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SOLID WASTE GENERATION CHARACTERISTICS: THE MALAYSIAN LOCAL AUTHORITIES' OUTLOOK

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Abstract
The large and increasing amounts of municipal solid waste (MSW) generated each year in several industrialised countries have raised concerns on the economic viability and environmental acceptability of the current generation activities. The planning of an optimal regional waste management strategy requires a reliable tool for predicting the amount and the corresponding composition of MSW likely to be produced. Furthermore, for integrated solid waste management, direct and indirect participation of local government's authority is essential. This paper focuses on the existing waste management characteristics of selected local authorities in Malaysia. As a case study, the research considers three local authorities in Selangor State, namely Selayang, Klang and Subang Jaya. This research further identifies the issues concerning the environmental effects due to indiscriminate solid waste disposal. The findings of the study are expected to provide useful guidelines to the MSW policy makers.

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INTRODUCTION

Municipal solid waste resulting out of rapid urbanization has become a serious concern for government departments, as well as for the public in most of the developing countries. Rapid growth of population and industrialization cause deterioration in the environment and places serious stress on natural resources. Further, indiscriminate disposal of solid waste has been a major cause for degradation of environment in most cities of the developing world. Apparently, there are two major problems due to poor and inadequate solid waste management. One is the loss of resourceful material and other is social cost due to health impact on rag pickers, community living in dumpsite surroundings and health of general public.

Williams (1998) stated that waste is an unavoidable by-product of human activities. Economic development, urbanization and improved living standards in cities are the major reasons behind have led increase in the quantity and complexity of generated wastes. The Environmental Act (1995) in the United Kingdom defined waste as "any substance or object, which the holder discards or intends to discard". A 'holder' means the producer of the waste or the person who is in possession of it, and 'producer' means any person whose activities produce waste, or any person who carries out pre-processing, mixing or composition of this waste. Table 1 shows the classification of waste on the basis of various factors.

The present paper focuses on solid waste whose classification uses a variety of schemes, i.e., physical (solid, liquid, gaseous), material (glass, paper, plastics), physical properties (combustible, non-combustible), origin (domestic, commercial, industrial, agricultural) and safety parameters (hazardous, radioactive).

In general, municipal solid waste consists of household and commercial wastes. It may also include wastes derived from civic amenities, street sweeping, and construction and demolition wastes from local authority sources. It can vary from one country to another and even vary from one region to another within the same country. It is highly heterogeneous and its composition depends on factors such as living standards, geographical locations including cultural habits of individuals, type of housing and seasons.

SOLID WASTE GENERATION IN MALAYSIA: BEFORE 1990

Solid waste management is associated with the control of generation, storage, collection, transfer and transport, processing and finally disposal of various solid wastes. Disposal

is carried in a manner that is in consonance with the best principles of public health, economics, engineering, conservation, aesthetics and environmental considerations. Kheng's (1986) estimated and projected data on the amount of solid waste generated in 20 municipalities of Malaysia are shown in Table 2.

From the amount of waste presented in Table 2, it is clear that the amount of waste in 1990 has been double the amount in 1980. This was expected with the growing urbanization and also the moderate trend of increase in waste generation at the rate of 2% per annum.

A survey of households in Klang Valley in1978 found solid waste generation rate to be only 0.23kg/capita/day. But the generation rate was predicted to increase to 0.54kg/c/day by 1985 (Kheng, 1986). The trend in generation rates is consistent with population growth, economic growth and consumption habit of the community.

It is expected that the steady economic growth and the rapid urbanization would greatly increase the utilization of raw consumer items thus far not available in rural areas. The change of consumption pattern among the people may be a major driving force in the increasing waste generation rate. Table 3 provides the generation rate (year 1990) of solid waste in Malaysia and some other countries.

SOLID WASTE GENERATION IN MALAYSIA: AFTER 1990

In the early nineties, the solid waste generation rate rose to 0.75 kg/c/day. Currently, the estimated average generation of solid waste is more than 1.0 kg/c/day. This represents a 200% increase within the last 20 years. The estimated solid waste generation in Malaysia in 1998 was approximately 15,000 tonnes/ day for a population of about 16 millions. It is further estimated that out of the 15,000 tonnes/day of solid waste generated, only 11,000 tonnes/ day (about 70% of the total) were collected. The remaining 30% of non-collected wastes is probably due to illegal dumping and diversion of waste during collection mainly for recycling purposes. Solid waste generation was projected to increase from 2.5 million tonnes in 1991 to 3.9 million tonnes in 2000. Over the past two decades the increased generation of solid waste has been reported not only in Malaysia but also worldwide with many ascribing it to industrialization. Since Malaysia is a multi-ethnic, multi-cultural and multi-lingual society and well-endowed with natural resources in areas such as agriculture, forestry, and minerals (Manaf et. al., 2009), which influence the generation characteristics of Malaysia Municipal Solid Waste.

