COMPOSITION AND GENERATION OF MUNICIPAL SOLID WASTE (MSW) IN MALAYSIA: BALAKONG CITY CASE STUDY

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Abstract. Municipal Solid Waste (MSW) management is one of the most challenging issues faced by most developing countries. Knowledge of solid waste generation and composition is necessary for accurate decision-making in terms of engineering design, planning and forecasting for the management strategy of urban waste. The objective of this study was to determine MSW generation and composition in an urban area of Balakong City, Selangor, Malaysia. The application of a linear model on solid waste forecasting was also performed in this study. A survey of household residents in eight housing areas in Balakong was carried out for one month from January to February 2011. Data were collected on a daily basis. In total, organic waste was the highest composition (5,344 kg, 68.6%) among the solid waste generated in all eight housing areas. Plastic and paper comprised of 10.4% (811 kg) and 9.5% (736 kg) of the solid waste generated. The least composition was glass (270 kg, 3.5%) and metals (204 kg, 2.5%). Other type of disposables comprised of 5.5% (419 kg) of the total solid waste generated. A linear model on solid waste forecasting has determined slightly higher prediction on solid waste generation with a statistically significant difference was obtained at $p < 0.05$.

Key words: Municipal solid waste, composition, generation, linear model, Balakong city.

Introduction. Municipal solid waste (MSW) or also known as "trash" or "garbage" refers to the common household waste generated within an urban setting. Solid waste as stated in Solid Waste and Public Cleansing Management Act 2007 [Act 672] can be defined as any scrap material or other unwanted surplus substance or rejected products arising from the application of any process; or any substance required to be disposed of as being broken, worn out, contaminated or otherwise spoiled; or any other material that according to this Act or any other written law is required by the authority to be disposed of, but does not include scheduled wastes as prescribed under the Environmental Quality Act 1974 [Act 127], sewage as defined in the Water Services Industry Act 2006 [Act 655] or radioactive waste as defined in the Atomic Energy Licensing Act 1984 [Act 304] [1].

Due to the growth in population and changes in lifestyle, the problem of increasing volume of solid waste composition and generation being faced is very serious, especially from anthropogenic sources and also the lack of awareness from the people concerned with respect to waste management and its implication on the environment for future generation [2]. In [3] stated that solid waste management is known as the discipline related to the control of waste generation. The disposal of waste has become particularly more difficult in urban areas due to the increasing population. At the same time, there is greater production of waste but the land availability for waste disposal is decrease.

Generally, in Malaysia, MSW is disposed of by the landfill method or incineration and only a small proportion (about 2%) is recycled or treated by biological composting [4]. However, in Selangor, all the MSW collected by the waste collectors is disposed of in an open dump landfill. The management of the landfill includes the monitoring and leveling of waste [5]. Many cities in Asian countries are facing serious problems in solid waste management. For instance, in India, it is observed that more than 90% of MSW is disposed of on land without taking any specific precaution, which poses a serious threat to the environment [6]. This is supported by [7] who have stated that the collection, segregation, transportation, and disposal of solid waste in India was inefficient and chaotic. The uncontrolled dumping of waste on the outskirts of towns and cities has created overflowing landfills, which have considerable negative environmental impacts in the form of pollution to the soil, groundwater, and air as well as contribute to the global warming phenomena.

Many previous studies focused on the characteristics of municipal solid waste at the final disposal sites [8, 9] and data on solid waste composition generally focused on the physical characteristics [10]. In [11] reported that, generally, waste generation and composition differ with the amount of prosperity and urbanization. Both the quantity and composition of solid waste vary from day to day. It also differs according to the seasons of the year, not only between countries, but also between nearest localities and between different types of property within the same town. The characteristics and composition of MSW depends on various factors, such as location, type of food consumed, living standards, commercial status and many more.

