

# Identification of the Municipal Solid Waste Characteristics and Potential of Plastic Recovery at Bakri Landfill, Muar, Malaysia

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## Abstract

The objective of this study was to evaluate the composition and characteristics of the generated municipal solid waste (MSW) in order to obtain information about the quantity of recoverable plastic at Bukit Bakri landfill Muar, Malaysia. Solid waste sampling and laboratory analysis were carried out according to the random sampling method based on American Society of Testing and Materials (ASTM) standards to determine the waste compositions and proximate analysis (moisture content, volatile matter, ash content and fixed carbon). The total quantity of MSW generated at the site was 330 ton/day made up of 25 individual types of waste. The main compositions of the generated waste were 39% food waste, 12% plastic waste and 16% paper which accounted for about 67% by weight. About 12% of disposed materials at Bakri landfill consisted of recoverable plastics of which 9% plastic film, 2% rigid plastic and 1% plastic foam. The average moisture content of the waste was between 50-58%. Although, there is significant volume of recoverable plastic at the disposal site (approximately 35 tons/day), this materials are still being land filled without any form of treatments. Based on the results obtained, this study has recommended the plastic recovery plan as a feasible MSW strategy to reduce the amount of disposed waste at Bakri landfill.

**Keywords:** municipal solid waste (MSW), landfill, random sampling, waste composition, proximate analysis, plastic recovery

## 1. Introduction

Municipal solid waste management (MSWM) is a major responsibility of local governments which typically consuming between 20 and 50 percent of municipal budgets in developing countries (Peter et al., 1996). During the recent decade industrialization, migration from rural area, urbanization, uncontrolled consumption and growth were the causes of increasing the waste and consequently the rise of the waste management problems in Malaysia (Osman et al., 2008).

Three primary sources of (MSW) are classified as residential area, institutional and commercial waste (Tariq et al., 2007). The two main factors that effect on type and quantity of waste are culture and society consumption pattern. Generally MSW consist of around twenty different categories: food waste, paper (mixed), cardboard, plastic (rigid, film and foam), textile, wood waste, metals (ferrous or Non-ferrous), diapers, news print, high grade and fine paper, fruit waste, green waste, batteries, construction waste and glass, these categories can grouped into organic and inorganic (Marine, 2007).

While the rural population still produces 0.8 kg/cap/day in Malaysia, the main problem seems to be the consumption-orientated urban middle-class that generates about 1.9 kg/cap/day of municipal solid waste (Shan Tee et al., 2009). Approximately in Malaysia, between 70 to 80 percent of municipal solid waste is placed in landfill (Sumiani et al., 2009). For many years landfill was inexpensive and the most common technique for solid waste disposal. Any type of waste was simply dumped in an open area of ground without any attempt for recovering or recycling.

Recovering is defined as part of solid waste management operation that prepares the waste material which is not useful for original user to be use in other manufacturing process (Gent et al., 2011). Certain type of waste such as plastic and metals are valuable as recoverable materials. Plastics are made from non renewable sources. Although plastics are not intrinsically dangerous, their resistance to natural biodegradation processes is the reason of taking up a huge amount of space in landfills. The life cycle of many plastic products are less than one year and afterwards the majority of these plastics are discarded to the disposal sites (H. Wansbrough & New Zealand Recyclers Ltd).

With regard to the quantity of plastic in disposal sites, the recovery goals are aimed primarily at separating these materials from the composting process and second to determining if it is worth to recover them via the recycling process (Katherine et al., 2009). Bakri landfill with area 800 m<sup>2</sup> was established in 1998. This landfill located in Bukit Bakri, Muar, Johor Darul Ta'zim to serve the city of Muar (350 kilometers south of Kuala Lumpur, capital city). Bakri landfill used as dumping site for household waste for around 22 years without any recorded data of the types, quantity and quality of solid waste. The sharp increasing rate of domestic waste generation in Muar compare to the percentage of recovery and recycling are the reasons that put the MSW department under pressure to make plan for finding the new disposal area or to introduces the new method for handling the waste material (Municipal Solid Waste Management Authority In Johor Bahru , 2010).

This study aimed to describe and classify the municipal solid waste collected from Bakri landfill to determine the feasible method for reduce the amount of disposed waste. In order to achieve this, the study focused to evaluate the potential of plastic recovery. Field work was carried out by using the combination of qualitative and quantitative methods, which was essential for the research.

## **2. Materials and Methods**

Research methodology consists of sampling selection method, sorting procedure, and laboratory analysis to determine the chemical and physical properties of accommodated components at Bakri landfill, Muar, Malaysia.

