MSW Management in Malaysia-Changes for Sustainability

Agamuthu Pariatamby

1 Introduction

Municipal Solid Waste is solid, other than emission or effluent, and is regarded as inevitable, valueless by-product due to human activities, and is generated at a rate and discarded after use when no longer needed by the generator. Waste consists of materials that are no longer considered valuable and subsequently disposed off (Tchobanaglous et al. 1993).

In Malaysia, urban waste generation increased 3 % annually due to urban migration, affluence and rapid development (Agamuthu 2001). In 2008, approximately 31,000 tonnes of waste were disposed off into 260 landfills in Malaysia (Agamuthu et al. 2009a, b). Municipal solid waste (MSW) problems have been gaining prominence in Malaysia due to the ever increasing waste generation and the ineffectiveness of the existing mechanism to tackle the problem holistically (Agamuthu and Fauziah 2006). Early management of solid waste involved very little effort since waste was generated at a manageable level and generally consists of organic materials such as food waste, paper, wood and others (Fauziah et al. 2007). This began to change with the increase in the human population and advancement in living standards. Quantity of waste generated increased together with the complexity of waste where plastic and other mixed waste became a significant portion in the waste stream. This called for an appropriate waste management system to avoid the proliferation of disease and the deterioration of environmental quality through pollution.

A. Pariatamby (✉)
Faculty of Science University of Malaya, Institute of Biological Sciences,
50603 Kuala Lumpur, Malaysia

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2 Changes in Waste Generation

The production of MSW has doubled or tripled in some industrial countries over the last two decades. Developing and transitory countries, which are becoming industrial nations, are also producing MSW at an alarming rate, particularly due to the rapid development of urban areas, the rural–urban migration and the increase in per capita income, as well as, the changes in consumption patterns brought by the development (Agamuthu and Fauziah 2006; Agamuthu and Khan 1997). Consistent data on rates of solid waste generation in Malaysia are lacking due to the absence of established activity in the MSW field. Urban population, which contributes more than 65 % of the total population, is the main waste generator. Table 1 shows the trends of waste generation in major urban areas in Peninsular Malaysia from 1970 to 2010.

The increase in urban population in Peninsular Malaysia from 6.05 million in 1988 to more than 16.5 million in 2007 resulted in the acceleration of waste generation in urban areas. The refuse generation rate has increased from 241 to 438 kg/capita/year. Kuala Lumpur, the capital city of Malaysia, showed increasing trends of waste generation since 1970. The initial generation of 98.9 tonnes/day in 1970 increased by approximately 300 % in 1980. To date, the waste generation in Kuala Lumpur had increased tenfold since 1990s from approximately 590–3,000 tonnes/day. Similar increasing trends were observed throughout 1996–2006 in most states in the country as indicated in Table 2. Increase in waste generation from 2000–2006 was 60 %, giving an average of 10 % increment annually for the past 6 years. In 1997, the total solid waste generated in Peninsular Malaysia was 5.6 million tonnes or 14,000 tonnes/day and of this 80 % was domestic waste, while the remaining 20 % was commercial waste.

By the year 2000, production of domestic and commercial waste reached 8.0 million tonnes/year, where one quarter of the total solid waste was generated in the Klang Valley. The total refuse tonnage was found to have increased two-fold to

Table 1 Generation of MSW in major urban areas in Peninsular Malaysia (1970–2012)

Urban centre	Solid waste generated (tonnes/day)							
	1970	1980	1990	2002	2006*	2009*	2010*	2012*
Kuala Lumpur	99	311	587	2,754	3,100	3,387	3,489	3,701
Johor Bharu (Johor)	41	100	175	215	242	264	272	289
Ipoh (Perak)	23	83	162	208	234	256	264	280
Georgetown (P. Pinang)	53	83	137	221	249	272	280	297
Klang (Selangor)	18	65	123	478	538	588	606	643
Kuala Terengganu (Terengganu)	9	62	121	137	154	168	173	184
Kota Bharu (Kelantan)	9	57	103	130	146	160	165	175
Kuantan (Pahang)	7	45	85	174	196	214	220	233
Seremban (N. Sembilan)	13	45	85	165	186	203	209	222
Melaka	14	29	47	562	632	691	712	755

* Estimated figure

Table 2 Generation of MSW in Peninsular Malaysia according to states (1996–2006)

States	Solid waste generated (tonnes/day)					
	1996	1998	2000	2002	2004*	2006*
Johor	1,612.9	1,785.35	1,914.95	2,093.17	2,255.27	2,429.93
Kedah	1,114.53	1,215.42	1,323.67	1,446.86	1,558.91	1,679.64
Kelantan	870.84	949.67	1,034.25	1,130.51	1,213.37	1,302.31
Melaka	433.26	799.97	514.56	562.45	604.84	650.43
Negeri Sembilan	637.4	695.1	757.01	827.46	889.82	956.89
Pahang	805.88	878.83	957.1	1,046.18	1,125.03	1,209.82
Perak	1,285.81	1,402.2	1,527.09	1,669.22	1,795.03	1,930.32
Perlis	164.61	179.51	195.5	213.7	229.81	247.13
Pulau Pinang	915.72	998.61	1,087.55	1,188.77	1,278.37	1,374.72
Selangor	2,379.89	2,595.33	2,826.47	3,089.53	3,322.38	3,572.79
Terengganu	743.21	810.49	882.67	964.82	1,037.54	1,115.74
Kuala Lumpur	2,105.43	2,305.29	2,520	2,754.54	3,025.32	3,322.72
WP Labuan	NA	NA	46	70	74.26	81.15
Sabah	NA	NA	NA	2,490	2,641.64	2,886.59
Sarawak	NA	NA	NA	1,905	2,021.01	2,208.42
Total	*13,069.48*	*14,588.77*	*15,586.82*	*21,452.21*	*23,072.60*	*24,968.58*

http://www.kpkt.gov.my/statistik/perangkaan2002
NA Not available
* Estimated figure

2.448 million tonnes/year in 1995 or an increase of 169,670 tonnes/year, which works out to about 13.5 % increase per year. For Kuala Lumpur alone, the waste production exceeded 2,800 tonnes/day in 1997, reached a generation of 3,000 tonnes in 2001 and is expected to be about 3,200 tonnes in 2017. In Selangor, the waste generated in 1997 was over 3,000 tonnes/day, and will reach 5,700 tonnes/day in the year 2017(Sekarajasekaran and Lum 1982). The generation of MSW in Malaysia currently has reached more than 31,000 tonnes/day with the highest generator being Selangor, where industrial activities are mainly concentrated. Selangor contributed approximately 14, 15 and 17 % of the country's total waste generation in 2002, 2004 and 2006, respectively. Labuan being the youngest developed town had the lowest solid waste generation of only 46 tonnes/day in 2002 and eventually increased to 82 tonnes/day in 2006. The MSW generated was 6.0 million tonnes in 1998 at an average per capita generation of 0.5–0.8 kg/day (Fig. 1).

Level of per capita solid waste generation changed accordingly with urbanization of more areas, as well as with the improvement to the people's quality of life in the country. The rate in the 1980s was 0.5 kg/day and had increased to 1.3 kg/day in 2006. Current rate ranged at 1.5–2.0 kg/day in most cities. This increasing trend could be due to the changes in consumption habits, as well as, the increasing affordability to consume more goods. The economic status of individuals has a direct impact on the waste generation and waste characteristics (Table 3).

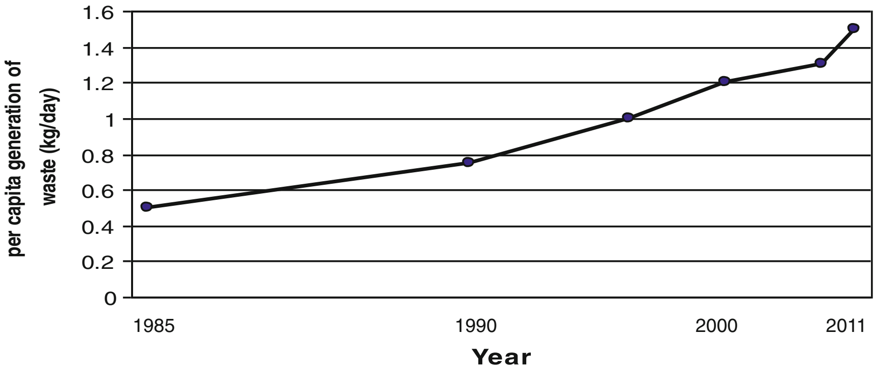

Fig. 1 Increasing trend in per capita generation from 1985 to 2011 (Agamuthu and Fauziah 2012)

Table 3 MSW generated from different economic households

Composition (%)	Socio-economic status		
	High	Middle	Low
Paper products	19.79	15.73	13.04
Plastic and rubber	21.05	18.61	13.01
Glass and ceramics	14.99	9.42	7.57
Food waste	24.13	29.77	31.86
Metals	8.80	12.75	9.15
Textiles	1.57	3.87	3.08
Garden waste	5.50	6.95	15.56
Wood	3.45	2.90	6.72
Total	*100.00*	*100.00*	*100.00*

3 Changes in Waste Composition

Waste stream consists of approximately 46 % organic waste followed by 14 % paper and 15 % plastic. Figure 2 illustrates the average composition of Malaysian waste.

The availability of comprehensive data on solid waste composition on a national scale is limited. A study conducted by the Ministry of Housing and Local Government (MHLG) reported that the solid waste composition in Malaysia was dominated by organic waste, followed by paper in the total waste stream (Hoorwerg and Thomas 1999). Similar trend was observed in 2003 indicating high percentage of organic waste present in the MSW composition as shown in Table 4.

Waste composition in Malaysia is dominated by organic waste comprising approximately 50 % of the total waste stream. Current waste composition indicates a very high percentage of putrescible waste, which mainly consisted of processed kitchen waste and food waste. Figure 3 indicates the average

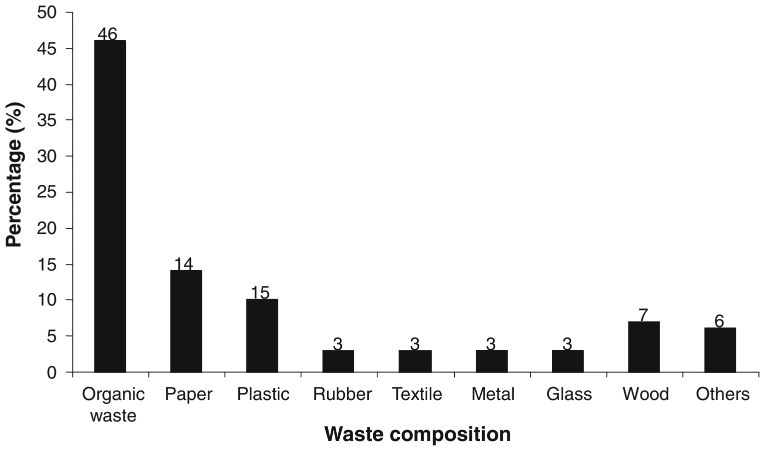

Fig. 2 Average waste composition received by Malaysian landfills

Table 4 Waste composition in Malaysia throughout 1975–2011

Waste composition	1975	1980	1985	1990	1995	2000	2003	2011
Organic	63.7	54.4	48.3	48.4	45.7	43.2	46.4	58
Paper	7.0	8.0	23.6	8.9	9.0	23.7	14.4	7
Plastic	2.5	0.4	9.4	3.0	3.9	11.2	15.0	12
Glass	2.5	0.4	4.0	3.0	3.9	3.2	3.0	3
Metal	6.4	2.2	5.9	4.6	5.1	4.2	3.3	6
Textile	1.3	2.2	NA	NA	2.1	1.5	2.8	3
Wood	6.5	1.8	NA	NA	NA	0.7	6.7	1
Others	0.9	0.3	8.8	32.1	4.3	12.3	8.4	10

http://www.kpkt.gov.my/statistik/perangkaan2002
Fauziah and Agamuthu (2003), Agamuthu and Fauziah (2011)

composition of waste received by the landfills in Malaysia. It is a worrying trend that the unconsumed food disposed ranged from 3–5 % which indicates the affluence of the Malaysian public.

