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A Study on Solid Waste Generation and Its Characterisation at UTHM Pagoh Campus, Muar, Johor

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Understanding the characteristics of solid waste within an institution is the first step towards enhancing the sustainability of Solid Waste Management (SWM). Universiti Tun Hussein Onn Malaysia (UTHM) Pagoh campus is a new campus situated in the Pagoh Educational Hub, Johor. To date, no studies have been conducted to determine the amount and types of waste generated at this campus. It is important to find out the generation and composition of waste before any recommendations for an integrated solid waste management program can be made. This paper presents the results of a waste audit conducted in 10 consecutive weeks, including lecture weeks, mid-semester break, and Ramadhan. Waste samples were collected from the campus buildings of the academic, cafeteria, and laboratory zone. The results indicated the waste generation rate during the lecture weeks was higher compared to the mid-semester break (average of 203.9 kg/day and 93.96 kg/day, respectively). Nonetheless, in the month of Ramadhan, the solid waste generation rate dropped to an average of 24.48 kg per week since the cafeteria zone produced no solid waste. Besides, the cafeteria was found as the main contributor to solid waste on the campus. The composition of the waste generated consisted of 63.4 % food waste, 20.7 % residual waste, 7.5% plastic, 5.4 % paper, 0.7 % metals, 0.7 % beverage cartons, 0.5 % aluminium, 1.0 % of other waste and 0.1 % glass. Lastly, the findings from this study should act as a baseline for the management of the university to enhance the waste minimisation program as a first step towards establishing a green campus.

Keywords: Solid waste characterisation; solid waste generation; waste management; higher learning institution

I. INTRODUCTION

Malaysia is a developing country undergoing rapid growth in terms of population, urbanisation, and industrialisation. In 2017, the average Municipal Solid Waste (MSW) generation in Malaysia was approximately 0.85 kg/capita/day depending on the economic and geographical factors of an area (Zainu & Songip, 2017). Past researches indicated that solid waste management is an area that requires educational concern and awareness for global preservation (Zainu & Songip, 2017; Abas, 2015; Baharum *et. al.,* 2016; Ioan *et al.,* 2012).

In Malaysia, Higher Learning Institutions (HLIs) play important roles in supporting tertiary education and sustainable development (Desa *et. al.,* 2012; Ghazvinei *et al.,* 2017). This is because HLIs are microcosms of societies made of large populations and diverse activities taking place on campuses such as learning, research, community service, and business development. Not only staff, but students need to understand and realise the negative impacts of improper SWM implementation on campus (Zhang *et al.,* 2011). For any waste management system and strategy to be successful, a waste characterisation

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study is vital for providing up-to-date and reliable data, especially on waste generation and composition (Badgie *et. al.,* 2012; Malakahmad *et. al.,* 2010; Taylor *et al.,* 2012).

Universiti Tun Hussein Onn Malaysia (UTHM) is one of the technical universities in Malaysia that has been given the responsibility to undertake more innovative and creative research and development (Aziati & Abdullah, 2014). In 2007, a separate UTHM campus was established at the Pagoh Educational Hub. UTHM Pagoh campus is strategically located off the Pagoh Interchange on the North-South Expressway (Exit 238) which is about 20 minutes from Muar, Johor. Being a new campus, studies have yet to be conducted on its waste management system. One of the campus's objectives is to move towards a green campus, thus, it is important to determine the solid waste generation and waste composition within all key campus operational areas to identify the best approach for waste management.

This study was carried out during Semester II 2017/2018. According to the Information Technology Centre of UTHM, there were 295 academic staff and a total enrolment of 4536 students in UTHM Pagoh during the semester. The population on the campus was approximately 5000, including students, academic staff, and non-academic staff. In this study, solid waste does not cover the hazardous or scheduled waste generated from laboratories and medical centers. The hazardous waste from laboratories is handled by private contractors. Furthermore, solid waste from landscape activities is excluded from this study as well.

II. MATERIALS AND METHOD

A clear guideline will help in determining the sample size, procedure, and duration to carry out the research. Before waste sampling was carried out, suitable apparatus and materials should be prepared to ensure smoothness of progress.

A. Sampling Area

The waste sampling was conducted in UTHM Pagoh Campus, which is illustrated in Figure 1.