Generally there are two formal types of sampling and analysis methods based on ASTM D 5231-5292 namely, random truck sampling and quartering. The sampling plan for this project was according to random truck sampling which was determined by considering the available facilities and background information of the site location. The first step in waste characterization was to obtain the detail information about the percentage of each individual component in the waste stream.

Recorded data from sorting process base on the trucks arrival indicate the percentage of each solid waste category at the disposal site and provide the information about the type and volume of MSW that disposed to the landfill and the respective of suitable recovery strategy. Manual sorting was performed by six sorters during six to eight hours, all sorting personnel had a complete knowledge to identifying the type of waste and technical requirements of the sorting process.

### *2.1 Method of Waste Characterization*

#### *2.1.1 Random Sampling*

This procedure was applied for collecting the representative municipal solid waste in waste stream. Base on the American Society for Testing and Materials (ASTM), The first step in random sampling method was a random pick up of the garbage bag from arrival waste loads (trucks) which is usually an amount of 15 or 20 kg per unit (MSW trucks). In this part only MSW trucks were considered to take the samples. Next, the waste was separated according to the selected classification such as wood, paper, class and green waste, each category was weighted by using a weight balance and the materials were discarded after recording the data. In order to obtain accurately measure of waste characterization the original plan called for sorting 200 kg of MSW which can be considered as a representative of the total MSW composition in study region.

#### *2.2 Proximate Analysis*

Proximate analysis consist of moisture content, ash content, volatile matter and fixed carbon determined by put the selected sample to different range of the temperature, between 100°C to 950°C. The laboratory methods to measuring the proximate analysis of samples in this research were carried out based on ASTM standard. This standard determine the condition of lab analysis such moisture and volatile content.

##### *2.2.1 Moisture Content*

The percent moisture of the MSW samples was determined by weighing 1 kg of the samples into a pre weighed dish and drying the samples in an oven at 105°C to a constant weight (ASTMD 3173). The percent moisture content (MC) was calculated as a percentage loss in weight before and after drying. Equation (1):

$$\% \text{ Moisture content} = [(\text{Wet Weight} - \text{Dry Weight}) / \text{Wet weight}] \times 100\% \quad (1)$$

### 2.2.2 Volatile Matter Content

The volatile matter content was determined by the method of ignition of the sample at 950°C. The triplicate samples of MSW material used in the moisture content determination were weighed and placed in a muffle furnace for 7 minutes at 950°C (ASTMD3175). After combustion, the samples were weighed to determine the ash dry weight, with volatile solids being the difference between the dried solids and the ash Equation (2):

$$\% \text{ VS} = [(\text{Dry sample weight} - \text{Ash weight}) / \text{Dry sample weight}] 100\% \quad (2)$$

### 2.2.3 Ash and Fixed Carbon Content

Ash content of waste is the non-combustible residue left after waste is burnt, which represents the natural substances after carbon, oxygen, sulfur and water. Analysis include of dried the samples at 750°C for 1 hour (ASTMD 3174). Fixed carbon defined by carbon found in the material which is left after volatile test. Fixed carbon is determined by removing the mass of volatile from the original mass of the sample. Equation (3):

$$\text{Fixed carbon (Wt\% wet basis)} = 100 - (\text{Wt\% moisture content} + \text{Wt\% Ash} + \text{Wt\% volatile matter}) \quad (3)$$

## 3. Results and Discussion

This part presents several graphical summaries of the disposed materials in Bakri waste stream which are divided into three major categories. Figure 1 presents the aggregated composition of main disposed groups of solid waste at Bakri.

An average of 330 tons of materials discharged daily at Bakri landfill. Quantity of MSW in this research is separated from the farming and wood waste which formed by industrial sector around landfill site. Municipal solid waste with almost 280 tons per day is largest fraction and the second largest component is farming waste which comprised 30 tons per day. The waste composition in Bakri varies according to the time of the year and depended of the different sources. Result from the waste composition in this research, provided on the September 2010 which is considered as a dry season in Malaysia. The major bulk density of the disposed waste in Bakri landfill presents in Figure 2.

