign to create public awareness on the importance of waste recycling and waste minimization. It is estimated that only 3 percent of total SWs generated nationwide are being recycled. Draft Concession Agreements between the government and the private waste service providers targeted 22 percent recycling, 8 percent composting, 17 percent incineration and 53 percent landfilling by 2020.

Currently, households in the privatized areas are required to place their waste bags in waste bins in front of their houses (kerbsides) and private collectors would collect the wastes twice - thrice a week. Payment for the collection services is currently made indirectly through the annual house assessment.

The local authorities set the tariff rate after consulting the private service providers. Therefore, households at this stage do not pay a separate payment for solid waste management fee and they are also not aware about the amount of tariff they are paying for the waste collection service. This, however, might change once the full fledge privatization process comes into being. Contractors may also wish to increase the quality of their services including substituting existing landfills with mostly sanitary landfills or incinerators, conventional open trucks with compactors or covered trucks. To offer these improved services, there may be a need to increase the service charge. Consumers will also be required to pay the service charge directly to contractors.

There are uncertainties in consumer awareness and attitude towards a number of waste management issues that may hinder the implementation of effective SW management options. A critical issue relates to consumer demand or willingness to pay with the types of services characteristics and disposal options that the private service providers can offer. The experience of the privatization project for sewerage services directly reflects this problem. A business group was awarded the privatization concession for sewerage services in 1996. But negotiation was under way for the entity to be "resold" to the government due to massive debts, much caused by consumer reluctance to pay for the perceived "unseen" services even though the tariffs have been reduced several times since its inception.

Given the above background, this case study addresses the following policy issues; What shall be the desirable future waste management programs, in terms of priorities over different service attributes and levels. The major service attributes that will be examined are: collection frequency, collection timing, mode of transportation, disposal options, and the provision of different type of containers to facilitate recycling or separation of waste at the household level.

Specifically, the objectives of this study are:

1. To elicit consumers' WTP for different service options – collection frequency, mode of transportation and the provision of facilities and containers to facilitate separation of waste at source (kerbside recycling).
2. To rank the characteristics of service in order of importance to consumers – collection frequency, mode of transportation, recycling facilities, and disposal options
3. To estimate the implicit price for each service attribute and the tradeoffs among the attributes.

Rationale of Study and Policy Relevance

This study provides two important insights for public and private policymakers in terms of incorporation of demand-side information into the design of MSW management services/attributes and fee schedules

This study will be of special interest to Malaysian regulators (Economic Planning Unit) of private concessions of MSW management as well as to the private waste collectors. This study derives estimates of the value of changes in individual attributes as well as changes in the aggregate level of service attributes. Therefore the results from this study can be used to produce estimates of the value of multiple service alternatives or the total value of a SW management package. This information can be used in negotiating an appropriate tariff rate with the current private service providers as well in the designing for future concession agreements and/or consideration of proposals by new private entities for new residential service areas.

An important contribution of this study is to minimize the problem of mismatch in terms of services that can be supplied by service providers (i.e, sanitary landfills vs open landfills options, less and regular vs more but irregular collection frequencies, conventional open trucks vs compactor, etc) and what the public really wants and is willing to pay for. In short, knowledge obtained from this study will help match the affordability of supply and public demand for waste services. To date, very few such studies have been conducted in Malaysia.

METHODOLOGY

Choice modelling (CM) was employed in this study. The aim of CM was to identify marginal values for SWM attributes. This is to allow identification of a desirable SWM plan from the demand side perspective.

The CM like the Contingent Valuation (CV) is a class of stated preference technique but has the unique flexibility to evaluate both alternative management options and the marginal values of non-market attributes that may be difficult to identify using a typical CV study because of lack of variation. With CM, it is possible to estimate the value of the individual attributes that make up an environmental good, such as increased waste collection frequency. The CM is also able to derive estimates of the value of changes in the aggregate level of non-market goods quality. The following section provides an overview of the background of CM.

Overview of CM

Many management decisions are concerned with changing attribute levels, rather than the loosing or gaining of the environmental good as a whole, of which the CV has the unique advantage. For the former, the CM has the unique strength. The CM is also able to derive estimates of the value of changes in the aggregate level of environmental quality. Therefore it can be used to produce estimates of the total value of multiple services or resource use alternatives. The main weakness of CM relative to CV is the added cognitive burden it imposes on respondents apart from its complexity in designing it correctly and its econometric estimation.

In CM questionnaires, respondents are posed with a series of choice sets, where each choice set contains usually three or more service or resource use options. Respondents are asked to choose their preferred option from each choice set. The options in each choice set contain common attributes, which can be at various levels. The combination of attribute levels for each option in each choice sets is designed using experimental design techniques. Similar to a CV study, before the choice sets are presented to respondents, there is a description of the study site, the research issues, the proposed policy changes and its implications on attributes which are being modeled.

The theoretical basis of CM is random utility theory (RUT). Under RUT it is assumed that that the utility function of a good can be broken down into two parts, one deterministic and one stochastic. Assume utility for an option *i* which depends on environmental attributes (Z) and socio-economic characteristics (S).

$$U_{in} = V(Z_{in}, S_n) + \varepsilon(Z_{in}, S_n) \quad (1)$$

The probability that individual *n* will choose option *i* over other option *j* is given by:

$$\text{Prob}(i/C) = \text{Prob}\{V_{in}+\varepsilon_{in}>V_{jn}+\varepsilon_{jn} \,;\, j \in C\} \quad (2)$$

where C is the complete choice set. It is assumed that the error terms of the utility function are independently and identically distributed (IID). A consequence of this assumption is the property of independence of irrelevant alternatives (IIA). The IIA states that the probability of choosing one alternative over the other is entirely dependent on the utility of the respective alternatives. This property may be violated by the presence of close substitutes in the choice sets as well as heterogeneity in preferences.

The probability of choosing option *i* is given by:

$$\Pr(i) = \frac{\exp^{\mu v_i}}{\sum_{j \in C} \exp^{\mu v_j}} \quad (3)$$

where $V_i = V(Z_i, S)$, V_i is the utility function, Z_i is a vector of environmental goods, S is a vector of market goods and socio-economic characteristics, and μ is a scale parameter, which is usually assumed to be equal to 1 (implying constant error variance). Equation (3) is estimated by means of a multi-nomial logit regression, which assumes that choices are consistent with the IIA property.

The most basic form of V_i is an additive structure, which includes the attributes from the choice sets only, eg:

$$V_i = C + \Sigma\beta_k X \quad (4)$$

where *C* is an alternative specific constant (ASC), β is a coefficient and *X* are attributes from the sets. The effect of attributes in the choice sets are captured by the *X* variables while *C* represents the effect of systematic but unobserved factors that explains respondents' choices. Technically *C* reflects the differences in the error terms. In a multinomial logit (or nested logit) with *j* options it is possible to have *J-1* ASC.

It is possible to include socio-economic and environmental attitudinal variables into the utility functions by estimating the variables interactively, either with the ASC or with any of the attributes from a choice set. An added advantage of CM is its flexibility to incorporate simultaneously the importance of economic, social and environmental factors in a valuation project.

In this study the experimental design is constructed based on the compensating surplus (CS) welfare measure. It measures the change in income that would make an individual indifferent between the initial (lower environmental quality) and subsequent situations (higher environmental quality) assuming the individual has the right to initial utility level. This change in income reflects the individual's willingness to pay (WTP) to obtain an improvement in environmental quality. Based on the indirect utility functions, the compensating surplus can be illustrated as follows:

$$V_0(S_i, Z_0, M) = V_0(S_i, Z_1, M\text{-}CS) \quad (5)$$

where M is income, Z_0 and Z_1 represent different levels of an environmental attribute, and S_i represents other marketed goods.

Using the results from the multinomial logit, the CS can be estimated by employing the following equation (Adamowicz, Louviere and Williams (1994)).

$$CS = -1/(\beta_{M)}\{\ln(\Sigma_i \exp^{V0)} - \ln(\Sigma_i \exp^{V1})\} \quad (6)$$

The above equation allows for the valuation of multiple sites. This study considers only one site. Therefore following Boxall et. al (1996) and Morrison, et. al (1998), equation (6) is reduced to:

$$CS = \{-1/(|\beta_M|)\}(V_0 - V_1) \quad (7)$$

where β_M is the coefficient of the monetary attribute and is defined as the marginal utility of income, and V_0 and V_1 represent initial and subsequent state, respectively.

Questionnaire Design

Choice Model

As discussed earlier, in CM, respondents are presented with multiple choice sets, where each choice set contains usually three or more management options. Respondents are asked to choose their preferred option from each choice set. The options in each choice set contain common attributes, which can be at various levels. The combination of attribute levels for each option in each choice sets are designed using experimental design techniques. Before the choice sets are presented to respondents, there is a description of the study site, the research issues, the proposed policy changes and its implications on household budgets and the environmental attributes which are being modeled.

Three focus groups and a pre test was employed to identify the non-market SW management attributes, the levels these attributes can take, to determine the appropriate format of the choice sets and the levels of price tags for each choice set. These are critical for the success of a CM exercise. The first two focus groups (5-6 people per group) solicited views from the general households (both house owners and renters) and the third from both public officials and private service providers. The pre test utilized some 60 respondents in Bangi, a small university town within the Kajang Municipality.

The Choice sets followed the standard L^{MN} experimental design where only the main effects are modeled. A Choice Modelling exercise in Malaysia by Jamal (2000) has shown that each respondent on the average can take no more than 5 choice sets. In the focus groups, three MSW management alternatives (one baseline and the other 2 represent an improvement of MSW management plan) and 6 service attributes were constructed. The preliminary choice of attributes was made in consultation with a private SW service provider and researchers in the field. An example of the choice set is shown in Table 1 below.

Table 1: An illustration of a Choice Set Presented in the Focus Group Analysis

Implications	Option 1 (Current management Option)	Option 2	Option 3
Collection frequency	Irregular - 3 times weekly	Alternate days (3 times weekly)	4 times weekly
Separation of waste at source by households	No separation at source needed	Yes – free containers & facilities provided	Yes – free containers & facilities provided
Time of waste collection	Irregular	Afternoon	Evening
Types of waste disposal methods	Open landfills	Sanitary	Incinerator
Mode of Transportation	Conventional trucks	Manually loaded compactor	Manually loaded compactor
Monthly charge	RM 15 3	RM 20	RM 25

If the above three management options were the only ones possible, which one would you prefer? If you choose the current option (Option 1), simply tick the first box as shown above.

The service attributes and levels that it takes for the 2 improved alternatives are as follows:

1. **Collection frequency** – 3 levels; irregular – 3 times weekly but irregular, 3 times weekly but regular, 4 times weekly
2. **Free provision of multiple containers for separation of waste at source** – 2 levels; separation at source not needed (baseline), respondents are required to separate waste at source - free multiple containers provided,
3. **Time of collection** – 3 levels; irregular time (baseline), afternoon only, evening only
4. **Types of waste disposal methods** – 3 levels; open landfills (baseline), sanitary, incinerator
5. **Mode of transportation** – 3 levels; conventional open trucks (baseline), manually loaded compactor, covered conventional trucks
6. **Monthly charge** – 3 levels; RM15 (baseline), RM20, RM25

The baseline option considers the baseline levels only while the other 2 options can take on any orthogonal mix of levels including the baseline level. Five choice sets were deliberated during the focus group.

We found that focus group participants were having extreme cognitive difficulty in determining their preferred choice. Most notably was the intransitivity of the levels. For instance some choice sets were given more improvements in the non-monetary attributes but was less on the monetary attribute. Note that in a CM, the mix of levels need not be transitive. For instance, a choice set which contains more environmental improvements need not necessarily be accompanied by a higher service charge. Each choice set is considered as a separate option, independent of the baseline option and any other option in the preceding choice sets.

We finally ended up with 5 attributes, dropping the Collection Time attribute as we thought that it would not be economically realistic to the service providers to commit on a fixed time in collecting the wastes. The levels chosen were further refined to consider the actual realities in the chosen survey areas. The number of alternatives were also reduced to two to facilitate the decision making process by respondents. The final attributes and levels are as follows:

1. **Collection frequency** – 3 levels; irregular – 3 times weekly but irregular, 3 times weekly but regular, 4 times weekly
2. **Free provision of multiple containers for separation of waste at source** – 2 levels; no separation at source needed (baseline), respondents are required to separate waste at source - free multiple containers provided,
3. **Types of waste disposal methods** – 2 levels; control tipping (baseline), sanitary
4. **Mode of transportation** – 2 levels; mix of compactor and conventional open trucks (baseline), mix of conventional covered trucks and compactor
5. **Monthly charge** – 4 levels; RM15 (baseline), RM20, RM25, RM30.

All of the above attributes and levels can be applied practically to all municipalities in Malaysia except for Petaling Jaya where a formal framework for waste separation at source was already in existence. In terms of waste disposal methods, most municipalities are considering "control tipping" and sanitary landfill methods. Incineration as a disposal option was dropped, as private service providers indicate that it might not be feasible in the short-run, where land for landfills in Malaysia is still in abundance. On the mode of transportation, most municipalities and private service providers are utilizing a mix of open trucks and compactor, as transfer of wastes normally involves two stages – first, from the households to a transfer site and secondly, from the site to the landfill area. Small conventional trucks are still needed due to infrastructural consideration - some municipality roads were not designed to withstand heavy vehicles. However, there is an understanding that the use of open trucks should be phased out. Therefore, the improved mode of transportation should well be a mix of compactor (manual or automatic) and conventional covered trucks. The range of monetary attribute (charge) reflects the WTP estimates of RM16 per month (Mourato, 1998) to obtain an improvement in MSW management collection and disposal services. Unofficial information indicates that the current average level of charge is RM15 - some households would pay more and some less, as the charge is based on "cross-subsidization".

An orthogonal design guide was used to determine the mix of attribute levels for the choice sets. Only the main effects were considered. Fifteen choice sets were organized into 3 blocks of 5 choice sets each. An example of the final choice set is shown in Table 2.

Table 2: An Example of the Actual Choice Set

Suppose Option 2 below is the only possible alternative to the current waste management plan (Option 1). Do you prefer to choose Option 1 (collection frequency – 3 times weekly but irregular, etc) or Option 2 (collection frequency – 3 times weekly and regular, multiple containers and facilities provided free of charge to facilitate separation of wastes at source, etc).

(Enumerator needs to forewarn the respondents that the waste service payment will be made directly to the service provider and it is to replace any waste fee that is implicit in the house assessment charge)

If Options 1, 2 and 3 were the only management options possible, which one would you prefer? (tick the box below your preferred option)

Implications	Option 1 (current management Option)	Option 2 (proposed plan)
Collection frequency	3 times weekly, irregular	3 times weekly, regular
Separation of wastes at source by households	Separation at source not needed	Waste separation required, facilities & containers provided free
Disposal method	Control tipping – less environmentally friendly	Sanitary landfill – highly environmentally friendly
Mode of Transportation	Mix of conventional open trucks & compactor	Mix of covered trucks & compactor
Monthly charge	Average RM 15	RM 25

If the above two management options were the only ones possible, which one would you prefer? If you choose the current option (Option 1), simply tick the first box and if you choose the second option, tick the second box.

Note that from Table 2, it is clear that the design of choice sets resembles the dichotomous choice CV format where any one respondent is presented with multiple resource allocation option, one at a time. The respondent has the choice to agree or disagree. If he/she agrees, it reflects his/her preference towards the proposed option over the baseline scenario and otherwise. Given the CM design and presenting it the way the dichotomous choice CV does, respondents find the choices more intuitive and less demanding cognitively. This is because respondents need only compare each choice set with the same baseline plan one at a time. In short this approach has the advantage of a CV in terms of easiness of response elicitation and the capability of a CM in modeling varying levels of resource allocation alternatives. The payment vehicle used in the CM was direct monthly payment to the service providers. It was assumed that households would need to pay for waste services directly to the service providers, the way they have been doing for other utilities. By that way households will be aware on how much exactly they are actually paying for waste services and it would also allow optimizing behavior should waste charges are based on a unit-based pricing system in the future.

The Study Areas and Sampling Strategy

Two study areas were selected for the study. First, the Kajang municipality area in the state of Selangor to represent one of the most fast developing municipalities in the country, being located in the midst of the affluent Klang valley and in the vicinity of the country's futuristic Putra Jaya and Cyber Jaya. The area also includes Bangi, a small but affluent university town. The other is the Seremban municipality, the second largest city in the southern region. It is only 30 km to the south of Kajang town. While a significant number of Seremban residents work and commute in the Klang valley areas, Seremban is quite a mature and "settled down" city relative to Kajang.

For the Seremban area, 600 head of households (or alternatively a working family member) (3 blocks @ about 200 respondents per block) stratified based on house types were sampled randomly. The residential areas representing Seremban municipality includes Taman Paroi Jaya, Taman Pertama, Taman Kelab Tuanku, Taman Panchor Jaya, Kampung Rumah KTM and Taman Bukit Chedong. For Kajang municipality, 300 respondents from residential areas - Taman Bukit, Taman Hijau and Bandar Baru Bangi were surveyed. For Kajang area, each block of CM questionnaires was presented to some 100 respondents on average. The CM survey for both areas was completed between February – July 2001.

Prior to conducting the survey, enumerators were given a series of training by the researcher. The focus of training, which included a role-play exercise, was on how to obtain cooperation from respondents and hints on handling questions that might arise given the complexity of both the CM (particularly the rationale for the intransitivity of the levels of attributes) survey as opposed to an ordinary socio-economic survey.

PROFILE ANALYSES

Total valid respondents for Kajang and Seremban municipalities were 859. Of these, Malays comprised 62 percent (533), Chinese 19 percent, Indians and others, 19 percent. About 49 percent (421) were females and 51 percent males. Mean age was 29 years. Respondents of age 35 years and above formed 30 percent of all respondents.

Most respondents (95 percent) did not employ maids. Only 5 percent reported to have at least 1 maid. Average number of household members who lived in the same house was 5.4 with some 52 percent having 3-5 family members. About 45 percent of the respondents reported having 1-2 members who were below 12 of age while the mean was 1.1. About 47 percent of the respondents had 2 working members in the household while 21 and 17 percents reported to have 1 and 3, respectively. The mean number of working household members was 2.4.

About 66 percent of respondents lived in their own houses, 28 percent lived in rented houses, 3 percent in employer provided house and another 3 percent living in friend-owned houses.

About 50 percent of respondents resided in either single or double storey linked houses, 15 percent in single storey semi detached houses, 11 percent in double storey semi-detached houses, 7 percent in apartments, 8 percent in single storey bangalow houses, 5 percent double storey bangalows, and 4 percent in village houses, and 0.5 percent in condominium.

About 54 percent of respondents had diploma level (college level) up to graduate level education. Most respondents had monthly income of RM2500 (22 percent), RM1500 (21 percent), RM3500 (17 percent), RM4,500 (11 percent) and RM500 (11 percent). Mean household income was RM3018 monthly.

Most respondents (91 percent) were not members of any environmental groups. Nevertheless, most respondents (82 percent) claimed that they were concerned about issues affecting the quality of MSW management. Only about 18 percent were not at all concerned.

Maximum number of wastes generated per week was 15 bags with only 1 respondent. About 68 percent reported 3 - 7 large size bags weekly. The mean number of bags generated was 4.6 weekly or 18.4 bags monthly.

The data revealed that about 96 percent of the respondents were concerned on the importance of waste reduction - 4 percent were unconcerned at all. Almost all respondents (99.8 percent) have heard about recycling in the media while about 67 percent have heard about a recycling program in their vicinity. Only 32 percent of all respondents oftenly or to some extent separate or recycle their waste while a large 68 percent have never or very seldomly done so. Interestingly, almost all respondents (99 percent) claimed that recycling will do good to the environment.

MODEL RESULTS

In the CM analysis, 2 models were employed. The first model considers the basic SWM attributes only while the second model considers the basic attributes as well selected socio-economic and environmental attitudinal variables.
Overall, 56 percent of respondents favored the improved plan over the baseline option. While the percentage of respondents favoring the improved plan decreased as monthly charge was raised, the percentage of respondents favoring the highest monthly bid was still substantially high. Specifically, 67 percent of respondents supported the improved plan when monthly charge was RM20, and 51 and 41 percent when monthly charge was raised to RM25 and RM30, respectively.

Baseline Model (Model 1)

This model follows the specification presented in Equation 4:

$$V_i = f\ (\text{COLLFREQ, SEPWASTE, WASDISPO, TRANSPTN, CHARGE})$$

$$V_i = ASC + \beta_1{*}\ \text{COLLFREQ} + \beta_2{*}\ \text{SEPWASTE} + \beta_3{*}\ \text{WASDISPO} + \beta_4{*}\ \text{TRANSPTN} + \beta_5{*}\ \text{CHARGE}$$

$(i = 1, 2, ASC = 0 \text{ for } V_i = 1)$

The following are the definitions for the variables used:

Dependent variable

V_i = utility of individuals *(1 = choice of option, 0 = non choice)*

Influence of systematic factor

ASC = alternative Specific Constant for option 2 *(improved plan)*

Independent variables

COLLFREQ = frequency of weekly waste collection

(1 = improved plan - 3 times regular and 4 times irregular, 0 = baseline plan)

SEPWASTE = separation of waste by household

(1 = improved plan, 0 = baseline plan)

WASDISPO = waste disposal method

(1 = improved plan, 0 = baseline plan)

TRANSPTN = transportation mode

(1 = improved plan, 0 = baseline plan)

CHARGE = monthly charge

It is expected that all the improved non-monetary attributes will influenced consumer utility positively. However, the monetary attribute (monthly charge) is expected to have a negative relation with utility.

CM With Socio-Economic Factors (Model 2)

This model considers several socio-economic and attitudinal factors.

V_i = f (COLLFREQ, SEPWASTE, WASDISPO, TRANSPTN, CHARGE, CONCERN, WASTEBAG, OPNSPACE, HOWORK, HOLIVING, RACE, MAID, SEPARATE, DKJG)

V_i = SC + β_1 * COLLFREQ + β_2*SEPWASTE + β_3 * WASDISPO + β_4*TRANSPTN + β_5 *CHARGE + γ_1 ASC*CONCERN + γ_2 ASC*WASTEBAG + γ_3 ASC*OPNSPACE + γ_4 ASC*HOWORK + γ_5 ASC*HOLIVING + γ_6 ASC*RACE + γ_7 ASC*MAID + γ_8 ASC*SEPARATE + γ_8 ASC*DKJG

(i = 1, 2; ASC = 0 for V_i = 1)

The definitions for the various notations are given below:

Dependent variable
V_i = respondent's utiliti *(1 = choice of option, 0 = non choice)*

Influence of systematic factor
ASC = alternative specific constant for option 2

Independent variables

EDUCATE = highest education level
(1 = diploma level and above, 0 = others)
CONCERN = concerns on general SWM issues
(1 = concerned, 0 = unconcerned)
WASTEBAG = number of large bags of wastes generated weekly
OPNSPACE = area of yard or space (square meter)
HOLIVING = number of household members living together
HOWORK = number of working household members
MAID = number of household maid
SEPARATE = whether respondents practiced waste separation
(1 = often or at times, 0 = never)
DKJG = area intercept dummy variable
(1 = Kajang municipality respondents, 0 = otherwise)

All coefficients for the non-monetary variables in the extended model are expected to be correlated positively with utility.

Results of the Basic Model

The results of the basic model are shown in Table 3 below:

Table 3: Results of the Basic Model

	Coeff.	Std. Err.	t-ratio	P-value
ASC	0.562	0.109	5.152	2.56E-07
COLLFREQ	0.147	0.064	2.283	0.022392
SEPWASTE	0.382	0.064	5.952	2.64E-09
WASDISPO	0.385	0.064	6.015	1.80E-09
TRANSPTN	0.263	0.064	4.096	4.19E-05
CHARGE	-0.105	0.007	-13.966	2.89E-15

Log likelihood function = -2797, R2 = 0.06, No. of obs. = 4295

The sign of the coefficient for all non-monetary attributes was positive. This suggests that improvements in all the non-monetary attributes lead to positive utility among individuals.
The finding that the coefficient for SEPWASTE was positive is rather striking and thought provoking as it denotes that households derive positive utility by the provision of recycling facilities and the mandatory kerbside recycling of waste, *ceteris paribus*. The positive coefficient for SEPWASTE may be deduced as the net increase in utility (benefits) accrued to the average household should adequate recycling facilities are provided to facilitate kerbside waste recycling, *ceteris paribus*.

CM With Socio-Economic Characteristics

Table 4 depicts the results of the CM with socio-economic and attitudinal variables.

Table 4: Results of CM with Socio-Economic and Attitudinal Variables

	Coeff.	Std. Err.	t-ratio	P-value
ASC	0.3741	0.2365	1.5818	0.1136
COLLFREQ	0.1960	0.0684	2.8629	0.0041
SEPWASTE	0.4257	0.0682	6.2350	4.52E-10
WASDISPO	0.4139	0.0678	6.0976	1.08E-09
TRANSPTN	0.3094	0.0683	4.5291	5.92E-06
CHARGE	-0.1246	0.0080	-15.4929	2.89E-15
ASC_CONCERN	0.5166	0.1692	3.0527	0.0022
ASC_WASTEBAG	-5.10E-02	1.39E-02	-3.6806	0.0002
ASC_OPNSPACE	0.0021	0.0004	5.2408	1.60E-07
ASC_HOWORK	0.1111	0.0296	3.7451	1.80E-04
ASC_HOLIVING	-0.0137	0.0210	-0.6541	5.13E-01
ASC_RACE	0.3234	0.0709	4.5615	5.08E-06
ASC_MAID	0.3033	0.1561	1.9423	5.21E-02
ASC_SEPARATE	0.0026	0.1082	0.0241	0.9807
ASC_LOC	-1.5210	0.0789	-19.2681	2.89E-15

Log Likelihood function = -2544, R2= 0.14, No. of obs = 4295

Results show that all socio-economic and attitudinal variables except SEPARATE were significant at least at the 5 percent level. All monetary and non-monetary attributes, like in the basic model were also significant and yielding the expected signs.

It is worthy to note that the variables OPNSPCE and HOWORK which signify income and wealth of respondents were highly sigificant at the 1 percent level. The positive and significant coefficient for RACE suggest that the malays on average tend to support improvements in solid waste management regime relative to the non-malays.

The coeffient for WASTEBAG was negative and significant. This implies that those who are large producers of wastes would prefer the current and lower cost management regime. The coefficient for Kajang area dummy (area intercept dummy) was negative and significant. This indicates that respondents from Kajang area on average exhibit a lower level of willingness to pay for improved solid waste management relative to that of Seremban.

From the results of the two models, it can be deduced conclusively that households support improvement in solid waste management plan, in terms of collection frequency, waste separation at source, disposal methods and mode of transportation.

Estimation of Implicit Prices

In this sub-section, the estimation of implicit prices for each attribute is undertaken. Implicit prices reflect the marginal rate of substitution (MRS) between each non-market attribute and the monetary attribute. It is estimated using the following formulae:

MRS = coefficient for the non-market attribute divided by coefficient for the monetary attribute, i.e.,

$$= \beta^{(\text{NON-MARKET})}/\beta^{(\text{MONETARY})}$$

Thus, implicit price reflects individual's WTP for the presence of an additional unit of non-market attribute, *ceteris paribus*. The estimation of implicit prices for each non-market attribute is shown below (Table 15):

Table 5: Estimation of Implicit Prices

Non market attribute	Basic model (RM) (Model 1)	Model with socio-economic factors (RM) (Model 2)
COLLFREQ	1.40	1.57
SEPWASTE	3.63	3.51
WASDISPO	3.67	3.32
TRANSPTN	2.50	2.48

The estimated implicit prices under the two models are found to be comparable.

Interpretation of Implicit Price

In the case of the basic model;

1) COLLFREQ = RM1.40. This means households on average are willing to pay RM1.40 per month for a change in collection frequency - from 3 times irregular to either 3 times every alternate day or 4 times per week, *ceteris paribus*.

2) SEPWASTE = RM3.63. This variable (SEPWASTE) relates to both the provision of recycling facilities by the waste service providers and the requirement that households separate/recycle their wastes at source or kerbside. The implicit price for SEPWASTE may be interpreted as the net increase in utility (benefits) (worth RM3.63) accrued to the average household should adequate facilities and free multiple containers are provided to facilitate waste recycling and separation at source, *ceteris paribus*.

3) WASDISPO = RM3.67. This suggests that households on average are willing to pay a charge of RM3.67 permonth if waste disposal method was improved from control tipping to sanitary landfill, *ceteris paribus*.

4) TRANSPTN = RM2.50. This implies that households are willing to pay a charge of RM3.50 per month if transportation mode was improved from a mix of compactor and open trucks to either compactor or a mix of compactor and covered trucks, *ceteris paribus*.

Estimation of equilibrium values for the non-monetary attributes

It is also possible to identify the tradeoffs between the non-monetary attributes that will leave individuals on the same utility level. This involves the identification of a reference implicit price, then divide it by the implicit price of interest, i.e.,

$$\text{Equilibrium values} = \text{WTP}^{(\text{REFERRED ATTRIBUTE})}/\text{WTP}^{(\text{SEARCHED ATTRIBUTE})}$$

Based on the implicit price for WASDISPO, the estimation of the equilibrium values is shown below:

Table 6: Estimation of Equilibrium Values For the Non-Monetary Attributes

Non-monetary attribute	Basic Model	Model 2	Ranking of importance (Model 2)
COLLFREQ	0.38	0.47	4
SEPWASTE	0.99	1.06	1
WASDISPO	1.00	1.00	2
TRANSPTN	0.68	0.68	3

The equilibrium values above can be interpreted (Model 2) conceptually as;

The utility derived by households on average as a result of a unit improvement in disposal method, *ceteris paribus* = the utility derived by 0.94 additional unit in the provision of recycling facilities, *ceteris paribus* = 2.13 unit improvement in collection frequency, *ceteris paribus* = 1.47 unit improvement in transportation mode. Since all the non-monetary attributes are indivisible, this analysis will only suggest the relative importance of each attribute to households. This implies that in terms of importance of attributes, SEPWASTE ranks top, followed by WASDISPO, TRANSPTN and COLLFREQ.
Estimating the Value of a Program

The CM technique can be used to estimate the value of a program, i.e. the compensating surplus (CS) for a given SWM package. Several management packages are considered and compared with that of the "business as usual" scenario (option 1). Using the results of Model 2, the following eight improvement scenarios were considered for Kajang and Seremban municipality, separately:

Base line scenario
Collection frequency 3 times and irregular
Waste separation at source not mandatory
Waste disposal method – less environmentally friendly - "control tipping"
Transportation – mixed of open trucks and compactor

Scenario 1
Collection frequency 3 times weekly every alternate day
Waste separation at source not mandatory
Waste disposal method – sanitary landfill
Transportation mode – mixed of open trucks and compactor

Scenario 2
Collection frequency 3 times weekly and irregular
Waste separation at source mandatory
Waste disposal method - sanitary landfill
Transportation mode – mixed of open trucks and compactor

Scenario 3
Collection frequency 3 times weekly and irregular
Waste separation at source not mandatory
Waste disposal method - sanitary landfill
Transportation mode – mixed of open trucks and compactor

Scenario 4
Collection frequency 3 times weekly and irregular
Waste separation at source mandatory
Waste disposal method – control tipping
Transportation mode – mixed of open trucks and compactor

Scenario 5
Collection frequency 4 times weekly and irregular
Waste separation at source mandatory
Waste disposal method - sanitary landfill
Transportation mode – mixed of open trucks and compactor

Scenario 6
Collection frequency 3 times weekly and irregular
Waste separation at source mandatory
Waste disposal method – control tipping
Transportation mode – mixed of covered trucks and compactor

Scenario 7
Collection frequency 4 times weekly and irregular
Waste separation at source mandatory
Waste disposal method – sanitary landfill
Transportation mode – mixed of covered trucks and compactor

Scenario 8
Collection frequency 4 times weekly and irregular
Waste separation at source not mandatory
Waste disposal method – sanitary landfill
Transportation mode – mixed of covered trucks and compactor

The estimate of the value of a management package is done using the following formulae and the results shown in Table 7.

$$CS = [-1/(|\beta_y|)]\ (V^0 - V^1)$$

Table 7: Estimation of Compensating Surplus or WTP Per month

Management Plan	Estimates of value (RM) (Kajang)	Estimates of value (RM) (Seremban)
1	19	23
2	21	25
3	17.6	21.3
4	17.8	21.4
5	23	26
6	20	24
7	25	29
8	22	25

Note that the WTP increases as more SWM attributes are improved. If all attributes are improved (Plan 7) average WTP would be RM25 and RM27 monthly, respectively, for Kajang and Seremban. As evidenced by the regression results earlier (negative coefficient for Kajang intercept dummy), the estimated WTPs for Kajang area were lower relative to that of Seremban.

Given knowledge about household preference towards SWM improvement, policymakers will be able to match between household demand and the firm's affordability of supply. For instance, should service providers wish to improve disposal method from control tipping to sanitary landfill while all others remain the same (scenario 3), than the cost of service ought to be some level below the estimated household's WTP (RM18).

SUMMARY AND POLICY IMPLICATIONS

This main aim of this study was to estimate the economic values of household preferences for improved solid waste management service attributes in Malaysia. The Choice

Model (CM) was employed on 859 randomly selected urban households in Kajang and Seremban areas.

This study has obtained estimates of marginal values of improved SWM service attributes and households WTP for improved MSW management services. In general, households highly value improvements in SW management plan. Specifically, it has been determined that households are willing to pay a premium for improvements in collection frequency, waste disposal methods, and transportation mode attributes. To obtain all these improvements, the model suggest that households on average are willing to pay RM25 (USD6.7) and RM29 (USD7.7), for Kajang and Seremban areas, respectively. Currently, monthly waste charges (indirect payment) are thought to be around RM15. This represents a premium rate as high as 100 percent. More specifically, the model (Model 2) ascertains that households on average are willing to pay a charge of RM1.57 per month for a change in collection frequency - from 3 times irregular to either 3 times every alternate day or 4 times per week, *ceteris paribus;* RM3.32 if waste disposal method was improved from control tipping to sanitary landfill, *ceteris paribus;* and RM2.48 if transportation mode was improved from a mix of compactor and open trucks to either compactor or a mix of compactor and covered trucks, *ceteris paribus*.

The CM has also shown that households derive positive utility from the provisions of recycling facilities and compulsory kerbside recycling with an implicit price (willingness to pay) of about RM3.51 monthly. In a related study (Jamal, 2003), using a CV technique, it was observed that respondents were not willing to pay additional waste charges for non-voluntarily compliance of kerbside recycling, despite the provision of free recycling facilities by service providers. Further studies are clearly needed to gain a better apprehension of such household behavior.

Generally, this case study has shown the demand perspectives of MSW management improvements. Results from the study can be used by service providers to identify any mismatch between what the public actually wants and are willing to pay for and the affordability of supply on the part of service providers. By this way, an efficient SW management outcome will be identifiable. Although there may be some controversies with regard to the recycling attribute, the CM results may lend support for the imposition of some additional levy for the provision and maintenance of kerbside recycling facilities.

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Socio-Economic Influence On Municipal Solid Waste Generation In Petaling Jaya

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ABSTRACT: Municipal Solid Waste (MSW) generation rate in Malaysia was found to vary according to the type of waste generator, land use and economic level. Waste was collected and sorted from five types of housing area (single-storey terrace, double-storey terrace, single-storey bungalow, double-storey bungalow and condominium) in Section 11 and 12, Petaling Jaya, Selangor Darul Ehsan. Residents in single-storey bungalow generate 17.6kg/week/dwelling of MSW, followed by double-storey terrace houses at 16.3kg/week/dwelling, single-storey terrace houses produced at 10.2kg/week/dwelling, double-storey bungalow 10.2kg/week/dwelling and condominium residents generated 7.3kg/week/dwelling. Per capita generation rate which depends on waste generated and number of people in the house, shows residents in single-storey bungalow generate 0.12-0.88kg/person/day of MSW, double-storey bungalow residents (0.14-0.41kg/person/day), single-storey terrace residents (0.11-0.52kg/person/day), double-storey terrace residents (0.20-0.62kg/person/day), condominium residents (0.12-0.26kg/person/day) and. Physical characteristics of MSW also differed for the various types of housing area. MSW pH values ranged from 5.08 to 6.20. Conductivity values of MSW ranged from 83 to 969µS and moisture content of MSW was from 36.59% to 76.16%. On the occupational aspect, public sector working residents generate more MSW (0.44kg/person/day) compared to private sector working residents (0.34kg/person/day) and students (0.24kg/person/day). Indian residents were found to generate more MSW, at 0.35kg/person/day compared to Chinese, 0.32kg/person/day while Malays generated, 0.29kg/person/day. Medium-income residents (RM1500-RM4000) generated less MSW at 1.26kg/residence/day while high-income residents (>RM4000) generated 1.38kg/residence/day and low-income residents (<RM1500) generated, 1.94kg/residence/day. Average MSW generation rate at Section 11 and 12, Petaling Jaya was range from 0.11-0.88kg/person/day and average waste composition are organic 42.0%, paper products18.2%, plastics 18.7%, glass 4.3%, non-ferrous metal 3.4%, ferrous metal 0.5%, polystyrene 1.1% and others 11.8%. Socio-economic factors; housing type, occupational type, race and income level play a major role in MSW generation while educational level has a minor influence.

Keywords: Municipal solid waste, socio-economic, waste composition, waste generation, physical characteristic

INTRODUCTION

Municipal Solid Waste (MSW) is mainly household waste and also includes organic waste from commercial and institutional outlets. Urbanization and industrialization in Malaysia has bought in many changes in quality and quantity of solid waste generated. MSW is highly heterogeneous and its composition reflects the affluence of the society, their way of life, their economic status and their social behaviour. The characteristics of MSW changes with time as the society evolves to the needs of development. For example, in Petaling Jaya, Malaysia, the amount of paper disposed increased by 3.5% in a period of less than 5 years, whereas the putrescible waste decreased from 55% to 48% within the same period (Agamuthu, 2001).

In 1997, the total solid waste generated throughout Malaysia was 5.6 million tonnes or 15,000 tonnes/day and of this 80% was domestic waste and the rest was commercial waste. In 1998, the MSW generated increased to 6.0 million tonnes, with an average of 0.5 to 0.8 kg per capita per day. One quarter of the total solid waste was generated in the Klang Valley, where Selangor generated the highest amount (2,375 tonnes) of waste. Per capita waste generation increased in Malaysia from 0.70 kg/person in 1990s to 1.20 kg/person in 2000 (Agamuthu, 2001).

Table 1 below shows the waste generation characteristics in the municipality of Petaling Jaya. By the year 2005 it is projected that the rate of generation will increase by as much as 50% compared to the current rate.

Table 1: Projected waste generation for Petaling Jaya

Year	Projected population	Total waste generation (tonnes/day)
2000	607,200	777.2
2005	695,000	959.1
2010	777,700	1158.8

Source: Master Plan on Solid Waste Management for Petaling Jaya Municipality (1990-2010).

Urban migration is one of the immediate causes of high-density populations in some cities including Kuala Lumpur and Petaling Jaya. The rapid increase in population is one of the increases in MSW generation.

METHODOLOGY

The study area is housing estates in Section 11 and 12, Petaling Jaya Municipality, Selangor Darul Ehsan. Five houses from each type of housing area (single-storey terrace, double-storey terrace, single-storey bungalow, double-storey bungalow and condominium) randomly identified. Waste collected from each house for one week, started on Monday till Sunday. Physical properties such as pH and conductivity determined using pH meter and Conductivity meter respectively. Then, the waste collected was separated into six categories; organic, paper, plastic, metal, glass and others. Separated waste materials were placed in individual containers to be weighed. Waste heated in oven at 105^{o}C to determine moisture content of waste.

RESULTS AND DISCUSSION

Housing Type

Table 2 shows the range of MSW generated and physical properties from five types of housing estates and Table 3 shows min of MSW generated and physical properties from five types of housing estates.

Table 2: Range of MSW generated and physical properties from various type of housing estates in Section 11 and 12, Petaling Jaya

Housing type	1	2	3	4	5
			Range		
Waste generated (kg/week/dwelling)	4.6-21.7	4.12-43.7	9.3-21.9	7.7-11.7	5.0-10.8
Per capita (kg/person/day)	0.11-0.52	0.20-0.62	0.12-0.88	0.14-0.41	0.12-0.26
Density (kg/m^3)	0.16-0.62	0.14-0.35	0.27-0.43	1.62-1.94	0.08-0.14
pH	5.1-6.0	4.6-6.0	5.8-6.1	5.7-6.4	4.7-5.5
Conductivity (µS)	211-257	296-969	441-538	405-526	83-109

[1]Single-storey terrace, [2]Double-storey terrace, [3]Single-storey bungalow, [4]Double-storey bungalow, [5]Condominium

Table 3 : Min of MSW generated and physical properties from various type of housing estates in Section 11 and 12, Petaling Jaya

Housing type	1	2	3	4	5
			Min		
Waste generated (kg/week/dwelling)	10.2	16.3	17.6	10.2	7.3
Density (kg/m^3)	0.30	0.22	0.33	1.73	0.13
pH	5.4	5.4	5.9	6.0	5.1
Conductivity (µS)	227	638	516	446	96

[1]Single-storey terrace, [2]Double-storey terrace, [3]Single-storey bungalow, [4]Double-storey bungalow, [5]Condominium

From Table 3, single-storey bungalow residents generate the highest amount of MSW per week (17.6kg/week/dwelling) but condominium residents generate lowest quantity of MSW per week (7.3kg/week/dwelling). Except condominium, residents from all housing type produced more than 10.0kg per week. From Table 2, single-storey bungalow residents generate high range of per capita generation (0.12-0.88kg/person/day) and condominium residents generate lowest range (0.12-0.26kg/person/day). Condominium residents are mainly undergraduate students and young professionals, where they will spend more time outside residence and therefore condominium residents generate less MSW. MSW from all type of housing area are acidic (pH<7) due to the food waste, which has deteriorated. Waste from condominium residents also has lowest density (0.19kg/m^3) due to polystyrene food packaging materials. Conductivity of double-storey terrace residents waste gives highest value (638µS) and condominium residents waste gives lowest value (96µS).

Occupational

Table 4 shows the range of MSW generated and physical properties from public sector employees, private sector employees and students and Table 5 shows min of MSW generated and physical properties from public sector employees, private sector employees and students.

Table 4: Range of MSW generated and physical properties from various occupational type residents in Section 11 and 12, Petaling Jaya

Occupational type	Public sector	Private sector	Student
		Range	
Waste generated (kg/week/dwelling)	4.1-19.4	7.7-11.5	5.0-43.7
Per capita (kg/person/day)	0.20-0.88	0.30-0.41	0.11-0.62
Density (kg/m^3)	0.14-0.28	0.20-1.94	0.08-1.81
pH	4.6-6.0	5.1-6.4	4.7-6.1
Conductivity (µS)	296-969	231-534	83-542

Table 5: Min of MSW generated and physical properties from various occupational type residents in Section 11 and 12, Petaling Jaya

Occupational type	Public sector	Private sector	Student
		Min	
Waste generated (kg/week/dwelling)	12.1	8.1	13.6
Density (kg/m^3)	0.22	1.12	0.37
pH	5.5	5.9	5.4
Conductivity (µS)	620	392	263

Table 5 shows, students generate high amount of waste per week per residence (13.6kg/week/dwelling) and private sector employees generate less waste (8.1kg/week/dweeling). Waste generation per dwelling from student was high due to high number of students per dwelling, which ranged from 4 to 19 students per dwelling. Number of residents per dwelling in non-student residences is only ranged from 3 to 6 residents per dwelling. Therefore, from Table 4, student has lowest per capita waste generation (0.11-

0.62kg/person/day), followed by private sector workers (0.30-0.41kg/person/day) and the highest was public sector workers (0.20-0.88kg/person/day). Waste from private sector employees has highest density (1.12kg/m^3) while conductivity value from public sector employees was highest (620µS). pH value which ranged from 5.4 to 5.9 shows acidic characteristic in waste collected.

Race

Table 6 shows the range of MSW generated and physical properties from Malay, Chinese and Indian residents and Table 7 shows min of MSW generated and physical properties from Malay, Chinese and Indian residents.

Table 6: Range of MSW generated and physical properties from Malay, Chinese and Indian residents in Section 11 and 12, Petaling Jaya

Race	Malay	Chinese	Indian
		Range	
Waste generated (kg/week/dwelling)	4.6-43.7	7.7-10.0	4.1-19.4
Per capita (kg/person/day)	0.11-0.62	0.29-0.37	0.12-0.88
Density (kg/m^3)	0.14-1.81	0.20-1.94	0.08-1.66
pH	4.6-6.1	5.7-6.2	4.7-6.4
Conductivity (µS)	83-542	257-534	96-969

Table 7 : Min of MSW generated and physical properties from Malay, Chinese and Indian residents in Section 11 and 12, Petaling Jaya

Race	Malay	Chinese	Indian
		Min	
Waste generated (kg/week/dwelling)	14.9	8.9	9.8
Density (kg/m^3)	0.51	1.05	0.40
pH	5.4	5.9	5.5
Conductivity (µS)	308	431	384

From Table 7, Malay residents in Section 11 and 12, Petaling Jaya generate high quantity of solid waste per dwelling (14.9kg/week/dwelling) and Chinese generate lowest quantity of solid waste (8.9kg/week/dwelling) while from Table 6, Malay residents generate lowest per capita waste (0.11-0.62kg/person/day) and the highest per capita waste generated by Indian residents (0.12-0.88kg/person/day). Malay residents in this study are mainly undergraduate student from University of Malaya and 4 to 19 students will share the house. Chinese and Indian residents in Section 11 and 12 are mainly family and only 3 to 6 residents per residence. Therefore, waste generation for Malay residents is highest but the per capita waste generation is lowest. Waste density of Chinese residents is highest (1.05kg/m^3) and lowest by Indians residents (0.40kg/m^3). Wastes from all races residence are acidic and conductivity from Chinese residents waste is highest (431µS).

Income

Table 8 shows the range of MSW generated and physical properties from low, medium and high income residents and Table 9 shows min of MSW generated and physical properties from low, medium and high income residents.

Table 8: Range of MSW generated and physical properties from low, medium and high income residents in Section 11 and 12, Petaling Jaya

Income	Low Income[a]	Medium Income[b]	High Income[c]
		Range	
Waste generated (kg/week/dwelling)	5.0-43.7	4.1-17.2	9.3-19.4
Per capita (kg/person/day)	0.11-0.62	0.16-0.49	0.29-0.88
Density (kg/m^3)	0.08-1.81	0.14-0.38	0.27-1.94
pH	4.7-6.1	4-6-6.0	5.7-6.4
Conductivity (µS)	83-542	231-969	344-538

[a]Monthly income below RM1000.
[b]Monthly income between RM1500 to RM4000
[c]Monthly income between above RM4000

Table 9: Min of MSW generated and physical properties from low, medium and high income residents in Section 11 and 12, Petaling Jaya

Income	Low Income[a]	Medium Income[b]	High Income[c]
		Min	
Waste generated (kg/week/dwelling)	13.6	8.8	12.3
Density (kg/m^3)	0.37	0.22	1.12
pH	5.4	5.4	6.0
Conductivity (µS)	263	523	475

[a]Monthly income below RM1500.
[b]Monthly income between RM1500 to RM4000
[c]Monthly income between above RM4000

From table 9, low income residents generated highest amount of solid waste (13.6kg/week/dwelling) and medium income residents generates lowest amount of solid waste per week (8.8kg/week/dwelling). Low income residents prefer to have their meal at home compared to medium and high income residents who like to have their meal outside. Table 8 shows per capita waste generation increase with income level. Low income residents generate lowest quantity (0.11-0.62kg/person/day), followed by medium income residents (0.16-0.49kg/ person/day) and highest by high income residents (0.29-0.88kg/ person/day). Per capita generation for high income group is high due to frequent disposed of bulk waste and high density waste such as wood products and glass, and also caused total density of MSW high (1.12kg/m^3), which is highest compared to other income group residents.

Education Level

Table 10 shows the range of MSW generated and physical properties from secondary and tertiary education level residents and Table 11 shows min of MSW generated and physical properties from secondary and tertiary education level residents.

Table 10: Range of MSW generated and physical properties from secondary and tertiary education level residents in Section 11 and 12, Petaling Jaya

Education level	Secondary	Tertiary
	Range	
Waste generated (kg/week/dwelling)	7.2-19.4	4.1-43.7
Per capita (kg/person/day)	0.14-0.88	0.11-0.62
Density (kg/m^3)	0.17-1.94	0.08-0.62
pH	5.7-6.0	4.6-6.1
Conductivity (µS)	257-969	83-932

Table 11: Min of MSW generated and physical properties from secondary and tertiary education level residents in Section 11 and 12, Petaling Jaya

Education	Secondary	Tertiary
	Min	
Waste generated (kg/week/dwelling)	11.3	10.4
Density (kg/m^3)	0.91	0.19
pH	6.0	5.7
Conductivity (µS)	506	271

Table 10 and 11 shows that people with secondary education level generate higher amount of solid waste per week per dwelling (11.3kg/week/dwelling), per capita waste generation (0.14-0.88kg/person/day), waste density (0.91kg/m^3), pH value (6.0) and conductivity (506µS) compared to people with tertiary education level. Even though the waste generated per dwelling by residents with secondary education level is higher than people with tertiary education level but the difference is less.

Waste Composition And Moisture Content

Table 12: Composition of MSW in Section 11 & 12, Petaling Jaya

Waste type	Percentage by weight (%)
Organic	42.0
Paper products	18.2
Plastics	18.7
Glass	4.3
Non-ferrous metal	3.4
Ferrous metal	0.5
Polystyrene	1.1
Others	11.8

Average MSW composition in Section 11 & 12, Petaling Jaya are organic 42.0%, paper products 18.2%, plastics 18.7%, glass 4.3%, non-ferrous metal 3.4%, ferrous metal 0.5%, polystyrene 1.1% and others 11.8% as shown in Table 12.

Average combustible matter is 80% and recyclable matter 45%, whereas the organic component is 42.0%. Moisture content of MSW ranged from 36.59% to 76.16%.

CONCLUSION

On the waste generation per dwelling aspect, socio-economic factors; housing type, occupational type, race and income level play a major role in MSW generation while educational level has a minor influence. Per capita generation, density, pH value and conductivity of MSW clearly influenced by all socio-economic factors discussed in this paper.

MSW from all type of housing area are acidic (pH<7) due to the food waste, which has deteriorated

Average MSW generation rate at Section 11 and 12, Petaling Jaya was 0.11-0.88kg/person/day and average MSW composition are organics 42.0%, paper 18.2%, plastics 18.7%, glass 4.3%, non-ferrous metal 3.4%, ferrous metal 0.5%, polystyrene 1.1% and others 11.8%.

Studies on socio-economic influence on MSW generation are important in every municipality for a better solid waste management and environmental management.