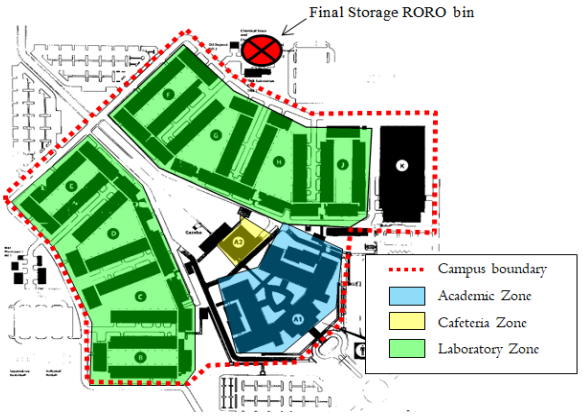

Figure 1. The layout of UTHM Pagoh Campus

In this research, the campus was divided into 3 zones. Each zone has different activities, number of structures, and functions (refer to Table 1).

Table 1. Descriptions of UTHM Pagoh campus layout

Zones	Building blocks	Functions	No. of units
Academic zone	A1	Administrative offices	294
		Lecture halls	24
		Meeting rooms	6
Cafeteria zone	A2	Cafeteria/dining area	1
Laboratory zone	B	Electrical Engineering Technology Laboratory	26
	C	Mechanical Engineering Technology Laboratory	17
	D		16
	E		9
	F	Civil Engineering Technology Laboratory	6
	G		14
	H	Chemical Engineering Technology Laboratory	17
	J	- Applied Science and Technology Laboratory - Computer and multimedia laboratory - General research laboratory	60

	K	Training and manufacturing facilities	Not operating

The academic zone consists of 324 units including administration and academic offices, lecturer rooms, and lecture halls. The cafeteria zone consists of 5 food stalls and a dining area for staff and students; while the laboratory zone comprises all the laboratories and workshops on the campus. At the time of the research, Block K was not in operation and thus, excluded from this study.

B. Data Collection

In Malaysia, no specific guidelines on waste composition and characterisation of solid waste at the institutional level exist (Baharum *et al.,* 2016). Hence, for this research, the waste collected will be categorised according to the Guidelines for Sampling of Household Solid Waste - Composition and Characterisation Analysis by the Department of Standards Malaysia (MS 2505:2012). MS 2505:2012 has provided several methods to determine waste composition depending on the objectives and scope of research (Kadir & Sani, 2016). Besides, MS 2505:2012 has been adopted in many waste composition studies conducted in Malaysia (Kam *et al.,* 2016). The number of samples and the sampling apparatus vary according to the research scope (Malaysia Standard, 2012). The sampling apparatus used in this research is shown in Table 2.

Table 2. Apparatus for waste sampling

Materials	**Descriptions**
Containers	Clean and light containers to store waste components temporarily before being weighed.
Garbage bags	Garbage bags of different colors are used to differentiate the source of waste: i) blue color for the academic zone; ii) black color for the cafeteria zone; and iii) green color for the laboratory zone.
Digital weighing scale	Weighing scale with a 30kg capacity and precision of 0.005kg.
Miscellaneous tools	Tools such as brooms, heavy-duty tarps, face masks, heavy-duty gloves and magnets for identifying iron from metals.

The waste sampling collection was carried out for 10 consecutive weeks, including lecture weeks and mid-semester break. Figure 2 illustrates the flow of the waste sampling collection. As shown in Figure 2, after the wastes were labelled according to their respective zones, they were manually sorted into dry and wet waste.

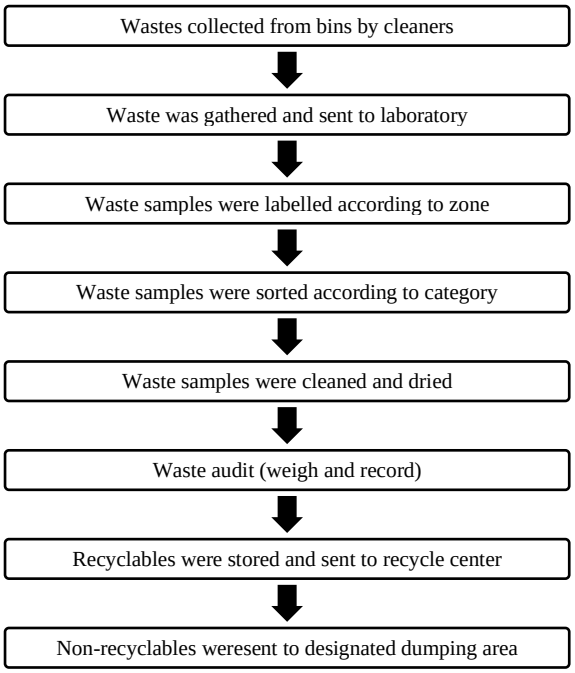

Figure 2. Waste sampling collection procedure

Dry waste such as paper, beverage cartons, plastics, glass, metals, and aluminium was separated from wet waste such as food and residual waste. The details of the waste components are shown in Table 3. Most of the dry waste was recyclable and can be stored while the wet waste was disposed of immediately after the waste audit.