Putrescible waste contributes approximately 46 % of the total waste received by landfills in Malaysia, followed by 14 % of paper waste and 15 % of plastics based waste (Table 4). The trends in MSW composition in Malaysia indicates that food, paper and plastic are the main components which form the solid waste generated in most places. The findings indicated that highest percentage was food waste at 41 % followed by 8 % plastic film and 6 % rigid plastic. The 7,200 tonnes of food wastes theoretically allowed the diversion of these fractions for biological treatment. The possibility to incorporate composting programs would also utilize the 6 % garden waste which would reduce approximately 45 % of the total MSW stream from being disposed off into landfills. The quality of the compost can be monitored and various additives available in the market offer

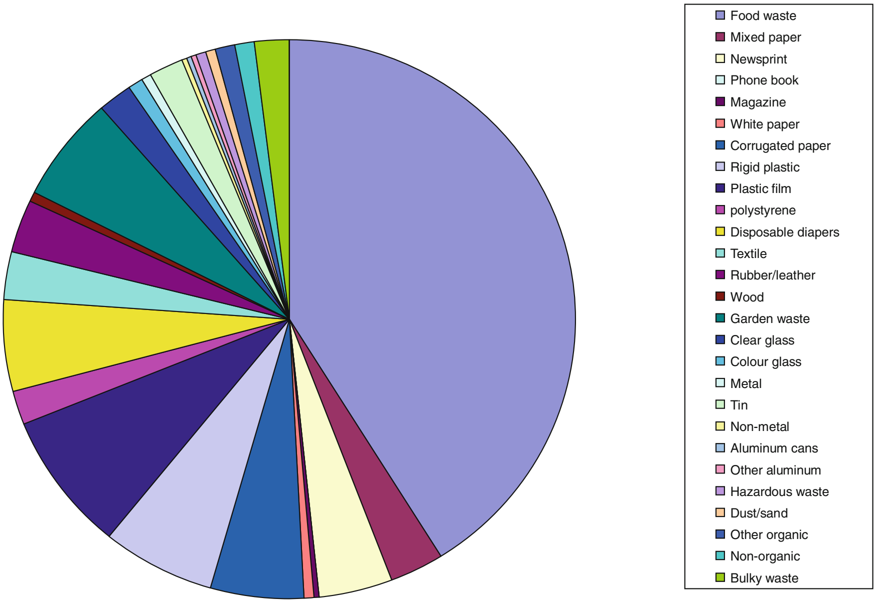

Fig. 3 Average composition of waste received by landfills in Malaysia

quality improvement of the compost from MSW, to generate a net profit of RM5.32 (US$1.51) million daily.

Besides composting, the putrescible components can also be converted into biogas. Biogas generation had gained importance worldwide where organic wastes are treated in anaerobic digestion chambers which convert landfills into bioreactors. However, due to lack of expertise and insufficient technology, the biogas conversion generally is not a convenient effort to manage the waste.

Other material recovery options include the recovery of paper, plastic, glass, and metals. A total of 40 % of the daily waste received by the landfills consists of recyclable components including 14 % paper, 15 % plastic, 3 % metal and 3 % glass.

Since Malaysian waste consists of non-degradable plastic, diversion of these plastic components is very crucial. Plastic composition has increased from 15 % in 2004 to 24 % in 2005 which means there is approximately 4,550 tonnes of plastic wastes in the 19,000 tonnes MSW generated (Kamariah 1998) (Fig. 4).

The waste composition also depends on the location of the landfill and the area served. Putrescible waste is highest in rural landfill (Table 5) and the composition is affected by the occupational activities within the area of service.

Similarly the landfill leachate characteristic is also influenced by the waste composition in these landfills.

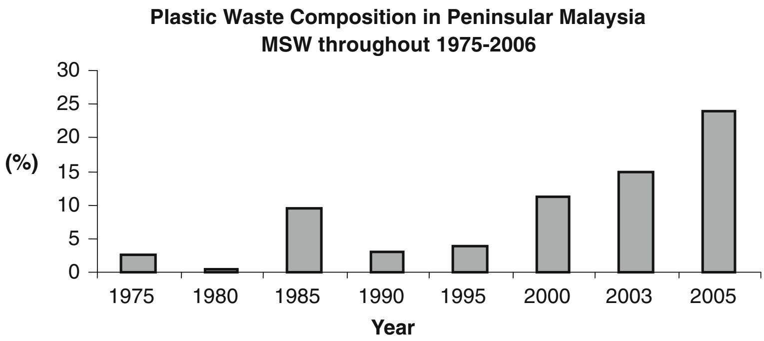

Fig. 4 Plastic waste composition in Peninsular Malaysia (Kamariah 1998; Kuman and Abdullah 2002; Yani and Rahman 2000)

Table 5 Municipal waste composition (% FW) in rural, sub-urban and urban landfills

Component	Rural landfill (Panchang Bedena)	Sub-urban landfill (Sungai Sedu)	Urban landfill (Kundang)
Age of landfill	9 years	13 years	12 years
Putrescible waste	58.67 ± 20.89	51.60 ± 11.89	42.02 ± 9.67
Paper	10.55 ± 2.52	10.90 ± 10.63	12.90 ± 5.32
Plastic	15.86 ± 1.89	18.60 ± 2.06	24.74 ± 4.11
Rubber	1.24 ± 1.07	3.00 ± 0.88	2.45 ± 1.27
Textile	3.59 ± 1.04	2.50 ± 1.39	2.48 ± 1.76
Metal	3.21 ± 0.33	3.90 ± 1.38	5.30 ± 3.18
Glass	2.18 ± 0.76	2.90 ± 1.0	1.84 ± 1.06
Wood	0.54 ± 0.36	2.00 ± 0.60	5.74 ± 0.64
Others, such as disposable diapers	4.16 ± 3.53	4.60 ± 0.70	2.53 ± 1.92

4 Changes in Management

Development of solid waste management programmes in Malaysia has taken place in phases. Up till the end of 1970s, the municipal solid waste management was quite primitive. Local district health offices were only to clean the streets and to haul away household wastes to municipal disposal sites assigned as authorized dumping ground.

Local Authorities (LA) were the main bodies responsible for the operation and management of solid waste on the ground. The LAs are mainly empowered through Provisions under the Streets, Drainage and Building Act 1974, Local Government Act 1976 and the Town and Country Planning Act 1976. The three types of LA in Malaysia comprise of City Halls, Municipal Councils and District Councils. Solid waste management in the LAs is handled by the Department of Urban Services. However, the privatization of solid waste management in the LAs, has delegated this function of solid waste management from some of the LAs to the private waste managers.

Therefore, the existing role of the LAs in terms of solid waste is evolving towards the enforcement of solid waste management rather than in providing solid waste management services. The LAs also act as the liaison between the public and the private waste managers in areas where the waste managers have taken over through the indirect billing system. In these areas, the public pays the LAs for the solid waste management services in their annual assessment, which the LAs then reimburse to waste consortiums. The LAs also monitor the private waste managers to ensure that they meet the required standard and quality of service.

Privatization in Malaysia was initiated as a national policy in 1983, to transfer responsibility and functions from the public sector to the private sector (Zainal 1997). The aim of privatization is:

- to relieve the financial and administrative responsibility of the government
- to improve efficiency and productivity
- to facilitate economic growth
- to reduce the presence of the public sector in the economy, and
- to assist the country in meeting its' national development policy goals.

The objective of privatization was to provide an integrated, effective, efficient, and technologically advanced solid waste management system. It is also expected to resolve the problems in solid waste management faced by the LAs such as finance, lack of expertise, illegal dumping, open burning and lack of proper solid waste disposal sites. Therefore, four private waste managing consortiums were appointed for the whole country, which are:

- Alam Flora Sdn. Bhd., which is responsible for the central and eastern regions (the Federal Territory of Kuala Lumpur, Selangor, Pahang, Terengganu and Kelantan). Their involvement in the latter three states is somewhat limited or totally nil.
- Northern Waste Industries Sdn. Bhd., which is responsible for the northern region (Perlis, Kedah, Penang and Perak). This consortium is non-functional and has been replaced.
- Southern Waste Management Sdn. Bhd., which is responsible for the southern region (Negeri Sembilan, Melaka and Johor) and
- Eastern Waste Management Sdn. Bhd., which is responsible for East Malaysia (Sarawak, Sabah and Federal Territory of Labuan).

At present, the privatization of solid waste management is carried out as an interim management agreement between the LA and the concessionaires concerned, where during the period, the level of services provided should not be less than that given by the LA. Generally the process of privatization shifted the burden from the LA to the waste consortia. Nevertheless the level of waste management services has been significantly improved with modern transporting vehicles and sanitary disposal sites.

5 Changes in Disposal Technology

In Malaysia, waste management trend has not experienced much change. In 1970s, MSW were mainly collected by the LAs to be dumped into the assigned disposal sites, which were operating as a typical open dumping ground. However, with changes in environmental consciousness in the 1980s and 1990s, and with the stipulation of various acts and regulations, waste disposal into the dumping ground was monitored to prevent accidents like fire and landslide. Regulations which concern solid waste disposal vary from one country to another (Lu et al. 2006; Gidarakos et al. 2006; Hui et al. 2006; Harison and Richard 1992).

In Malaysia the concern was more on pollution control. It was only in recent years that more attention was focused on the solid waste management issues, when the impact of improper management was considered a highly potential risk of pollution, that alternatives for waste disposal were suggested. Among the most controversial issue was the construction of incinerator plants to cater the ever increasing rate of waste generation. The ever increasing waste generation shortens the span of a landfill that more and more new area has to be converted into disposal sites.

With the population expansion experienced throughout the globe, scarcity of land had caused price of land to increase constantly. With less and less land available for development, other alternative options were seriously looked into. This includes the land-reclamation option. Land use subjected to reclamation includes ex-mining land, wetland, ex-landfill and coastal area (Misgav et al. 2001). Reclamation of land has been practiced in many places including London (Greenwich/Plumstead), Boston, Macau and Hong Kong (Karakiewicz and Kvan 1997). Malaysia had reclaimed approximately 1,214 ha of land in the coastal region in order to provide more space for urbanization (Karakiewicz and Kvan 1997). Variety of materials can be used to reclaim land. Among the most commonly used are the construction and demolition wastes which generally consisted of inert materials such as brick, cement and others. In developing nations, filling up 'unwanted' area for reclamation purpose is sometimes conducted with the dumping of municipal solid waste. However problems arise later such as H_2S emission or As and Hg contamination of soil. These will be discussed later in the case studies.

The problem of MSW disposal is likely to become more acute with the land available for landfills becoming scarce. In addition, landfill sites must be environmentally and socially acceptable so as to avoid any untoward problems and must be sufficiently buffered from human settlements to prevent odor, health risks and groundwater contamination.