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Study On Malaysian Waste Minimization Behavior Of Malaysians

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Abstract: Research on household waste minimization have mainly focused on recycling. It is argued here that there is also a need to focus on reuse and reduction of waste, which deals more on waste prevention. The diversity of waste minimization behavior is therefore emphasized. This paper analyzed the declared reduction, reuse and recycling behavior of 2300 household in Malaysia, where 28 percent of respondents practiced recycling, while 58.4 percent of respondents practiced reuse of products. This paper concludes that there is a need to look into different waste minimizing behavior in implementing waste reduction approach rather than only focusing on recycling behavior.

Keywords: Reuse, reduce, recycling, source reduction, waste minimization, pro-environmental behavior

INTRODUCTION

Recycling is one of waste management method that expects society to manage their waste once it has been produced. Recycling, like land filling and incineration is a method to manage solid waste. In contrast, reduce and reuse aim to manage waste by minimizing the waste generation with emphasized placed on waste prevention. Whereas other waste management method deal with waste as an output, reduce and reuse considered as waste management alternative that avoid waste from being generated. In its scope, waste reduction is far more comprehensive. In all, reduce, reuse and recycling could be considered as waste minimization behavior.

METHOD

The data presented below was part of a nationwide survey on Municipal Solid Waste Management under the IRPA Project (No Project 04-02-02-0017) funded by Ministry of Sciences Technology and Environment. A total of 2300 respondents were randomly interviewed, representing the Northern, Central, Southern, Eastern regions of Peninsular Malaysia and East Malaysia (Sabah and Sarawak). A simple descriptive statistics was use to analyse various waste minimizing behaviors using a Statistical Package for Social Sciences (SPSS). The questionnaire responds rate was 92 % that is 2300 questionnaire collected from 2500 distributed.

RESULTS

Recycling

From the survey, about 93% of the respondents indicated they know about recycling program although only 28% practiced it by source separation. The type of recyclables separated are listed in Table 1, showing most recyclers separate news papers, followed by glass and cans. Most recyclers (72%) do recycling by sell them to door to door itinerant buyers while only 11% bring it into recyclable bin (Table 2).

Table 1: Type of Recyclables Separated

Type of Recyclable Separated	Frequencies	Ranking
News Paper	546	1
Glass	480	2
Can	413	3
Paper	350	4
Plastic	291	5
Metal	281	6

Table 2: Various Recyclable Collection Method

Various Recyclable Collection Methods	Frequency	Percentage
1. Sell recyclable to door to door itinerant buyers	465	72
2. Put recyclable on garbage bin	355	55
3. Bring to recyclable bin	71	11
4. Give to child to bring to school	67	10

In any attempt to change people's behavior one must address the problem of barriers than prevent people from recycling. The non-recycler stated their barriers to participate in recycling as listed in table 3. Mean value closer to '1' shows greater barrier and closer to '2' means lesser barrier.

Table 3: Survey questions on perceived barriers to recycling

Barriers to Recycling	Mean Value	Standard Deviation
1. There is not enough time to sort, store and bring the items	1.2991	0.46
2. No recycling program	1.3422	0.48
3. There is not enough room to store the items	1.4143	0.49
4. Place to receive recyclable items far from home	1.4137	0.49
5. Recycling programs not mandatory	1.4563	0.49

1: Yes 2 : No

Our study shows that most of barriers to recycling are lack of time and programs, as indicated from the least mean value from the series of statement that answer 'Yes'. When the survey was conducted in 1999/2000 the second recycling program was still not implemented.

Reduce

Our study indicates that 57% of the respondents know how to reduce their garbage, with 31% doing that by separating their recyclable items from their garbage.

The other 20% of respondents indicate they know about waste minimization program compare to 93% knowing of recycling program and 65% knowing about door-to-door itinerant buyer.

However only 14.4% practiced waste minimization in various ways as listed in Table 4 shows various minimization practices that indicate from the respondent answer 'Yes' from each statement on waste minimization practice.

Table 4: Participation in various waste minimization practice

Various Waste Minimization Practice	%
1. Reuse disposable items	11.7
2. Take into a account container reuse ability when buying product	11.1
3. Repaired broken product and reuse it	10.3
4. Take into account durability when buying product	10.0
5. Take into account reuse-ability when buying product	9.7
6. Take into account packaging when buying material (such as, avoid using plastic when buying vegetables)	8.4
7. Take into account material renewability when buying product	7.3

Reuse

Table 5 exhibits the results of frequency analysis on various reuse behaviors. On average 58% of the respondents practice it as home-based activities.

Table 5: Home-based activities of reuse behavior

Detailed of reuse behavior	Percent
1. Use disposable items different from initial purposes, such as use bottle milk to store food.	78.2
2. Repair old materials	59.7
3. Donate to others to reuse it.	52
4. Sells as disposable/recyclable items	43.6
Average	58.4

Reuse behavior may also be analysed from the respondents' decisions in purchasing some products; "whether they think the products as recyclable products or recyclable packaging?". As indicated in Table 6, the result shows that only 27.3% of the respondents thinks about recycle products and recyclable packaging in their decision to buy the products, whereas 38.3% of the respondents did not think about that. However, the result also shows that a great number of respondents (34.3%) never think about that. In general 66% of the respondent did not think about recyclable product and recyclable packaging in their decision in buying products.

Table 6: Consumer considerations of reuse behavior

Questioned: Do respondent think about recyclability of products and recyclable packaging in their decision on buying products?	Frequencies	Percent
Answers :		
Yes	629	27.3
No	881	38.3
Never	790	34.3
Total	2,300	100.0

DISCUSSION

Many researches focus on recycling as a first step towards the adoption of waste minimization behavior (Derksen & Gartrell 1993, Berger 1997). Recycling has been the cornerstone of waste management policy directed at consumers. The success of recycling campaign program may sensitize to individual to consider other environmentally related behavior. Thus recycling could function as a first step in developing an environmentally sustainable society. However, some findings contradict with this statement as discuss below.

Reuse and recycling behaviors can be considered representative instances of conservation practices. According to De Young (1991) reuse refers to source reducing, whereas recycling refers to waste reducing.

Source reduction, in its most basic sense, is an old behavior pattern (De Young et al. 1993). Actions such as repairing a damaged item rather than creating or buying a new one, saving used materials for reuse and producing objects that maximized efficient use of limited raw materials are among the reuse behavior pattern.

Our study indicates that various practice on reuse behavior are more prevalent than recycling source separation. Various practices on reuse behavior such as use disposable items different from initial purposes, use of bottle milk to store food, repair of old materials, donate to others to reuse it and sell the disposable/recyclable products are more practiced than source separation. It shows that 58% of reuse behavior are home-based activities while 28% are on source separation practice. Hence, here is potential to develop waste minimization that emphasize on reuse practices at home.

A comparison between home-based activities and consumer buying decision on recyclable products that reflect reuse behavior shows a different pattern. In our study, 27% of respondents consider consumer product characteristics such as recyclable products and recyclable packaging, compare to 58% on home-based activities.

Some researches state that various reuse behavior classified as home-based activities and consumer decisions are two different things.

Margai (1997) shows that by developing the recycling and waste prevention index (reduce/reuse) to analyze changes in waste reduction behavior in a low-income urban community in New York, waste prevention activities were not quite as successful as the recycling efforts. Although many residents were active participants in the recycling program, few were regularly involved in waste prevention activities such as reusing materials, buying concentrates or refillable items.

Another behavioral research on conservation motives assumed that individuals act according to what they perceive to be their greatest economic self-interest (Costanzo, et al. 1986). Result of our study perform such trend that is a higher frequency for home-based activities on reuse behavior rather than respondent participation on source separation. Our study on recycling method shows that most of recycler sell recyclable item to door-to-door itinerant buyers also shows an economic self-interest pattern.

It is possible to explain that people are more familiar with source reduction behavior at home and therefore are more able to alter them compare to change consumer-buying habit. However, further research is needed to better understand these findings.

Similar findings to our study was shows in a research by De Young et al. (1993). His research on 'promoting source reduction behavior' indicates that participants were reusing aluminum foil than buying items with less packaging.

The existence of facilities are among the important factors that support the waste minimization behavior. Our findings show that barriers to recycling are experienced by non-recycler. Research by De Young (1991) shows 'recycling is too much hassle' and 'there is not enough room to store the items' as main barriers to recycler. Hageman (1989) and Wang et al (1997) argued in their findings that factors related to facilities that made both practice easier are more relevant in determining the individual participation in any waste prevention program.

Logically it is assumed that a generalized environment concern factor underlies different types of pro-environmental behavior (e.g. recycling, energy conservation and water conservation). As stated above a recycling behavior can relates to reduce or other pro-environmental behavior. However, some empirical evidence indicates otherwise (Cook & Berrenberg 1981). Some authors have argued that recycling and reuse are two different kinds of environmental behaviors, which explains why determinants of one may be unrelated to the other (Oskamp et al. 1991, Ebreo & Vining 1994, Margai 1997).

CONCLUSION

Finally this paper concludes that any difficulties that household faced in implementing various waste minimization behavior would impact to their participation. Whereas reuse practice that are already familiar in Malaysia have the potential to be developed and implemented in various household activities rather than focus on household recycling participation in the situation where recycling programs and facilities are minimum.

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Comparative Assessment Of Alternative Waste Recycling Schemes In Thailand Using Two Multicriteria Analysis Techniques

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ABSTRACT: European Commission (EC) guidelines for Environmental Impact Assessment (EIA) and the Rapid Impact Assessment Matrix (RIAM™) were used as a framework for assessing three alternative waste handling scenarios in Southern Thailand, and the results were compared with earlier assessment results obtained using a the Recycling of Nutrients in Waste (RENUWA) multiple criteria assessment (MCA) methodology. The two analyses should point to the most sustainable sanitation system of the proposed alternatives. The results are used to verify if EU guidelines can fit a developing country scenario and if the simple RENUWA MCA methodology can produce similar results as the established RIAM tool with EU guidelines. However different in framework and application, both EIA's produced similar outputs, although differences in social componenets were noted. The stakeholder participatory analysis showed to be effective in assessing project impacts in the environment.

KEYWORDS: Multi-criteria analysis, MCA, environmental impact assessment, EIA, public participation, European Union, guidelines, waste recycling, developing countries.

INTRODUCTION

Environmental Impact Assessment (EIA) is mandatory in most projects in industrialized countries and becoming common in developing countries (Glasson et al., 1999). Many EIA's are based on MCA (Multi Criteria Analysis) techniques, which weight the project's parameters in a holistic manner. MCA is used as a decision support tool for planning and as project realignment tool as new data is constantly fed into the MCA. Some MCA's are complex in terms of frameworks and techniques, whereas others are simpler in their approaches (Yoon & Hwang, 1995).

An example of a simple MCA is RENUWA (REcycling plant NUtrients in WAste), which was developed by Schouw (2002) as part of a feasibility study of alternative waste handling scenarios in Southern Thailand. The output from RENUWA is an aggregated feasibility score. Another MCA-based tool is RIAM (Rapid Impact Assessment Matrix), which has earlier been used for appraising several development projects (Pakastia & Jensen, 1998). RIAM specifies criteria to score and weight each parameter and presents the partially aggregated outcome graphically. In principle, parameters can be defined freely and stakeholders may be involved when evaluating parameters irrespective of the MCA tool used.

Independently of the methodology used, MCA is expected to give a picture of the impact caused by an intervention in an area. This picture is however distorted by many factors such as uncertainty in data, difficulty in assessing present and future states of the environment and subjectivity in evaluating parameters, and it is complicated by policies, guidelines and stakeholders' conflicts.

In order to start to understand how those items can influence an MCA output when conducting EIA in development projects, a simple study is set up: the comparison of the RENUWA and RIAM MCA techniques using the same basic data but using partially different assessment parameters. The objective is to assess the implications of methodological differences when conducting MCA's. The paper compares only the results of these MCA's and not the influence of each of the MCA's elements and assumptions in their final output.

SITE AND RECYCLING SCENARIOS

Kuan Lang is a suburb of Hat Yai, the largest city in Songkhla Province, Thailand. About half the people in Kuan Lang (26,000 inhabitants) live as rice or rubber farmers in the rural area. The other half live as merchants or employees of factories in the periurban area.

Due to the intensification of the agricultural production during the last decades, the soils are being depleted from organic material and plant micronutrients. Consequences are low crop yield and soil erosion (Sombatpanit et al., 1995; Tonmanee and Kanchanakool, 1999; Mutert, 1995). At the same time, human wastes are discharged to streams and lakes or disposed at landfills, causing degradation of the water bodies, quickly filling the landfills and creating unhygienic conditions for the human settlements (Polprasert 1996, Emsong 1999, Schouw et al. 2002a,b). Thus, three waste handling scenarios with varying use of nutrient recycling were suggested for Kuan Lang (Schouw, 2002):

Scenario (option) 1: existing system consisting of septic tanks with drainage pits, wastewater discharge to surface water and disposal of solid kitchen waste at landfills

Table 1: RIAM matrix. Parameters are aggregated under each category and scored under each criterion. Ranges are shown in square brackets.

Category\Criteria	A1 – Importance of condition [0,4]	A2 – Magnitude of change/effect [-3,3]	B1 – Permanence [1,3]	B2 - Reversibility [1,3]	B3 - Cumulative [1,3]
Physical Chemical (PC)					
Biological Ecological (BE)					
Economic Operational (EO)					
Social Cultural (SC)					
Range meaning	*Local to global*	*Disadvantage to benefit*	*Temporary to permanent*	*Reversible to irreversible*	*Non-cumulative to cumulative*

Scenario (option) 2: modified system consisting of septic tanks with subsurface trickle irrigation to gardens, gray wastewater treatment in waste stabilization ponds and community composting of solid kitchen waste

Scenario (option) 3: alternative system consisting of composting latrines handling human excreta and solid kitchen waste and watering gardens with gray wastewater.

METHODS

Data collection

The basic data used in this paper was collected from various sources during a research project where the primary investigator resided in Thailand during several periods and worked in close collaboration with local stakeholders (Schouw et al., 2002a,b,c,d). The procedures associated with applying the two MCA techniques and presenting the results are explained below.

RENUWA

The basis for applying the RENUWA methodology was a participatory approach based on interviews and workshops with local farmers, laborers and merchants as well as representatives of municipal institutions and non-governmental organizations. The workshops played a role both when drawing up the three project scenarios (described above), identifying assessment parameters (scoping) and scoring and weighting of evaluation parameters (Schouw et al., 2002d).

This process led to 17 assessment parameters divided in three categories: environmental, social and economic (see table 3). For each parameter the project scenarios were ranked through discussions and voting at the workshops. Each parameter was then normalized within the three scenarios and simple additive method was used to aggregate the parameters in each category and weigh the categories based on preferences for environmental, economic and socio-cultural impacts.

The outcome from RENUWA was a single feasibility score for each scenario, see Schouw (2002) for details.

RIAM and EU guidelines

Rapid Impact Assessment Matrix (RIAM) is an EIA tool for pre-evaluating the consequences of a project. Assessment parameters can be defined freely within four impact categories: physical/chemical environment (PC), biological/-ecological environment (BE), economic/operational environment (EO) and social/cultural environment (SC) RIAM consists of a framework with focus on clearness of reporting the often subjective assessment of impacts, thus presenting results in a matrix of parameters versus criteria as shown in Table 1.

An environmental score (ES) is calculated for each assessment parameter as ES=A1xA2x(B1+B2+B3) where the 5 criteria (A1 to B3, each scored within a range) represent different features of the parameter (see table 1). The environmental scores for all assessment parameters are then divided into 11 ES categories (-E, -D, …, N, D, E, where N is neutral) and a histogram is finally prepared by stacking parameters with the same ES category. Histograms can be prepared for all parameters or for each impact category, see Figure 1 for examples. The graphical reporting increases the transparency of the results and the process behind the assessment. For details on RIAM, please refer to Pastakia & Jensen (1998).

European EIA checklists (European Commission, 1996a,b) were used as basis for the scoping process when identifying assessment parameters for inclusion in the RIAM analysis. These checklists are built on experience from the member countries on what can be relevant for the environment and helps addressing some of the most common issues of development in Europe. Doing the RIAM analysis, the EU guidelines provided a checklist of more than hundred parameters. We selected the parameters we judged relevant and removed parameters that resulted in a nil score for all three scenarios, which left 45 parameters; 12, 16, 5 and 12 parameters in the SC, EO, BE and PC impact categories (see table 2).

The scoping was conducted in the office and was only semi-independent from the scoping conducted as part of the RENUWA analysis, since the primary investigator of the RENUWA study also participated in the RIAM study. An effort was made to minimize bias in the scoring of parameters.

RESULTS

Comparison of RIAM and RENUWA parameters

As mentioned, the 17 RENUWA parameters are divided into three categories: environmental, economic and social whereas RIAM has four impact categories, PC, BE, SC and EO. An attempt was made to match each RENUWA parameter into the RIAM impact categories (Table 3).

Table 2: selected EU EIA guidelines used to build RIAM

Category	*Code*	*Parameter*
Socio / Cultural environment	SC1	Land use conflicts
	SC2	Reduction in surrounding and value
	SC3	Loss of tourism
	SC4	Loss of amenity
	SC5	Displaced or converted land use
	SC6	Creation of development potential
	SC7	Local labor market
	SC8	Scavenging working environment
	SC9	Public health
	SC10	Employment generated by municipality
	SC11	Stakeholder conflict of interest (Dissatisfaction)
	SC12	Degree/importance of public participation
Economic / operational environment	EO1	Local labour market
	EO2	Security of cash income generation
	EO3	Public health
	EO4	Income for municipality
	EO5	Drinking water regulation
	EO6	Solid waste regulation
	EO7	National development directive
	EO8	Regional development directive
	EO9	Local development directive
	EO10	Other organization/NGO development Perspectives
	EO11	Creation of development potential due to improved agricultural output
	EO12	Wastewater regulation
	EO13	Sanitation regulation
	EO14	Fertilizer application regulation
	EO15	Air quality regulation
	EO16	Recycling efficiency, as an alternative to import chemical fertilizers
Biological / ecological environment	BE1	Bio diversity
	BE2	Exposure to pathogens during waste handling
	BE3	Damage to agriculture due to application of toxic compounds
	BE4	Exposure to pathogens in water body
	BE5	Increase land fertility
Physical / Chemical environment	PC1	Degraded environment
	PC2	Odor
	PC3	Soil instability
	PC4	Water quality due to landfill leachate
	PC5	Landfill gas explosion risk
	PC6	Litter creation
	PC7	Particulate concentration from transport
	PC8	Toxic gasses from transport
	PC9	Water quality, due to mistakes during O&M
	PC10	Groundwater quality due to toilet discharge
	PC11	Surface water quality from grey wastewater discharge
	PC12	Landfill gas global effect

Table 3: RIAM-RENUWA parameters comparison

RIAM categories	Parameter	RENUWA categories	Possible/partial match (RIAM)
PC	Water pollution risk	Environment	PC1, PC4, PC10, PC11
	Air pollution risk	Environment	PC7, PC8, PC12
BE	Soil pollution risk	Environment	BE3
	Hygiene condition	Environment	BE2, BE4, PC9, SC8, SC9, EO3
	Energy Resource, consumption of fossil energy sources	Environment	
	Water Resource, consumption of water	Environment	
	Nutrient Resource, consumption/recovered quantity	Environment	BE5, EO16
	Organic Resource, recovered quantity	Environment	BE5
SC	Cultural accept by non-farmers (waste handlers)	Social	SC11
	Cultural accept by farmers (waste handlers/receivers)	Social	SC11
	Practical accept by non-farmers (waste handlers)	Social	SC11
	Practical accept by farmers (waste handlers/receivers)	Social	SC11
	Institutional Accept	Social	SC2-7, SC10
EO	Cost benefit analysis based on average private **farmers'** economy (waste handlers)	Economy	
	Cost benefit analysis based on average private **non-farmers'** economy, e.g. merchants, laborer, governmental employee (waste handlers/receivers)	Economy	
	Cost benefit analysis of the local municipality	Economy	EO4
	Institutional Accept	Social	EO5-10, EO12-14

Not all RENUWA parameters can be represented in the RIAM matrix and vice-versa – various matches are only partial, if possible. In addition, some RENUWA parameters are represented by more than one RIAM parameter. The opposite is also true.

RENUWA

The feasibility scores resulting from the original RENUWA study are 0.21, 0.23 and 0.56 for scenario 1, 2 and 3 respectively (Schouw, 2002).

RIAM

The outcome of RIAM is a graphic illustration of the three scenarios and a quantification of their environmental impacts, divided into physical/chemical (PC), biological/ecological (BE), social/cultural (SC) and economic/operational (EO) environs (Figure 1). Scenario 3 (composting latrine and local grey wastewater recycling) has the most positive/less negative score of the three in relation to physical/chemical and economical/operational impacts. The biological/ecological and social/cultural impacts are in the same range for scenario 3 and 2 (composting plant, subsurface trickle irrigation and waste stabilization ponds). The existing scenario 1 has the most negative impact.

To be able to compare the RIAM results with the RENUWA results, the latter has been transformed from its original one-feasibility-score into the same subdivision as RIAM (PC, BE, SC, EO). These results are illustrated in Figure 2. Scenario 3 has the highest feasibility score with respect to the physical/chemical (PC), economical/operational (EO) and biological/ecological (BE) impact categories of the three studied scenarios. However, the social/cultural (SC) feasibility is highest for the existing scenario 1. Just like in the RENUWA study the overall feasibility of scenarios 1 and 2 are lower than the feasibility of scenario 3.

Comparing the results of applying the two MCA tools to the South Thailand case study shows that scenario 3 in general is the best alternative. The socio/cultural parameters were defined very differently in the two tools; the SC parameters of RENUWA covered only about 1/12 of the SC parameters of RIAM, which resulted in the most substantial difference in results.

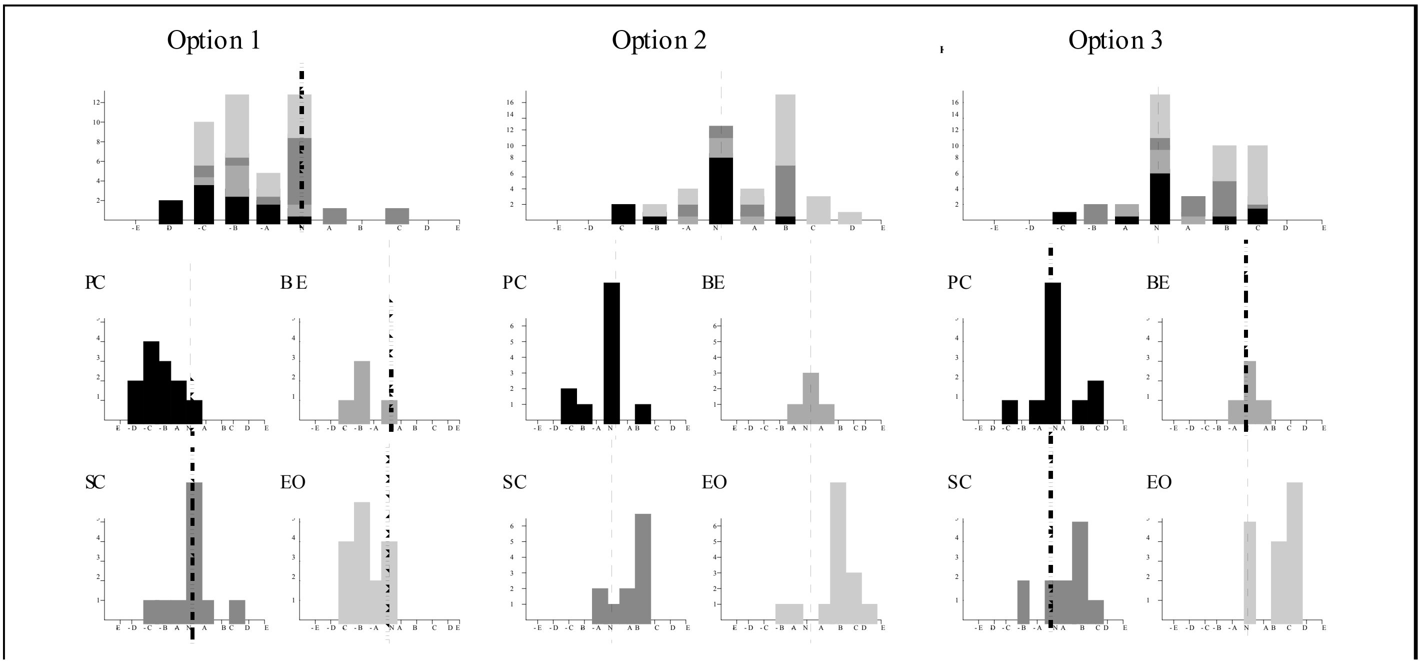

Figure 1: Results of RIAM analysis, divided into PC, BE, SC and EO categories. The vertical dotted line indicates the division between negative(left) and positive (right) impact in a given category; the further away from the center, the larger the impact.

DISCUSSION

General considerations

RIAM and RENUWA, although distinctly different in structure and methodology, presented similar trend results, as the existing system (scenario 1) seems to be more harmful to the environment than the modified one (scenario 2) and this more than the alternative one (scenario 3).

EU guidelines, used as a checklist for building the RIAM matrix, has given relevant parameters for solid waste and infrastructure interventions, although it is not made for recycling. It covers a broad range of environmental parameters and is reasonable with respect to socio-economics. The analysis for Kuan Lang did not search for extra parameters to be added onto the EU guidelines, and comparison between RIAM and RENUWA is "as is".

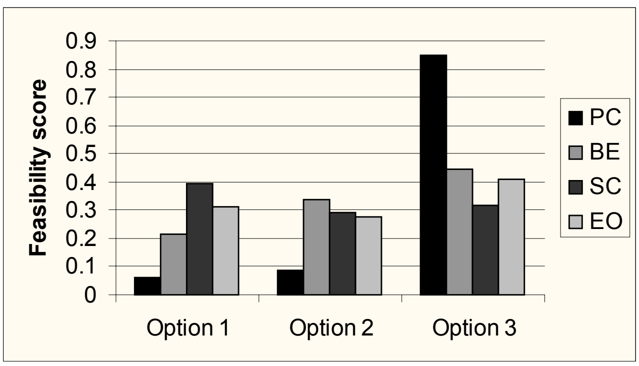

Figure 2: RENUWA results converted into RIAM categories

From scoping to presentation

From the EU parameters listed, more than 50 were used during the scoping and 45 after the post-scoping. Thus, if the guidelines had the advantage of easing the finding of "needed" parameters, it induced unnecessary parameters to be included in the analysis: these few parameters were removed because during the scoring they produced neutral results. Thus, the analysis could lead either to the same results as with fewer parameters (as only more neutral values would be added) or to erroneous outputs, if parameters would influence analysts to assert values different than zero to parameters that a priori would have little or no impact.

Comparing RENUWA to RIAM, it was realized that many fewer parameters were necessary in RENUWA to obtain similar results. 75% of the RENUWA parameters were covered by the RIAM analysis. The parameters from RENUWA were agreed among nonprofessionals and scored in the same fashion. That leads us to think that environmental assessment is not an exclusive expert craft, as locals have a vast knowledge of their environs, not always quantitatively but qualitatively. Whereas experts tend to consider all possible parameters to a given intervention, locals will guide the analysis by the understanding of the surroundings and base actions on common sense and essential parameters, what can lead them to good results.

Besides, public participation has the advantage of bringing experts and nonprofessionals together in a forum where they can work together towards reducing scoping size and compilation time.

Although the parameters have been distinct, the presence of an expert in both analyses could have led to similitude in final scoping, what could have contributed to the results' resemblances. The same can be noted to the scoring process.

Otherwise, scoring in the two MCA's is very different: RIAM is more complex as it pre-identifies criteria and ranges; RENUWA is freer in the scoring. That is interesting because both scorings give similar overall results. A remark can be made for the RENUWA's SC category, which shows higher scoring for scenario 1. Two points can be addressed: the fact that RENUWA was "converted" from three to four categories and that some SC parameters included "practical accept" of the scenario. While the first point could induce some distortion in the results, the second grant status quo to scenario 1, allowing for some inertia to changes.

Presentation of the two MCA's were very different. Whereas RENUWA provide a final number to each scenario, RIAM gave a visual presentation of the four categories built in one graph, providing for an independent analysis of the results.

All in all, analysis of the environmental impact can make use of different points-of-view, approaches and techniques to an issue in question and still arrive at basic congruent conclusions. It is important to take an overall discussion on the validity of MCA: it could be that MCA is an intermediary step for a more holistic analysis, since it has shown here to produce similar results in varied forms of data collection, scoping, scoring, analysis and interpretation, in pre- and post-assessments and including different analysts. The study could be hinting to deeper common features by which MCA's (EIA's) are one way of assessing and interpreting them.

Complementary studies will carry on identifying issues of assessment in different MCA tools.

CONCLUSION

Different MCA techniques can arrive at similar results: local community, using local knowledge and analysis, studied their environmental scenarios and arrived at similar results as experts using more sophisticated MCA tool.

EU guidelines have helped in presenting a broad checklist from which representative parameters in the context of the developing country's area could be used.

RIAM and RENUWA have proven to be valuable for assessing environmental issues in development projects.

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Valued-Added Products From Municipal Solid Waste

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ABSTRACT: Municipal Solid Wastes (MSW) from Kajang contains OF 58% putrescible waste, 10.2% paper, 2.8% metal, 2.70% glass and plastic 14.8%, and these are separated before composting and recovery can yield approximately RM50.00 per tonne. The organic content of MSW was as high as 67%, is suitable for biological treatment. The moisture content of MSW was between 65% to 75% while the C/N ratio of untreated MSW ranged from 30 to 80. Composting trials were carried out using MSW with additives such as goat manure (GM) and chicken manure (CM). The investigation indicated that MSW can undergo composting even without additives due to the presence of its' indigenous microbes, but it took about 8 weeks. However, the rate of composting increased with the addition of GM and CM and composting completed within 4 weeks. The C/N ratios of the compost after 4 weeks, ranged from 16 to 21, while the initial C/N ratios of the mixtures was 30 to 55. Application of the compost to water convolvus or "kangkung" (*Ipomea reptans*) showed that the compost enhanced leaf length by 10% to 50% compared to plants grown with inorganic fertiliser, at the same total nitrogen level.

Keywords: Composting, Recovery, Municipal Solid Waste, Planting Trial, Economics.

INTRODUCTION

Waste generation within Malaysia was found to depend very much on the sources of municipal solid waste (MSW). The generation rate varies greatly depending on the premises (house, shop, etc.), affluence of population (low income or high income), occupation or business. Malaysians generate about 72% compostable waste, comprising organic waste, paper, textile/leather and wood. The amount of plastic waste, which accounts for 16% is considered very high and is typical of a fast developing nation [Agamuthu, 2001].

The composting process has always occurred in nature. In recent years, however, composting practice and technology have increasingly relied upon scientific principles. Most modern composting operations consist of three basic steps: (a) processing of the municipal solid waste (MSW), (b) decomposition of the organic fraction of the MSW, and (c) preparation and marketing of the final compost product. Success of these operations, to a large extent, depended on proper accomplishment of the decomposition step [Hamoda, 1998]. Composting is a viable option for MSW treatment because it is cheap compared to many other treatment methods [Colacicco, 1982; White, 1995].

Composting of the MSW not only allows the waste to be degraded biologically but also produced a commercial product with the production of good compost. The application of compost to agricultural soil is recognised as an effective method of improving productivity in agro ecosystems [Fauziah, 2001].

In this study, the recovery yield of MSW in 1 tonne loading was determined from the recycled items/materials. Composting of MSW is an alternative treatment and disposal option to prevent environmental degradation. The composting experiment was conducted by adding goat manure (GM) and chicken manure (CM) to MSW. Field trials were conducted to determine the suitability of the application of the compost to plant (Kangkung, *Ipomea reptans*) leaf length.

MATERIALS AND METHODS

Waste Separation / Composition

The municipal solid waste was separated into various items or materials such as paper, metal, glass, plastic, textile, rubber, wood and organic waste and this was done in the landfill, the weight of each item was taken and recovery yield per tone of waste was determined according to the market price.

Composting Trials

Additives such as goat manure (GM) and chicken manure (CM) were added to MSW respectively. The mixtures of MSW and additives at different ratios are given in Table 1. The MSW without any additives was the control. The composting trial was carried out over a period of 4 weeks.

Table 1: Composting trial combinations with various ratios.

Combination	Ratio	MSW (kg)	Goat Manure (kg)	Chicken Manure (kg)
C1	100%	40	-	-
C2	2:1:1	20	10	10
C3	2:1	26.67	13.33	-
C4	1:1	20	20	-

Composting Pile

For each combination, the mixture was placed into 617mm x 437mm x 305mm bin in triplicates. The trial was carried out inside a roofed and partially walled hut in Institute of Biological Sciences' mini farm.

Sampling

Composite samples were taken from the middle of the bins at 0, 5, 10, 15, and 30 days. Approximately 100 g of samples were taken in triplicate each time.

Analysis

Carbon was determined using the Shimadzu TOC-5000A Analyser while the total nitrogen content was determined by the Kjeldahl method using a Tecator Kjeltec 1030 Analyser [Association of agricultural Chemists, 1975]. Moisture content was determined by placing samples at 110^{O}C in an oven for about 24 hours until a constant weight was obtained [American Public Health Association, 1985].

Planting Trial

Planting trial was set up to test the potential of the compost as organic fertilizer. The compost was tested at various combinations with different percentage of soil (Table 2), with each combination in triplicates. The plant used in the trial was "kangkung" (*Ipomea reptans*), which was planted in 0.10m x 0.10m x 0.20m, polybags. The compost used was on total-N basis, and 10% of compost contributed 0.07% to 0.1% of nitrogen while 50% of compost contributed 0.37% to 0.54% of nitrogen. The length of the "*kangkung"* leaf was measured and compared with *kangkung* grown with inorganic fertilizer, at the same nitrogen level for 40 days.

Table 2: Various combinations of garden soil and compost in planting trial.

Plot	Combination
1	K1/C = Control (100% Garden soil)
2	K2/C = 98% Garden soil + 2% Inorganic fertilizer
3	K1/C1 = 90% Garden soil + 10% Compost (100% MSW)
	K2/C1 = 50% Garden Soil + 50% Compost (100% MSW)
4	K1/C2 = 90% Garden soil + 10% Compost (MSW + Goat manure + Chicken manure; 2:1:1)
	K2/C2 = 50% Garden Soil + 50% Compost (MSW + Goat manure + Chicken manure; 2:1:1)
5	K1/C3 = 90% Garden soil + 10% Compost (MSW + Goat manure; 2:1)
	K2/C3 = 50% Garden Soil + 50% Compost (MSW + Goat manure; 2:1)
6	K1/C4 = 90% Garden soil + 10% Compost (MSW + Goat manure; 1:1)
	K2/C4 = 50% Garden Soil + 50% Compost (MSW + Goat manure; 1:1)

RESULTS AND DISCUSSION

Waste Composition And Recovery

Waste used in this study contained about 58% of putrescibles, 14.8% plastic, 10.2% paper, 0.9% rubber, 1.4% textile, 2.8% metal, 2.7% glass and 2.0% wood (Table 3). The recovery yield from the recycled items/materials can reached up to approximately RM50.00 (Table 5) per 1 tonne loading, and this amount is according to the market price (Table 4). This amount comprised of RM14.80 of plastic, RM5.10 of paper, RM28.56 metal and RM1.35 glass. If this amount of recovery yield is applied to total waste generated by Malaysians daily, which is 16,000 tonne, the recovery yield of MSW in Malaysia will be RM800, 000 per day!

Table 3: Price of recycled items / materials per kg with conditions and some examples.

Items / Material	Price per kg	Conditions	Some example
Aluminium Cans	RM1.00	Crushed	Soft drink cans
Tin Cans	2 cents	No rusty tins	Food, biscuit & milk tins
Paper	5 cents	No food wrappers	Newspapers, magazines, telephone books, cardboard boxes.
Glass bottles / jars	5 cents	Clear or coloured	Vitamin, jam and drink bottles
Plastic	10 cents	--	Drink bottles / straws, Tupper wares, plastic bags, wrappings.
Useable clothing	15 cents	No torn clothes or rags	Adult's / children clothes.

Source: Petaling Jaya Community Centre [8]

Table 4: Average of municipal solid waste (MSW) composition per tonne at Sungai Kembong landfill, Kajang.

Items	Percentage (wt, %)
Plastic	14.8
Putrescibles	58.0
Paper	10.2
Rubber	0.9
Textile	1.4
Metal	2.8
Glass	2.7
Wood	2.0
Others	7.2
TOTAL	100.0

However, there is no fixed price for the recycled items and the erratic price fluctuations favour incineration or landfilling; the latter where land is not a constraint factor. More recently, environmental economists argue that the cost of recycling actually increases the price of that commodity compared to the original product produced from natural raw materials. For instance, recycled paper costs more (in Malaysia) than paper of original raw materials [Agamuthu, 2001].

Table 5: Recovery yield from municipal solid waste (MSW) in 1 tonne lorry.

Items	Price per kg	Percentage (wt, %)	Total (RM)
Plastic	10 cents	14.8	14.80
Putrescibles	-	58.0	-
Paper	5 cents	10.2	5.10
Rubber	-	0.9	-
Textile	-	1.4	-
Metal	RM1.02	2.8	28.56
Glass	5 cents	2.7	1.35
Wood	-	2.0	-
Others	-	7.2	-
TOTAL AMOUNT		100.0	**49.81 ≈ 50.00**

C / N Ratios

The C/N ratio before composting ranged from 30 to 55. The C/N ratio for C2, C3 and C4 was intentionally started at 30:1, as 30 to 40 times available carbons is required compared to nitrogen in organisms activities, that this ratio would be the most favourable for composting [Agamuthu, 2003]. After 4 weeks of composting, the C/N ratios for the mixtures were from 16 to 21 (Figure 1.0). This result showed that the addition of additives such as goat manure (GM) and chicken manure (CM) to MSW, not only enhanced the composting process but gave ideal C/N ratios to the final composts. Combination of MSW + GM + CM with 2:1:1 ratios, gives the best C/N ratios, which is 16:1.

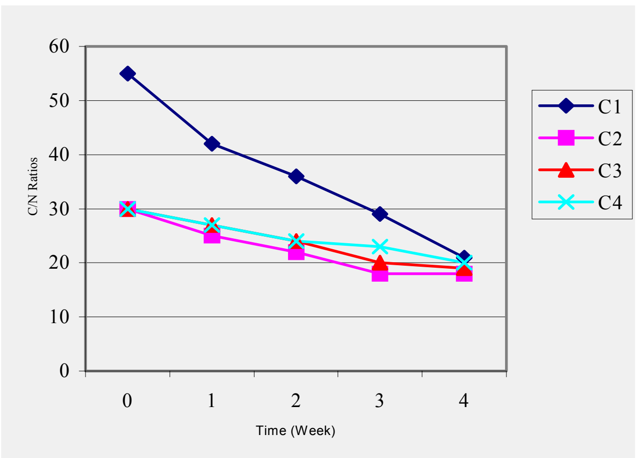

Figure 1. C/N ratios of compost mixtures for 4 weeks

C1 = Control (100 % Municipal Solid Waste / MSW)
C2 = MSW + Goat Manure + Chicken Manure (2:1:1)
C3 = MSW + Goat Manure (2:1)
C4 = MSW + Goat Manure (1:1)

Planting Trial

Planting trial was conducted for forty days in 0.10m x 0.10m x 0.20m polybags. The result showed that the plant labelled as K2/C2, which was planted in the mixture of 50% garden soil + 50% compost (MSW + GM + CM; 2:1:1), gave the longest leaf, which was 18cm within 40 days (see Figure 3). This is compared with *kangkung* planted in 98% garden soil + 2% inorganic fertilizer, where the length of leaf was 9 cm within 40 days. This result showed that the combination of MSW + GM + CM; 2:1:1 can enhance the leaf length of *kangkung* by 50%.

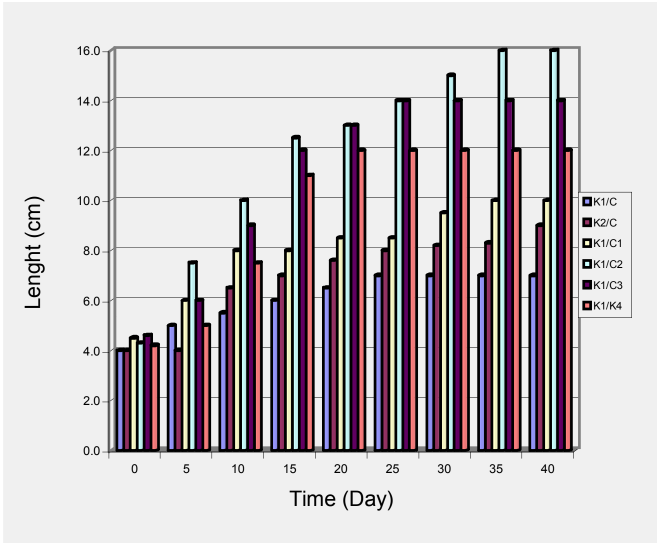

Figure 2. Leaf Length (*kangkong*) with 10% compost.

K1/C = Control (100% Garden soil)
K2/C = 98% Garden soil + 2% Inorganic fertilizer
K1/C1 = 90% Garden soil + 10% Compost (100% MSW)
K1/C2 = 90% Garden soil + 10% Compost (MSW + GM + CM; 2:1:1)
K1/C3 = 90% Garden soil + 10% Compost (MSW + GM; 2:1)
K1/C4 = 90% Garden soil + 10% Compost (MSW + GM; 1:1)

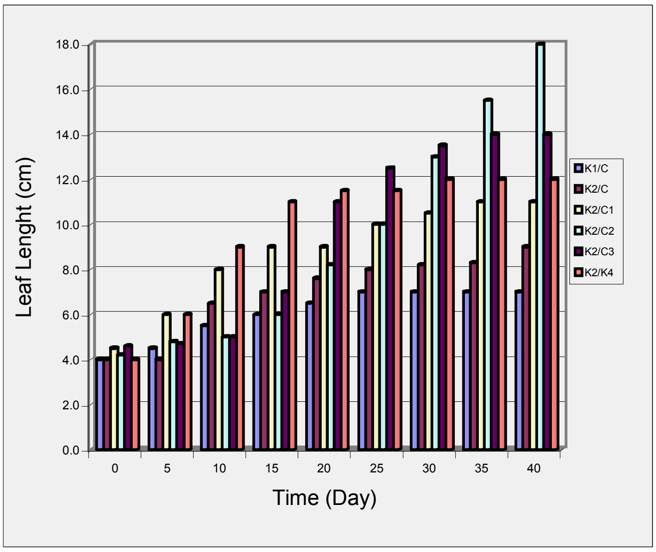

Figure 3. Leaf length *(kangkong)* with 50% compost.

K1/C = Control (100% Garden Soil)

K2/C = 98% Garden Soil + 2% Inorganic fertilizer

K2/C1 = 50% Garden Soil + 50% Compost (100% MSW)

K2/C2 = 50% Garden Soil + 50% Compost (MSW + GM + CM; 2:1:1)

K2/C3 = 50% Garden Soil + 50% Compost (MSW + GM; 2:1)

K2/C4 = 50% Garden Soil + 50% Compost (MSW + GM; 1:1)

CONCLUSION

The recovery yield from the recycled items/materials can reached up to approximately RM50.00 per 1 tonne loading. Addition of additives such as goat manure (GM) and chicken manure (CM) to MSW, not only enhanced the composting of MSW but gave ideal C/N ratios to the final composts, which was 16:1. Application of the mixture of 50% garden soil + 50% compost (MSW + GM + CM; 2:1:1), to water convolvus or *kangkung* (*Ipomea reptans*) showed that the compost enhanced leaf length from 10% to 50% compared to plants grown with inorganic fertiliser, at the same total nitrogen level.

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Waste Management and Sustainable Development: The Journalists' Role

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ABSTRACT: Journalists have often been described as the fourth estate of the realm because they are the watchdog of the society and have the ability, capability and well withal to shape the society positively via accurate gathering, processing and reporting of information cum news. Waste Management and Sustainable Development has been two important phenomenons that have faced every nation that wants to forge ahead in relation to economic prosperity. Journalists' have a great role to play in this regard especially in the areas of massive environmental education campaign to all the stakeholders concerned with environmental issues as well as to the general members of the public.

Keywords: Waste management, sustainable development and role of journalists

INTRODUCTION

Environmental journalism is a relatively recent phenomenon. Three decades ago, few journalists wrote about environmental issues in any depth. Concerns about natural resources and habitats were not yet a widespread grassroots issue. Today, most news organizations especially those in the developed world recognize that the environment is a major story.

Covering the environment can no longer be regarded as an exotic beat. But it will most likely always be a complicated one. Environmental issues have economic, political, sociological and public health connections. They transcend borders. In developing countries, where the need for growth is particularly strong and the potential for ecological damage severe, the issue is heightened. Timely and accurate reporting of environmental issues such as improper waste management and sustainable development is more necessary now than ever. This is so because as the world has become a global village via hi-technology, whatever affects one nation or a sub-section or a continent obviously affects others either directly or indirectly.

On the other hand, the generation of toxic or hazardous waste is an unfortunate but inevitable by-product of modern industry. Excessive exposure to certain toxic wastes may lead to serious human health effects and even deaths in some cases. Thus arises the social question of whether the economic benefits derived from any such are worth the costs in human life, and suffering, resulting from pollution. This is a question, which only the society can answer balancing the scientific evidence audits moral values against the political and economic situation and social expectations of a nation, and the world at large.

Besides, industries may create occupational health risks for their employees in their work environment and also public health risks due to pollution of the surrounding air, water and land environment. Improper waste management may thus pose serious health risks for both. It may also pose potential threats to public health during transportation to and processing or dumping at the final disposal site.

Furthermore, the environment is an important and critical issue of our time. Manifestations of environmental degradations and improper waste management affect all countries of the world directly or indirectly. It is on the basis of the above that environmental journalists have a crucial role to play in relation to complementing government efforts in the areas of enacting waste management and sustainable development policies and other related issues by ensuring constant gathering, processing and dissemination of environmental news to the members of the public as at when due through the media of information meant for it.

Moreover, this paper attempts to define waste management as it is applied to hazardous cum toxic wastes and wastes generated from homes, sustainable development and environment. Efforts are also made to buttress the various roles of environmental journalists in waste management as well as unveiling the factors responsible for poor coverage of environmental issues.

Finally a broad recommendation is made to help journalists rise up to the challenges as well as problems associated with waste management and sustainable development.

WASTE MANAGEMENT DEFINED

Waste management has to do with ways and techniques to get rid of worthless, damaged materials that are of no use. It might be poisonous wastes from chemicals, manufacturing firms, nuclear wastes and contaminants from other areas or sources.

According to Oxford dictionary hazardous is defined as "causing danger or risk" and toxic is defined as "of or caused by, or acting as a poison". From the above definitions, one can see that hazardous and toxic wastes are called based on the presence of certain compounds within the waste rendering it hazardous or toxic. However, domestic waste, which is not, classified as hazardous or toxic contains compounds such as copper or nickel compounds.

In addition, waste management are aimed at ensuring that wastes are managed soundly to minimize risk, ambiguity, uncertainty and doubt.

SUSTAINABLE DEVELOPMENT DEFINED

The basic concept governing sustainable development is that environment and development is inter-related. Development cannot be based on deteriorating environmental resource base and the environment cannot be protected when growth neglects the full costs of environmental destruction. These problems cannot be treated separately by fragmented institutions and policies as they are linked in a complex system of cause and effect.

According to World Commission on Environment and Development, sustainable development means "development that meets the needs of the present without compromising the ability of future generations to meet their own needs". Economic growth is usually measured by level of per capita income that has been attained by a country. Rapid economic growth can be fuelled by the exploitation of natural resources both renewable and non-renewable. Growth, which makes excessive use of natural resources leading to over-exploitation, can have detrimental effects on the resource base and the environment. Private maximization of profits and short-run considerations to accelerate growth often ignore social costs and environmental consequences.

Besides, the structural changes that accompany socio-economic development are often exacerbated by high rates of population growth. For instance, where land is scarce, great pressure is placed on the land arising from the demand for food. Human ability to make proper use of natural resource will be reduced with the presence of poverty, thus adding greater stress to the environment. Poverty is the major source of environmental degradation, which undermines sustainable development in both developing and industrialized nations.

As result of the above, stagnant and deteriorating growth must be rectified as there is a strong relationship between economic growth, reduction of poverty and the enhancement of the quality of the environment. Therefore, economic growth must be encouraged especially in developing countries and this will, at the same-time, help in the enhancement of the environmental resource base.

Nevertheless, growth which is necessary measured in terms of material wealth alone is an inadequate measure of the progress of human kind. New paradigms of growth must evolve in which sustainable equity; social justice and security are firmly embedded as major social goals. Development planners should take into account in their reckoning of national wealth, not only conventional economic indicators, but also the state of the stock of natural resources. Better income distribution, reduced vulnerability to natural disasters and technological risks, improved health and preservation of cultural heritage; all contribute to the quality of that growth.

On the other hand, to achieve sustainable development, environmental journalists must be in the forefront in relation to gathering, processing and dissemination of information to the members of the public on proper waste management practices. They can do this by creating massive awareness via both the print and broadcast media aimed at educating the entire globe on the need to implore "caution and care" in waste management and disposal.

Besides, it is the duty of environmental journalists to ensure that governments pursue genuine economic developments that adequate and prompt information are relayed to commensurate it with the pace of development, so that both can move along without being a threat to each other. Firstly, the idea behind this assertion is that informed society goes hand in hand with rate of development both socially, culturally, economically and politically. Secondly, this has become necessary because the more citizens of any nation are environmentally educated and friendly, the more the environment is protected and economic growth maintained and sustained.

ROLES OF ENVIRONMENTAL JOURNALISTS

Before going into the basic roles of environmental journalists in waste management, as well as, in other environmental cum sustainable development issues, it is pertinent to ask the question; "who is an environmental journalist? A more restricted definition of environmental journalism according to Sharon M. Friedman (1988) is "Environmental Journalism is that which covers environmental concerns on a continuing scale, from those that are international in scope to those that are smaller-scale and personal. It includes problems and positive activities. International problems worth covering includes the ever-present growth of human populations, poverty and lack of food to feed increasing numbers of people and inter-related problems of environmental destruction such as deforestation, desertification, soil erosion, and habitat. International positive activities includes the concerted efforts led by United Nations to limit the amount of ozone in the atmosphere, international treaties to protect endangered species and cooperative efforts among nations to help transfer appropriate technologies.

Nationally, there are problems of increasing urbanization and the accompanying air, water and noise pollution as well as waste management and disposal that are part of the environment beat. Positive national activities would include sustainable development planning projects that take into account preservation of national resources".

In my view, environmental journalism is the dissemination of information on the need to protect and preserve the basic core of our environment and thus continues to introduce changes for better living of the people. This can be achieved only through mounting comprehensive environmental education programmes to sensitise, motivate and educate different cross-sections of the society. The success of environmental journalism would depend mainly on the mass awareness, involvement and participation of all and sundry.

On the other hand, environmental journalism by P.R.R. Sinha (1983) entails "Given journalists the opportunity to report about the world we live in, it relates both to a personal world comprising health, home, village, town, country or region and to the earth itself comprising land, sea and air. It can be natural and man-made or any where between the two as nature and man are in constant interaction with each other. In other words, they are dove-tailed in a cause and effect relationship".

