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Abstract

Municipal solid waste is one of the major environmental problems faced by the Malaysian municipalities. Each year, there are about 8 million tonnes of solid waste being generated which accounts to each person generates about 1kg of solid waste per day. This solid waste volume is still increasing at the rate of 1.5% per year due to increase in urbanisation, change in living standards and consumption patterns. While the solid waste volume increases, there is getting lesser and lesser disposal site for the municipal solid waste. Majority of the landfills in Malaysia are crude dumping ground and thus cause various environmental problems such as health hazards, surface water and ground water contamination, odours, etc. Sanitary landfills offer a viable option for the Malaysian municipalities to deal with the environmental hazards caused by open dumps practice within its financial constraints. If sanitary landfills are conducted properly, the negative environmental impacts can be kept to a minimum level. There are other treatment and/or disposal methods such as incineration and composting which could moderate the solid waste problems but they are not economically and socially viable at this moment. Solely depending on the disposal method to solve the solid waste problem is not a permanent cure. Thus, waste reduction, recovery and recycling play important roles in tackling the pressing solid waste problems.

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Abbreviation

DUCED	Danish University Consortium for Environment and Development
GDP	Gross domestic product
IPCC	Intergovernmental Panel on Climate Change
MHLGM	Ministry of Housing and Local Government, Malaysia
MSW	Municipal solid waste
NIMBY	Not in my backyard
OECD	Organisation for Economic Cooperation and Development
RCEP	Royal Commission on Environmental Pollution
UNESC	United Nations Economic and Social Council
UNFCCC	United Nations Framework Convention on Climate Change
USEPA	United States Environmental Protection Agency
VOC	Volatile organic compound
WHO	World Health Organization

1 Introduction

Solid waste is the by-product of human activities, as long as there is production and consumption, residual material will be generated. These residual materials can be reused, recycled or reclaimed for energy and nutrients. Otherwise these elements will ultimately be released to the environment either to the sea, the land or the atmosphere. The environment has the capacity to dissolve these residual materials and transforms them into harmless materials or nutrients over a period of time. But when the waste amount outstrips the ability of the environment to assimilate, it will pose hazard to the environment as well as human. The current approaches to solid waste management by large are unsustainable.

In the publication, *Our Common Future* (1987) which is more well known as Brundtland Report defined sustainable development as "*to ensure that it (development) meets the needs of the present without compromising the ability of the future generations to meet their own needs*". The failure of the authorities in recognising the need to protect the human health, natural resources and the environment would result in discarding solid waste in uncontrolled disposal method or without prior resources recovery treatment. This would lead to loss of natural resources especially non-renewable resources and leave environmental problems for the future generation to deal with. Thus, an environmentally sound waste management should be implemented to reuse, recycle and reclaim the resources from depleting in order to ensure that we are not consuming what should be left for the future generations and also to minimise the contamination and effects of the solid waste to the environment.

1.1 Problem Definition

It has been observed that the solid waste generation in Malaysia has increased concurrent with the development of the country. For the past 20 years, Malaysia has undergone an economic growth with the rate of 5.2% (World Development Indicators database, 2001) (Agamuthu, 2001). While at the same time, solid waste has showed a stable growth with the economic development of the country with the rate of 1.5% per year (DUCED, 2001). The solid waste generated per capital has increased from 0.5kg/capital/day in the 1980´s to current volume of 1kg/capital/day. This represents a 200% increased in 20 years (Agamuthu, 2001). Such a great increase in the municipal solid waste is mainly due to the urbanisation process, increase in population, increase in per capital income and changes in consumption patterns. These factors have not only increased the solid waste volume but also changed the characteristics of the solid waste which have made it more complex for the municipalities to handle.

The current municipal solid waste management in Malaysia is far from sufficient and efficient in handling the increased amount of solid waste and its different composition due to lack of funds and expertise. Most of the municipalities are lack of adequate funds for waste treatment and disposal. About 40% to 70% of the service budget of the municipalities and district councils have been used for solid waste management (MHLGM, 2001). But this is barely enough to conduct a sound and efficient waste management system and almost all waste is ended up at the landfill without pre-treatment.

At present, majority of local authorities dump the solid waste in the unsanitary landfills. There are only about 10% of the landfills with leachate collection and gas venting facilities (Ghazali, et al, 1997). The improper management of the landfills have led to environmental and social problems:

- Groundwater and surface water contamination within and surrounding the landfill areas
- Bad odours from landfills without daily cover
- Air pollution from the open burning at the landfill areas
- Flooding
- Noise hazard from the collection vehicles
- Unaesthetic environment
- Scavenging activities at the dumpsites or landfills
- Health hazard to the waste management workers, scavengers and those who live close to the landfill areas

Thus, there is an emerging need for the local authorities to tackle these problems by looking for a more efficient and environmentally sound disposal method where sanitary landfill has been identified to be one of the options. With its proper design, maintenance and post closure monitoring, sanitary landfill offers a sustainable way in handling the ever-increasing municipal solid waste.

1.2 Objective

The idea of this thesis is based on the hypothesis that sanitary landfill is a safe long-term solid waste disposal method with minimal environmental degradation. According to research done by Ness (2000), landfill bioreactor cells are not only more environmentally sound where they return most resources back to the system but they are also more economically viable compared to incineration. Thus, the main objective of this thesis is to investigate if sanitary landfill is a viable method in treating solid waste in achieving the environmental, economic and social balance.

1.3 Scope

Solid waste management is a very wide topic where it involves the generation, storage, collection, transfer and transport, processing, treatment and disposing the solid waste with the best environmental and social consideration. Within the scope of waste management, it includes all administrative, financial, legal, planning and engineering functions. In this paper, the focus will be only on the municipal solid waste disposal method, namely sanitary landfills. The various environmental and socio-economic impacts will be discussed in order to understand the importance of the interaction between the design, operation and maintenance of the landfills with the environment. A case study of Malaysia landfills will be presented to investigate if sanitary landfills could be the aspirin to solve the municipal solid waste problems. In addition to that, an effort to look for a better alternative in handling municipal solid waste is discussed in this paper as well.

1.4 Limitation

This study is focused on the municipal solid waste as a whole which is mainly household waste, commercial waste and institutional waste. Since the main focus of this paper is on landfilling as the final disposal method for municipal solid waste, other treatment or disposal methods are not the main discussion of this paper. The Malaysia case study is limited by the lack of comprehensive and accurate data on solid waste in Malaysia. So far there were only two nationwide surveys on Malaysia solid waste and the data were rather old. The first survey was done in 1988 while the second survey was done in 1994. Thus, in order to better reflect the current solid waste situation, data from the some recent regional surveys and other resources are used in this context rather than the national survey data.

1.5 Methodology and Materials

This thesis work is basically a theoretical research which based on the previous researches in the field of solid waste disposal methods. Various literatures are reviewed and analysed in an integraded manner in order to draft out the background discussion for the Malaysia case study. All the data used in this thesis is secondary data from various surveys. These data have been compared, combined, rearranged and analysed for the discussion purpose. A causal-loop diagram has been used as a guideline to guide through the flow of the discussion of this paper.

2 Theoretical Background

Landfilling is the only waste disposal method that can deal with all kinds of materials in the solid waste stream and it is also the simplest and cheapest way of disposing solid waste. If the landfilling could be carried out in a proper manner coupled with well-managed solid waste collection and transportation system, this would form the very fundamental level for the solid waste management (Rylander, 1998). In many developing countries, landfilling could just mean open dumping where there is no proper controlled tipping to cover the waste and to treat the by-products from the landfill. Thus in order to avoid the potential hazards posed by open dumping, sanitary landfill has been taken as a method of disposing solid waste without creating nuisances or hazards to public health or threatening the environment. It utilises the principles of engineering to confine the solid waste to the smallest practical area and volume and cover it with a soil layer at the conclusion of each day's operation.

There are different opinions about the sustainability of landfill. Some scholars hold the opinion that if landfills are constructed and maintained in a proper manner and with resources recovery facilities available, landfilling is a sustainable method in handling municipal solid waste. While the others doubt the sustainability of the landfill. According to them even the best engineered landfills will somehow pose some environmental threats to the ecosystem. If these effects are not shown at this time period, they will be left for future generation to deal with. Landfill is actually a time bomb waiting for its right time to explore. The next section an explanatory model, causal loop diagram, will be used to explain the cause and effect relationship within the municipal solid waste disposal system.

2.1 Causal-loop Diagram

Causal-loop diagram (CLD) is an effective tool to assist us to understand, structure and conceptualise problems in a systematic way. It can be used to evaluate and to understand the cause and effect between different components within a defined system. And further to predict the overall behaviour of the system and the sequence of different causal links will behave (Haraldsson, 2000). There is no one-way relation between all these elements. All the problems are interrelated. The cause of one element could be an effect of another element. In order to have a clearer picture of the functioning system of the landfill and its impacts to the environment, economic and society, a CLD will be used for illustration.

The following diagram (Figure 1) illustrates the various cause-effect relationships between different components in the municipal solid waste disposal system. The arrow (→) shows the causation between one component to another while the " + " and " – " indicates the direction of change (Haraldsson, 2000).