In 1990, there were about 230 waste disposal sites in Malaysia with an average area of 15 ha (Table 6). More than 80 % of these sites had a remaining operating lifetime of less than 2 years.

The management and operation practices at most of these sites were relatively poor. About 60 % of these sites were open dumps and thus did not have

Table 6 Number of landfill sites in Malaysia throughout 1990–2009

Years	1990	1998	2003	2009
Total	230	177	144	270

*including illegal dump

appropriate studies, lack of cover materials, inadequate facilities like weighbridges and fencing, and lack of pollution control measures including leachate and gas emissions piping systems. Lorries and trucks collected waste and transported them directly to the disposal sites with no waste recovery system. Thus, the currently practiced system has caused recovery of reusable material impractical and would shorten the life span of the existing landfills (Fauziah and Agamuthu 2003).

There are many challenges and issues faced by Malaysian MSW managers particularly in dealing with the disposal sites. The traditional waste management system practised by local governments and the municipalities was inefficient and was very unsustainable when Malaysian waste generation per capita increased to 0.5 kg in the late 1980s and to more than 1.3 kg of waste in 2009 (Agamuthu et al. 2009a, b; EPU 2007). In certain cities like Kuala Lumpur and Petaling Jaya, the generation increased to 1.5–2.5 kg per capita (Agamuthu et al. 2009a, b). To date, annual waste generation in Malaysia has reached 11 millon tonnes with more complex and heterogeneous compositions mainly with putrescible waste (557 %), paper (13 %) and plastic (19 %) (Fauziah and Agamuthu 2009a, b). The smaller portion of the waste contained wood, rubber, metal, glass, textile and miscellaneous with the contributions of 7, 2, 4, 3, 3 and 0.5 %, respectively (Fauziah and Agamuthu 2004).

World Bank (1999) reported that waste management is one of the three major environmental problems faced by most municipalities including those in Malaysia which is closely related to the unsustainable landfilling practices. In 1998 alone, 228 licensed dumping sites were reported to the Ministry of Science Technology and Environment of Malaysia, and these caused contamination to the surrounding areas (Haznews 1998). This was due to the fact that project developers and local authorities failed to adhere to the guidelines stipulated for the development of a disposal site. Various factors influenced the management of a landfill. Among others is human factor which include attitude problems and public participation.

Human factor plays an important role in establishing an appropriate management of a landfill. This is due to the fact that human activities are the main generators of waste that requires proper treatment system. In more environmentally-concerned nations, positive attitude leads to high public participation in matters concerning the environment. Therefore, implementing strategies that involved the public, such as source separation, can be achieved in due time. As a result, wastes can be managed efficiently and landfills are more sustainable, with longer life-span and operating period.

Although Malaysia is a country with rapid economic development, public participation in environmental issues is very low. Though various campaigns such as recycling adverts have been launched to instil the awareness among Malaysians, it failed to mould the community to respond positively. The concern and awareness among the public in Malaysia are not parallel with the living standards that their participation towards sustainable waste management such as 3Rs is severely lacking. Currently, official recycling was only at 5 % (though estimates indicate up to 15 %). Studies indicate that more than 70 % of Malaysians are aware of recycling concept but less than 25 % are actually participating in 3R activities (Irra 1999; Fauziah et al. 2009). More than 70 % Malaysians implied that they refuse to recycle since the recycling facilities provided is insufficient while 65 % indicated that recycling is an inconvenient practice for them (Fauziah et al. 2009). As a result, more than 80 % of the recyclables in the waste stream are disposed off into landfills. This caused the volume of MSW to increase at 3 % per year rather than decrease with efficient recycling practices.

In addition to that, illegal dumping has become a serious matter to be tackled by waste managers (Agamuthu and Fauziah 2011). In 2003, 500 drums of paint sludge and glue were dumped illegally at a ravine in an isolated disused land that more than RM12 million (US$3.4 million) was spent for the cleaning-up (The Star 2002). In the Klang Valley alone, more than 52 illegal dump sites or 'hotspots' were reported to accumulate more than 933 tonnes of waste. The wastes cleared from these illegal dumping sites are sent to landfills that consequently landfill space will be exhausted earlier than anticipated. As a result, it hinders the practice of sustainable landfilling as wastes collected did not undergo any pre-treatment prior to disposal. This un-planned activity will increase the management cost of the landfills that existing practice is no-longer sustainable. The occurrence of illegal dumping is generally due to the 'not bothered' attitude among the waste collectors whose main concern is to profit from their illegal action.

Also, the NIMBY (Not In My Backyard), LULU (Locally Unacceptable Land Use) and NOTE (Not Over There Either) syndromes are very intense among Malaysians that siting of landfill on appropriate site becomes extremely difficult. Similarly with the construction of pre-treatment facilities such as compactor stations and transfer stations, it was always sturdily opposed by the public and non-governmental agencies (NGOs) (Agamuthu et al. 2009a, b) The strong resistance from the public towards new waste management or disposal facilities had caused the siting of a landfill to move further away from city center that developing the area incurred higher cost for the construction of non-existing infrastructures.

Even though Malaysia is a developing country with progressive economy, economic constraints are among the issues to be tackled in establishing sustainable landfilling practices. From the economic point, the challenges arise from lack of funding and the increase in the price of land.

The lack of financial assistance from the government for waste management in Malaysia had prompted in well-established and multinational company to bid for tender in providing waste treatment and disposal facilities. As a result, sanitary landfills in Malaysia are only owned by companies such as Worldwide Landfill Sdn. Bhd., Alam Flora Sdn. Bhd. and KUB Berjaya Environ Sdn. Bhd which belong to established companies namely Worldwide Holdings Bhd., DRB-Hicom Holdings Bhd, and Berjaya Corp Bhd., respectively. The waste management in the country seems to be monopolized by these companies when the actual issue of concern for other waste companies is the unavailability of financial aid to bid. To make matters worse, the existing National Policy on waste management in the country discourages financial institutions such as banks to invest in waste management projects. Therefore, waste managers with small capital are impeded from improving their disposal sites. Loans from banks are unavailable that smaller waste management companies will have no opportunities to venture into the establishment of sustainable landfills. As a result, most waste managers normally aimed for "just enough" to comply with the regulations instead of "self-sustained landfills". In addition to that, the increase in the price of land has resulted with new landfills being located at areas with very minimal infrastructure or none at all in order to minimize the capital cost of the landfill.

The fact that landfills are seen as a mere burden and not as a commodity in Malaysia is another aspect that impedes establishment of sustainable landfills. This is because landfills are mere disposal sites for waste that once a landfill is closed, it retains no further economic value. Typically this resulted from the fact that the revenue from tipping fees is no longer available for the landfill managers once the landfill ceased its operation. The absence of gas harvesting system resulted with landfill not being able to generate revenues from methane conversion. Collection of landfill gas to be converted into electricity is not feasible and non-economical since most landfills in Malaysia are less than 60 ha in size. In addition, most of the landfills in Malaysia are non-sanitary landfills that rely mainly on natural clay lining as the landfill liners. The establishment of these disposal sites were mainly based on the traditional concern of getting rid of waste. These landfills are not designed with the intention to generate resources such as methane to profit the landfill managers. Therefore, existing non-sanitary landfills in Malaysia only practice passive release of landfill gas where the installation of gas pipes are done as the waste cells are receiving waste.

Only the newly established landfills are designed with appropriate landfill liners to prevent leachate migration to the groundwater system and suitable gas collection system to harvest the gas. Air Hitam Sanitary Landfill, the first sanitary in Malaysia produced 2 MW of electricity from the conversion of methane. Similarly, newer sanitary landfills are capturing landfill gas for the purpose of energy conversion. However, the national policy on energy practiced by the country fails to enhance this green approach. This is due to the low price of electricity in the country where the electricity tariff for Malaysia ranges from RM0.15 (US$0.05) to RM0.43 (US$0.13) per kWh (MIDA 2012). It is at a low end due to government subsidies. As a result, the electricity tariff deprived the market potential of electricity produced via the conversion of landfill gas.

Aside from economy, the existing policies in the country also make sustainable landfilling difficult to achieve. This institutional factor also becomes a major issue of concern. Institutional factor hampers the practice of sustainable landfilling in the country due to the lack of proper waste management policy. The absence of an appropriate policy hinders the implementation of an integrated waste management system in Malaysia. As a result, 3Rs is not mandatory and waste separation is totally absent. Though the MSW stream contains significant amount of retrievable materials, non-existence of source segregation makes resource recovery very costly. In addition, the waste disposed into landfills in Malaysia is highly commingled with wet and putrescible components that moisture content of the waste may reach 70–80 %. This indiscriminate practice of non-separated MSW disposal into landfill is highly un-sustainable. It translates to the loss of valuable resources such as metal components, paper and plastics, and the degradation of the environment with increased environmental pollution from leachate and landfill gas. Aside from that, the un-sustainable practice also resulted with the shortening of landfill life-span where waste cells which can be optimized with only garbage also catering the recyclable items. As a result, a sustainable landfilling practice is not achievable.

Besides the lack of appropriate policy, waste management is also highly political. Competitions among the ruling parties in the countries are jeopardizing the waste management system. Since waste management is a very sensitive issue, it is usually used to fish votes among the people during election. Together with the indifferent attitude among the public, environmental concern including issues on appropriate waste management are impossible to experience improvement. Even the newly passed Solid Waste and Public Cleansing Management Act 2007 are ridiculed by opposing parties with the claim that the Act deprives public rights. This has resulted with the federal government ‘playing safe’ in passing statement regarding this issue as to avoid loss of voters in the coming elections. It is seen as the lack of political will of the ruling government to improve current waste management system. Thus, no voluntary effort was taken by most waste managers to improve the current state of their landfills. As a result, 90 % disposal sites in Malaysia remains as non-sanitary landfills which lack pollution prevention features such as bottom lining, leachate treatment and gas collection system. As most developing countries, more than 15 % of 187 million tonnes of Malaysian carbon emissions were contributed by landfill gases emission.

On the other hands, landfills often cause concern and fear among the community residents. Water pollution, both surface and ground water, gas explosion and odor are some of the common impacts caused by presence of landfills. Generation of landfill leachate remains an inevitable consequence of the practice of waste disposal in landfills. Leachate often contains high concentration of organic matter and inorganic ions including heavy metals and therefore highly contaminating. The subsequent migration of leachate away from landfill boundaries and the release to the adjacent environment for example water bodies is a serious environmental pollution concern and a threat to public health and safety.

The composition of landfill leachate exhibits spatial and temporal variations depending upon site operations and management practices, refuse characteristics, internal landfill processes as well as age factor (Hoeks and Harmsen 1980). Research shows that the concentration of many constituents in landfill leachate decreases with refuse age (Table 7). Leachate concentration peaks when landfill life is within 2–3 years of refuse placement and gradually declines in ensuing years.