From the above definitions one can deduce that environmental journalism embraces creating environmental consciousness among the people, planners, decision makers and professionals about protection, preservation, and improvement of environment on a lasting basis. The success of environmental journalism would depend on desirable change in thinking and doing of the people. It is therefore absolutely essential to make appropriate communication choices because the gamut of not only transmission but also application of its knowledge is quite crucial when it comes to desirable change in knowledge, attitude, skill and behaviour of the people.

Environmental journalists are expected to find ways of communicating crucial messages and issues like waste management and sustainable development to the broadest mass of people in order to create awareness among them. They are given the task and duty to bring the crucial issues and problems regarding development and environmental programmes to the authorities concerned. Environmental journalists should be seen as the bridge between creating awareness between environmental experts and communicators on one hand and passage of environmental information to the masses effectively on the other hand.

Having clearly explained cum defined who an environmental journalists is, the question that looms large at this stage is "what are the roles of an environmental journalists? First and foremost, it is the duty of environmental journalists to embark on environmental education. Environmental education has to do with organising mass media activities aimed at sensitising the society on the need to be environmentally friendly. Governments might come up with good and sound environmental laws and legislations with a view to making the environment a better place for all and sundry. But without journalists rising up to their basic roles as educators, voice of the voiceless, and defender of the defenceless and above all the fourth estate of realm, these laws would become inevitably a toothless bulldog.

My recent research study on the "Efficacy of Environmental health Journalism of Pennsylvania State USA and Malaysia" has shown that environmental education by the media in Malaysia is still in the process of evolving, developing and becoming when compared to Pennsylvania State USA where it has become a part and parcel of the lifestyle of the media and the entire citizenry.

Priority Factor

Furthermore, it is the role of journalists to learn to make environmental stories a daily affair and give such stories front-page priority rather than issues like politics and economics. This has become necessary so that people know the importance attached to environmental cleanliness and hygiene. Whether journalists like it or not, it is their responsibility to ensure that waste management and sustainable development as well as other environmental issues is reported regularly.

Role As Educators

Journalists should organize workshops, conferences and seminars promptly with a view to educating the members of the public. For economic growth to be sustained and maintained, journalists should come up with waste management programs that would enable the citizens and the society at large to implement such programs fairly, equitably and effectively.

Besides, journalists should understand that it is their duty to come up with three fold mission with a view to expanding information, knowledge and education to help the society and government address waste management and sustainable development issues through education, professional training of environmental organizations and non-governmental organizations, public outreach activities and deployment cum transfer of new environmental applications and techniques to the people via media advertisements such as planning billboards at highways and other designated centres.

Environmental Action Plan

Environmental journalists has the duty to come up with environmental news coverage action plan that would assist various levels of government and private companies in environmental restoration, waste minimization, pollution prevention and sustainable development. The above has become necessary because it will help the government and other stakeholders to select, direct and conduct environmental projects and activities that would not be extremely harmful to the environment. Again, the commencement of this kind of environmental awareness programs by journalists would as well help states, industrial organizations, educational institutions, tribal agencies and above all rural communities to be committed and relevant in environmental issues.

Dissemination Of Relevant Information

Another role of journalists in waste management and sustainable development is that they have the duty to design and disseminate significant information on critical waste management and sustainable development issues. This would enable the members of the public to know about variety of issues concerning waste management issues within and outside their localities.

Role As Watchdog

Besides, accepting an educational role for the media, however, does not negate another key function of environmental journalists that is being a watchdog. Being a watchdog is one of the prime goals of investigative journalism. Environmental journalism cannot be carried out effectively without journalists doing more underground work and herein lies the power and knowledge of investigation. For journalists to perform this role, he or she needs to have some knowledge of the situation. Being a watchdog means trying to find out if all that should to be done is being done and, if not, why not. Environmental journalists have the responsibility to keep informed, even when they are faced with bureaucratic barriers.

Role As Information Disseminator

Environmental journalists have the duty to carry essential information for prevention and control of improper waste management health risks and exposures to the members of the public. Such information that centres on protecting the general public includes proper methods of storing and transportation of wastes, as well as final treatment or disposal to avoid contamination of community food and water supplies. Journalists are also expected to emphasise their reporting on monitoring by government agencies to ensure compliance with governmental environmental quality standards.

FACTORS RESPONSIBLE FOR POOR COVERAGE OF ENVIRONMENTAL ISSUES BY JOURNALISTS

Environment affects everyone. From environmental degradation, improper waste management and disposal, biodiversity, endangered species, to today’s air and water pollution resulting from advances in technology and development, environment is a major part of our daily life.

While these issues have been part of environmental periodical reporting for decades, environmental issues like waste management and sustainable development have come to a hurt in periodicals of news reporting especially in developing countries were the resources and fund for training of journalists are rarely available. Thus there are numerous factors that have contributed to poor coverage of environmental issues by journalists. They range from short complexity and technicality of environmental reporting to short deadlines, lack of press freedom, inadequate training etc.

Complexity And Technicality Problem

In the early 1980s, journalists began addressing environmental and food safety issues. By the time these types of issues received their attention, however, the issues were so complex that many journalists were overwhelmed by their complexities and technicalities. Whereas journalists had been trained in how to write ordinary new-stories, they are ill-equipped to fully understand the complex relationship between disseminating information to the members of the public as at when due and the consequences of not living up to the expectations cum demands of their profession. If information is tainted, the newly empowered readers and viewers often reacted (or over reacted) in a misinformed manner (LayMay and Dennis 1991). This assertion by LayMay and Dennis means that when journalists fails to report objectively, knowledgeably, they would be faced with the problem of lack of confidence by the members of the public. Thus media education has become necessary.

Lack Of Press Freedom

This is one the main issues that has rendered journalists ineffective in the discharge of their professional duties especially in countries with authoritarian regimes. Because journalists are afraid of molestation, harassment and undue detention and imprisonment, most news editors and managers find it difficult to publish stories that are against the government or that of the interest of those in authority. In this kind of society, journalists more or less do not embark on investigative reporting or criticise the government but rather they become megaphones of such regimes thereby jeopardising the right of the society cum citizens to have access to objective and fair information. Thus in a situation like this, journalists forget their primary function of being the watchdog of the society.

Deadlines

Most hard news articles are written under tough and intense deadlines of hours and not days. Even if environmental story like waste management and sustainable development has good news peg, there still may not be enough time to investigate all of its ramifications properly.

Short deadlines also means lack of interpretative and investigative journalism, yet this is precisely where journalists play their most important roles as educators and watchdogs. Here they tell their readers what things or events means, putting events and issues into context. As a result of short deadlines, journalists are forced to use stories handed to by their sources rather than talking to more knowledgeable people or sources. It is a very big problem and has constituted a set back in environmental journalism

RECOMMENDATIONS

Journalists have a professional responsibility to educate the people on proper waste management practices, sustainable development and other environmental issues. To fairly present all sides of a story, journalists should strive to use wider variety of sources for factual information, rather than relying heavily on governmental sources. All facets of waste management and sustainable development issues should be explored rather than merely relying on easiest sources to furnish information. This can only be achieved if journalists are proficient in securing diverse and accurate information under a society that tolerates absolute freedom of the press.

Again, journalists (and editors) should be given adequate training in science and environmental writing techniques in order for them to meet up with the scientific nature of environmental reporting. Most journalists are afraid to cover the environment beat because they lack the knowledge and experience to understand the jargons involved. Environmental reporters are expected to turn scientific gibberish into clear, concise language. They should understand that most newspaper readers, television viewers or radio listeners have neither time nor inclination to turn to the dictionary to decipher environmental terms.

Environmentalists, governments and other stakeholders should voice their concerns and opinions of journalists inadequate cum lukewarm attitude regarding the coverage of waste management and sustainable development issues as well as other environmental problems to both journalists and other news managers within and around them. They should always make journalists to realise that they have the responsibility to report news both accurately and fairly. However, all the responsibility for policing the journalism profession does not rest with journalists. The general public has a responsibility to asses information in an open and evaluative manner. If either group fails in their duties, responsible reporting and consumption of waste management and sustainable development reporting will not occur. If this process fails, both government, environmentalists and the members of the general public are likely to suffer from the commission or omission, of practices that either positively or negatively affects waste management and other environmental issues.

Above all, journalists must all remember to follow–up stories. Even the best, concise, most-well written story will have a minimal impact if it appears just once in a newspaper or on a newscast. As with other stories, the environment has to be kept in the forefront of the news. Important stories have to be revisited to keep readers and viewers up to date on the latest development

CONCLUSION

The environment will always be a hard story for journalists to cover. In some ways, of course, the story of our destruction of the environment continues. It is essential to report on the conflicts between rich and poor nations, between corporations and municipalities and people who live on the edge of waste dumps, between scientists with different opinions of our problems and different opinions about how to solve them.

Environmental journalists should understand that their inability to educate the members of the public properly on the need to manage their wastes effectively and efficiently, will eventually result in environmental degradation anywhere and thus would cause unforeseeable consequences elsewhere. As a result, we are all part of the environment, and we cannot poison the earth, its waterways or its air without eventually poisoning ourselves.

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6 Urban Environment/Health & Safety

Urban Environmental Quality And Its Impact On Urban Dwellers: A Model For The Klang Valley Basin

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INTRODUCTION

Urbanization provides the driving force and acts as a catalyst for growth and development of a region or country. As dynamic entities the activities within urban areas must be sustained. There are three main factors that regulate the continual growth of an urban area. These are often related to (1) urban commerce, (2) population increase – employment opportunities and (3) the transfer of goods and information.

Urban growth and commerce are intricately linked. Although it is not entirely clear which fuels, which, urban areas usually provide a natural locus for economic growth. Commercial and industrial activities usually concentrate in urban areas because of the economies of scale these areas offer, besides, urban areas also provide fast, cheap transportation and flexible but highly productive labour markets. Urban areas also facilitate diffusion of products, ideas and human resources between urban, sub-urban and the rural areas. Industries and commercial activities in cities in turn, attract other ancillary services to support them and this interdependency provides the urban areas with more competitive advantages.

In addition to economic activities, population increase and other demographic forces too underlie urban growth. In most developing countries today, natural increase contributes as much as that by rural-urban migration to the increase in urban population. Another contributor to urban growth is the reclassification of city boundaries, which often result in dramatic changes in the urban size. The increase in the urban population has various social and economic implications, which in turn has their toll on the environment. By itself, rural-urban migration manifests many problems, closely tied to employment, housing and other basic amenities. Thus, although most migrants feel that relocation to the city has improve their situation, many others are unable to find work and forced to take up ill-paying or hazardous jobs, unable to generate enough income to meet their basic needs and thus join the ranks of the urban poor. The general consensus today is that, although poverty has for many years been concentrated in the rural areas, the shift of population from rural to urban has made poverty an increasingly urban phenomenon. The World Bank estimated that by year 2000, about half of the developing world's absolute poor will be in urban areas. In Malaysia about 12 Million of its inhabitants live in urban areas. The United Nations Population Division reinforced this survey by stating that by 2020 the total number of the urban population would be closed to 20 million.

Finally and very closely related to the above is employment opportunities which remains a significant problem in most cities of developing countries, largely because the formal economies of these countries are unable to absorb the enormous influx of workers into the cities. Thus, a substantial number of the urban poor make their living through involving in the informal sectors.

Urban growth thus promotes economic advantages to other aspects of life: higher income, improved health, higher literacy, and improved quality of life to the less tangible advantages like access to information, diversity, creativity and innovation. However, along these benefits come environmental and social ills- including a diversity of problems from lack of access to clean drinking water to urban air pollution, green house gas emissions. These problems have become the major concern among social and physical scientists, policy makers and planners. The main issue of concern is the sustainability of the urban system both as a suitable habitat for mankind and in terms of their ecological and environmental support system. Evidences have shown that with the rapidity and the manner at which urbanization and urban growth is taking place, the general state of the environment as well as the quality of life in some parts of the urban areas are rapidly deteriorating.

Urban Growth And The Disruptions Of Natural Process Regimes

Urban areas can be regarded as "*living systems*" or "*super-organisms*" which need resources (environmental and human) to sustain them and also for their continual growth and evolution. However, growth is not only related to changes in *form structure* but also within the environmental setting where growth is taking place and by doing so obliterates and modifies existing *environmental process regimes* there and that of adjoining environments. Each form of urban growth is associated with different phases of development activities. These activities in themselves can either change the frequency and magnitude (intensity) of certain processes and can also contribute to the formation of new processes. The increase frequency and intensity of urban floods are often related to the phases of activities associated with the development of urban built up areas. In another example the intensity of *corridor winds* are also associated with phases of activities associated with high-rise development, which not only realigned wind paths but also promotes convergence, thus increasing wind velocity and force. The disruption of natural process regimes can also bring about new processes into the urban system. The *urban heat island* phenomena is a classic example of new processes been injected into the urban system. Urban built up areas are generally made up of energy absorbing materials, such as asphalt, bitumen, glass, and concrete. Urban built up areas are generally denser and agglomerates toward the urban centers. During night time, the materials reemit back the energy thus creating a dome shaped temperature inversion within the urban areas. In the last decade the Klang River Basin also had experienced a number of man-induced processes that includes, riverbank slumping, rapid mass movement processes and urban pollution (air, water and land). Figure 1 shows how urban growth and the various development activities associated with it could disrupt the various natural process regimes within an urban area. This figure describes that urban resource development would involve a number of development activities. Each development activity can disrupt and be associated with a new process regime. Khairulmaini (1993), for example, describes the relationship between housing development and its associated phases of activities and the different process response regimes (Figure 2). In the study, it was observed that, the initial phases of land clearing and leveling subject the area to surface wash processes that culminate into rills and gullies, which eventually leads to much sediment removal from the area.

Urban resource development must lead to the generation of wastes and by products as a result of *work* performed, which is disposed of within and eventually outside of the Klang River Basin. The generation of wastes can occur in any of the major subsystems of the urban environment (Figure 3). For example urban pollution is associated with waste pollutants in the atmospheric systems, whilst industrial effluents are disposed of as wastewaters in urban streams and drainage networks. Plate 1 for example shows the relationships between urban wastes and its impact on the land system. Plate 1 also describes the interrelationships between the environmental subsystems of urban areas. Here, the immediate impact of urban wastes would be to impose new processes on the land system. For example, depending on the type and content of waste, toxicfication of the land system would occur, which would eventually make its way into the adjoining groundwater subsystems or if the waste is burnt this would impose itself on the atmospheric subsystem. It is during these process of disruptions to urban environmental process regimes and the generation of wastes that the KRB generate environmental problems that cover over a range of human resident spatial scales- the household, community neighborhood, the city, the region and globally (Fauza and Khairulmaini 1995).

Figure 1.Urban Growth And The Disruption Of Natural Process Regimes

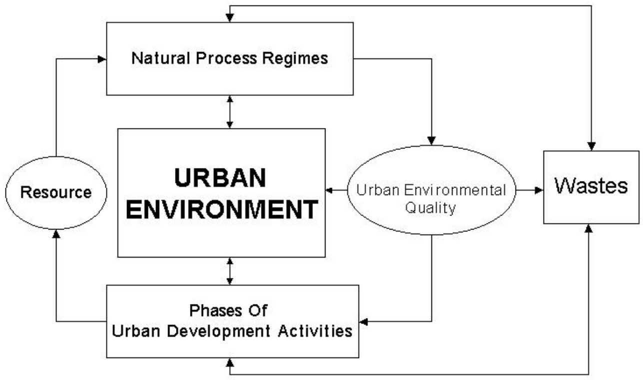


Figure 2. The Relationships Between Development Activities And Environmental Degradation During A Housing Development Project

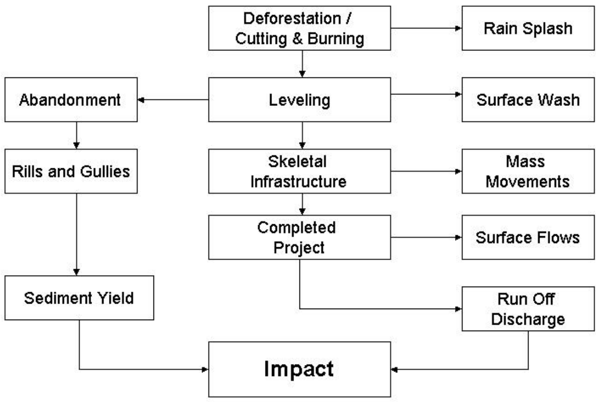


Plate 1. The Relationships Between Urban Wastes And Adjoining Environmental Subsystems

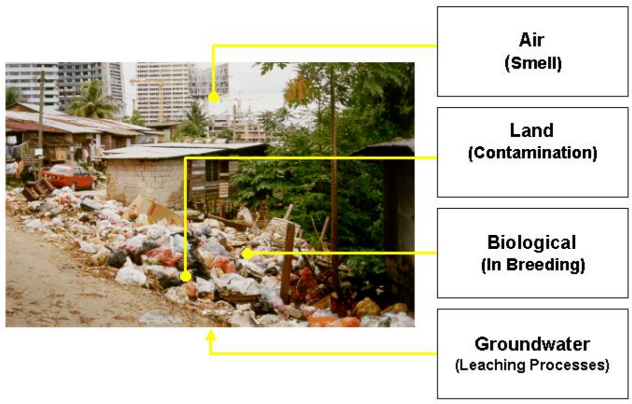
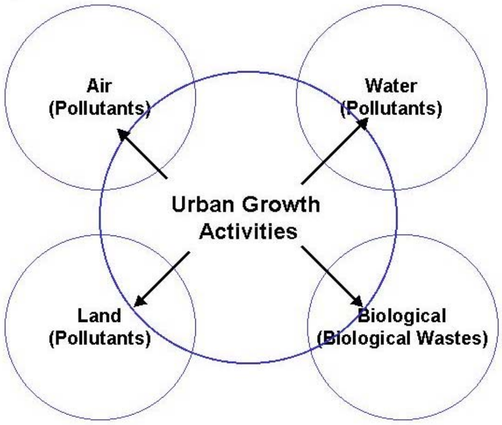


Figure 3. Urban Growth, Waste Production & The Urban Environment



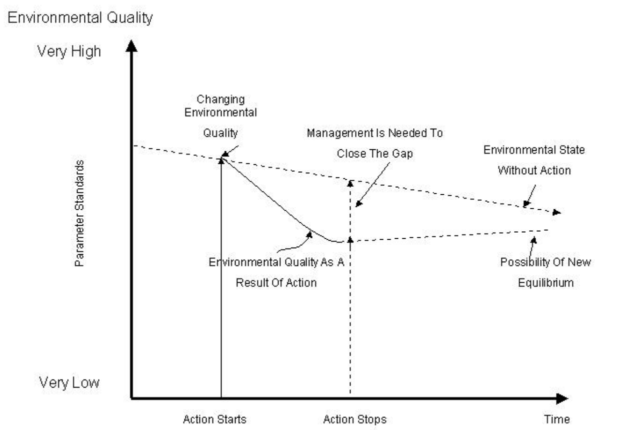


Figure 4. Changing Environmental Parameter Standards Influences Environmental Quality Which Would Then Influence Human Well-Being

Parameters Of Urban Environmental Quality

Changing process regimes including the generation of wastes, are related also to changes in the values of individual environmental or system parameters or the sudden intrusion in to the system of a new environmental parameter. For example, in the case of urban floods, *time to peak* value describes *the rate of change* of the occurrence of an urban flood prior to the onset of a rainfall event. This *time to peak* value can change as a result of the urban growth processes mentioned earlier, which can be either rapid / instantaneous or reduced.

Urban pollution, however, introduces new parameters into the system. This could include various types of gases, solids and also water vapour, which are generally nonexistent prior to growth. The change in values of urban environmental parameter or the introduction of new parameters describes the state of urban environmental quality. However, of more immediate concern here, is the effect of this quality of the environment on the urban dweller. Figure 4, for example describes how a change in the environmental parameters can be related to the state of environmental quality and its relationship to the urban dweller.

For example urban haze, often associated with vehicular emissions can contribute to an increase in carbon monoxide gases in the urban environment, which would be detrimental to the health of the urban dwellers. However, it must be understood here that at any single moment in time the state of environmental quality is dependent on the cumulative effect of all environmental parameters that are considered to be detrimental to human health. What this means is that as the urban areas developed, sustained by urban population growth it would contribute more and more to the defilation of environmental quality.

Urban Environmental Quality And Well-Being of Urban Dwellers

The state of the urban environment also creates a range of social impacts. Urban environmental quality may influence human comfort and impair human health, cause economic and other welfare losses, or damage the ecosystems on which both the urban and rural areas depend. Urban environmental quality is related to a change in environmental parameter standards. These changes affect the urban environmental quality, which would than affect the urban dwellers health. Firstly, changing environmental parameter standards would influence human well-being and comfort based on some level of human tolerance (Figure 5). Figure 5 describes the existence of threshold values in human comfort and health levels. These threshold values describe an upper maximum and lower minimum tolerance levels. These tolerance levels, however, would differ between individuals. The recent haze episode in the KRB, for example could be a serious discomfort to certain people and a severe health hazard to others. The relationship between tolerance, comfort and health, however, need not necessarily be in a continuum. Secondly, changing environmental parameter standards could also lead to the formation of destructive positive feedback loops which would eventually lead to a system's destruction. Thirdly, the destruction of environmental subsystems would eventually lead to economic loss and failures.

Most urban environmental problems involve all three of these impacts, either directly of indirectly. For example, urban air pollution has a direct impact on human health, increasing the incidence of respiratory diseases. Its impact on economy is mainly indirect, arising largely from productive losses due to ill health.

Environmental problems within the KRB vary for area to area and are influenced by such variables as the area's size and rate of growth, income, local physical setting, local climate, presence of institutional capabilities and more important the social structures and demographic profiles of the inherent communities (Figure 6). Especially where local governments are weak or under-financed, rapid economic and population growth in the area concerned can exacerbate these problems. Environmental management tends to be more difficult when the areas are located on marginal lands within the KRB. In such cases these areas are outside the responsibility of agencies that deals directly with environmental management.

In poor neighborhoods, the most threatening environmental problems are usually those close to home. The dangers of exposure to environmental risks are high, especially for women and children, the aged and those who are sick. Inadequate household water supplies are typically more crucial to people's well being than polluted waterways. There is also often more exposure to indoor pollution and from uncollected wastes in these areas to pose as a health risk to the people there. These problems, so prevalent in the KRB, stems from a myriad of causes, including the inability or unwillingness of local governments to provide for the basic needs of the people in poor neighborhoods, which in turn stems from a lack of revenue-generating capacity. Another key factor is the poor's lack of access to permanent land for housing.

As income increases, urban households in the KRB consume far more resources, such as energy, water and building materials and generate far more of certain types of wastes. Yet the rich and those who can afford to do so devote part of their wealth to measures that protect them from environmental hazards. The problems close to home are the first to improve as income increases, because they are most threatening. However, while these improvements reduce personal exposure, they often simply shift the problem elsewhere. Household and commercial garbage for example are usually disposed at city dumps located within the vicinity of community neighborhood. Lack of investment in urban infrastructure, and weak enforcement of environmental protection laws and regulations tend to exacerbate these problems.

Figure 5. The Relationships Between Changing Values In Environmental Parameters & Human Threshold Levels

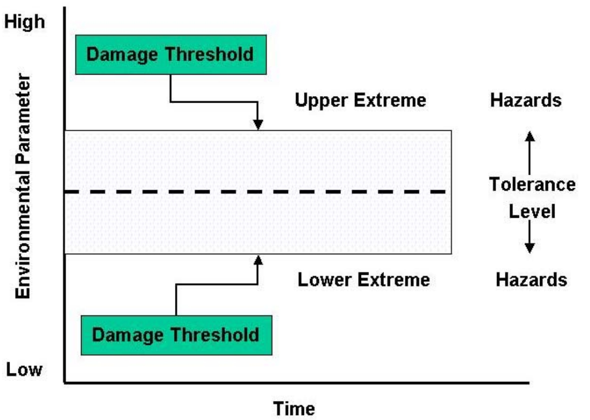
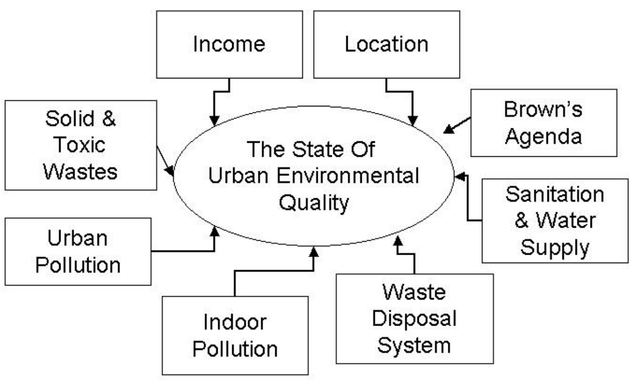


Figure 6. Determinants of Environmental Degradation



The geomorphological setting of the KRB is also a critical determinant of its environmental problems. The basin is bounded by highlands (The Melawati Range) toward the interior that prevent dispersal of air pollutants. In addition to this, it must also be understood that within the basin there is a natural mechanism of removal (air circulation systems and water pathways). Air circulation patterns associated with day-night cycles provides excellent modes of removal and so too the Klang River and its tributaries (Khairulmaini 2001). However, such cycles are also associated with energy gradients that are associated with only a certain amount of work. What this means is that the more pollutants and sediment that are in the systems the ability of the cycle mechanisms to perform as modes of transports would be severely limited and there is going to be a lagged in pollutant and sediment removal.

The Brown Agenda is another critical determinant of environmental problems in urban areas such as the KRB. Indeed, over the past two decades the global agenda has shifted away from local and regional problems such as air pollution and inadequate water supplies to urban flash floods toward vast global concern such as ozone depletion, climate change as well as loss of biodiversity. Aware of this shift from the "green" agenda toward the problems confronting urban areas, a number of researchers, international donor agencies, and non-governmental organizations over the past few years have advocated a renewed focus on the "brown" agenda – that is, the problems of pollution, poverty and environmental hazards in urban areas. The adverse effects of indoor pollution on child mortality and female life expectancy are of no less global proportion than say, the destruction of tropical forests, and in immediate human terms, they may be the most urgent of all worldwide environmental problems (Rossi et. al. 1991). This is not to argue for less attention to global concerns, but for the recognition that urban and global concerns are intertwined and must both be address accordingly.

One of the greatest threats to urban dynamics and human health is the quantity and quality of water resources in the KRB. Industrialization areas, commercial centers and housing estates require ample supply of water for their daily cycle of activities. The KRB still faces problems in terms of water supply even though the existing dams operate at maximum capacity. The proposed development of the Selangor Dam is a step towards overcoming of this problem.

However, the worst affected would be the marginal areas in the KRB – the squatter settlements in the basin. In the KRB, the number of urban residents at squatter settlements with access to an adequate water supply is still considered poor. Definition of what constitutes an adequate amount of safe drinking water and sanitation could be problematical. Although the local government classify the existence of a water tap within 100 meters of a house is adequate. Such a tap does not guarantee that the individual household will be able to secure enough water for good health. Neighborhood communities are often served by one tap. In some cases communal taps only function for a few hours per day, so residents have to wait in long lines to fill even one bucket. Households cannot obtain sufficient water for washing, laundry, and personal hygiene if it takes too long to fetch and if the water has to be carried over long distances. The only remedy would be to use the rivers. The proportion of the urban squatter population covered by sanitation services is even smaller. Poor sanitation poses health hazards through several dimensions, including direct exposure to faeces near homes, contaminated drinking water, ingestion of fish from polluted waters, and ingestion of produce that has been fertilized by wastewater (White 1994). Inadequate access to water and sanitation facilities is the main cause for the intestinal diseases – diarrhea and intestinal worm infections that is not uncommon at such areas.

In the KRB, wastewater treatment is still not 100 percent being carried out. Disposal of domestic and commercial wastewater remains a major problem. During heavy rainfall, untreated wastewater is released through overflow drains and sewers. This problem becomes quite acute in the marginal squatter areas.

Data are scarce on the contribution of indoor pollution to regional pollution and of its impact to immediate communities especially in the marginal squatter areas. However, in 1992 the World Bank identified indoor pollution as one of the four most critical global environmental problems. Indoor pollution contributes to acute respiratory infections in young children and chronic lung diseases and cancer in adults. Trapped heat and smoke within very cramped housing conditions observed in most squatter homes must aggravate discomfort and induced low health status amongst the squatters especially the poor (McGranahan 1993).

Urban air pollution remains as one of the biggest determinants of environmental degradation in urban areas. The KRB is exposed to a cocktail of industrial, vehicular and energy generating sources. Urban air quality in the KRB has generally improved over the last decades, largely from advances in controlling emissions from stationary sources such as industrial plants. Rising motor vehicle use, in part reflecting the increasing dynamism of the KRB now poses the greatest threat to air quality. Here a number of stringent controls have been enforced such as car pooling, expanding public transport systems and the use of unleaded petrol. Urban air pollution not only impairs human health but also damages crops, vegetation and man-made structures, including historic monuments. These effects are more difficult to quantify. However, acid rain and transported air pollutants from vehicles and heavy industries have been known to have contributed to decline of forest tract downwind of urban areas.

Urban areas generate tremendous amounts of solid waste and these amounts increase with the most affluent business and commercial centers and the richer housing estates. In low-income squatter settlements, garbage collection is often nonexistent, either because these settlements fall outside "official" service areas or because garbage trucks are unable to maneuver along narrow, unpaved and very poor streets. Uncollected domestic waste is the most common cause of blocked urban drainage channels, increasing the risk of flooding and vector borne diseases. In the KRB, the urban population is serviced by municipal waste collection. However, with their higher consumption levels, they confront ever-increasing mounds of garbage. The problem of allocating land for garbage disposal thus posed an immediate problem in the KRB. In some instances illegal garbage dumping have contributed to river and groundwater pollution within the basin. Municipal solid waste sites often handle both domestic and industrial wastes, including hazardous wastes. Without proper disposal, toxic chemicals can leach into water supplies. The health effects of hazardous wastes remain controversial, yet are generally believed to pose a far smaller threat than those associated with biological pathogens in the urban environment.

A Model of Urban Environmental Quality and Urban Quality of Life

The relationships between urban environmental quality and the well being of urban dwellers in the KRB can be depicted through a series of process response linkages. The use of a canonical diagram in this case facilitates a quick appreciation of the sequence of process response relationships that occur between urban growth, resource utilization, environmental degradation and hazards within the basin. Figure 7 describes the general linkages of environmental degradation within the KRB. It must be stressed here that environmental hazards – situations in the environment (state of environmental quality) where system's parameter standards increased or decreased in values making the environment detrimental to human comfort and health occurs at different spatial scales and would affect not only the different hierarchy of human occupancy in the basin but also the different social structures and demographic profiles of the KRB population. For example, indoor pollution – which could be attributed to increase in heat, smokiness, increased in certain type of gases and smell would be more critical amongst the urban poor in the KRB especially amongst the women, children, the sick and the aged. Open-air pollution, however, would be felt at a larger scale such as the city limits and would posed a threat on the comfort and health amongst the residents of the KRB irrespective of social structures and their demographic profiles (Packer et. al. 1994).

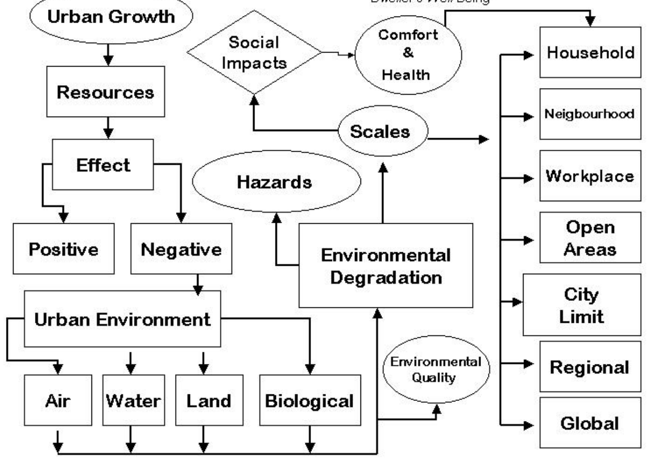
Figure 7 also shows that environmental hazards are situations that reflect a depreciation of environmental quality within each major subsystem of the environment. For an urban area this could be viewed based on the (1) general classification of environmental subsystems into air, water, land and biological, or (2) the naturally occurring spatial units of drainage basins and its subsystems. For example smell pollution from uncollected rubbish heaps within the vicinity of a neighborhood is attributed to an increase of certain type of gases for example hydrogen sulphide in the environment as a result of decomposition of rubbish. The strength of this form of pollution is dependent on the amount of this particular gas been released as a result of composition. This means that environmental degradation can be quantified and measured. However human environmental quality tolerance level could also is a subjective matter as human beings have different tolerance levels, which thus influence the comfort and health levels of human beings.

Urban Environmental Management

The complex determinants of urban environmental problems and the process response linkages they have on environmental quality and human well-being (comfort and health) underscore the magnitude of the urban environmental management challenge in the KRB if not the world. In terms of global impact, the most pressing need would be to improve well being of the urban poor in their local settings, especially the aged, children and women. However urban environmental management must cater also for the need of all inhabitants irrespective of social structure or demographic profiles as most urban health problems are derived through vector borne sources and touches every one of the urban areas inhabitants.

Improving environmental health and quality of life will require a significant departure from the piecemeal approach that has dominated urban management in this country since the 19 Century, in which each problem is considered in isolation. Most discussions of urban environmental management still resort to a listing of priority problems, as if each exists independently. Recognizing the synergistic factors affecting the quality of life of the urban population especially the poor, there is increasing attempts within the KRB to devise integrated strategies. These activities tend to incorporate diverse municipal agencies, often under an umbrella structure, that work with different stakeholders including local communities to improve local infrastructure such as water and sanitation services, along with providing of health programs, preschool education, and consciousness amongst local communities. To some extent these project activities represent a step forward in urban environmental management planning. However, there are many obstacles to multi-sector strategies for improving environmental health of urban areas. Chief amongst this is the difficulty of integrating disciplines as diverse as engineering, medicine, social welfare, and economics. Multi-sector approaches to urban environmental management pose a major challenge to both local governments and international lending agencies, which must coordinate responses and overcome the political divisions within urban areas. To succeed, any strategy must not only address the actual concerns of the community affected -which may not match the priorities of the government or the development agency sponsoring the project, but also in order to maintain a long lasting effect any urban development programme must adopt an approach based on the understanding of natural system dynamics rather than the traditional – sectoral approaches based on either administrative or economic criteria (Fauza and Khairulmaini 2000).

Figure 7. A Simplified Urban Growth, Urban Environmental Quality & The Urban Dweller's Well Being



An integrated approach towards urban environmental management can help remedy these problems. There are two levels to this approach:

1. The need for a comprehensive understanding of natural process response dynamics within a defined framework of natural system boundaries, for example, drainage basins (Khairulmaini and Fauza 1998),
2. The implementation of good urban governance within an overall framework of drainage basin development planning and management.

Conclusion: The Way Forward

It has been accepted globally that urban areas play a vital role in the social and economic development of any country; this is especially true in the case of the Klang River Basin – the premier urban region of the country. Urban growth and the urbanization process of this basin builds diversified and dynamic economies which raise productivity, create jobs and wealth, provide essential services, and absorb population growth, and had become the key engines of economic and social advancement in the country. Thus, to become a more efficient and productive urban region essential for national economic growth and welfare, equally strong urban economies generate the resources needed for public and private investments in infrastructure, education, health and improved living conditions. However, the development potential of the KRB is increasingly threatened by environmental deterioration. Aside form the obvious effects on human health and well-being, environmental degradation directly impedes socio-economic development. Air, water and land pollution and biological manifestations, for example, impose extra costs on business and industry, and on households as well as public services. Inefficient use and depletion of natural resources raises input prices and operating costs throughout the economy, and also deters new investment. Heightened risk from environmental hazards has the same effect. In terms of impact, it is usually the poor who suffer most cruelly and directly from environmental degradation, although the lives and health of all urban residents can also be affected. Failing to deal with the problem today, moreover, leads too much greater problems (and cost) in the future because of the phenomenal growth rate of the KRB. For development achievements to be truly "sustainable", cities and urban regions must find better ways of balancing the needs and pressure of urban growth and change with the needs and constraints of the environment. There are many encouraging signs, however, that environmental deterioration is not a necessary or inescapable result of urbanization and economic change. However in KRB such success seemed to be short lived, as environmental degradation tends to be rather synergistic with the rate of economic development in basin. Indeed, mounting evidence from all structures and levels of society including perceptions of non-governmental organizations in the KRB shows that the fundamental challenge has to do with urban governance: learning how to better plan and more effectively manage the process of urban development, avoiding or alleviating problems while realizing the positive potentials of city growth and change. New and more positive approaches to urban management can help to mobilize and effectively apply local resources at all levels of the urban society.

A common focus of many innovative and effective ideas and approaches being worked out today is a central concern with the actual process of urban environmental planning and management. Experiences from all over the globe – despite their vast differences in physical, economic, social and political situations seemed to increasingly converge on this same viewpoint. This evolving framework of Urban Environmental Planning & Management (EPM) can be characterized as comprising, in general, four closely interrelated elements or aspects:

- Identification and Prioritization of Urban Environmental Issues and Involvement of Stakeholders
- Formulating Urban Environmental Management Strategies
- Formulating and Implementing of Environmental Action Plans, and
- Institutionalizing Urban Environmental Planning & Management

Based on information gathered from a wide variety of cities and urban regions, a number of "Urban Environmental Planning and Management Guidelines" (UEPMG) can be suggested, each of which reflects the knowledge and insights – the "lessons" – gained through different experiences. These guidelines identify and describe ways which cities and urban areas have found to be effective in moving towards sustainable development and thus comprise a useful framework for a regional / global approach to implementing the urban environmental agenda. The UEPMG can be grouped under five main categories,

- Better Environmental Information and Technical Expertise
  - Preparation of basic overview information
  - Involvement of stakeholders
  - Setting of priorities
  - Clarification of priority issues
- Better Environmental Decision Making
  - Clarification of issue-specific policy options
  - Consideration of implementations options and resources
  - Building broad-based consensus on issue-specific objectives and strategies
  - Coordination of environmental and urban development strategies

- Better Implementation Of Environmental Strategies
  - Application of full range of implementation capabilities
  - Agreement on action plans for implementation

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Environmental Issues For A Fishing Village In The District Of Kudat, Sabah, Malaysia

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ABSTRACT: This paper presents findings of a study on the evaluation of environmental aspects of a fishing village in the district of Kudat, Sabah, Malaysia. The issues like clean water and electricity supplies, sanitation appropriateness, garbage disposal management, education level, employment status, and the housing standard were investigated. Data were gathered through field observations, interviews, and written questionnaire surveys. The collected data were then tabulated, organized, and analysed. Findings indicated that the (1) conditions of basic facilities like clean water and electricity supplies, sanitation appropriateness, garbage disposal management, and housing standard were very poor, (2) residents' levels of income were low, (3) social activities in the community were absent, and (4) the levels of education and knowledge concerning social and environmental awareness were low. The study had implications on environmental education goals: knowledge, awareness, skills and the positive participation in improving their quality and standard of living. Recommendations include the needs to establish immediate actions on the improvement level and programs of education, health programs, basic facilities and infrastructure development, reorganization of economics, and recommendations for further detailed research.

Keywords: Environmental awareness, ignorance, sanitation, garbage disposal, clean water

INTRODUCTION

Sabah gained independence and joined Malaysia in 1963. Kudat is one of the districts located on its northeast coast occupying an area of 1,300 km^2 (Fig. 1). It has a population of 65,989 (Department of Statistics, 2003). The main products of the area are wet and dry rice-paddy, rubber, cocoa, palm oil, and fishing industry.

Kampung Bahagia (where the research was conducted) is one of the villages in the District of Kudat, Sabah. It is located very near to the sea (Fig. 2) which has a population of about 3,000 people (Department of Statistics, 2003). Majority of the residents are from low income families from fishing activities. The community is facing major developmental and socio-economical problems due to unemployment, low level of education, and absence of public health. Due to low standard of education and environmental knowledge, the ignorance of the community has affected this residential area. The environment has become filthy and smelly, thus attention and immediate development actions are needed.

OBJECTIVES

The objectives of this study are to (i) evaluate socio-economic and environmental status of the village, (ii) estimate the degree of the problems, (iii) assist the policy maker in identifying the above-mentioned problems, and (iv) recommend possible solutions to these problems.

PROBLEMS

The major problems afflicting the community are unemployment, shortage of clean water supply, lack of proper sanitation, improper garbage disposal, schooling and housing facilities.

i) Unemployment

More than 50% of the Kampung Bahagia residents are fishermen. Most of them have initial or older fishing boats. Their income is minimal which can only suffice to feed their families on day-by-day basis.

ii) Clean Water Supply

A continuous and proper clean water supply has been the major problem to the residents. They depend on the shallow man-made wells they construct in the area which are not suitable environmentally. The physical properties of the water are salty, brownish, and smelly. Even so, the residents use it for al purposes, unassumingly.

iii) Proper Sanitation

Another major problem that is faced by the community of Kampung Bahagia is sanitation. A proper places for sanitation or public toilets are not found either publicly or individually. Most of the residents in the community defecate in the sea, along the beach, in the bush, behind big rocks or anywhere convenient on the ground. These activities create other environmental problems along the residential area, playing ground and the beach itself.

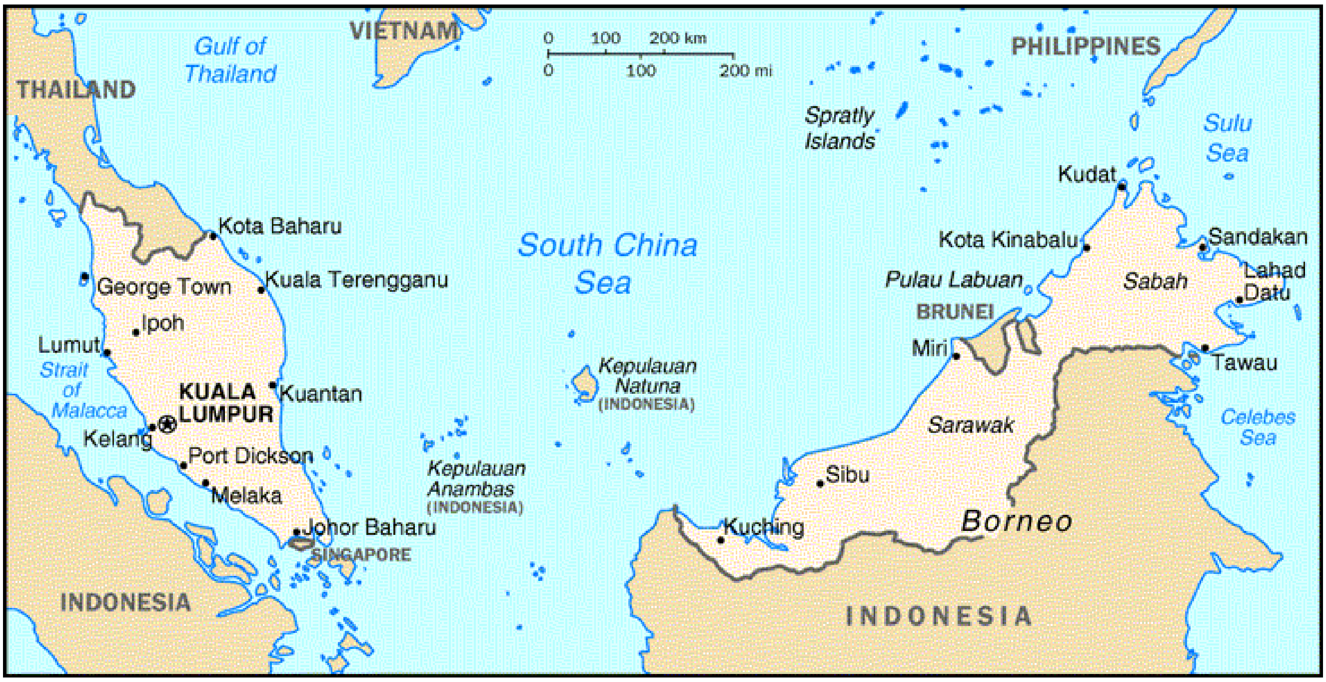

Figure 1: Map of Malaysia, the Location of Sabah and Kudat Town

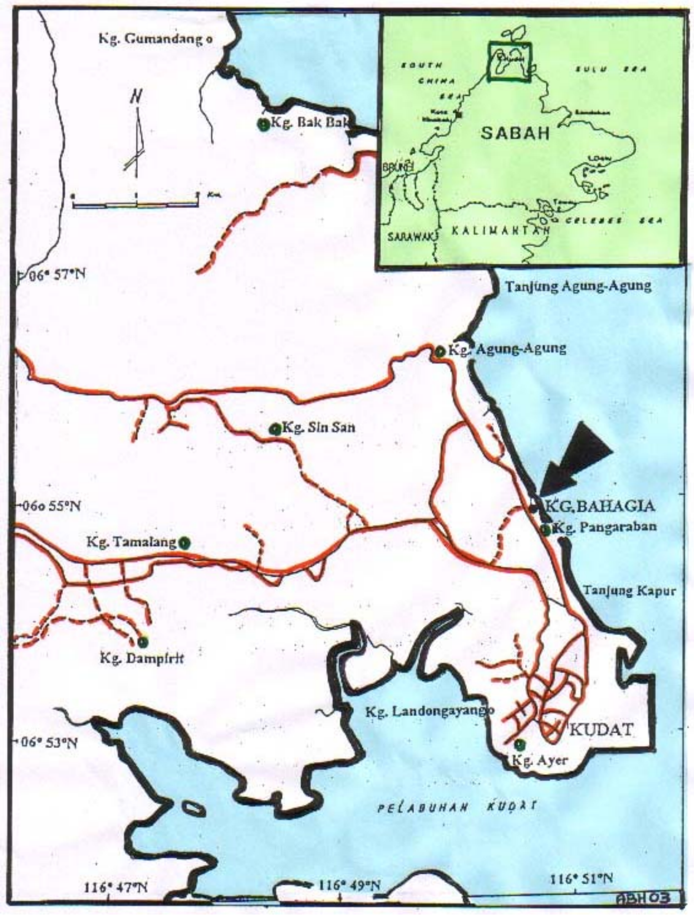

Figure 2: Location of the Study Area

iv) Electricity Supply

Kampung Bahagia is located only about 1.5 km from Kudat town but has poor electricity supply.

v) Proper Garbage Disposal Area

The community is deprived of any proper garbage disposal place. Most of the time, they dump their garbage anywhere in the surrounding without concern for the community health.

vi) Education

No school has been built in Kampung Bahagia. Children of the village go to school at the adjacent area. Even though available schools in the vicinity are quite near but majority of the families cannot afford to send their children to school due to their low of income. This is resulting to the very minimal standard of education for this community and thus contributes to the quality of their living.

vii) Appropriate Housing Scheme

Good and proper housing scheme for settlement is also other major factor that determines the quality of living. Residential houses in Kampung Bahagia community are built without proper planning. The houses are constructed very close to each other, side-by-side. As a result, the residents face difficulty in obtaining better access road for communication and/or facilities to promote a better way of living.

METHODOLOGY

The study involved several stages of collecting data, starting from preliminary preparation, field observation to the community, personal oral interviews, distributing questionnaire surveys, data organization / tabulation / analysis / interpretation, and writing the reports.

i. Field observations

Three field observations to the community were conducted to collect required data.

ii. Personal oral interviews

About 200 residents of the village participated in personal interviews during the field observations. The objective of this interview was to collect primary data as much as possible.

iii. Distributing questionnaire surveys and writing the report

Written questionnaire surveys were distributed to the residents through random selection. They were asked to complete the demographic data, their knowledge and/or perceptions and their need related to environment. The respondents indicated their perceptions concerning their knowledge and environmental needs based on five-point scale as listed below:

4 = A complete extent
3 = A moderate extent
2 = A little extent
1 = No extent
0 = Do not know

The completed questionnaire surveys were collected for analysis, interpretation and written for the research.

DATA ANALYSIS AND INTERPRETATION

After the field survey, the data gathered were collected for analysis using Statistical Analysis System (SAS) 6.06 program (Cody, 1987; Jaffe, 1989). Computation of the percentage and mean were used.

FINDINGS AND ANALYSIS

Based on the available data obtained from the study, the problems were divided into two categories: (I) demographic, and (II) perceptions on environmental knowledge and need. The results were reported in terms of percentage and mean. The data obtained from the different phases of investigation had served as the framework in the writing and presentation of the paper.

I) Demographic Data

Of the total residents sample (n = 230) for this study, 52% were males and 48% were females. Their ages ranging from 30 years (12%) to above 40 years old (32%), with 96% of them were married and 4% were single. Most families had children between one to more than six in a family. The detail information of the data is found in Table 1.

Table 1: Demographic Data

Gender:

ITEM	RESPONDENTS (%)
Male	52
Female	48

Age (years):

< 30	12
31 - 35	20
36 - 40	36
> 40	32

Number of children in the family:

1 - 2	08
3 - 4	50
5 - 6	25
> 6	17

Of all the 230 residents surveyed, 8% found out to be working for the government, 40% fishermen, 20% self-employed, and 32% did not have steady employments. Almost majority of them (60%) having incomes below RM

400.00 to more than 4% with monthly income of RM 500.00 (Table 2 shows the detail distribution of occupations and monthly income).

Table 2: Residents' Occupations and Monthly Incomes

Occupations of the residents:

ITEM	RESPONDENTS (%)
Government servants	08
Fishermen	40
Self-employed	20
Not employed	32

Incomes (RM):

< 300.00	60
301.00 – 500.00	36
> 501.00	04

About 92 residents (40%) of Kampung Bahagia were fishermen. They have been living in this community ranging from less than five (20%) to more than 16 years (24%) (Table 3 illustrates the distribution length of their stay).

Table 3: Residents' Occupations and Monthly Incomes

Length of stay (Years):

ITEM	RESPONDENTS (%)
< 5	20
6 - 10	40
11 - 15	16
> 16	24

II). Perceptions on Environmental Knowledge and Need

Table 4 illustrates residents' perceptions in terms of basic facilities and need in disposing their household garbage. The findings were reported in the form of means on the degree of agreement based on the five-point scales mentioned earlier.

a. Basic Facility Needs

Data analysis found that this community was lacking from all kinds of basic facilities like clean water and electricity supplies, proper sanitation and garbage disposal place.

Final data analysis indicated that majority of the residents got their water for daily use from wells, some from their neighbour or from rivers nearby. The water obtained, however, is not suitable for drinking and cooking purposes. Detail results on the perception of basic facility needs are presented in Table 4.

Table 4: Residents' Perceptions on Basic Facility Needs

Need of Basic Facilities	MEAN RESPONSES
Clean water	4.00
Proper electricity supply	4.00
Sanitary	3.96
Proper garbage disposal	3.96

Water resources:

Man-made wells	3.92
Ponds	1.52
Rivers	1.28
Neighbourhood	1.72

Use of water resources:

Cooking	3.36
Drinking	3.36
Washing/Bathing	3.52
Everything	3.40

b. Perceptions on Environment

Responses on the need of proper sanitation showed that majority of residents defecated in the sea, on the beach, in the bush, and also anywhere convenient on the ground. It was also found that no residents had their own proper toilet.