Depending on the economic status of the area, the per capita solid waste generation rate varies from 0.45 to 1.44 kg/c/day. The national average generation rate estimated for 1991 to 1993 was about 0.7 kg/c/day and has increased to 0.8 kg/c/day from 1994 to 1999 and year 2000.

The national average generation rate and the amount generated is skewed towards the fast developing and urbanized regions or cities like Kuala Lumpur and cities in Klang Valley, Penang, Johor Bahru and Kuching. Table 4 shows solid waste generation at some local authorities in Malaysia in the year 2000.
Global municipal solid waste generated in 1997 was about 0.49 billion tons with an estimated annual growth rate of 3.2- 4.5% in developed nations and 2-3% in developing nation (Manaf et. al., 2009). It is a fact that rapid urbanization and industrialization have changed the characteristics of solid waste generation. With population growth at the rate of 2.4% per annum (Manaf et. al., 2009), the municipal solid waste (MSW) generation also increases, which makes MSW management critical.

The most important legislature for Solid waste management in Malaysia is as Environmental Quality Act from 1974; Action plan for beautiful and clean (ABC) Malaysia of 1988; 3rd Outline Perspective Plan (OPP3) for 2001- 2010; National Strategic Plan for solid waste of 2005; 9th Malaysian Plan for 2006- 2010; National waste minimization plan for 2006- 2020; Solid waste and public cleansing management Act from 2007.

IMPACT ON HEALTH

Due to the absence of standards for handling municipal wastes, it is the municipal workers who are most affected by the occupational health hazards of waste handling activities. In addition to municipal workers, the rag pickers who operate informally for long hours rummaging through waste also suffer from various occupational health diseases. In addition to occupational and environmental health, injury issues also need to be given due consideration in the context of waste management. Contaminated leachate and surface run-off from land disposal facilities affecting downstream ground and surface water quality, volatile organic compounds and dioxins in air-emissions increasing cancer incidence and psychological stress for those living near incinerators or land disposal facilities. Drain clogging due to uncollected wastes lead to stagnant waters and hence mosquito vector breeding is few of the environmental health issues which affect the waste workers as well as general public.

Until now, landfills are the primary method adopted for disposal of Municipal Solid Waste (MSW). Although land filling is one of the cheapest ways of disposing MSW, however, the consequential environmental problems may result from contaminated sites in the future. This risk, together with the lack of adequate landfill space in many municipalities, has been one of the main reasons why in recent years numerous cities and counties in United States and Western Europe have considered incineration as an alternative to deal with MSW. But incineration is not immune of problems either. Incineration

reduces the volume of MSW by about 90%, this process produces considerable amounts of residue. In addition, heavy metals and polychlorinated dibenzo-p-dioxins (PCDD) and polychlorinated dibenzofurans (PCDF) are found in emissions of waste incineration plants. PCDD/Fs enter the atmosphere primarily as combustion by-products from incineration, and since these compounds are semi volatile and hydrophobic, they accumulate in organic-rich media such as soils, sediments, and biota.

Problems associated with the disposal of municipal solid waste have become a source of public concern worldwide as awareness of potential adverse environmental impacts and health threats from solid waste has increased. Communities are concerned on the generation and management of solid waste to the extent of refusing to allow new disposal sites near their homes, often after witnessing the legacy of existing facilities. Under these circumstances, the development of national policies for the management of solid waste becomes an absolute necessity. Further, there is no gainsaying of requirement of appropriate technical solutions that ensure environmental protection and proper management plans that support an acceptable solution for the disposal of municipal solid wastes.

The main objectives of the present research, in the context of selected local authorities of Malaysia, are the followings:

- To study the various characteristics of the municipal solid waste generation
- To evaluate the quantities and composition of solid waste generated
- To identify the potential business related with solid waste generation strategy
- To prescribe some recommendations for better management of MSW

A BRIEF REVIEW OF PREVIOUS WORKS ON SOLID WASTE GENERATION

Rapid urbanization and population growth in cities in developing countries is expected to bring an increase in the overall waste generation in the coming years. If these increased wastes are not properly managed, a greater danger may be imposed upon a region. Zia and Devadas (2008) have analyzed the waste management practices for Kanpur, a North Indian city and found that the overall management is inefficient, outdated and unscientific. To immediately arrest the problem, they have put forward a large number of recommendations some of which are the following:

- Source segregation of waste
- Introduction of extended producer responsibility (EPR)
- User-charge system as per the income class
- Improving the collection system
- Preparation and adoption of an integrated waste management system

- Participation of all stakeholders including informal waste-recycling sector
- Decentralized treatment plants
- Compliance of MSW rules by people and authorities

Manga *et al.* (2008) comment that inadequate financial resources, low level of enforcement of regulations and poor governance lead to poor solid waste management in many African cities. By means of a case study, the authors highlighted some of the waste management related problems in Cameroon. They conclude that in the country, solid waste management services are rudimentary, essentially collect and dump type of routine activities; current regulations do not adequately address waste handling and disposal. Further, there are inefficiencies in the implementation of wastes management policies due to the lack of coordination between several governmental agencies and the local councils.