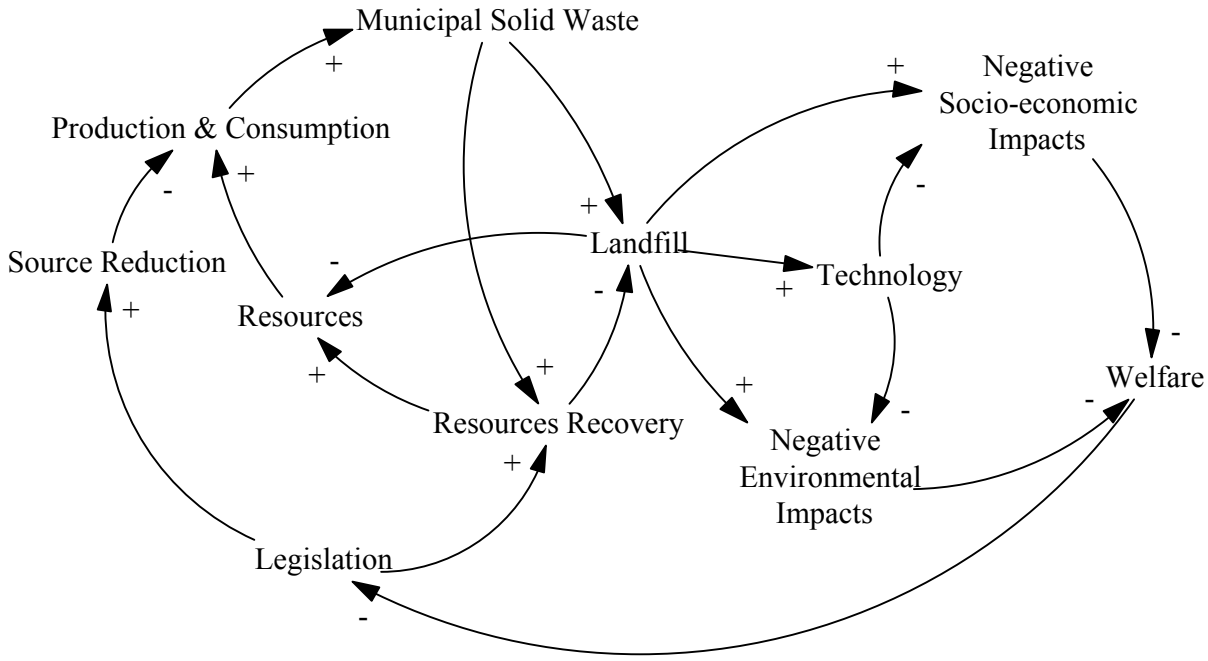


Figure1: Causal Loop Diagram

In the human society, whether it is a modern economic or subsistence economic, production and consumption are inevitable. And solid waste is the by-product of these activities. When the production and consumption increase, this will in crease the municipal solid waste. The magnitude of change in municipal solid waste will be influenced by different factors such as population, per capital income, industrialisation, urbanisation, living standards, seasons, etc. When the municipal solid waste accumulates, the local authorities must find a way to dispose it. The easiest, simplest and most probably the most thrifty way to dispose municipal solid waste is to dump it at crude dumping landfills. Dumping all municipal solid waste in landfill without any recovery will cause the natural resources deplete and will in a way have negative effects on

usage, productions and ultimately lower consumption which might in turn lower the living standard. On the other hand, haphazard dumping municipal solid waste at the landfill will lead to various negative environmental and socio-economic impacts such as ground water and surface water pollution, air pollution, health hazard and so on. These impacts will have severe chain reactions which will cause the degeneration of public welfare.

In realising that crude dumping is not the only solution of handling the increasing municipal solid waste problems, the local authorities or the landfill managers will bring in new landfill technologies in order to prevent or at least to minimise the negative impacts that crude dumping landfills will lead to. Lining system, leachate collection and treatment and gas venting facilities will be installed at the landfill. By doing so, the socio-economic and environmental impacts will be reduced and thus indirectly public welfare will increase as compared to the situation where crude dumping is practised.

Even with the new installed technologies, problems still exist. As long as the production and consumption activities are going on, the municipal solid waste will increase and the public welfare will still be threatened. They will, via various channels, complain to the authorities and this will lead to legislation to tackle the municipal solid waste problems. A legislation that brings to source reduction and resources recovery can reduce the municipal solid waste being sent to landfill in two different ways. Firstly, the source reduction policy will reduce the production and consumption which will reduce the municipal solid waste from being generated and of course the municipal solid waste that will be sent to landfill for disposal. The second solution is resources recovery where the municipal solid waste will first be sent for pre-treatment such as recycling, composting and incineration in order to recover as much resources as possible. These recovered resources will be added up to the resources availability to produce more goods. So the actual municipal solid waste that is sent to landfill for final disposal will be significantly reduced.

3 Disposal Method: Landfill

Among other disposal methods, landfill is the only significant method for final disposal of municipal solid waste. In spite of the low upfront capital and low expertise is needed when compared to other disposal or treatment methods, landfill can accept all sort of waste. Other treatment methods such as composting, incineration, pyrolysis and biogastification can significantly reduce the waste volume and can recover resources during the treatment process, but they will always have some residual left for final disposal at the landfill. In countries such as Japan and Switzerland where the incineration rate is high, 74% and 80% respectively (Agamuthu, 2001), landfill is still needed as the ultimate disposal method.

3.1 Landfill Siting, Design, Operation Maintenance and Post-Closure Maintenance

Sanitary landfill offers a simple, acceptable and economic solution for disposal of solid waste and reclaim of sub-marginal land. Despite of the technological advantages attested to it, sanitary landfill could cause environmental problems should it be mismanaged (Mato, 1999). Therefore, a

careful planning, maintenance and monitoring of sanitary landfill is essential to protect the environment and in determining its sustainability.

3.1.1 Landfill Siting

Land acquisition for landfill construction is always not an easy task because of the difficulty in locating the suitable site and in obtaining administrative clearance and public consensus. Public will generally oppose to the decision for the landfill situated near their neighbourhood, the NIMBY (Not In My Back Yard) syndrome. This is because they are driven by the fear of unknown and the distrust of the government in securing the safety of the landfill (Tammemagi: 1999). Thus it is important to find a site which is technically suitable and at the same time safeguarding the interest of the community especially in relation to the health issue and compensation that they should be received.

Basically, landfill site selection will go through three stages namely potential site selection, candidate site selection and final site selection. Different criteria have to be taken into consideration during the each stage of selection which is shown in the following table (Table 1):

Table 1: Criteria for different stages of site selection

1st Stage: Selection of Potential Site	2nd Stage: Selection of Candidate Site	3rd Stage: Final Site Selection
- Haul distance - Location restriction - Available land area - Possibility of acquisition - Public consensus - Site access	- Soil condition and topography - Climatologic conditions - Hydraulic conditions - Environmental conditions - Ultimate use for the completed landfill	- Environmental acceptability - Financial feasibility

Sources: Sakurai, 1990; Tammemagi, 1999

During the first stage of site selection, it is mainly to identify all potential areas that can be constructed into landfill. While the second stage is to investigate if the selected sites are suitable to set up landfill facilities and to determine what kind of landfilling method and design would be best suited for the selected site. It is because the geology and hydraulic conditions to great extend will influence the landfilling method and landfill management strategies. For example, if the natural attenuation is present at the selected area, then the site should be designed to allow leachate to attenuate slowly by natural process. If the condition is not present, then artificial liners should be installed to prevent water sources contamination. The third stage would be the final selection of the suitable site for landfill where the candidate site with the highest environmental acceptability and financial feasibility will be selected.

3.1.2 Landfill Design

After a site has been selected, a proper designed landfill should incorporate the following features according to sound engineering principles and environmental codes of practice in order to prevent and to minimise any negative environmental impacts during the waste degradation process:

i) Base liner system that will contain leachate within landfill and prevent the leachate percolate through the landfill cell and contaminate the ground water
ii) Leachate collection system that will remove the leachate
iii) Leachate treatment system that will remove organic matter from the leachate
iv) Daily soil covering to avoid flies and vectors breeding
v) Final cover or top liner that will reduce infiltration and promote runoff
vi) Diversion of surface runoffs around site to prevent water from filtering into the landfill
vii) Gas venting to prevent and/or reduce landfill gases migration
viii) Buffers at the boundary of the site
ix) Internal drainage
x) Proper access roads

Liner design, in particular, should follow a set of rigour measures in order to prevent any possible leachate leakage and nearby surface water and groundwater contamination. Leachate collection and gas venting facilities are no less important in minimising the landfill environmental impacts.

3.1.2.1Lining and Capping

In order to prevent leachate from polluting the surface water and ground water, there are two alternative landfill management strategies that can be adopted for leachate control:

i) A site that is engineered to contain waste and leachate. The liner system consists of a composite base liner system of a soil and geo-membrane component overlaid by a geo-synthetic leachate collection layer.
ii) A site that allow leachate attenuated slowly by natural process. The liner system consists of a soil base and granular leachate collection system

The composite base liner consists of an upper geomembrane liner and a lower compacted soil. In United States the minimum requirement for the geomembrane is at least 30mm thick, and if a high density of polytheylene (HDPE) geomembrane is used, the minimum thickness required is 60mm. The compacted soil liner must be at least 60cm in thickness and with a hydraulic conductivity of less than 1×10^{-7} cm per second (USEPA, 1994). But as concerned by Allen (2001), the lifespan of the landfill liner is yet to be sure and there is a high probability that the leachate could form and leach through the artificial liner as the liner deteriorates along time and the interaction with the chemical components in the landfill cell. He suggested that the landfill should be situated at land with natural hydrogeological characteristics which can contain and naturally attenuate contaminants to acceptable level instead of trying to contain the contaminants within the landfill by relying on artificial liners.

A final cover or cap is important in landfill design too. It should be designed in a way that can reduce infiltration and promote runoff and evaporation. In order to do so, a low permeable or impermeable liner will be laid on top of the waste. Runoff control is essential because it can carry leachate near the surface of the landfill to nearby surface water sources, such as streams or rivers and cause contamination.

3.1.3 Operation Maintenance

A safe design of landfill is barely enough to ensure the safety of the public and the environment protection, it requires a well-managed operation which should include the following:

i) Waste Identification and Restriction
Landfill operators should identify different type of waste that is entering the landfill. This is to prevent hazardous waste from being delivered and co-disposed with other municipal solid waste at the landfill. They should be authorised to reject any waste until it is identified to be safe and acceptable at the landfill site.
ii) Daily Cover
The working face should be kept as small as possible and it should be covered by the end of each day operation or in a more frequent interim. Daily cover is used to control disease vectors from breeding, scavenging activities by rodents, seagulls, crows, odours and windblown littering.
iii) Run-on and runoff control
Run-on control is to prevent water from outside the landfill from entering the landfill cell because the additional water will increase the leachate production. While the runoff control is to prevent the escape of contaminants from the landfill area.
iii) Safety
The operation should be implemented in a way that will not threaten the workers' health and safety. They should be well informed with the risks and associated symptoms due to exposure to various types of waste especially hazardous waste that might be sent to municipal solid waste landfill for co-disposal. A protective equipment should be provided to the site workers and public access should be restricted in order to minimise the risks.
iv) Landfill Gas Monitoring and Management
When waste is undergoing decomposition, gases such as carbon dioxide, methane, hydrogen sulphide, etc will be produced during the process. These gases can pose potential hazards such as explosion, asphyxiation, offsite gas migration as so on. A routine gas monitoring is essential to control the gases movement, especially the methane gas. The methane gas is odourless and highly combustible thus a proper gas venting and treatment facility should be installed to avoid potential hazard. If the energy recovery technique is available, methane gas should be processed to produce bio-fuel.
v) Leachate Management
If the leachate that produced during the degradation process is not collected and treated, it will contaminate the nearby water resources. Other than to equip with the leachate collection and treatment facilities, ground water monitoring should be done from time to time to ensure that the leachate does not percolate through the liners. The nutrients that contain in the leachate can be recovered by irrigating the weak leachate to the woodland or grassland.

vi) Special Waste
Some waste such as batteries, sewage sludge, incineration ash and hospital waste normally discard together with other municipal solid waste. These wastes should be handled with different procedures and disposed separately from the municipal solid waste.