Table 7 Characteristics of raw landfill leachate

Parameter	Jeram sanitary landfill	Bukit Tagar sanitary landfill	Panchang Bedena disposal site (rural)	EQA 1974 standard 2009
BOD_5 (mg/l)	27,000	26,379	348	20
COD (mg/l)	51,200	36,413	5,056	400
pH	7.35	6.6	8.1	6.0-9.0
TSS (mg/l)	NA	14	1.6	50
Cd (ppm)	NA	7	ND	0.01
Cu (ppm)	NA	7	1.0	0.20
Pb (ppm)	NA	13	41.7	0.10
Zn (ppm)	827.7	31	675.7	2.0
Mg (ppm)	32	59	36,533.3	NA
K (ppm)	1,130	923	NA	0.05
Ammoniacal-N (mg/l)	0.085	4,329	NA	5
Hg (ppm)	0.05	NA	NA	0.005
Fe (ppm)	97.76	74.0	NA	5.0

NA Data not available, *ND* Elements not detected

Landfill leachate, in many cases, is highly contaminating and can degrade surface and ground water resources. In Malaysia, the traditional source of drinking water had been surface water. It is therefore very important that municipal landfill is properly sited, designed, managed and maintained so that the sources of water are protected from leachate pollution.

6 Changes in Awareness

The concern over waste management and disposal parallels an increased appreciation of the concept that people, as the custodians of the environment with waste production being increasingly regarded as an antisocial activity rather than as the necessary and inevitable consequence of the demands of a consumer society. Public has the main task in creating an efficient waste management system since they are the main stakeholders that generate volumes of waste. Their participation and awareness regarding environmental issues is very crucial to ensure the success of proper waste management systems. Urbanization improves the standard of living and the transformed population consumed goods and services at a more rapid rate, which increases the rate of waste generation as well. In Asian cities, waste generation is projected to escalate to more than 1.8 million tonnes per day in 2025 when more areas are urbanized.

Even the best waste management system would not succeed without the participation of the public. Obviously, the public plays an important role in improving the environmental state of a nation due to the fact that public is the main stakeholder in this issue. The level of environmental awareness of the society would determine the effectiveness in public participation towards environmental matter. Studies based on questionnaires and interviews were conducted at nine landfill areas throughout Selangor, the fastest developing state in Malaysia, to establish the level of environmental responsiveness among the public regarding MSW related issues.

Approximately 84 % of the respondents from all levels of urbanization knew the meaning of recycling, however, the practice of recycling was quite low with the respondents from sub-urban areas being less responsive than those from urban and rural areas (Suite101.com 2003). The high percentage of the knowledge among the respondents probably was contributed by the effectiveness of campaigns launched by the ministry, the local government and the NGOs. Among the sub-urbanites, there was high level of environmental awareness but their participation in environmental programs is very minimal. This possibly was contributed by the fact that most of them 'do not walk their talk'. 56 % of the respondents from both rural and urban areas participate in recycling activities, generally more encouraging than the sub-urban population. The presence of more recycling centers in urban areas and recycling personnel among the rural community would probably enhance recycling rate.

Majority of the respondents agreed with the suggestion to establish more recycling centers in order to encourage recycling activities. Willingness to separate waste for recycling purposes was high, with rural respondents giving highest percentage (68 %) as they would have more time to spare for the activity. This is followed by the urban respondents particularly when recycling is convenient with the establishment of recycling center and it gives good monetary returns. Generally, more than 50 % of the respondents from all areas are willing to pay more for environmental friendly products possibly because most of them possess some knowledge on environmental issues and somewhat aware of the serious environmental degradation. A percentage of 98 % are willing to follow the regulations imposed by the government, if the implementation would improve the environmental quality in Malaysia.

This indicates the importance of environmental policy implementations to improve the environmental state as majority of the respondents felt that they need to oblige with the government's ruling. In conclusion, it can be stated that awareness related to MSW issues existed, however more steps should be taken to increase the participation of the public to seriously improve the quality of the environment.

In 1970s, with very low generation of MSW, the issue was not considered critical that very minimum attention was focused on creating awareness among the public. However, as the generation increased steadily over the years, the government had realized the solidness and seriousness of MSW problems in the country that more campaign were launched to establish awareness and to create environmental consciousness among the general public. During the 1980s, the government had launched various campaigns including the introduction of the Action Plan for A Beautiful and Clean Malaysia in 1988 and recycling campaign in the consecutive years. However, due to a very minimal response from the general public, the campaigns failed, though the awareness among the public increased slightly.

A survey carried out in 1999 showed that, 59 % of the respondents are moderately aware, where, they have some basic knowledge and are mildly aware of solid waste issues. While this is relatively satisfactory, 10 % of the respondents have no knowledge and are unaware of MSW such issues. Result on "willingness to co-operate and/or participate in recycling programs" survey shows that, only 55 % of the respondents stated their willingness as opposed to 45 % who are were unwilling.

Over the years, Malaysian awareness especially in recycling campaigns is increasing. A survey showed that 93 % of Malaysian are aware of recycling program (Fauziah and Agamuthu 2004). However, from the 93 %, only 28 % Malaysian practiced it through source-reduction. The survey indicated that, the most preferable method Malaysian recyclers do recycling are by selling the recycle materials to door-to-door itinerant buyers (72 %). Above survey also showed that, only 20 % of Malaysians were aware about waste minimization campaigns, which is comparatively low with recycling campaigns (93 %).

On the other hand, average of 58 % Malaysian practiced home-based reuse activities such as; repair old materials, donate to others to reuse it, sells as recyclable items and use disposable items different from initial purpose (e.g. use milk tins to store dry food products). It's believed that, awareness in waste minimization campaigns will increase with more waste minimization facilities provided to public and more waste minimization activities implemented.

7 Changes in Recycling Activity

Recycling and resource recovery from MSW occurs at a minimal level, where the national rate of recycling is estimated at 1–2 % of the total waste stream. It is mainly conducted by scavengers and municipal waste collector crews. Currently, recycling is initiated by LAs and NGOs. In 1993, the MHLG launched the first National Recycling Program involving 23 LAs with the main aim to reduce waste disposal and promote resource recovery concept (Kamariah 1998). However, the performance was very poor with only 10 LAs succeeding that a second National Recycling Program was initiated in November 2001 (Kuman and Abdullah 2002).

Currently it is estimated in Petaling Jaya, more than half of the collection crews are involved in retrieving recyclable items reaching approximately 24.5 tonnes/day or 5.2 % of the total waste disposed. Meanwhile, dumpsite scavengers in Petaling Jaya recycle about 3.9 tonnes of waste per day or almost 1 % of the total waste disposed. Consequently, the total resource recovery from the waste stream is about 28.4 tonnes of waste per day or about 6 % of the total waste stream. Reports also indicated that for the period of June 1999 to November 1999, as much as 50,660 kg of recyclable materials was recovered, valued at approximately RM4000.

Table 8 Recyclable wastes collected from year 1993–1998 in Malaysia

Years	Recyclable materials collected (kg)			
	Paper	Metals	Glass	Plastic
1993	446,713	79,169	55,803	48,584
1994	1,703,431	552,574	293,408	162,794
1995	338,699	78,389	1,865	18,771
1996	940,121	567,451	185,020	186,549
1997	260,667	13,600	0	4,010
1998	70,130	51	0	0

Source http://www.kpkt.gov.my/statistik/perangkaan2002

In Kuala Lumpur, approximately 672.3 tonnes or 22 % of the total waste stream were recyclable items, with paper contributing 41 % of the total recyclable items of about 3,000 tonnes/day. If properly recycled, the recovered resource would yield as much as RM55, 260.00 daily.

Based on the figures for Kuala Lumpur and Petaling Jaya, it is anticipated that the potential for maximum resource recovery through recycling is approximately 22 % while potential for recourse recovery through scavenging reached 6 % indicating that recovery through recycling is a growing industry and is profitable.

Realizing the market for recyclable materials, the draft Concession Agreement between the private managers and the Government set targets for waste diversion and recourse recovery. The interim targets aim to achieve a 3 % recycling rate in 2003 and consequently a 1 % increment annually to achieve a 22 % recycling rate in 2020. Table 8 shows that there were no trends in recycling activities and the amount of recyclable materials collected were high in the beginning but decreased over the following years and some reached zero.

8 Changes in Economics of Waste Management

Table 9 shows the National Waste Treatment Goal. Malaysia currently only depends on landfill method for waste disposal. Average disposal cost is RM30 per tonne of MSW while an estimated RM400 million was spent to landfill 7.8 million

Table 9 National waste treatment goal and current scenario in Malaysia for the year 2002

Treatment	Malaysia	National goal		
	2002	2001	2005	2020
Recycling	5.0	3.0	7.0	22.0
Composting	0.0	0.0	4.0	8.0
Incineration	0.0	0.0	11.9	16.8
Inert landfill	0.0	0.0	9.2	9.1
Sanitary landfill	95.0	97.0	67.9	44.1
Total	100.0	100.0	100.0	100.0

tonnes of MSW in 2003. The disposal cost will increase since MSW generation is increasing annually at the rate 2–3 %.

Once thermal treatment plant (incinerator) in Kuala Lumpur is ready for operation, it is expected to manage 11.9 % of MSW in 2005 and 16.8 % of MSW in 2020. Number of landfills will reduce when the incinerator is in operation.

Waste-to-Energy technology like Refuse-Derived-Fuel (RDF) is now in pilot-scale research phase in Kajang, Selangor. It is expected to convert about 30 % of the MSW to RDF fuel pellets with the market price of RM50 per tonne.

Based on National Waste Treatment Goal (Table 9), increase in recycling and composting activities will generate more revenue from recycled materials and compost. Recycling and composting industries would create more jobs and investment opportunities too.

Positive change has also been seen in the energy sector as the Malaysian government is promoting the utilization of renewable energy. This is possible with the high potential of biomass from agricultural wastes (estimated at 665 MW) and domestic waste for energy conversion. Table 10 details the current energy dependency according to sources.

With the implementation of the Renewable Energy Policy in 2010, wastes have been identified as a potential source for renewable energy as detailed in Table 11.

Nevertheless, there are various issues and challenges in the utilization of waste and biomass as energy sources. Table 12 details these major issues in Malaysia.

However, it is hoped that the newly proposed policy under the Renewable Energy/Malaysia Building Integrated Photovoltaic (MBPIV) of Ministry of Energy, Green Technology and Water would pave better future for waste and biomass utilization as renewable energy sources.

Table 10 Sources of energy supply in Malaysia

Energy sources	Reserves	Duration of production (years)	Production capacity
Oil	400 Mt	10	Decrease (35 Mt against 39 Mt in 2003)
Gas	2,500 Gm^3	50	Increasing rapidly and reached 61.5 Gm^3 in 2006
Coal	1 Gt	–	–

Table 11 Cumulative quota on renewable energy capacity (MW)

Year	Biomass	Biogas	Mini-hydro	Solar PV	Solid waste	Total
2011	110	20	60	9	20	219
2015	330	100	290	65	200	985
2020	800	240	490	190	360	2,080
2025	1,190	350	490	455	380	2,865
2030	1,340	140	490	1,370	390	4,000
2040	1,340	410	490	7,450	410	10,100
2050	1,340	410	490	18,700	430	21,370

Table 12 Issues arising from the utilization of biomass and waste as energy sources in Malaysia

Factors	Issues
Policy barriers	Limited incentives on biomass utilization
Supply and demand	No reliable data on actual potential of biomass slow implementation of 5th Fuel Policy (RE, including biomass) Limited effort to regulate and enforce biomass programs
Environment	Current technologies are inefficient and polluting
Financial and technical	High initial investment Limited local technologies and equipment Poor financial support, no record on biomass industry
Institutional barrier	Limited coordination among the local agencies Unwillingness of the industry to change and to be proactive

9 Policy and Regulations for MSW

9.1 Solid Waste Management and Public Cleansing Management Act

The 88 pages Solid Waste and Public Cleansing Management (SWPCM) Act were under review for more than 10 years before it was finally approved in July 2007. The main objective of the Act is to improve and ensure high quality services in managing solid waste. The Act which is adapted from Best Management Practices in solid waste management i.e. from Japan, Denmark, Switzerland, Germany and United States, focused mainly on public cleanliness management. The main strategies are to tackle the 3R issues namely reduce, reuse and recycling of solid waste, interim treatment and final disposal of solid waste. It includes amenities from roads and toilets to drains, food courts and grasses by the roadsides. Main features of SWPCM Act:

- With the passing of the Act, the authority over solid waste and public cleansing is shifted from states and local authorities to the federal government.
- The cost of waste management will be shared between the federal government and the local authorities where this will allow the local authorities to be rid of waste management cost by directing funds to a federal corporation.
- The functions of the appointed Federal Corporation cover the whole aspect which is deemed necessary in ensuring the implementation and the success of an effective solid waste management.
- The Act covers solid waste from commercial centers, public sites, construction sites, households, industrial zones and institutions, as well as, imported solid wastes.

