American Journal of Environmental Sciences 6 (5): 422-427, 2010
ISSN 1553-345X

Solid Waste Characterization and Recycling Potential for University Technology PETRONAS Academic Buildings

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Abstract: Problem statement: In many countries such as Malaysia, it is increasingly more difficult to find suitable locations for landfills, which are accepted by the population. These circumstances are to be found all over the world and make new strategies for waste management necessary. **Approach:** Integrated Solid Waste Management (ISWM) systems are one of the greatest challenges for sustainable development. But for any ISWM system to be successful, the first step is to carry out waste characterization studies. Therefore, the study was conducted to characterize the quality and quantity of generated solid waste at University Technology PETRONAS (UTP) academic buildings to suggest a recycling system with emphasis on recycling container size and arrangement. **Results:** Initially, a survey was conducted to highlight the existing situation of recycling activities and recycle bins condition in the campus. Then, six different sampling points were selected at campus academic complex and solid waste from those points was characterized for both term-time and semester break periods. Procedure of sampling involved unloading and analyzing a quantity of produced daily waste at each building in a controlled area. The integrity of all received waste was maintained regardless of the odor or physical decay. While survey outcomes shows that 80% of students and staff were interested to take part in recycling activities only 53% of them have practiced in it and the main reasons were that 75 and 83% of them could not find suitable and enough number of recycle bin, respectively. In another development it was obtained that up to 80% of produced materials at academic building are recyclable while paper percentage is predominant with 40% and 33% during term-time and semester break, respectively. Food waste was detected in all samples which could lead cross contamination, value drop and development of odor and flies. The solid waste generation was varied between 8.8-2.4 kg day^{-1} in term-time and semester break, respectively. **Conclusion/Recommendations:** These results showed providing suitable and enough number of recycling bins would encourage more people to participate in recycling activities. This will lead to more efficient waste segregation and reduction of waste load to the landfills. Therefore, a small or medium size three-compartment container system is suggested to be used in academic building of the campus which collects all paper and cardboard in first container, all plastic, glass, tin cans, aluminum and any other metals in second container and food waste in the third container.

Key words: Solid waste characterization, recycling, integrated solid waste management

INTRODUCTION

Integrated Solid Waste Management (ISWM) systems are one of the greatest challenges for sustainable development (De Vega *et al*., 2008). ISWM can be defined as the selection and application of suitable techniques, technologies management programs to achieve specific waste management objectives and goals (Tchobanoglous *et al*., 1993). A hierarchy in waste management can be used to rank actions to be implemented programs within the community. The US Environmental Protection Agency (1989) has defined this hierarchy as source reduction, recycling, waste combustion and landfilling. For any ISWM system to be successful, the first step is to carry out waste characterization studies (De Vega *et al*., 2008). Because of the heterogeneous nature of solid wastes, determination of the composition is not an easy task. Strict statistical procedures are difficult, if not impossible, to implement. For this reason more

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generalized field procedures, based on common sense and random sampling technique have evolved for determining composition (Tchobanoglous *et al*., 1993).

In many countries such as Malaysia, it is increasingly more difficult to find suitable locations for landfills, which are accepted by the population. These circumstances are to be found all over the world and make new strategies for waste management necessary. In addition, the promotion of waste minimization and recycling are important components of modern waste management strategies (Malakahmad *et al*., 2008). Tremendous increase in solid waste generation in Malaysia can be observed from 1996-2008, while population growth rate has been decreased from 2.55-1.66 % in same duration (Fig. 1).

This perspective clearly indicates that waste generation per person is increasing rapidly in Malaysia.

Changes in lifestyle, particularly in the urban areas, have led to more severe waste problems. Packaging of convenient household goods is free flowing and carefree attitude of the society resulted in huge quantities of waste. Plastics, which are not degradable constitutes a high proportion of modern day wastes. Most of the waste collected (about 95%) is disposed to landfill. The remaining waste is incinerated, recycled or dumped illegally. The increasing amount of solid wastes generated has resulted in a reduction in landfill capacity. The authorities are also concern about the impact of landfill operation and the transportation of solid waste.

Many researchers have studied the solid waste management in university campuses. De Vega *et al*. (2008) found almost 65% of generated solid waste in university campus to be recyclable. Therefore, a program for segregation and recycling is feasible on a University Campus (De Vega *et al*., 2008). Another research indicates that improved source separation performance could increase the recycle rate to 84% (w/w) in the concourse area (Mason *et al*., 2004).