Source: USEPA, 1994; Boswell, 1998

3.1.4 Post-closure Maintenance

Finally when the landfills are full, they must be covered with a low permeable cap in order to prevent the rainwater from filtering through and mix with the waste which would lead to more leachate production. A continuous monitoring of the groundwater quality and the methane gas buildup at the closed landfill site is required in order to prevent the environmental problems associated with those. In the United States, the minimum post-closure maintenance and monitoring period is 30 years. But as concern has been shown by Allen (2001), the waste in the landfill might take longer time period to reach its stabilisation state[1] than the mandatory aftercare period and the durability of the liner is yet to be sure. Thus, there is a possibility of pollutants leaching through the liner and contaminate the environment. This is especially critical for the "dry tomb"[2] type of landfill where the waste degradation has been slowed down and its impacts has been prolonged to a longer time period which could take a century to reach its stabilisation.

3.2 Landfill Vs Environmental Impacts

Disposal of waste in the landfill can cause serious environmental problems if the landfills are not properly designed and constructed. During the waste degradation process, the temperature within the landfill will increase. And with the high percentage of methane, this will cause fire hazard. Other environmental threats that posed by dumpsites and landfills including stench, water pollution, air pollution and potential health hazards.

3.2.1 Water Resources

When waste is deposited in the landfill cell, the water content inside the waste and water from rainfall and surface water drainage will lead to leachate production. The amount of leachate produced is depended on the amount of water that percolates through the landfill cell and mix with the waste. The more water content in the waste, the more leachate will be produced. This leachate will leach through the landfill either vertically or laterally. The lateral movement will happen when an impermeable immediate cover is used for daily cover and this may cause surface

[1] Stabilisation state of waste will only be achieved when all the degradable materials in the landfill are decomposed and the inorganic components will not be released in the form of leachate and give rise to the environmental pollution or harm human health (Robinson, 1997) (Röhrs, 1998)

[2] Dry tomb landfill is a landfill that constructed with impermeable liner and cap system to restrict the water from filtering into the landfill which in turn will minimise the leachate production. Theoretically, dry tomb landfill does not pose threats to environment because the leachate production is little and the impermeable liner will prevent the leachate from percolate out the nearby water resources.

water contamination. The vertical movement will bring leachate passed through rock and reach the aquifer. The leachate which picks up soluble heavy materials such as heavy metals and acids in the waste will eventually contaminate the ground water. If this ground water is extracted as drinking water supply, it can be hazardous to human (Wilson, 1981).

In order to protect groundwater from potential contamination, an impermeable liner have to be laid inside the landfill cell and its surface must contain drains to allow rainfall to run off. This containment strategy to keep the pollutant and inert waste within the landfill has been favour by the EU waste management and legislation where artificial liner system will be used (Allen, 2001). It is believed that the lining system can wholly contain the leachate produced during the waste degradation process and thus prevent water sources pollution. But according to Dr. Montague, the landfill liners cannot hold the leachate and the toxic materials within the landfill site forever and it will leak eventually. The durability of the artificial liner system is still unknown and waste degradation might take decades or even centuries to achieve its inert state so it leaves the landfill to a high probability for leachate leakage problems (Allen, 2001). According to a laboratory experiment, researchers found that volatile organic chemicals such as toluene and xylene, can eat through synthetic liners and leave the landfill unable to hold the leachate within it (Breen, 1990). In other words, for long-term there is no guarantee of the durability in the lining system. The leachate and toxic materials might percolate and leach through the liners to get underground and cause ground water pollution. The modern sanitary landfill only postpones the impacts to the future generations.

3.2.2 Atmospheric Impacts

At the landfill site, there are large amount of landfill gases will be emitted to the atmosphere during the waste degradation process. These landfill gases mainly consist of carbon dioxide and methane. With its high emission of methane, at about 50 % to 60%, landfill has been regarded as one of the major sources of methane emission. According to a research, the release of 1kg of methane will cause an equivalent contribution of 35kg of CO_2 to global warming over a 20-year time span. (IPCC, 1992) If the landfill lacks of comprehensive and effective gas venting or collection system, the methane will escape into the air and make a significant contribution to global warming. This green house effect will bring consequences of changes and disturb the balance of the ecosystem such as the raise of global sea levels and extreme weather condition like heavy flooding and severe droughts. Therefore a proper gas venting and collection system is essential in controlling the release of methane gas into the atmosphere.

Even though on one hand, landfill will have negative effect on global warming, on the other hand, landfill has the capacity to accumulate organic carbon and thus can balance the increased of CO_2 (Bramryd 1979). During the landfilling process, organic carbon will be accumulated in the fermentation rest especially those fossil fuel derived products such as plastic and other synthetic materials, and organic carbon that may be contained in household waste. The annual accumulation of organic carbon in the world's landfills has been estimated to around 100 x 10^{12}gC per year (Bramryd 1982, 1983). As Bramryd (1997) indicated in his study, if the emission of the methane can be effectively controlled and utilised, landfill is actually acting as a sink for organic carbon and thus gives a positive effect to the global warming.

According to some other researches, landfill will not only act as a sink for CO_2, it is a sink for methane as well. A field study in Illinois, United States, found that the landfill surface was consuming atmospheric methane gas rather than emitting the landfill methane. This is because the well-aerated soils coupled with the effective gas recovery system has reduced the landfill methane gas (Bogner, et al, 1995). With proper gas collection and treatment system, landfill can balance the increasing concentration of CO_2 and methane that emitted by other sources.

Other than methane and CO_2, gases emitted from the landfill consist of some trace levels of carcinogenic-organic chemical such as vinly chloride, toluence and benzene. These carcinogenic gases will bring negative effect to the human health if they are above the safe standards.

3.2.3 Public Health

Uncontrolled dumping at the dumpsite poses a significant hazard not only to the site workers but also those who live close to the disposal facilities and those who derive their income from these sources. Most of the time, local authorities always receive public complaints about bad smell and odours coming from the open dumpsites and landfills without daily soil cover. But the impact is more than just merely stingy smell, it threatens public health. One of the components found in the volatile organic compound (VOC), benzene, is a recognised carcinogen and exposure to $1\mu g/m^3$ produces a lifetime risk of 4×10^{-6} for leukaemia (WHO, 1987) This has been further confirmed by a preliminary research carried out by the New York State Health Department, there is a correlation between the risk of having cancer and the toxic gases escaping from the landfill. They found that women who live near the landfills have four times higher risks of developing leukaemia and bladder cancer than women who do not (Long Island Business News, 1998). According to the research done by James and Stack (1997), the VOC in the ambient air increased followed by the introduction of the leachate collection facilities. Thus, it is crucial for landfill not only to have leachate collection facilities but also facilities to treat leachate in order to reduce the VOC compound in ambient air to a safe level so that it will not threaten site workers and the residents' health.

Poorly managed dumpsites and landfills are also the breeding bed for vector-borne diseases such as dengue fever whose prevalence can be traced to poor waste disposal (UNESC, 2001). Some cities have experienced epidemics that have resulted in significant lives and economics loses. In a study of municipal waste management in India, it was found that 23% of the studied household experienced at least one episode of gastrointestinal illness in a one month period and another 18% at least one episode of typhoid or cholera or jaundice during the one year period due to reuse of untreated waste in agriculture (Sundaravadivel, et al, 2000). With the proper maintenance of the sanitary landfill especially daily covers, vector breeding and habitation can be prevented and epidemic such as dengue fever and plague could be avoided.

3.3 Landfill Vs Socio-economic Impacts

Landfill will not only lead the environmental destruction but also create other socio-economic problems if it is not conducted in a proper and well-managed manner. The immediate perception about landfill is the unaesthetic view where waste is dispersed by wind and animals. Closely

related to this is the odour that lingers out from the landfill site. Residents who stay at the down wind will always suffer from the odour and to the worst case their health might be affected by the pollutants. Other than that, dumpsites which are without daily cover will also attract scavengers to look for income at the site, this will not only create nuisance to the landfill staff but to the neighbourhood as well. The impacts of the landfill will indirectly lower the property value of the nearby areas. Despite of the negative impacts, with proper design and operation maintenance, landfill can reclaim sub-marginal land which otherwise would be unsuitable for any kind of landuse purposes. Sanitary landfill can be developed into a recreation area for the residents.

3.3.1 Scavenging Activities

The recycling in the developing countries is largely depended on scavengers in recovering materials. This is done by scavengers at the dumpsites looking for recyclables for exchange of money. These scavengers constitute the poor and vulnerable segments of the population who face multiple problems and are perceived as a nuisance not only to the landfill operation but also to the society (Medina, 1998). Sometimes scavengers could hinder the effective flow of landfilling operation and to some extend could pose danger to environment by setting fire at the landfill or dumpsite (Nasir, et al, 1997). Compared to others, scavengers are most exposed to health hazard posed by the landfill. They are normally not equipped with any safety boot, glove or mask when they are scavenging at the landfill site. These scavengers, mostly young and low income people are vulnerable to waste related diseases such as AIDS infection due to contacting with the infected medical instruments that disposed at the dumpsite (Mato, 1999).