In the case of household garbage, majority of the disposing their garbage in the sea or on the beach, by burying in the ground, or by throwing it anywhere surrounds their houses (Table 5).

Table 5: Residents' Perceptions on Basic Facility Needs

Method of Sanitation	MEAN RESPONSES
Own toilet	0.16
Bush	1.32
Beach/Sea	4.00
Anywhere convenient	1.64

Method of Disposing Garbage	
Burning	3.56
Burying	1.64
Beach/Sea	3.88
Anywhere convenient	1.48

Key:

4 = A complete extent
3 = A moderate extent
2 = A little extent
1 = No extent
0 = Do not know

Analysis data of Kampung Bahagia residents on the extent of knowledge on environment found that majority of them only had "*a little*" knowledge related to environment (Table 6 and Fig. 3).

Table 6**:** Residents' Knowledge on Environment

EXTENT RESPONSES	RESPONDENTS (%)
A complete extent	0
A moderate extent	20
A little extent	56
No extent	4
Do not know	20

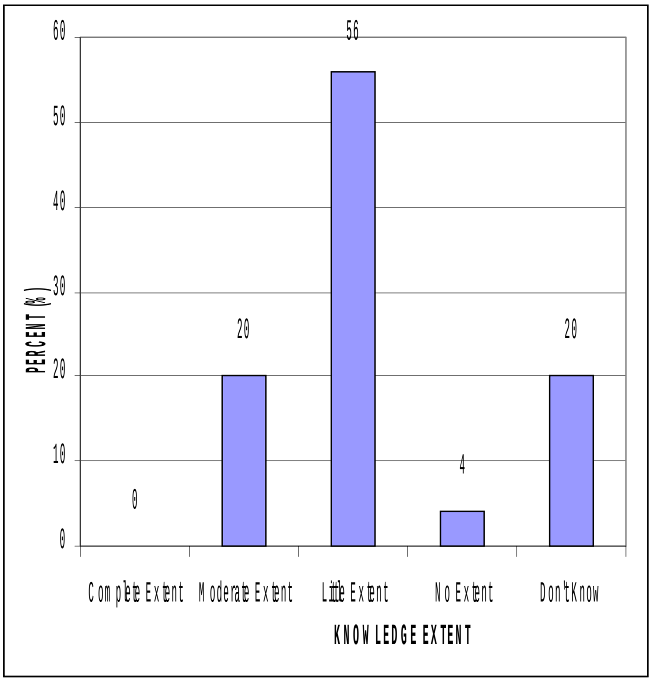

Figure 3: Residents' Knowledge on Environment

CONCLUSIONS

Based on the findings presented in this paper, the following conclusions were drawn:

1. The community of Kampung Bahagia needed basic facilities like supplies of clean water and electricity, sanitary, and garbage.

2. The residents had low level of income below the standard of living.

3. The absent of social activities in the community.

4. Their levels of education and knowledge concerning the environmental awareness were very low.

5. All results found in this research seem to have an impact on the environment (EIA=environmental impact assessment) and social (SIA=social impact assessment factors).

RECOMMENDATIONS

The conclusions resulting from the study suggest **four** major recommendations for improvement:

1. Immediate actions on improving the level of education, health program, infrastructure developments, and basic facilities should be established top the community.

2. The community should be organized economically, educationally, and developmentally to keep abreast on the development of the country.

3. Improve the economy of the community by building them advance fishing boats so that they would be able to increase their income and at the same time to uplift their standard of living.

4. Further and follow up research and/or study for this community need to be conducted.

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Squatter Settlements And The Environmental Management Of Canals In Chiang Mai, Thailand

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INTRODUCTION

Projects targeting environmental problems can be seen as platforms for interaction between different social groups and stakeholders. Furthermore, such projects may function as forums for social change, through the promotion of dialogue, co-operation and partnerships between low-income groups and those with power and influence - typically local authorities and land developers. In that perspective, environmental development projects could be seen to bring into focus environmental issues that to different extents are relevant to inhabitants of a locality or region. However, environmental development projects, despite their potential in creating spaces for co-operation, do not in practice carve a neutral space free of political interests and risk therefore becoming the scenario of power struggles and social conflict. In view of that, we ask in this paper: what role does the *environment* play in the actions and discourses by different stakeholders in *environment-targeted* projects? For the terms and formulation of a project as an environmental project carry in themselves a problem definition, which will guide the forms and scope of environmental management.

This paper discusses issues of political influence and power struggles in connection with environmental projects through the lenses of a low-income settlement in the City of Chiang Mai, North Thailand. That low-income settlement has been an object of intervention in four different projects/programmes in the last five years, namely, (a) the Urban Communities Environmental Activities project, a community driven initiative implemented with the support of the public organisation Community Organisation Development Institute and the NGO People's Organisation for Participation (POP); (b) the Chiang Mai 30 year Master Plan designed by the Lanna Architects Association for Chiang Mai Municipality; (c) the Living City Project elaborated by the Department of Town Planning at Chiang Mai Provincial Government, following an initiative by the Prime Minister Mr. Taksin Shinawatra, who is originally from Chiang Mai; and (d) the Programme for Conservation of Historic Monuments, currently under implementation by the Department of Fine Arts (Central Government).

The study of this particular settlement, Kampaeng Ngam, touches upon a number of issues, which, we believe, have a broader regional scope, notably relevant to other urban areas in Thailand. Especially important in this connection is the type of urban development that has taken place around canals (khlongs), where environmental decay has come to the foreground and where low-income communities have squatted on land owned by the Government. This type of development, which can be found in cities throughout Thailand, has become in many instances the ground for social conflict between these low-income communities fighting for the right to stay on squatted land, and governmental authorities, which attempt to evict them. In addition, low-income settlements, and the canals along which they are situated, have been targets in environmental projects supported by international donors, public organisations and NGOs.

In this paper, we look at the involvement by different actors (central and local authorities, public organisations, NGOs as well as local communities) who have a stake in Khlong Mae Kha (Chiang Mai) and the areas alongside it. We look at how the issue of environmental decay has been dealt with in the projects and programmes supported or implemented by these actors and at the political agendas behind their environmental discourses.

Historical Background

Chiang Mai was founded by King Meng Rai in the end of the XIII Century as the new capital of Lanna Kingdom, which comprised 17 provinces in Northern Thailand. Chiang Mai was originally laid out as an almost perfect square fortress with an additional, outer, earthen and brick wall. Kanmpaeng Din, as the outer wall is called, follows a semi-circular layout stretching in a north-south direction along Khlong Mae Kha.

The historical importance of Khlong Mae Kha goes back to the foundation of Chiang Mai, as it was one of 7 elements, which determined the choice of location of the Old City. Khlong Mae Kha has its source in the Mae Ta Chang River and in the Mae Hyuak River. Both flow from the Suthep-Pui mountain range. It is about 11,370 metres long, between 1 metre and 10 metres wide and approximately 2.5 metres deep (Niwat Tuntayanusorn 1997: 1-16).

Throughout its history, the development of Chiang Mai has been closely correlated with trading routes, notably the Silk Route. Development prior to 1962 consisted of settlements inside the southern boundary of Kanmpaeng Din, in the north outside the old city wall and east of the River Ping (which has drawn a commercial route both by land and by water). The area along Khlong Mae Kha between the old city wall and the Ping River was initially not occupied because it was subjected to seasonal floods.

In the period between 1962 and 1982 the Thai Government elaborated the first four National Economic and Social Development Plans, which promoted an accelerated industrialisation programme for Thailand. And since the Fourth Plan (1977 – 1981), all of Thailand's five-year National Economic and Social Development Plans have included policies designed to promote economic growth outside of Bangkok Metropolitan Region and thus economic, political and administrative decentralisation. Chiang Mai was selected to be the main urban centre for economic development in the Northern Region. The economic growth of Chiang Mai attracted poor rural migrants, who settled in informal settlements, some of which were located in the banks of the Khlong Mae Kha (Yoddumnern-Attig & Attig (1993), cited in Yoddumnern-Attig Bencha *et al* 1999).

Informal Settlements in Chiang Mai

Sattayanuruk (1999) identifies three types of informal settlements in the city of Chiang Mai, according to tenure status, namely (a) settlements on land owned by residents, (b) settlements on rented land and (c) squatter settlements.

The first type of occupation has been characterised as informal by Sattayanuruk, because those settlements, which are typically over 50 years old, lack basic services – not provided by the Municipality. Informal settlements on rented land quickly become overcrowded and new generations of urban dwellers who would normally build their houses on their parents' plot have no choice but to squat on public land. This is the case of Kampaeng Ngam community, which has settled in the area between Khlong Mae Kha and Kanmpaeng Din. Immigration is also an important factor contributing to the growth of squatter settlements. Together with new generations of poor urban dwellers, immigrants from rural areas squat on public land along canals, such as Khlong Mae Kha.

Most of those who form a second generation of shantytown dwellers have had very limited access to education, for their parents could not afford to send them to school. This second generation is mostly employed as non-specialised labour with limited earning capacity. Local people have only little chance to own land (Sattayanuruk, 1999).

Informal Settlements along Mae Ka Canal and Kampaeng Ngam Community

Tantayanusorn Niwat, in a survey carried out in 1997, identified 17 informal settlements along Khlong Mae Kha – 11 of these settlements are under the jurisdiction of Chiang Mai Municipality (Tantayanusorn, N., 1997, p. 34). More than half (63.64%) of these were designated squatter settlements (Chiang Mai Municipality, 2000). The fact that the choice of location of squatter settlements along the Mae Kha Canal is dictated by the availability of public owned land on which to squat and not by a wish to be located near Khlong Mae Kha is supported by data gathered through interviews with members of the communities in question.

The case of Kampaeng Ngam Community is particularly controversial because it is primarily located on land owned by the Department of Fine Arts – a central Government institution in charge of the protection and restoration of historic monuments. To make matters even more sensitive, some houses in Kampaeng Ngam were until very recently located on the remnants of Kanmpaeng Din. They have since been moved as part of a negotiation between Kampaeng Ngam community and the Department of Fine Arts.

Kampaeng Ngam started off with 4-5 families, which could not be accommodated in the neighbouring informal settlement on land owned by the Buddhist temple Wat Huay Fay. The land occupied by Kampaeng Ngam was originally farming land. The growth of Kampaeng Ngam was boosted by the arrival of young families, which could not settle on the plot occupied by the house of their parents in the neighbouring settlement. In addition migrants from the rural district of Chiang Mai Province came to live in Kampaeng Ngam, increasing the size of its population. In 1955 a slaughterhouse was located in the vicinity of Kampaeng Ngam further encouraging the growth of the Kampaeng Ngam. In later decades, the central location of that settlement has been a central factor in its growth.

Similarly to other informal settlements in Thailand, Kampaeng Ngam has neither sewage infrastructure nor garbage collection service. Nearly half of the 132 families in Kampaeng Ngam are ethnic hill-tribe people who migrated from the mountains surrounding Chiang Mai. The remaining families are from low-lying areas around the city.

Environmental Deterioration

A 1978 report about the quality of the water of Mae Ka Canal shows that Mae Ka Canal was already heavily polluted then (Sinclarenight and partner limited et al, 1983). The quality of the water was at that time classified as standard type 5, that is, unsuitable for drinking or bathing (Pormkattikaew Sakorn, 1995; Prungkaew Intira,1999). In a recent study, Kold, Rasmus and Lundtofte (2002) have found that the waste produced by informal settlements along Khlong Mae Kha only marginally contributed to its pollution. Still, Kampaeng Ngam dwellers are often perceived to be responsible for the pollution of the Khlong Mae Kha. In and article published in the "Northern Citizen" in February 2003, for instance, it is proposed that the pollution of the Mae Kha could be solved by providing sewage infrastructure to the squatter settlements in question (Northern Citizen, 2003). Such conception clearly perpetuates the perception of squatter settlements as those responsible for the pollution of the Mae Kha.

When interviewed, Kampaeng Ngam residents stated that, in their view, the main source of pollution of Khlong Mae Kha are private companies, such as a slaughterhouse and a factory located upstream.

The historical city wall, Kanmpaeng Din, on the other hand, has been destroyed in several areas, notably in the city centre. Particular destruction of the historic wall has taken place in connection with construction of commercial buildings as a result of the development of tourism. There seems, nevertheless, to be more tolerance for this kind of illegal occupation by more wealthy private parties.

Eviction Threats

Kampaeng Ngam has been under increasing threat of eviction. Such threat has recently come to a head with the elaboration of plans by the Department of Fine Arts to restore Kanmpaeng Din and the moat (Mae Kha and Koowai canals).[1]

The processes set off by these projects and the risks of eviction of the informal communities along Khlong Mae Kha have involved several interest groups and organisations. Amongst those are, as mentioned above, Chiang Mai Municipality, the Department of Fine Arts, the Lanna Association of Architects and of special interest in this paper, two organisations that have had a distinct role in their support to the communities facing eviction threats, namely, the Community Organisation Development Institute (CODI) and the NGO, People's Organisation for Participation (POP).

In this paper, we look at the community of Kampaeng Ngam and the above mentioned organisations, examining the way environmental issues are addressed in the light of each group's different political agendas.

Chiang Mai Municipality

Chiang Mai Municipality plays an important role in the status granted to informal communities. Such a status is a function of services provided or not by Chiang Mai Municipality, such as water and electricity supply, garbage collection, sewage infrastructure, health service and in particular house registration.[2] House registration affects a household's access to basic services such as children's public schooling, public health care and the right to vote.[3] Votes in elections for mayor have figured as the main reason for households in informal communities to be given the right to house registration by the Municipal Government – that is, house registration is used for political purposes. The same is true of provision of services to informal communities. Kampaeng Ngam community has been given financial support by the Municipality for the implementation of environmental improvements such as paved footpaths, piped water and electricity, and for cleaning Khlong Mae Kha.

But the political and administrative roles of Chiang Mai Municipality are often in conflict. Whilst a master plan has been in the past year developed by the Lanna Architects Association for the Municipality of Chiang Mai, which proposes the creation of a park and a promenade along Khlong Mae Kha (see for instance Northern Citizen, 2003b), the Mayor of Chiang Mai stated in a meeting with the community of Kampaeng Ngam on 21st February 2003 that he would work for the right of these communities to stay in their current location along Khlong Mae Kha. Considering that the land is owned by the Department of Fine Arts (Central Government), this is a source of further conflicts. At the same meeting, the elected community leader for Kampaeng Ngam community, Khun Namtheep Payopo, referred to the relationship between governmental bodies (central, provincial and municipal), concerning projects for Khlong Mae Kha, as one characterised by conflict. In the above-mentioned meeting with the community of Kampaeng Ngam, on the 21st February 2003, the Mayor of Chiang Mai presented in four occasions in his address his plead for votes in the coming election.

The Department of Fine Arts (DFA)

DFA (Central Government) has commissioned the elaboration of rehabilitation studies for the City of Chiang Mai, which include a proposal for the restoration of the fortification system consisting of the city wall and the moat (Mae Ka and Koowai canals). The 200 years old city wall, Kampaeng Din, is according to DFA a potential element for boosting tourism. In addition, it is the view of DFA that the communities located along Klong Mae Kha are spoiling an historical site.[4] DFA's policy is one of preservation of Kampaeng Din as an historical monument and the eviction of the informal communities located in the area to a site 10 kilometres away from Chiang Mai city centre. A DFA official has openly stated that Kampaeng Din, Khlong Mae Kha and the area in between them form a historical monument that should not be squatted upon by informal settlements. In a meeting with the Kampaeng Ngam community on February 2002, the DFA official in question has conceded that informal settlements such as Kampaeng Ngam be allowed to stay on their current location, under the condition that the dwellings directly built on Kampaeng Din were moved down to the land between the wall and the moat. A scheme was then presented by the NGO, People's Organisation for Participation (POP), developed in collaboration with architects hired by the Community Organisation Development Institute, which fulfilled the requirements presented by DFA. After the meeting with Kampaeng Ngam community, the DFA official stated in an interview conducted by the present authors that such a concession was only a temporary one. In the long term, a project for the preservation of that historical monument was to be implemented.

Following that meeting, Kampaeng Ngam community implemented with the assistance of the Community Organisation Development Institute (CODI) and POP the

[1] At the time this paper was written, negotiations were taking place between authorities and Kmapaeng Ngam and other Khlong Mae Kha communities fighting against eviction (see Northern Citizen, 2003a). A National Housing Authority (NHA) project has been designed to house Khlong Mae Kha (and other) squatter settlements in the Nong Hoi District (Northern Citizen, 2003b, Chiang Mai News, 2003).

[2] In 1996, the Government of Thailand passed a law, which gives people in informal settlements a possibility to register their houses at the provincial registry department (Gill Teena Amrit, 2002: 2).

[3] Lapanun Patcharin *et al* (1999:160-161) pointed out the beneficial results of registering the population of a squatter settlement in Khon-Khaen province, in the North-east of Thailand. Children in that community were given access to basic education adults were able to use a number of public services such as health care.

[4] This view was openly stated by a DFA official in an interview conducted by the authors.

removal of the houses on Kampaeng Din to a neighbouring site. The Mayor of Chiang Mai was taken to see the new houses in the meeting between government officials, human right and slum dwellers representatives with KPN community on the 21st February 2003.

Lanna Architects Assosiation

The Lanna Architects Association role has been that of a consultant to the Municipality of Chiang Mai in the elaboration of a 30 year Master Plan covering an area of 30 Km2, entitled: "Urban Design Strategy & Design Guideline 2020."

"Urban Design Strategy & Design Guideline 2020" outlines a vision for the future of Chiang Mai, with a strong focus on the conservation of its historical heritage. Such a heritage includes both buildings such as Buddhist temples as well as urban elements such as Kampaeng Din and the Mae Kha Canal.

The proposal for the outer fortification of the city of Chiang Mai is to restore the wall and the moat and to create a park in the area. Community participation is built in the project through the inclusion of public hearings. The project is in its concluding phase and will be made public in the near future.

Community Organisation Development Institute (CODI) and the Urban Communities Environmental Activities (UCEA)

Community Organisation Development Institute (CODI),[5] a public organisation under the National Housing Authority (NHA), has consistently implemented community development programmes, which adopt a bottom-up approach since its inception in 1992. Such programmes aim both at improving the living conditions of the urban poor communities and at strengthening their organisational capacity. [6] They range from the provision of credit to poor communities, through the organisation of savings groups, to loans for housing improvement and income generation.[7] (UCDO, 2000, p.1)

In its role as a support mechanism CODI has stood as a catalyst in a process of social change. Such a process, which aims at promoting "a large scale community-driven development movement," places the decision making and managing responsibilities largely on communities and community networks.[8]

In 1996 the Danish Government, through its now extinct environment and international aid agency, DANCED (Danish Co-operation for Environment and Development)[9], provided the Thai Government with a US$ 1.3 million grant for a project targeted at the improvement of environmental conditions in urban areas occupied by low-income communities. CODI had the responsibility of implementing the project in a number of urban areas in Thailand.

The Urban Communities Environmental Activities (UCEA) project (1996-2002) follows, as the name suggests, DANCED's overall policy of placing local communities at the centre of environmental programmes and giving them responsibilities for decision making, design and implementation. (Boonyabancha, 1999, p.103)

In line with CODI's approach, the Urban Communities Environmental Activities (UCEA) project focuses on a process where environmental improvement is not an end in itself, but a means for promoting social change (Ribeiro et al, 2000). In addition, the environment is attributed a transitory role for two main reasons: (a) the focus of UCEA is on activities as tools for people's education and empowerment; (b) the low-income communities in question are under the threat of eviction by the local authorities, so that the location and pattern of their settlements may be altered in the short term.

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5 The Urban Community Development Office UCDO merged in July 2000 with the Rural Development Fund to become CODI.

6 In order to achieve that, CODI relies on a revolving fund which is made available to all urban poor groups who organise themselves to apply for loans for their development projects. According to a recent survey, by 2000 "over half Thailand's 2,000 urban poor communities in 50 provinces… linked together into 103 networks through a broad range of community development activities, including housing, income generation, environmental improvement, community enterprise and welfare" were members of CODI. (UCDO, 2000, p.1)

7 UCDO encouraged the communities to identify their own problems and needs, and to acquire the necessary funding to address them. One vehicle for this is the Urban Community Environment Activities (UCEA) project. It was launched by UCDO in Chiang Mai, a city in northern Thailand, in 1996, with funding from the Danish government's Danish Cooperation for Environment and Development agency. UCEA finances only self-help projects, channeling small grants to poor urban settlements to improve infrastructure and amenities. In October 2000, UCDO was renamed the Community Organization Development Institute (CODI), after merging with the Rural Development Fund, a Thai government fund for rural development. Despite the new name, CODI will continue to emphasize link the poor through networks at various levels, and helping them gain enormous confidence and more control over their lives and futures.

8 CODI relies on collective instances represented by community groups and increasingly by community networks to achieve a type of management and decision making which aims at representing the interests of socially and economically excluded groups. In that way, CODI aims at providing alternatives to decision-making initiated by authorities (local or central), by learned professionals (specialists, academics), by NGOs and by individuals with illegitimate power within communities (e.g. community leaders [called *Nakleng*] involved in criminal activities, such as drug traffic), (see for instance Phongpaichit and Piriyarangsan, 1994). CODI reports occurrences of misuse of power and funds within the sphere of its activities (UCDO, 2000, p.12), but has documentation to support the argument that community-lead processes are self-regulatory and that mismanagement and corrupt practices will be counteracted in time within community groups and networks. (UCDO Update, 2000)

9 DANCED was established in 1984 with the objective of contributing to the greatest possible extent to the protection of the environment and nature in developing countries. With the ascension of Venstre (a right wing liberal party) to power in November 2001, international development aid by Denmark was severely cut down. In addition, the environmental concerns which figured very high on the political agenda of the Social Democratic Party, were relegated to a second plan. DANCED was done away with and its projects were placed under the Danish Development Aid (DANIDA).

"UCEA aims at changing interactions and power relationships between organisations, networks, groups and individual stakeholders in a complex setting," through a focus on environmental management. (DANCED, 1999, p.9)

UCEA adopts a bottom-up approach, in which communities are the main actors in the processes of problem identification, project design, decision-making, budget management and implementation.

Public participation in environmental projects aims amongst other things to create ownership of interventions (sidewalks, bridges, etc.) by the community involved. By actively contributing to a project, from decision-making, through design, to implementation, the community will, thus, be in a better position to appropriate the project as its own and to look after its maintenance. UCEA could be seen as a radical example of that approach, through its focus on environmental *activities* instead of environmental *products*.

UCEA gives priority to the process of learning and to strengthening the organisational capacity of communities (Boonyabancha, 1999, p.102, Ribeiro et al, 2000, p.3). An example of that is the project for the restoration of the embankment of Mae Ka Canal in Chiang Mai where it crosses Kham Phang Ngam settlement.

Mae Ka Canal used to be very narrow at Kham Phang Ngam, causing floods during the rainy season. Access to and from the community was cut off and, amongst other problems, children were prevented from going to school. The community decided therefore to widen the canal in order to channel the excess of water. The community planned and executed the restoration of the embankments of Mae Ka canal, but it was destroyed by new floods. After a second restoration, the embankment was destroyed once more (Ribeiro et al, 2000, p.16). In a recent visit to the settlement of Kampaeng Ngam (February 2003), the authors have witnessed the new restoration of the embankment through the use of plants, whose roots should help to hold the soil in place.

The case of the reconstruction of the Mae Ka Canal embankment was taken up in an interview with the director of CODI and overall responsible for the implementation of UCEA, Ms. Soomsook Boonyabancha, and her point was that the priority in that as well as in other UCEA projects was the process of learning by the local people. The fact that the community identified a problem, provided a solution, implemented it and then learned from their mistakes was the most important thing. (Ribeiro et al, 2000, p.3)

Activities can be seen in the context of UCEA as methods for actualising the community, for the empowerment of people, for promoting participation, social networking and learning in the community. Such an approach reflects CODI's overall policy:

"CODI helps people to play a role in the development of their own areas. People see, people learn and they can believe they can do it. [CODI is interested in] the processes that will get the essence of the people out" (Interview with Boonyabancha in Ribeiro et al, 2000, p.4)

Under the administration of Prime Minister Taksin Shinawatra, CODI has come to play a prominent role in the improvement of housing conditions to the poor. A national governmental programme aiming at the provision of tenure of land to urban squatters is currently under implementation under the direction of CODI.

POP

CODI made use of its national network in association with local organisations to implement UCEA in different urban areas throughout Thailand. In the case of Chiang Mai, CODI's main local partner in implementing UCEA was the People's Organisation for Participation (POP).

POP is a nationwide NGO, whose Chiang Mai branch has worked for many years with informal settlements with insecure land tenure. With the implementation of UCEA a network of squatter communities along Khlong Mae Kha was formed and POP assisted them in dealing with various problems related to the environmental deterioration of the Canal. Some of the problems were local, such as the decay of the banks of Khlong Mae Kha in the settlement of Kampaeng Ngam. Other problems were and still are common to all the settlements, such as the heavy pollution of the water of Khlong Mae Kha. Especially concerning the latter case, CODI and POP worked with a network of canal communities in organising events, such as a canal cleaning weekend, that could help to change the fact that those communities are perceived by many as being responsible for the pollution of Khlong Mae Kha. By helping to change that perception these communities could stand in a stronger position in their fight against eviction.

Gill Teena Amrit (2002) quotes Bonrueng Pala rangsi, a member of the Kampaeng Ngam community, where he states: "Not only have we been working together to clean up the canal, we have also been planting trees along the canal and are now preparing to make a new bridge (across the canal)…" A number of interviews conducted by the authors as well as articles (e.g. Northern Citizen 2003a) support the argument that the perception by Kampaeng Ngam residents of their role in the maintenance of the canal has been strengthened through their participation in environmental projects supported by POP and CODI.

Concerning the sources of pollution of Khlong Mae Kha, it is the knowledge of Chiang Mai Provincial Government[10] that the squatter settlements along the Mae Kha Canal contribute only marginally to the pollution of its waters[11]. The problem

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[10] Interview with Head of Town Planning Department at Chiang Mai Provincial Government (12-02-03).

[11] A study has been carried out by students from the Danish Technical University under the supervision of environmental engineer Henrik Bregnhøj, which documents the fact that the squatter settlements contribution to the pollution of Khlong Mae Kha is marginal. The main sources of pollution of the canal in the municipal

of pollution of Khlong Mae Kha is of more complex nature. It relates to the fact that Chiang Mai's sewage system only partially services the area under the jurisdiction of the Municipality of Chiang Mai (outside Chiang Mai Municipality no sewage system as such has been implemented). A number of private and public institutions, notably small factories, use Khlong Mae Kha to dispose their wastewater (see report by Kold, Rasmus and Lundtofte, 2002).

Tourism and Historical Identity

Tourism is the dominant economic activity in Chiang Mai (see Ribeiro & Heitmann 2002). The importance of tourism can be illustrated by the number of guest arrivals in the year 2000 in the city of Chiang Mai, which reached 1,894,910 (Thailand in Figures 2001 – 2002, 2001: 481). A conception of environmental management in terms of the promotion of tourism thus emerges as an important factor in the formulation of the "Urban Design Strategy & Design Guideline 2020," by the Lanna Architects Association, in the "Living City" project by Chiang Mai Provincial Government and in the preservation programme by the Department of Fine Arts. The fact that the very development of tourism has led to an accelerated economic growth and a rapid depletion of the environment of Chiang Mai is however not addressed in the formulation of the above-mentioned projects.

A conception of environmental management in terms of the promotion of tourism in those projects focuses on appearances that some consider an eyesore and thus discourage tourism. Such an attitude was visible through the protests against the construction of highway flyovers proposed by the Highway Department (Central Government). Organisations, which included the Lanna Association of Architects and the Chiang Mai Tourist Board were strong opponents of such a highway development.

However, such a conception begs the question of what factors may be relevant for the economy of tourism. It focuses on an aestheticisation of the environment to the detriment of robust policies and programmes, which address environmental degradation in the light of aspects such as economic development, education, and infrastructure (transport, sewage and electricity).

UCEA, which was discontinued with the Danish Government's decision to cut down on its international aid budget, stood as an alternative to the above-mentioned projects. With its focus on the empowerment and education of poor urban communities in environmental management, UCEA reached beyond short term political agendas.

But UCEA stood as an isolated initiative and there is little sign that its experiences and approach have a chance of being integrated in the other programmes and projects dealing with the City of Chiang Mai and more specifically with Khlong Mae Kha.

There seems to be very little communication between the above-mentioned projects. In an interview on the 26th February 2003, the director of the Lanna Architects Association acknowledged the lack of communication and co-ordination between the organisations responsible for the different projects that deal with Khlong Mae Kha and the informal settlements along its embankments. This lack of communication is seen here not simply as the lack of a forum for dialogue between the different stakeholders, but as a deeper divergence of political agendas and economic interests concerning the physical and cultural environment of Chiang Mai and the status of the informal settlements in the area.

The combination of a search for a quick-fix to solve environmental problems, the lack of public participation and the lack of co-ordination between different projects and stakeholders make the provision of a robust solution to the upgrading of Khlong Mae Kha an unlikely scenario.

Instead, the process of urban development and environmental management in the City of Chiang Mai is dominated by struggles at political, economic and cultural levels. At a political level, there is a struggle between central and local governments and civic representation. As we have argued, each of these political levels has a different agenda and relates to the others in complex and often conflicting ways. As pointed out earlier, divergences and conflicts are sometimes found within an institution, such as Chiang Mai Municipality.

The recent development, in which CODI plays a central role in the implementation of a central Government policy, by promoting the tenure of land to the urban poor, is an (unexpected) example of sudden reversal in the political balance, which will no doubt improve the chances of the communities settled along the Mae Kha to remain in their current location.

The economic level involves a complexity of interests by the private sector, ranging from companies which channel their sewage into Khlong Mae Kha to owners of land along that canal. Of especial interest to this paper are the interests associated with the tourist industry, which are closely related to the cultural issue of historical identity of the City of Chiang Mai and of the Mae Kha Canal. The point by Rem Koolhaas in his article "The Generic City" (Koolhaas, 1996) about the effect of mass tourism in undermining historical identities is relevant to the present discussion.

As we have attempted to document, urban development in Chiang Mai and notably housing conditions of squatter communities along Khlong Mae Kha is being shaped by conceptions of environmental management and historical identity by local and central Government and correlated political agendas. Environmental management appears in the light of an aesthetisation through the creation of parks and eviction of squatters: a move which only superficially addresses the current environmental problems of Khlong Mae Kha and its surroundings. Attitudes to environmental management go also hand in hand with the preservation of an

area are coming from point sources, which convey water from areas remote to Khlong Mae Kha.

historical identity. Conceptions of how such historical identity is affected through the complex urban developments taking place in Chiang Mai as a result of accelerated urban development boosted by tourism are, however, highly diffuse.

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The Importance Of Post-Occupancy Studies On Indoor Air Quality In Buildings As One Of The Environmental Management Approaches Towards Public Health

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ABSTRACT: A brief review of the thermal comfort requirements under the equatorial climate is presented. Post-occupancy evaluation of buildings are conducted to evaluate the outcome of the architectural design and its implementation. A proposal is made to use the post-occupancy evaluations of the buildings as a means of assessing the indoor air quality and hence the quality of life in the building.Malaysia is located close to the equator and hence is subjected to a very harsh, hot and humid climate. The Solar radiation intensities are quite high, coupled with high relative humidity values. Due to the increased affluence of the population, air conditioning of buildings (both commercial and residential) has become one of the design necessities. It is thus imperative to determine the optimum design conditions for thermal comfort, so that we can utilise the natural energies to achieve thermal comfort or to minimise air-conditioning for effective energy conservation strategies. Also, in recent years, public interest and awareness in Indoor Air Quality (IAQ) issues have greatly increased. The root of the problem is the design of buildings and the concern to reduce the energy consumption in them. Building related illnesses and Sick building syndrome are a kind of manifestations of this. They are due to the exposure of the occupants to excessive levels of concentration of pollutants due to inadequate or improper ventilation in the building.

Keywords: Indoor Air Quality, Post Occupancy Evaluation, Thermal Comfort, Malaysia

1.0 INTRODUCTION

The Honourable Minister for Science, Technology and the Environment, Government of Malaysia, Datuk Law Hieng Ding[1], mentioned in 1997 “that a healthy indoor and outdoor environment is critical to our daily lives, be it at work or at home. Any human activity, which undermines the quality of our environment, has to be addressed at source. In this respect various forms of atmospheric pollutants such as those, which we have experienced, can have a negative effect on our physical health, economy and social well being. The need to nurture a healthy Built Environment both within and without is never in question. While we can introduce new technology to look after and maintain good quality of the indoor environment, if such actions unwittingly result in generating more pollutants outside the indoor environment, we have then achieved nothing”.

The design of energy efficient buildings is now seen as highly desirable by most planning authorities. Mean radiant temperatures are important considerations of thermal comfort. There are different types of equatorial climates varying from the hot dry to the hot humid. It is the hot humid climate that has posed difficulties in achieving a thermally comfortable environment indoors. Sun is the single most important natural element to be considered in building design. It affects virtually every design decision and has a direct impact on the indoor thermal comfort as well as on the energy budget of the building, if it is air-conditioned.

The main features of a hot-humid climate, like that of Malaysia and Singapore [1][2], are the relatively uniform temperatures, high relative humidities and abundant rainfall due to its proximity to the equator. There are no large diurnal variations in temperature. Also, throughout the year the temperatures are fairly uniform. The mean monthly temperature does not vary by more than 1.1 °C from the mean annual value of 26.6 °C. The average diurnal variation of temperature is about 7.0 °C. Excessively high or low temperatures are rarely experienced. For the period 1934 to 2000 the highest temperature recorded is 35.8 °C and lowest is 19.6 °C. The mean annual R.H. over the period 1934 to 2000 is 84%. However, there are large diurnal variations from 60% to 95%. The mean daily maximum and minimum values are 96% and 64% respectively. There are no distinct seasons and rainfall occurs during every month of the year. The mean annual rainfall is 2369 mm. December is usually the wettest month of the year with an average monthly rainfall of 280 mm and July if the lowest with an average monthly rainfall of 160 mm.

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[1] The opening address by the Hon. Minister for Science, Technology and the Environment, Datuk Law Hieng Ding, “Asia Pacific Conference on the Built Environment - Intergrating Technology with the Environment” at crystal ballroom, P J Hilton, 4 November 1997

[2] Numbers in parentheses refer to the references at the end of the text.

2.0 THERMAL COMFORT STUDIES [1-13]

There is a wide variation in thermal requirements and in thermal sensitivity between individuals in a given group [2]. The aim should be to create conditions for optimal thermal comfort to satisfy the highest possible percent of the group. Probably at best only 80% of the occupants would be comfortable at any one time under the best possible conditions. The individual differences in preferred temperatures would arise in part from the differences in the clothing, activity and acclimatisation to the local climate. Hence, results of comfort studies made elsewhere may not necessarily be applicable to the equatorial conditions .Many research workers in Malaysia and Singapore have done extensive studies on thermal comfort in buildings. Nila [3,4] has done post occupancy evaluation of thermal comfort in school buildings. The examination of the results shows the critical role of air movement in buildings.

The later studies [3,9] show that there are increases of air temperatures from the studies that were conducted 10 years earlier. Hence, it can be said that due to the temperature gains in the urban areas such as Kuala Lumpur, achieving thermal comfort by passive design is more imperative, to achieve energy conservation. Azni and Sayigh [5] working with a fairly large group of subjects have suggested that the earlier ideas of adaptive thermal comfort is correct. A more detailed study of defining parameters of thermal comfort in buildings in Malaysia has been carried out by Abdul Malik and Young [6], where the aim has been to determine a Malaysian thermal comfort temperature and comfort zone. Noor Azizah[7] has carried out a survey in sub-urban area of Kuala Lumpur. The measurements have been taken over a long term and the buildings were in comparable micro climate zone. Rao and Ho[10] conducted experiments in six single storey buildings without side wall enclosures [hawker stalls]. The designs of the buildings were fairly uniform. However the environment inside had been made warm by the radiant heat from the cooking stoves as well as by the solar radiation absorbed and re-radiated by the roof. The subjects came from all walks of life. They were asked to evaluate the environment for thermal comfort. A total of 435 comfort survey opinions were collected. The assessment percentages were compared with the corrected ECI [which was corrected for radiation]. The optimum neutral temperature was 25 C [77 F], when corrected for radiation, when 59% of the subjects felt neither warm nor cool. The PMV values as measured indicated 25 C as the mid-range temperature. There was good agreement between the opinion survey and the PMV data when Webb's CECI was used. Lim, Rao and Rao [11], Lim and Rao[12], Rao [13] conducted studies in some junior colleges and secondary schools in Singapore. The number of people in the rooms were almost the same though might not be equal. Windows were on both sides of the room even though the actual site configurations may slightly vary. The age grouping and the type of work done were similar. Some 160 teenagers and young adults were asked to evaluate their environments and a total of 1319 recordings were made at 1/2 hourly intervals during a normal day for each location using Fanger's comfort meter, anemometer, psychrometer and solarimeter. The survey at schools give similar results as the hawker centres. There was no need to correct for radiation and air temperature was used for the computations. The neutral temperature according to ECI was 25.2 C and is almost identical to the figure obtained earlier. Similarly the PMV value of the comfort meter was recorded at 25.1 C. It may be concluded that the ECI is still applicable with the amendment of the neutral condition to 25 C instead of 26 C as originally proposed by Webb.

3.0 AIR-CONDITIONING [13]

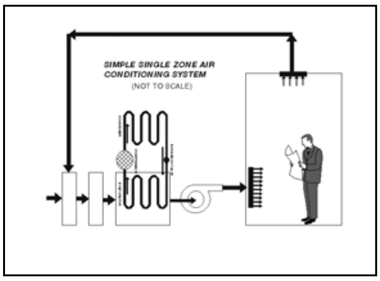


Figure 1: A Simple Single Zone Air-conditioning System

Air-conditioning is defined as a process that heats, cools, cleans and circulates air and controls its moisture content. Ideally, it does all these simultaneously and on a year round basis. Thus air conditioning makes it possible to change the condition of the air in an enclosed area. Since modern man spends most of his life in enclosed spaces, air conditioning is actually more important in the present day context. Figure 2 shows a simple air-conditioning system. Some of the building materials used in construction have been found to be responsible for indoor air contamination. In fact air-conditioning systems aggravate the problem further. Also a near fatal disease, called Legionnaires' disease is propagated by one of the components of the air conditioning system. Before we go further, it is essential to understand how an air-conditioning system functions to produce cold air.

4.0 CHILLED WATER AIR-CONDITIONING SYSTEMS [13]

In this system heat from air passing through the air-handling unit is collected by chilled water and is transferred to the refrigerant passing through the evaporator coil. The heat from the refrigerant is transferred to the cooling water in the condenser. The cooling water carries the heat away to the cooling tower where it is dissipated in the atmosphere. Thus the chilled water system is an indirect system where the refrigerant chills water, which is then circulated through pipe work to the air-handling units, which can be located anywhere in the building.

5.0 INDOOR CLIMATE [2,14-16,20]

The indoor climate essentially deals and concerns itself with common work and occupied spaces. It is how well the indoor air satisfies the three basic requirements for human occupancy, viz.,

- Thermal comfort requirements.
- Maintenance of normal concentrations of respiratory gases and,
- Dilution and removal of contaminants and pollutants to levels that are below health or outdoor discomfort thresholds.

Indoor air quality in buildings may be defined as "the quality of air that affects one's health and well-being". This component is often overlooked by architects, owners, building managers and by the occupants themselves. This situation leads to unhealthy and unpleasant indoor environment. The architects, in particular, have to recognise that the design of the building can affect the IAQ in the building. Table 1 presents a sample of target values of indoor climate factors, as proposed in the Finnish Indoor air quality and climate publication. These values are used to specify the target IAQ at an early stage in the construction project.

Indoor climate has become more important for health and comfort of people as people stay approximately 90% of their time indoors. Thus the quality of indoor air is more important than the outdoor air. Good IAQ should be one of the important goals when designing and constructing a building.

The final quality of the indoor air is influenced by the air-conditioning system and equipment, by the ways of construction, performance of construction and materials used, and by the operation and maintenance of buildings. To achieve good and acceptable IAQ all the above should be taken into consideration in all the phases of design, construction and operation of the building.

6.0 INDOOR AIR QUALITY IN AIR-CONDITIONED BUILDINGS [15-22]

Because of the energy crunch experienced in l973, buildings have been increasingly made tighter to prevent air infiltration into buildings. Also, for reasons of economics, 80% to 90% of the indoor air is re-circulated in most of the buildings. Because of these reasons, the incidence of "tight building syndrome" in office buildings has increased rapidly. All over the world, many instances of eye and throat irritations, headaches, nausea and fatigue in air-conditioned buildings have been investigated. In most cases, specific chemical or microbial causes were not identified.

There have been a number of incidents where large numbers of office workers have become ill and these illnesses have been traced to a particular source of indoor air pollution. Hypersensitivity pneumonitis, humidifier lung, Legionnaires disease and mass psychogenic illnesses have been reported in many buildings. A report issued by the American Society of sanitary engineering has linked leaking refrigerants to Legionnaires' diseases.

- *Sick Building Syndrome [14,20]*

The buildings at issue are often large and represent work environments. In hundreds, perhaps thousands, of buildings a surprisingly similar set of symptoms occur that include several or most of the following,

(i) Mucous membrane irritation
(ii) Eye irritation
(iii) Headache
(iv) Odour
(v) Skin irritation/rash
(vi) Sinus congestion
(vii) Cough
(viii) Sore throat
(ix) Shortness of breath
(x) Dizziness/Fatigue
(xi) Wheezing and hypersensitivity

Large numbers of people are typically affected. They usually complain that the environment is "stuffy". In fact, the causes are difficult to determine. It is apparent that multi-disciplinary approaches are required for the successful analysis and solution of the sick-building syndrome problems.

- *Legionnaires' Disease[17,18]*

This disease is caused by "Legionella Pnemophilia" bacteria. The bacteria is usually water borne. The disease manifests itself with loss of appetite, tiredness, muscle-ache and headache. Within a span of a day high fever develops, accompanied by dry cough and shivering. There could be accompanying diarrhea and stomachache. The disease got its name in 1976, when 221 retired Legionnaires' among a group who met for a get-together in a hotel in Philadelphia, U.S.A. contracted it. Twenty-nine of them died. About forty-six people died of the disease at Stafford General Hospital in the U.K. The bacteria has been found in the cooling tower water at Heathrow Airport. It has also been found in many office and educational buildings in Singapore.

The disease can only be caught by inhaling droplets of infected water. The water in the cooling tower is usually recirculated over a period of few months. The water is usually treated with chemicals to prevent growth of bacteria. The temperature of the water going to the cooling tower is around 45 to 55 deg C and the water is returned from the tower at about 30 deg C. The temperature and humidity conditions within the cooling tower are ideal for growth of bacteria. To prevent the growth and spread of the bacteria, it is necessary to have a proper maintenance schedule and to follow the same rigorously.

Leaking refrigerants have also been attributed to the spread of the Legionnaires' disease. A urine analysis of those who caught the disease has revealed the presence of fluorides. This links the disease to inhalation of leaking refrigerant which has been pyrolised (catalysed by heat) into fluorophosphene gas. In U.S.A., there has been an attempt to add odourisers to the refrigerants, to detect leakage of the refrigerants. However, it has not been very successful, as the industry has not adopted it whole-heartedly.

7.0 SOURCES OF INDOOR AIR POLLUTION [14-16,20]

Some of the important sources of indoor air pollution are,

- Building and fitting materials
- Furniture
- Tobacco smoke
- Microbial growth (mould, mites, algae etc)
- Cooking and open combustion
- Cleansers
- Pesticides
- Human activities like playing etc.,
- Exhaust from automobiles
- Photocopying machines etc.,

The trends in the construction techniques leading to increased use of resins, solvents and adhesives etc., ate a cause of concern. These materials can and do emit organic vapours , especially during the first few months of occupancy of the building. Coupled with lower ventilation rates the problem is compounded. The materials and sources of concern include formaldehyde from resin-bonded wood products, adhesives and wall insulation as well as solvents in glues, cement, foams, paints and vinyl tiles. High levels of emissions from building materials are difficult to be compensated by increased ventilation.

Also, it is not always possible to select ventilation rates taking into account the emissions from the building materials as the finishing materials are selected at a later stage during the construction process. There are several chemicals that are emitted from building and interior decoration materials into room air. They can originate from the aging of the materials or due to the manufacturing process. Improper use of materials may also be a reason for the emissions. To achieve low concentration of chemicals, the main controlling method should be the use by the architect of low-emitting materials. Subsequently, increase of ventilation rates could be adopted to reduce the concentrations.

8.0 VENTILATION SYSTEM HYGIENE (19,20)

The hygiene of the air-conditioning and ventilation system is very often neglected, largely because the ducts are inaccessible and are out of sight. When buildings are refurbished and are retrofitted, many a times the air-conditioning system is left unaltered. Duct cleaning as an important item in the refurbishment process is omitted. Additionally, not much conclusive data is available about contaminants accumulating in the air-conditioning ducts and their effects on IAQ. Engineers generally do not have deeper knowledge of microbial contaminants and methods to control them. Engineers need such knowledge to solve the problems encountered in practice.

The engineer should exercise caution in the selection of duct materials and their roughness etc., The surface roughness of the duct would influence the deposition of particles within the duct. Many glass fibre or porous ducts deteriorate over time and would release the fibres into the air stream. They can also collect moisture leading to fungal and bacterial growth. There should be sufficient allowance of spaces around the ducts for inspection and subsequent cleaning.

9.0 POST OCCUPANCY EVALUATION [21-26]

Post Occupancy Evaluations provides an indication of major successes and failures in a building's performance. It can be used to improve and explain the performance of a building. It is useful not only to the occupants and owners but also to the designers, who can learn about both their mistakes and successes and can apply these findings to future projects.

New buildings require proper system design and commissioning to achieve good IAQ. This process confirms that the building systems perform as intended, are tested adjusted and balanced. It also ensures that the documentation, training and an operation and maintenance plan are complete. All of the parties involved; the building owner, the property manager, and the operations and maintenance staff, must continue this commitment to provide a well maintained system. Over time, as changes occur – new office layout, different occupancy levels, new equipment, different job activities, changing work periods – then "recommissioning" of the building's systems should be done in order to reflect these changes.[21]

9.1 A Typical Post-Occupancy Evaluation [22]

Such an evaluation would comprise:

- Reviewing energy and environmental performance against benchmarks
- Assessing of building operation, management and control
- Supervising building pressure tests and other examinations
- Managing surveys to assess occupant satisfaction

Benefits of Post Occupancy Evaluation include: [22]

- **Fine tuning new buildings:** By understanding how buildings support and/or frustrate activities, they can be fine-tuned and management practices adjusted. Very often, slight adjustments to buildings and the ways they are used offer significant benefits to users.
- **Improving design for future buildings:** By designing new facilities with an understanding of how similar buildings perform in-use, mistakes can be avoided and successful design features capitalised upon.

- **Accountability:** Post Occupancy Evaluation is a valuable tool for assessing building quality - essential when organisations are required to demonstrate that building programmes are being responsibly managed.
- **Cost savings**: Post Occupancy Evaluation identifies ways people can use buildings and equipment more efficiently and more cost-effectively. Dysfunctional or seldom-used building features can be eliminated or replaced.

- **Renovating existing buildings:** Post Occupancy Evaluation is an important tool in planning the refurbishment of existing buildings. It helps clarify perceived strengths and weaknesses to focus resources where they are needed. It is also used to identify where building design adjustments are needed to support changing practices, markets, legislation and social trends.

- **Staff and/or customer relations:** Post Occupancy Evaluation involves building users in defining how buildings work for them. This participation has been shown to engender greater commitment to solutions, and more willingness to accept shortcomings.

1. **Preparation (2-3 weeks):** Identification of user groups, timetabling, selection of participants, letters of invitation.

2. **Interviews (1 week):** Small groups of like users are interviewed while walking through the building, which provides the prompt for their comments and observations. A review session is held to verify comments, establish priorities and review the process. Observation studies and written questionnaires may also be used.

3. **Analysis & Reporting (3-6 weeks):** Documentation of participant findings, generation of recommendations, compilation of a report and presentation.

Proposed Questionnaire
Indoor Air Quality (IAQ) Survey

Objectives: To check any physiological and psychological discomfort experienced by building occupants. To determine the nature and the causes of discomforts; seriousness and frequency of discomfort; and the duration of occupants exposure to the indoor environment.

1. In which environment do you feel healthier? (please tick)
   Inside the building ___ Outside___

2. Please indicate (tick) the level of satisfaction that you feel regarding the air quality inside the building:
   Satisfactory ___ Acceptable ___
   Unsatisfactory ___ Terrible ___

3. What kind of discomfort do you experience in the building? (please tick)
   Breathing problem_____ Watery eyes___
   Running nose_____ Headaches___
   Dizziness ___ Wheezing ___ Coughing __
   Nausea ___ Irritation (skin, eyes) ___
   Fatigue/ lethargy___ Sore Throat ___ Stress ___
   Others (please specify) _______________

4. What do you think are the causes of the discomforts that you experience? (please tick)
   Bad/strong odours ___
   Particles in the air (dust, vapour, etc.)___
   Cigarette smoke ___
   Automobile exhaust ___
   Human activity (working, playing, etc.) ___
   Microbial growth (mould, mites, etc)___
   Wall paints___ Carpets___ Furnishing___
   Photocopy machine___ Air temperature___
   Bad lighting condition ___
   Others (please specify)_______________

5. How serious do you rate the discomfort that you experience in the building (please tick)
   not significant ___ mild ___ serious___
   very serious___

6. How frequent do you experience these discomforts inside the building? (please tick)
   Seldom___ quite frequent___frequent___
   all the time ___

7. Do you usually continue to experience these discomforts when you leave the building?
   Yes ___ No ___

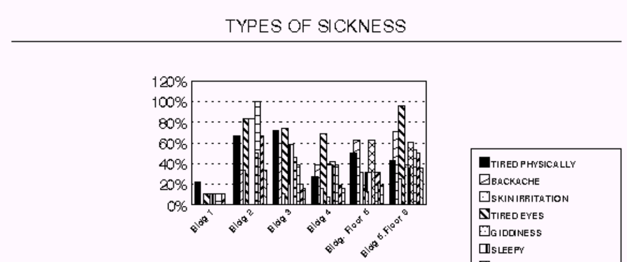
8. Approximately, how long do you stay inside the building each day? (please tick)
   1 to 5 hours ___ 5 to 10 hours ___
   More than 10 hours ___

While not a routine part of the construction quality assurance process, only through a review of building operation performance and the assessment of building occupants can the success of the construction be fully evaluated. There are many forms the post-occupancy evaluation (POE) can take. But in all cases, it should include a survey of building occupants comfort and satisfaction with the building environment. This survey must be done with standardized questionnaires.[23]

- *C.K. Choi Building, USA [24]*

A post-occupancy evaluation found that most building occupants had a favourable overall impression of the building. Occupants were particularly positive about the indoor air quality, lighting system and the aesthetics/ambience of the building. On the negative side, occupants complained of cold winter temperatures and high summer temperatures in some parts of the building. The most common complaint dealt with was excessive noise due partially to the operable windows that allow traffic noise to penetrate the building. [24]

- *Post Occupancy evaluation and IAQ studies in Six buildings in Singapore [25]*



TIRED PHYSICALLY	22.2%	66.7%	71.8%	26.9%	50%	42.9%
BACKACHE	0%	33.3%	46.2%	38.5%	62.5%	71.4%
SKIN IRRITATION	0%	33.3%	10.3%	15.4%	31.3%	25%
TIRED EYES	11.1%	83.3%	74.4%	69.2%	18.8%	96.4%
GIDDINESS	0%	0%	20.5%	7.7%	12.5%	39.3%
SLEEPY	11.1%	83.3%	59%	38.5%	31.3%	35.7%
HEADACHE	0%	50%	46.2%	42.3%	62.5%	60.7%
SNEEZING/RUNNING NOSE	11.1%	100%	38.5%	38.5%	18.8%	53.6%
SORE THROAT	11.1%	66.7%	20.5%	19.2%	31.3%	50%
COUGH	0%	33.3%	15.4%	15.4%	18.8%	35.7%

Figure 2: Post Occupancy evaluation and IAQ studies in Six buildings in Singapore [25]

Figure 2 summarises the results of a POE and IAQ study done by one of the authors (Rao) in Singapore[25]. The study was carried out on 6 buildings and the occupants were asked to respond to a survey questionnaire. Subsequently the IAQ was confirmed by using the instrumentation. This proves the utility of doing post occupancy evaluation studies as a tool to evaluate the indoor air quality in buildings.