Table 3. Components of waste

Category	Component	Description of materials
Dry waste	Paper	Mix paper, card box, newspaper, boxboard, magazines, disposable hot beverage cups, etc.
	Beverage cartons	Carton box used for packaging liquids: milk, juices, coconut milk, etc.
	Plastics	All types of plastics, which include Polyethylene Terephthalate (PET) bottles, High-Density Polyethylene (HDPE), food packaging films, Polypropylene (PP), Polyvinyl Chloride (PVC), and other plastics.
	Glass	Bottles, mugs, containers, mirrors, bulbs, etc.
	Metals	Ferrous material: food cans, aerosols, keys, cutlery, biscuit tins, bike parts, etc.
	Aluminium	Beverage cans, aluminium foil, etc.
	Others	Other organic and non-organic waste
Wet waste	Food waste	Food material results from the processing, storage, preparation, cooking, handling, or consumption of food.
	Residual waste	Tissue, diapers, sanitary waste, swept dust, and contaminated components.

III. RESULT AND DISCUSSION

The results of this study were divided into 2 parts: waste generation and waste composition.

A. Waste Generation

Table 4 summarises the total amount of waste generated at the campus in 10 consecutive weeks according to different zones. During the sampling period, a total of 5979.97 kg of solid waste was generated on the campus. Figure 3 illustrates the solid waste generation on campus according to zones.

Table 4. Summary of solid waste generation

Description / Week	Solid waste generated (kg)			
	Academic zone	Cafeteria zone	Laboratory zone	Total
W1	144.79	1018.26	72.38	1235.43
W2	116.17	305.97	47.66	469.80
W3	166.11	665.72	74.55	906.38
W4	137.77	842.67	143.77	1124.21
W5	115.02	587.47	53.70	756.19
W6	43.36	461.42	42.99	547.77
W7	70.97	482.23	42.56	595.76
W8	110.50	-	50.46	160.96
W9	70.55	-	20.44	90.99
W10	48.44	-	44.04	92.48
Total	1023.68	4363.74	592.55	5979.97

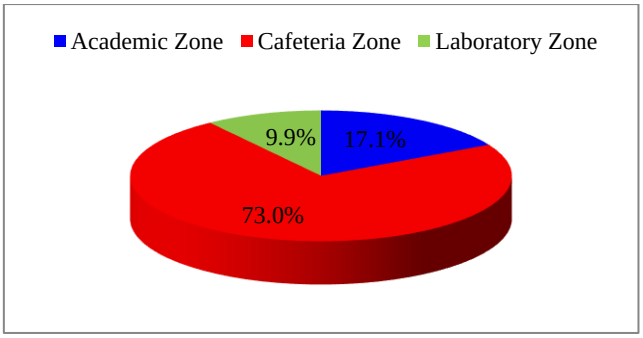

Figure 3. Waste generation according to zone

Based on Figure 3, it can be concluded that the cafeteria zone was the main contributor to waste generation on campus. The cafeteria generated a total of 4363.74 kg of solid waste, which is approximately 73% of the total waste generated in 10 weeks, even though it did not generate any waste in the last 3 weeks of the sampling period. This is supported by findings by Gebreeyessus *et al.* (2018), Jaafar *et al.* (2017), and Okeniyi and Anwan (2012) which revealed that cafeterias are the leading source of waste generation in a university campus. Meanwhile, 17.1 % of solid waste from the campus was generated from the academic zone, followed by 9.9 % from the laboratory zone.

In general, Week 1 recorded the highest amount of solid waste collected throughout the sampling period, i.e. 1235.43 kg (refer to Table 4). The waste generated in the last three weeks (Week 8 – Week 10) ranged from 91.0 kg to 160.9 kg, which showed a drastic reduction compared to the results obtained during regular lecture weeks.