Though scavenging could cause some nuisances to the landfill staff and the neighbourhood, an attempt to abolish scavenging of waste would lead to mechanical separation and the cost of the recyclables would be not favourable for recycling (Nasir et al, 1997). And as for landfill without sorting facilities, the total elimination of scavenging could lead to the loss of the materials which could otherwise be recovered.

3.3.2 Property Value

Landfill siting will bring adverse affect on land values. There is a norm that public will put a lower value for property near the landfill. This is because landfill is considered as one of the environmental disamenities which will reduce the public welfare such as by causing health hazards and unaesthetic view. Thus, the existence of landfills will greatly influence purchasers' buying decision and their bargaining power. According to a research in Ohio, United States, the property values tend to have negative correlation with landfills, assuming other environmental disamenities remain unchanged (Hite, et al, 2001). The external costs of the landfill that reflect on the lower property value might lead to unequal distribution of environmental quality where the disadvantaged socio-economic group will migrate to the areas near landfill site because of the lower housing price (Hite, et al, 2001). The property value impact of landfill will not only lower the housing price but also cause unequal distribution of environmental goods among different socio-economic group.

3.3.3 Sub Marginal Land Reclamation

Sub-marginal land carries low economic value and is in low priority in landuse planning. A reclaim of sub-marginal land could be done by proper landfill design and end use planning. The filling of exhausted quarries and clay pits could help to restore these lands for future use. Prior to that, the landfill should be constructed to proper standards including the liners, cap, leachate and gas collection and treatment system, this is to ensure that the landfill is suitable for further landuse purpose after its closure.

A closed landfill can be reconstructed into a recreation park or golf course. As one of the successful landfill reclamation examples given by Rasmussen (1999), the Lyon Township Community Park is successfully converted from a landfill (with its buffer areas and support facility sites) into 270 acres of recreation park under the landfill/recreation projects in Michigan. The recreation park features tennis courts, picnic areas, trails and playground. For countries where land is scarce such as Hong Kong and Singapore, landfilling could be used as a strategy for not only to deal with the waste disposal problem but also to reclaim the coastal areas. Other cities such as Malmö and Copenhagen are also using landfilling to extend its coastal lines (Bramryd, 2001). The upfront requirement for land reclamation is that the landfill must be engineered in a way that comply with the sound environmental principles.

4 Other Disposal Methods

4.1 Composting

Composting is an aerobic degradation of organic fraction of the waste to yield a stable humus-like product which can be used as a soil conditioner (Wilson, 1981). Using composting as a treatment of solid waste can significantly reduce the solid waste volume especially in countries where organic waste and yard waste is predominant. But if the waste is comprised of high percentages of non-compostable waste such as rubber, glass, metals and plastic, a separation needs to be done before composting (Agamuthu, 2001). Preparation waste prior for composting is an important step because the organic and inorganic fractions in the waste need to be separated in order to avoid contamination of compost with potential toxic metals. Generally, composting is an environmental friendly, hygienic and usually contains substances of very low toxicity. (Agamuthu, 2001). According to Agamuthu (2001), compost is a nutrient rich substance which can improve the soil texture and important for plant growth and development. But Wilson (1981) holds the opposite opinion that compost is a low grade fertiliser which only has value as a soil conditioner.

4.2 Incineration

In countries where the land is scarce and the solid waste generation rate is increasing with an accelerating rate, incineration offers a solution to deal with the solid waste problems. Incineration can reduce the volume of waste by about 90% and the remaining residual ash will go to landfill. This will extend the life span of the landfill to a longer term. But on the other hand, the

incinerated ash contains high level of heavy metals which have higher possibility of leaching rate (Bramryd, 2001). If the waste to energy technology is available, incineration could provide energy recovery and the revenues generated would offset its high operation cost. In some industrialised countries, a high proportion of municipal solid waste has gone to incineration for energy recovery (Table 2).

Table 2: The current state of MSW incineration

Country	% of MSW incinerated	Energy Recovery (%)	Energy Recovery: Type
Austria	8.5%	100%	-
Belgium	54%	30%	HW/ST/E
Czech Republic	4%	77%	-
Denmark	65%	100%	Mostly district heating
Finland	2%	100%	-
Germany	34%	88% of the plants has energy recovery capacity	E/ST/HW
Japan	74%	Most plants	District heating/E
Luxembourg	69%	100%	E
Norway	20%	89%	-
Sweden	56%	100%	Mostly district heating
Switzerland	80%	72%	-
UK	8%	37%	HW/E
USA	16%	76% of the plants has energy recovery capacity	-

HW= hot water, ST=steam generation, E= electricity generation (given in order of level of use)
Source: European Energy from Waste Coalition (1993); Warmer Campaign (1990); RCEP (1993); MOPT (1992); OECD (1993).

But not all waste is suitable for incineration in order for energy recovery. Waste with low calorific value might need fuel supplement for combustion. The difference in characteristic of waste composition in developed countries and industrialised countries offers incineration a solution which could be economical to use but quite the contrary to developing countries. In developing countries, a high moisture and organic content with a small percentage of combustible materials in waste contribute to lower calorific values. Incineration of wastes with low calorific values would generally not be self-sustaining, and hence, energy recovery will not be economical. Moreover, due to problems of emission of toxic air pollutants from incineration plants in industrialised countries, this technology is not suitable to be implemented in countries that face technical constraints in controlling the potential air pollution (Sundaravadivel, et al, 2000).

5 Case Study of Malaysia

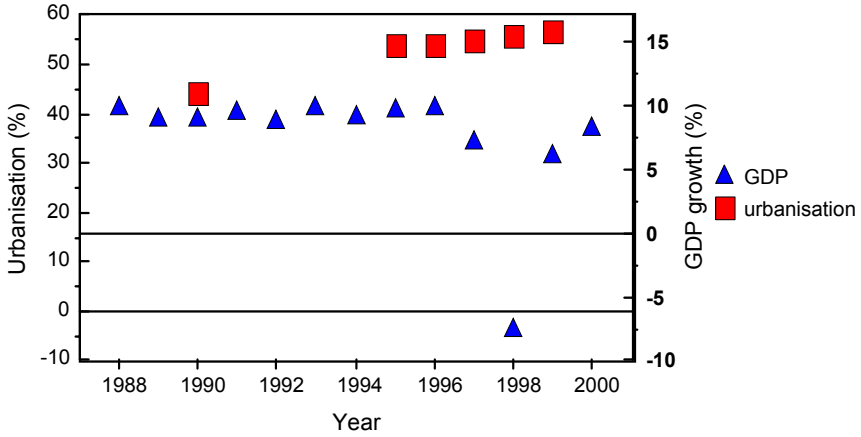
5.1 Background

One of the major consequences of rapid economic growth, urbanisation, industrialisation and population growth is the massive generation of solid wastes. As a country that moving forward to achieve the industrialised country status by the year 2020, Malaysia cannot escape from facing the solid waste management problems. As indicated in World Bank report (1993), solid waste is one of the major environmental problems faced by most municipalities in Malaysia. The municipalities are not only facing the increasing municipal solid waste and its rising complexity, they are also lacking of funding to carry out the sound solid waste management. The lack of a uniform national solid waste policy coupled with insufficient legislation has further complicated the solid waste problems in Malaysia.

5.1.1 Waste Generation and Composition

The amount of solid waste has been increasing continuously since the 1980's. The per capital waste generation has increased 2 folds from 0.5kg/capital/day in the early 1980's to current volume of 1kg/capital/day (Agamuthu, 2001) The huge increased in solid waste generation attributes to the rapid economic growth, increasing urbanisation, rising living standard, changes in consumption pattern and increasing population. The following Figure 2 and Figure 3 show the amount of solid waste generated has been moving at the same direction with the GDP growth, urbanisation and the increase in population.

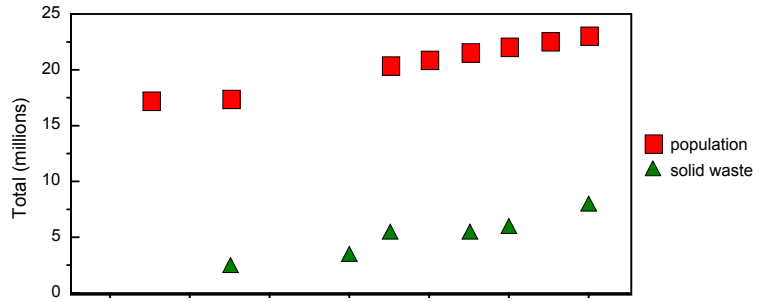
Figure 2: GDP growth rate* and urbanisation rate in Malaysia



Note: * GDP growth rate is based on the 1987 constant price

Source:
a) Department of Statistics, Malaysia, 2001
b) World Development Indicators database, 2001

Figure 3: Total population and total solid wastes generated in Malaysia



Source:
a) Department of Statistics, Malaysia, 2001
b) World Development Indicators database, 2001
c) Agamuthu, 2001
d) Gregory, 1996

For the past two decades, Malaysia has gone through a rapid economic growth and urbanisation process (Figure 2). The steady economic growth has led to an increase in per capital income and the living standard. This has changed the consumption patterns where more packaging and disposable products are consumed. This increased in production and consumption and the change in consumption patterns also attributes to the urbanisation process where more and more rural people move to urban areas where a huge portion of the generated waste is from the urban areas. According to a survey done by Nasir, et al (1998) on 30 local authorities in Malaysia, it is found that the per capital generation rate varies from 0.45 to 1.44kg/capital/day which the lowest waste generation rate was from a rural area while the highest waste generation rate was from an urban area. This clearly shows that the urban population generates more waste than the rural population as they have different living standard and consumption patterns. The solid waste production has thus inevitably increased due to the urbanisation and economic growth (Figure 3). Population which grows at a rate of 2.6% per year also increases the solid waste generation (Department of Statistics, Malaysia, 2001). Solid waste has increased from 2.5 million tonnes per year in 1991 to estimated 8 million tonnes per year in 2000 (Agamuthu, 2001).

Just as the per capital solid waste generation rate varies between different areas, the solid waste composition varies in different parts of the country as well. Generally, the solid wastes in Malaysia are mainly organic in nature and have low calorific value and high moisture (Figure 4). Basically, rural areas have higher organic waste compared to urban areas. The composition of the solid waste of different areas is shown in the Table 3.