10.0 CONCLUSIONS

This paper briefly reviews the thermal comfort requirements under the equatorial climate. These are based on actual measurements done in Malaysia and in Singapore on a fairly large population sample. The research presented here-in is the work done in Malaysia and in Singapore over the past decade.

The building design teams led by the architects and engineers have a responsibility during the design, construction and operation of the building to have an acceptable and good indoor air quality. It is necessary to specify materials that have low emissions, provided their performance is equal. The construction process should not aggravate the problem.

The categories for indoor climate, construction cleanliness and finishing materials shall be selected at an early stage in the construction project. The client should be involved with the design team during such a process. High emissions of building materials are difficult to be compensated by increased ventilation. Microorganisms growing in air conditioning systems and ducts, are now known to have caused outbreaks of respiratory illnesses all over the world. Pneumonia caused by Legionnaires' bacteria is also known to be relatively common. A large percentage of the population appears to have been exposed to this organism; perhaps they have developed immunity to it. Leaking refrigerants are also potential carriers for the spread of the disease. The ventilation system may be unwittingly transmitting the disease throughout the building. The air conditioning system designer as well as people maintaining the building and building services, have an added responsibility to prevent the growth of the bacteria and the eventual spread of the disease. It is necessary to be aware of the problem and attack at its source, before the diseases affect and harm many more innocent occupants of air-conditioned buildings and those who happen to pass by those buildings.

Post occupancy evaluation of buildings should include questionnaires on the indoor environment and thermal comfort [25, 26]. It is suggested that such a tool could be used effectively to provide a healthy indoor building environment to its occupants.

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Healthy Workplace Concept: A Case Study On Its Implementation In Malaysia

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ABSTRACT: A working adult will spend minimum one third of their time in workplace, this is an inevitable circumstances, however it does not mean that they are paying equal amount of attention on the safety of their workplace as what they do on the road and at their home. In fact, occupational and non-occupational safety is equally important. As the world-leading organisation of health, the World Health Organisation (WHO) has come out with a guideline on Healthy Workplace (HWP). In Malaysia, the government is in the progress of evaluating and assessing the guideline with the intention of adopting it. This paper reports an investigation on a government organisation implementing the healthy workplaces concept based on WHO guidelines with some amendments to suit the local culture and function of the organisation. Members of the organisation were interviewed based on the questionnaire recommended by WHO guidelines with some modifications. The case study attempts to incorporate ISO 14000 Environmental Management System (EMS) into the implementation of this healthy workplace concept. The result of this case study revealed that ISO 14000 system is able to set a framework to implement healthy workplace concept provided the organisation has a strong commitment in the implementation. Furthermore, the organisation needs to be sensitive when developing a system that is suitable to implement this concept. HWP is workable for all kinds of organisation but the success of the implementation of HWP and its sustainability depends very much on the action plan developed by the top management.

Keywords: Healthy Workplace (HWP), Environmental Management System (EMS), Occupational Safety

INTRODUCTION

It is quite well known that workers spend at least one third of their time at their workplaces. Hence it is important for workers to ensure that they are working in a safe and healthy workplace. According to World Health Organization (WHO) publication: Global Strategy on Occupational Health for All in 1995, only 5%-10% of workers in developing countries and 20%-50% of workers in industrialized countries have access to adequate occupational health services. In a recent occupational health data indicate that 40-50% of the world's population is exposed to hazardous conditions in the work place. There will be between 68 million to 157 million of new cases of occupational diseases arising as a consequence of various types of work related-exposures.

A healthy workplace simply means a place where everyone works together to achieve an agreed vision for health and well being of workers and the surrounding community (WHO 1999A). From its definition, healthy workplace involves multi-institutional and multi-dimensional effort, it also involves commitment and partnership to implement a healthy workplace initiative be it a national, provincial or local setting. An unhealthy workplace has far-reaching effects, it ranges from poor work performance, susceptible to ailments, no harmony in the family to the increase of social and economical problems in the society.

It is also said that, the healthy workplace concept is a building block for sustainable development. In the Agenda 21 (UN 1999), there are quite a lot of elements related to health, safety and well being of an individual at workplace. This concept is also believed to be one of the antidotes to the increase of mental health problems.

There is a need for a system that can be implemented to improve workers' lifestyle, especially at their workplaces which they spend one third of their time there. The health status of workers' workplace will shape their lifestyle both directly or non-directly, be it immediately or chronically.

THEORIES

There are many theories and approaches related to the HWP concept. In this case study, three theories which are suitable for target and nature of this study have been chosen.

WHO Guidelines

Satisfying work in a safe and pleasant environment is a source of health and well-being. Yet the physical, psychological and organizational work environment is all too often responsible for injury and disease. A lot of challenges need to be overcome in achieving a healthy and sustainable future, one of them is to ensure health and environment are enhanced by economic development. There should be a balance for these three aspects of environment, health and economy. No doubt, industrialization has contributed vast improvement in health such as increased revenue, better living conditions and improved services, but on the other hand, industrialization is also the main culprit for introduction of health hazards to workforce and the general population. Such hazards are felt either directly through exposure to harmful agents and practices, or indirectly through environment degradation.

According to Karasek and Theorell (1990), mechanical factors (e.g. work processes and equipment), physical factors (noise, heat and radiation) and chemical agents are the main problems in industry, while pesticides, heavy physical work, organic dusts, biological factors (e.g. infections), and accidents are the occupational burdens in the area of agriculture. In addition 30-50% of the workers in industrialized countries experienced psychological stress, unlike environmental stressor, occupational stressor are multi-cause and it is closely related to the results from the work organization (e.g. workload, repetitive work, shift work and overwork).

Another main factor for the increase of occupational hazards is the transfer of hazardous industries; the divergent needs of industrialized and developing nations often lead to a double standard in the control of industrial hazards. Established standards frequently differ between countries and may be determined by, more often than not, economic, political and educational factors, rather than the most crucial factor- health protection.

A healthy workplace aims to:

- Create a healthy, supportive and safe work environment;
- Ensure that health promotion and health protection become an integral part of management practices;
- Foster work styles and lifestyles conducive to health;
- Ensure total organizational participation; and
- Extend positive impacts to the local and surrounding community and environment.

Two concepts are crucial to the achievement of healthy workplaces- the protection of health and the promotion of health. Basically the healthy workplace will bring benefit to both the organization and the employee as well as shown in Table 1.

The development of healthy workplace requires efforts from all sectors at national, provincial, local and workplace levels. A relevant government department should initiate the process. Key participants are the government departments responsible for enforcement of occupational and environmental health legislation. Ideally the healthy workplace initiative should be part of the implementation strategy of all relevant regulatory agencies and service providers. In this way, the health and labour inspectors, environmental managers, health centre personnel, employer associations and trade unions will support the initiative and convey a similar message. If the regulatory agencies do not endorse the initiative and its guidelines, it will not be effective.

Other stakeholders in this initiative include occupational health and safety organizations, health promotion/public health organizations, health insurance providers, environment health and protection groups and consultants in organization development.

Table 1: Benefits of HWP to Organization and Employee (WHO 1999)

To the organization	To the employee
A well-managed health and safety programme	A safe and healthy work environment
A positive and caring image	Enhanced self esteem
Improved staff morale	Reduced stress
Reduced staff turnover	Improved morale
Reduced absenteeism	Increased job satisfaction
Increased productivity	Increase skills for health protection
Reduce health care/insurance costs	Improved health
Reduced risks of fire and litigation	A healthy family and community

In order to implement the healthy workplace concept, the following steps need to be taken:

- Ensure management support
- Establish a coordinating body
- Conduct a needs assessment
- Prioritised needs
- Develop an action plan
- Implement the action plan
- Evaluate the process and outcome
- Revise and update the programme

There are some components and checkpoints that are used to indicate or reflect the major elements of a healthy workplace, which are :

- Workplace policies
- The organizational environment
- The physical environment
- Lifestyles and personal health skills
- Health services
- Impact on the external environment

These checkpoints provide example and criteria whereby an organization can use to measure their progress in becoming a healthy workplace. The list is not all-inclusive. In fact, there may be other checkpoints more relevant to the situation in particular countries and workplaces

Agenda 21

Since Healthy Workplace is a building block for sustainable development, workplace related issues have been emphasised in the Agenda 21 document. There are 4 sections and 40 chapters in this document. Three out of four sections have mentioned workplace related issues, namely:

Section 1, Chapter 6: Protecting and Promoting Human Health

Ensure public health education in workplace is provided and strengthen

Establish industrial hygiene

Emphasize on preventive strategies to reduce occupational derived diseases

Section 3, Chapter 29: Strengthening the role of workers and their trade unions

- Give high priority to protection of working environment
- To reduce occupational accidents, injuries and diseases

Section 4, Element 34
Transfer of environmentally sound technology
This is to protect the developing countries so that the technology transfer is safe to the workplace. In China and South Korea, there are incidents whereby the developed countries have transferred hazardous technology to the developing countries whereas the technology itself was banned in those developed countries (WHO, 1999B).

ISO Standards

Healthy Workplace concept can appear to be very abstract when it comes to the implementation stages. The ISO 14000 system is one of the ideal systems that could set a framework or template in the implementation of this concept.

Through the Environmental Management System (EMS) of the ISO 14001, management can incorporate the healthy workplace concept to the policy of the organization. This will provide direction and a sense of purpose when the organization is implementing the concept. During the policy setting, healthy workplace implementation progress can be quantified and made tangible to everyone in the organization.

The EMS can also strengthen the commitment of healthy workplace implementation in every level of the organization for they need to submit a progress report based on the EMS requirement and improve the system continuously (ISO 1996). There will be a close monitoring and self-corrective programme in the EMS, audits should be conducted to ensure that the healthy workplace concept is adopted effectively and align with the need of the organization.

The EMS also requires the organization to comply with various legal aspects; some of the regulation involved is link to the implementation of healthy workplace (e.g. Factory and Machinery Act, Occupational Health and Safety Act). In addition, EMS also requires an emergency response plan to be in place, and a constant training and drill needs to be conducted for these purposes. These are non-direct ways to ensure that the workplace is safe and the sense of security can be instilled in every staff.

METHODOLOGY

A need assessment was conducted according to WHO Regional Guidelines for Healthy Workplace, and from this guideline 2 tools were being applied namely;

- Walk Through Survey

A workplace inspection was conducted at an organization named YRC to identify the hazards and potential health risks in the physical and organizational environment. Collecting administrative information was also part of this activity.

- Questionnaire

The questionnaire used is based on WHO HWP guidelines but has been modified to suit the local culture and the background of the target organization. During the initial stage of the questionnaire the response from the organization was not very encouraging, hence a different strategy was adopted. Interview session was added as a tool for data collection, the respondents were interviewed when they were answering the questionnaire. This approach has help to get more information for the study.

A comparison was also carried out against an organization that has conducted the Healthy Workplace survey. This organization has a different background and setting from YRC. The identity of this organization could not be disclosed. However, the organization is a manufacturing company (private sector) and owns by a big corporation.

In the results and discussion section, the constraints and barriers of implementing the concepts were discussed. Furthermore, suggestions were also presented in implementing the HWP concept in Malaysia and also highlight the related agency involved.

RESULTS

i) Results from Walk Through Survey

- Background of organisation

YRC is a governmental lab-based institution and has 6 laboratories. Just like any other government office, YRC has 2 working shift, whereby shift one works from 7:30am to 4:00pm and shift two works from 8:15am to 4:45pm.

- Facilities

Rating of the facilities was carried out and it followed the following criteria:
Good - The facilities are more than enough for the workers
Average - Facilities are just enough for the workers, additional workers may cause insufficient facilities
Below Average – Facilities are there but very few and lack of varieties. The facilities are poorly maintained
Poor – No such facilities

The facilities of the organization can be divided into two major categories:
i. The Welfare Facilities:
In order to meet the basic and recreational needs of the workers, several facilities are provided and the ratings are shown below:

Facilities	Rating
Sport facilities	Below Average
Child care (Taska)	Average
Cafeteria	Average
Meeting Room	Average
Car Park	Average

ii. The Sanitary Facilities:

There are three toilets allocated for the female staff and another three for the male staff. However, only one facility is situated near to the workplace for both group of staffs. The rating for the sanitary facilities is just average.

Issues discovered

1. Handling, Storage and Disposing of Chemicals

This laboratory based organization deals with various chemicals. The chemicals are of flammable, corrosive and poisonous in nature. However, during the walk through survey, it has been discovered that the storage of the chemical is unsystematic and hazardous; acids are stored together with flammable chemicals, virgin chemicals are stored with used chemicals, chemicals are not labelled properly and some of the chemicals are received without the Material Safety Data Sheet (MSDS). The disposals of the chemical do not follow the first in first out basis, and many of the waste chemicals are stilled stored in the laboratories. Some of the workers have the wrong perception that they need to dispose the waste chemicals only once the quantity achieves a certain level. Spill tray was not properly set up in the laboratories and six laboratories do not have a standardized system to handle and dispose waste.

2. Clinical Waste

YRC also generates clinical waste. It has contracted out the clinical waste to a vendor but no monitoring has been carried on the performance of the vendor. There were incidents whereby the vendors did not collect the waste on time and records of the collection were not kept up to date.

3. Location of Taska (Child Care Centre)

The childcare centre located directly below the toxicology laboratory and next to the microbiology laboratory. The children are taking their breakfast and lunch daily at the taska. On average, a child will spend 7 hours in the childcare centre, 5.5 days a week.

4. Clean Room Construction

Currently YRC heavy metal laboratory is being upgraded. A clean room (a confined area whereby the air quality, ventilation, temperature and humidity are under strict control in order to maintain a desired level for the parameters mentioned) is needed in order to ensure that the trace heavy metal testing is conducted under a very clean environment.

During the construction, there are bound to be safety and cleanliness issues. The construction may also cause air and noise pollution to the working environment if it is not well planned.

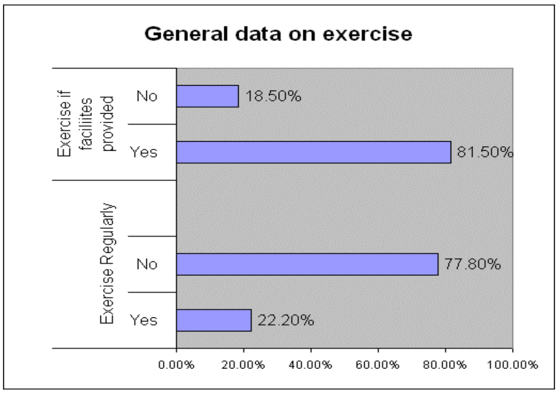
5. Lack of Personal Protective Equipment (PPE)

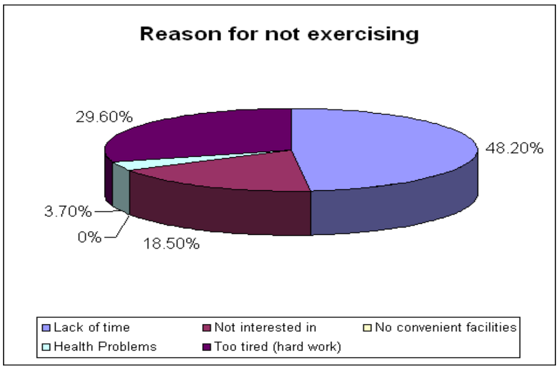
Not all the laboratory personnel are safety conscious, some of the laboratories are equipped with PPE while some are not. PPE like goggles and facemasks are not available in certain laboratories. Gloves and first aid kits are available in all of the laboratories.

ii) Results from the questionnaire responses

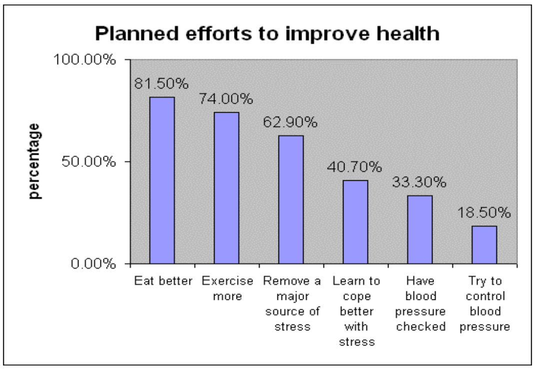
From the survey, results are analysed based on the three categories, namely, health promotion issue, relating to job and life, and health interest. As for the comparison with the private sector, only the data of the key question is provided, this is to protect the confidentiality of the company involved. The data obtained from the private company has been rounded up to the nearest percentage.

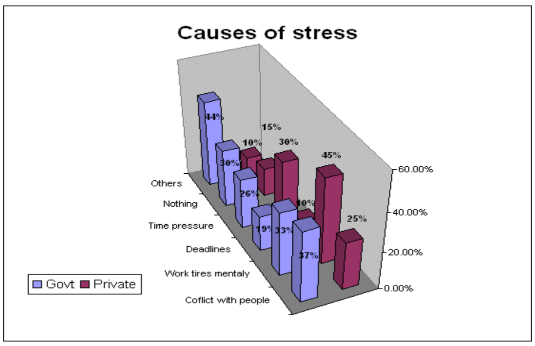
Section1: Health Promotion Issue





Section 2: Relating to Job and life





Section 3: Health Interest

DISCUSSION

From the survey results and the interview session with the staff, YRC needs to understand their constraints and barriers in their implementation of the healthy workplace (HWP) concept.

As mentioned in the theory, ISO 14000 offers a system or framework of implementation for the organization. YRC is still considering in the infant stage for the implementation of EMS for they are just awarded with the certification, but because of EMS the implementation of HWP is made easier in YRC. Looking at the fact that there are still a lot of health hazard issues need to be settled thus a lot of maintenance need to be done on the EMS system for YRC.

The implementation of HWP, involve the commitment of the whole organization and not only a small interest group. Staff from the top management to the laboratories technologists need to be serious in adopting HWP concept at their work station. There is a lack of group work and the delegation of tasks was not clear in certain area. Due to the lack of sense of belonging and fixed mindset among the staff, commitment is still quite weak in YRC.

The HWP concept is still quite new in Malaysia. Training programme that is available is still limited. YRC has difficulties in getting source for guidance for the HWP implementation. In addition the awareness of HWP is still low in the organisation.

From the data of the questionnaire, most of the staff complaint that the air quality is bad and the workspace is poorly designed. During the interview some of the staff complaint that the confine workspace makes them feel uneasy and thus affect their work performance.

When YRC conducted the first vendor audit on their waste disposal contractor, they discovered a lot of problems and these match with the observations made during the walk through survey. Their passive approach on the vendor activities has a potential for health hazard problems.

Red tape is always a constraint for any organisation, action could not be taken as quickly as possible. Several stages and steps need to be taken in order to implement a decision. This has caused the implementation of HWP to be delayed most of the time.

CONCLUSIONS

In short, YRC is at the stage of formulating an action plan for their healthy workplace concept. This stage can be done effectively based on the observations from the walk through survey, the questionnaire results, and the ideas contribute by the staff during the interview sessions.

However, there are still a lot more to be implemented in order for YRC to become a champion in HWP. In spite of that, the concept is workable for YRC because of their commitment and the EMS system that is already in place. As long as YRC follow an action plan that is designed base on their own situation and willing to revise it regularly to suit the progress, HWP can be implemented smoothly.

ACKNOWLEDGEMENTS

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The Risks of Ammonia Rail Transportation: Computer-Aided Quantitative Risk Assessment Approach In Estimating Human Error Probabilities Associated To Train Speeds

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ABSTRACT: This paper details the finding of the Quantitative Risk Assessment (QRA) undertaken to determine the effects of human error probabilities and train speed on the estimated risks for the transportation of ammonia by rail. The transportation of ammonia by rail from the Petronas Fertilisers Kedah (PFK) Plant in Gurun, Kedah to Chemical Company of Malaysia (CCM) Chemical's facilities in Port Klang was used as the basis for the case study assessed in the QRA. The QRA methodology adopted for the case study was based on the approach recommended by the American Institute of Chemical Engineers (AIChemE) as well as the methodology developed by Det Norske Veritas (DNV). Two software programs were used in the analysis: RAMAS Risk Calc software developed by Applied Biomathematics Ltd. to facilitate human error uncertainty calculations using the fuzzy arithmetic approach and SAFETI v5.2 software developed by DNV for the consequence modelling and overall risk calculations.

Keywords: Quantitative Risk Assessment, Human Error, Individual Risk, RAMAS Risk Calc., SAFETI v5.2.

INTRODUCTION

This paper details the finding of the QRA carried out to determine the effects of human error probabilities, estimated using the Human Error Assessment and Reduction Technique (HEART) method and the effects of train speed on the estimated risks for the transportation ammonia by rail. The current transportation of ammonia by rail from the PFK Plant in Gurun, Kedah to CCM Chemical's facilities in Port Klang was used as the case study in the QRA.

Rail is favoured as the means of transport medium compared to other modes, such as road transport due to its ability to carry large loads. As a result, there has been a steady increase in the use of railways as the means of transport of hazardous materials throughout the world in recent years. According to the Association of American Railroads, there are more than 600 freight railroads operating today in North America. North American railroads alone operate over 173,000 miles of track and generate over $42 billion US dollars in annual revenues. However, as with road and other transportation modes, there have been many occurrences of rail/train accidents involving releases of hazardous materials. Of these accidents, rail transportation accidents involving ammonia releases have resulted in multiple fatalities, evacuation of people and/or loss of property.

It should be noted that the QRA was limited to the analysis of risks from accidental releases of ammonia during rail transport mode only and does not include the risks during loading and/or unloading activities.

METHODOLOGY

Figure 1 presents the QRA methodology adopted in the study, which is based on the approach recommended by AIChemE and DNV.

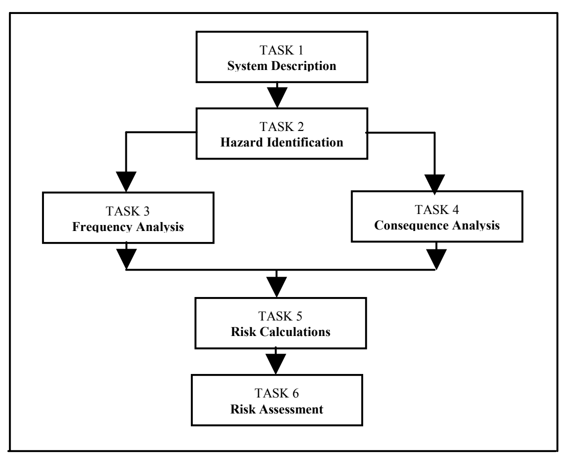

Figure 1: QRA Methodology Flowchart

System Description

The first stage in the QRA process, highlighted as "TASK 1" in the figure above is to define the "system"; i.e. define the boundaries of the case study to be analysed. System definition is an essential part of a QRA as it enables identification of what should be included in the study and what should not.

The case study assessed in the QRA is based on the existing ammonia transport operations by CCM Chemicals, which imports ammonia from the PKF Plant in Gurun, Kedah to its storage facilities at Port Klang. CCM Chemicals demand for ammonia requires the transportation of 35,000 ton per year of anhydrous liquefied ammonia from the fertilisers plant. In order to meet this demand, Petronas will load 20 rail car tanks every 3 to 4 days. Each of the rail tank cars will have a maximum capacity of 30 tons. However, as a safety precaution, each railcar will only be filled up to 25 tons to allow for expansion properties of ammonia. Therefore, each shipment of ammonia amounts to about 500 tons and this equates to approximately 70 trips per year to meet the required demand.

The case study rail transport route stretches from Gurun, Kedah in the north of Malaysia to Port Klang, northwest of Kuala Lumpur. The total distance of the route is approximately 450 km, and covers a wide area, west coast of Peninsular Malaysia.

Hazard Identification

The hazard identification step, identified as "TASK 2" in the figure above, is the most important component of a QRA, since the hazard identification and failure case definition process have a major impact on the type and the accuracy of calculated risk results.

The objective of the hazard identification process is to focus on the type and nature of hazards, which may be present and require further evaluation to determine the level of risks they present. In other words, hazard identification provides a list of failures and failure combinations, which can lead to accidents. The initiating events, which may give rise to the hazards such as equipment failures, are also identified. This process is usually carried out using a mixture of experience from previous QRA studies and expert judgement.

Figure 2 shows the description of a rail tank car presented in the transportation risk analysis by Rhyne, W., which was used as the basis for the selection of failure scenarios for case study assessed in the QRA. The most common leak sources upon an accident for the rail tank car are from the tank head, tank shell, valve dome, liquid & gas valves and the manway. These sources are however, dependent on the type of accident causes that subsequently result in failure of the above mentioned tank car equipment. The primary causes of equipment failures resulting in releases of ammonia for the rail tank car shown in the figure below has been identified as follows:

- Impact forces failing tank car
- Crush forces failing tank car
- Puncture forces failing tank car
- Thermal forces failing tank car

The first three causes were considered in the case study whilst the fourth, equipment failures due to thermal forces was not considered in the analysis due to the physical and chemical properties of ammonia. Ammonia is a material that is difficult to ignite in the open air as its flame is unstable and cannot propagate itself. Although explosion could occur in flammable mixtures in vessels or enclosed spaces, ignition is difficult and the possibility of an explosion in the open is generally discounted. Therefore, only releases of ammonia from the tank car due to impact, crush and puncture forces were considered in the analysis. The failure scenarios identified above were then categorised into the common types of rail accidents that could potentially cause these failures. Based on historical data, the most common rail accident types are collisions and derailments.

Failure cases for non-accident related releases; i.e. faulty valves, defective seals, etc. were also been included in the analysis.

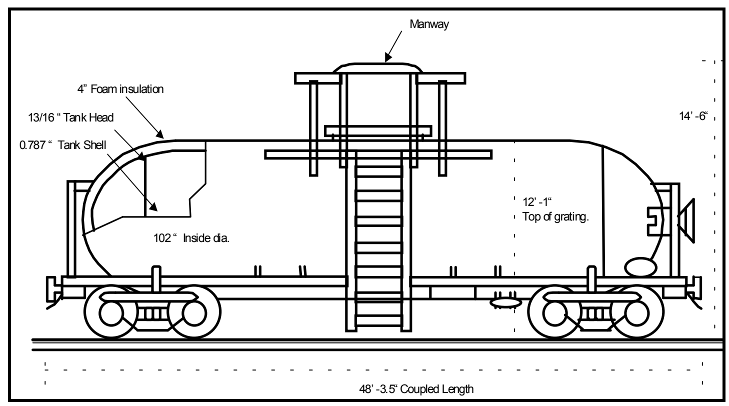

Figure 2: Rail Tank Car for Ammonia Transportation

Frequency Estimation

Following the hazard identification process, the probability or frequency of each accidental event is then estimated based on information gathered from historical data. This part of the QRA is identified as "TASK 3" in Figure 1. However, historical data applied only relates to failure frequencies of equipment and does not include probabilities of human error causing accidents. In reality, most accidents are caused by or enhanced by human error rather than equipment failures. Therefore, human error contribution for each failure scenario assessed was estimated using HEART (Human Error Assessment and Reduction Technique), which is a simplistic method developed by Williams, J.C. for quantifying human reliability. The HEART technique was considered an appropriate method for use in the analysis since it is best used for rule-based behaviour such as maintenance tasks and process operations and was found to be applicable for rail transportation operations. The overall human error probability for each applicable failure scenario identified was calculated based on the chosen "generic task" and "error producing conditions" described by the method using the following equation:

$$HEP = p\prod_{i=1}^{n}(x_i(f_i - 1) + 1)$$

where: p = generic task nominal probability

f_i = error producing condition change factors

x_i = the extent of the error producing conditions (from a scale of 0 to 1).

It should be noted that there are many uncertainties involved in assessing human error probabilities accurately, thus the QRA analysis further included the use of fuzzy arithmetic to facilitate a lower and upper bound for the calculated human error probabilities and subsequently the failure frequencies for each scenario. To facilitate this human error uncertainty calculation, the RAMAS Risk Calc. software developed by Applied Biomathematics Ltd. was used to calculate the fuzzy based human error probabilities.

The calculated frequencies were then assessed for different train speeds to determine the effects of train speeds on the overall risk results. The following equations adopted in the study by A.D. Little for the US Department of Transport was used to determine the number of rail tank car derailed or damaged:

$$\text{Number of Derailed Cars} = 1.7 \times V^{0.5}$$

$$\text{Number of Damaged Cars} = 1.25 \times V^{0.5}$$

where V = train speed in miles per hour

The operational train speed for the case study transportation of ammonia was estimated as 70km/hr with the possibility of an upgrade to 90km/hr. In the QRA, three different train speeds were chosen; the operational train speed at 70km/hr, the design speed as 90km/hr and a lower speed at 40km/hr to account for the train speed when travelling past train stations, towns, etc. The estimated number of derailed and damaged cars was then multiplied with the estimated frequencies determined from historical data but modified to account for human error contribution to determine the failure frequencies of each scenario for the three train speeds considered in the analysis.

Consequence Modelling

Consequence modelling is also an integral part of the QRA process, and is highlighted as "TASK 4" in Figure 1.

Consequence modelling determines the physical effects of the hazards posed by a release of ammonia and the extent of the damage, which may ensue; i.e. harm to people.
The particular outcomes of the ammonia release modelled for each of the scenarios considered in the case study depends largely on the following:

- Initial conditions of ammonia
- Discharge modelling ammonia
- Dispersion modelling of ammonia
- Toxic effects of ammonia

In the QRA study, the software package **SAFETI** (**S**oftware for the **A**ssessment of **F**lammable, **E**xplosive and **T**oxic **I**mpacts) developed by DNV was used to model the resulting behaviour of the released ammonia and the extent of damage expressed in terms of distance to certain effect levels. The software is an industry accepted state-of-the-art software, which has been validated using comparisons with observations during both experiments and real life incidents. Two basic models within the SAFETI package was used to determine the release characteristics: an instantaneous release to model rail car tank rupture scenarios and release through a sharp edged hole for rail car tank leak scenarios. For the dispersion modelling of the ammonia cloud upon release, the software package uses the self-embodied Unified Dispersion Model (i.e. consisting of Turbulent Jet, Dense Turbulent Plume, Slumping Dense Plume and Passive Dispersion phases), which uses a number of models, each applicable in its own range, and match the cloud parameters as the program changes between models.

Risk Calculations

The frequencies and consequences for each scenario identified in the analysis are then combined to form measures of overall risk, expressed in the form of Individual Risk using the SAFETI software. This step is highlighted as "TASK 5" in Figure 1. In the QRA, the individual risks were defined as the risk experienced by a member of the public.

The calculated risk results were then compared to the levels corresponding to the guideline individual risk criteria for public in Malaysia. This guideline stipulates that for residential area, a risk level of 1×10^{-6} per year is considered acceptable.

RESULTS

The results of the analysis shows that human errors increases the calculated failure frequencies for all relevant scenarios considered by a factor of approximately 0.47 to 1.97 times the calculated failure frequencies based solely on equipment failures only. Of all the scenarios analysed to ascertain the effects of human error contribution, the highest contributing event was the failure of the rail car tank head due to impact forces from either train collisions or derailments, accounting for an increase by a factor of about 2.

Table 1 presents the overall individual risks calculated using the SAFETI program for the three different train speeds considered in the case study. The results are expressed in the table below as the effect distances to the specified residential area risk criteria of 1.0×10^{-6} per year. Note that the effect distances are presented as within a range due lower and upper bound failure frequencies estimated after inclusion of human error probabilities, which were estimated using the fuzzy arithmetic approach.

Table 1: Individual Risk Results for Case Study

Risk Level (per year)	**Distance from Centre of Railway Track (m)**		
	Train Speed at 40 km/hr	**Train Speed at 70 km/hr**	**Train Speed at 90 km/hr**
1.0×10^{-6}	480 – 600	700 - 870	880 - 950

The risk results show that the individual risk results based on levels corresponding to the guideline individual risk criteria of 1×10^{-6} per year for public in Malaysia extends to about 480m – 950m, depending on the train speed prior to collision or derailment. The effect distances to the specified residential area risk criteria clearly demonstrates that most of the surrounding areas; i.e. villages, housing areas, etc., some of which are located close to the train tracks are exposed to higher risks levels than the specified acceptable risk criteria. The table above also shows that the effects of the three different train speeds on the risk results are small in comparison to the total risk effect distances. The effect distances for the different train speeds are about 100 – 200 m from each other.

CONCLUSIONS

It is concluded that human error contribution does have a profound effect on the estimated failure frequencies for the scenarios assessed in the analysis, and subsequently the risks results. Based on the findings of the case study, human error contribution could potential increase the calculated risks by a factor of 0.5 to 2 times the risks based solely on equipment failures only.

It is also concluded that the relatively high-risk values calculated for the surrounding population located approximately 500 - 1000m away from the tracks indicate a need for caution in the planning and operations of the transportation of ammonia cargoes. Priority should be given for moving ammonia transported trains through populated areas as quickly as possible to minimise exposures. An integrated emergency response plan should be adopted, and should involve all relevant authorities including communities located close to the train route to facilitate an emergency response in the event of an accidental release of ammonia during transportation.

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The Primary Cause of Accidents at Workplace – A Review

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ABSTRACT: Many root causes are involved in the development of an accident. Reviewing industrial accidents highlighted that `software failures' were more frequently the primary cause of accidents. This also provides evidence that the development of root causes may exist with many companies and arise at different stages of the life cycle of the plant as revealed from the Bhopal accident.

Keywords: Bhopal Accident, Root causes, Hardware errors, Operator related errors, Information/Communication related errors and System related errors.

INTRODUCTION

Accidents normally result from a combination of actions, errors or failures either on the part of people or equipment or both. The Health and Safety Executive (HSE, 1991) described the terms "accident" and "incident" as follows:

Accident:- Includes any undesired circumstances which give rise to ill health or injury; damage to property, plant, products or the environment; production losses, or increased liabilities.

Incident:- Includes all undesired circumstances (near accident) and near misses which have the potential to cause accidents.

An accident does not have one cause but involves plenty of root causes. Philley (1992) defined root cause as "an underlying cause which was a direct link in the sequence of events and which has a feasible potential for being corrected". This could be seen and understood when examples of disaster that occurred are studied. Gephart (1984) in explaining environmental disasters gave an example that the sinking of the Ocean Ranger offshore drilling platform and consequent loss of 84 human lives was caused by both bad weather and the crew's lack of knowledge of platform operation. From this disaster it can be seen that the occurrences of disaster are due to more than one type of cause. This reflects the statement made by Kletz (1984) that the deeper we go in analysing an accident/incident, the more causes we find.

ELEMENT OF FAILURES

In this paper, it is very important to look further at the elements that brings about the accidents/incidents in the workplace. As described by HSE (1985) the occurrence of most accidents involves an element of failure in control or managerial skill. This is clearly seen when some industrial accidents data are examined. From 1186 fatal UK industrial accidents occurring between 1981-1983 (as shown in Table 1), the analysis shows that "software" failures were more frequently the primary cause of accidents than were "hardware" ones. In this context HSE does not refer to computer software but to work practice as distinct from work equipment. The vast majority of these "software" failures involved unsafe systems of work and the failure of employees to comply with good practice.

Table 1: Analysis of Fatal Accidents Occurring in Premises Between 1981-1983 (HSE, 1985)

Case No.	Reason For Accident Occurring	Primary Cause	Secondary Cause
1.	Unavoidable/not reasonably practicable precaution.	192	-
2.	Cause not elsewhere classified.	9	-
3.	Data insufficient.	25	-
	Hardware Failures		
4.	Inadequate standard of design / construction of plant, tools, equipment involved in the accident.	78	28
5.	Inadequate standard of installation of above.	9	9
6.	Inadequate standard of maintenance of above.	39	29
7.	Failure to provide safe place of work (hazardous conditions).	298	152
	Software Failures		
8.	Misinterpretation of commands.	1	2
9.	Inadequate training, supervision, and instruction.	68	96
10.	Failure of/or to provide Permit To Work system.	22	7

11.	Failure to comply with good practice, i.e. unsafe act on part of employee.	279	108
12.	Unsafe system of work being used on part of employer (usual work activities).	147	68
13.	Unsafe system for transporting materials, equipment (inside/outside premises).	12	7
14.	Unsafe system for handling materials/equipment.	7	10

The table above provides statistical evidence that an understanding of organisational management failures are of great importance to reduce the frequency of major disasters. In general it is fair to assume that operators wish to avoid death or injury.

Other evidence that highlighted strong components of management failure or examples of errors committed at management level combined with a mixture of other organisational failings could be seen from some documented accidents such as Bhopal, Chernobyl, Challenger, Herald of Free Enterprise, Kings Cross, Clapham, Flixborough, Grangemouth, Bantry Bay and Piper Alpha. The major catastrophe in Bhopal which involved the release of the highly toxic chemical methylisocyanate (MIC) on 3rd. December 1984 caused the death of over 2500 people and injured more than 200 000 people was considered by researchers as the worst industrial disaster in terms of fatalities (Bowonder, 1987). The major cause that brought about the accident was reported to be due to failures in the safety systems which were incorporated in the plant for preventing the release of MIC

ANALYSIS OF BHOPAL ACCIDENT

A detailed analysis of Bhopal accident was carried out to look at the failure types (e.g. technical failure, management failure, operator failure and government failure) that brought about the accident. The factors that caused the accident to be so severe were categorised into four levels of errors namely as Hardware Errors, Operator Related Errors, Information/Communication Related Errors and System Related Errors as shown in the first column of Table 2. However, looking at the errors themselves, it is felt that instead of highlighting the general management failure, it is beneficial to focus the management failures by splitting them accordingly to the departments concerned in the company (see Table 2; column `Type of Failure'). This would enhance the importance of having good coordination in managerial aspects within the departments. Failure to do so may lead to accidents.

Table 2: Analysis of Bhopal Accident

a) Hardware Errors

	ERRORS	TYPE OF FAILURE
1.	Scrubber capacity insufficient	Technical failure
2.	Refrigeration plant was not operational	Operational / Production management failure
3.	No automatic sensors to warn temperature increases	Design failure
4.	Pressure indicator and temperature indicator not working	Maintenance management failure
5.	Inadequate gas masks	Organisational management failure
6.	Flare tower was disconnected	Operational / Maintenance management failure
7.	Vent gas scrubber not in active mode	Operational / Maintenance management failure
8.	Plant modification connecting RVVH and PVH	Design / Project management failures
9.	Use of iron pipelines for MIC	Design / Project management failures
10.	Manual mechanism for switching off scrubber	Technical failure
11.	No regular cleaning of pipes and valves	Maintenance management failure
12.	No online monitor for MIC tanks	Design failure
13.	No indicator for monitoring position of valves in control room	Design failure
14.	Pressure monitor indicated a reading of 10 Psig when actual pressure is 40 Psig	Maintenance management failure
15.	Water curtain can only reach 10 meters height	Design failure
16.	Maximum range of pressure gauge 35 Psig, so operator did not know the exact presure	Technical failure

b) Operator Related Errors

	ERRORS	TYPE OF FAILURE
1.	Reduction in operating and maintenance staff	Organisational management failure
2.	Using a non trained Superintendent for MIC plant	Organisational management failure
3.	Failure of shift operator to communicate information on pressure increase to the next operator	Organisational management and operator failures
4.	Repressurizing the tank when it failed to get pressurized once	Operational / Production management and operator failures
5.	Issuing orders for washing when MIC tank failed to get pressurized	Operational / Production management and operator failures
6.	Not following the safety precautions while washing	Organisational / Production

	MIC lines	management failure
7.	Not confirming the leak when police officials enquired	Operator failure
8.	Not operating the warning siren until the leak became severe	Emergency management and operator failures
9.	Switching off the siren immediately after starting it	Emergency management and operator failures
10.	Failure to recognize that the pressure rise was something abnormal	Operational / Production management and operator failures
11.	Failure to use the empty MIC tank to release the pressure	Operational / Production management and operator failures
12.	Failure to recognize the seriousness of the leak	Operator failure
13.	Failure to inform Works Manager as soon as the leak started	Organisational management and operator failures

c) Information/Communication Related Errors

	ERRORS	TYPE OF FAILURE
1.	Panic reaction in the plant since no emergency plan	Organisational management failure
2.	Ad hoc response by operators	Organisational management failure
3.	No emergency plan for city	Government failure
4.	No risk analysis before plant modification	Organisational management failure
5.	Information on possibility of runaway reaction not communicated	Emergency management failure
6.	Doctors did not learn of treatment	Organisational management failure
7.	Information on precautions of how to minimise MIC effects not communicated	Organisational management and Government failures
8 .	Information of wind movement not disseminated	Government failure
9.	Information on differential sensitivity not disseminated	Organisational management failure
10.	Not informing public about a possible emergency in the neighbourhood	Organisational management failure
11.	Significance of alarm siren not known to public	Organisational management failure
12.	Toxicity of MIC not assessed and dependent on the information provided by the firm	Government failure
13.	Delay in providing information on line of treatment	Government failure
14.	No action initiated on press reports about poor safety	Organisational management and Government failures
15.	Acting on the clue that large scale storage of MIC not permitted in other countries	Government and Organisational management failures
16.	Considering phosgene as more toxic compared to MIC	Organisational management failure
17.	Absence of a toxic information centre	Government failure
18.	Confusion about gas released caused problems for medical emergency handling	Organisational management failure
19.	No action was initiated on the enquiry report of the earlier accident	Organisational management and government failures

d) System Related Errors

	ERRORS	TYPE OF FAILURE
1.	Not evaluating safety levels required	Design / Organisational management failures
2.	Not improving safety after audits	Design / Organisational management failures
3.	Poor emphasis on systems safety	Design / Organisational management failures
4.	No improvements in safety even after six accidents	Design / Organisational management failures
5.	Decision to store MIC in large scale	Design management failures
6.	Coming up of large settlements close to the works	Government failure
7.	Permitting the settlements to become regular settlements	Government failure
8.	Poor evacuation measures	Government / Organisational Management failures
9.	Medical emergency procedures became controversial	Organisational management / Government failures

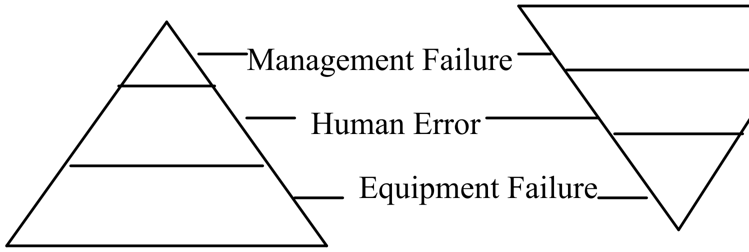
10.	No intermediate storage, hence contamination potential	Design management failure
11.	Storing 55 tonnes of MIC while usage daily was 5 tonnes	Production management failure
12.	Decision not to shift factory when applied for license	Organisational management / Government failures
13.	Not updating safety levels while switching to large scale storage of MIC	Production management failure
14.	Neglecting the safety even after six accidents	Organisational / Production management failures
15.	Neglecting safety management at the unit	Organisational / Production management failures
16.	No action on earlier accident analysis reports	Organisational management / Government failure
17.	Failure to release the telex message on MIC treatment from corporate HQ	Emergency management failure
18.	Failure to monitor whether the recommendation of safety audit implemented	Production / Organisational management failures
19.	Heavy reliance on inexperienced operators	Production management failure

The table clearly shows that many root causes are involved in the development of an accident. These root causes may exist from many departments in the company. Hence adequate coordination within the department is very important to ensure adequate safety management is in place.

THE IMPORTANCE OF HAVING GOOD MANAGEMENT COOPERATION

As we know accidents do not just happen and they are preventable. Hence safety can be managed. Adequate cooperation given from the management team would successfully minimise the failure. As evidence Brian (1988) gave examples of the lost-time injury frequency rate recorded from two chemical companies in United States namely as Air Products and DuPont. In 1974 Brian reported that the lost-time injury frequency rate per 10^6 man hours worked for Air Products was 1.6, but after taking a leadership role in safety by the management team, the lost-time injury frequency rate for Air Products had been reduced to 0.04 in 1985. This gave a forty-fold reduction in eleven years. Similarly to DuPont, the industry leader in safety management which recorded an injury rate of 0.2 in 1974 was able to achieve a reduction of a factor of ten, giving them a rate of 0.02 in 1985. The drastic improvements of these two companies happened due to the management of the company, from the top to the bottom, who became totally involved to operating in a first class, safe manner.

From the above examples it can be seen the importance of a management's responsibility in improving the safety at workplace. In handling materials for example, it is a responsibility of the management personnel to know the conditions of the materials being handled and the presence of process safeguards in the workplace before determining if hazardous conditions exist. The level of understanding in major accident prevention can best be summarised by means of the diagram as shown in Figure 1 (Kletz, 1991). The left hand-side as described by Kletz represents the relative effort spent to the prevention of equipment failure, human error and management failures whereas the right-hand side represents the actual importance which should come in practice.



Effort expended   Actual importance

Figure 1: The Effort Expended on the Causes of Accidents and the Actual Importance (Kletz, 1991)

CONCLUSION

The quality of safety management on any site has a very significant effect on frequency failure rates. Hence the quality of process safety management needs to be properly managed.

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Monitored Community Noise Pollution In Selected Sensitive Areas Of Kuala Lumpur

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ABSTRACT: This article focuses on the monitoring of community noise pollution in sensitive areas of Kuala Lumpur that include Blue Boy Mansions residential area and LaSalle Secondary School in busiest part of Klang Valley. The objectives of the article were to monitor and to assess the existing noise levels at the selected sites. A modular precision Sound Level (SLM) type one was used in the measurements. The measurements were taken for 24-hour in the residential area and from 6 am to 7pm in the school area (schooling hours). The measurements were taken at an interval of ten minutes and each measurement lasted for five minutes at appropriate points in accordance with ISO 1996-1:1982, ISO 1996-2:1987 and ISO 19896-3:1987. Equivalent Continuous Sound Level ($L_{eq,}$), Sound Level exceeded 10% of the measurement period (L_{10}), Sound Level exceeded 90% of the measurement (L_{90}), minimum noise level (L_{min}), and maximum noise level (L_{max}) were measured to assist in assessing the existing noise levels at the selected sites. Results showed that the monitored noise levels in terms of $L_{eq,}$ in residential area ranged between 52.1 dB(A) to 72.7 dB(A) and in the school area ranged between to 68.2 dB(A) to 73.7 dB(A). These levels highly exceeded the level recommended by the (WHO) World Health Organisation ($\rho \leq 0.001$).

Key words: Monitoring, Noise, Pollution, Community, Sensitive, Kuala Lumpur

INTRODUCTION

Noise is defined as unwanted sound (Thorpe and Holmes, 1976). Noise, in the large parts a subjective phenomenon, relates to the reaction of people to certain types of physical sound. Noise is unwanted sound, annoying, disturbing, or in particular situation it can cause damage (Millne, 1979; Kryter, 1970; Bugliarello, 1976; Gunniff 1977; Davies and Crornwell, 1991; Sato, 1990). Noise has also been defined as undesirable sound, wrong sound, distributive sound in wrong place and wrong time (Magrab, 1975; May, 1978). Its audible acoustic energy adversely affects the physiological or psychological well-being of people (Kryter, 1985). Any form of noise is considered as pollution if it causes annoyance, sleeplessness or any other stress situation.

Community noise pollution (CNP), which is also known as residential noise or domestic noise, is defined as noise emitted from all sources except noise at the industrial workplace (WHO, 2000). Main sources of community noise include road, rail and air traffic, industries, construction and public work, and the neighbourhood noise. The main indoor noise sources are ventilation systems, office machines, home appliance and neighbour. These definitions reflect that noise pollution is a complex phenomenon (Bugliarello, 1976), which is different from other pollutants in the following ways:

1. Noise is transient; once the noise source is eliminated the environment is free of it.
2. It is possible to make some form of estimation for other types of pollutants in terms of how much material can be introduced into environment before harm can be done. However, it is difficult to monitor cumulative exposure to noise or to determine how much is too much.

In the United States of America (USA) the League for the Hard of Hearing (2000) estimated that twenty eight (28) millions people have hearing loss. It added that to be present for just fifteen (15) minutes on many New York City subways a day over time can affect your hearing.

In the European Union (EU) an estimate of more than 40% of the population is exposed to daytime traffic noise exceeding 55 dB(A) in terms of L_{eq}, and 20% are exposed to levels exceeding 65 dB(A) (WHO, 2000). When all transportation noise is considered, more than half of all EU citizens are estimated to live in zones that do not ensure acoustical comfort to residents. At night, more than 30% are exposed to L_{eq} exceeding 55 dB(A), which is not conducive to sleep (WHO, 2000; Elfaig, 2002).

In Malaysia noise pollution was determined by the Department of Environment (DOE) as one of the physio-chemical parameters that must be addressed in conducting Environmental Impact assessment (EIA) for certain project development (DOE, 1991). It ranked as a third pollution problem after air and water pollution in terms of number of complaints received (DOE, 1995). A noise level of 82 dB(A) L_{eq} has been reported in some selected residential areas of Kuala Lumpur (Elfaig, 2002).