Many solid waste disposal researchers have concluded that recycling as one of the most viable disposal strategies. According to Alhumoud (2005), recycling can be promoted by encouraging separation at the source which can be achieved through financial incentives, legislation and raising environmental awareness. However, he finds that majority of the Gulf Co-operation Council (GCC) states have not set regional or national recycling targets. Government policies on the environment exist but are poorly implemented. Public awareness programs lacked the necessary coverage, intensity and continuity to correct the apathetic public attitude towards the environment.

In addition to qualitative research as above, a number of tools have also been developed to manage MSW. The latest tools include a multiple regression model (Chang *et al.*, 2007) for lower heating value (LHV) for MSW, evolutionary simulation optimization (Huang *et al.*, 2005) for large scale planning problems and other planning applications containing significant sources of uncertainty.

Estimation of present and future waste generation and composition of different types of waste are essential for long-term efficient and economical waste management planning. These estimates are used to determine the type, size, design and location of waste treatment and disposal facilities. The statistical data on the quantification of wastes are usually by weight, although sometimes it may be more appropriate to report the data in the unit of volume. For example, plastic bottles for recycling are often reported as volume rather than weight (Agamuthu, 2001).

Analysis of the composition of wastes may also be based on the source of the waste, so that industrial waste might be analyzed in terms of chemical composition, and clinical and household wastes might be either material types such as glass, paper, metal etc. or by-product types such as glass containers, tins, etc. In addition to weight

and composition, the energy value, moisture content, volatile content and elemental composition may also be found by a series of standard tests.

There are two approaches which are generally adopted for estimating waste quantity and composition: (1) questionnaires to the producers of the waste, (2) direct analysis of the waste stream either at the point of waste production or the waste treatment facility (Williams, 1998). Usually, the questionnaire covers areas such as type and quantity of waste, the waste collection and disposal methods used by the organization, the type of containers used for the waste, general categories and subcategories of the waste, description of the process generating the waste, detailed description of the waste in terms of the percentage of components in the waste, physical form of the waste, proportion of packaging, transport methods, location of disposal site, weight of the waste, etc.

Waste properties have both engineering and economic significance. In addition to their impact on the assessment of landfill performance, the unit weight and compressibility of waste materials influence storage capacity and the resulting economic evaluation of landfill projects.

According to Fassett *et al.* (1994), the following characteristics and conditions of municipal solid waste make determination of its engineering properties difficult:

- The inconsistent and heterogeneous composition of landfill material results in widely variable properties.
- Samples of sufficient size representative of field condition are difficult to obtain.
- The erratic nature of waste particles makes sampling and testing difficult; there are no generally accepted sampling and testing procedures for waste materials.
- Waste properties change with time, depth and location.

MSW generally consists of many different constituents, and these constituents are often porous and not fully saturated. Based on an analysis of numerous types of waste and a comprehensive review of the literature, some elements are categorically identified for the classification purposes. From the observation it was found that some wastes are readily biodegradable, others are slowly biodegradable and some are not degradable. By means of compaction equipment used in most landfills at present, it is found that the compaction ratio of loose weight to compacted waste, usually remain within the range 2:1 ~ 3:1. The average unit weight of compacted solid waste is usually 55 to 70 lb/ ft³ (55 ~ 70 kN/m³) for modern solid waste landfills (Xuede *et al.,* 2002).

Solid waste is a particulate material and its behaviour resembles that of soils in many ways. Like soil, the strength of MSW appears to increase with increasing normal load

applied on the waste. According to Fassett *et al.* (1994), factors believed to affect the strength properties of MSW are the following:

- The organic and the fibre content in the waste;
- The age of the waste placed in the landfills, and the extent to which it has decomposed;
- The mode of placement (i.e., compaction effort, lift thickness and amount of daily cover).

The strength of MSW is a function of the direction of shear stress and is primarily frictional in nature (Landva, 1990). Estimates of solid waste strength have been made using the following approaches (Singh and Murphy, 1990):

- Direct laboratory and field testing
- [a] Back-calculation from failures and load tests, and
- Indirect in-situ testing

METHODOLOGY

A complete record of data on the amounts of MSW or total solid waste generated in Malaysia is difficult to obtain. Different sources in each local authority may use a different definition of solid waste and solid waste generation. Therefore, to study various characteristics of solid waste generation in Malaysia, in the present study, we considered only three local authorities from peninsular Malaysia out of 147 in the country. These local authorities considered as representative of whole 147 authorities in Malaysia are Selayang, Klang, and Subang Jaya, all from the state of Selangor.