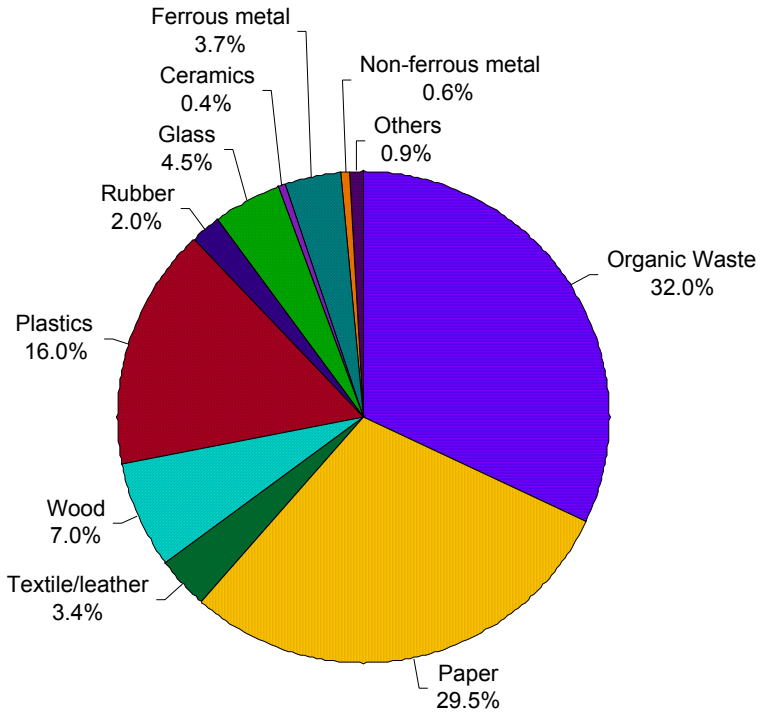


Figure 4: Malaysia solid waste characteristic (% by weight)
Source: Ridhuan, 1995

In comparison to developed countries such as United States. where organic waste is only one tenth of the total solid waste, Malaysia has relatively high percentage of compostable organic waste (Warmer Bulletin, 2000). It is important to recognise the differences of the waste composition between the countries because it would influence the most suitable treatment or disposal methods for the country.

Table 3: Waste composition of selected cities/towns in Malaysia

Area	Composition (% weight)				
	Organic	Paper	Plastics	Metal	Others
City (Kuala Lumpur)	48.4	30.0	9.8	4.6	7.2
Moderate Urban (Seremban)	35.0	10.0	2.5	5.0	25.0
Rural (Muar)	63.7	11.7	7.0	6.4	11.2

Source: THT/UPM Survey, 1994

5.1.2 Legislation and Institution

Even though solid waste is one of the three major environmental problems that faced by the Malaysian government, it is still lack of legislation and policies in tackling the problem. Currently, there are three legislations relevant to municipal solid waste management, namely, Local Government Act (1976), Street, Building and Drainage Act (1974) and the Town and Country Planning Act (1976). There is another legislation, the Environmental Quality Act (1974), has provision for scheduled and hazardous waste, but it does not address the issue of municipal solid waste. It only indirectly touches on odour contributed by discharge of waste (Agamuthu, 2001). Since legislation is the backbone for policy formation and enforcement (Naane, 1998), the absence of basic legislation on municipal solid waste has restricted the formulation of national policy on solid waste management and thus has handicapped government's effort in implementing the sound solid waste management. Currently, a solid waste Act is being drafted for submission to the Parliament but the scope and the content of the proposed Act are still unknown. (Agamuthu, 2001).

The other problem in relation to solid waste management is that there is no single agency responsible for solid waste management. According to the legal provision, it is managed fractionally by different agencies, i.e. Local Government Department and Department of Environment. This has resulted in inefficiency and unsound environmental practise. Thus a clear legislation and a sole responsible government agency are essential in government's effort to establish a sound solid waste management strategy.

5.2 Current Disposal Method

Landfill is the sole disposal method in Malaysia. Other methods such as incineration and composting are at a negligible scale. It is estimated that 95% of the municipal solid waste have gone for landfilling and only 5% are recycled (The Star, 6 January 2001). Even though there is a huge amount of municipal solid waste that goes to landfill, the landfilling practise in Malaysia is far from environmentally sounded. Among 230 landfills in Malaysia, only 10% are equipped with leachate treatment and gas venting facility while 51% are just open dumpsites (Ghazali, et al, 1997) (Agamuthu, 2001). According to Ministry of Housing and Local Government Malaysia (1999), out of 177 landfills in Peninsular Malaysia, only 6% are sanitary landfills and 50% are crude dumping sites (Table 4).

Table 4: Types of landfills in Peninsular Malaysia

States	Open dumps	Controlled Landfill	Sanitary Landfill	Total
Perlis	0	1	0	1
Kedah	7	5	1	13
Pulau Pinang	0	2	1	3
Perak	7	17	2	26
Selangor	7	9	2	18
Negeri Sembilan	7	6	0	13
Melaka	2	2	1	5
Johor	15	15	0	30
Pahang	22	8	2	32

Terengganu	9	8	1	18
Kelantan	14	3	0	17
Kuala Lumpur	0	0	1	1
Total	90	76	11	177

Source: MHLGM, 1999

As we can see from the above data, most of the landfills are not adequately protected against environmental impacts. Most of them are just crude dumping landfills or controlled tipping landfills. Thus it is hoped that with proper implementation of sanitary landfill, the environmental impacts can be minimised.

5.3 Feasibility of Sanitary Landfill in Malaysia

In view of the current municipal solid waste problems that are faced by the Malaysian local authorities, there is an urgent need for them to come out with a sound disposal method to deal with the increasing solid waste problems both in volume and complexity. The current disposal method which in large is crude dumping is not environmentally sound and it gives rise to environmental problems and public health problem. On top to this, the local authorities are facing constrains in shortage of landfill for final disposal. It is estimated that 78% of the landfills in Peninsular Malaysia will be full for closure in near future (MHLGM, 1999). Thus, there is an emerging need for the local authorities to look for an alternative way in tackling the solid waste problems which includes sanitary landfill, composting, incineration, etc. In order to find out if sanitary landfill is a feasible cure for current solid waste problems in Malaysia, there are three elements should be taken into consideration namely environmental, economic and social elements.

5.3.1 Environmental Considerations

It is important to conduct landfilling in an environmental sound manner in order to protect the environment, public health and natural resources. Currently, the municipal solid waste disposal method in Malaysia, which is landfilling, is poorly conducted and managed. Municipal solid waste is disposed improperly and resulting in health threats, damage to the environment and loss of natural resources. It is hoped that sanitary landfills that are equipped with the leachate collection and gas venting facilities, ground water monitoring, closure and post-closure care will reduce the chances of environmental degradation. The following section will discuss how the sanitary landfill could improve the environmental situation in Malaysia if it is constructed and maintained in a proper manner.

5.3.1.1 Leachate Management

Leachate is a liquid consisting of moisture generated from landfill during the waste degradation process. When leachate is produced and moving inside the landfill, it picks up soluble heavy metals and acids from the waste. Leachate has high content of iron, chlorides, organic nitrogen, phosphate and sulphate (Preez and Pieterse, 1998). When this highly contaminated leachate leaves landfill and reaches water resources, it will cause surface water and ground water pollution.

The municipal solid waste composition in Malaysia is mainly organic in nature and has high moisture content at about 75% (Agamuthu, 2001). These waste characteristics have caused more leachate being produced than inorganic waste with low moisture content. The heavy rainfall precipitation[3] in the country has further increased leachate production. Due to lack of impermeable capping system and run-on control, the heavy rainfall will filter through the landfill and reach the waste. Thus, it is essential that the sanitary landfill is constructed with proper liner system and installed with leachate collection system in order to prevent or at least to minimise the negative environmental impacts that caused by the current landfilling practice.

Majority of the landfills in Malaysia are without leachate collection facilities. A regional survey on 30 local authorities, only 4 out of 69 landfills being surveyed have leachate collection (Nasir, et al, 1998). The lack of leachate collection facilities coupled with most landfills do not have impermeable liner system, leachate will easily leache out and contaminate the nearby water resources. One of the examples is the pollution of the Michu River with the leachate from Ampang landfill. Ampang landfill is an open dump that does not have a proper leachate collection system and without base liner to contain the leachate within the landfill. This has caused the leachate leaches out from the landfill and ends up with polluting the Michu River (Agamuthu, 2001).

As has discussed in section 3, the artificial liner system has no long-term guarantee to contain the leachate within the landfill forever. So when adopting the sanitary landfill concept to the country's current disposal practice, instead of relying 100% on the artificial liners, it is important to utilise the natural geo-hydrological condition when selecting the landfill site so that the leachate can attenuate slowly according to the natural process. If the above condition is not present, leachate can be recirculated to irrigate the waste within the landfill to accelerate the waste decomposition process.

5.3.1.2 Landfill Gas Management

When waste decomposes over time, gaseous products will be generated. During the first stage of degradation which is aerobic degradation, oxygen will be consumed and carbon dioxide will be formed. When the degradation process slowly moves from aerobic condition to anaerobic condition, the CO_2 level continues to be high, gradually falling as the methane concentration builds up (Wilson, 1981). Other than methane and CO_2, there are also some trace level of gases being generated during the degradation process including hydrogen, nitrogen, etc (Table 5). These gases especially methane and hydrogen are highly flammable and if they are not collected and flared off, they will lead to potential fire and explosion hazard. According to THT/UPM survey (Nasir, et al, 1998), 33% of landfills in centre region in Peninsular Malaysia have been reported fire outbreaks due to lack of gas venting and flaring facilities.