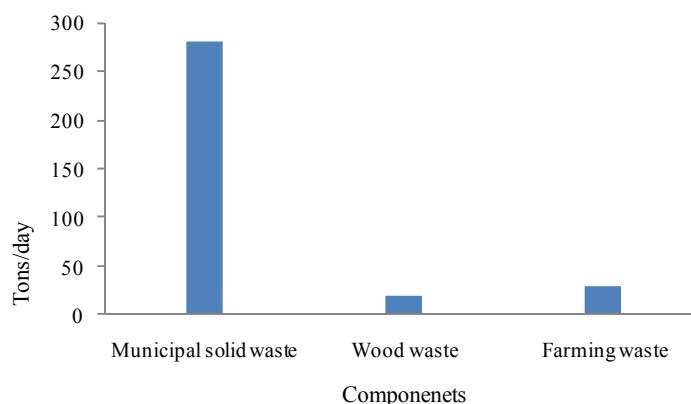


Figure 1. Quantity of aggregated disposal solid waste (Tones/day)

As Figure 2 indicates organic waste such as, food and fruit waste followed by plastic and paper make up the largest fraction of generated wastes in Bakri. Top seven individual materials were most prevalent in the Bakri disposed waste stream included of food waste (39.0 percent), mixed paper (10.0 percent), plastic film (9.0 percent) fruit waste (9.0 percent), diapers (8.0 percent), news print (6.0 percent), cardboard (5.0 percent), and yard waste (3.0 percent). The high percentage of plastic can be explained by increasing the number of packaging factories around Bakri landfill. The waste materials from these manufacturing mostly include of high volume of different type of plastic which are mixed with a small amount of paper, glass and textile.

This is expected, increasing the population, migration and on the other hand industrialization during the past few years is the main reasons of increasing the quantity of municipal solid waste. Ferrous and non ferrous material, rubber, leather and glass had the small fraction of MSW in this landfill (Table 1). High percentage of recyclable

components show the landfill in Bakri has potential for provide the recovery facilities. The recovery process can be considered as one the acceptable methods to handle and decrease the high volume of plastic and the others recyclable materials.

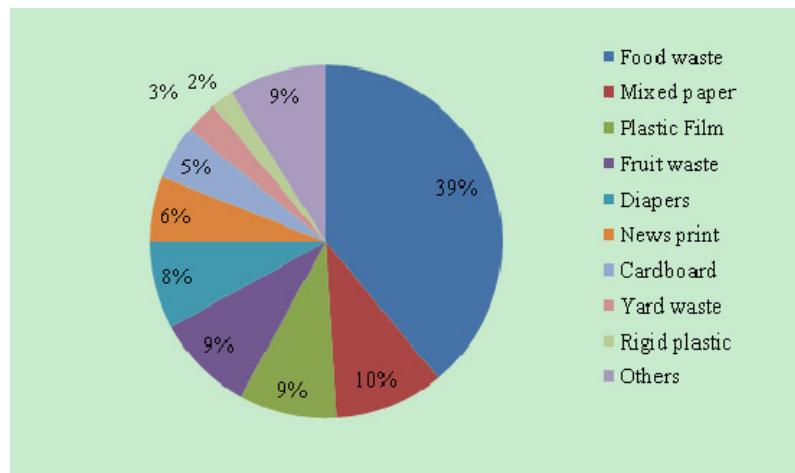


Figure 2. Municipal solid waste composition

The compared result of MSW composition study in three landfills in Malaysia, Kuala Lumpur, Penang and Bakri are shown in the Table 1. Based on the observation the following discussion can be made:

Table 1. Comparison of waste characteristic in Kuala Lumpur, Penang, Bakri (Piao et al., 2006; Sivapalan et al., 2005)

| Component           | Kuala Lumpur(KL)<br>Weight% | Penang Weight % | Bakri (Muar)<br>Weight % |
|---------------------|-----------------------------|-----------------|--------------------------|
| Food waste          | 37.42                       | 39.51           | 38.85                    |
| Paper(mixed)        | 8.7                         | 10.3            | 9.28                     |
| Cardboard           | 1.59                        | 2.34            | 4.63                     |
| Plastic(Film)       | 10.978                      | 7.41            | 9.3                      |
| Plastic(Foam)       | 1.65                        | 1.87            | 1.31                     |
| Plastic(Rigid)      | 3.28                        | 2.5             | 1.75                     |
| Textile             | 3.4                         | 2.16            | 1.11                     |
| Rubber/leather      | 1.318                       | 0.04            | 1.76                     |
| Others              | 1.394                       | -               | 1.74                     |
| Wood waste          | 2.776                       | 1.96            | -                        |
| Yard waste          | 3.178                       | 3.09            | 3.37                     |
| Organics            | 0.45                        | -               | 0.04                     |
| Inorganic           | 1.714                       | -               | 0.755                    |
| Glass(Clear)        | 1.608                       | 1.1             | 1.683                    |
| Glass(coloured)     | 1.068                       | 0.67            | 0.02                     |
| Metal(Aluminum)     | 0.22                        | 5.79            | 0.06                     |
| Batteries/Hazardous | 0.15                        | -               | 0.05                     |
| Diaper              | 5.8                         | 2.5             | 7.90                     |
| Fruit waste         | 5.5                         | 6.5             | 9.23                     |
| Metal(Ferrous)      | 0.274                       | 0.45            | 1.21                     |
| News print          | 7.5                         | 12.7            | 5.96                     |