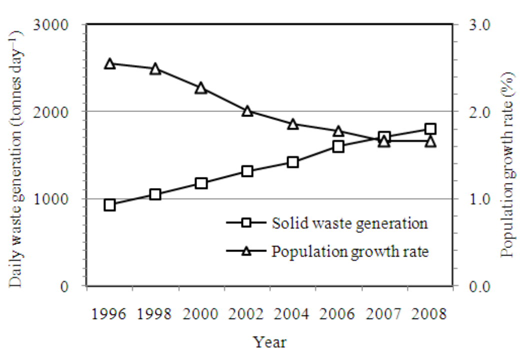

Fig. 1: Daily waste generation (Agamuthu, 2008) versus population growth rate in Malaysia (World Bank, 2010)

In another development, the Azcapotzalco campus of the Universidad Autónoma Metropolitana (UAM-A) could reduce the amount of solid wastes delivered monthly to municipal collecting services, considerably. For the period of three years, UAM-A has sent for recycling: 2.2 tons of glass bottles; 2.3 tons of PET bottles; 1.2 tons of Tetrapak packages and 27.5 kg of aluminum cans (Espinosa *et al*., 2008). Also based on a survey of 1400 students and staff at Massey University, New Zealand, significant relationships were found between self-reported recycling behavior and attitudes toward recycling, self-reported recycling behavior and campus occupation (student, postgraduate student, academic staff, or general staff) and self-reported recycling behavior and place of work (Kelly *et al*., 2006).

University Technology PETRONAS (UTP) is built on a 400 hectare (1,000 acre) site located at Bandar Seri Iskandar, Perak, Malaysia (UTP website, 2010: http://www.utp.edu.my/theUniversity/25.01.2010). The first construction for new academic complex was completed in 2004. The new academic complex includes mainly chancellor complex and academic buildings. Another two points of the new academic complex is where the buildings commonly known as Pocket C and Pocket D is situated. The university has a population of 7199 which includes 684 staff and 6515 students (5674 undergraduates and 841 post graduates) (UTP Human Resource website, 2010: http://pww.utpnet.petronas.com.my/utphr/index.php?option=com_frontpage&Itemid=1,28.01.2010). This study aims to estimate solid waste generation rate and assess the solid waste characterization and recycling potential at the selected academic buildings to introduce a recycling program system in the campus with emphasis on recycle container size and arrangements.

MATERIALS AND METHODS

Survey: A survey including six questions was prepared and distributed among students and staff in the campus. The participants were selected according to the gender, age, academic disciplines and position. The survey aims were to clarify attitude and mindset of the participants as well as the facilities shortages for recycling activities in the UTP.

Generated solid waste characterization in the field:

Location of study: The study was conducted at University Technology PETRONAS (UTP) academic buildings. Currently 16 buildings are available while 7 are yet to be constructed. Each building is assigned to a program. Some programs have several buildings. The buildings are named with numbers (Fig. 2). On the way from the chancellor complex to Pocket D, the buildings are Building 23, Building 22, Building 21 and Building

20. From Pocket D to Pocket C, the buildings are Building 19 up to Building 15. From Pocket C to Pocket B that is yet to be built, only Building 14 and Building 13 are available and are in use now. From the chancellor complex to the not-yet-built Pocket A, there are Building 1 up to Building 5. The numbered buildings are generally similar in design. Six buildings (1, 3, 13, 16, 18 23) were selected for sampling based on the offering programs and location. The ground, first and second floor of the buildings consists of laboratories and discussion rooms and third floor is the lecturers' offices.

Period of study: Two periods was identified and selected for waste characterization. In the first period which was "semester break" there were basically no undergraduate students in the campus, but the number of postgraduate students and staffs remained relatively unchanged. Second period was term-time when the campus was at its maximum population of all students and staffs.

Sample identification and characteristic: The procedure of sampling involved unloading and analyzing a quantity of produced daily waste at each building in a controlled area that is isolated from winds and separate from other activities. The integrity of all received waste was maintained regardless of the odor or physical decay to make sure that all the components are measured. Sampling was done after office operation hours when almost there were no activity inside the buildings and all wastes were collected by workers and placed at storage rooms. Total generated waste in each building was collected and weighed. Then, the bags were marked to avoid reweighing of the same bag in next sampling round. Next sampling round was done after 2 days. Totally samplings were done three times a week for each building for a month in each period. Then, mean value was calculated for generation rate in each building and waste composition as overall number for all buildings.

Fig. 2: The campus map with sampling points indication

RESULTS AND DISCUSSION

Survey out comes: Total number of 107 questionnaire were collected and results indicated that 80% of the participants are interested for the recycling activities and 79% of them have mentioned that they can recycle more which shows that the attitude of participants for this activity is positive, but only 53% of them have done it. They have mentioned that unavailability of suitable and enough recycle bins have discouraged them to participate more and finally they have mentioned that while they are interested for recycling activities they do not keep their recyclables to find a recycle bin and will through the waste in the ordinary bins (Fig. 3).