[3] The annual precipitation in Malaysia ranges from 2000mm to 2500mm (GeoVision Productions, 2000)

Table 5: Typical composition of landfill gas

Component	% by volume
Methane	63.8*
Carbon dioxide	33.6
Oxygen	0.16
Nitrogen	2.4
Hydrogen	0.05
Carbon monoxida	0.001
Ethane	0.005
Ethene	0.018
Acetaldehyde	0.005
Propane	0.002
Butanes	0.003
Helium	0.00005
Higher alkanes	<0.05
Unsaturated hydrocarbons	0.009
Halogenated compounds	0.00002
Organosulfur	0.00001
Alcohols	0.00001
Others	0.00005

Source: Department of Environment, 1989

* The figure for methane reported in this data set is considered high. A typical methane gas concentration would be about 50%-60% (Agamuthu, 2001) (Wilson, 1981)

Open dumping without any sort of gas venting facilities will not only cause fire hazard to the locals but, to the macro sense, it contributes to air pollution and global warming. This is because both the CO_2 and methane have significant share to the contribution of global warming. As a country that has signed the Kyoto Protocol ratification (UNFCCC, 2001), Malaysia has its obligation in phrasing out the gases that would contribute to the global warning. As indicated in the Article 1 (a) (viii): *Limitation and/or reduction of methane emissions through recovery and use in waste management, as well as in the production, transport and distribution of energy* (UNFCCC, 1997), an upgrade of current crude dumping landfill practice to sanitary landfill with gas venting is essential in the country's effort in complying with Kyoto Protocol provision.

5.3.1.3Public Health

Bad odours, scavenging rats and crows, flies, smoke, fires are what have been closely related to open dumpsites. This scenery is not only an eye sore but indeed it threatens pubic health. The nearer the dumpsites are to the residential areas, the higher possibility the residents being exposed to the potential health hazard. According to THT/UPM regional survey in Malaysia (Nasir, et al, 1998), about 35% of the dumpsites or landfills are situated less than 500 meters from the residential areas. 25% of the residents who live less than 500 meters from the landfills suffer from the stench. The bad smell is mainly because there is no gas venting facility to trap the landfill gases. So when these gases namely sulphur escapes to the atmosphere, it will create smell problem.

Secondly, there is also a potential cancer risk for the residents in the neighbourhood. The exposure to the benzene found in the leachate and ambient air at the landfill site could produce higher lifetime risk for leukaemia (WHO, 1987). Even though the VOC level for landfills in Malaysia does not reach a dangerous level, it is important to take precaution steps to ensure that the VOC will not pose any cancer risk to the site workers and nearby residents. The benzene level found at the Kelana Jaya landfill, which does not have leachate treatment facility, is less than 1μg/m^3 which is still lower than the practical limit[4] of 5μg/m^3.

About 51% of the landfills in Malaysia are still open dumpsites. Discarded tyres, plastic containers, tin cans, etc and stagnant water pond at the dumpsites without daily covers would create a favourable condition for the vectors to breed such as Aedes mosquitoes. These mosquitoes will transmit dengue viruses to human through biting. According to Sakuri (1990), dengue fever has been considered as one of the most important health problems that caused by poorly managed solid waste system in the developing countries. For the past three decades, Malaysia has been one of the endemic countries for dengue (WHO, 1997). Thus, the waste must be covered at least every alternate day to avoid water, rain water to be contained in the discarded container at the landfills and consequently prevent Aedes mosquitoes from breeding. It is crucial for the local authorities to take preventive strategy to avoid any epidemic that might be caused by the poor conducted landfill.

5.3.1.4 Natural Resources

In Malaysia there is a very low recycle rate of 5%. The natural resources such as scrap iron, aluminium, copper, paperboard, paper, etc which could otherwise be reused and recycled are long buried with other waste inside the landfill. This is because there is low offsite recycling at the household level and low onsite recycling. There is no sorting facility at the dumpsites to recover the recyclables from other wastes. The recycling activities at the site is mainly carried out by scavengers but their effort in recovering materials is quite limited due to lack of favourable market price for the recyclables. Only recyclables with good market price will be picked up by scavengers. Other materials which are less favourable in price will be ignored by them. Thus, a sorting facility to recover materials at the landfill sites is pre-requisite for sanitary landfill. Other than recovering raw materials, resources can also be recovered from degraded waste such as nutrient recovery from the leachate and energy recovery from methane provided that the resources recovery technology is available.

If sanitary landfill is conducted efficiently, it could recovery non-renewable resources but on the other hand, sanitary landfill would consume a larger land area. Since the landfill site together with the buffer zone requires a large land area, some forest areas would have to be cleared up for the purpose. This will lead to the lost of tropical rainforest which is rich with biodiversity and lost of the function of the rainforest as the carbon sink and water catchment areas. And if the closure of the landfill were not properly conducted, the possibility of reusing the land would be very low because of the instability of the land structure (Gregory, 1996). For example, the Ayer Hitam forest reserve has been degazetted and converted into sanitary landfill (Gregory, 1996). If the

[4] WHO does not have safe level for benzene but 5μmg/m^3 is commonly used as a practical limit (ENDS, 1996).

closure and post-closure of the said landfill is not conducted in a proper manner. The areas would be lost forever and cannot be allocated for any other landuse purposes.

Summary of environmental considerations:
Summarising the about discussed environmental issues, there is no doubt that sanitary landfill will provide a more secure and better environmentally sound disposal system than crude dumping landfill. If the sanitary landfill is engineered according to environmental codes of practice and maintained properly, if offers a sustainable way in handling municipal solid waste. In order to avoid any possible hazards that could occur, it is important to ensure the following conditions are present:

i) There must be pre-sorting before the waste is disposed at the landfill in order to recover materials
ii) Hazardous waste should be forbidden to be co-disposed at the municipal solid waste landfill
iii) An impermeable liner system should be installed together with leachate collection and treatment system. Ground water monitoring should be done from time to time to ensure no ground water contamination
iv) Gas venting and flaring system to prevent explosion or fire at the landfill site as well gas monitoring system to make sure no landfill gases be escaped freely to the atmosphere

5.3.2 Economic Considerations

Economic consideration plays an important role in determining the most suitable disposal method as well as environmental consideration. As Wilson (1981) put it "*the methods of financing both revenue and capital expenditure may have an important influence on the choice of a waste disposal strategy*". It is pointless to adopt disposal technologies that are completely not affordable by the country. Other disposal methods such as pyrolysis, incineration and composting offer alternatives in handling the increasing municipal solid waste. But the financial constraints that are faced by the local authorities should be taken into consideration before rushing into any disposal methods. Currently, 40% to 70% of the local authorities budget is allocated on solid waste management (MHLGM, 2001). Any further allocation of budget to solid waste management, in order to use more costly disposal methods, would mean some other development projects or services would have to forgo.

Relatively, the capital cost and the operation cost of sanitary landfill are much lower than other disposal methods. The required capital to set up a sanitary landfill with the capacity of handling 4000 tonnes of waste per day is about RM30 million* while incinerator would cost up to RM1.5 billion for the capacity of only 1200 tonnes of waste per day (Gregory, 1996) (The Sun, 24 September 2000). This shows that sanitary landfill is more economic where building a sanitary landfill with 330% higher capacity than incinerator only cost 2% of what it cost for building incinerator. There is also a huge difference between the landfill and incineration operating cost. The operating cost for landfilling ranges from RM3.50 to RM10 per tonne with the average of RM7 per tonne while incineration would need as high as RM160 per tonne in burning the waste (Nasir, et al, 1998) (MHLGM, 2001). Even though the high capital and operating cost of incineration can be offset by some of the waste converted by energy recovery technology, the

cost is still way too high for the Malaysian government to bear. Currently, the tipping fee for landfilling is only RM2 to RM5 per tonnes. If incineration has been opted as disposal method, big portion of the cost would have to be transferred to the public by imposing higher disposing fee. This will be a burden to the people especially those who live at the marginal line.

Comparing to composting, sanitary still offers a more economic viable way of disposing. It costs between RM25 to RM35 to compost a tonne of municipal solid waste in an open heap. If the composting were done in enclosed vessels, the cost would go up to RM150 per tonne. On the other hand, disposing solid waste at the landfill costs about RM32 per tonne (Agamuthu, 2001). The other constraint with the composting is lack of favourite market for the compost. The quality of the compost varies due to the municipal solid waste composition. This unstable compost quality makes it less compatible with chemical fertilisers.

(* USD1.00 = RM3.80)

5.3.3 Social Considerations

Social consideration is another important element in determining the feasibility of sanitary landfill. Generally, people are reluctant to have landfill to be situated near their neighbourhood even though the landfill is equipped with the leachate collection and treatment facilities, gas collection facility, daily cover, large buffer zone, etc. People are not convinced that the sanitary landfill will not pose any threats to them. Basically, as long as the disposal site is not located in their neighbourhood, there will not be many objections from the people (Tammemagi, 1999). This typical NIMBY syndrome is not only present when selecting the sanitary landfill sitting, it applies to other disposal methods as well such as incineration, composting, etc. There are few factors that lay behind this NIMBY syndrome. First of all, fear of unknown. Even though theoretically if the disposal method is engineered with the latest technology and follows the strict environmental codes of practice, the pollution and health hazards could be totally prevented or reduced to the minimum level, the long-term environmental hazards are still uncertain. Secondly, the decreasing welfare that is associated with wherever the disposal site located. According Hite, et al (2001), the people who live nearby to landfill site are generally perceived as lower socio-economic group. Property value in this neighbourhood is relatively low as compared to other areas.

Furthermore, building a sanitary landfill would consume a large land area. This will compete with other landuse purposes such as road construction, dam construction, housing scheme and other public services and utilities. Due to the increasing land scarcity, one development project has to forgo for another. If landfill has been chosen for the purpose, the opportunity for other development projects will have to be sacrificed. On the other hand, if the sanitary landfill is well designed, managed and monitored, it can be converted into recreation park and garden, golf course, car parking areas, etc (Rasmussen, 1999) (Bramryd, 2001). A good example for conversion of closed landfill to recreation park is at the sanitary landfill in Malmö, Sweden.

Feasibility of sanitary landfill:
In order to eliminate the negative environmental impacts posed by current landfilling practise and taking the financial and technical abilities into consideration, sanitary landfill seems to be the only solution. Other method such as incineration is yet to be practical for the local authorities to adopt due to the financial and technical constraints. Some would still argue that sanitary landfill will not solve the increasing volume of solid waste and thus incineration is necessary. But it has to bear in mind that does not matter what types of disposal methods being adopted, there are always pros and cons towards them. The most important is the practicality of the method and how can it be carried out with the best of its capacity and with minimum environmental and socio-economic impacts. As Agamuthu (2001) indicated in his book, the ideal disposal methods should be environmental friendly with optimum recycling, economically less demanding and socially acceptable. As to volume reduction issue, incineration might be able to solve the problem in the short-term but it is not a permanent cure. Source reduction and recycling play more important role in reducing the waste volume. Thus, it is essential to go back to the root causes of the solid waste problems and tackle them from there.