9.2 Funding

In order to cope with expenditure in waste management cost, a fund has been administered. The Solid Waste and Public Cleansing Management Corporation Fund consist of:

- income of the Corporation from investments
- allocations provided by the Parliament for the purpose of the management of solid waste and public cleansing
- income sourced from property of the Corporation
- consultancy fees from services provided by the Corporation
- other sources
- loan money by the Corporation
- money earned from operation of projects
- donations and contributions received from any sources
- other money lawfully obtained by the Corporation.

The financial issues are to be tackled in a very sensitive manner so as to ensure that this issue will not become the major drawback of an effective waste management system. This is very crucial as the privatization of the solid waste management system from 1980s to early 2007 failed due to lack of budget and the inability among some of the concessionaires to generate income to cover their expenditure. The interim agreement with the concessionaires prevented the companies from expanding investment and obtaining bank financing (Tan 2007).The inclusion of the financial section in the Act is hoped to overcome this problem thoroughly.

9.3 Payment

Punitive measures are provided in the Act to tackle problem of consumers who refuse to pay the waste disposal fees. The failure of a person to settle the collection fees will allow the licensed concessionaire to take the case to the Tribunal for Solid Waste Management. A fine up to RM5,000 (US$1,316) and RM50 (US$13) for each day of the continuation of the offence is proposed.

9.4 Responsibilities of Waste Generators

The Act also listed the responsibility of the waste generator to conduct waste separation in order to promote recycling and retrieving valuable components from the waste stream. Under clause 74 of the Bill, it is an offence if a person fails to separate the waste generated by the premises. By committing the offence and upon conviction the person is liable to a fine not exceeding RM1000 (US$263).

9.5 Enforcement

In terms of enforcement, it is also improved with the enforcement provision clause in Part IX of the Solid Waste and Public Cleansing Management Bill. According to the clause, an authorized officer may:call for, examine, make copies or extract any book, document, instrument or record which is in custody or control of any person pertaining to any matter under the Act;

- visit, enter, inspect and examine with or without previous notice any solid waste management facilities;
- investigate to ensure proper maintenance and sanitation, matters related to safety and health, the effects of any operation or practice, presence and accumulation of noxious gas, in any solid waste management facilities, land or other premises;
- take samples of any material found at the solid waste management facilities on land, water or air.

Upon failure to comply with the regulations stated in the Act, the convicted solid waste management facilities can be ordered by the court to cease its operation. The authorized officers are also empowered to stop, search and seize vehicles suspected of carrying anything prohibited by the regulations. This is meant to curb the increasing rate of illegal dumping faced by the local authorities. A stricter penalty can be imposed on a person upon conviction of this offence, which includes RM10, 000 (US$2,632) or less than 6 months imprisonment or both. With continuous offence, offender is liable to a fine not exceeding RM1000 (US$263) for everyday or a part of a day during which the offence continues after conviction.

9.6 3R

The implementation and enforcement of 3R are also listed in the Bill under Part X where solid waste generators are required to reduce the generation of solid waste, to use environmental friendly materials, limit the generation, import, use, discharge or dispose specified products, implement coding and labeling on products to promote recycling, and utilize any method to reduce adverse impact of MSW on the environment and to reduce, reuse and recycle MSW. Failure to comply will subject the offender liable to a fine not exceeding RM10,000 (USD2,632) or imprisonment not exceeding 6 months or both.

With the source separation, the authority targets to reduce 40 % MSW sent to the landfill. Aside from material recycling program, other waste management technologies have been identified. Among others are anaerobic digestion, composting and thermal treatment. The diversion of MSW from landfilling is very crucial as the generation of pollution from disposal sites is inevitable and the risk increase significantly when disposal sites lack of appropriate pollution confining measures such as landfill liners and leachate treatment system.

Various campaigns have been organized since 2000 to promote 3R activities among Malaysians. However, the recycling rate in particular has been very low and was not able to significantly reduce the volume of waste sent to landfills for disposal. Nevertheless, unofficial recycling was found to be more than 15 % of the total waste generated. Yet, the refusal of the unregistered recyclers to participate in the data collection has disabled the capability of the authority to capture the actual recycling rate in the country. Thus, extensive campaigns have been launched since September 2011 to promote proper recycling activities. This campaign involved various mass media including advertisement in television, radio and websites. The recycling target for 2020 is 22 %.

Additionally, a range of incentives have been introduced to encourage the public to participate in the 3R activities. Promotions of these activities were carried out in schools and learning institutions, in government offices and residential areas, and in public places such as hypermarkets and shopping complexes. The promotion of the 3R activities also involves the participation of voluntary bodies including the non-governmental agencies (NGOs) and residential associations. Apart from recycling and the 3R activities, the authority also strategized the possibility of converting waste to value added products. In order to formulate the strategies

Among the options taken into consideration by the authority to divert the MSW by 2015 are biological treatments of organic waste and thermal treatments. A major discussion was organized by authority recently from end of March 2012 to mid April 2012 which indicated their seriousness in finding most appropriate technologies to solve the MSW issues in Malaysia. The discussion involved more than 150 stakeholders including relevant government agencies, research institutions, industrial sectors and private entities in waste management, NGOs, media and others. The outcomes of the discussion include the identification of several strategies to be implemented by the government to enable the reduction of 40 % MSW sent to landfill and the reduction of greenhouse gases by 38 %. Results obtained from the 3 weeks discussion were disseminated to the public via the authority Open-day Events. The events were held at four main cities in Malaysia.

Composting and anaerobic digestion are found feasible due to the fact that the technologies are rather simple and the resources are available. As for the capital investment, though composting plant incurs smaller capital than anaerobic digestion plant, the latter has bigger market potential. This is so as biogas is more marketable in Malaysia than MSW compost. This is due to the recent government policy that promote the generation of renewable energy including energy from waste. Yet, both options were thoroughly analyzed and the implementation of these technologies would be dependent on its suitability to the regions. The most recent progress in diverting organic component from the waste stream is the introduction of the co-composting of putrescible waste with the sewage sludge in the communal sewage treatment facilities in urban areas.

The diversion of organic components from the MSW stream was found viable through several feasible studies conducted throughout the country. However, the strategy to promote material recycling namely paper, plastic and metals was still being studied. Nevertheless, regulations stipulated under the Act is seen somewhat promising. This is so as the Act also introduced the take back and deposit refund systems. This applies to the manufacturer, assembler, importer or dealer to take back specified products for the purpose of recycling or disposal. Deposit refund system can be implemented in order to help the efficiency of the take back system. Upon failure to comply, a fine of up to RM10, 000 (US$2,632) or imprisonment up to six months or both can be imposed. Under the control of waste generation clause, unauthorized person are not allow to deposit, transport, separate or store MSW, or allow the escape of solid waste from their possession. A fine between RM10, 000 (US$2,632) and RM100, 000 (US$26,320) or jail term of up to 5 years can be imposed on any offender. This clause had removed the role of scavengers in increasing the rate of recycling in the country. Positively, this would prevent the adverse impacts related to sanitation to the scavengers and curb the larceny of valuable materials such as aluminum and iron-based components, which are frequently committed by irresponsible personnel.

Currently, there are eight regulations which have been enacted under the SWM Act 2007 though more are still in the draft stage and as such are still confidential. The eight existing regulations are as follows:

1. Solid Waste and Public Cleansing Management (Manner of Appeal) Regulations 2011
2. Solid Waste and Public Cleansing Management (Prescribed Solid Waste Management Facilities and Approval for Construction, Alteration and Closure of Facilities) Regulations 2011
3. Solid Waste and Public Cleansing Management (Compounding of Offences) Regulations 2011
4. Solid Waste and Public Cleansing Management (Licensing) (Management and Operation of Prescribed Solid Waste Management Facilities) Regulations 2011
5. Solid Waste and Public Cleansing Management (Licensing) (Undertaking or Provision of Collection Services for Household Solid Waste, Public Solid Waste, Public Institutional Solid Waste and Solid Waste Similar to Household Solid Waste) Regulations 2011
6. Solid Waste and Public Cleansing Management (Licensing) (Undertaking or Provision of Transportation Services by Long Haulage) Regulations 2011
7. Solid Waste and Public Cleansing Management (Licensing) (Undertaking or Provision of Public Cleansing Management Services) Regulations 2011
8. Solid Waste and Public Cleansing Management (Scheme for Household Solid Waste and Solid Waste Similar to Household Solid Waste) Regulations 2011.

The eventual implementation of these regulations will undoubtedly enhance waste management in Malaysia.

9.7 Policy Recommendation for Integrated Solid Waste Management in Malaysia

Policy Recommendation 1.

A National Integrated Solid Waste Management Strategy for Malaysia shall be formulated which will contain the mechanisms, goals and priority areas for action.

Policy Recommendation 2.

Legislation shall be developed to address Key Issues in Solid Waste Management.

Policy Recommendation 3.

Incorporation of Integration shall be done in the Solid Waste Management Process.

Policy Recommendation 4.

Utilization of Economic Instruments shall be emphasized to Reduce Solid Waste Generation and Increase Solid Waste Resource Recovery.

Policy Recommendation 5.

Development and Support of Market for Solid Waste Recovered Materials shall be intensified.

Policy Recommendation 6.

Communication of Information on Solid Waste Management shall be emphasized to all relevant stakeholders.

Policy Recommendation 7.

Promotion and Funding for Research and Development in Solid Waste Data and Solid Waste Management shall be emphasized.

10 Local Case Studies

10.1 Ampang Landfill (Closed Landfill)

Ampang landfill is located within Bukit Seputeh Forest Area, under the jurisdiction of Majlis Perbandaran Ampang Jaya (MPAJ). It is approximately 2 km from Hulu Langat town. Solid waste from Ampang and Hulu Langat areas had been disposed at this landfill since 1980s. In 1995, the average amount of solid waste dumped in this area was 287 tonnes/day. This landfill was merely an open dump and lacked proper leachate and gas collection system. In 1998, two major incidents involving landslide and fire took place and due to safety reasons this landfill was later closed. Table 13 presents the characteristics of the landfill leachate during its active stage and after it was closed.

