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Energy potential from municipal solid waste in Malaysia

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Abstract

The average amount of municipal solid waste (MSW) generated in Malaysia is 0.5–0.8 kg/person/day and has increased to 1.7 kg/person/day in major cities. This paper highlights the MSW characteristics for the city of Kuala Lumpur. Currently, the waste management approach being employed is landfill, but due to rapid development and lack of space for new landfills, big cities in Malaysia are switching to incineration. A simple evaluation was conducted to establish the amount of energy that would be recovered based on the characteristics of the MSW if it were to be incinerated. From the characterization exercise, the main components of the Malaysian MSW were found to be food, paper and plastic, which made up almost 80% of the waste by weight. The average moisture content of the MSW was about 55%, making incineration a challenging task. The calorific value of the Malaysian MSW ranged between 1500 and 2600 kcal/kg. However, the energy potential from an incineration plant operating based on 1500 ton of MSW/day with an average calorific value of 2200 kcal/kg is assessed to be at 640 kW/day.

Keywords: Municipal solid waste; Energy potential; Calorific value; Composition; Incineration

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1. Introduction

Over the past decade, Malaysia has enjoyed tremendous growth in its economy. This has brought about a population growth along with a great influx of foreign workforce to cities. This resulted in an increase in the amount of waste generated. The national average is at 0.5–0.8 kg/person/day, but in the cities the figures have escalated to 1.7 kg/person/day. Currently, an average of 2500 ton of municipal solid waste (MSW) is collected every day for the city of Kuala Lumpur and is being dumped at the Taman Beringin landfill. The lifespan of this landfill has already expired and in response to this the city council built a transfer station at the Taman Beringin landfill as a temporary solution, which was put into operation in October 2001, to facilitate the transfer of the waste to a new site. At the same time, the government have planned for a gasification unit with ash melting incineration system for the city of Kuala Lumpur with a capacity to incinerate 1500 ton of MSW/day to be operational by the year 2005. The city council is also looking at an integrated approach to solid waste management as an alternative to the old concept of just dumping all the waste that is generated.

This new outlook by the city council has brought about activities such as waste recycling and recovery followed by incinerating the waste to recover the energy with only the final inert material being considered for land filling. This will reduce the burden on the landfill and also open opportunities for new technologies in treating the MSW. Unfortunately, for such a system to work, basic data on the quantity, and quality of waste that is generated are essential. There have been many publications on the characteristics of the waste that is generated in Malaysia [1–4] but they are not comprehensive enough to identify actually who is generating what, how much and how frequently. This is essential for the design of any facility, as it will give an insight into the waste quality and quantity not only for now but also for the future and its effects on the treatment technology adopted.

As mentioned above, data on the kind of waste generated in Kuala Lumpur are not an indication of all the waste that is received by the landfill. According to the operators of the landfill, there is also some waste from Selangor, which is being sent to the landfill. According to a survey carried out by a firm for the city council in 1993 [5,6], the generation of MSW for some selected areas in Kuala Lumpur is shown in Table 1. However, the present literature does not highlight the complete characteristics on the composition and the calorific value of the waste that is generated in Kuala Lumpur. Hence, this paper will present the characteristics of MSW and its possible use for power generation.

2. Materials and methods

MSW for this study was obtained from trucks, which serviced the area of Kuala Lumpur. Sampling was carried out during the months of May and June 2001 on a total of 20 collected samples. The selection of the source of MSW generators was randomly predetermined to accommodate all types of sources (i.e. high-, medium- and low-income residential households, institutional, commercial and other sources).