6 Recommendations

In view of the increasing municipal solid waste problems both in volume and complexity, there is no single method that can solve the problems. Municipal solid waste problems should be tackled from various angles based on an integraded system with a combination of different techniques. It is important that the combination of methods should be complementing and not competing with each other. In addition to that, the solid waste management system should be tailored made to suit the local, regional and national conditions (USEPA, 1988) (Rylander, 1998). Basically no matter which combination of the methods being adopted, it should be inline with the following priority:

i) Reduction and reuse
ii) Recycle and recovery
iii) Final disposal

6.1 Reduction and Reuse

Waste reduction should have a top priority in the solid waste management hierarchy. It reduces the amount and the toxicity of waste before they entering the municipal waste stream (Franklin Associates, 1999). There are several ways of source reduction:

Redesign	The producers should redesign the products and packages in order to: - reduce the quantity of materials and the toxicity of the materials used - lengthening the products life to delay for disposal
Reduce material used	Consumers should change their consumption behaviour to reduce waste generated such as buying in large quantity or in refillable package in order to reduce the packaging. Removing from commercial mailing list could also significantly reduce the paper waste.

Reuse of product and packages	Examples of reuse including using refillable containers, washable plates, glass instead of using disposable products. Durable goods such as furniture and appliances can be resold or donated to the needy family.

Source: Franklin Associates, 1999

Source reduction is rather a prevention technique to reduce the waste from being generated. The success of source reduction is very much depended on the attitude of producers and consumers which involves legislation, social perception, education and so on. Along with the increasing living standard, Malaysians are developing the "use and throw" consumption behaviour where there are more and more disposable products being consumed. This consumption pattern should be inverted in order to reduce the waste from entering the waste stream. On the other hand, emphasis should be placed on producers because preventing waste from being generated must begin with the product and the production process (Rylander, 1998). In Malaysia there is yet any emphasis on source reduction as a major part of the solid waste management. It is imperial in the recycling program to encourage people to reuse products.

6.2 Recovery

Recovery of materials means removing municipal solid waste from waste stream for the purpose of recycling (Franklin Associates, 1999). The distinction between source reduction and recovery is the former prevents waste from entering the waste stream while the later retrieves the recyclables from the waste stream. According to a study in South Korea, the diversion of 36% of total waste from landfills saved at least 40% of the space for future disposal (Oh, 1995).

Malaysia has a very low recycling rate, out of 40% of the recyclables only 5% is being recycled (The Star, 6 January 2001). There is barely any source separation at the household level. Most Malaysians lack of awareness about the solid waste problems and lack of incentive to recycle. The recycling activities are mainly carried out by waste collection workers, scavengers and scrap dealers. There is not much household participation in the activities. In order to encourage recycling among the public, the Ministry of Housing and Local Government has launched a nationwide recycling program in late 2000. The first stage of the campaign is mainly to bring up the awareness and to educate the public to sort their waste for what can be reused, recycled or composted. But it is still a long, tough way to go in order to achieve the targeted 22% recycling rate (Agamuthu, 2001). This is also partly because Malaysia is still lacking of a systematic recyclables industry. Some of the recyclables have to be exported to other countries to be processed due to lack of processing facilities within the country (Sin Chew Jit Poh, 12 November 2001). This will hinder the government's effort in encouraging recycling.

Even with the maximum source reduction and recycling, there will still be some waste left for treatment and final disposal. Waste treatment could be done in many ways to recover energy and nutrient from the waste. Composting is one of the resources recovery treatments. The nutrients captured inside the waste can be recycled in the form of compost. Composting is yet to be widely practised in Malaysia. It is mainly for composting agriculture products which give more

homogenous input. Municipal solid waste is generally sent to landfills for final disposal. The problems that associated with the composting in Malaysia includes:

i) Lack of reliable market for compost due to the price factor and competition from chemical based fertiliser.
ii) The quality of the compost is not stable. It is because the input is highly variable and no pre-sorting at the household level to separate the organic waste from inorganic wastes.
iii) It involves high cost for large scale mechanical composting which includes pre-treatment and sorting facilities

Composting offers an environmentally sound way in handling solid waste. It can significantly reduce the waste volume up to 75% on a dry weight basis (Agamuthu, 2001) and it has minimum negative environmental impacts. But composting is yet to be practical in Malaysia unless the aforesaid problems are solved.

In most European countries, incineration has been used to reduce the waste volume and at the same time recover energy as heat or electricity. There is a proposal to have incineration in Malaysia but for the time being it is rather impractical because:

i) It is highly capital intensive and has high operation cost
ii) The municipal solid waste in Malaysia has low calorific value and high moisture content which would require fuel to combust the waste
iii) Pre-sorting and pre-treatment are necessary to sort off wet organic waste
iv) It produces toxic substances from burning heavy metal or contaminated waste
v) It may cause air pollution by releasing heavy metals and chlorinated organic pollutants like dioxins, furons and hexachloric benzene (Bramryd, 2001)
vi) The air pollution control devices are costly and difficult to handle and dispose of (The Star, 24 October 2000)

6.3 Final Disposal

Landfill is the ultimate disposal method. Regardless what treatment methods have been used, there will always be some residuals left to be disposed at the landfill. Even though landfill is in the lowest hierarchy of the solid waste management, it plays an equal role as incineration and composting in source recovery if it is equipped with resource recovery facilities. The nutrient can be recovered by irrigating the weak leachate to woodland or grassland. A good example would be leachate irrigation scheme in the forest in Helsingborg, Sweden. While the energy can be recovered from the methane gas where it can be processed into bio-fuel.

In view of the constraints in having incineration and composting in Malaysia, landfill will remain to play a crucial role in handling municipal solid waste. Even though there is a recycling campaign going in the country, it still needs a long time for it to achieve its mature stage. In Germany, it took about 25 years to reach the mature stage of recycling where 30% to 40% of the solid waste is recycled (The Sun, 24 September 2000). How long do we need to reach that stage? And how long do we have? It is estimated that 80% of the 230 landfills in Malaysia will soon be full for closure (Nasir, et al, 1997) and the land for new landfill is getting scarce to find. There is a proposal to set up an incineration plant in Kuala Lumpur to moderate the pressing solid waste problems but it is rather impractical due to the high social costs of incineration, RM500 per tonne

of waste compare to only RM35 per tonne for sanitary landfill (Nasir, et al, 1998). Thus, it is more appropriate to improve the current landfills situation i.e. from crude dumping landfills to sanitary landfills. The following improvement can be done to minimise the negative environmental and socio-economic impacts (Sakurai, 1990):

i) Daily cover
ii) Improvement of access road
iii) Construction of fencing
iv) Weighbridge
v) Ensure of no open burning at the disposal site
vi) Establishment of surface drainage system to divert rainwater from filtering into landfill cell
vii) Introduction of buffer zone between disposal site and housing area
viii) Construction of leachate collection and gas venting facilities
ix) Ensure no co-disposal of hazardous waste

If the sanitary landfill is properly designed and maintained, it will have less negative environmental impacts compared to other methods. It is of course impossible to make overnight changes to upgrade all the crude dumping landfills to sanitary landfills. The improvement of the landfill has to be done gradually according to the country's condition and financial and technical abilities. The Ampang Jajar landfill in Seberang Perai is an example how the local authorities managed to convert the dumpsites into sanitary landfill within two years by using its limited financial resources and expertise (Ramly and Mamat, 2001). Instead of simply transferring the sophisticated landfill technologies which is definitely beyond the financial and technical abilities of the municipality, the Seberang Perai Municipality sought advice from Japanese International Corporation Agency to upgrade the landfill by localising the techniques used.

In order to provide more efficient solid waste management and to release the financial burden of the local authorities, solid waste management has become part of the country privatisation policy. There are four consortium companies which have been appointed for 20 years concession for solid waste management in 4 different regions (Agamuthu, 2001) (Nasir, 1998). It is important to note that the local authorities have to ensure the standard of services that provided by these concession companies are not deteriorated and the environment disamenities that associated to solid waste is kept to the minimum.

7 Conclusions

The current disposal system in Malaysia is not conducted in an environmentally sound manner and thus it leaves various environmental problems for the authorities to deal with. The authorities are eagerly looking for a solution to solve the piling up solid waste related problems such as negative environmental impacts, land scarcity and increasing solid waste. Even though various alternative methods have been identified but they are not economically and socially viable. Sanitary landfill is still the most cost-effective and appropriate method for waste disposal in Malaysia. Since most of the current landfills in Malaysia have a poor code of landfill practice, it is important for the authorities to improve the current state of landfilling practice. Though sanitary landfill may partially solve the solid waste problems, the tumour remains. Thus, it is essential to tackle the problems from the root cause, i.e. to reduce the waste from being generated. A further study on source reduction and how it involves various aspects such as psychology, education, market system, social background, etc to achieve its goal could be as a guideline for the authorities to tackle the solid waste problems from the root.

8 References

Allen, A. (2001). Containment landfills: the myth of sustainability. *Engineering Geology, 60*, 1-4, 3-19

Agamuthu, P. (2001) *Solid waste: principles and management with Malaysian case studies.* Kuala Lumpur: University of Malaya Press.

Bogner, J., Spokas, K., Burton, E., Sweeney, R. and Corona, V. (1995). Landfills as atmospheric methane sources and sinks. *Chemosphere, 31*, 9, 4119-4130.

Boswell, J.E.S. (1998). Update on the landfilling of treated hazardous waste in South Africa.. In *14th Waste Congress*, 12-15 October 1998, Gauteng, South Africa.

Bramryd, T. (1979), Effects of man in the biogeochemical cycle of carbon. In *The global carbon dioxide cycle* (Bolin, Degens, Kempe and Ketner, eds). SCOPE 13; 183-218. New York: Wiley and Sons.

Bramryd, T. (1982). Fluxes and accumulation of organic carbon in urban ecosystems on a global scale – In *Urban Ecology* (Bornkamm, Lee and Seaward, eds), 3-12. Oxford: Blackwell Scientific Publications.