Therefore, enough number of proper recycle bins are necessary in the campus while on the other hand the limitations regarding to the costs, aesthetic aspects and simplicity of maintenance and transportation should be considered.

Solid waste characteristics: Table 1 shows the generated waste breakdown at UTP academic buildings. For the term-time period, results showed that paper is the largest composition with percentage of 40%, follow by food waste (30%), plastic (15%), cardboard (10%), tin/aluminum (4%), Glass (1%) and no metal found during the test. Presence of food waste will cause contamination of other waste components including the recyclable materials especially paper and cardboard and it could reduce their value for recycling. On the other hand biodegradable wastes such as food waste will almost immediately start to undergo microbiological decomposition as a result of the growth of bacteria and fungi (Tchobanoglous *et al*., 1993). This scenario will get worse in humid and high temperature environment of tropical countries like this case study in Malaysia. In addition, if wastes are allowed to remain in storage containers which were open at the university for extended period of time, flies can start to breed and odorous compounds can develop.

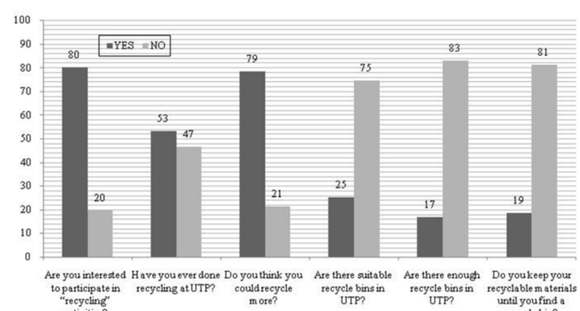

Fig. 3: Survey outcomes

Table 1: Waste composition during the term-time and semester break

	Percent by weight		Percent variation*	
Waste	Term-time	Semester break	Decrease	Increase
Paper	40	33	21	
Food waste	30	20	50	
Cardboard	10	9	11	
Plastics	15	15		
Glass	1	5		80
Tin/ aluminum	4	5		20
Metals	0	13		100
Total	100	100		

*: Based on the semester break

While the percentage of food waste reduces to 20% during semester break period, the percentage for paper (33%), cardboard (9%) plastics (15%) and tin/aluminum (5%) remained relatively same. Besides that, considerable increase was found in percentage of glass (5%) and metals (13%), which is probably due to some demolition activities.

In addition as illustrated in Table 1 variation in the percentage distribution of waste components was calculated. Because variations are known to occur, the distribution of components is a critical factor in the management decision process, a special study should be undertaken if possible to assess the actual distribution. For example percent variation for glass and metals (80 and 100 % respectively) is quite large which occur during semester break. Therefore, the recycling program has to clarify any future plan and action for these two items as their amount during term-time is very low.

The results in both periods show up to 80% of generated waste in the area of study are recyclable. This result is in agreement with other studies (De Vega *et al.*, 2008; Mason *et al*., 2004; Espinosa *et al*., 2008). It should be mentioned that separation at source before collection and/or any diversion is significant as this element can have major effect on the characteristics of the waste and public health. Furthermore, waste diversion has been mandated by law in some developed countries such as United States (Tchobanoglous *et al*., 1993) while in developing countries it is common for scavengers, the informal sector, to participate in solid collection activities. This is due primarily to inadequate municipal services, which create a large need for informal waste collection (Mihelcic and Zimmerman, 2010). Therefore, separation at source of generation is one of the most positive and effective ways to be implemented at the campus. But it should be mentioned that successful recycling systems require careful consideration of cost involved and of the markets for recycled good.

In the next step, different recycling systems were considered for the separation program as the effectiveness of waste separation program depends on the type of system used for the collection and separation of wastes (Tchobanoglous *et al*., 1993). Conventional separation system offers separate containers for plastic, paper and aluminum cans. But there are some other systems which combine some of the recyclables in one container to save money, space and labor. Based on the achieved results (Table 1) second option is more feasible in the case of study of UTP. A three-container separation system can be suggested to collect all paper and cardboard in first container, all plastic, glass, tin cans, aluminum and any other metals are placed in second container and food waste in the third container. Food container are suggested to be covered and unloaded everyday while for the other two based on generation rate weekly collection can be practiced. Additional separation, possibly at Materials Recover Facilities (MRF) will be required.

Solid waste generation rate: While qualitative studies lead to the importance of separation and arrangement of container for the receiving wastes, quantitative studies can be used as waste generation estimation as well as volume selection for the containers. Typically, the types and capacities of the containers used depend on the characteristics and types of solid wastes to be collected, the type of collection system in use, the collection frequency the space available for the placement of containers. As generation rate plays an important role for the selection of containers and their size, the study was conducted to measure the generation rate at the campus (Fig. 4).