Previous studies conducted by Malakahmad and Nasir (2010) and Tiew *et al.* (2011) indicated that the waste generation rate on campus differs between regular lecture weeks and semester breaks. However, in this research, the results indicated that even though the last three weeks of the sampling period were lecture weeks, the month of Ramadhan affected the amount of waste generated on campus. During Ramadhan, all Muslims are required to fast from dawn to sunset. Therefore, the reduction in food and drink consumption resulted in a steady drop in the waste generated on campus. This is in line with the statement from Malaysia Standard (2012) which reported that some abnormal activities would have an impact on the sampling results such as change of weather condition, festive season, and semester break.

The chart shown in Figure 4 shows the waste generation rate ranged between 181.27 – 247.08 kg/day on normal lecture weeks (Weeks 1, 3, 5, 6, and 7). On average, the waste generation rate for regular lecture weeks is 203.90 kg/day. During the mid-sem break (Week 2), the average waste generation rate is 93.96 kg/day, which is approximately half the amount of regular lecture weeks. The waste generation rate of lecture weeks (Weeks 8-10) during Ramadhan ranged from 18.5 - 32.2 kg/day (average 24.48 kg/day), which is approximately 12% lesser than the normal lecture weeks.

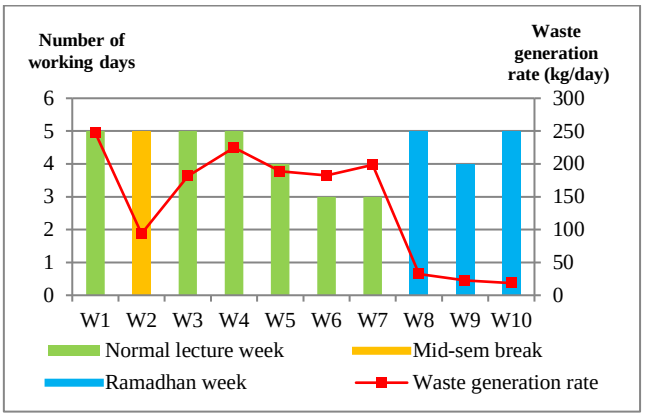

Figure 4. Waste generation in 10 weeks

B. Waste Composition

As mentioned earlier, every zone at the UTHM Pagoh campus has different functions, which would result in different waste compositions. Table 5 summarises the results of the waste composition of dry waste and wet waste according to the respective zones.

Table 5. Solid waste composition at UTHM Pagoh campus

Zone	Waste composition (kg)		
	Dry waste	Wet waste	Total
Academic	515.8	507.88	1023.68
Cafeteria	209.13	4154.61	4363.74
Laboratory	224.44	368.11	592.55
Total	949.37	5030.6	5979.97

Overall, 84.1 % of solid waste generated on the campus is made up of wet wastes, which are food waste and residual waste. The fraction of wet waste and dry waste generated seems to vary with the function of buildings. From the total waste generated in the cafeteria, up to 95.2 % is made up of wet waste. The building for administrative and academic activities had a balance fraction between wet waste and dry waste, where dry waste (50.4 %) is only slightly more than wet waste (49.6 %). Surprisingly, the wet waste generated from the laboratory building is more than the dry waste, where wet waste constitutes a larger fraction of 62.1 %.

Figure 5 shows the global solid waste composition on the campus. From a total of 5979.97 kg of solid waste generated, food waste formed the highest percentage (63.4%), followed by residual waste (20.7%). On the contrary, dry waste only constituted approximately 15.9% of the total waste composition on campus. Dry waste comprised 7.5% plastic, 5.4% paper, 0.6% metals, 0.7% beverage cartons, 0.5% aluminium, 1.0% other waste and 0.2% glass. In addition, the waste composition for different zones is illustrated in Figure 6.