Bramryd, T. (1983). Human impact on the biogeochemical cycling of carbon between terrestrial ecosystems and the atmosphere. *Environmental Biogeochemistry*, *35*, 301-313.

Bramryd, T. (1997). Landfilling in the perspective of the global CO_2 balance. In: *Proceedings Sardinia 1997, 6th International Landfill Symposium*, Cagliari, Italy, 11-16. Cagliari, Italy: Environmental Sanitary Engineering Centre.

Bramryd, T. (6 November 2001). Personal Communication.

Bramryd, T. (16 November 2001). Personal Communication.

Breen, B. (1990). Landfills are number one. *Garbage, 2*, 5, 42-48.

Danish University Consortium for Environment and Development. (2001). *Solid waste reduction strategy: a Model for sustainable solid waste management and practices*. [Online] Available: http://www.duced-iua.dk/network/Project%20Proposals/MUCED5.htm [5 June 2001]

Daskalopoulos, E., Badr, O. & Probert, S.D. (1998). An integraded approach to municipal solid waste management. *Resources, Conservation and Recycling, 24*, 1, 33-50

Department of Environment. (1989). Landfill gas. *Waste Management Paper No. 27*. Department of Environment, UK.

Department of Statistics, Malaysia. (2001). [Online]. Available: www.statistics.gov.my/bahasa [25 October 2001].

EEWC. (1993). Waste to energy – an audit of current activity. Report prepared for the European Energy from Waste Coalition. January 1993.

Environmental Data Services. (1996). *ENDS Report 257*, 15-16

Franklin Associates (1999). *Characterization of municipal solid waste in the United States: 1998 update*. Report No. EPA-530. Kansas.

GeoVision Productions. (2000). *General information on Malaysia*. [Online]. Available: http://www.geovision.com.my/malaysia [9 November 2001]

Ghazali, A.W., Nasir, M.H., Muda, A. (1997). Domestic and commercial waste: present and future trends. *State of The Environment in Malaysia*. Penang, Malaysia: Consumers' Association of Penang.

Gregory, R. (1996). *Waste management in Malaysia: issues and initiatives related to conservation of biodiversity and critical habitats*. Petaling Jaya, Malaysia: WWF Malaysia.

Haraldson, H. (2000). *Introduction to causal-loop diagrams*. Lecture handout. Lund: LTH

Hite, D., Chern, W., Hitzhusen, F., Randall, A. (2001). Property-value impacts of an environmental disamenity: the case of landfills. *The Journal of Real Estate Finance and Economics, 22*, 2-3, 185-202

Intergovernmental Panel on Climate Change. (1992). *The supplementary report to the IPCC scientific assessment*. Cambridge: Cambridge University Press.

James, K. J., Stack, M. A. (1997). The impact of leachate collection on air quality in landfills. *Chemospere, 34,* 8, 1713-1721

Medina, M. (1998). Scavenger cooperatives in developing countries. BioCycle, 39, 6, 70-73.

Mato,.R.R.A.M. (1999). Environmental implications involving the establishment of sanitary landfills in five municipalities in Tanzania: the case of Tanga municipality. *Resources, Conservation and Recycling, 25*, 1, 1-16

Ministry of Housing and Local Government, Malaysia. (1999). Fakta-fakta asas pengurusan sisa pepejal di kawasan pilihanberkuasa tempatan [Solid waste management factsheet at local authorities areas]. [Online]. *Jaringan Kerajaan Tempatan*, 1, 5-6. Available: http://www.kpkt.gov.my/jkt/asset_jkt/bulletin_penerbitan_frm.htm [6 September 2001].

Ministry of Housing and Local Government, Malaysia. (2001). *Program kitar semula* [Recycling Programme]. [Online]. Available: www.kpkt.gov.my/jkt/asset_jkt/kitarsemula.htm [24 July 2001]

Montague, P., Hazardous Waste News (various issues). Environmental Research Foundation. Annapolis, Md

MOPT. (1992). *Residous solidos urbanos*. Report by Luis Ramon Otero Del Peral for Ministerio de Obras Publicas y Transportes, Madrid.

Naane, E. L.M. (1998). Bostwana's waste management strategy. In *14th Waste Congress*, 12-15 October 1998, Gauteng, South Africa.

Nasir, M.H., Ghazali, A.W., Yusoff, M.K., Sulaiman, W.N. (1997). Waste recycling: problems and prospects. *State of The Environment in Malaysia*. Penang, Malaysia: Consumers' Association of Penang

Nasir, M.H., Yusoff, M.K., Sulaiman, W.N., Rahman.R.A. (1998). Issues and problems of solid waste management in Malaysia. In M.N.H. Hassan, L.A. Abudullah, I. Komoo, *National review on environmental quality management in Malaysia: towards the next two decades,* (179-225). Kuala Lumpur: Institute for Environment and Development.

Ness, B. (2000). An economic comparison of municipal solid waste treatment systems in sweden. LUMES (Thesis work). Lund, Sweden

OECD. (1993). *Environmental data compendium*. Paris: Organisation for Economic Cooperation and Development.

Oh, H.S. (1995). Applying economic instrument to waste management system in Korea. *NETTLAP 3rd, Training and Resource Development Workshop on Environmental Economics*, Osaka, Japan.

Preez, L., Pieterse, T. (1998). Case study on leachate management at the Weltevreden solid waste disposal site. In *Sardinia 1997. 6th International Landfill Symposium*. October 1997, S. Margherita di Pula, Italy.

Ramly, N.H., Mamat, I.B. (2001). Step by step improvement of the Seberang Perai Malaysia Landfill site by using appropriate technology. In *Proceedings Sardina 2001, 8th International Waste management and Landfill Symposium*, 1-5 October 2001, Cagliari, Italy. 121-129. Environmental Sanitary Engineering Centre.

Rasmussen, Gaylan A. (1999). Reclaiming landfills for recreation. *Parks & Recreation, 34*, 1, 56-62.

RCEP. (1993). *Incineration of waste. Royal Commission on Environmental Pollution*. 17th Report. HMSO, London.

Ridhuan, M.I. (1995). Sanitary landfill development in Malaysia. Paper presented at a short course on "Practical of landfill design". School of civil Engineering, University Science Malaysia.

Robinson, H. (1997). Leachate re-circulation and cost effective treatment. In *Sardinia 1997. 6th International Landfill Symposium*. October 1997, S. Margherita di Pula, Italy.

Röhrs, L. (1998). Assessing the rate of degradation of co-disposed sewage sludge and municipal refuse. In *14th Waste Congress*, 12-15 October 1998, Gauteng, South Africa.

Rylander,H. (1998). Global waste management. In *14th Waste Congress*, 12-15 October 1998, Gauteng, South Africa.

Sakurai, K. (1990). *Improvement of solid waste management in developing countries*. Japan International Cooperation Agency.

Sin Chew Jit Poh. (12 November 2001). Setting up solid waste industry. [Online]. Sin Chew Jit Poh. Available: http://news.sinchew-i.com [12 November 2001]

Shafii, I. (1997). Toxic chemicals and hazardous waste management in Malaysia: an overview. *State of The Environment in Malaysia*. Penang, Malaysia: Consumers' Association of Penang

Study shows landfills can raise risk of cancer. (1998). *Long Island Business News*, Issue 35, 10A. New York: Long Island Commercial Review Inc.

Sundaravadivel, M., Vigneswaran, S., Doeleman, J.A. (2000). Waste management in semi-urban areas of India: appropriate technological strategies to overcome financial barriers. *Environmental Engineering and Policy, 2*, 2, 91-104.

Tammemagi, H. (1999). *The waste crisis: landfills, incinerators, and the search for a sustainable future*. New York: Oxford University Press.

Warmer. (1990). Waste incineration. *Warmer Bulletin Factsheet*. January 1990.

Warmer Bulletin. (2000). Waste strategy for England and Wales. *Warmer Bulletin, Journal of Sustainable Waste Management*, No. 73, July 2000, 4-7.

World Bank. (1993). *Malaysia – managing costs of urban pollution*. Report No. 11764-MA. Washington DC: The World Bank.

United Nations Economic and Social Council. (2001). Sustainable human settlements development and environmentally sound management of solid wastes. In: *Commission on Sustainable Development acting as the preparatory committee for the World Summit on Sustainable Development – organisational session*, [Online], United Nations Centre for Human Settlement, 30 April – 2 May 2001. Available: http://www.un.org/esa/ [25 September 2001]

United States Environmental Protection Agency. (1988). *The solid waste dilemma: an agenda for action*. United States Environmental Protection Agency.

United States Environmental Protection Agency. (1994). *Design, operation, and closure of municipal solid waste landfills (Seminar Publication)*. Cincinnati, Ohio: U.S. Environmental Protection Agency.

UNFCCC. (26 October 2001). *Kyoto Protocol: status of ratification*. [Online]. Available: http://www.unfccc.int/cop6_2/convkp/index.html [10 November 2001].

UNFCCC. (1997). Kyoto Protocol to the United Nation Framework Convention on climate change. [Online]. Available: http://www.unfccc.de/resource/docs/convkp/kpeng.html [10 November 2001].

Wilson, D C. (1981). *Waste management: planning, evaluation, technologies*. New York: Oxford University Press.

World Development Indicators database. (2001). [Online]. Available: http://.devdata.worldbank.org/data-query/ [5 October 2001]

World Health Organisation. (1987). *Air quality guidelines for Europe*. Copenhagen, Denmark

World Health Organization. (1997). *Dengue haemorrhagic fever: diagnosis, treatment, prevention and control*. [Online] Geneva: World Health Organization. Available: http://www.who.int/emc/diseases/ebola/Denguepublication [8 November 2001].

World Commission on Environment and Development (1987) *Our common future*. Nairobi: United Nations Environment Programme.

The Star. (24 October 2000). Mixed Troubles?. [Online]. Available http://aplikasi.kpkt.gov.my/akhbar.nsf [13 September 2001].

The Star. (6 January 2001). Practise recycling, says Ong. *The Star*. [Online]. Available http://aplikasi.kpkt.gov.my/akhbar.nsf [13 September 2001].

The Sun. (24 September 2000). Hot answers to a burning question. *The Sun*. [Online]. Available http://aplikasi.kpkt.gov.my/akhbar.nsf [13 September 2001].