Malaysia is tropical country situated in the central part of Southeast Asia and it lies between the longitudes 100^{o} and 120^{o} east and latitudes formed by the Equator and 7^{o} north. A characteristics tropical climate is warm and humid throughout the year, which has experienced in Malaysia. In this climate average air temperatures range from $21^{o}$to 32^{o}C and relative humidity ranging from 80 to 90%. Rain tends to occur between November and February on the east coast of Peninsular Malaysia. On the west coast of Peninsular Malaysia, the rainy seasons are April- May and October- November.

Selayang Local Authority: This authority consists of one of the fastest developing lands in the Klang Valley. Within 54,559 hectare, this area consists of many potential assets in various development schemes that contribute to the country's economic foundation. Located next to Kuala Lumpur, this sub-urban area is one of the most developing corridors in the Klang Valley.

Transportation system such as Lebuhraya Utara-Selatan (PLUS Highway), Lebuhraya Kuala Lumpur-Karak, Lingkaran Tengah (MRR II Highway) and Light Rail Transit System (LRT) have increased the overall transportation facility in Selayang. A good road system connecting this area with other districts had been identified as an excellent potential for Selayang to be the centre of 'Borong dan Pergudangan' (wholesale), which are now moving out of Kuala Lumpur.

Klang Local Authority: Klang is located in the west coast of Selangor and acts as one of the Klang Valley metropolitan areas. Located within a good communication district system, road connection and express highway had made this area with an easy access to the City Centre of Kuala Lumpur and other towns such as Shah Alam, Petaling Jaya, Putrajaya, and Cyberjaya.

The whole area under the jurisdiction of the Klang Authority is 57,117.90 hectare that consists of:

- Structure Planning Klang area – 54,917.85 hectare
- Additional area Structure Planning of Klang which consists of Structure Planning
- District of Petaling and part of the District of Klang – 2, 200.05 hectare.

The Klang town is the city centre for the Klang district. The area has become a centre for main commercial activities, district administration centre and is known as the Royal City for Selangor State. The Klang town has also been identified as the oldest town in Selangor. Based on Selangor State Development Plan, their targeted developmental activities proposed by the Klang Authority are:

- Develop as the National Port City
- Transportation centre
- Maritime and Industrial Centre
- Royal city
- Well planned residential area

The overall land use has been divided into the following zones:

- Maritime Industry Zone
- Residential Zone
- Industrial Zone
- Commercial Zone
- Reservation Zone
- Agriculture Zone

Subang Jaya Local Authority: Subang Jaya (MPSJ) is located in one of the most developed areas in Klang Valley. This area is situated between the border of Dewan Bandaraya Kuala Lumpur (DBKL) management area at the North East side, Majlis Perbandaran Petaling Jaya area up North, Majlis Perbandaran Shah Alam at the West, Majlis Perbandaran Kajang at the East side and Sepang district at the South.

The development of MPSJ is based on social obligation that garners towards providing the excellent community facilities especially in terms of education, health, safety and recreation. The development is also gearing up to build an image as a clean city that is harmonious with the surrounding environment.

STUDY PLAN

The present research, conducted in 2009, is driven by the planning or experimental design of the waste composition study. Sound statistical experimental design can be shown in the literature to be effective in eliminating known sources of bias, guarding against unknown sources of bias, ensuring that the study provides precise information regarding the responses of interest, and guaranteeing an economical design.

Standard source categories may include single-family and multi-family residential (urban and rural), mobile homes, commercial (retail and office), institutional, and industrial. The number of sources selected for study is a function of study objectives and waste load characteristics. A thorough investigation of contracting company records, household records, and municipality information provide the background information necessary to identify all possible sources of waste generation. Changes to household categories to reflect these source/ generator categories is considered to facilitate the study.

The role of demography on solid waste generation will also be investigated in order to better characterize the waste generation activities in the entire area. Further, seasonal and economic influences play a significant role in determining the types and amounts of waste generated in an area. Ignoring their influence in planning, a wastes composition study can seriously bias results. Ideally, one sampling event per calendar season should be planned, resulting in a minimum of four sampling events in a given year.