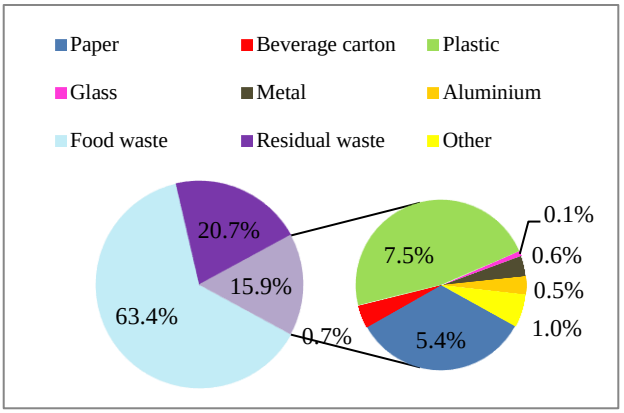

Figure 5. Overall solid waste composition of UTHM Pagoh

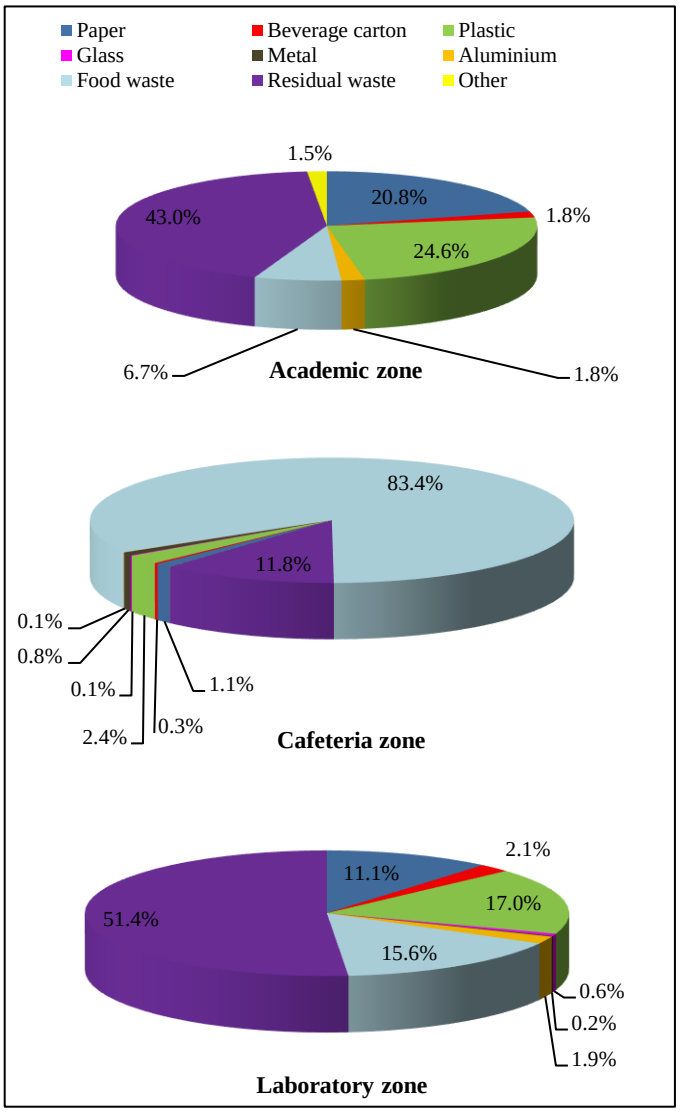

Figure 6. Solid waste composition for different zones

As shown in Figure 6, the cafeteria zone has been identified as the main source of food waste generation. During the sampling period, about 95.9 % of food waste was solely generated from the cafeteria zone. This is because the cafeteria zone is the main area for dining and catering. The food waste from this zone consisted of raw materials from food preparation, spoiled food, eggshells, and leftovers from dining halls. On the other hand, the composition of food waste generated from the academic and laboratory zones consisted of leftovers from packed food and snacks such as bread, biscuits, and cakes. As mentioned in Table 1, the academic zone consists of administrative offices, lecture rooms, lecture halls, and meeting rooms where most of the university's activities take place. Besides paper and plastic, the greatest portion of beverage cartons and aluminium across the campus was collected from the academic zone. However, no glass and metal wastes were collected from this zone. In the laboratory zone, residual waste has the highest composition of residual waste (51.4 %) and only 15.6 % of food waste was collected.

However, it is somewhat surprising that residual waste was the second largest fraction of the total waste composition at the UTHM Pagoh campus. Residual waste refers to waste that is unrecoverable, unrecyclable, contaminated, and destined to be disposed of at landfills. The residual waste in other zones is more than 40%, except for the cafeteria zone (11.8%). The high percentage of residual waste indicated poor SWM or inefficient waste separation at the campus. Malakahmad and Nasir (2010) and Tiew *et al.* (2011) strongly recommended that separation at source could be an effective practice to recover recyclable items and thus reduce the amount of residual waste in landfills. Therefore, it is recommended that the campus should practice waste separation at the source. Different garbage bins for food waste, general waste, and recyclable items should be placed around the campus to encourage members of the university community to separate their waste. Apart from that, educational and awareness campaigns should also be conducted at the campus to foster awareness on separation at source.