A study conducted by the DOE in 1981-1982, showed that the noise levels in 96% of the surveyed areas in Kuala Lumpur, Ipoh, and Pulau Penang failed to meet the WHO recommendation. A follow up survey in 1984 indicated that noise environment continues to deteriorate. As such, noise

levels in residential areas had exceeded the recommended level 100% of the time compared to 96% in 1982 (DOE, 1985). In all the selected residential areas results showed that 10% of the population were exposed to noise levels exceeding 73 dB(A).
At the school compounds similar situation also existed throughout Peninsular Malaysia. A survey of noise levels conducted by the DOE (1982) in school areas in Kuala Lumpur, Ipoh and Penang indicated that over 85% of the time the L_{eq} level exceeded the acceptable noise recommendation of 55 dB(A) as shown in Table 1.

Table 1: Noise Levels in terms of L_{eq} at the Boundary of Schools 1981-1982

% of schools	Town	No. of schools	Town	No. of schools	Town	No. of schools
	Kuala Lumpur	46	Penang	43	Ipoh	17
10	71 dB(A)		76 dB(A)		76 dB(A)	
50	62 dB(A)		69 dB(A)		71 dB(A)	
90	52 dB(A)		52 dB(A)		59 dB(A)	

Source: DOE 1982.

Table 1 shows that noise levels in 10% of all selected schools exceeded the 55 dB(A) recommendation by the WHO for outdoor school areas. Such levels may affect teachers' and students' performance. In 1985 a survey conducted by DOE showed that 10% of the samples taken in Federal Territory of Kuala Lumpur and Penang revealed that schools were exposed to noise levels exceeding 69.5 dB(A).

In a more recent study, a similar noise problem was also found around some selected schools especially those within the Federal Territory of Kuala Lumpur as shown in Table 2 (DOE, 1995).

Table 2: Noise Pollution at Selected Schools: 1995 Study

School Area	School Name	Noise Range dB(A)
Federal Territory of Kuala Lumpur	S.M. Victoria Institution	47-60.8
	S.M. St. John	53.3-64.8
	S.M. Convent Bukit Nanas	49.3-65.9
	SRK. St. John 1and 2	57.4-71.1
Johor	S.M. Sultan Ibrahim	59.8-72.2
	Maktab Sultan AbuBakar	48-64.6
Melaka	SRK St. Francis	47.5-75.2
Terenganu	S.M. Sultan Sulaiman	56.9-67.5

Source: DOE, 1995.

Table 2 reveals that all the schools monitored were exposed to a maximum noise level exceeding the 55 dB(A) L_{eq}, the level recommended by the WHO, which could affect students' concentration and their ability to learn. It suggested that this problem could be solved by relocating the affected schools to more conducive areas that is free from noise pollution, or by constructing noise barriers that could absorb some of the traffic noise.

METHODOLOGY

Study Site

The study sites are deliberately selected as the sites that suffer from CNP. Accordingly, two areas, namely, residential (Blue Boy Mansions), and school (LaSalle Secondary School) were selected in the busiest part of Klang Valley.

Noise Monitoring Procedures

The noise monitoring processes consisted of 24-hour noise measurements at appropriate points in residential area and for twelve hours (12h) at the selected schools 7am to 6pm in school area (schooling hours) and 7am to 10pm in hospital area. The measurements were taken during these hours with an interval of ten minutes and each measurement lasted for five minutes on weekdays. The primary objective of this measurement was to determine the existing noise levels at the selected sites to show the real situation. As such, a type 1 modular precision Sound Level Meter (SLM) and a Statistical Analysis Module (SAM) were used. The SLM was calibrated at 93.8 dB(A). The SLM was placed at a height of 130 cm above the ground and at a distance of 500 cm from the receivers. These measurements were done in accordance with ISO 1996-1:1982, ISO 1996-2:1987 and ISO 19896-3:1987.

Noise Monitored Parameters

Various noise level data recorded at the measurements points in terms of levels exceeded certain proportion of the measured time is an important way of assessing the annoyance from community sound. This is due to the fact that the sound varied and fluctuated over time. Thus, the descriptors Equivalent Continuous Sound Level ($L_{eq,}$), Sound Level exceeded 10% of the measurement period (L_{10}), Sound Level exceeded 90% of the measurement (L_{90}), minimum noise level (L_{min}), and maximum noise level (L_{max}) were measured to assist in assessing the existing noise levels at the selected sites

The Logarithmic and mathematical models that were used to calculate noise levels were based on average and expression of sound levels variation over time using Equations1 and 2 (Nelson, 1985; Schultz, 1972) as shown below:

$$L_{eq} = 10Log_{10}\frac{1}{T}\left[t_1 * 10^{\left(L_1/10\right)} + t_2 * 10^{\left(L_2/10\right)} + ... + t_n * 10^{\left(L_n/10\right)}\right] \quad [1]$$

Where

$L_{eq,}$ is equivalent continuous sound level ,
T: is the time for which sound is described
t_1, t_2,…t_n are the time period for which sound levels are L_1, L_2…L_n and so on

$$L_{eq} = L_{50} + \frac{(L_{10} - L_{90})^2}{56} + (L_{10} - L_{50}) \quad [2]$$

RESULTS AND DISCUSSION

The results presented the existing outdoor monitored CNP in selected residential and school area. Meanwhile, the assessment procedures of the monitored CNP at the selected areas consist of comparing an actual noise exposure (measured levels) with the WHO recommended level for outdoor residential and school area.

CNP in Blue Boy Mansion Area

The results of noise levels measurements in the Blue Boy Mansion area (BBM) have shown that the existing noise level exceeded the recommended WHO levels for L_{eq}, day and night hours. For example L_{eq} ranges between 64.3 dB(A) at the minimum level to 73.7 dB(A) at the maximum level during day hours as shown in Figure 1. These levels greatly changed

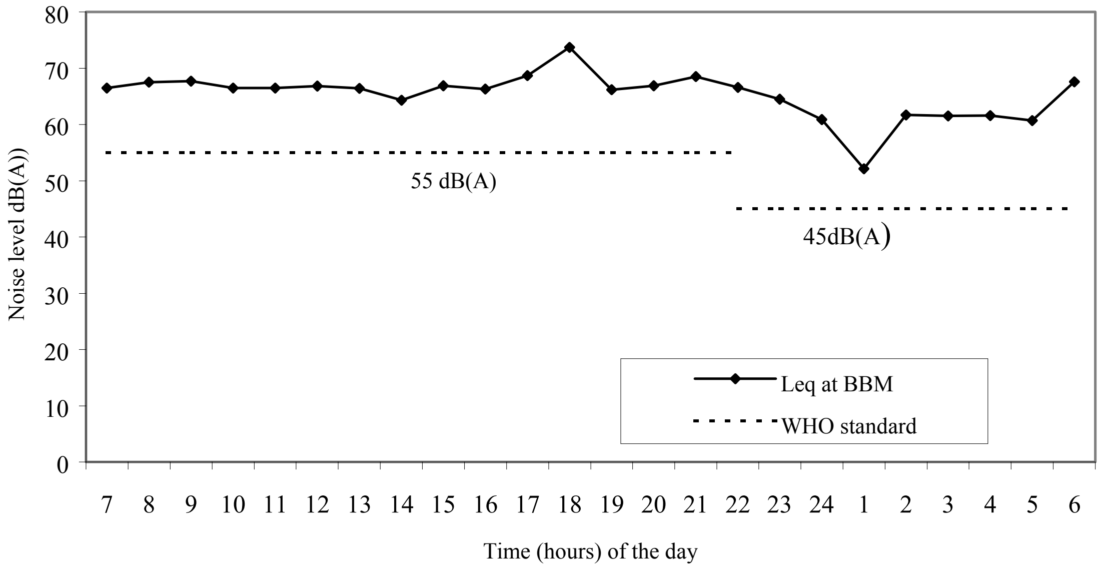

Figure 1. Comparison between measured L_{eq} in BBM Area during a 24 hour Measurement and WHO Recommendation

during night hours and they ranged between 52.1 dB(A) to 67.6 dB(A), at the minimum and maximum levels. In numerical terms the average of these levels exceeded the WHO recommended level by 22.4% at the maximum level and by 7% at the minimum Level. Other monitored noise parameters are also high as shown in Figure 2.

The results of statistical analysis on the measured levels showed that there is a highly significant difference ($p < 0.01$) in the noise levels between the Blue Boy Mansion area and the WHO recommendation as shown in Figure 1. Such results indicated that the speech intelligibility is moderately affected, sleep is widely disturbed and the possibility of Noise Induced Hearing Loss (NIHL) is minor.

The moderate existing noise level at this place is due to the system of the land use pattern as BBM is located 40 meters from the main road coupled with a few business activities as shown in Figure 3 The study further identified that the transportation system and lack of proper attenuation and unsatisfactory planning decision are the main contributing causes of community noise pollution.

Figure 3. A Typical Transportation System in Blue Boy Mansion Area (2002)

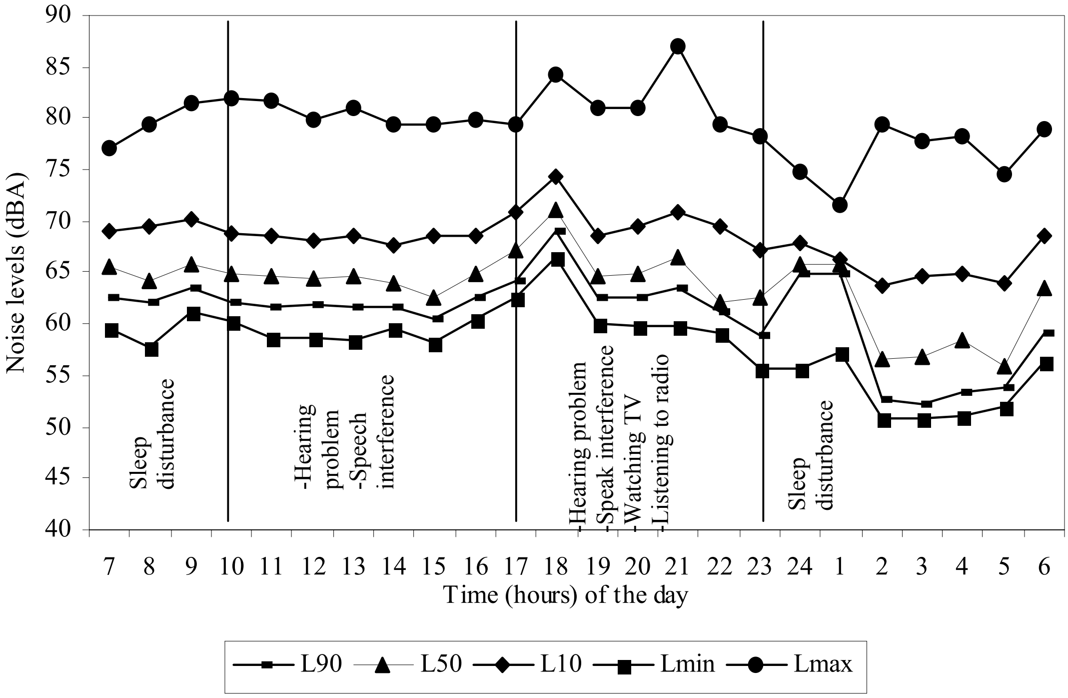

Figure 2: Different measured noise parameters and related noise effects at BBM

Monitored Noise Level in LaSalle Secondary School

This part analyses and discusses the existing outdoor CNP Level in LaSalle Secondary School in Kuala Lumpur. Duration of the noise measurements are presented in the methodology. Results revealed that the noise levels in terms of L_{eq} ranged between 67 dB(A) to 75 dB(A) and this exceeded the 45 dB(A) level recommended by the WHO (1980) for the school areas. It also showed that the existing noise levels in terms of L_{10} ranged between 68.2 dB(A) at the minimum level to 73.7 dB(A) at the maximum. In numerical terms, the existing noise levels exceeded the recommended level by 20% at the minimum level and 30% at the maximum level as shown in Figures 4. This high noise level would result from land use pattern, as the school is located near a busy main road as shown in Figure 5.

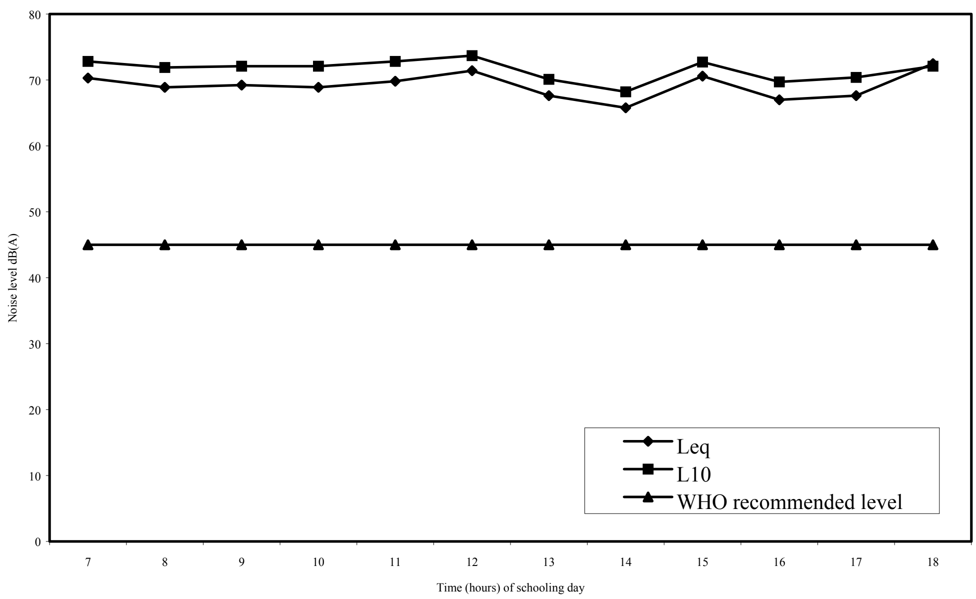

Figure 4: Noise Levels in terms of L_{eq} and L_{10} in LaSalle Secondary School

Figure 5. A Typical Traffic Flow near LaSalle Secondary School

CONCLUSION

The study has shown that the monitored community noise pollution in selcted residential and school areas (Blue Boy Mansion and LaSalle Secondary School) highly exceeded the level recommended by the World Health Organisation for residential and school areas and highly fluctuated over time. The monitored noise level in terms of L_{eq} in the residential area ranged between 52.1 dB(A) to 72.7 dB(A) during day and night time and in the school area ranged between to 68.2 dB(A) to 73.7 dB(A) during school hours. Such monitored noise levels can cause sleep disturbance, interfere with speech and may affect students and teachers' performance as they interfere with speech communication and message extraction, which are the main mechanisms of teaching. Through proper use of vegetation or noise barrier can help reduce the noise level at these places.

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Exhaust Fan And CFD To Improve Indoor Environment

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ABSTRACT: This work is concerned with determining the best location for a ventilating fan in a kitchen of a double storey house in Subang Jaya using the tracer gas decay method and computational fluid dynamics codename PHOENICS. Results showed that improper location may cause short circuiting of airflow as distinctly shown using a smoke test. Our results showed that the best location for a kitchen exhaust fan is on the exterior wall, 0.3m mid-way above the louvered windows where air exchange rate increased from 0.01 h^{-1} (all doors and windows shut without exhaust fan) to 7 h^{-1} when kitchen door and windows opened, exhaust fan was switched on. The minimum air exchange rate required for a house is 2 h^{-1} (UBBL 1984).

Keywords: Indoor Air Quality (IAQ), CFD, Tracer-Gas, Exhaust Fan.

INTRODUCTION

Malaysia's unique climate of hot and humid condition and wok style cooking call for specialized strategies to combat the problems of overheating and indoor odor from cooking activities. The trend towards high density housing e.g. flats and condominiums has led to increased concern about indoor air quality (Davies et al, 1997, Adam, 1995).

Extractor fan has two functions i.e. (1) removing contaminants from source and (2) preventing migration of contaminants by drawing air into the source room. Literature shows limited work on determination of air exchange rate has been reported. There is a need to quantify some units for ventilation rates as well as to determine the air exchange rate in a typical urban dwelling in Malaysia. Reported related works in other countries are listed in Table 1 Knoll, 1992).

An exhaust fan can help reduce concentrations of indoor pollutants in the kitchen provided it is located strategically. Use of computational fluid dynamics requires data from experimental values as input boundary conditions.

OBJECTIVE

The general objective of the study was to locate the optimum fan location using tracer gas concentration decay method. Specific objectives were as follows

- To measure pollutants and indoor air quality (IAQ) parameters (temperature, relative humidity, air velocity, sound pressure level, lighting level, carbon dioxide)
- To locate best exhaust position using computational fluid dynamics methods

METHODOLOGY

(a) Preliminary Investigations

Sulphur hexafluoride (SF_6) is recommended but availability of equipment and tracer was a problem. After some research, carbon dioxide was chosen as the tracer-gas for this study and the concentration decay technique is to be employed. This method involves injection of a known amount of tracer into a given space. Slope of rate of concentration decay versus time will give the air change (ach) in unit per minute or per hour (refer to Appendix B, after Charlesworth, 1988).

(b) Kitchen design

A random survey of 76 kitchen layouts in the Klang Valley revealed that the kitchen layout in the selected house double storey house in Subang Jaya represents at least 90% of kitchen layout (see Appendix C) i.e. the sink is facing the external wall and stove is located at the adjoining wall (party wall) between houses.

(c) Computational Fluid Dynamics

Computational Fluid Dynamics code name PHOENICS was selected for preliminary work on location and on fan height from the floor. Preliminary data from initial field measurements were used as input for boundary conditions. Due to time and grid size constraints, the worse case was selected for fan size, i.e. 510 CMH instead of 876 CMH (25 inch fan). Besides, it is a bit difficult for a burglar to go through a 20 inch hole.

Computational model of a kitchen with 2.5m(W) x 2.8m(D) x 3.0m(H) (volume = 21m^3) and a toilet with 1.5m(W) x 1.3 m (D) x 2.7m (H). The kitchen is fitted with a window of 1.9 m (W) x 1.0m (H) (area = 1.9 m^2) and an exhaust fan with

Table 1: Review of National Standards and Design Considerations (Knoll, 1992)

Country	Ventilation Standard	System Requirement	Common System	Weather	Common Dwelling	Ventilation Problem
Australia	Not available	Fixed ventilator	Ceiling vent	Mild climate	Detached single story timber	Radon
Belgium	NBN D50-001	Exhaust in service rooms	Open able windows	Moderate	Low rise detached	Condensation, odors, radon
Canada	Natural ventilation openings for kitchen, bath	Local extract in kitchen, bathrooms	Old houses natural ventilation	Severe (-35 ºC)	Detached bungalows	Radon, condensation, formaldehyde, combustion gases
Denmark	Min 0.5 ach kitchen, bathroom	Ducted ceiling ventilator, wall vents	Natural ventilation through two vertical ducts	Moderate climate	1-2 story housing units	None
Finland	Guidelines for bedroom, living areas, kitchen, bathroom, toilet >0.4ach	Approvals for fresh air intake	Mechanical exhaust system	Severe (-30 ºC)	High and low rise buildings	Condensation, stuffiness, odors
France	Exhaust flows	Air supply in habitable rooms, service rooms have mechanical exhaust	90% flats, 70% individual dwellings mechanical exhaust system	Mild climate	High and low rise dwellings	Radon, draught from inlets, incorrect operation of vents
Germany	1.0 -1.5 ach habitable rooms, bathroom, toilet 6 ach	-	Natural ventilation via open able windows	Moderate to severe	Detaches low rise buildings	Draughts from inlets
Italy	Kitchen 1 ach, Bathroom 2 ach	Open able window min 1/8 floor area	Natural ventilation	Mild climate	High rise buildings, detached low rise	-
Japan	5.5 dm^3/s. person, exhaust for combustion apparatus	-	Natural ventilation, exhaust fans in service rooms	Mild - moderate	Detached wooden houses, high rise apartments	Radon, combustion gases from open heaters
Netherlands	7 dm^3/s. person, exhaust for kitchen, toilet	Exhaust by vertical ducts to roofs, 1 m^3 opening for natural ventilation	Natural ventilation, >13m building use mechanical exhaust	Moderate	Two story buildings	Condensation, draughts
New Zealand	-	Open able windows 5% floor area in each room		Mild climate	No information	Condensation
Norway	-	Each room kitchen 30 cm^2 opening, bathroom exhaust	Natural supply through wall vents	Severe climate	Low rise wooden houses, high rise apartment	Draughts from inlets
Sweden	0.35 $dm^3/s\ m^2$ floor area for dwelling, kitchen bath service 10 $dm^3/s\ m^2$	Kitchen, bathroom have local mechanical system	Mechanical exhaust for new homes buildings	Severe	High and low rise buildings	Condensation, radon
Switzerland	Local Authority or German standards	Exhaust ventilation requires inlet openings	Natural ventilation	Moderate to severe (Alpine)	Wood Alpine, concrete urban	Condensation, combustion gases
United Kingdom	1 ach habitable room, 3 ach service rooms	Ventilation opening 1.75m above floor level, 40cm^2 vents background ventilation	Natural ventilation , exhaust duct in kitchen	Moderate	Detached low rise buildings	Condensation, draughts

maximum volume flow rate of 510 CMH (20 inch fan). This lower value is chosen to create a worse scenario for the kitchen and toilet. The toilet is fitted with a louver and a door which is used to separate the kitchen and the toilet. The following computed results are presented for a situation when the toilet door and kitchen windows are either in open or closed conditions (4 cases).

Assuming constant fluid properties (air density of 1.225 kg/m^3 and kinematic viscosity of 1.46x10^{-5} m^2/s), the continuity and the Navier-Stokes equations in stationary Cartesian Coordinates are discretized using a finite volume method. The resulting algebraic equations are solved iteratively using a tri-diagonal matrix algorithm. A linear and false time step relaxation methods were used on discretized pressure correction and momentum equation respectively to accelerate the convergence. The iterative processes were terminated when the total absolute error is less than 1x10^{-3} and the mass and momentum were balanced.

Boundary conditions

Four test cases had been studied when the exhaust fan operating at its maximum volume flow rate of 510CMH and the computed results are arranged as follows:

1. The kitchen window and toilet door are opened.
2. The kitchen window are opened and the toilet door is closed
3. The kitchen window is closed and the toilet door is opened
4. The kitchen window and the toilet door are closed.

For case 1and case 2 in which the kitchen window is opened, it is assumed that the outside air enter the kitchen are with face velocity of 0.05 m/s.

(d) Experimental

Studies were conducted in the kitchen and adjoining toilet of a double storey house in Subang Jaya in March and August 2002. Measurements of sound pressure level, carbon monoxide (CO), carbon dioxide (CO_2), relative humidity (RH), wet and dry bulb temperatures inside and outside the house were taken for all conditions. The eight conditions measured for kitchen and toilet were as follows:

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Table 2: Experimental Conditions for Kitchen

Condition	Window	Door	Fan	
			on	off
1	closed	closed		
2	closed	closed		
3	open	closed		
4	open	closed		
5	closed	opened		
6	closed	opened		
7	opened	opened		
8	opened	opened		

For each condition, the experimental involved sealing the window and kitchen entrance with a layer of plastic, injection of carbon dioxide gas, a period of mixing, followed by a period of concentration decay where measurement of concentration decay was monitored. The plastic layer was placed during all conditions to determine worst scenario for the kitchen.

Measurement of Concentration Decay

Concentration decay technique (from Charlesworth, 1988) can be measured using:

$$C_{g(t)} = C_{g(0)}\, e^{-It} \qquad \text{Equation 1}$$

Where:

$C_{g(t)}$ = concentration tracer gas at time , t (ppm)
$C_{g(0)}$ = concentration tracer gas at time equals zero (ppm)
I = Air exchange rate

If the concentrations of tracer gas are plotted against elapsed time on semi-log paper, then the negative slope equals to I (h^{-1}). Relative humidity measurements made on a grid-like spatial location around the stove and a heat source temperature of 60 º C from the stove was used for simulation work.

RESULTS

(a) Computational Fluid Dynamics

A two-dimensional computed velocity vectors will be presented at 3 planes in Cartesian coordinate system, plane y = 0.75 and 2.75m and plane z = 1.06 m. Limitation of CFD code limits orientation of plan.

Typical CFD result is shown below where the kitchen window and toilet doors are opened (plan view).

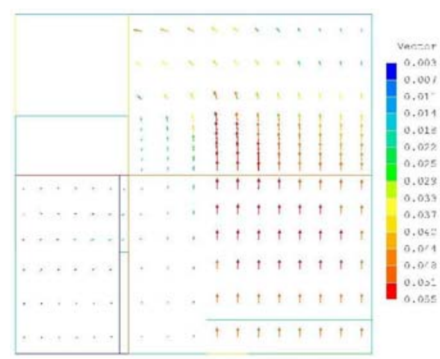

Figure 1a: Velocity vector at plane y=0.75m

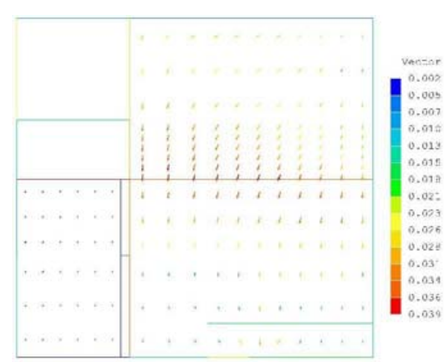

Figure 1b: Velocity vector at plane y =2.75 m

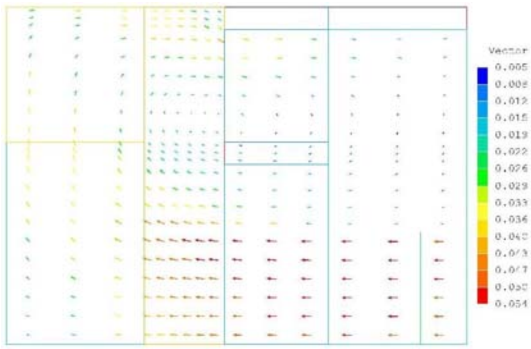

Figure 1c: velocity vector at plane z=1.06m

For the condition considered, the velocity vector in Figure 1a shows that a large flow of the incoming air through the kitchen window merged with a weak flow from the toilet area. Figure 1b however shows that the air flow is towards the fan location. Figure 1b also shows that the counter flow is due to a recirculation which occupies mainly the upper region of the kitchen, and extent toward the left wall of the kitchen. The flow re-circulation suggests that the mass flow rate of air exhausted by the fan is less than that of the incoming flow rate. Large flow rate of incoming flow also creates a low pressure region in the kitchen and this induce a weak flow from the toilet

(b) Field Measurements

Kitchen

Studies conducted in a double-storey house in Subang Jaya revealed that the background air change was 0.01 h^{-1}on a hot day (average 35 ºC external temperature, wind velocity 0.01 m/s throughout the day) using CO_2 as the tracer gas. With the ventilating fan fixed in the middle of the external wall, the air change improved to 1.2 h^{-1} with window and door closed (same internal and external conditions) and the owner noticed that deposition of soot and oil deposits had reduced. Potential of improving further the air change calls for a complete layout change, where the wall separating the family area from the kitchen is to be removed, as suggested from CFD simulations. This is beyond our scope of work as we are limited by:

a. stove is located on the side of party wall
b. layout of the kitchen cannot be altered
c. existing condition can be improved by proper positioning of 510 CMH fan as this represents worst scenario
d. Entrance to the kitchen is always closed during the experiment to simulate worst scenario such that weather effects are minimized.

Smoke particles were used to show visual impact of using ventilating fan as highlighted in the video clip. In this case use of ventilating fan alone did not improve the air change in the kitchen if location and height is not suitable.

Measurements of pollutants in the kitchen for various conditions were done together with external outdoor temperature. Each condition was monitored for 15 minutes which excluded preparation time; this was due to restriction of time. The sound pressure level emitted by the fan remained at 48 dBA at 1 m away from source, CO at 4 ppm, outside temperature between 31.5 – 32 ºC, inside temperature 31ºC, relative humidity 65%, lighting level was 35 lux and weather was calm except for condition 6.

Use of ventilating fan helped improve the ventilation effectiveness by at least 30% but ventilation effectiveness can increase to 60% or even higher, depending on external wind conditions. Combinations of window and door arrangement (opened or closed) helped to improve air change in the kitchen, but the door has a more positive effect than the window due to the door is without louvers to block the rush of air coming into the kitchen and also of its skinny shape (height/width ratio > 1.2). Without ventilating fan, the air exchange rate was between 0.01 – 2.0 h^{-1}, depending on window and door conditions. Use of ventilating fan helped improve the air exchange rate from 1.2 to 7.3 h^{-1}, depending on window and door conditions. Clearly, use of ventilating fan alone helped to improve the air exchange rate to 1.2 h^{-1} when window and door were closed on a calm hot day (see Table 3).

CONCLUSION

Application of tracer gas concentration decay technique together with computational fluid dynamics provides a powerful tool in locating optimum position of kitchen exhaust fan. Use of extractor is effective in removing contaminants from the kitchen and can help in improving of ventilation in a kitchen from 0.01 to at least 1.2 h^{-1}. The fan is effective when it is properly placed.

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Table 3: Summary of Results for Kitchen in Subang Jaya

Condition	Window	Door	Air Exchange rate(h^{-1}) FAN		η_r (%)	CO ppm	RH %	Temp In ºC	Temp Out ºC
			Off	On					
1	closed	closed	0.01		-	4	65	31	31.5
2	closed	closed		1.2	0.3	4	65	31	31.5
3	open	closed	0.2		-	4	65	31	31.5
4	open	closed		3.5	0.35	4	65	31	32
5	closed	opened	0.2		-	4	65	31	32
6	closed	opened		6.6*	0.6*	4	65	31	32
7	opened	opened	2.0		-	4	65	31	32
8	opened	opened		7.3	0.4	4	65	31	32

* Outside condition was windy

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Uniform Building by Laws (1984)

Environmental Assessment Of Household Waste Disposal In Kuala Lumpur

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ABSTRACT: In recent years the problem of solid waste disposal has gained growing interest among authorities and scientists. Debates concerning landfilling, incineration and recycling are becoming increasingly intense and eyes are opening around the world to face the problems of health hazards and pollution caused by illegal dumping, unsanitary landfilling and other inconsiderate waste disposal. An environmental assessment of the household solid waste disposal system in Kuala Lumpur, Malaysia, has been carried out using life cycle assessment tools in order to determine in which stages of the system the major pollution burdens occur. In 2002 41,100 ton household waste were produced per month in Kuala Lumpur. Practically all household waste is landfilled (99.75%); 90% at Air Hitam Sanitary Landfill south of the city and 10% at Taman Beringin Landfill in the northern periphery of the city. Most of the waste going to Air Hitam Sanitary Landfill is primarily taken to a transfer station for compaction and transfer to hauling vehicles. 0.25% of the household waste is recycled within the fractions of paper, glass, plastic, aluminium and other metals; mainly by use of communal collection at centralized recycling stations. Awareness programs are running in order to increase recycling and introduce composting. An Excel model has been prepared to predict environmental impact potentials in future scenarios of changed waste compositions and changed treatment technologies. Scenarios for 2008 (gasification), 2015 (intermediate) and 2020 (industrialized) have been put up. In 2002 landfilling at Air Hitam Sanitary Landfill was found to constitute the greatest environmental impact potential of the stages in the system per ton of household waste collected as the majority of the waste is taken there. However per ton of waste handled in the respective stages of the system Taman Beringin Landfill is the most polluting. Collection and recycling are relatively insignificant regarding environmental concerns. When including gasification in future scenarios the picture stays the same. Landfilling has the highest overall environmental impact potential per ton of waste over a 100-year period. The overall environmental impact potentials from the system decrease throughout the scenarios as landfilling gives way for thermal treatment and recycling. Sensitivity analyses do not indicate possible changes in the conclusions due to uncertainty in the values used in the assessment.

Keywords: Household Solid Waste, LCA, Landfilling, Thermal Treatment, Waste Management

INTRODUCTION

Countries with a fast economical development often experience that their waste treatment facilities can not follow the rapidly increasing amounts of produced waste. An example hereof is the Federal Territory of Kuala Lumpur (Malaysia), which is growing fast both economically and demographically. Currently more than 99% of the waste produced in Kuala Lumpur (KL) is landfilled (Alam Flora, 2002). The two existing landfills are scheduled to close down latest by the end of 2004 leaving an urgent question of where to dispose of the waste in the highly populated Klang Valley (the industrial centre of Malaysia) in which Kuala Lumpur is situated. Environmental awareness is increasing among citizens and politicians enhancing the role of the environment when discussing future waste treatment technologies. The local authorities have indicated gasification as the future for waste handling in KL. In 2008 a thermal treatment plant using gasification technology with ash melting is expected to commence operation to treat approximately half of the household waste in KL. The plant, which will be the biggest of its kind in the world, is facing strong opposition from the population due to lack of information on human toxicity of the exhaust emissions.

This investigation includes a description of the current household solid waste disposal system in KL including relevant mass flows and emissions. Emission-based environmental impact potentials have been calculated for the parameters of global warming, ozone depletion, acidification, photochemical ozone formation, nutrient enrichment and eco- & human toxicity within each stage of the system as well as for the system as a whole. The stages include collection (active collection, transfer station and hauling to landfill), landfilling and recycling. Future scenarios for 2008 (gasification), 2015 (intermediate) and 2020 (industrialized) have been put up to include thermal treatment and altered ratios of waste to the respective treatment facilities. Table 1 lists the environmental parameters and some compounds responsible for the potential effects.

Table 1: Environmental parameters included

Environmental parameter	Compounds
Global warming	e.g. CO_2, CH_4, CO, NMHC
Ozone depletion	e.g. CFC, HCFC
Acidification	e.g. SO_2, NO_X, H_2S, NH_4
Photochemical ozone form.	e.g. C_2H_4, C_6H_6
Nutrient enrichment	e.g. NO_3^-, NO_2^-, NO_X, NH_4
Eco- and human toxicity	e.g. Heavy metals, dioxins

METHODOLOGY

The assessment is build from empirical data to the extent these were available. Four months of data collection has been conducted in KL. The incomplete documentation of emissions from collection and the various treatment facilities in KL have, however, made introduction of some general data a necessity.

Applying life cycle assessment (LCA) tools to an environmental assessment of solid waste disposal enhances the possibility of obtaining both stage specific and holistic results in the analysis (McDougall et al., 2001).
To obtain the environmental impact potentials the emissions from the system have been normalized to milli person equivalents[1] (mPE) and weighted mPE in order to be able to compare the respective emissions. Danish normalization and weighting factors from Wenzel et al. (2000) have been used as no values have been identified for Malaysian standards. The impact assessment is built on previous studies carried on the environmental effects of various emission compounds. Environmental impact *potentials* are used as the actual impacts are highly dependent on the sensibility of the recipients (Wenzel et al., 2000).

The functional unit is one ton of collected household waste with a timeframe of 100 years. The cradle of the assessment is the point at which the waste is collected; the grave of the assessment is final emissions from collection, landfilling, thermal treatment and remanufacturing that will occur within 100 years; while the breadth of the assessment is the direct processes included in handling of waste and thus disregarding e.g. manufacturing of trucks and construction of landfills. The assessment is limited to include environmental impacts from emissions in the respective stages of the system thus disregarding resources consumption and working environment. The sensitivity of the surroundings has been omitted in the quantitative assessment due to lack of specific knowledge of the areas.

As the functional unit of this assessment is per ton of household waste the emission data has to be allocated to one ton of waste rather than an outlet concentration. This allocation poses problems when it comes to landfilling in which emissions to air and water from one ton of waste is released over a period of more than 100 years. For landfill gas three models (EMCOM, LANDGEM (1997) and a Laboratory Scale Model (Ehrig, 1996)) have been used as base for the calculations. For leachate the calculations of amounts produced over time must include a differentiation between leachate produced before and after the top cover is applied. For calculation of percolation through the bottom membrane the HELP (2002) model has been used.

A flexible excel model including the emissions from the respective stages in the system and normalization and weighting factors have been prepared to calculate the environmental impact potentials (EIP) of the system and to provide a flexible tools capable of instantly calculating new EIP when changes are introduced to the system.
The results of the assessment have been submitted to a sensitivity analysis in order to locate possibly critical uncertainties in the results that may influence the conclusions.

[1] Person Equivalent: The EIP that an average person constitute per year.

HOUSEHOLD WASTE DISPOSAL IN KL

Kuala Lumpur (KL), the capital of Malaysia, is situated 3˚ N 102˚ E inland at the Western side of Peninsula Malaya. The climate is tropical. The area has no specific rainy season, but is somewhat affected by the South West Monsoon from April to October. outline of the city is shown in Table 2.

Table 2: Outline of KL

Parameter	Quantity & unit
Area	243.65 km^2
Population (2000)	1,423,900
Households (2000)	290,592
Density (2000)	5,844 persons/km^2
Growth rate (2000)	3.3%

/DBKL, 2000/

The waste-collection company in KL, Alam Flora Sdn. Bhd., has estimated the population to 1,800,000 (Alam Flora, 2002) to include illegal residence and pendants who are producing waste to be collected as well.

As a federal territory Kuala Lumpur has a local government and is not included in any of the 13 states in Malaysia. Kuala Lumpur is surrounded by the state of Selangor.

Since a National Master Plan for Solid Waste has not yet been worked out, there is no well-established definition of Household Waste on national level (Zaini, 2002). In order to determine the amount of household waste produced in Kuala Lumpur it has been necessary to find an appropriate definition of it. After a study on how the waste is collected in KL, the definition shown in Box 1 was chosen as the one most suited for this study.

Box 1: Definition of household waste in KL

Household waste is all waste collected by the compactor-lorries. This includes:

- All types of waste produced in the house, including:
  - Garbage
  - Small size garden waste
  - Small size ”bulky waste”
  - Hazardous waste thrown in the garbage bin
- Light commercial waste produced by shops and restaurants

The waste is not necessarily collected by compactors, open lorries are also used in few cases

The general household waste characteristics of KL are depicted in Table 3.

Table 3: Household waste characteristics of KL

Household waste, mean values	Amount & Unit
Generation rate	0,7 - 0,8 kg/pers/day
Combustible fraction	90-95 %
Moisture content	55 %
Bulk density	260 kg/m^3
Calorific value*	8.4 MJ/kg

*The calorific value may decrease by up to 30% in rainy periods
The values in Table 3 are based on an average of a number of surveys carried out in 2000-2001.

Alam Flora is caretaking the collection and disposal of household solid waste, commercial solid waste, community solid waste, institutional- construction- and industrial solid waste, as well as cleansing of streets and drains. The company likewise manages the Taman Beringin Landfill and a transfer station in the northern periphery of KL and a number of recycling centers of which 12 receive household recyclables. The collection of household waste in KL has been divided into 8 areas of which Alam Flora personnel operate in some whereas other are operated by subcontractors.

The garbage fraction of the household waste is collected through curbside collection, mainly by compactor trucks (8 or 12 m^3) whereas the recycled fraction is handled through communal collection in which the citizens bring their recyclables to the recycling centers.
The garbage is taken to the transfer station and transferred to hauling vehicles, which transport the waste to Air Hitam Sanitary Landfill (AHSL) south of KL. Some household waste ends up at Taman Beringin Landfill (TBL), which officially does not accept household waste. This is due to cleansing of illegal dumping of household waste, which is taken to TBL.

Collection

Through an extensive analysis of the logbooks of the compactor trucks and a daily updated database of mileage, fuel consumption and waste collected at the respective collection routes, the fuel consumption per ton waste per kilometer has been calculated. The collection has been divided into collection route and cruise to and from the transfer station. For the calculations of the cruise fuel consumption the simulation program SEEK[2] was used.
The analysis and calculations resulted in Equation 1.

Equation 1: Diesel consumption for collection trucks

$$A = 0.05 \cdot NC + 0.24 \cdot C$$

A: diesel consumption in l/ton
NC: length of the normal cruise in km
C: length of the collection route in km
Both 0.05 and 0.24 are in l/(ton · km)

[2] SEEK: Simulation program for estimation of truck fuel consumption and respective emissions. Developed by the Danish Technological Institute, 8000 Århus C (Denmark) (2000)

The diesel consumption per ton of waste collected is 7.2 l/ton in average.
It has not been possible to retrieve data on the amount and composition of leachate from the trucks.

The transfer station (TS) commenced operation in May 2002. At the transfer station the waste is shredded and compacted into hauling vehicles, which transport the waste the 50 km to AHSL. Data for the transfer station are given in Table 4.

It has not been possible to acquire composition and amounts of leachate from the transfer station.

Table 4: Transfer station data

Parameter	Amount & Unit
Maximal hrs. capacity	270 ton/hrs.
Design capacity	1,700 ton/day
Current daily average	1,100 ton/day
Current monthly average	34,630 ton/month
Electricity consumption	7.7 MJ/ton
Diesel consumption TS-AHSL	3.2 liter diesel/ton

(Transfer Station, 2002)
TS: Transfer station, AHSL: Air Hitam Sanitary Landfill

Air Hitam Sanitary Landfill

The Air Hitam Sanitary Landfill (AHSL) is currently (2002) the only sanitary landfill accepting household waste in Malaysia (2002). It is located in the Air Hitam Forest Reserve in Mukim Petaling, just outside the southern periphery of Kuala Lumpur. It started operation at the end of 1995 and is expected to reach its full capacity by 2004. 95% of the total waste treated at the landfill is domestic. The remaining 5% is either commercial (4%), inert or sludge. The average amount of landfilled household waste collected in KL is 36,900 tons pr month.
The landfill has been constructed in 5 phases. Each phase comprises three cells, except for phase 4, which is a double cell. The cell sizes are about 1.0 to 1.3 hectares. The bottom liner is a 2mm tick High Density Polyethylene (HDPE) geomembrane and sits directly above the clay liner. The leachate is treated in two sequential batch reactor aeration/oxidation ponds and then discharged into the Sg. Rasau River Stream. The amount and composition of the leachate is under continuous control (Kamarudin, 2002), but it has not been possible to collect specific data showing the changes over time and thus the values are assumed constant in this assessment. The gas produced at the landfill is collected by 13 gas wells and successively flared off. Around 300 m^3 of gas are collected each hour. The landfill gas composition is 50-55% CH_4 and 45-50% CO_2 (AHSL, 2002). After closure of the landfill the gas will be utilized for production of electricity. The amount and quality of the gas is measured twice a year.
Scavengers are not allowed at the landfill.
For Air Hitam Sanitary Landfill and future landfills 40 years of leachate and gas treatment and gas flaring with an efficiency of ~99% are assumed.

Taman Beringin Landfill

The Taman Beringin Landfill (TBL) is the only operating landfill within the territory of Kuala Lumpur. It is located in Jingang Utara, in the northern periphery of KL on a 12 hectares piece of ex-mining land. It started operation in 1991 (Nasir et al., 1999) under administration of the City Hall and has officially been taken over by Alam Flora the first of January 1997. It was initially scheduled to close down by year 2000 but since no sufficient alternative has yet been located, it is still operating.
The landfill is officially closed for dumping of household waste. However, in this assessment around 4,100 tons are estimated to enter the landfill each month since May 2002. The estimation is based on a total amount produced of 41,100 ton waste whereof 36,900 ton are landfilled at Air Hitam Sanitary Landfill and around 100 ton are recycled. The household waste enter the landfill mainly in form of collected "illegally dumped waste".
TBL has no liners. A daily soil cover of gravel (however insufficient) is applied. Some of the leachate is treated in two aeration ponds, however, the leachate collection is insufficient and much of the leachate is released directly to the nearby river. There is no gas collection system and thus no flaring. A great number of surveys have been carried out on the composition of the landfill leachate. However, as many types of waste are disposed of at the landfill and this assessment is restricted to household waste the results cannot be used in this assessment. The leachate composition from Air Hitam Sanitary Landfill is thus applied to TBL.
Extensive scavenging of recyclables is taking place at the landfill.

Future landfills

The construction of two new sanitary landfills has been planned. These should be operational in 2004. No specific technical data on the future landfills is available. Emission data from Air Hitam Sanitary Landfill is assumed representative for the future landfills.

Recycling

Recycling constitute only app. 0.25% of the household waste in KL even though the amount is rising month by month throughout 2002 (Azwati, 2002). The main collector of household recyclables is Alam Flora. The citizens can "sell" their recyclables for cash at the recycling stations. Another recyclables collector is Azhar Sidek Recycle.
The recycling stations receive various types of paper and cardboard, glass, plastic, metals and aluminium. The average amounts collected per month from households in summer and fall 2002 are given in Table 5.

From the recycling stations the recyclables are transported to pretreatment or directly to remanufacturing, mainly in the vicinity of KL.

Table 5: Recycling amounts per month 2002

Fraction	[Ton/month]
Paper	79.9
Glass	6.4
Plastic	7.2
Metals	7.6
Aluminum	1.4
Total	102.5

(Azwati, 2002) & (Sidek, 2002)

Waste flow

Figure 1 gives an overview of the total amount and flow of household waste collected and treated in Kuala Lumpur. The values reported in the mass flow are mainly based on the period of May – September 2002 for curbside collection and May to October for recyclables. Note that recycling amounts are significantly lower than the garbage amounts. The future gasification plant and landfills are marked in dotted boxes. As the household waste generation and the curbside collection amounts are approximated, 14 tons are "missing".

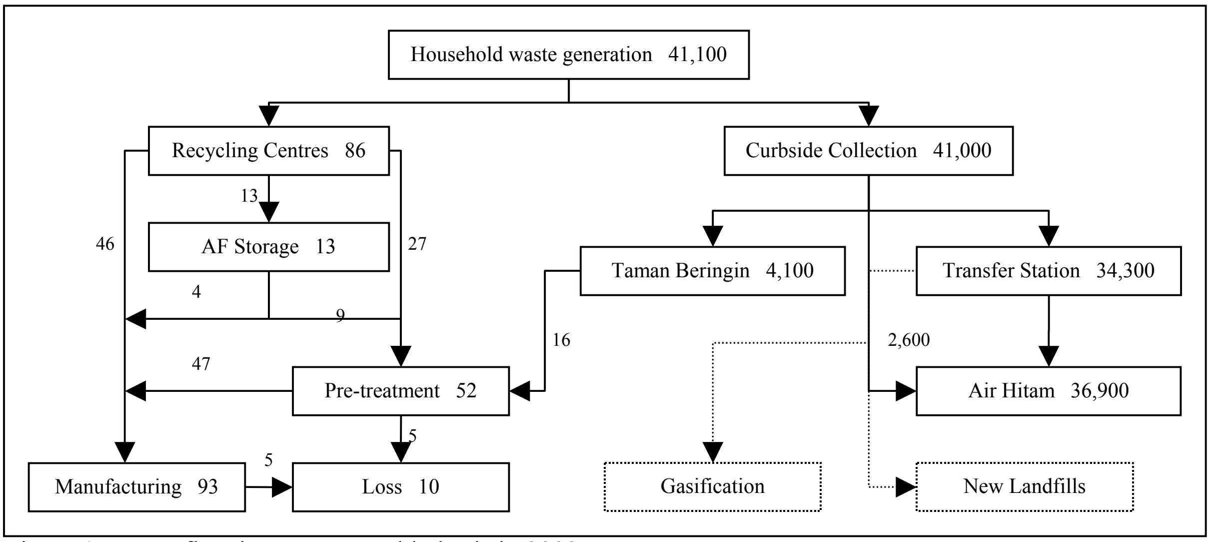

Figure 1: Waste flow in KL on monthly basis in 2002: The dotted boxes and connectors indicate future instalments. It should be noted that the recyclables amounts are significantly lower than the curbside amounts. As the household waste generation and the curbside collection amounts are approximated, 14 tons are "missing".

Thermal Treatment

The vast amount of waste produced in KL and the limited land availability to dispose of the waste via landfilling has led the government to decide for thermal treatment with energy recovery as the future way of waste disposal despite fierce opposition from the population and NGOs who fear outlet of especially dioxins. The scheduled plant, which is expected to commence operation in 2008 (The Star, 2002) will use gasification technology with ash melting. With a capacity of 1,500 ton/day the plant will be the biggest of it's kind in the world.
The plant will be situated in low density Taman Tasik Semenyih, Broga, app. 40 km south of KL (The Star, 2002).
At this point (November 2002) an EIA report without specific technical descriptions or expected emissions is the only accessible documentation. Thus emission data from existing plants have been used in the assessment.

RESULTS

The results are given in diagrams showing the normalized environmental impact potentials (EIP) in milli-person equivalents (mPE) for the respective environmental impact parameters. Positive values indicate environmental burdens whereas negative values indicate environmental savings.
Figure 2 and Figure 3 show the EIP per ton of waste in the respective stages and per ton of waste collected respectively. The EIP from Taman Beringin Landfill (TBL) are primarily caused by landfill gas whereas the major pollution source from Air Hitam Sanitary Landfill (AHSL) is leachate.
Per ton of waste in each stage (collection, AHSL, recycling and TBL) TBL constitute the highest EIP. Collection and recycling are practically insignificant. Per ton of household waste AHSL is more or less the sole pollutant as the vast majority (90%) of the waste is taken there. EIP from recycling is relatively non-existent due to the negligible amounts of household waste recycled (0.25%).

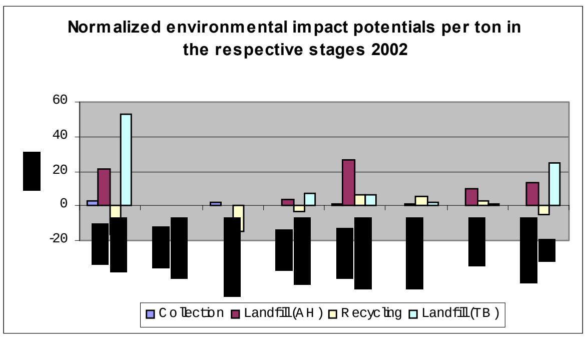

Figure 2: The landfills clearly constitute the highest environmental impact potentials for the system per ton of waste in the respective stages.

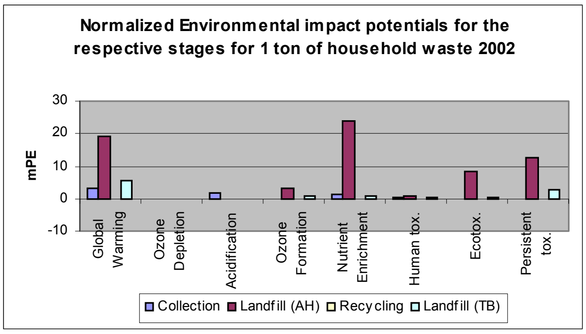

Figure 3: Air Hitam Sanitary Landfill is relatively the sole polluting stage in the system per ton of collected household waste.

In collection, the major EIP stem from the active collection. The EIP from collection of recyclables is insignificant compared to the impacts from remanufacturing and the savings from substituting manufacturing from raw materials.

Figure 4 reveals that EIP from gasification is remarkably lower than for landfilling.

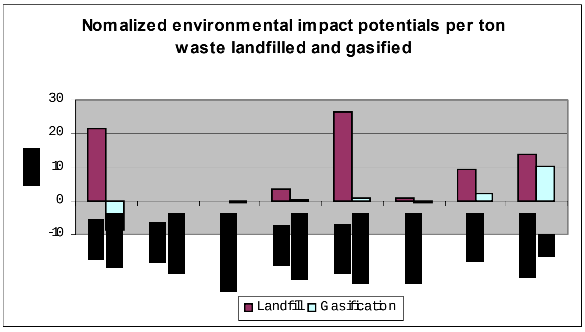

Figure 4: Environmental impact potentials from gasification are remarkably lower than for landfilling.