Collection routes should be thoroughly examined to determine the types of generators represented. Certain routes may be homogeneously single family residential, and others are mixed. Mixed loads may present challenges to accurately characterizing some sources, particularly for rural areas. If mixed loads cannot be separated by source, attempts should be made during sampling to estimate the fraction of each source represented in the load. Information regarding waste receipt patterns and

procedures for weighing and recording of the data from the vehicle should be obtained from the contracting collection company and/or household records. Private collection companies should encourage providing detailed records.
Each waste generator type represents a specific proportion of the population of the geographical area to be studied. A percentage of vehicle loads representative of the waste generator category's percentage of the population should be taken to get a clear picture of that waste generator's contribution to the waste stream.

Three sets of questionnaires were developed to collect information from various stakeholders of solid waste management. These questionnaires were as follows:

- Municipal questionnaire
- Technical questionnaire
- Contractor questionnaire

FINDINGS AND DISCUSSION

The data collected are presented in Tables 5, 6, 7, and 8. Table 5 shows the amounts of waste handled in the three local authorities in 2000 and 2002. On the basis of responses on municipal questionnaire, we have the following observations which are valid for all the three local authorities: Selayang, Klang, and Subang Jaya.

- A common solid waste generation takes place at the households.
- None of the local authorities categorize generated solid waste.
- Number of landfills in each of the local authorities is one.
- All three local authorities (L. As) consider 'recycling' as the major strategy to reduce MSW generation.
- All the L. As are of the opinion that privatization should be extended in solid waste
- management.
- All the L. As have programs to educate and raise public awareness about reducing, reusing, and recycling.
- All the L. As encourage the integration of preventive strategies internally through the use of regulations.
- All the L. As receive general circulars on solid waste generation.
- All the L. As use waste generation assessment procedure as a tool to analyze waste generation products, policies or other activities.

Some of the characteristics which are valid for only certain local authority are the following:

- Selayang L. A. adopts quantitative approach to rate contracting agency's performance, whereas, the other two L. As adopt triangulation for the same purpose
- Only Selayang considers incineration as the strategy to reduce MSW
- Only Klang receive sector specific information on solid waste generation
- Environmental impact assessment is done only by Klang

Second part of responses was collected on technical questionnaires. We have the following observations that are valid for all the three authorities:

- All the three authorities use compacting and roll off type of trucks to collect solid waste
- All the authorities are on "On Duty" to handle service during holidays
- All the three authorities use landfilling as the disposal method within the municipality
- Percentage of recycled municipal solid waste was less than 5%
- Have incineration as the vision towards municipal solid waste reduction

The observations that are not valid for all the three authorities are the following:

- Recycling as a disposal method is used by Klang and Subang Jaya, whereas Selayang does not use this
- Lack of infrastructure was cited as the major constraint by Selayang. Klang and
- Selayang also cited lack of funds, lack of private sector investment, land for waste disposal as the major constraints for MSW management. However, Klang cited lack of technology as the major constraint for the same
- Apart from the infrastructure, recycling also has been a goal for most of the authorities
- On the procedure of safety and health measures, 'National Institute of Safety and Health' is followed by most of the authorities. Department of Health and WHO are also followed by some of them
- On the health record keeping for workers and rag pickers, the responses are mixed

The third and final questionnaire was communicated to two contractors, namely, Alam Flora (Selayang), and Alam Flora (SJ). On most of the items, both the contractors have similar opinions. Some are discussed in the following:

- Both do not collect hazardous waste, special and clinical wastes.
- Weather, flash floods, traffic jam cause deviations from both the contractors' schedule.
- Both the contractors' drivers operate 6-12 hours a day.

- Both the contractors agree on the existence of coordinating body or agency responsible to oversee and support the implementation of official policies towards improving municipal solid waste management.
- Both of them have programs to educate and raise public awareness about reducing, reusing and recycling wastes.
- The common tools used to analyze waste generation products, policies, etc are environmental performance evaluation, environmental impact assessment, and waste generation assessment.
- Both keep health records for workers and rag pickers.

Observations that are valid for only one of the two contractors are summarized below:

- Alam Flora (SJ) has special trucks for special routes, whereas, Alam Flora (Selayang) does not have this.
- Alam Flora (Selayang) designs solid waste collection routes on the basis of load intensity, zone and vehicular capacity, but Alam Flora (SJ) does this on the basis of the latter two.
- Increasing vehicular capacity, R&D, and public awareness are Alam Flora (Selayang)'s future plan to deal with increasing amount of solid waste. On the other hand, Alam Flora (SJ) considers only increasing vehicular capacity and public awareness for the same purpose.
- Alam Flora (Selayang) follows the guidelines of National Institute of Safety and Health, Department of Health and WHO for safety and health. But Alam Flora (SJ) follows only National Institute of Safety and Health for the same purpose.