This study was aimed to measure the MSW generation and composition in eight selected housing areas in Balakong, Selangor. Balakong is a large township in Selangor, Malaysia consists mainly of residential condominiums, office complexes and factories which significantly produce high volume of waste. The knowledge on the composition

and volume of MSW generation is important as a basis of planning for a waste management system in the country. This study also performed a solid waste forecasting by the solid waste linear modelling using the raw data collected from this study. These studies provide baseline information on the rate of waste generation and the volume of waste generated by composition which is important for a waste management system planning in the country.

Methodology. The study area that has been chosen involved households from eight housing areas located in Balakong. Balakong is situated exactly at the boundary of Kajang and Cheras. The surrounding area of this town is busy with small, light and middle industries. Balakong consists of various shopping malls that are frequented by tourists and locals. Based on the map given by Kajang Municipal Council (KMC) 34 and analysis from Malaysia's Department of Statistics, the study area consists of 4,433 residents [12]. The housing areas involved in this assessment were Taman Taming Jaya (TTJ), Taman Balakong Jaya (TBJ), Kampung Kenangan Indah (KKI), Taman Sri Indah (TSI), Taman Impian Ehsan (TIE), Taman Setia 2 (TS2), Taman Cheras Jaya (TCJ) and Taman Desa Karunmas (TDK). Fig. 1 shows the locations of the study area.