Table 1
Waste generated by various sectors in selected districts in Kuala Lumpur [4]

District	Residential	Industry	Commercial	Office	Market	Hospital	Wood waste			Others	Total
							Road	Park	Fallen tree		
Kepong	103.2	83.7	13.6	3.1	25.7	0.7	26.5	0.0	14.3	131.3	402.1
Setapak	111.3	6.9	39.8	7.1	4.8	5.1	14.0	2.6	6.3	9.0	206.9
City center	182.8	68.0	157.1	41.5	24.1	8.3	40.6	13.3	16.7	132.2	654.5
Damansara	95.7	12.7	17.5	6.4	0.4	2.8	8.7	0.2	8.6	42.7	195.7
Cheras	69.8	34.2	24.5	6.1	6.9	0.6	23.1	4.7	8.4	34.2	212.5
Old Klang Road	67.8	29.1	15.2	3.9	4.8	0.0	29.0	1.5	16.5	23.9	191.8
Outskirts	16.4	18.8	6.3	0.9	1.1	0.0	2.0	1.4	0.7	12.9	60.5
Total	647.1	253.4	244.1	68.9	67.8	17.5	143.9	23.7	71.5	386.2	1924.0
Percentage	33.6	13.2	12.7	3.6	3.5	0.9	7.5	1.2	3.7	20.1	100.0

The identification of the source has been based on the major activity or lifestyle that was practiced by the population along the route taken by the specified truck. The sampling and sorting protocol adopted by this study is that recommended by Corbit [7]. The spot sampling method requires that the samples be taken from a few trucks (about 8–10 trucks from the same source) where an amount of waste (about 30–50 kg) is to be taken and the total amount collected will form a sample size of about 200 kg, which is then sorted. The sorting is carried out based on 23 different components. The identified truckloads were weighed at the incoming weighbridge and directed to a precleaned flat surface where segregation of the waste to its components was carried out. Segregated waste components were weighed while the samples were taken for further analysis at the laboratories. Calorific value determination was in accordance to the American Society for Testing and Materials (ASTM) [8].

3. Results and observations

The results of the MSW composition study are shown in Table 2. The observation that could be made is that there is an obvious difference between the amount of food/organic generated by the residential premises as compared to that generated by the institutional and commercial sectors. The highest food waste generator is the low-income residential sector. There is no concrete reasoning for this but it could be suggested that the low-income residents cook and eat in their respective houses, thus generating food waste. In contrast to this, the high-income people tend to have meals outside more frequently resulting in less food waste. Another observation is the fact that the organic components accounted for up to 85–90% of the MSW with the rest being the inorganic portions. Lastly, it is also important to note that the samples collected did not cover industrial areas and also other minor contributing sources such as river cleaning, road sweeping, construction waste, municipal garden maintenance, etc. which were more specific wastes.

Apart from taking samples from specific sources, this study also attempted to take samples at random, covering all sources. The results are shown in Fig. 1 and indicate that the composition of the MSW has the same trend as indicated in Table 2 but it is important to note that these results were obtained from random sampling and cover all sources. The figure only shows data on the organic components of the waste, which accounts for about 85% of the total waste. The inorganic portion has been lumped into one for this graph because of the small amount.

Apart from this, other observations are that the range between maximum and minimum for the food/organic component is very large. This is due to the large variance, which is contributed by the different generation sources. Another observation is that food, paper and plastic are the main components by weight. Some of the components did show some large difference between the maximum and minimum values. The arguments could be based from the observations in Table 2 and they are as follows:

Table 2
Average composition weight percentage of components in MSW generated by various sources in Kuala Lumpur