In general and as expected, the pollution strength of the leachate reduced after the landfill was closed and this enhances the leachate quality, ranging between 1.9 and 91.4 %. BOD reduced 91.4 % reduction from 1,025.8 mg/l during landfill operation to 87.8 mg/l after the landfill was closed while COD was reduced

Table 13 Characteristics of Ampang landfill leachate before and after closure

Parameter	Before closure	After 5 years of closure	DOE standard		Percentage of reduction
			A	B	
BOD5 (mg/l)	1,025.8	87.8	20	50	+91.44
COD (mg/l)	3,087.5	1071.5	50	100	+65.2
pH	7.85	7.7	6–9	5.5–9.0	+1.9
Turbidity (NTU)	224	125.5	–	–	+43.97
TSS (mg/l)	618.0	194.0	50	100	+68.6
Hardness (CaCO3) (ppm)	680	510	–	–	+25.0
Sodium (ppm)	687	315	–	–	+54.1
Chloride (ppm)	2,500	1200	1.0	2.0	+52.0
Kalium (ppm)	785	350	–	–	+55.4
Magnesium (ppm)	35	9.1	–	–	+74.0
Plumbum (ppm)	0.030	0.027	0.10	0.5	+10.0
Ferum (ppm)	45	22	1.0	5.0	+51.1
Manganese (ppm)	0.187	0.041	0.20	1.0	+78.1

65.2 %. The quantities of Fe were found to be generally high compared to other municipal landfills. This is probably because of large amount of scrap metals disposed in this landfill.

Other parameters for example pH was found to be neutral in the leachate collected from the closed landfill, whereas during its active life, the leachate was found to be slightly acidic. This is probably due to high production of acids from aerobic and anaerobic degradation by indigenous microbes.

The heavy metals content in the leachate were above the standard stipulated in the EQA 1974. Mg concentration in the leachate was 35 ppm before closure and 9.1 ppm, after closure, while the Environmental Quality (Sewage and Industrial Effluents) Regulations 1979 sets its limit as 0.2 ppm for Standard A. However, the concentration of heavy metals reduced 50 % after closure except for Pb. The consecutive sections discuss the issues related to the closure and post-closure of the four case studies in detail.

10.2 Air Hitam Sanitary Landfill

Air Hitam Sanitary Landfill was to accommodate the disposal of waste from Klang Valley with an annual capacity of 550,000 tonnes of MSW. It began its operation in 1995 and was originally planned for closure in 2007. However, the landfill space was exhausted in 2005 due to the 3 % annual increase of MSW with approximately 6 million tonnes of waste deposited. In addition, the encroachment of residential areas to the fringe of the landfill made it unsuitable to operate actively. Even though the raw leachate contained very high concentration of pollutants, the on-site leachate treatment facilities managed to remove and reduce the pollutant to the limit allowed. The quality of leachate discharged from this landfill adheres to the Malaysia EQA 1985.

The landfill gas system is also properly regulated and managed. It involved an active system where landfill gases were extracted from vertical wells. Approximately 30–40 % of the gases generated are CO_2 while 50–60 % are CH_4. Two landfill gas power generation plants utilized the extracted CH_4 from the landfill to generate 1 MW power each where it had been sold at RM0.30 (US$0.08) per kilowatt hour and 5 % royalty under a 15-year Renewable Energy Power Purchase Agreement. The landfill has become the blueprint of energy conversion technology with a capability of 2 MW. The closure of this landfill was conducted according to plan followed by post-closure procedures. The closure of the landfill involved the capping of waste cell with non-permeable liner which primarily containing PVC to reduce intrusion of precipitation, and the appropriate gas venting system to ensure a proper extraction of landfill gas. Post-closure procedures for the landfill include the layering of biocover and rehabilitation of the area with suitable plants.

10.3 Closure of an Open-Dumping Site

While Air Hitam landfill is a sanitary landfill, Kundang landfill was a mere open-dumping ground covering approximately 80 acres of land which has been operating since late 1996. This disposal site received approximately 300 tonnes MSW daily until 2005. The landfill area is lined with natural clay liner that a few ponds formed from depression of the geographical landscape and collects leachate. As a result, less importance was given to the management of the leachate. The landfill had no leachate treatment system and the leachate accumulated in the ponds was left unattended. Eventually, the leachate were mixed and diluted with surface water and flushed into the adjacent river, Kundang River. The characteristic of the leachate is indicated in Table 14.

Leachate analysis results indicated that approximately 280,440.00 g/day of COD were released into the river. Table 15 illustrates the amount of pollutant released daily.

Fortunately, due to the presence of the natural clay layer, the leachate was only contained in the ponds. Since leachate did not seep through, the groundwater system was left unharmed.

In October 2006, Kundang landfill was identified to be one of the contributors towards the incident of drinking water contamination in Klang Valley resulting in its immediate closure by the government. Immediate action taken by the landfill manager was to cap the waste cells with suitable covering material to prevent penetration of precipitation, followed by the capping of the whole area with geomembrane to further reduce leachate generation. Even though approximately 40 % leachate was reduced, leachate still contaminates the river adjacent to the landfill with minimal changes in the pollutants intensity.

Table 14 Characteristics of leachate from Kundang landfill

Parameter	Kundang landfill (urban)	EQA 1974	
		Standard A	Standard B
BOD5 (mg/l)	27.5 ± 0.7	20	50
COD (mg/l)	6232 ± 1824	50	100
pH	7.43 ± 0.04	6–9	5.5–9
TSS (mg/l)	0.06 ± 0.01	50	100
Hardness (CaCO3) (mg/l)	429 ± 240	–	–
Cd (mg/l)	Not detected	0.01	0.02
Cr (mg/l)	0.19 ± 0.02	–	0.05
Cu (mg/l)	0.003 ± 0.002	0.2	1.0
Pb (mg/l)	0.03 ± 0.01	0.1	0.5
Zn (mg/l)	0.06 ± 0.04	0.2	1.0
Mg (mg/l)	4.25 ± 0.42	–	–

Table 15 Impact on river pollution caused by leachate contamination

Parameter (g/day)	River adjacent to Kundang landfill
BOD5	1 238
COD	280 440
TSS	2.7
Hardness ($CaCO_3$)	19 320
Cd	Not detected
Cr	8.7
Cu	0.14
Pb	1.22
Zn	2.7
Mg	191

In addition to the lack of leachate treatment facility, this landfill also does not have a proper gas venting system. The only regulative measure taken by the landfill's management was installing vertical gas pipes. Approximately 7 m high, perforated PVC pipes with 25 cm diameter were erected throughout the landfill to allow passive release of the landfill gas into the atmosphere. The monitoring of the landfill gas throughout the landfill area indicated that these gases, particularly CH_4, ranged at a low level (0.05–2.0 ppm). The gases were released without any treatment.

Even though Kundang landfill is closed, it is still contaminating the environment. It is mainly due to improper planning of the dumping site at the initial stage that no precautionary measures were taken into consideration. At the current stage, grasses particularly *Bromus hordeaceus* were planted to avoid soil erosion. The area is left without any development plan since the issue of leachate is not solved. The closure of the landfill did not achieve the target to isolate the pollutants from contaminating the surrounding environment. This scenario is common throughout the country since most of the landfills which operated from 1980s were mere open-dumps. The reclamation of landfills for other types of land use can be made possible with proper post-closure procedures. The redevelopment of the ex-landfill is one example of reclamation for other land-use.

10.4 Ex-Landfill Used for Development

The ex- landfill which is located in Kelana Jaya district in Selangor was closed in 2000. It covers approximately 138 acres. More than 1.57 million m3 of MSW had been deposited of which contained 40 % organic materials. The area was a former tin mining pool that was used as a landfill since 1981 and currently, it is being developed into residential and commercial land. To complicate the matter, the area accommodates 70 % completed terrace houses, high rise apartments, and commercial buildings. No record of post closure assessment is available that the site is assumed not properly closed. Prior to the development of the area, most developers excavated and removed the deposited waste where only a small portion of the waste remained.

Leachate samples analyzed indicated that BOD5 averaged at 78 mg/l while COD at 230 mg/l exceeded the EQA Standard B limit (50 and 100 mg/l, respectively). However, it only concentrated at one main sampling point which is due to the presence of waste within the area. Groundwater analysis from the same area also indicated high TOC (460 mg/l) while pollutions at other groundwater sites were insignificant. There is a possibility of groundwater contamination with leachate that seeps from the remaining waste.

The surrounding soil was heavily contaminated with metal elements which exceeded the Dutch Intervention Value. Table 16 shows the results of surface and deep soil analysis.

The highest value among the elements in surface soil is arsenic (64.4 mg/kg). The elevated as level is probably due to the disposal batteries and industrial waste. Hg on the other hand was 11.5 mg/kg. This again could have originated from disposed batteries or fluorescent bulbs. The toxic nature of these elements warrants immediate remediation to prevent long-term effects on the occupants of the area. Although wastes have been removed from most of the development area, the residues from the wastes have migrated into the soil and contaminated the soil surface. As and Hg are of particular concern due to its highly toxic nature. Furthermore, contaminated surface soil may result in pollution of surface and ground water via run-off.

Gas analysis indicated that H_2S and CH_4 were below the detection limit with an exception at the site with waste. The exceptional site recorded 5 % LEL (equivalent to 0.25 % CH_4). The concentration of gas at the area is low and its emission was intermittent. The study indicated that pollution sourced from the area where waste has not been excavated yet. Therefore, rehabilitation and redevelopment of this area requires the wastes to be removed from the site. Also, the area can be justified as safe for residential and commercial purpose if contact to surface and deep soil can be prevented.

Table 16 Average concentration of metal and non-metal elements in surface and deep soil from the ex- landfill

Parameter	Unit	Surface soil (5 cm from ground surface)	Deep soil (5 m below the ground surface)	Dutch intervention standard
Phosphate	mg/kg	2.5–5.5	0–13.6	–
Flouride	mg/kg	2.4– 7.0	0.5–0.9	–
Sulfate	mg/kg	30.2–946.3	4.2–10.2	–
pH	na	5.8–9.9	7.3–8.2	–
Chloride	mg/kg	6.3–238.3	2.1–8.1	–
Nitrate	mg/kg	4.7–83.3	0.5–5.0	–
Nitrite	mg/kg	1.1–2.9	Not detected	–
Zn	mg/kg	7.7–129.8	Not detected	720
Sb	mg/kg	0–3.0	Not detected	15
Cd	mg/kg	0–0.6	Not detected	12
Cr	mg/kg	0.5–14.1	Not detected	380
Cu	mg/kg	2.3–17.3	Not detected	190
Pb	mg/kg	2.7–148.0	Not detected	530
Ni	mg/kg	0.3–5.0	0–9.0	210
Ag	mg/kg	0–1.2	Not detected	15
Tl	mg/kg	0–58.0	Not detected	15
As	mg/kg	8.8–64.5	0.3–2.7	55
Hg	mg/kg	0–1.4	8.5–11.5	10

While redevelopment of the ex- landfill is possible with appropriate measures, it is not yet occupied and preventive measures can be implemented to avoid exposure to toxic substances. However in the study area of the ex-mining land where people had been staying for the past few years, the improper reclamation causes detrimental effects to the resident.

10.5 Ex-Mining Area Used as MSW Dumpsite

The ex-mining area is located at the southern part of Petaling Jaya. Petaling Jaya is one of the fastest developing city that land price is excruciatingly high. Therefore, the city council had conducted an extensive reclamation activity on approximately 114 acres of the ex-mining pond. The objective of the reclamation was to allow the area to be more economically viable. Since the 1980s, the reclamation was carried out by filling the ponds with domestic, industrial, and construction debris. The absence of any enforcement had resulted with indiscriminate disposal of toxic and hazardous wastes too. As a result, tremendous amounts of H_2S are emitted to the surrounding area. The surrounding area was already developed and occupied that the release of this gas had caused a lot of problem to the residents. From the study, H_2S was recorded as high as 200 ppm. Figure 5 depicts the trend in H_2S emission over the past 3 years.