POLICY AND REGULATION

Many factors affect waste management improvement activities in the developing countries. The shortage of adequate funds for waste treatment and disposal is mainly due to the low priority given to this aspect compared to other more pressing factors of development like infrastructure and industrialization. Shortage of skilled manpower is another factor especially in fast developing countries like Malaysia. Imported labour brings with associated problems such as increased vulnerability in diseases and social disorders including crime. Furthermore, lack of disposal sites is evident in some smaller nations and because of that, waste management problems have escalated. Following are some of the issues and problems in solid waste management in Malaysia:

- Lack of adequate and efficient waste disposal facilities in or outside industrial areas;
- The total amount of hazardous and toxic waste generated by industries in Malaysia is estimated at 417,000 metric tonnes per year and it is expected to increase between 8% - 9% per year;

- Exposures of man and environment to the dangers of radioactive materials;
- Disposal undertaken without proper control and supervision can cause long-term negative impact;
- Illegal and unregulated factories that produce hazardous materials add more pressure to the pollution problem in urban areas;
- Lack of comprehensive guidelines on the disposal of scheduled and hazardous wastes.

By the year 2020, the quantity of MSW generated was estimated to have increased to 31, 000 tons. Most studies on MSW generation used load- account analysis, which is based on waste collected and disposal in landfills.

CONCLUSIONS AND RECOMMENDATIONS

Based on the survey data, we find that the average generation rate per person according to official census and records of the local authorities ranges from 0.6 to 0.76 kg/capita/day in the three selected local authorities, and these figures are less than those obtained through quantitative and house-to-house methods in many other studies.

The solid waste disposal method used in these municipalities is landfilling. Due to increasing population and thus solid waste increase, it is an imperative to consider the improvement of disposal of solid waste, by other disposal methods such as incineration, taking into account that the humidity in the selected area is very high and may affect the incineration efficiency. It is also necessary to improve in the 3 Rs (i.e., reduce, reuse, and recycle).

An integrated waste management (IWM) approach is currently the most desired system for solid waste management. IWM consists of the total waste management system whereby waste is managed from source to source (a cradle to grave approach). Apart from waste treatment either by traditional methods or by innovative methods, IWM also emphasizes waste minimization through waste recovery, reuse or recycle by improving the efficiency of the overall management system for all types of wastes, composting, incineration and landfilling.

We put forward the following recommendations for more efficient solid waste management.

- Monitoring and evaluation unit at solid waste management's contracting companies should avoid conflict of interest at their facilities. This is best done if the government obliged all contracting companies to include a governmental

monitoring and evaluation unit at their facilities for transparency and optimum results.

- Recycling is one of the most desired and effective methods for solid waste disposal. A minimum of 10% should be targeted in the near future.

- More awareness on solid waste management should be created to individual citizens and organisations so that everyone avoids wastes thereby reducing solid waste.

- Systematic safety and health procedures should be applied specially on worker and rag pickers.

- Appropriate statistical models should be used to measure the effectiveness of solid waste disposal on soil, ground water and air.

- Further studies on the collection and disposal of solid waste should be carried out in order to smooth out and integrate the solid waste management activities.

The findings of the present study may provide useful guidelines to the policy makers on the effective management of MSW in Malaysian. Modification of MSW generation rates is caused by the demographic factors and facilities.

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Table 1: Classification of Waste

No.	Factor	Waste
1	Origin	• Clinical • Household • Urban • Industrial
2	Form	• Liquid • Solid • Gaseous • Slurry • Powder
3	Properties	• Toxic • Reactive • Acidic • Alkaline • Inert • Volatile • Carcinogenic
4	Legal	• Special • Controlled • Household • Industrial • Commercial

Table 2: Aggregate amount of solid waste in 20 municipalities of Malaysia (up to 1990)

No.	Year	Amount of solid waste (million tons)
1	1970	0.363
2	1980	1.093
3	1990	2.005

Table 3: Generation rate of solid waste in Malaysia and some other countries (1990)

No.	Country	Kg/ c/ day	Volume/day/l
1	Malaysia	0.7	3.5
2	Singapore	0.85	4.25
3	Philippines	0.5	2.00
4	United kingdom	0.845	6.40
5	USA	1.25	12.00

Table 3: Solid waste generated at various local authorities in Malaysia (2000-2010)