Energy recovery from gasification substitutes conventionally produced electricity resulting in environmental savings on especially global warming.

The critical compounds (compounds for which a relatively small change leads to significant changes in the results) in the system have been found to be:
Collection: NO_X and CO_2
Recycling: Depends on fraction
Landfilling: Landfill gas: Methane and Benzene
Leachate: Ammonium and Cadmium
Gasification: Mercury (and Dioxins)
Outlets of dioxins would have to increase by a factor 100 to constitute significant changes in the overall EIP from gasification, but given the extreme toxicity of dioxins it is still a compound that must be given special attention.

In the future scenarios thermal treatment and recycling are expected to gain more ground and thus the overall EIP of the system decrease throughout the scenarios. It is not until the 2020 scenario (70% thermal treatment, 10% landfilling and 20% recycling) that EIP from collection and recycling becomes significant to the overall EIP of the system.

Sensitivity analyses are carried out in the respective stages (collection, landfilling, gasification and recycling) of the system on areas associated with uncertainty and critical compounds. It has been found that change of conditions and emissions in the respective stages within realistic proportions will not affect the results in a manner that would change the conclusions.

CONCLUSIONS

An environmental assessment has been carried out on the household solid waste disposal system of Kuala Lumpur using LCA tools. Available data on emissions from the respective stages of the household waste disposal system in Kuala Lumpur have proven too scarce to conduct an exhaustive environmental assessment based on case specific data. The conclusions of this project are thus based on a combination of theoretical and empirical data.

In 2002 TBL had the highest environmental impact potentials per ton of waste. Landfilling at AHSL was, however, found to constitute by far the greatest environmental impact potential of the stages in the system per ton of household waste collected due to the vast amounts of waste going to the landfill. None of the sensitivity analyses carried out have revealed any reason to argue with this result as higher pollution from the landfill was mainly the result at changed conditions.

When including gasification in future scenarios the environmental impact potentials will decrease for each ton of waste diverted from landfilling to gasification as landfilling still has the highest overall environmental impact potential per ton of waste over a 100-year period.

Collection has no immediate influence on the total system impacts in 2002. Only when the highly polluting landfilling is diminished in the 2020 scenario collection becomes influential. Collection must, however not be disregarded on this account without further investigations as it takes place in highly populated areas and thus may constitute a local health hazard.

The overall environmental impact potentials from the system decrease throughout the scenarios as landfilling gives way for thermal treatment and recycling. The primary energy balance for the system likewise reveals higher and higher savings due to electricity production in thermal treatment and energy savings in recycling.

Political and economical incitements to constructing a thermal treatment plant are thus supported by environmental aspects.

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7 Hydrology

The Implementation Of A Water Model On The Water System At Mae Moh Project Area, Lampang

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ABSTRACT: It is revealed that the water quality in Mae Moh Reservoir (down stream receiver) was deteriorated by a considerable amount of contaminated water from mine drainage and power plants effluence. This study aims to investigate both water quantity and quality through a water model. A water model was constructed for prediction from year 2001- onward on the basis of water balance and continuity equations to present monthly and annual water flow, concentration and chemical load of Total Dissolved Solid (TDS) and Sulfate (SO_4^{2-}), which were significant water pollutant. The water model was constructed from databases, which were based on the data and information in the five years period, 1996-2000. The model validation have been done in year 2001 by comparing between predicted model and actual model. The result was shown that at 95% (62SD) confidence interval, the mean of predicted value and actual value of TDS and SO_4^{2-} load at Mae Moh Reservoir were equalized. It can be concluded that the test result was acceptable and water model can be used as a tool for Mae Moh water system management. According to the predicted water model year 2006, Mae Moh mine discharged water is 10.762 Mm^3/year, with pH value of 7.31, TDS and SO_4^{2-} concentration of 2547.69 mg/l and 1802.52 mg/l respectively. Mae Moh power station effluence is 14.59 Mm^3/year, with pH value of 7.07, TDS and SO_4^{2-} concentration of 610.25 mg/l and 357.80 mg/l respectively. At Mae Moh Reservoir, the out flow is 83.667 Mm^3 and the concentration of TDS and SO_4^{2-} are as high as 1501.40 mg/l and 822.09 mg/l respectively in year 2006.

Keywords: Mae Moh water system, Water Model, pH, TDS, SO_4^{2-}

INTRODUCTION

Mae Moh project is associated with a number of potential environment aspects. As a consequence of water quality in Mae Moh Reservoir (down stream receiver) was deteriorated by a considerable contaminated water from mine drainage and power station effluence. Water system at Mae Moh project area was growing importance of water management and environmental issues. This study aims to investigate both water quantity and water quality through a water model for management of the water system and minimizing environmental impacts in Mae Moh basin. Mae Moh project area is located in Mae Moh district, Lampang province, 630 kilometers north of Bangkok as shown in Figure 1. It locates 26 kilometers south east of Lampang township. Geographically, it is located in a basin called Mae Moh basin lying in the N-S trending between latitude 18^{o} 16' to 18^{o} 25' longitude 99^{o} 34' to 99^{o} 46'. The basin area covers 135 km^2 with 8 km. wide and 17 km. long. Topography of the project area is generally flat with slightly rolling terrain. The basin is bounded by steep rugged mountain range of Pre-Tertiary rocks to the north, and Quaternary basalt to the south. The average altitude is approximately 320 meters above mean sea level. The climate of the area is characterized by definite wet and dry seasons. The southwest monsoon starts from May to October. The dry season starts in late October and lasts until April where cool weather is during December to February. The annual mean temperature of the area (1961 - 1996) is 25.9^{o}C with mean maximum temperature of 29.5 ^{o}C in April and mean minimum temperature of 13.9 ^{o}C in January. A maximum wind speed of 64 kilometers per hour has been recorded at Lampang, but the average wind speed is generally low throughout the year.

Figure 1: Map of Thailand and Mae Moh project Location

The mean annual rainfall is 1,076 mm with 85-95% of annual rainfall occurring during the southwest monsoon. The variation of annual rainfall is about 20% above the mean.

METHODOLOGY

The study works such as survey and review all necessary data ,information and water system component linkage have been done by following the flow work as shown in Figure 2.

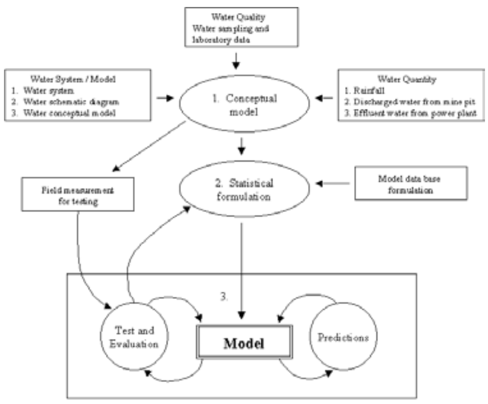

Figure 2: The three successive steps of the water quantity and quality investigation and water model building processes

The process, which ends with the formulation of a statistical conceptualization of the Mae Moh water model, usually starts from an underlying balance of both water quantity and quality on a major part of the water system and environmental aspects. Mostly, it has used the secondary data and information collected by The Electricity Generating Authority of Thailand (EGAT) , such as detail of water system components, hydrological information, water sampling, laboratory data, descriptive data from literature, field knowledge and existing experience. It was considered crucial to base the formulation of a water model on an underlying conceptual framework as shown in Figure 2. Hereafter, three successive steps of the work flow of conceptual aspects are discussed.

Mae Moh Water System

About 30 water components of Mae Moh water system around the Mae Moh project area consist of 12 inpit mine sumps, 3 outpit mine sumps, 3 settling ponds, 3 wetlands, 6 reservoirs, one weir, and 2 points along Mae Moh stream, which were studied during year 1996-2000. The 13 main components from 30 components were considered as the important model components, which have been stated in water model. The 13 main components consist of 5 reservoirs, one weir, 3 settling ponds, 3 wetlands, and one outpit sumps (see figure 3), which have been computed as a model database in each components for the model reference. The 13 main water resources could be categorized into 3 groups, which based on the water quality. Thus the 3 groups of water resources were natural water, drainage water and contaminated water as follow:

(1) Tha Si Weir	Natural Water
(2) Mae Kham Reservoir	Natural Water
(3) North-East Settling Pond	Drainage Water
(4) North-East Wetland	Drainage Water
(5) Upper Huai Luang	Natural Water
(6) Sump E	Drainage Water
(7) South-West Settling Pond	Drainage Water
(8) South-West Wetland	Drainage Water
(9) Huai Sai Reservoir	Contaminated Water
(10) South Settling Pond	Drainage Water
(11) Lower Huai Khing	Natural Water
(12) South Wetland	Drainage Water
(13) Mae Moh Reservoir	Contaminated Water

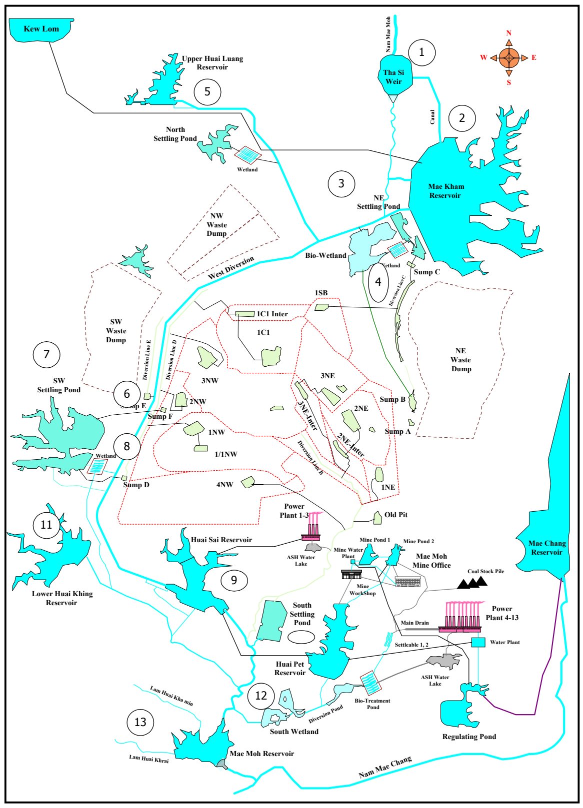

Figure 3: Mae Moh Water System

Mae Moh Water Model

The water model has been constructed from a number of Mae Moh water system components as shown in Figure 3, which represent each of the processes in the water balance. The model consists of flow diagrams and symbols showing linkages between components (for example ; reservoirs, settling ponds, weirs, wetlands, in-pit and out-pit mine sumps, diversion lines, canals and drainage systems) and detail of monthly and annual information of both water quantity and quality for each components of water model as shown in Figure 4.The information of water model were related and referred from water model data bases, which were designed to assist in solution, evaluation and prediction of both water quantity and quality for each of 13 main components (see Figure. 3 – 4) of Mae Moh water system .

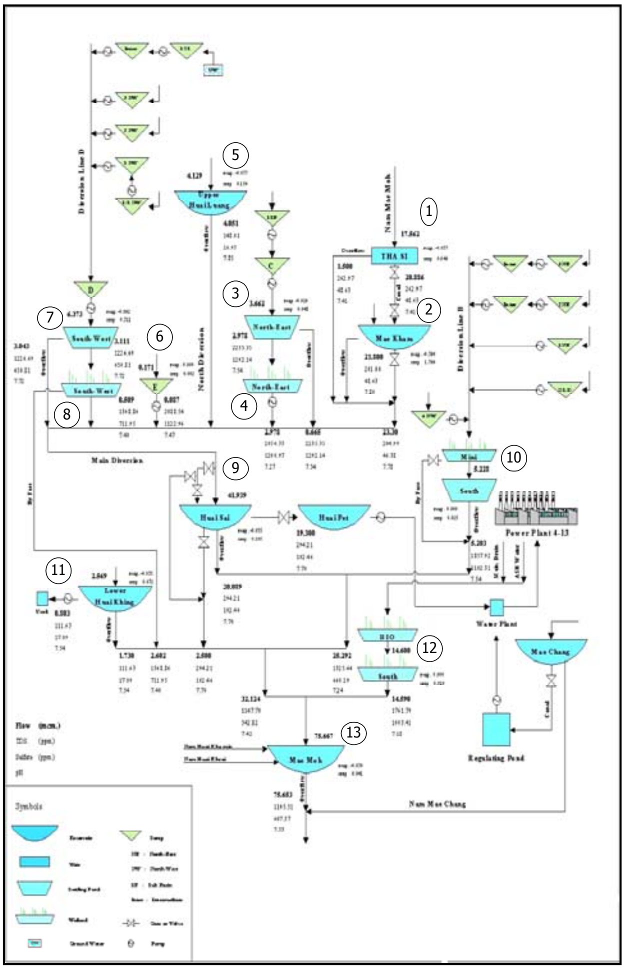

Figure 4: Mae Moh Water Model

Water Quality

In order to obtain the whole perspective on the characteristics of water quality and variation in quality of water through space and time within the project area, the 30 sampling stations have been carefully identified for this study. The sampling stations for water quality cover various conditions of the surface runoff system within the project area ranging from the natural baseline to every subsequent stage of water flowing through mining operations, power generation processes and other related activities. Therefore, any potential source pollutants discharging into the surface runoff system have been well covered. Sampling programs have been designed to embrace the seasonal variation of water quality during the high, intermediate, and low flow condition throughout the year. Water sampling and analysis in study area has been done (Information : year 1996-2000, Prediction : year 2001-onward). Approximately 1511 samples were taken during year 1996-2000 (302 samples per year) from 30 locations around Mae Moh Mine and Power Stations area as shown in figure 5. Water samples were analyzed in different parameters and different frequency. The water analysis results are carefully considered and approvingly concentrated in the area of pH value, Total Dissolved Solids (TDS) and Sulphate (SO_4), which are the significant water pollutant occurred from Mae Moh Project activities.

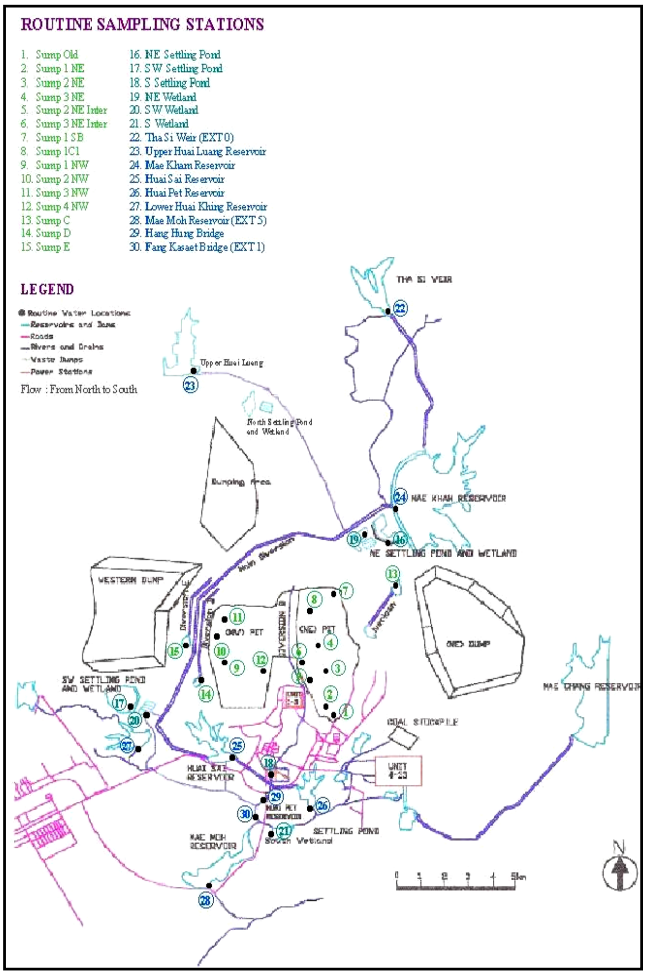

Figure 5: Water Sampling Locations

Water Model Database

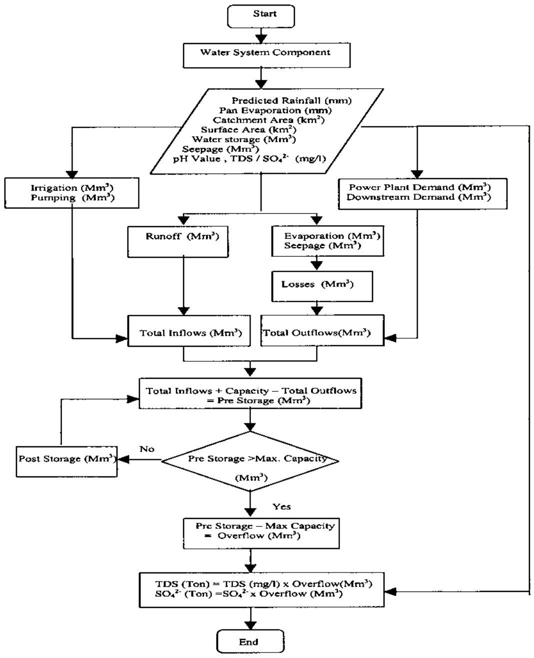

Figure 6: The water model database calculation flowchart

The water model database calculation flowchart is shown in figure 6. The flowchart shows processes to calculate the water quantity and water quality in concentration and chemical load of TDS and SO_4^{2-} for each water component of
Mae Moh water system. This spread sheets are computed for the reference of monthly and annual information of 13 major components of water model .

The basic conditions and assumptions for constructing the water model are stated as below;

(1) The water levels of reservoirs, settling ponds and others
main components of water system are at the normal high water level at the beginning of the first month of the year (after rainy season).
(2) The mean annual seepage from reservoirs and settling ponds are 5% (Mae Moh EGAT. Water Management Manual, Report No. N7300-4101, September 1998).
(3) The summary of statistics of monthly and annual rainfalls were computed from selected station (Old mine office) which was the representative stations in the study area.
(4) The rainfall data (year 1974-2000) was proceeded by using Time Series for rainfall prediction from year 2001- onward.
(5) Most of secondary data and information for this study were referred from EGAT sources, year 1996-2000.
(6) The reactions of TDS and SO_4^{2} on biological and physical process are negligible.

RESULTS AND DISCUSSION

The water model information was referred from databases, which were based on the data and information in the five years period of 1996-2000. The model validation have been done in year 2001 by comparing between predicted model and actual model. The Paired – Sample T Test was performed at Mae Moh Rreservoir between the predicted model and the actual model in 2001. The testing was done into 2 pairs of mean of TDS load (tons) and SO_4^{2-} load (tons), which the results were shown in Table 1.

Table 1: Paired Samples Test

	Comparison	Paired Differences Mean (ton)	Standard Deviation (ton)	Standard Error Mean (ton)	95% Confidence Interval of the Difference		t	df	Significa (2-tailed)
					Lower (ton)	Upper (ton)			
Pair 1	TDS Predicted TDS Actual	1553.610	5995.6044	1662.8815	-2069.4975	5176.7175	.934	12	.369
Pair 2	SO_4^{2-} Predicted SO_4^{2-} Actual	845.8231	3219.2928	892.8712	-1099.5761	2791.2222	.947	12	.362

The first pair result shows that the differences mean was 1553.61 tons with standard deviation of 5995.6044 tons and standard mean error of 1662.8815 tons, while the level of significant (2 tailed) was 0.369. It means that the paired differences mean of TDS load from predicted model and actual model was in the range of 95% (±2 SD) confidence interval. The second pair test result shows that the difference mean was 845.82 tons with standard deviation and standard error mean of 3219.2928 and 892.8712 tons respectively, while the level of significant (2 tailed) was 0.362. It mean that the paired differences mean of SO_4^{2-} load from predicted model and actual model was in the range of 95% (±2 SD) confidence interval. From these results of quality testing on the complex Mae Moh water system, it can be concluded that the test result was acceptable and water model can be used as a tool for Mae Moh water system management. The implementation of water model on Mae Moh water system can be used and valid until the water system has no major change. Therefore, the water model should be remodeled to cover the all changing components (if any). This will be minor change in the program and the validity of the model will be able to use until the end of mining operation. The water model present details of monthly and annual information of water flow, pH value, concentration and chemical load of Total Dissolved Solid (TDS) and Sulfate (SO_4^{2-}), which were significant water pollutant in Mae Moh water system.

The Mae Moh project discharged water was the combination of mine drainage and power plant effluence, which were the pH value of 7.32and7.20 respectively. From pH value > 6 and alkalinity greater than acidity, the low metal concentration is probably not significant in prior estimating environmental effects. Coal mine drainage ranges widely in composition from acidity to alkalinity. The pH value is most commonly either in the range 3 to 4.5 or 6 to 7.5 with fewer intermediate or extreme value. As a consequence of quality of mine drainage discharged from Mae Moh mine pit, it can be categorized in Type 5 Water (Skousen and Ziemkiewicz, 1996), which is neutralized acid mine drainage (AMD) with pH > 6 and high TDS, SO_4^{2-} concentrations. Three scenarios of the event and the interactions of mine drainage and water at Mae Moh Reservoir in year 2006 have been set for model implementation practice as below.

Scenarios 1 What happen on mine drainage system in year 2006.

Scenarios 2 How the mine excess water quantity controlled affect the water quality in Mae Moh Reservoir in year 2006.

Scenarios 3 How the mine excess water quality controlled affect the water quality in Mae Moh Reservoir in year 2006.

Scenario 1

According to actual model year 2001 and predicted model year 2006 the results are shown in Table 2, Table 3 and Table 4.

Table 2: The Water Quantity and Quality of Mae Moh Project Drainage (Actual 2001)

Locations	Volume (Mm^3)	Concentrations		
		TDS(mg/l)	SO_4^{2-} (mg/l)	pH
Mine Drainage	8.144	2274.23	1407.22	7.32
Power Plant Drainage	14.590	1169.00	665.34	7.20
Total	22.73	1565.20	931.27	7.24

Table 3: The Water Quantity and Quality of Mae Moh Project Drainage (Predicted 2006)

Locations	Volume (Mm^3)	Concentrations		
		TDS(mg/l)	SO_4^{2-} (mg/l)	pH
Mine Drainage	10.762	2,547.69	1,802.52	7.31
Power Plant Drainage	14.590	610.25	357.80	7.07
Total	25.352	1,432.70	971.09	7.17

Table 4: The comparative mine discharged water year 2001 and 2006

Location	Prediction(1) Year 2006	Actual(2) Year 2001	Difference(1)-(2)	
	Volume (Mm^3)	Volume (Mm^3)	Volume(Mm^3)	%
Diversion B	6.100	3.788	2.312	61.04
Diversion C	1.186	0.844	0.342	40.52
Diversion D	3.476	3.508	-0.032	-0.91
Total	10.762	8.144	2.622	32.21

The mine excess water in year 2006 have to be discharge by pumping out through diversion line B, C and D are 6.100 Mm^3, 1.186 Mm^3 and 3.467 Mm^3 respectively and totally is 10.762 Mm^3. While the mine discharge water in year 2001 is 8.144 Mm^3. Thus, the excess water in mine pit year 2006 is greater than excess water in year 2001 by 2.622 Mm^3 or 32.21%. The average mine drainage concentration of TDS and SO_4^{2-}in year 2006 are as high as 2,547.69 mg/l and 1,802.52 mg/l, which are obviously greater than those TDS and SO_4^{2-}concentration of mine discharged water in year 2001. At Mae Moh Reservoir, the out flow volume of 83.667 Mm^3 in year 2006 is greater than the out flow volume of 80.928 Mm^2 in year 2001 by 2.739 Mm^3 or 3.38% of volume in year 2001. The average concentration of TDS and SO_4^{2-} are as high as 1501.40 mg/l and 822.09 mg/l respectively in year 2006. It is shown that TDS concentration exceed the guide line of industrial effluent water for irrigation, which is equal or less than 1,300 mg/l

Scenario 2

This scenarios simulate the water model year 2006 to provide upgrading water quality options at Mae Moh Reservoir by manipulating the mine discharged water. The model show how mine discharged water will affect water quality at Mae Moh Reservoir. The criteria of keeping 100% and 50% volume of mine discharged water has been set for mine discharged water manipulation. The results are shown in Table 5 and Table 6

Table 5: Part of Mae Moh Water System Situation Year 2006 Keeping Mine Discharged Water (Case : TDS)

Keeping Volume (%)	Mine Discharged Water (Mm^3)			Mae Moh Reservoir		
	Divesion B TDS 1789.50 mg/l	Divesion C TDS 3125.82 mg/l	Divesion D TDS 3624.82 mg/l	Manipulation TDS Before (mg/l)	TDS After (mg/l)	Difference (%)
100	6.100	1.185	3.476	1501.40	1385.50	7.72
50	3.050	0.593	1.738	1501.40	1448.11	3.55

Table 6: Part of Mae Moh Water System Situation Year 2006 Keeping Mine Discharged Water (Case : SO_4^{2-})

Keeping Volume (%)	Mine Discharged Water (Mm^3)			Mae Moh Reservoir		
	Divesion B SO_4^{2-} 1285.26 mg/l	Divesion C SO_4^{2-} 2429.72 mg/l	Divesion D SO_4^{2-} 2496.34 mg/l	Manipulation SO_4^{2-} Before (mg/l)	SO_4^{2-} After (mg/l)	Difference (%)
100	6.100	1.185	3.476	822.09	710.43	13.58
50	3.050	0.593	1.738	822.09	770.70	6.25

In case of using criteria keeping 100% and 50% volume of mine discharged water, the TDS concentration at Mae Moh Reservoir will be decreased from 1501.40 mg/l to 1385.5 mg/l and 1448.11 mg/l or 7.72% and 3.55% respectively. While the SO_4^{2} concentration will be decreased from 822.09 mg/l to 710.43 mg/l and 770.70 mg/l or 13.58% and 6.25% respectively.

Scenario 3

The water model has been simulated to predict Mae Moh water system year 2006. The Water treatment is created for upgrading mine discharged water quality, which will affect water quality in Mae Moh Reservoir. The amount of excess water in mine pit will be treated 100% and 50% volume at 95% and 90% of TDS and SO_4^{2} removal.

Table 7: Part of Mae Moh Water System Situation Year 2006 ; Treat 100 % and 50 % of Mine Discharage water at 95 % TDS Removal

Treated Volume (%)	Mine Discharged Water (Mm^3)			Mae Moh Reservoir		
	Divesion B 95% TDS 1693.48 mg/l	Divesion C 95% TDS 2969.52 mg/l	Divesion D 95% TDS 3508.47 mg/l	Manipulation TDS Before (mg/l)	TDS After (mg/l)	Difference (%)
100	6.100	1.185	3.476	1501.40	1262.44	15.92
50	3.050	0.593	1.738	1501.40	1382.47	7.92

Table 8: Part of Mae Moh Water System Situation Year 2006 ; Treat 100 % and 50 % of Mine Discharage water at 90 % TDS Removal

Treated Volume (%)	Mine Discharged Water (Mm^3)			Mae Moh Reservoir		
	Divesion B	Divesion C	Divesion D	Manipulation		
	90% TDS 1604.35 mg/l	90% TDS 2813.23 mg/l	90% TDS 3323.82 mg/l	TDS Before (mg/l)	TDS After (mg/l)	Difference (%)
100	6.100	1.185	3.476	1501.40	1275.02	15.06
50	3.050	0.593	1.738	1501.40	1388.57	7.51

The results in Table 7-8 show that, in case of 100% and 50% volume of mine discharge water treatment at 95% and 90% TDS removal, the water quality in Mae Moh Reservoir will be upgraded as TDS concentration from 1501.40 mg/l to 1262.44 mg/l, 1275.02 mg/l, 1382.47 mg/l and 1388.57 mg/l or 15.92% , 15.06% , 7.92% and 7.51% respectively.

Table 9: Part of Mae Moh Water System Situation Year 2006 ; Treat 100 % and 50 % of Mine Discharge water at 95 % SO_4^{2-} Removal.

Treated Volume (%)	Mine Discharged Water (Mm^3)			Mae Moh Reservoir		
	Divesion B	Divesion C	Divesion D	Manipulation		
	95% SO_4^{2-} 1220.995 mg/l	95% SO_4^{2-} 2308.231 mg/l	95% SO_4^{2-} 2371.519 mg/l	SO_4^{2-} Before (mg/l)	SO_4^{2-} After (mg/l)	Difference (%)
100	6.100	1.185	3.476	822.09	652.03	20.68
50	3.050	0.593	1.738	882.09	734.4	16.74

Table 10: Part of Mae Moh Water System Situation Year 2006 ; Treat 100 % and 50 % of Mine Discharage water at 90 % SO_4^{2-} Removal

Treated Volume (%)	Mine Discharged Water (Mm^3)			Mae Moh Reservoir		
	Divesion B	Divesion C	Divesion D	Manipulation		
	90% SO_4^{2-} 1220.995 mg/l	90% SO_4^{2-} 2308.231 mg/l	90% SO_4^{2-} 2371.519 mg/l	SO_4^{2-} Before (mg/l)	SO_4^{2-} After (mg/l)	Difference (%)
100	6.100	1.185	3.476	822.09	660.99	19.60
50	3.050	0.593	1.738	882.09	741.91	15.89

In Case of 100% and 50% volume of mine discharge water treatment at 95% and 90% SO_4^{2-} removal, the water quality in Mae Moh Reservoir will be upgraded as SO_4^{2-} concentration from 822.09 mg/l to 652.03 mg/l, 660.99 mg/l, 734.4 mg/l and 741.91 mg/l or 20.68%, 19.60%, 16.74% and 15.89% respectively as shown in Table 9 and Table 10.

From above scenarios, the mine discharged water manipulation should be the combination of mine excess water quantity and quality controlled measures. For example, the 100% volume keeping of mine discharged water or zero discharged policy should be performed in dry season and 50% volume keeping and 50% volume treatment at 95% TDS and SO_4^{2-} removal can be applied in wet season. Therefore, the early of these measures are applied, the better of water quality is at Mae Moh reservoir.

CONCLUSION

The study provides a comprehensive analytical framework useful in long-term planning, development and management of conjunction use of Mae Moh water system. Applicability of the proposed methodologies is illustrated in a representative Mae Moh water system components, such as the upline natural water resources, the mine drainage system, power station effluence, other water used for Mae Moh project activities and down stream receiving reservoirs in Mae Moh Basin.The study considers a conjunctive use system with a stream diversion, reservoirs, outpit and inpit mine sumps, weir, settling ponds and wetlands as the Mae Moh water model components.This study has considered several important issues related to the water quality and quantity of Mae Moh water system to create and construct a water model. The water model itself consists of a main diagram with symbols showing the major part of overall water system at Mae Moh basin and a series of water model databases to assist in information management, predictive capability and information presentation. Throughout the study, an attempt has been made to maintain an appropriate balance between simplicity and reality. The model validation have been done in year 2001 by comparing between predicted model and actual model. The result was shown that at 95% (62SD) confidence interval, the mean of predicted value and actual value of TDS and SO_4^{2-} load at Mae Moh Rreservoir were equalized. It can be concluded that the test result was acceptable and water model can be used as a tool for Mae Moh water system management.The implementation of water model on Mae Moh water system can be used and valid until the water system has no major change. Therefore, the water model should be remodeled to cover the all changing components (if any). This will be minor change in the program and the validity of the model will be able to use until the end of mining operation. The water discharged from Mae Moh project was the combination of mine drainage and power plant effluence, which were the pH value of 7.32 and 7.20 respectively. From pH value > 6 and alkalinity greater than acidity, the low metal concentration is probably not significant in prior estimating environmental effects. The water model presented details of annual information of water flow, pH value, concentration and chemical load of Total Dissolved Solid (TDS) and Sulfate (SO_4^{2-}), which were significant water pollutant. According to the predicted water model year 2006, Mae Moh mine discharged water is 10.762 Mm^3/year, with pH value of 7.31, TDS and SO_4^{2-} concentration of 2547.69 mg/l and 1802.52 mg/l respectively. Mae Moh power station effluence is 14.59 Mm^3/year, with pH value of 7.07, TDS and SO_4^{2-} concentration of 610.25 mg/l and 357.80 mg/l respectively. At Mae Moh Reservoir, the out flow is 83.667 Mm^3 and the concentration of TDS and SO_4^{2-} are as high as 1501.40 mg/l and 822.09 mg/l respectively. The water model can be used as a tool for integrated coal mine and power plants water management. It is possible to apply for both of source reduction and recycle/reuse methods in order to achieve waste water minimization in a coal mine and power plants area.

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Does Damming Alter Coastal Water Quality?

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ABSTRACT: Thai people have always been agricultural-based although natural water from the rain is not enough to sustain the year-round agricultural practice. More than 40 large scale dams were constructed between 1960 and present. The number of big dam projects in Thailand is much greater than in neighboring countries. Regulation of river flow by damming has been found substantially reduced dissolved silicon (DSi) delivery by rivers to the coastal sea in some area. Whereas removal of N and P in reservoirs can be compensated for by anthopogenic inputs in the drainage basins, no such compensation occurs for Dsi. In the study of Rajjaprabha dam, the biggest multipurposed dam in southern Thailand, it was found that damming has controlled the quality of withdrawal water to the downstream river. In the reservoir, a marked vertical thermal discontinuity, thermocline, was clearly seen at the depth of about 15 m. Anoxic condition was found beneath thermocline. Below thermocline, nitrate was rapidly decline to non-detectable concentration, whereas ammonia, nitrite and reactive phosphate concentrations increased with depth. The DSi concentration in surface water was higher than in lower water. The water was released to downstream from the cool anoxic layer of the reservoir. Substantially increasing of nitrate, partly from oxidation of ammonia and nitrite, and phosphate concentrations in the lower river was influenced by high agricultural activities within the watershed. The DSi:DIP and DIN:DIP atomic ratio in the lower riverine water were found to be declined at the river mouth. The DSi:DIN ratio in the river plume was still much higher than 1 (Redfield ratio, DSi:DIN:DIP = 16:16:1), this indicated that the riverine export of dissolved silica was still sufficient to serve marine diatom, which are abundant constituents of coastal phytoplankton, in the Bandon Bay. Part of the reasons might be the higher rate of dissolution of silica in tropical region. Although decreasing of DSi concentrations and the DSi:DIN ratio in this coastal sea is yet not seem to affect coastal diatoms population, the prolonged period of damming and non-controlling fertilization will keep changing in DSi:DIN:DIP ratio. This might be possible to shifts in phytoplankton species composition which consequently affect on coastal biogeochemical cycles and food web structure observed.

Keywords:

Dissoved silica, ammonia, nitrite, phosphate, nutrients removal, Rajjaprabha dam, Tapi-Phumduang River

INTRODUCTION

Thai people have always been agricultural-based although natural water from the rain is not enough to sustain the year-round agricultural practice. The first earth-filled dam was built across a valley near Sukhothai over 700 years ago. According to the population growth, more than 40 large scale dams constructed between 1960 and present, the number of big dam projects in Thailand is much greater than in neighboring countries. The main aims of building dams are (i) to store water from each annual flood, achieving regulated releases of water for irrigation etc, (ii) to generate hydroelectric power, and (iii) to control the floods.

The quality of aquatic systems is a reliable indicator of the ongoing environmental changes. In the last few decades, intensification of agricultural activities and urbanization lead to increases in the concentrations of nutrient elements such as nitrate (N) and phosphate (P) in rivers, lakes and coastal waters. Deforestation enhances top soil erosion increasing river sediment loads. River damming and river diversions, on the other hand, cause a reduction in sediment inputs. Various man-made structures, such as large scale hydrological alternations in river drainage basins or partial diversion, have led to reduction of river inputs to the sea due to the retention of materials in reservoirs behind dams and on land (Ittekkot and Arain, 1986). Over the same period, dissolved silica (DSi) carried by rivers significantly decreased as a result of numerous hydraulic management programmes (Humborg *et al*., 1997).

Humborg *et al.* (1997) has demonstrated the change in relative amounts of nutrient element (N, P and Si) carried by Danube River in Romania to the Black Sea. More frequent occurences of toxic algal blooms and a decline in fisheries have also been reported (Humborg *et al*., 1997; Humborg *et al*., 2000). Whereas these removal of N and P in lakes and reservoirs can be over compensated by anthropogenic enrichment in the drainage basins at the downstream of the reservoirs, no such compensations have been observed for DSi. The decrease in DSi in the river water after the dam operations demonstrate clearly in the cases of Danube River Dam (Humborg *et al*., 1997; Humborg *et al*., 2000) and the Nile River (Wahby and Bishara, 1980).

In the coastal waters, diatoms form an essential part of the aquatic food chain and play a critical role in the biogeochemical cycles. Diatom populations are sustained by Si inputs from rivers. The deficiency of DSi with respect to N and P has been hypothesized to be at the basis of the replacement of diatoms by non siliceous, often less desirable, phytoplankton (Humborg *et al*., 1997; Officer and Ryther, 1980). The occurrence of potential toxic flagellate blooms has become more frequent in many coastal areas all over the world. In consequence, changing phytoplankton assemblage will have repercussion on the entire pelagic food web and might have enormous economic impacts. These results alarm that damming of rivers worldwide may significantly affect the food web structure and biogeo-chemical cycling in coastal seas which account for about 30-50% of global oceanic production.

Apparently, rivers in the Monsoon Asia are transported large quantities of N and P as suspended particulate because, in addition to agricultural and domestic wastes, rivers carry massive amounts of eroded sediment from upper watersheds resulting from deforestation. A significant relationship between freshwater injection during the monsoon season and an increased flux of carbon (C) and Si to the deep ocean has been shown for the receiving waters of the Ganges/ Bramaputra (Reemtsma *et al*., 1993; Schäfer *et al*., 1996). However, Si which has source-transport sink characteristics distinct from N and P may also play a vital role in food web characteristics of coastal seas in the monsoon Asia which discharges the highest freshwater volume to the ocean. Damming changes the water discharge which subsequently causes changing in chemical, physical and biological conditions of the river. The possible eco-logical effects in the sea might have important implications for this region where fertilizer use is rapidly increasing and major rivers are being dammed at alarming rates. However societal benefits of dams and reservoirs are obvious, and include the modulation of river flow between wet and dry periods, irrigation for agriculture and the production hydro-electric power. Therefore, it might not be the question if a dam is built, but how a new dam can be built to minimize undesirable side effects. In addition, the difference in the basin geological composition is also reflected in the dissolved constituents in the water. In this study, the physico-chemical conditions and the distributions of dissolved inorganic nutrients have been investigated both in the reservoir and along the downward stream.

STUDY AREA AND SAMPLING SITES

The Rajjaprabha Dam is a rock-filled reservoir with a capicty a capacity of approximately $5{,}640 \times 10^6$ m^3. It is the biggest multi-purposed dam in southern Thailand, located in Kao Sok National Park and Khlong Saeng Sanctuary, Suratthani Province. The dam was built across Khlong Saeng which flows to join Klong Sok and consequently flow into Phumduang River. The Phumduang River then joins Tapi River at Phunphin District (30 km west of Suratthani), and flows through Muang District and Municipality then empties into Ban Don Bay which is connected to the Gulf of Thailand. The Ban Don Bay, therefore, receives most of the freshwater runoff from two major river basins, namely Phumduang and Tapi, with an area of 6,125 and 5,460 km^2, respectively (Figure 1). The geological composition of thr basin is mainly pebbly mudstone which consists of pebbles of quartzite, granite, limestone and alternated shale and sandstone. It was first operated in 1987.

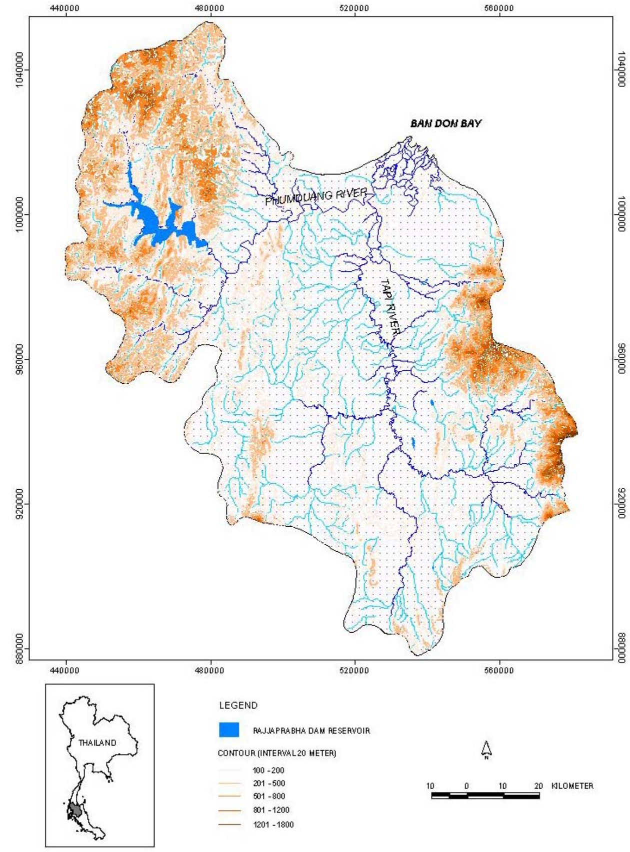

Figure 1: The Tapi-Phumduang River Basin, flows into the Ban Don Bay which is connected to the Gulf of Thailand, consists of two watersheds namely Tapi and Phumduang. The Rajjaprabha Dam was built at the upper reach of Phumduang River and regulated the flow of Phumduang River, while Tapi River has a natural flow.

The highest precipitation in the Phumduang watershed (Phanom and Ban Takhun Districts) occurs in August-September according to the Southwest Monsoon (May-September), while in the Tapi watershed occur in November due to the Northeast Monsoon (October-January) (Figure 2). The high flows, therefore, normally occur during August-December. The flow of the Phumduang River is highly regulated by the Rajjaprabha Dam which located on the upper reach, while the Tapi River has a natural flow. The annual volume of water released from the Rajjaprabha Dam reservoir to the lower basin is controlled for the purposes of salinity control, irrigation, navigation, industry and domestic consumption (Figure 3). However, the discharge of the Phumduang River still exhibits a periodic variation with a cycle of one year (Wattayakorn *et al*., 2001). Average annual stream flows of the Phumduang and Tapi Rivers are 265×10^6 and 300×10^6 m^3, respectively (Wattayakorn *et al*., 2001)

Forest resources on the uplands of the Tapi-Phumduang basin have been dramatically convert to rubber plantations. During last two decades (1980-2001), forest area in the basin decreased by a total of 4,572.19 km^2, a decline of about 53.6%, while rubber plantation area increased by 3,745.54 km^2, equivalent to 185.5% (ICSLB, 2002). This landuse practice led to deterioration of the basin's natural environment, notably through soil erosion, sedimentation.

The major sources of wastewater discharged into the Ban Don Bay are human settlements, industrial factories and fishery ports and aquaculture activities along the Tapi-Phumduang River (PCD, 1998). The water volume of sewage and industrial effluents is small relative to freshwater input and is assumed negligible.

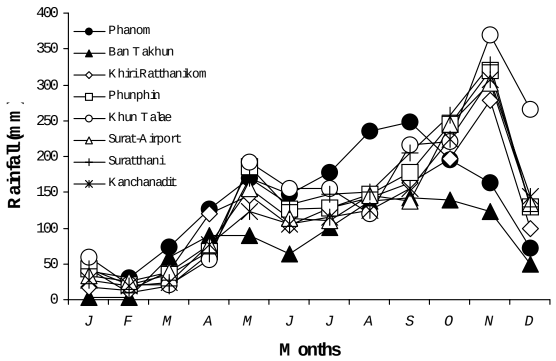

Figure 2: Mean monthly precipitation for Suratthani province in 1976-2000. (Source: Thai Meteorological Department)

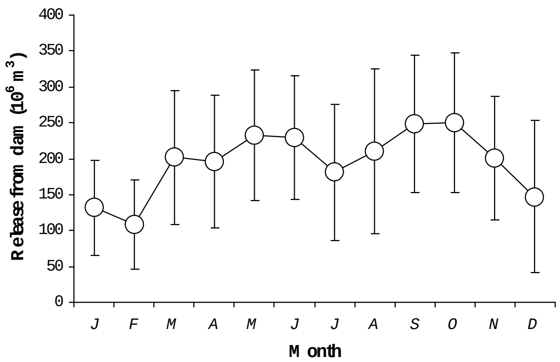

Figure 3: Average annual volume of water released from the Rajjaprabha Dam reservoir for 1987-2001. (Source: Electricity Generating Authority of Thailand)

SAMPLING AND ANALYTICAL METHODS

Five stations in the Rajjaprabha Dam reservoir (RJP-1 to RJP-5) and fifteen stations from downstream (RJP-6 to RJP-20) were selected to investigate changing of water quality (Figure 4). Vertical samples in the dam stations have been taken in order to investigate reservoir's stratification. Only surface water, at approximately 1-m depth, has been collected in the downstream stations. The water samples were collected in June (dry season) and December (wet season) 2002.

Temperature, pH, conductivity and salinity were measured during sampling using a multiparameter water quality monitoring system (HORIBA® model U-22). Water samples for dissolved oxygen determination were carefully tranferred from water sampler into BOD bottle, and were analysed by iodometric method (Winkler-Black Method) (Strickland and Parsons, 1972). Adequate of water was transferred into plastic bottles, and brought back for alkalinity determination after return to the Laboratory. Alkalinity was operationally analysed by using Gran-titration as decribed in Grasshoff *et al.*, (1999)

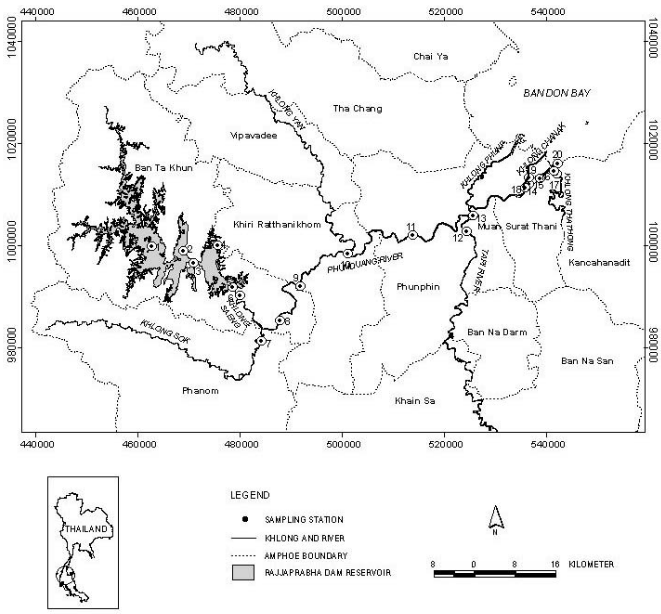

Figure 4: The locations of sampling stations in Rajjaprabha Dam reservoir (RJP-1 to RJP-5) and downstream (RJP-6 to RJP-20), Suratthani province.

Water samples for determination of dissolved inorganic nutrients (ammonia, nitrite, nitrate, phosphate and silicate) were immediately filtered through a Whatman® GF/C (47 mm diameter). The filtered samples were then determined immediately after filtration using colorimetric methods as described by Grasshoff *et al.* (1999).

RESULTS AND DISCUSSION

Vertical profile of water temperature in the Rajjaphabha Dam reservoir suggested that the water was stratified. A marked vertical thermal discontinuity, thermocline, was clearly seen at the depth of about 15 m. The water in the reservoir is stratified throughout the year due to the absorption of solar radiation of the surface layer. The finding agrees with previous study of EGAT. The stratification is confirmed with pH and dissolved oxygen vertical profiles (Figure 5). Surface water's pH in dry season (June) was higher than in wet season (December). Epilimnion oxygen concentration was near 100% saturation, while beneath thermocline is anoxic.

Vertical profiles of alkalinity and dissolved inorganic nutrients were presented in Figure 6. In general, the concentrations of nitrate, nitrite and reactive phosphate above thermocline in dry season were lower than in wet season. However, nitrate data of station RJP-5 (at the front of the dam) in wet season had similar pattern as in dry season. Below thermocline, nitrate was rapidly reduced to ammonia, nitrite. Increasing of nitrite, ammonia and reactive phosphate concentrations with depth associated to the degradation of dead cells and organic debris. DSi in surface water was slightly lower than in metalimnion, subsequently decreased with depth. The concentration of dissolved silica in in the surface layer in wet season was slightly lower than in dry season. Higher alkalinity has been found in the deeper water.

As can be seen in Figures 5 and 6, all variables were altered by processess occured during retention period (such as consumption, remineralization, transformation and elimination).

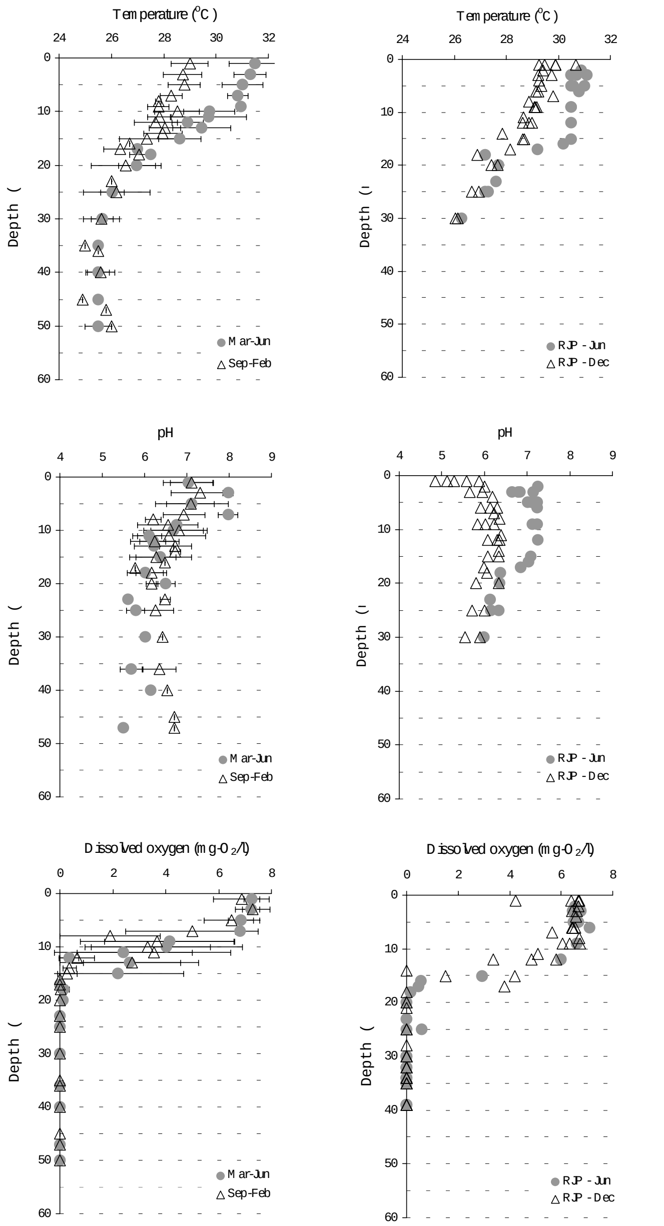

Figure 5: Vertical profiles of temperature, pH and dissolved oxygen in the water of the Rajjaphabha Dam reservior. Left – The profiles in years 1988, 1990 and 1991 (data source: EGAT). Right – The profiles in June and December 2002 (this study).