Sources	Residential high income (%)	Residential medium income (%)	Residential low income (%)	Commercial (%)	Institutional (%)
Food/organic	30.84	38.42	54.04	41.48	22.36
Mix paper	9.75	7.22	6.37	8.92	11.27
News print	6.05	7.76	3.72	7.13	4.31
High grade paper	–	1.02	–	0.35	–
Corrugated paper	1.37	1.75	1.53	2.19	1.12
Plastic (rigid)	3.85	3.57	1.90	3.56	3.56
Plastic (film)	21.62	14.75	8.91	12.79	11.82
Plastic (foam)	0.74	1.72	0.85	0.83	4.12
Pampers	6.49	7.58	5.83	3.80	1.69
Textile	1.43	3.55	5.47	1.91	4.65
Rubber/leather	0.48	1.78	1.46	0.80	2.07
Wood	5.83	1.39	0.86	0.96	9.84
Yard	6.12	1.12	2.03	5.75	0.87
Glass (clear)	1.58	2.07	1.21	2.90	0.28
Glass (colored)	1.17	2.02	0.09	1.82	0.24
Ferrous	1.93	3.05	2.25	2.47	3.75
Non-ferrous	0.17	0.00	0.18	0.55	1.55
Aluminum	0.34	0.08	0.39	0.25	0.04
Batteries/hazards	0.22	0.18	–	0.29	0.06
Fine	–	0.71	2.66	0.00	0.39
Other organic	0.02	0.00	–	1.26	1.00
Other inorganic	–	0.27	0.25	–	8.05
Others	–	–	–	–	6.97
Total	100.00	100.00	100.00	100.00	100.00

- Food/organic—high contribution by the residential sector (up to 60%) but low contribution by the institutional sector (about 25% only). This is almost the same with the maximum and minimum shown in Fig. 1.
- Mix paper, newsprint—although Table 2 does not show much difference between the various sources, Fig. 1 does. By visual observation during the sorting process, the amount of paper waste that came in from the institutional sector was much more when compared to that coming in from the other sources. This could be the reason for the large variance in the maximum and minimum range.
- Plastic film—there is a difference in the amount of plastic film waste which is generated by the three different residential sectors. It could be concluded that income has a direct impact on the amount of plastic waste that is generated, as it clearly shows that the high-income people throw away the maximum amount of plastic waste, whereas the low-income people throw away the least. The range between the high income and low income in Table 2 does correspond to the maximum and minimum range pictured in Fig. 1

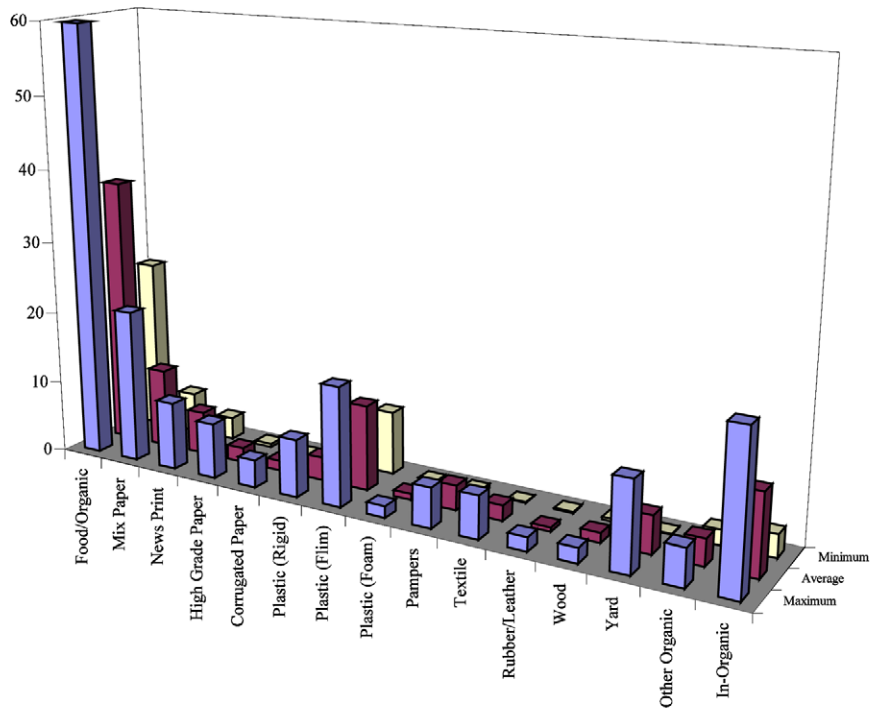

Fig. 1. Composition of MSW sampled at random.