Generation rates vary from 2.4 kg day^{-1} during semester break in building 23-8.8 kg day^{-1} during term-time in same building. As building 23 is the nearest building to the chancellor complex and during term-time many students pass through this building to do their administrative jobs there. During term-time the waste generation rate was found to be 6.2, 6.3, 5.4, 6.5 and 3.5 kg day^{-1} in Buildings 1, 3, 13, 16 and 18, respectively.

Table 2: Data on the type and sizes on containers used for onsite storage of solid waste

	Capacity			Dimensions*	
Type	Unit	Range	Typical	Unit	Typical
Small					
Container, plastic or galvanized metal	gal	20-40	30	in	20 D×26H
Barrel, plastic, aluminum, or fiber		20-65	30	in	20 D×26H
Disposable paper bags					
Standard		20-55	30	in	15W×12d×43H
Leak-resistant		20-55	30	in	as above
Leak proof		20-55	30	in	as above
Disposable plastic bag				in	18W×15d×40H
				in	30W×40H
Medium					
Container	yd^3	1-10	4	yd^3	72W×42d×65H

*: D = Diameter, H = Height, L = Length, W = Width, d = depth; **Note:** gal×0.003785 = m^3, in×2.54 = cm, yd^3×0.7646 = m^3, ft ×0.3048 = m

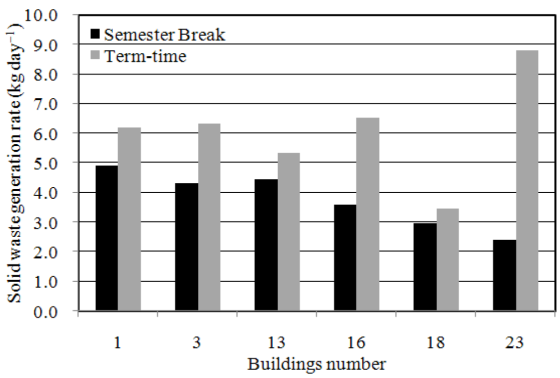

Fig. 4: Solid waste generation composition during term-time and semester break

The generation rate variation in the buildings mostly depends on the population and different activities in each building. Semester break period shows smaller values for all buildings due to population drop. Generation rate for buildings 1, 3, 13, 16 and 18 was found 4.9, 4.3, 4.5, 3.6, 3.0 kg day^{-1}, respectively. Generally, containers are categorized in three groups based on their size; capacity vary between 20-65 gal for small, 1-10 yd^3 for medium and 12-50 yd^3 for large containers (Tchobanoglous *et al.*, 1993). According to the data obtained on waste generation rate, small and medium size containers seem to be the suitable choices.

Table 2 contains possible materials and dimensions for small and medium containers. The advantage of medium size containers is that they can also accept bulky waste while small containers are not large enough to hold bulky waste. On the other hand as unloading take place manually in the campus, heavy containers could cause problem for workers.

For materials selection, safety issues should be considered as in a development at University of Michigan, the University's Fire Marshal noted that recycling bins located in public areas should be of non-combustible construction. The Rubbermaid recycling bins placed in public areas for the last 5 years did not meet this requirement, so steel bins were reintroduced to the campus (University of Michigan website, 2010: http://www.plantops.umich.edu/grounds/recycle/PDF/New_ Recycling_Bin_Guidelines_FAQs). Color coding for the containers and plastic bags is essential which will lead to easier separation as well as collection

CONCLUSION

Tremendous increase in solid waste generation in Malaysia can be observed from 1996-2008, while population growth rate has decreased from 2.55-1.66 % in the same duration which indicates an increase in waste generation rate per person. Therefore, integrated solid waste management systems are required to be implemented as a toll for sustainable development. One of the key elements for integrated solid waste management is solid waste separation which contributes to a successful recycling program. The results show almost 80% of generated solid waste in academic buildings of the campus was found to be recyclable. Paper was predominant compound followed by plastic. The presence of food waste was considered a barrier for waste recycling. A system that contains three separate bins (small or medium sized) for food waste, paper and the rest of generated waste was suggested for initial waste separation in the campus while additional separation at MRF will be required.

ACKNOWLEDGMENT

The researchers gratefully acknowledge the supports provided by the University Technology PETRONAS (UTP) management for presentation and publication of this study. In addition, the effort from

Engineering Team Project (ETP 33, Sem. Jan. 2010) for the part of questionnaires distribution and data compilation is fully appreciated.

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