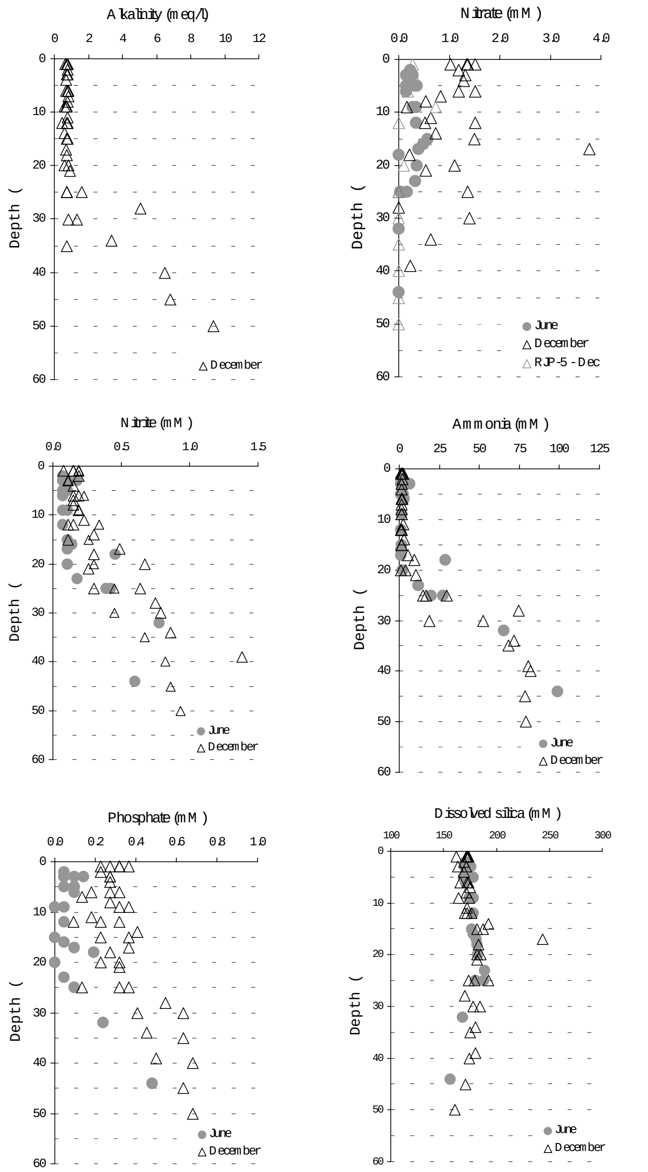

Figure 6: Vertical depth profiles of alkalinity, nitrate, nitrite, ammonia, phosphate and dissolved silica in the water of the Rajjaphabha Dam reservior during June and December 2002.

The downstream, the Tapi-Phumduang River, received water released from the dam reservoir at the depth of approximately 30 m below the surface. Therefore, the water was released from the anoxic layer of the reservoir. The quality of water released from the Rajjaprabha Dam reservoir in June and December 2002 was presented in Table 1.

Changes of water quality in downstream was shown in Figure 7. Cool water released from the reservoir was slowly warm up to about 30-31°C. The pH, slightly low, of water from the reservoir was increased to about 6 to 7 downstream. The anoxic water from the reservoir was immediately, after releasing, mixed with high dissolved oxygen water from Klong Sok, giving higher disoslved oxygen content. Generally, dissolved inorganic nutrient concentration were increased downstream. The concentration of ammonia decreased sharply, which associated to significant increasing of dissolved oxygen. This suggested that ammonia from the reservoir's withdrawal water were consequently oxidized to nitrite and then nitrate. Phosphate concentration at RJP-7 (Wat Ta-Kun) increased by 4-fold indicating large input in this area. This is not surprising due to an expanding of agricultural drainage, rubber plantation, during the last two decades (ICSLB, 2002). Intensive appication of fertilizer in the area was so expected. The exceed N and P (from fertilizer) were thus accumulated in the soil which consequently be leached out to the stream. At the same time, the human population increased along with extensions of urban water supplies and sewage collection systems. Elevation of dissolved inorganic nutrients when water flow pass through the municipality (RJP-13 to RJP-15), which resulted from anthropogenic input, were observed.

Table 1: The quality of water released from the Rajjaprabha Dam reservoir (at the depth of approximately 30 m below the surface) in June and December 2002.

Parameters	Jun 2002	Dec 2002
Temperature (^oC)	27.3	26.9
pH	6.15	5.71
Dissolved oxygen (mg-O_2/L)	0	0
NO_3 (μM)	0.16	ND
NO_2 (μM)	0.39	0.45
NH_4 (μM)	19.67	14.96
PO_4 (μM)	0.10	0.36
DSi (μM)	179.9	179.3

The concentration of DSi in the outflow of the dam reservoir was approximately 30 μM lower than in Klong Sok (Figure 6). Regarding to geological setting of the area, the dam reservoir is situated in the mainly pebbly mudstone which consists of pebbles of quartzite, granite, limestone and alternated shale and sandstone, while geological composition of the Klong Sok area comprises of more limestone (ICSLB, 2002). This difference reflected in the dissolved constituents in the waters.

Regarding to the fact that dissolved inorganic N (DIN) and dissolved inorganic P (DIP) downstream have increased as a consequence of fertilizers and detergents use in the watershed, the removal of DIN and DIP (by phytoplankton activity) within the dam reservoir during retention period can be compensated by anthropogenic inputs in the drainage basins. Although the removal of DSi found no compensation in some area such as Danube River (Humborg *et al*., 1997), this may not be the case of the Tapi-Phumduang River. The dissolution rate of Si in the tropics is proned to be high resulting from geological composition and a high rate of weathering. Moreover, high deforestation in upper watershed of this basin during the past two decades causes higher eroded sediment which has high surface area to be reacted.

Changing in Si:N:P ratios can potentially have profound impacts on the phytoplankton community both in terms of increasing algal abundance and by altering the relative abundance of species present (Jickells, 1998). Table 2 shows the stoichiometric ratios of dissolved inorganic nutrients (DIN:DIP, DSi:DIP and DSi:DIN) along the stream. The atomic ratios in RJP-6, which received water from the reservoir, showed no difference among season. In general, higher ratios of DIN:DIP and DSi:DIP were found in wet season. This indicates high N and Si input from the drainage basin in the wet season. Similar ratio of DSi:DIN found in both season. This suggested that anthropogenic N emission carried by the Tapi-Phumduang river was almost the same rate as washed out DSi from the drainage area. The decreasing of DIN:DIP and DSi:DIP values in lower riverine water implied an existing of removal processes in the area. Slightly increased in DSi:DIN ratio was found at about 60 km upstream from the river mouth resulting from the input of Khlong Yun (RJP-10, see Figure 4).

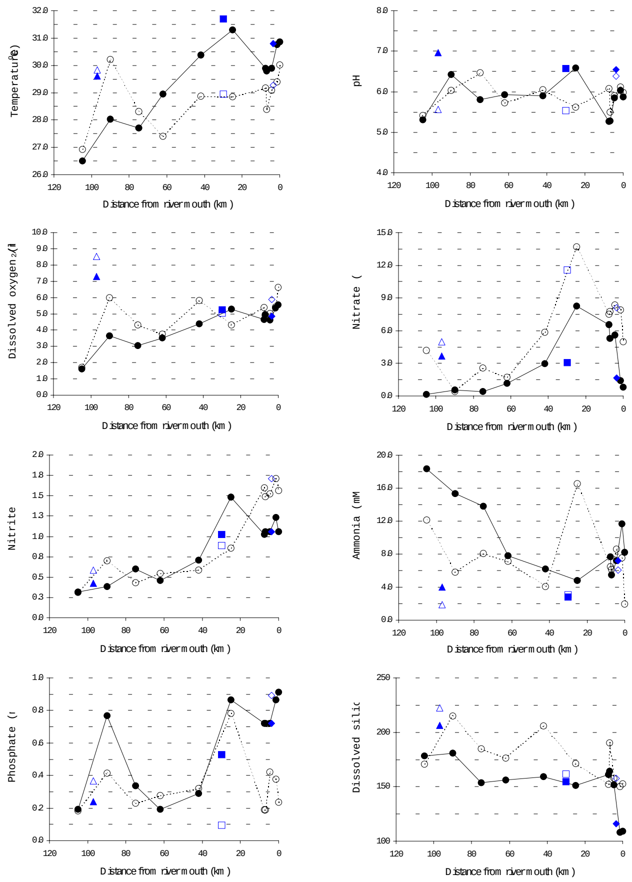

Figure 7: Changes of temperature, pH, dissolved oxygen, nitrate, nitrite, ammonia, phosphate and dissolved silica in the main waterway of Tapi-Phumduang River as a function of distance from the river mouth in June and December 2002. Solid symbol : water collected in June 2002; Open symbol : water collected in december 2002. Main stream (circle), Klong Sok (triangle), Tapi River (square) and Klong Ta-Tong (diamond).

The DIN to DIP ratios at the mouth of the Tapi-Phumduang estuarine water in dry season were generally lower than the biotic 16:1 (Redfield ratio) (Tables 2). This finding is similar to what have been found in the nearby area by Wattayakorn *et al.* (1993) (Wattayakorn *et al*., 2001), but not in the case of the wet season. The DSi:DIN ratio in river plume much higher than 1 (Redfield ratio, Si:N:P = 16:16:1) in both seasons indicated that the riverine export of DSi (salinity at the river mouth was 10 psu in dry season and 7 psu in wet season) was sufficient to serve marine diatom, which are abundant constituents of coastal phytoplankton, in the Bandon Bay.

Table 2: Stoichiometric ratios of dissolved inorganic nutrients along the stream in June and December 2002. (Distance from river only shown for the main stream; RJP-7 : Klong Sok; RJP-12 : Tapi river; RJP-16 : Klong Ta Tong 1; RJP-17 : Klong Ta Tong 2; RJP-19 : Klong Cha Nak 1; RJP-20 : Klong Cha Nak 2)

Station	km from river mouth	DIN:DIP		DSi:DIP		DSi:DIN	
		Jun	Dec	Jun	Dec	Jun	Dec
RJP-6	105	99	92	938	947	9	10
RJP-7	-	34	20	860	601	25	30
RJP-8	90	21	17	235	524	11	31
RJP-9	75	44	48	451	803	10	17
RJP-10	62	50	34	822	630	17	19
RJP-11	42	34	33	549	643	16	20
RJP-12	-	13	172	292	1797	22	10
RJP-13	25	17	40	174	219	10	6
RJP-14	7.5	21	82	224	802	11	10
RJP-15	4.5	19	44	211	376	11	9
RJP-16	-	16	45	124	395	8	9
RJP-17	-	14	18	161	177	12	10
RJP-18	-	16	81	228	1002	14	12
RJP-19	-	15	26	219	342	14	13
RJP-20	0	11	37	120	686	11	19

CONCLUSIONS

Although it was expected that hydrological regulation by damming would decrease in dissolved nutrient concentration exported to the coastal area, it was not appear to be the case of the Ban Don Bay. The supply of all dissolved inorganic nutrients are in excess of requirement. The quantitative and qualitative nutrient signature of the downstream outflow into the Ban Don Bay depended on upward processess of consumption, remineralization, transformation and elimination. The freshwater part (upstream) of the Tapi-Phumduang river in June and the whole river in December are P-limited system (N:P >16). In contrast, N is the limiting factor for phytoplankton production in the estuarine section in June (N:P <16).

In relative to N and P, Si is not a limiting factor. However, it can not yet be concluded due to the lacking of historical data particularly dissolved silica which consider not to be directly related to pollution. In addition, there are some limitation of this work including not yet covering marine system of the bay and no total N and toal P data. Also, water-sediment interaction, which alters DIP concentrations via adsorption/desorption reactions in this area, is ill-defined and has not yet been taken into account in this study. Since the trend of terrestrial inputs in addtion to the loss of intertidal habitats important for denitrification is likely to be increased in this area. Nutrients fluxes are likely to continue to rise and Si:N ratios will likely to fall. This might be possible to shifts in phytoplankton species composition which consequently affect on coastal biogeochemical cycles and food web structure observed. Further study is needed to clarify the biogeochemical processes in the system.

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Hydrological Analysis Of Klang And Ampang River Catchments

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ABSTRACT: This study presents the hydrological analysis of the lumped catchment, Klang River and Klang River and its tributary, Ampang River catchment. The hydrological analysis will be carried out to obtain the design flood hydrograph using rainfall runoff model. The resulting hydrographs are then input into hydraulic models to route the design flood hydrographs through river channels to evaluate the capacity and conveyance of those particular rivers (Klang River and Ampang River). The basic analysis method for this research involved the use of a rainfall runoff model in conjunction with the design rainfall calculated from a frequency analysis of the recorded data. The objective of this hydrologic study is to determine the discharges with the Average Recurrence Interval (ARI). The design rainfall data consist of the rainfall depth, temporal pattern and the areal reduction factor. The rainfall depth will be calculated by using a frequency analysis of recorded station with different rainfall over the upper and lower part of the catchment.

Keywords:

Flood hydrograph, design rainfall, ARI, frequency analysis, rainfall depth, temporal pattern and areal reduction factor

INTRODUCTION

The Klang River catchment and its tributary Ampang River which situated in the city of Kuala Lumpur have been subject to flooding at various times during its history. The largest flood in the recorded history of Kuala Lumpur occurred in January 1971 when heavy rainfall occurred over the whole of the catchment during the first five days of January. There are 62 chainages along Klang River and Ampang River for this research area with the total length of 5.25km from Jalan Ampang (upstream) to Jalan Tun Razak (downstream). The location Map of Klang River and its tributary, Ampang River is show in Figure 1.

Figure1: Location Map of Klang River and Ampang River.

Kuala Lumpur is warm and humid throughout the year, as characterised by the equatorial climate, and has an average annual rainfall varies from 2,000mm to 2,500mm with spatial variation shown in Figure 2.

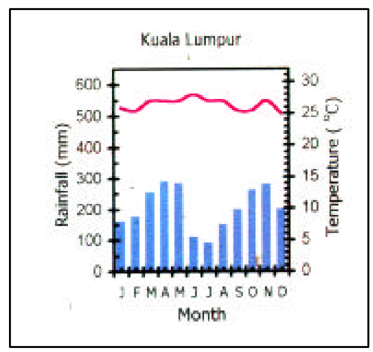


Figure 2: Temporal Distribution of Rainfall in Kuala Lumpur

The frequency and intensity of rainfall in Malaysia is much higher than in most countries, especially those with temperate climates. Drainage practices and methods which have been developed in other countries may not always be suitable for application in Malaysia. The design calculations for these methods have been adjusted in The Urban Stormwater management Manual for Malaysia to suit Malaysian conditions.

OBJECTIVE

The objective of the research is to obtain the design rainfall and design flood hydrograph using rainfall runoff model. These resulting hydrographs will be the important sources for most computational hydraulic modelling.

DESIGN RAINFALL

Rainfall is, obviously, the driving force behind all stormwater studies and designs. An understanding of rainfall processes and the significance of the rainfall design data is a necessary pre-requisite for preparing satisfactory drainage and stormwater management designs.

Rainfall data from Kuala Lumpur station and Ampang rainfall station had been selected for the design hyetograph generation. Table 1 and 2 show the design rainfall for Kuala Lumpur and Ampang

ARI (years)	Storm Duration (hours)								
	1/4	1/2	1	3	6	12	24	48	72
2	37	55	70	81	85	90	106	124	140
5	43	64	78	93	102	111	135	188	200
10	48	70	83	101	114	124	154	175	220
20	52	75	89	109	125	137	173	230	250
50	58	82	96	119	139	155	196	267	290
100	64	87	107	140	165	202	262	296	320

Table 1: Design Rainfalls for Kaula Lumpur

ARI (years)	Storm Duration (hours)								
	1/4	1/2	1	3	6	12	24	48	72
2	32	52	68	84	90	93	119	137	155
5	38	59	81	100	112	117	157	185	206
10	42	64	90	11	126	132	182	216	239
20	46	68	98	121	140	147	206	247	271
50	51	75	109	134	159	167	238	286	312
100	72	95	124	162	188	225	282	303	318

Table 2: Design Rainfalls for Ampang

Design rainfall hyetograph

The precipitation in Kuala Lumpur is generally dense but short; therefore, design rainstorm for 30 minutes duration and 3 hours duration will be significant as these two durations will occur frequently. Figures below show that the design rainfall hyetograph for 30 minutes and 3 hours.

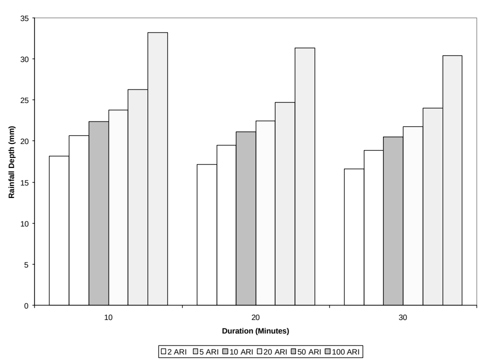


Figure 3: Design Rainfall Hyetograph for 30 Minutes Rainstorm at Ampang Catchment

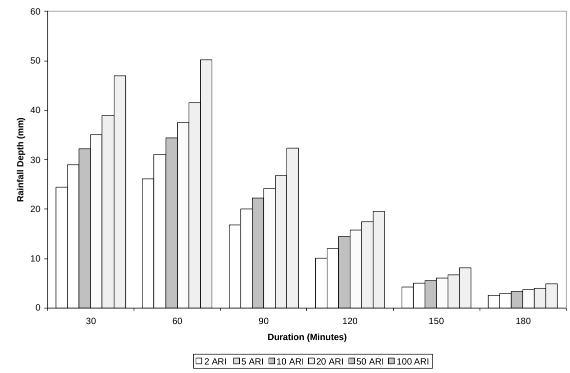


Figure 4: Design Rainfall Hyetograph for 3 hour Rainstorm at Ampang Catchment

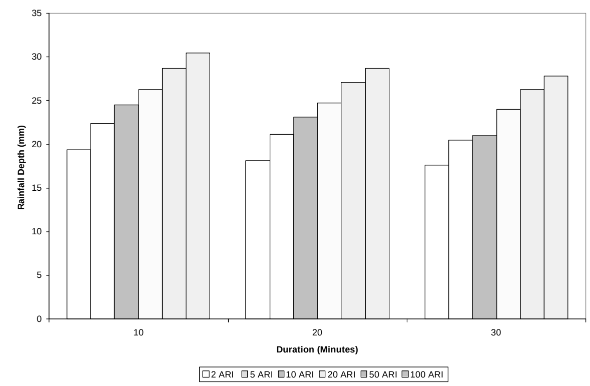


Figure 5: Design Rainfall Hyetograph for 30 Minutes Rainstorm at Kuala Lumpur Catchment

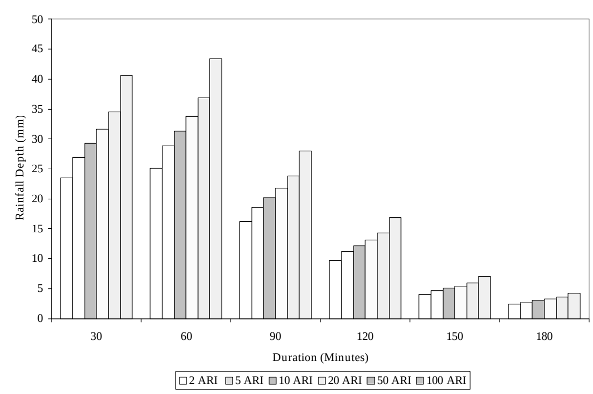


Figure 6: Design Rainfall Hyetograph for 3 hour Rainstorm at Kuala Lumpur Catchment

Rainfall Intensity-Duration-Frequency (IDF) relationship

Rainfall depths at Kuala Lumpur and Ampang catchment can be further proceed and converted into rainfall intensity where, Intensity = rainfall depth/ duration, which are then presented in IDF curves. These curves are particularly useful in stormwater drainage design because in most computational procedures require rainfall input in the form of average rainfall intensity. There are three variables, frequency, intensity and duration. These variables are related to each other and the data are presented as curves displaying two of the variables which are intensity and duration, for the range of frequencies. Figure 6 and 7 shows that the IDF curves for Kuala Lumpur and Ampang.

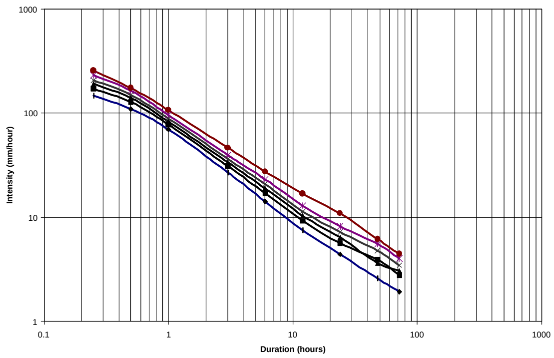


Figure 7: IDF Curve for Kuala Lumpur

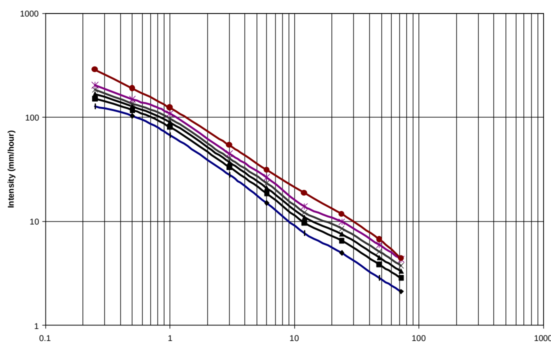


Figure 8: IDF Curve for Ampang

DATA SIMULATION

The simulation of the precipitation data for the lumped catchment (Klang River and Ampang River catchments) had been carried out to obtain the predicted runoff hydrograph and an outflow at C (the catchment outlet). The Klang River is located in the central part of the west coast of Peninsular Malaysia and one of its major tributary, Ampang River join in the city centre. The federal capital of Kuala Lumpur and its important neighbouring urban area (Ampang) are located in the centre of the catchment.

One of the general requirements is to divide the catchment into sub-catchment. The total area of the catchment is approximately 58.99 km^2. This catchment is divided into four sub-catchments with two upper sub-catchments (SUB 1 and SUB 2) and two lower sub-catchments (SUB 3 and SUB4). Four events at different sub-catchments had been selected for the watershed modelling. The area for every sub-catchment is shown in Table 3. The Klang and Ampang river catchment plan with sub-catchments is shown in Figure 9.

Sub-catchment Number	Area (km^2)
1	20.53
2	18.44
3	15.94
4	4.08
Total Area	58.99

Table 3: Area for every sub-catchment

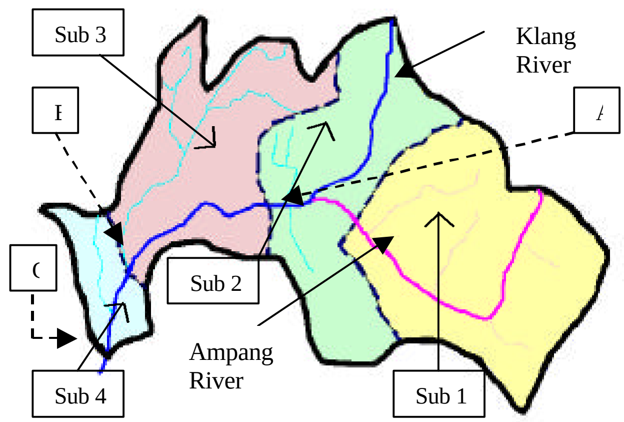
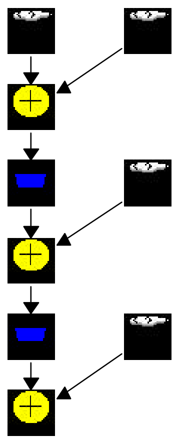


Figure 9: The Klang and Ampang river catchment plan

The HEC-1 program was run using the preceding data set. The information in Table 4 show that the master summary output by the program. Figure 10 show that the schematic of HEC-1 computational order.

Operation	Station	Peak Flow	Time of Peak	Average Flow for Maximum Period			Basin Area
				10-Day	30-Day	90-Day	
Hydrograph at	SUB1	15.15	240	4.30	1.90	1.19	20.53
Hydrograph at	SUB2	11.12	240	4.44	1.73	1.07	18.44
2 Combined at	A	26.27	240	8.74	3.63	2.25	38.97
Routed to	A to B	24.38	240	8.76	3.63	2.25	38.97
Hydrograph at	SUB3	17.78	240	3.56	1.54	0.94	15.94
2 Combined at B	B	42.16	240	12.32	5.17	3.19	54.91
Routed to	B to C	42.91	264	12.28	5.16	3.19	54.91
Hydrograph at	SUB4	4.55	240	0.91	0.39	0.24	4.08
2 Combined at	C	47.46	264	13.19	5.56	3.44	58.999

Table 4: The master summary output by HEC-1



ional order

The computed hydrograph at A at figure 11 show that the discharge from sub-catchment 1 (SUB1) and sub-catchment 2 (SUB2) and the discharge at A from SUB1 and SUB2. Figure 12 show the computed hydrograph between points A and B after routing.

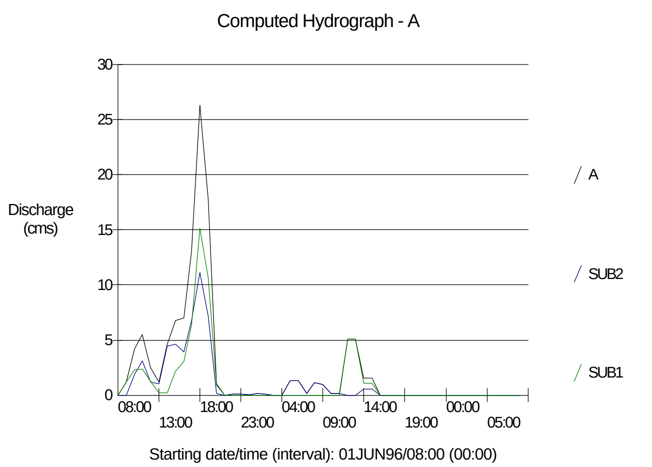


Figure 11: The computed hydrograph at A

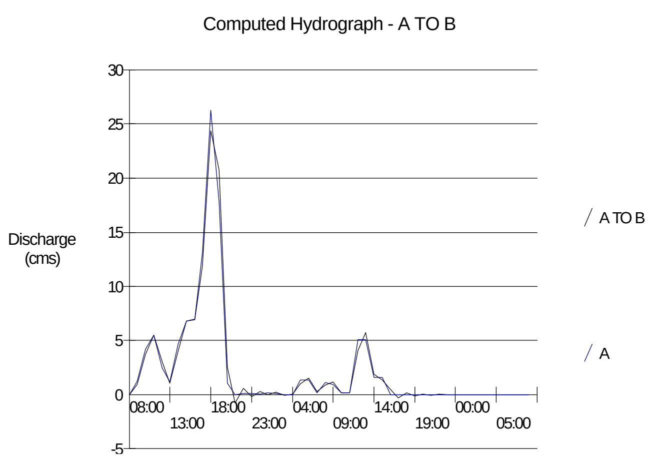


Figure 12: The computed hydrograph for A to B

The computed hydrograph at B at figure 13 show that the discharge from sub-catchment 3 (SUB3) and between points A and B after routing and the discharge at B from SUB3 and between points A and B. Figure 14 show the computed hydrograph between points B and C after routing.

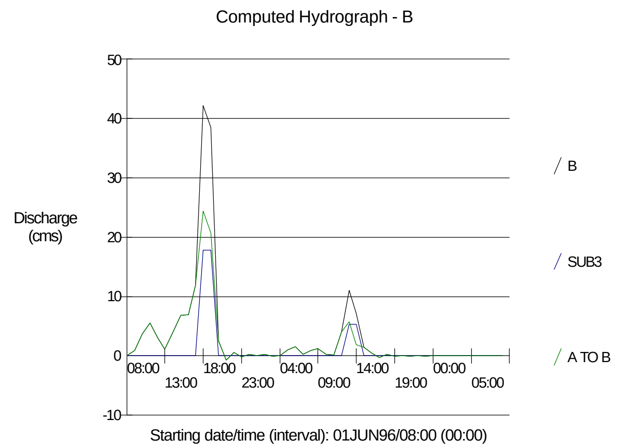


Figure 13: The computed hydrograph at B

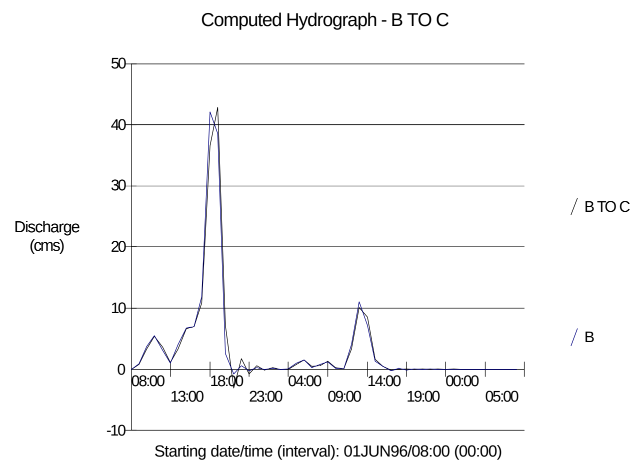


Figure 14: The computed hydrograph for B to C

The computed hydrograph at C at figure 15 show that the discharge from sub-catchment 4 (SUB4) and between points B and C after routing and the discharge at C from SUB4 and between points B and C.

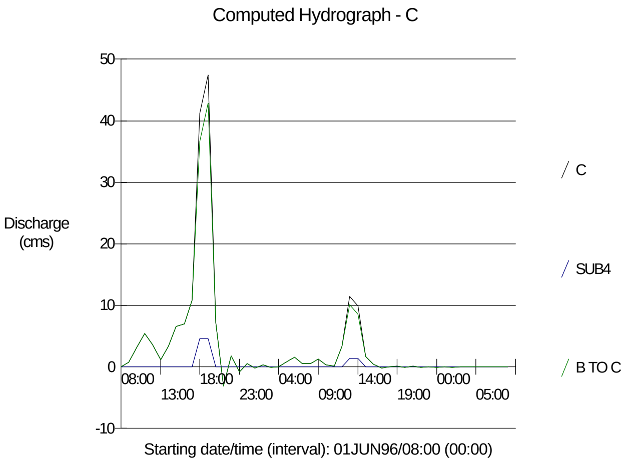


Figure 15: The computed hydrograph at C

DESIGN HYDROGRAPH

Hydrograph is a graphical or tabular representation of runoff rate against time. Hydrographs are also used for designs on non-homogeneous watersheds, such as where significant variation in land use, soil types, or topography exists within the watershed. Due to the rapid development around Kuala Lumpur area, this is especially necessary where parts of watersheds undergo land use change such as urbanization or deforestation. Figure 15-18 shown the design hydrographs for Kuala Lumpur and Ampang for 30 minutes and 3 hours base on 2, 5, 10, 20, 50 and 100 Average Recurrence Interval (ARI)

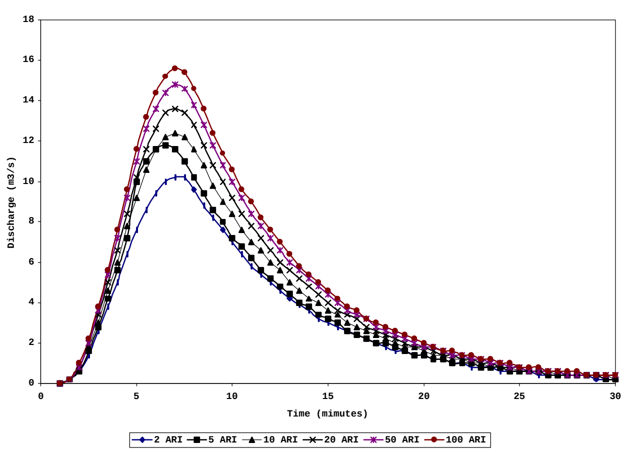


Figure 16: Design Hydrograph for Kuala Lumpur for 30 Minutes Design Rainfall

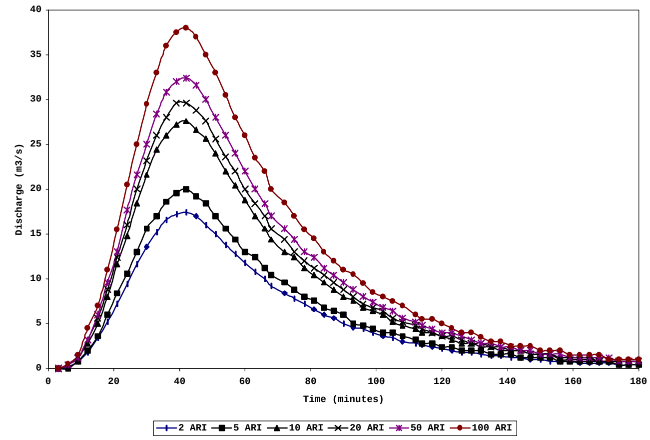


Figure 17: Design Hydrograph for Kuala Lumpur

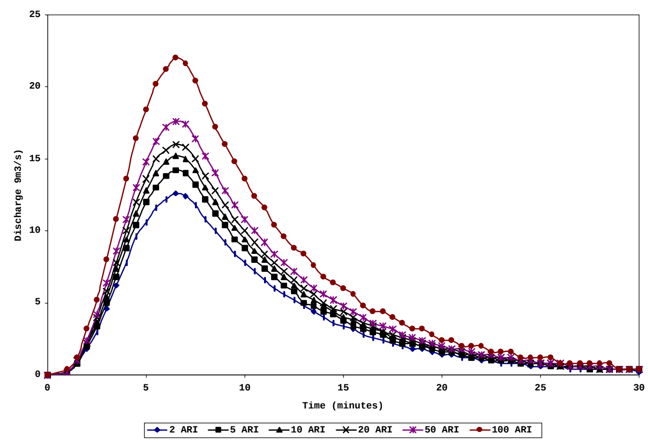


Figure 19: Design Hydrograph for Ampang for 30 Minutes Design Rainfall

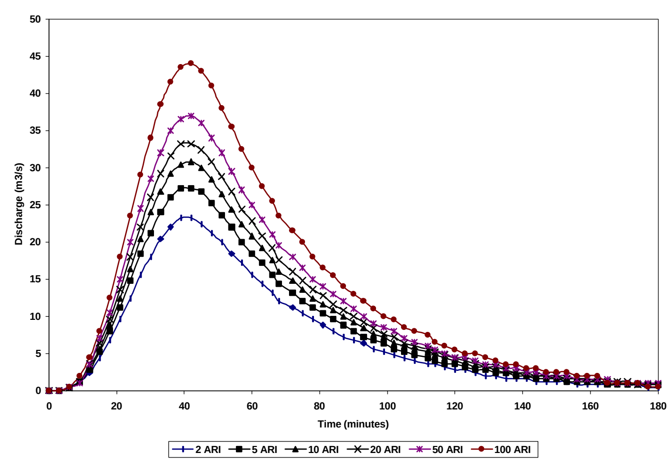


Figure 20: Design Hydrograph for Ampang for 3 Hours Design Rainfall

DATA AVAILABILITY

Useful hydrological data have been collected. These data required in the rainfall runoff model are rainfall data, water level data and flow data. These data are shown at Table 3.

Rainfall Data	Water Lever Data (Stage)	Flow Data
✓ Yearly ✓ Daily ✓ 12-hourly	✓ Yearly ✓ Daily ✓ 3-hourly ✓ 6-hourly ✓ 12-hourly	✓ Daily

Table 4: Several Hydrological Data Base on Yearly, Daily and Hourly

CONCLUSION

The hydrological analysis provides design hydrographs for the hydraulic studies which are requires to develop and test flood mitigation in the catchment. The design hydrographs cover average recurrence intervals of 2,5,10,20,50 and 100 years and are for location throughout the catchment on the Klang River and its' major tributary, Ampang River. From the hydrologic aspect, the hydrological analysis generated results and hydrographs are useful for review on the retention pond utilization and the effectiveness of the proposed flood mitigation measurements.

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The Semenyih Basin Classification: Method And Evaluation

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ABSTRACT: The Semenyih Basin consists of 36 sub-basins with areas ranging from 1.37 to 35.57 km,^{2} and contains seven different major land uses such as forests; agricultural land; settlements; and industry; rubber and oil palm plantations; ex-mining land and water bodies. In order to classify each sub basin, the relationship between the seven land use categories of the Semenyih Basin was evaluated based on five indicators, i.e. a) water quality and water quality index, b) hydrological aspects such as surface compaction and drainage density, c) grade of weathering, d) landform or slope gradient, and e) population density. The methodology for the basin classification result in four outcomes, namely (a) “Good”, indicating that the whole area is covered by forests or rubber plantation or characterized by water quality index Class I or IIA. (b) “Fair”, the land use in the area is mostly plantations such as rubber plantation or fruit trees or indicated by water quality index Class IIB. (c) “Slightly Disturbed”, characterized by settlements and other activities such as oil palm plantations, quarries or mine or indicated by water quality index Class III, and finally, (d) “Disturbed” sub basin, characterized by urban and industrial activities or indicated by water quality index Class III to V. The Semenyih Basin classification based on the detailed evaluation of the 36 sub-basins indicated that 11 forested sub-catchments can be classified as “good”; 10 agricultural and forested sub-catchments as “fair”; eight agriculture and settlement sub-catchments as “slightly disturb” and seven urban sub-catchments classified as “disturbed”.

INTRODUCTION

The Semenyih Basin, which has a total area of 266.60 km^2 consists of 36 sub-catchments with areas ranging from 1.37 to 35.57 km^2. It contains seven different land uses, five different lithologies and has a variety of landforms ranging from steep land to flatlands. The study area is located about 30 km south east of Kuala Lumpur (Figure 1).
A watershed refers to part of the land area that drains water to a particular stream, river and or lake. The watershed is considered as a dynamic system where history and time can be important as the drainage basin passes through the various stages of its evolution (Chorley *et al.* 1984).

The Semenyih Watershed was evaluated in terms of the relationships between land use changes, human activities and four physical parameters, i.e. water quality, geology (grade of weathering and slope gradient), hydrology (surface compaction) and human population within the watershed.

The total population in the study area was only 24,702 in 1980 (Khoo, 1980), increased to 34,312 in 1991 (Khoo, 1995) and dramatically increased to 66,554 in 2000 (Department of Statistic, Malaysia). Invasion of the Semenyih Basin by human activities started beginning with the exploration of tin mines as the first land use change category in this area, followed by shifting agricultural activity and clearing of forested land to make way for rubber plantations (Jamaluddin Md.Jahi, 1999). Fast development in the Semenyih Basin started in 1995 and since then the basin has steadily grown with development of new settlements. In the early 1990’s, the density of industries in the Semenyih Basin was considered low (0.03%) compared to other districts (1.7%) in the Klang Valley (Jamaluddin Md.Jahi, 1999b). Urbanization and industrialization has been identified as the main causes of pollution in the study area (Muhammad Barzani *et al.*1999, 2002 a). A basin protection strategy was also proposed by Muhammad Barzani *et al.*(2002 b).

METHODOLOGY

The methodology of the study is based on four steps viz.

1. Division of the Semenyih Basin into land use categories and sub-catchments.
2. Identification of land use activities in every sub-catchment.
3. Determination of the relationship between land use and five categories of physical parameters in the Semenyih Basin.
4. Verification of the Semenyih Basin classification system.

RESULT AND DISCUSSION

EVALUATION OF SUB-CATCHMENTS

The land use in the Semenyih Basin can be divided into seven categories, namely: a) Forest; 2) Agriculture; 3) Rubber; 4) Oil Palm; 5) Urban and Industry; 6) Ex-Mining and 7) Water bodies (Figure 2). A qualitative evaluation was carried out by comparing each category of land use with the five physical parameters for every sub-catchment of the Semenyih Basin (Table 1).

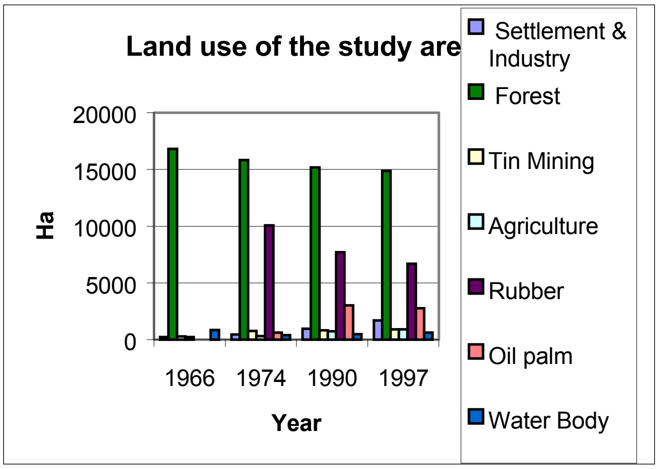

Figure 2: Land use pattern of the study area during 1966 to 1997.

1) The scale for the Water Quality Index (WQI) is divided into four categories: a) Class I and IIA (for water supply without treatment or conventional treatment), b) Class IIB (recreational use with body contact), c) Class III (livestock drinking) and d) Class III to V (irrigation only). WQI classification is based on INWQS for Malaysia (DOE, 2001), which is Class I (Clean) is ≥80; Class II and III (Slightly Polluted) range between 79 to 60 and Class III to V (Polluted) is ≤59.
2) Surface compaction is hydrological characteristics scale to relate the impact of land use. Classification of surface compaction is based on the distribution of vegetative cover and geological aspects. Surface compaction will be lesser in the forest areas or in the weathered rocks but high in the urban areas.

The influence of surface compaction on runoff coefficient also depends on the expanse of man-made pavement and surfaces and can be reflected from the drainage density. Four classifications of surface compaction are: a) Land area with 30% or less compaction, b) Land area with 30 to 50% of compaction, c) Land area with 50 to 70% of compaction, and d) Land area with 70% or more of compaction.

3) Description of rock mass weathering grade is basically based on the IAEG (1981) rating; fresh rock is Grade I, slightly weathered rock is Grade II, moderately weathered rock is Grade III, highly weathered material is Grade IV, completely weathered materials (Grade V) and residual soil (Grade VI). Weathered profile type B rock is most common in the forest areas and generally comprise of different grades, from I to VI (Ibrahim Komoo, 1989).

4).The slope gradient or landform is a morphological pattern of the area and is very much influenced by rock hardness. The landform of the Semenyih Basin is basically divided into four slope categories: a) Slope less than 10^0 or flatland, b) Slope between 10 to 20^0 ranging from flat to rolling land, c) Slope between 20 to 45^0 ranging from rolling to steep land, and d) Slope of more than 45^0 or steep land.

5) The estimation of population density is based on total population per square km area. Population density reflects the level of human activity in certain places; generally, the higher the activity, the greater is the pollution level in the receiving water bodies. Urban and industrial areas usually are characterized by high population density, while forest is the lowest

Table 1: Analysis of the basin based on five physical parameters and their associated scales.

A. Water Quality and Water Quality Index			
Class I	Class IIA	Class IIB	Class III-V
- Excellent water quality -Conservation for natural environment -Water supply without treatment	- Good water quality - Conventional treatment - Aquatic life protection	- Recreation use - Fisheries protection	- Livestock drinking - Irrigation - Advanced treatment
B. Surface Compaction			
30% or less	30%-50%	50%-70%	70% or more
- High soil moisture - Low runoff coefficient - Permeable surface - High infiltration	- High to moderate soil moisture - High to moderate infiltration	- Moderate to low soil moisture - Moderate to low infiltration	- Low soil moisture - High runoff coefficient - Impermeable surface - Low infiltration
C. Grade of Weathering			
Grade I-VI	Grade II-VI	Grade III-V	Grade III-IV
-Ranging from fresh rock (Grade I) to Residual soil (Grade VI)	- Ranging from Slightly weathered rock (Grade II) to Residual soil (Grade VI).	- Ranging from moderately to completely weathered material	- Ranging from moderately to highly weathered material
D. Slope Gradient			
$<10^0$	10^0-20^0	20^0-45^0	$>45^0$
- Flat land	- Flat to rolling land	- Rolling to steep land	- Steep land

E. Population Density			
≤ 12 persons/km^2	12 to 149 persons/km^2	150 to 400 persons/km^2	> 401 persons/km^2
Low population density	Low to moderate population density	Moderate to high population density	High population density

The results of the analysis between land use and the five physical parameters of the Semenyih Basin are summarized in Figure 3.

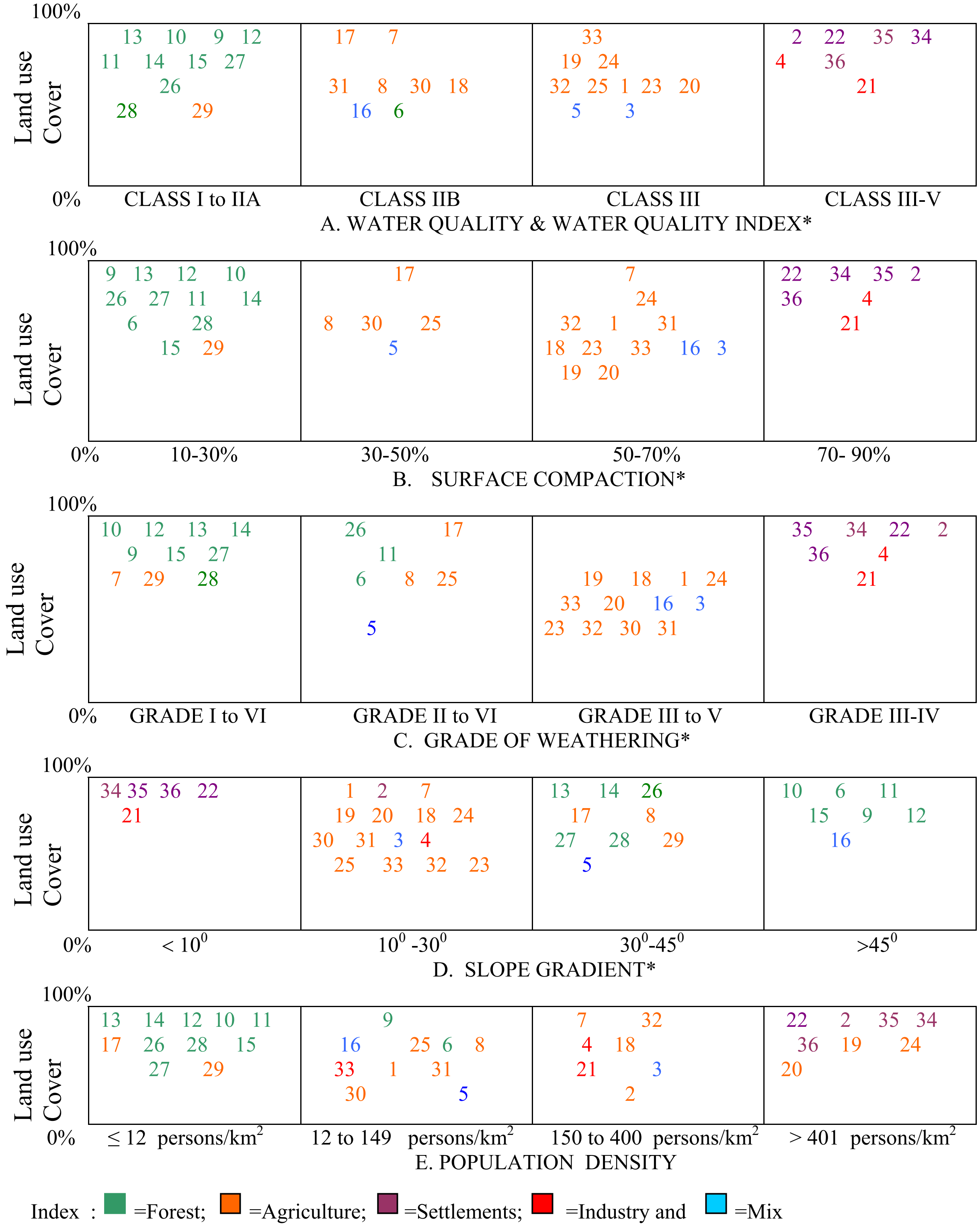

Figure 3: Position of sub catchments of the Semenyih Basin between land use activity and water quality and water quality index (A); land use and surface compaction (B); land use and grade of weathering (C); land use and slope gradient (D); land use and population density (E)

CLASSIFICATION OF THE SUB-CATCHMENTS

Only three physical parameters were selected to classify the 36 sub-catchments in the Semenyih Basin, namely 1) water quality index, 2) surface compaction, and 3) population density. Additionally, certain categories of land use were chosen to express human activity in order to support the classification (Table 2).

The four basin classifications are: (a) "Good", characterized by natural forest; water quality index Class I or IIA; ≤ 30% surface compaction; ≤ 12 persons/km^2 of population density; and ≤10^0 of slope gradient. (b) "Fair", characterized by plantation area; water quality index Class IIB; 30 to 50% surface compaction; 12 to 149 persons/km^2 population density; and 10^0-20^0 slope gradient, (c) "Slightly Disturbed", characterized by settlements, agriculture and mining activities; indicated by Class III; 50-70% surface compaction; 150 to 400 persons/km^2 population density; and 20^0 to 45^0 slope gradient, and (d) "Disturbed" sub-catchment, characterized by developed areas, especially urban and industrial areas; indicated by Class III to V; 70% or more surface compaction; ≥ 401 persons/km^2 population density; and >45^0 slope gradient.

Table 2: Four criteria of basin classification of the Semenyih Basin.

Criteria			
A. Good	B. Fair	C. Slightly disturb	D. Disturbed
Characterized by: - Class I and IIA of WQI ≤ 30% of surface compaction ≤ 12 persons/km^2 of population density - Protection area for water catchment	Characterized by: - Class IIB of WQI - 30-50% of surface compaction - 12 to 149 persons/km^2 of population density - Plantations area	Characterized by: - Class III of WQI - 50-70% of surface compaction - 150 to 400 persons/km^2 of population density - Agriculture and mining areas	Characterized by: - Class III-V of WQI - 70 or more of surface compaction - ≥ 401 persons/km^2 of population density - Most developed area

OUTPUT OF THE CLASSIFICATION

Evaluation of the 36 sub-catchments of the Semenyih Basin was carried out based on the relationships between three physical parameters, i.e. surface compaction, population density and water quality index of each sub-catchment and standardization of basin classification was provided from four criteria of basin classification in this contact such as good, fair, slightly disturbed and disturbed basins.

The result of the basin analysis show that eleven forested sub-catchments or 31% of the basin is classified as "Good"; ten agricultural and forested sub-catchments or 28% of the basin is classified as "Fair"; eight agricultural and settlements sub-catchments or 22% of the basin is classified as "Slightly Disturbed" and seven urban sub-catchments or 19% of the basin is classified as "Disturbed" basin. The distribution of each category of basin classification, which is drawn from the findings of this research, can be used as a benchmark reference for future studies of the Semenyih Basin.

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