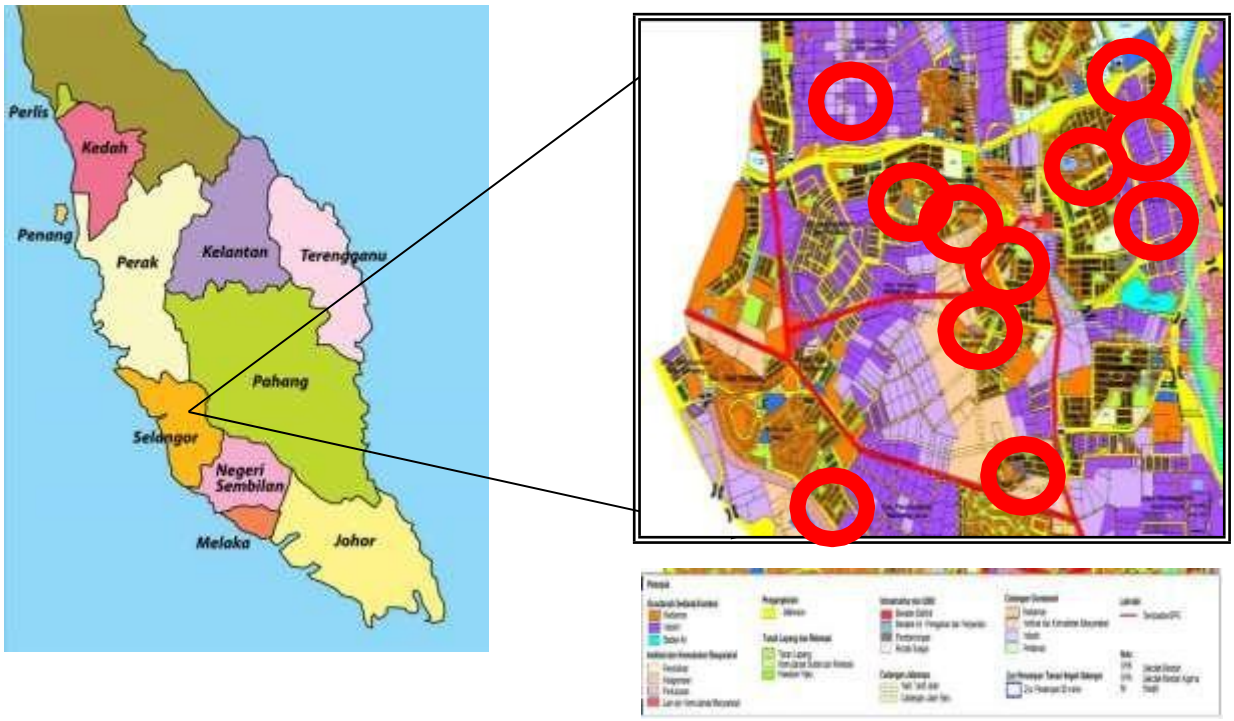

Fig. 1. The locations of the study area in Balakong

The information on the volume of waste generation and its disposal management were gathered in this study. The average production and components of Municipal Solid Waste (MSW) were determined using a household sampling survey. The type of residential areas that were involved in this study is terraced houses. Plastic bags were given to around 100 respondents for each house on 19th and 20th January 2011. Each participating household was issued with 60 plastic bags for 30 days. They were allocated with two plastic bags per day for depositing their daily wet waste and dry waste separately. Wet waste mainly consists of food and organic waste, while dry waste comprises paper, plastic, metal, glass and others. All the solid waste generated by the respondents was weighed using a balance with a scale from 0 to 50 kg. The data were collected every evening starting from 23rd January 2011 until 21st February 2011. The waste was sorting into several components which are organic waste, paper, plastic, glass, metals and others. From the survey, data collected were analysed using Microsoft Excel 2007. The average daily and monthly generation of solid waste were calculated and are displayed in the form of tables and graph for database and monitoring for local authorities and decision makers for current and future planning.

In order to predict the solid waste generation, a linear model was used, which was first tested on the data obtained from the study area. A linear model was designed such that it could be simple and complete; therefore, the data generated and the results can be easily understood and manageable. In this expert system, one linear model was created for the purpose of forecasting waste composition generation and profit. The formula for solid waste forecasting is as in Equation (1)

$$SWGp * ((100 + PA)/100)^{F-P} \quad (1)$$

where SWGp = Solid Waste Generation present, PA = Percentage of Assumption (4% increasing) and F-P = Future – Present

This formula was used in Saeed et al. [13] in his research on the assessment of municipal solid waste generation and recyclable materials potential in Kuala Lumpur, Malaysia. Solid waste generation present (SWGp) is the amount of waste generated at the present time, which will be a baseline indicator for the calculation of this linear model [14].

Results and discussion. Table 1 shows the average generation of solid waste composition at Balakong in per capita per day. In general, among of all types of waste, organic waste was the highest followed by plastic, paper, glass, metals and other disposables [15, 16]. Organic waste comprised of kitchen waste, leaves, wooden matter, paper, cloths, gunny bags and other inseparable material. From the table, organic waste (0.420 kg/capita/day) and metals (0.035 kg/capita/day) were the highest waste produced in Site 7 in this study. Paper (0.088 kg/capita/day) and glass (0.058 kg/capita/day) were the highest waste produced in Site 8 in this study. Plastic (0.085 kg/cap/day) and others (0.048 kg/capita/day) were the highest waste produced in Site 3 in this study.

Table. 1. Average generation of solid waste composition at Balakong in per capita per day

Average Composition (kg/Capita/Day)						
Housing Area	Organic Waste	Paper	Plastic	Glass	Metal	Others
Site 1	0.348	0.038	0.038	0.000	0.003	0.030
Site 2	0.370	0.055	0.045	0.013	0.005	0.018
Site 3	0.365	0.053	0.105	0.003	0.003	0.048
Site 4	0.275	0.028	0.033	0.010	0.005	0.015
Site 5	0.413	0.043	0.030	0.023	0.010	0.015
Site 6	0.298	0.028	0.033	0.010	0.013	0.025
Site 7	0.420	0.078	0.083	0.040	0.035	0.040
Site 8	0.365	0.088	0.085	0.058	0.033	0.040

Note: Site 1 - Taman Taming Jaya (TTJ), site 2 - Taman Balakong Jaya (TBJ), site 3 - Kampung Kenangan Indah (KKI), site 4 - Taman Sri Indah (TSI), site 5- Taman Impian Ehsan (TIE), site 6 - Taman Setia 2 (TS2), site 7 - Taman Cheras Jaya (TCJ), site 8 - Taman Desa Karunmas (TDK)

Table. 2. Average generation of solid waste composition at Balakong in per capita per month