IV. CONCLUSION

Identifying the characteristics of solid waste in HLIs is a pre-condition for initiating any sustainable waste management practice. To summarise, the solid waste generation rate at UTHM Pagoh Campus varied during regular lecture weeks, mid-semester breaks, and Ramadhan lecture weeks. Besides the amount of waste, the composition of solid waste generated differed according to the academic, cafeteria, and laboratory zones. Generally, the academic zone contributed to the majority of dry waste on the campus, where most of it consisted of papers, beverage cartons, plastics, and aluminium waste. More than 90 % of food waste was generated by the cafeteria, whereas residual waste constituted more than 40 % of waste in the academic and laboratory zones. To minimise the amount of residual waste, it is recommended that solid waste separation at the source should be implemented on the campus.

V. ACKNOWLEDGEMENT

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VI. REFERENCES

Abas, MA 2014, The Issues of Policy Implementation on Solid Waste Management in Malaysia, no. January 2015.

Aziati, AHN & Abdullah, NH 2014, 'Knowledge transfer of university-industry partnership in Malaysian technical university: preliminary findings', pp. 0–7.

Badgie, D, Armi, M, Samah, A, Manaf, LA & Muda, AB 2012, 'Assessment of municipal solid waste composition in Malaysia: management, practice, and challenges', vol. 21, no. 3, pp. 539–547.

Baharum, MR, Kam, HW, Jin, S & Chua, L 2016, 'Perceived strategic implication of solid waste recycling across Malaysian higher education institutions', vol. 00091.

Desa, A, Abd Kadir, NB & Yusooff, F 2012, 'Environmental awareness and education: a key approach to Solid Waste

Management (SWM) – A case study of a university in Malaysia', in Waste Management Luis Fernando Marmolejo Rebellon, vol. 2, IntechOpen, pp. 64.

Gebreeyessus, GD, Berihun, D & Terfassa, B 2018, 'Characterization of solid wastes in higher education institutions: the case of Kotebe Metropolitan University, Addis Ababa, Ethiopia', Int. J. Environ. Sci. Technol., no. Arega 2016.

Ghazvinei, PT, Mir, MA & Darvishi, HH 2017, University Campus Solid Waste Management - Combining Life Cycle Assessment and Analytical Hierarchy Process, Switzerland: Springer International Publishing.

Ioan, C, Onose, DA & Raluca, S 2012, 'Waste management in public educational institutions of Bucharest city, Romania', vol. 14, pp. 71–78.

Jaafar, I, Ibrahim, TA, Mat Ila, NH & Mohd Zaki, NS 2017, 'Waste audit in UMT campus: generation and management of waste in cafeteria and food kiosk', J. BIMP-EAGA Reg. Dev., vol. 3, no. February, pp. 1–62.

Kadir, AA & Sani, MSAM 2016, 'Solid waste composition study at Taman Universiti, Parit Raja, Batu Pahat', IOP Conf. Ser. Mater. Sci. Eng., vol. 136, no. 1.

Kam, HW, Baharum, MR & Chua, SJL 2016, 'A review of commercial waste recycling policy in Malaysia', Int. J. Environ. Sustain. Dev., vol. 15, no. 4, p. 404.

Malakahmad, A, Za, M & Nasir, M 2010, 'Solid waste characterization and recycling potential for University Technology PETRONAS academic buildings', no. May 2014.

Malaysia Standard 2012, Guidelines for Sampling of Household Solid Waste - Composition and Characterisation Analysis (MS 2505:2012).

Okeniyi, JO & Anwan, EU 2012, 'Solid wastes generation in Covenant University, Ota, Nigeria: characterisation and implication for Sustainable Waste Management', vol. 3, no. 2, pp. 419–424.

Taylor, P, Karak, T, Bhagat, RM & Bhattacharyya, P 2012, 'Critical reviews in environmental science and technology municipal solid waste generation, composition, and management: the world scenario municipal solid waste generation, composition, and management', no. October 2012, pp. 37–41.

Tiew, K, Watanabe, K, Ezlin, N, Basri, A, Zain, S & Basri, H 2011, 'Reducing waste disposal from Universiti Kebangsaan Malaysia campus by 2-bins recycling system', vol. 2, no. March, pp. 31–35.

Zainu, ZA & Songip, AR 2017, 'Policies, challenges and strategies for municipal waste management in Malaysia', vol. 3, no. 1.

Zhang, N, Williams, ID, Kemp, S & Smith, NF 2011, 'Greening academia: Developing sustainable waste management at higher education institutions', Waste Manag., vol. 31, no. 7, pp. 1606–1616.