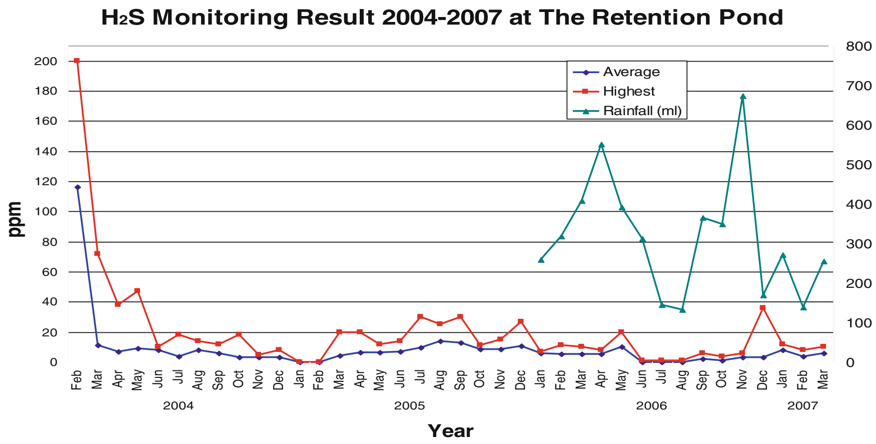

Fig. 5 H_2S emission from February 2004 to March 2007

Due to the improper regulation on the rehabilitation of the area, contamination to surface water by gypsum caused the release of H_2S to the surrounding area. The high concentration of the gas in the surrounding atmosphere also had caused very bad corrosion problem due to the H_2S conversion from gas form to sulphuric acid. Leachate contamination was also serious where some of the pollutants exceed the standard allowed by Malaysian EQA 1985. Table 17 indicates the concentration of the pollutants in leachate at four sampling points.

Table 17 Leachate analysis from four sampling points in the study area

Parameter	Unit	Range	Average	Standard B
BOD	mg/l	23.5–42.0	33.0	50
COD	mg/l	51.5–128.0	82.9	100
pH	–	4.7–7.1	6.5	5.5-9.0
Sulphide	mg/l	0.9–10.4	3.8	0.5
Ammoniacal-N	mg/l	13.4–17.8	16.1	Not available
Phosphate	mg/l	1.6–315.6	80.2	Not available
Sulfate	mg/l	55.0–132.5	101.6	Not available
Chloride	mg/l	22.1–37.8	27.3	Not available
Nitrate	mg/l	0–2,687.1	671.8	Not available
Cd	mg/l	Not detected	0.0	0.02
Cr	mg/l	Not detected	0.0	0.05
Pb	mg/l	Not detected	0.0	0.5
Fe	mg/l	0.1–16.3	4.4	5
Ag	mg/l	0–0.6	0.2	Not available
As	mg/l	0–0.3	0.2	0.1
Hg	mg/l	Not detected	0.0	0.05
Se	mg/l	Not detected	0.0	Not available
Ba	mg/l	0.2–0.3	0.2	Not available

Sulphide level was seven times more than the limit allowed. This has called for the need for proper monitoring of waste disposal activity within the area and stricter enforcement. The study has indicated that the water body was heavily contaminated with various pollutants that reclamation should only be conducted using inert materials. In order to stop the problem of H_2S release to the surrounding environment, drastic actions should be taken which include covering of existing drains, diverting the surface water channel from the ponds, and installing gas venting system. This is to ensure that the level of H_2S in the atmosphere can be brought down to a less hazardous level. The case study in this area proved that improper planning of the closure and post-closure of a dumping site can be very detrimental to the environment, particularly to the inhabitants of the respective area.

10.6 Landfill Cover Strategy for Leachate Management

In 2009, Malaysians generated more than 10 million tonnes of solid waste which were disposed off into 190 landfills/dumps throughout the country (Agamuthu and Fauziah 2010). Due to leachate contamination in the Klang valley water catchment in 2007, immediate ruling was ordered by the Federal government of Malaysia which saw the closure of many non-sanitary landfills adjacent to river and upgrading of operating landfills. These upgraded open dumps were installed with appropriate facilities to enable control tipping, and daily compaction and soil cover. However, the foundations of landfills are the same without lining system which allowed leachate and landfill gas to migrate to the groundwater system and the surface water.

The production of leachate is mainly due to infiltration of precipitation and groundwater intrusion (Bagchi 1994). Malaysian MSW landfill produced 150–200 l/tonne of leachate or approximately 2.1×10^7 l/day (Agamuthu et al. 2010). The leachate generation is enhanced due to the high moisture content of Malaysian waste at approximately 70 % (Agamuthu and Fauziah 2010). Additionally, Malaysia also received heavy rainfall of 3,000 mm annually. With more than 90 % of Malaysian landfills lacking engineering waste containment system, (e.g. compacted clay liner, geomembrane or geosynthetic clay liners) it allows precipitation to infiltrate into the waste cells to produce leachate. Therefore, it is crucial that landfills were covered appropriately with an effective landfill final-cover system, in order to reduce the infiltration of precipitation into the waste cells, and thus control the leachate generation. An evaluation to determine the effectiveness and the efficiency of different combinations of landfill final-cover systems in preventing water infiltration was conducted, based on water balance components (WBCs) which include surface runoff, evapotranspiration, lateral drainage, and leachate generated. Thus, the quantity of leachate generated reflects the performance of landfill besides other quantity of WBCs.

To determine leachate mitigation, a specific program namely Visual Hydrologic Evaluation of Landfill Performance (VHELP) was utilized. The program was designed to perform water balance analysis of landfill cover systems and the waste cells. The output included the rapid estimation of the amount of excess water or overflow, evapotranspiration, liner leakage, drainage and leachate collection that can be generated from the operation based on the water balances, while the input data (Petaling Jaya, Selangor) includes climate including growing season, average relative humidity, mean monthly temperatures, maximum leaf area index, evaporative zone depth and latitude, and landfill design (includes slope surface, maximum drainage distance, layer thickness and subsurface materials characteristics). Additionally, data for precipitation, air temperature and solar radiation were also included into five models as shown in Fig. 6.

10.7 Influence of Cover System Designs on Surface Runoff

T-2 cover system showed maximum quantity of surface runoff with a depth of 557.05 mm while T-1, T-3, T-4, and T-5 has 168.93 mm, 269.07 mm, 244.49 mm and 189.47 mm respectively. For T-2 cover system, the topsoil became saturated during rainfall due to the presence of geomembrane barrier of low hydraulic conductivity and overlaid soil barrier layer. This resulted with higher quantity of surface runoff. On the other hand, T-3, T-4, and T-5 cover systems which incorporate lateral drainage materials underlying the topsoil allow lateral drainage of rain water resulting with an unsaturated condition of the topsoil and less surface runoff. The additional or contributing layers assisted in minimizing the downward passage of surface water into the refuse (Oweis 1994).

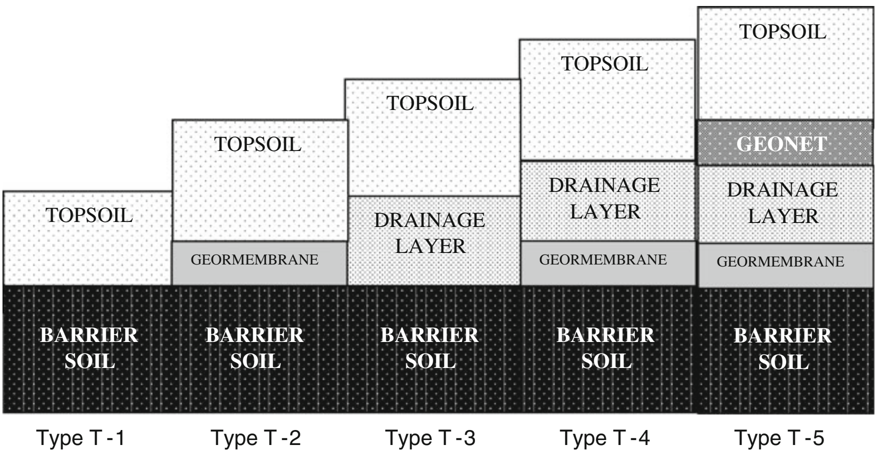

Fig. 6 Types of landfill cover system investigated

10.8 Influence of Cover Systems on Evapotranspiration

The various designs of cover system showed very minimal changes in the values of evapotranspiration. The amount of water evaporated and transpired were consistent at an average value of 1,838 mm. Evapotranspiration process is independent to the type of cover system resulting with consistent value particularly when similar properties of topsoil layer is used. This is also because evapotranspiration is a function of temperature, evaporative zone and wind speed (Oweis 1994).

10.9 Influence of Cover Systems on Lateral Drainage

T-5 depicted the highest volume (1,265.92 mm) of collected lateral drainage due to the presence of geonet. This enhanced passage to drain the liquid from the system (Bagchi 1994). T-4 is less efficient than that of T-5 with leachate collected at 1,062 mm, due to the absence of the geonet material in the design followed by T-3 which collected lateral drainage was recorded at 597 mm. The absence of drainage material resulted with low volume of lateral drainage as in T-1 and T-2. By incorporating the drainage materials water infiltration into waste layer had significantly reduced. As a result, the generation of leachate can also be reduced (Agamuthu et al. 2009a, b).

10.10 Influence of Cover Systems on Leachate Generation

The key indicator of the efficiency of the different cover system can be depicted based on the leachate generation. The highest volume of leachate was generated in system which lacked appropriate lining system that prevents water intrusion. Based on the various combination of the different layering materials, T-1 cover system generated the largest volume of leachate (1,345 mm), followed by T-3, T-2, T-4, and T-5.

T-1 system was found to generate the largest discharge mainly due to the lack of drainage material. Similarly, T-3 system which geomembrane barrier was absent also failed to prevent water intrusion. Thus, the absence of drainage material in addition to the geomembrane layers resulted with the generation of higher volume of leachate. On the other hand, composite cap, such as geomembrane, over a layer of compacted clay (GM/GCL) with an appropriate final cover will avoid water intrusion which can be translated into the generation of lesser amount of leachate in the landfill (Qasim and Chiang 1994).

Different values of WBCs were derived with different layering system where various combination of layering materials was incorporated. The influence of the

Table 18 WBCs values by different cover system

Water balance components (WBCs) (mm)	Type of cover systems				
	T-1	T-2	T-3	T-4	T-5
Precipitation	3,364.05	3,364.05	3,364.05	3,364.05	3,364.05
Surface runoff	168.93	557.05	269.07	244.49	189.47
Evapotranspiration	1,849.59	1,846.57	1,833.06	1,832.02	1,830.06
Lateral drainage collected	–	–	597.32	1,162.48	1,265.92
Leachate generated	1,345.53	960.43	668.67	125.06	78.6

various cover-system namely T-1 to T-5 on the WBCs can be summarized in Table 18.