Average Composition (kg/Capita/Month)						
Housing Area	Organic Waste	Paper	Plastic	Glass	Metal	Others
Site 1	10.448	1.120	1.163	0.033	0.058	0.928
Site 2	11.095	1.625	1.330	0.405	0.185	0.490
Site 3	10.940	1.583	3.120	0.110	0.090	1.443
Site 4	8.255	0.815	0.955	0.290	0.148	0.443
Site 5	12.395	1.265	0.890	0.675	0.328	0.478
Site 6	8.895	0.838	1.010	0.263	0.360	0.748
Site 7	12.608	2.295	2.448	1.185	1.080	1.210
Site 8	10.950	2.640	2.558	1.755	1.005	1.233

Note: Site 1 - Taman Taming Jaya (TTJ), site 2 - Taman Balakong Jaya (TBJ), site 3 - Kampung Kenangan Indah (KKI), site 4 - Taman Sri Indah (TSI), site 5- Taman Impian Ehsan (TIE), site 6 - Taman Setia 2 (TS2), site 7 - Taman Cheras Jaya (TCJ), site 8 - Taman Desa Karunmas (TDK)

Following data presentation for the average solid waste composition generated by capita in housing areas per day and per month, the solid waste composition generation for households in Balakong City for 1 month is presented in Table 3. The data from Table 3 show that Site 7 had the highest amount of waste composition generation with a value of 1,677 kg/month followed by Site 5 with a value of 1218 kg/month. From the total weight, organic waste comprises the highest portion, which was about 1,016.1 kg in site 7 and 942 kg in site 5. Glass and metals contributed to the smallest amount of waste generated in both areas. The lowest total of waste generated for a month was recorded in Site 6 with the total of 582. Organic waste constituted 427 kg of the total waste generated in Site 6 while the two lowest waste composition values were for metal (17.3 kg) and glass (12.6 kg). However, it should be noted that the number of houses that took part in this study was different among the housing areas and the total waste produced was directly influenced by the number of households involved.

Table. 3. Composition and generation of solid waste at Balakong City household for 1 month

Sources Location	Composition (kg/Month) (%)						
	Organic Waste	Paper	Plastic	Glass	Metal	Others	Total
Site 1	710.4 (75.9)	76.2 (8.1)	79.0 (8.4)	2.2 (0.2)	3.9 (0.4)	63.0 (6.7)	935
Site 2	532.5	78.1	63.8	19.5	8.82	23.5	726

	(73.3)	(10.8)	(8.8)	(2.7)	(1.2)	(3.2)	
Site 3	612.6 (63.3)	88.6 (9.2)	174.7 (18.0)	6.1 (0.6)	5.0 (0.5)	80.8 (8.3)	968
Site 4	627.5 (75.7)	61.9 (7.5)	72.6 (8.8)	22.1 (2.7)	11.2 (1.4)	33.6 (4.1)	829
Site 5	942.0 (77.3)	96.2 (7.9)	67.7 (5.6)	51.4 (4.2)	24.9 (2.0)	36.23 (3.0)	1218
Site 6	427.0 (73.4)	40.2 (6.9)	48.5 (8.3)	12.6 (2.2)	17.3 (3.0)	35.9 (6.2)	582
Site 7	1016.1 (60.6)	183.4 (10.9)	198.9 (11.9)	89.02 (5.3)	89.4 (5.3)	100.0 (6.0)	1677
Site 8	476.0 (56.0)	111.4 (13.1)	105.7 (12.4)	67.0 (7.9)	43.3 (5.1)	46.0 (5.4)	849.3
Total (kg)	5344	736	811	270	204	419	7784
Total (%)	68.6	9.5	10.4	3.5	2.5	5.5	100

Note: Site 1 - Taman Taming Jaya (TTJ), site 2 - Taman Balakong Jaya (TBJ), site 3 - Kampung Kenangan Indah (KKI), site 4 - Taman Sri Indah (TSI), site 5- Taman Impian Ehsan (TIE), site 6 - Taman Setia 2 (TS2), site 7 - Taman Cheras Jaya (TCJ), site 8 - Taman Desa Karunmas (TDK)

In total, organic waste made up the highest composition (5,344 kg, 68.6%) among the solid waste generated in all eight housing areas. Plastic and paper comprised of 10.4% (811 kg) and 9.5% (736 kg) of the solid waste generated. The least composition was glass (270 kg, 3.5%) and metals (204 kg, 2.5%). Other type of disposables comprised of 5.5% (419 kg) of the solid waste generated (Table 3).