States	2000			2001			2010		
	Population	*Waste (t/day)*	*Waste (kg/c/d)*	*Population*	*Waste (t/day)*	*Waste (kg/c/d)*	*Population*	*Waste (t/day)*	*Waste (kg/c/d)*
Selangor	3,325,261	2826	0.8499	3,408,393	2955	0.8670	5,460,000	6670	1.2216
Johor	2,252,882	1915	0.8500	2,309,204	2002	0.8670	3,350,000	3463	1.03358
Sabah	2,115,546	1481	0.7000	2,688,000	2064	0.7679	3,210,000	3257	1.0146
Sarwak	2,007,528	1405	0.6999	2,052,528	1437	0.7000	2,470,000	1797	0.7275
Perak	1,796,471	1527	0.8500	1,841,559	1597	0.8672	2, 350, 000	2412	1.0262
Kedah	1,557,259	1324	0.8502	1,596,190	1384	0.8671	1,950,000	2023	1.0372
Kuala Lumpur	1,400,000	2520	1.8000	1,435,000	2935	1.8362	1,670,000	3620	2.1680
Labuan	66,146	46	0.6954	67, 812	49	0.7129	90,000	75	0.8283
P. Pinang	1, 279,470	1083	0.8504	1,311,457	1137	0.8670	1,560,000	1600	1.0254
Kelantan	1,216,769	1034	0.8498	1 247,148	1081	0.8667	1,540,000	1586	1.0298
Pahang	1,126,000	957	0.8484	1,154,150	1001	0.8673	1,500,000	1541	1.0270
Terengganu	1,038,436	883	0.8503	1,064,397	923	0.8672	1,040,000	1064	1.0233
N. Sembilan	90,597	757	0.8500	912,862	791	0.8665	1,020,000	1050	1.0294
Melaka	605,361	515	0.850	620,495	538	0.8670	820,000	842	1.0272
Perlis	230,000	196	0.852	235,750	204	0.8653	260,000	275	1.0552
Putrjaya	-	-	-	-	-	-	89,000	74	0.8300

Source: Manaf, L. A et al (2009), Malaysian Government (2006), Zaini S. (2011)

Table 5: Amount of waste handled in Year (2000 ~2010)

Local Authority	Total Amount of Solid Waste (Ton/year)	Total Amount of Solid Waste (Ton/Day)	Population (c)	Solid Waste Generation Rate (kg/c/Year)	Solid Waste Generation Rate (kg/c/Day)
Selayang					
2000	97, 090	266	416,837	233.60	0.64
2002	122, 640	336	441,847	277.4	0.76
2010	196, 005	537	559, 000	350.4	0.96
Subang Jaya					
2000	105, 485	289	437,121	240.9	0.66
2002	131, 765	361	463,348	284.7	0.78
2010	208, 415	571	583, 000	357.7	0.98
Klang					
2000	123, 005	337	562, 239	219.0	0.60
2002	141, 255	387	595, 973	237.3	0.65
2010	223, 577	612	747, 000	299.3	0.82

Table 6: Municipal questionnaire data

No.	Characteristics	Local Authority		
		Selayang	Klang	Subang Jaya
1	Municipal solid waste generation			
	• Household	✓	✓	✓
	• Industrial		✓	
	• Municipal	✓	✓	
2	Average MSW generation			
3	Does municipality categorize generated solid waste?			
	• Yes			
	• No	✓	✓	✓

No.	Characteristics	Local Authority		
		Selayang	Klang	Subang Jaya
4	Rating of contracting agency's performance • Quantitative • Qualitative • Triangulation	✓	✓	✓
5	No. of landfill • One • Two • More than two	✓	✓	✓
6	Strategy on the reduction of MSW • Incineration • More land filling • Recycling	✓	✓ ✓	✓
7	Do you think that privatization should be extended in SWM • Yes • No	✓	✓	✓
8	Is there any coordinating body or agency responsible to oversee and support the implementation of official policies towards improving MSWM? • Yes • No	✓	✓	✓
9	Does your municipality have programs to educate and raise public awareness about reducing, reusing and recycling waste? • Yes • No	✓	✓	✓
10	Please indicate whether you have encouraged the integration of preventive strategies internally through the use of • Regulations • Financial incentives • Institute building • An environmental management system	✓	✓ ✓	✓

No.	Characteristics	Local Authority		
		Selayang	Klang	Subang Jaya
11	What kind of information do you regularly receive on SWG? • Sector specific • General circulation • Investment • Technical	 ✓	 ✓ ✓	 ✓
12	Do you use tools such as the following to analyze waste generation products, policies, or other activities? • Environmental performance evaluation • Environmental accounting • Environmental impact assessment • Life cycle assessment • Waste generation assessment • Eco labeling • Eco design	 ✓	 ✓ ✓ ✓ ✓	 ✓ ✓ ✓

Table 7: Technical questionnaire data

No.	Characteristics	Local Authority		
		Selayang	Klang	Subang Jaya
1	Types of trucks used in the collection of solid waste • Compacting • Roll off • Both of the above • Other (please specify)	 ✓ ✓ ✓	 ✓ ✓ ✓ Open truck, Tractors	 ✓ ✓ ✓ Open tipper
2	How do you handle service during holiday? • On Duty • Stand-By • Off Duty	✓	✓ ✓	✓