Finally, the MSW was put through proximate analysis, ultimate analysis, calorific value and heavy metal content. The results are presented in Table 3. The most significant result is probably the moisture content, which indicates that it is very wet. Malaysia, being a country with a tropic climate, enjoys an abundant amount of rainfall throughout the year. Coupled with this is the fact that Malaysians generally dispose of their garbage in makeshift containers, which allow rainfall to get in, causing the garbage to collect water. This affects the calorific value of the waste, which is only about 2200 kcal/kg. This calorific value is very low for self-sustaining combustion, thus making incineration of this kind of waste an uneconomical option. As for the other parameters, there is not much difference as compared to the MSW generated in countries in Europe and America.

4. Energy recovery option by incineration

In the waste management hierarchy, waste to energy (WTE) has been considered as a mode for the recovery of resources that must be considered before ultimate disposal of the final inert materials. As indicated above, the average calorific value of the Malaysian MSW is about 2200 kcal/kg, whereas the maximum and

Table 3
Various data on the characteristics of Kuala Lumpur MSW

Proximate analysis (wet)	Weight %
Moisture content	55.01
Volatile matter content	31.36
Fixed carbon content	4.37
Ash content	9.26
Elemental analysis (dry)	
Carbon content	46.11
Hydrogen content	6.86
Nitrogen content	1.26
Oxygen content	28.12
Sulfur content	0.23
Heavy metal (dry)	ppm
Chlorine	8.840
Cadmium	0.99
Mercury	0.27
Lead	26.27
Chromium	14.41
Other parameters	
Bulk density (kg/m^3)	240
Net calorific value (kcal/kg)	2180

minimum values could range between 2640 and 1540 kcal/kg, respectively. The Government of Malaysia has suggested the use of thermal treatment to partly solve the waste management problem currently being faced by the major cities. There is a general tendency for the government to go for the gasification technology with ash melting system as it has superior emission control systems. The capacity of the plant that is suggested for the city of Kuala Lumpur is 1500 ton/day. There are a few other cities which are planning for such a system. However, the technology that is being acquired from Japan does not conform to the best available technology not entailing excessive cost (BATNEEC) concept. The government have requested for a thorough evaluation of the project. One such evaluation is the amount of energy that would be recovered from the incineration process.

Hence, a simple evaluation was carried out to evaluate the amount of energy that could be recovered if the MSW generated were to be incinerated. The evaluation was based on the net amount of energy that could be obtained per ton of the MSW treated. The basis for the calculation was that the incineration used the gasification technology with heat recovery of the hot gasses at 25% efficiency. The evaluation was done based on the average, maximum and minimum calorific values recorded for the MSW generated in Kuala Lumpur.

Based on the treatment technology described above, the results were tabulated and are shown in Table 4. It is very clear that incineration gives the best returns in terms of the amount of energy recovered. However, in evaluating the type of

Table 4
Amount of energy recoverable from MSW by incineration

Material	Treatment technology	WTE conversion efficiency (%)	Calorific value of fuel (kcal/kg)	Energy recoverable/ton of fuel (kW)	Total energy recovered (based on 1500 ton/day) (MW)	Energy recoverable (normalized to per ton of MSW input) (kW)
MSW	Incineration	25	2200	639	960	639
MSW	Incineration	25	1500	436	655	436
MSW	Incineration	25	800	233	350	233

technology that is best suited, it is important to evaluate the amount of energy that is needed to treat the waste and account for the environmental effect of employing such treatment technologies. Weighing all the three factors in hand and keeping in mind the fact that the MSW generated in Malaysia is high in organic and moisture content, other treatment technologies might be more adoptable in treating the MSW.

5. Conclusions

From the results, a conclusion can be made that the amount of organic waste is still the highest. A comparison of the waste from different sources indicated that it is the same as the results obtained by targeted sampling. The sampling by source did give a good understanding of the waste that is generated by the different sources. Finally, when evaluating the amount of energy that could be recovered by incineration, it could be said that incineration does give high returns on energy while staying low on environmental effect and on the energy consumed to treat the MSW. Hence, this technology needs to be developed and understood in order to be implemented for treating the waste generated in Malaysia.

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