According to CPHEEO [17], waste in developing cities, generally, has high organic content, which is more than 50% and a low energy value, which is about 3,350–4,200 kJ/ kg. Furthermore, the eating habits of the locals influence the organic waste generation rate in the country [18]. The waste composition recorded by the Government of Malaysia [19], in the yearly report showed similar trend where organic waste constitute of 45% of the total waste followed by plastic (24%), others (15%), paper (7%), metal (6%) and glass (3%).

Plastic and paper composition in household waste were the second and third highest in this study. This was possibly due to the changes in the household lifestyle, as there is a preference for buying a variety of ready-made foodstuff in packaging as well as reading materials. The amount of paper and plastics including materials, such as food containers and wrapping materials in this study, was noted to be much lower than in developed countries, such as the USA (65 %) and Western Europe (48 %) [20]. Metals were rarely found in the household waste in this study possibly because the community realizes the importance of recycling.

All the metal is usually sold for recycling purposes because of the high price offered, which is about RM 2.5/kg compared to plastic and paper with a price of RM 0.45/kg and RM 0.1/kg, respectively [14]. A study by [21] mentioned the role of the informal sector in waste minimization through recycling, and it has been proven that recycling rates by the informal sector is quite high, which is within 20 % to 50 %. The Recycling Programme, which involves 23 local authorities or Pihak Berkuasa Tempatan (PBT) throughout the country, was launched in 1993 and constitutes the main agenda in Malaysia. The Ministry of Housing and Local Government [22] organized this programme to promote recycling by households, institutions, factories and the public. Later on, this activity was taken over by the Department of National Solid Waste Management. The main priority of this move concerns the reduction and recovery of controlled solid waste [23].

The MSW collection services and management in most of developing countries is insufficient, non-scientific, disorganized, and informal. Insufficient public and private funds, and corrupt management of public sanitation systems are the other factor that influence it [24, 25, 26, 27]. The public waste collection service in developing countries is undoubtedly a major concern due to the unknown quantity and type of MSW collected, the amount recovered and recycled, inadequate selection of final disposal sites and the inefficient reutilization and recycling programmes [28]. In the absence of formalized waste segregation practices, recycling has only emerged as an informal sector using out-dated technology, which causes serious health problems to waste-pickers [29].

Fig. 2 shows the Graph of total waste generated (kg) versus duration of the study (days). The graph shows the positive increased trend of total waste generated in the study area by days. The total generation of waste has increased from 16.8 kg in the 1st day of the study to 167.9 kg in the 10th days and 504.7 kg in the 30^{th} days. MSW generation in Malaysia is mainly influenced by the increasing population and rapid urbanization as well as other indirect factors. This was shown through the generation amount of municipal solid waste from Kuala Lumpur State Territory, which was delivered to the Taman Beringin Transfer Station (TBTS) with a recorded value of 2,000 tonnes per day in 2010.