Table 7: Technical questionnaire data

No.	Characteristics	Local Authority		
		Selayang	Klang	Subang Jaya
3	Average percentage of MSW composition			
	• Paper	15	18	
	• Plastic	15	17	
	• Glass/Ceramic	5	3	
	• Metals	5	2	
	• Textile/Leather	5	2	
	• Food waste	40	25	
	• Rubber		2	
	• Garden waste		26	
	• Construction/demolition debris			
	• Wood			
	• Garbage			
	• Miscellaneous	15		
4	Types of disposal methods used within the municipality			
	• Land filling	✓	✓	✓
	• Recycling		✓	✓
	• Incineration			
5	Percentage of recycled municipal solid waste			
	• Less than 5%	✓	✓	✓
	• 5% - 10%			
	• 10% - 20%			
	• More than 20%			
6	Maintained parameters: engineering properties of MSW			
	• Moisture content			
	• Unit weight	✓	✓	✓
	• Bulk density			
	• Porosity			
	• Hydraulic conductivity			
	• Field capacity			
	• Compressibility			
	• Shear stress			

No.	Characteristics	Local Authority		
		Selayang	**Klang**	**Subang Jaya**
7	Major constraints faced in municipal solid waste management • Lack of infrastructure • Lack of funds • Lack of technology • Lack of private sector investment • Other (please specify)	 ✓ 	 ✓ ✓ 	 Lack of public awareness
8	Vision towards municipal solid waste reduction • Incineration • More land filling • Recycling	 ✓ 	 ✓ ✓	 ✓ ✓
9	Procedures for safety and health measures municipality/company follows regarding solid waste management • National Institute of Safety and Health • Department of Health • WHO • Other (please specify)	 ✓ 	 ✓ 	 ✓ Medical check ups every 6 months
10	Do you keep health records for workers and rag pickers for disease associated with municipal solid waste? • Yes • No	 ✓	 ✓ 	 ✓

Table 8: Contractor questionnaire data

No.	Characteristics	Local Authority	
		Alam Flora (Selayang)	**Alam Flora (Petaling Jaya)**
1	Municipal solid waste generation		
	• Household	✓	✓
	• Industrial	✓	✓
	• Municipal	✓	✓
	• Others	Bulky waste/ Garden waste	Institutional/ Commercial
2	Are there any contractual exclusions of waste generator type that you don't serve?		
	• Hazardous waste	✓	✓
	• Special waste	✓	✓
	• Clinical waste	✓	✓
3	Types of trucks used		
	• Compacting	✓	✓
	• Both	✓	✓
	• Roll off	✓	✓
	• Others	Open trucks	Open trucks
4	Are there special trucks for special routes? If so, what are they?		
	• Yes		✓
	• No	✓	
5	How do you design solid waste collection route?		
	• Load intensity	✓	
	• On the basis of zone	✓	✓
	• Vehicle capacity	✓	✓
6	What factors influence deviations from your schedule?		
	• Weather	✓	✓
	• Flash floods	✓	✓
	• Traffic jam	✓	✓
	• Others		Lorry breakdown
7	How do you handle service during a holiday?		
	• On duty	✓	✓
	• Stand-by		
	• Off duty		

No.	Characteristics	Local Authority	
		Alam Flora (Selayang)	**Alam Flora (Petaling Jaya)**
8	What hours and days do your drivers operate? • 1-6 hours • 6-18 hours • 6-12 hours • 18-24 hours	 ✓	 ✓
9	What are your company's future plan to deal with increasing amount of solid waste? • Increase vehicular capacity • R&D • Public awareness	 ✓ ✓ ✓	 ✓ ✓
10	Is there any coordinating body or agency responsible to oversee and support the implementation of official policies towards improving municipal solid waste management? • Yes • No	 ✓	 ✓
	Does your municipality have programs to educate and raise public awareness about reducing, reusing and recycling waste? • Yes • No	 ✓	 ✓
11	What kind of information do you regularly receive on SWG? • Sector specific • General circulation • Investment • Technical	 ✓ ✓	 ✓
12	Do you use tools such as the following to analyze waste generation products, policies, or other activities? • Environmental performance evaluation • Environmental accounting • Environmental impact assessment • Life cycle assessment • Waste generation assessment • Eco labeling • Eco design	 ✓ ✓ ✓	 ✓ ✓ ✓

No.	Characteristics	Local Authority	
		Alam Flora (Selayang)	**Alam Flora (Petaling Jaya)**
	Procedures for safety and health measures municipality/company follows regarding solid waste management		
	• National Institute of Safety and Health	✓	✓
	• Department of Health	✓	
	• WHO	✓	
	• Other (please specify)		
	Do you keep health records for workers and rag pickers for disease associated with municipal solid waste?		
	• Yes	✓	✓
	• No		