Food and yard waste: population identified as first reason for increasing the solid waste. Although Kuala Lumpur (KL) as capital city has largest population in Malaysia but there is no obvious difference between amounts of

food waste in KL and other main cities. This is predictable and can be refer to food consumption and social activity in this city. For example, more people and workers tend to have meal in restaurant and cafe which has positive effect on decreasing the food waste that goes to land fill site.

Mixed paper, news print: Although this table doesn't show the much difference between the percentage of these materials on sites, but base on visual observation during the study period, amount of paper waste that formed by Kuala Lumpur city was collected by private sector companies for recycling or cardboard manufacturing processes and only the rest that couldn't be sort out from the other waste come to the landfill, but in Bakri waste materials goes to the landfill site without any surveillance.

Diaper, textile and rubbers: The large variance in amount of diapers in Bakri with KL is a result of growing population around this area. This is expected that increase the population in the next few years attends with multiply the problems in municipal solid waste management. Textile is a major materials discharged by industrial and commercial activities. Since Kuala Lumpur is developing city, it is expected to increase the Textile with increasing the industrials area around this city.

Plastic: The three years period in Malaysia 2006-2009, was characterized by increase 3.7% in total percentage of plastic in MSW. As shown in the Table 1 there is not much different between the amount of plastic waste in KL and Bakri, but the percentage is higher than Penang. This may be attributed to the increase in the number of offices, factories, commercial area, plastic manufacturing and greater use of plastic for food packing in those areas.

### 3.1 Quantities of Recyclable Materials

The quantity in tones of common recyclable materials that disposed at Bakri per day presents in Figure 3. As this figure indicates, paper with near 45 tones is largest fraction of the disposed materials compared with plastic and metal. recyclable plastics, cardboard and metals were found relatively lower disposal rate- about 35, 15 and 3 tons respectively, but the overall quantity of them still significant .the common type of waste materials that is found in this landfill included, newspapers, manuals, books, office paper, catalogues and paper box, metals such as aluminum cans, drinking cans and tin containers of food beverage like milk. Plastic is consist of soft drink and juice bottle mineral water bottle, food and sauce containers, liquid soap, detergent bottles shampoo, lotion bottles and the majority plastic bags.

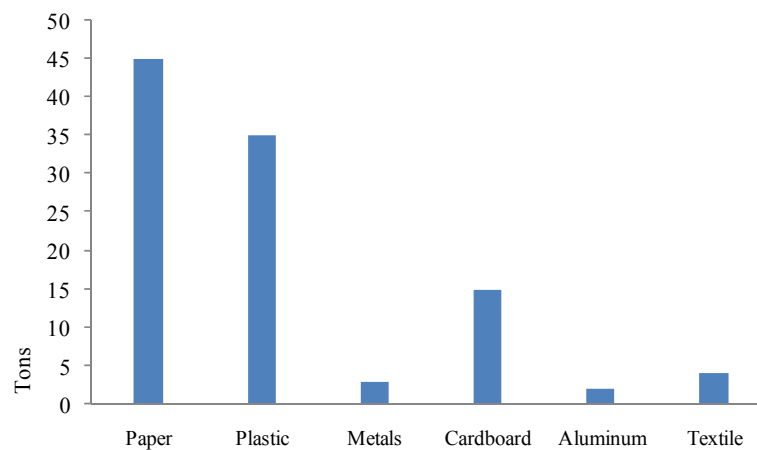


Figure 3. Quantity of recyclable materials in waste stream (Tons/day)

#### 3.1.1 Quantity of Each Individual Type of Plastic and Paper

Quantity of each individual type of plastic and paper waste in Bakri indicate in Figure 4. The plastic film with almost twenty five tons per day is a largest fraction of plastic in the waste stream and mixed paper and news print are the other largest fractions of disposed material in this landfill site. It is expected that with increasing the usage of plastic film in wide range of products and packages, the amount of this plastic also increase in disposal sites. Plastic film, typically used for industrial packaging, especially food manufacturing. Plastic film can vary by resin and color; it may also be made of one layer of plastic or as many as ten layers depending on the

complexity of the package and this is a main reason of increased usage of this type of plastic in industrial process.