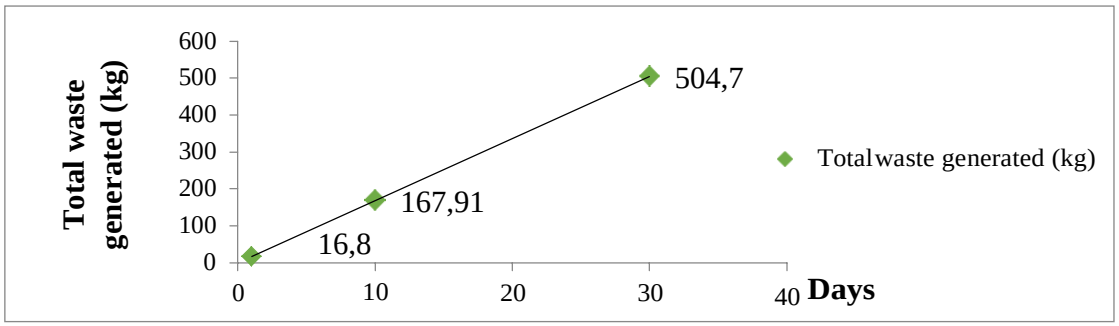

Fig. 2. Graph of total waste generated (kg) vs. duration of the study (days)

The average waste generation for each person is 1.2 kilograms per day [14]. Generation of solid waste in Kuala Lumpur was estimated to be 3,478 tons/day with a population of around of 2.150 million in year 2005. The average waste generation from any person is 1.6 kilograms per day [30]. Based on the World Bank Report 2012 [31], about 3 billion residents generated almost 1.3 billion tonnes of solid waste per year. However, in year 2012, with a population of 28 million, Malaysia generated around 33,000 tonnes of solid waste per day and the MSW management there is facing crucial challenges.

The MSW generation rate has been accelerated by several factors, including rapid population and economic growth, and also changes in lifestyle, which cause its management to be a challenge worldwide [32]. During the early stages, since population density was low, the solid waste was disposed on open air land spaces. However, nowadays, increasing amount of solid waste become one of the consequences of global urbanization [7]. There are many authors have reported that the generation of solid waste by a country is proportional to its population and the mean living standards of the people [33, 34, 35, 36].

In order to predict the solid waste generation, a linear model was used, which was first tested on the data obtained from the study area. A linear model was designed using Equation (1), and from the equation, the predicted data for solid waste generation was developed from the daily data recorded in the study area.

Analysis statistics of validation model t-Test was used to these data. The result collected was shown in Table 5. The t-test shows significant difference of the mean value between predicted and the raw data in the model with the p value < 0.05. This indicates the model over predicted is valid.

Table. 4. Predicted data for organic waste generation in Balakong

Days	Raw Data (kg)	Predicted (kg)
1.	356.78	x
2.	402.10	*(1 day)*
3.	322.05	*(2 day)*
4.	438.20	*(3 day)*
5.	423.00	*(4 day)*
6.	598.30	434.07
7.	756.75	489.21
8.	481.25	391.82
9.	442.30	533.13
10.	429.10	514.64
11.	483.25	727.92
12.	491.20	920.70
13.	646.15	585.51
14.	646.90	538.12
15.	493.70	522.06
16.	423.55	587.94
17.	379.10	597.61
18.	435.90	786.14
19.	558.60	787.05
20.	616.95	600.66
21.	677.20	515.31
22.	412.30	461.23
23.	536.90	530.33
24.	475.75	679.62
25.	368.10	750.61

26.	429.10	823.91
27.	653.75	501.62
28.	730.15	653.22
29.	505.82	578.82
30.	544.60	447.84
Total	12119.23	18354.05

Table. 5. Analysis statistics of validation model t-Test: Two-Sample Assuming Equal Variances

	Variable 1[a]	Variable 2[b]
Mean	528.6668	598.3684
t Stat	-1.99643	
P(T<=t) one-tail	0.03*	
t Critical one-tail	1.67	
P(T<=t) two-tail	0.05*	
t Critical two-tail	2.01	

Note: [a] predicted, [b] raw data, * significant difference between raw and predicted data at p value < 0.05

Conclusion. In Balakong City, the findings of the municipal solid waste composition indicate a great variability. For the composition of the solid waste, organic waste recorded the highest value followed by plastic, paper, glass, metal and lastly other inseparable material. In this study, the patterns of the MSW composition generated on a daily and monthly basis are similar. Based on this and previous studies by others that has been show the linear model is very suitable to use for making forecast especially to determined waste generation in term of long term and short term period.

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