The WBCs values on precipitation of all cover-system showed insignificant difference. On the other hand, other components namely surface runoff, evapotransporation, lateral drainage collected and leachate generation differed with different cover-system. T-2 exhibit the highest runoff (557 mm), followed by T-3 and T-4. The lowest surface runoff value was by type T-1(168.93 mm). The volume of water collected from lateral drainage was highest by T-5 (1,265 mm) followed by T-4 (1,162.48 mm).. Based on the result, T-1 depicted the generation of 1,345.53 mm, the highest volume of leachate among the five combinations while T-5 produced the lowest at 78.6 mm. Based on WBCs, T-4 and T-5 cover systems were at a level acceptable by USEPA, which is below 300 mm.

Based on the performance in mitigating leachate generation and the cost incurred, T-4 was recorded to be the most cost-effective system for a tropical climate. On the other hand, when heavy precipitation is not a factor, T-3 is more economical since T-3 is slightly more expensive than that of T-4.

10.11 Organic Material as Bio-Cover to Reduce Methane Release

In Malaysia, 95 % of the 30,000 metric tons of MSW generated annually is disposed in landfills. As of 2011, there are 166 operating disposal sites with only 11 being sanitary landfills. However, most of the disposal sites in Malaysia are small dumpsites that are not commercially viable to harvest methane for energy use. Therefore these landfills are still emitting methane passively, which is a potent greenhouse gas, which has a global warming potential 25 times more than carbon dioxide. Since collection of methane gas from these landfills are not commercially viable, the best low cost option would be to mitigate landfill gas emissions using Bio-Cover to oxidize the methane to CO_2.

Bio-Cover is a layer of soil/compost that oxidizes methane to carbon dioxide as the landfill gas pass through the cover material. The methanotrophic bacteria present in the compost are responsible for the methane oxidation. The oxidation potential of different cover materials used could be further enhanced through the utilization of dedicated methanotrophic bacteria

Below are the summary of the Bio-Cover Performance Index (BPI) of different materials tested in landfill and laboratory. The effective microbes applied in the experiments were *Methylomonas sp* and *Methylococcus sp*.

Cover materials	Bio-cover performance index ($\mu g g^{-1} h^{-1}$)
Sewage sludge (20 % sludge + 80 % compost)	108.8×10^3
Empty fruit bunch (60 % EFB + 40 % compost)	92.2×10^3
Sawdust (40 % sawdust + 60 % compost)	28.6×10^3
Compost with effective microbes	26.9×10^3
Compost	18.9×10^3
Compost (laboratory)	0.19×10^3
Black soil (laboratory)	0.09×10^3

The utilization of organic materials, which are normally discarded as waste, is innovative to be used as Bio-Cover material. Under Tropical conditions these material could be effectively used to reduce the methane released from landfills via oxidation.

10.12 Material Flow Analysis and MSW Management

Using Material flow analysis (MFA) (also referred to as substance flow analysis; SFA) as an analytical method of quantifying flows and stocks of materials or substances in a well-defined system such as a landfill. MFA could be incorporated as a waste management tool. Three main areas of application for MFA in waste management are in waste analysis, evaluation of waste management processes and evaluation of waste management systems. MFA can be applied to a waste management system for the illustration of material flows and processes, including different detail grades, considering altered frameworks, accounting and analyzing the regarding system in terms of the material and energy efficiency, supporting the material flow management by analyzing the opportunity to distribute waste, flows to various constructions, considering technical, economic and ecological framework conditions, analysis of critical points, development of measures for optimisation, and as definition of a base line scenario to assess future development. Methodology used for MFA studies include Statistical and MSW management data collection, laboratory work for material and substance data, and material or substance flow modelling using software such as STAN or Excel.

Research was done on the substances, Al, C and N in a landfill. From the results, the composition of waste in the landfill was identified, the input and output was calculated and mass balance done using Excel and STAN to produce the MFA of C, N and Al in a landfill. Material flow determination for C and N showed that, in one year of landfilling, 29 % of the input of the organic C left the landfill via gas pathway while less than 1 % escaped via leachate pathway and more than 70 % of the organic C was still in the landfill sink. The largest part of total-N, almost 80 % remained as landfill stock while less than 5 % N was discharged from landfill via leachate pathway. The 51 % of NH_3-N released from landfill body was of concern in the long run. The landfill gas emissions are made up of $CH_4 = 51$ %, $CO_2 = 36$ % and CO = 4 %. Modeling of Al, C and N flow in a sanitary landfill showed that the landfill is a sink for C and Al. C and N was dominantly exported in landfill gas and leachate while Al was dominantly in the soil and leachate. Current research is looking into the MFA modelling and assessment of global warming potential at an organic farm and a conventional farm and also the municipal solid waste flow in Kuala Lumpur.

References

Agamuthu P (2001) Solid waste: principle and management. University of Malaya Press, Kuala Lumpur, pp 9–27

Agamuthu P, Fauziah SH (2006) MSW disposal in Malaysia: landfill management. In: Proceeding of the 2nd expert meeting on solid waste management in Asia and the Pacific islands in the Kitakyushu international conference centre, Kitakyushu, Japan, 23–24 Nov 2006

Agamuthu P, Fauziah SH (2010) Challenges and issues in sustainable landfilling in a transitory country- Malaysia. In: Proceedings of 1st international conference on final sinks, Vienna, Austria, pp 67–68, 23–25 Sept

Agamuthu P, Fauziah SH (2011) Challenges and issues in moving towards sustainable landfilling in a transitory country-Malaysia. Waste Manage Res 29(1):13–19

Agamuthu P, Fauziah SH (2012) Current situation of MSW management in Malaysia. In: The proceedings of the Asia Pacific landfill symposium. 8–11 Oct 2012

Agamuthu P, Khan N (1997) Solid waste characteristic and quantification in effective solid waste management. Ecotone Mangament Sdn. Bhd. Kuala Lumpur, pp 2–10

Agamuthu P, Fauziah SH, Khidzir K (2009a) Evolution of solid waste management in Malaysia: impacts and implications of the solid waste bill, 2007. J Mater Cycles Waste Manage 11(2):96–103

Agamuthu P, Khidzir K, Fauziah SH (2009b) Drivers of sustainable waste management in Asia. Waste Manage Res 27(7):625–633

Agamuthu P, Fauziah SH, Khidzir KM (2010) Sustainable 3R practice in the Asia and Pacific Regions: the challenges and issues. In: Agamuthu P, Tanaka M (eds) Municipal solid waste management in Asia and the Pacific Islands, 1st edn. Penerbit ITB, Indonesia

Bagchi A (1994) Design, construction, and monitoring of sanitary landfill. Wiley, New York, pp 56–78

Economic Planning Unit (EPU) of the Prime Minister's Department (Malaysia) (2007) Ninth Malaysia plan 2006–2010. http://www.epu.jpm.my/rm9/html/english.htm. Accessed 3 July 2007

Fauziah SH, Agamuthu P (2003) Municipal solid waste composition in Selangor (Malaysia) landfills. In: Paper presented at NARED conference, Kuching, Sarawak, Malaysia, 25–27 Sept 2003

Fauziah SH, Agamuthu P (2004) Towards an improved municipal solid waste management in Malaysia: a possibility or a fiction? In: Proceedings of the environment 2020: urban environment, Seri Kembangan, Selangor, pp 5, 28–29 Sept 2004

Fauziah SH, Agamuthu P (2009a) Recycling of household organic waste in Malaysia: the challenges. Prog Environ Sci Technol, vol II. Part B. Science Press, pp 2234–2240

Fauziah SH, Agamuthu P (2009b) Sustainable household organic waste management via Vermicomposting. Malays J Sci 28(2):135–142

Fauziah SH, Noorazamimah Aiza A, Agamuthu P (2007) Closure and post-closure of landfills in Malaysia—case studies. In: Proceedings of the international solid waste association conference, Amsterdam, The Netherlands, 24–26 Sept 2007

Gidarakos E, Havas G, Ntzamilis P (2006) Municipal solid waste composition determination supporting the integrated solid waste management system in the island of Crete. Waste Manage (Oxford) 26(6):668–679

Harrison EZ, Richard TL (1992) Municipal solid waste composting: policy and regulation. Biomass Bioenergy 3(3–4):127–143

Haznews (1998) Landfill problems in Malaysia. http://www.allbusiness.com/environment-natural-resources/toxic-hazardous/8108427-1.html. Accessed 25 April 2010

Hoeks J, Harmsen J (1980) Methane gas and leachate from sanitary landfills: research digest, (Schierbeek EW). ICW, Netherlands, p 32

Hoorwerg D, Thomas L (1999) What a waste: solid waste management in Asia. In: Working paper series for Asia and Pacific Region, The World Bank (urban development division), Washington D.C

http://www.kpkt.gov.my/statistik/perangkaan2002

Hui Y, Li'ao W, Fenwei S, Gang H (2006) Urban solid waste management in Chongqing: challenges and opportunities. Waste Manage (Oxford) 26(9):1052–1062

Irra MS (1999) Sustainable waste management: an awareness study on cleaner technologies in the Klang Valley. Master's Thesis, University of Malaya

Kamariah N (1998) Dealing with a load of rubbish. J Green Wave 2:50–52

Karakiewicz J, Kvan T (1997) Regaining the sense of city: a history of reclamation and public spaces in Macau. In: Proceedings of the east west conference 1997, U.S.A

Kuman MY, Abdullah F (2002) An interview concerning role of the Government in encouraging the effective Constructive solid waste management system. Ministry of Housing and Local Government, Kuala Lumpur

Lu L, Hsiao T, Shang N, Yu Y, Ma H (2006) MSW management for waste minimization in Taiwan: the last two decades. Waste Manage (Oxford) 26(6):661–667

MIDA (2012) http://www.mida.gov.my/env3/index.php?page=electricity-rates

Ministry of Housing and Local Government (2004) Personal Communication

Misgav A, Perl N, Avnimelech Y (2001) Selecting a compatible open space use for a closed landfill site. Landsc Urban Plan 55:95–111

Oweis IS, Dakes G, Marturano T, Wiere R (1994) Soil-cover success. Civil Eng Mag ASCE, Reston, 64(10):58–59

Qasim SR, Chiang W (1994) Sanitary landfill leachate. Technomic Publishing Company, Inc., 851 New Holland Avenue, Box 3535, Lancaster, PA, 17604

Sekarajasekaran A, Lum WK (1982) Sanitation and waste disposal treatment methods: planning and implementation, development and the environmental crisis: a Malaysian case. Consumers' Association of Penang, Penang

Suite101 (2003) Environmental affairs—free Suite101 course. http://www.suite101.com/lesson.cfm/17295/650/3#ixzz0mHc3wPFl. Accessed 27 April 2010

Tan CL (2007) Cautious act. Star two. http://www.reach.org.my/index.php?option=com_content&task=view&id=530&Itemid=57. Accessed 19 Jan 2009

Tchobanaglous G, Theisen H, Vigil SA (1993) Integrated solid waste management. McGraw Hill International, New York, pp 125–157

The Star (2002) Chin Wai Nee- what should we do with all the garbage?

World Bank (1999) What a waste: solid waste management in Asia. http://siteresources.worldbank.org/INTEAPREGTOPURBDEV/Resources/whatawaste.pdf. Accessed 10 April 2008

Yani H, Rahman R (2000) Pemulihan Sumber Sampah Sarap di Bandaraya Kuala Lumpur. In: Proceedings of the national seminar on environmental management issues and challenges in Malaysia, UKM Bangi, 25–26 July 2000

Zainal (1997) Kesan Penswastaan Terhadap Kepuasan Kerja dan Tekanan Kerja. Satu Kajian dalam Agensi Awam yang Diswastakan. Thesis. Fakulti Pengurusan Perniagaan. UKM, Bani