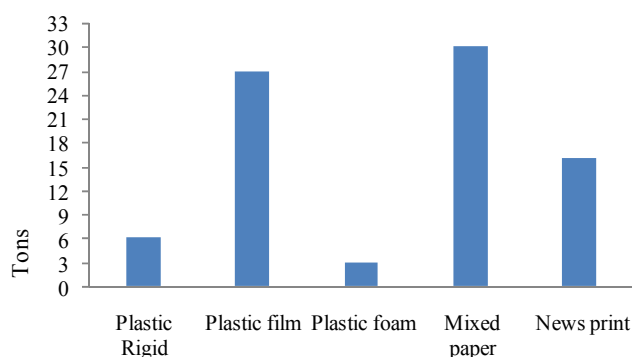


Figure 4. Quantity of each individual type of plastic and paper (Tons/day)

### 3.2 Proximate Analysis Result

Following the waste characteristics analysis, Table 2 shows the recorded result from proximate analysis of components in Bakri landfill.

#### 3.2.1 Moisture Content

The moisture content is measure with the amount of water lost from materials upon drying to a constant weight. It is directly affected by physical and chemical properties of material which enable it to absorb the exiting water in the environment. Table 2 shows the comparison result from moisture content analysis of the each individual category in Bakri. Based on laboratory analysis result, food waste with 75-82 percent, diaper with 80-85 percent and fruit husk with 59-70 percent have the highest moisture content in this landfill. This analysis indicated the volume the moisture for plastic is approximately twenty one percent.

#### 3.2.2 Fixed Carbon, Volatile and Ash Content

Table 2. Obtained results from proximate analysis of collected sample at bakri landfill

| Components         | Moisture content (% by weight) | Moisture content% | Ash content% | Volatile matter% | Fixed carbon% |
|--------------------|--------------------------------|-------------------|--------------|------------------|---------------|
| Food waste         | 75-82                          | 30.7-33.5         | 14.0         | 80.0             | 6.0           |
| Mixed Paper        | 30-41                          | 3.1-4.3           | 9.0          | 84.0             | 7.0           |
| Plastic            | 21-23.5                        | 0.54-0.82         | 1.4          | 97.0             | 12.0          |
| Diaper             | 80-85                          | 7.09-7.5          | 20.0         | 73.0             | 7.0           |
| Yard waste         | 13-38                          | 0.47-1.3          | 20.0         | 75.0             | 7.0           |
| Fruit husk         | 59-70                          | 5.65-4.6          | 27.0         | 64.0             | 9.0           |
| News print         | 13-18                          | 0.82-1.1          | 9.5          | 85.0             | 5.5           |
| Corrugated paper   | 8-10                           | 0.39-.5           | 12.0         | 76.0             | 12.0          |
| Textile            | 5.5-9.5                        | 0.07-0.1          | 7.5          | 74.5             | 18            |
| Rubber/Leather     | 1.5-3.2                        | 0.04-0.06         | 22.0         | 65.0             | 8.0           |
| Metal(Non-ferrous) | 5.5-9.5                        | 0.00-0.00         | 12           | 14               | 74.0          |
| TOTAL              |                                | 50.0-58.0         |              |                  |               |

Fixed carbon is the carbon remaining on surface as charcoal. The high percentage of the fixed carbon in waste materials such as metals (74%) shows that this element requires a longer detention time on the surface of the furnace to achieve complete combustion compared to paper waste, food waste or even textile that has low fixed carbon load. Table 2 also shows that the high percentage of ash content in fruit husk, rubber and leather with twenty seven and twenty two percent respectively, dominating in the ash content percentage. Volatile matter is

that portion of the wastes which is converted into the gas phases during the heating process (950°C). As shown in Table 2, the percentage of volatile content is relatively high between among the total of MSW fraction in this disposal site.

#### 4. Conclusion

According to the data on the composition of waste from Bakri area, it observed that, disposal waste is mainly consisting of food waste, plastic and paper which all together account for about 55 percent of the dumped MSW. Based on the result from sorting process of the disposed waste, landfill contains of sufficient quantity of waste plastic (about 35 tons per day) but unfortunately the attention paid by the authority towards this direction is not sufficient enough to tackle this issue. The result of the various analyses on quality of plastic in the waste shows the mixed plastic is mostly combined with other waste materials such as paper and soil which should be removed to achieve the high quality of recovered plastic. Common assessment and analyzing the present data from waste generation rate in this area can be estimate that the solid waste generation in the city is presently very high and may become worse in future.

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