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Preliminary Study for Designing a Yard Waste Composting Facility in Universiti Kebangsaan Malaysia

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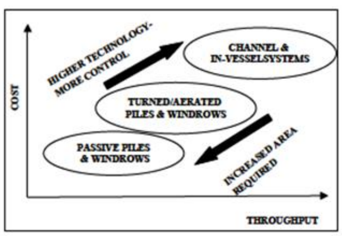
Graphical abstract



Abstract

Composting has been occurring naturally with the decomposition of organic matter by microorganism and is the best technique in yard waste management to produce landscape fertilizer. This article discusses the management of yard waste in UKM and determines the feasibility of using windrow composting for mixed yard and food wastes. The amount of yard waste generated in Universiti Kebangsaan Malaysia (UKM) approximately is 2.36 tonne/day. An estimated the total of 3.36 tonne of yard and food waste is generated per day at UKM, which would require 8 rows of 42-meter long windrows. The contents of the windrows are periodically turned (mixed) to ensure homogeneity, increase porosity and to assist aeration. This study complements the concept of the UKM Zero Waste Campus by producing a valuable material from waste.

Keywords: Yard waste; composting; windrow; UKM

1.0 INTRODUCTION

Yard waste is vegetative matter resulting from gardening, horticulture and landscaping (Mohee 2007). Yard waste consists of grass clippings, leaves and tree branches from gardens, public places, graveyards and green spaces (Bilitewski *et al*. 1997). The majority of this material is generated on a seasonal or cyclical basis (Rogoff *et al*. 1994). Yard waste can be composted to produce fertilizer that returns nutrients to the soil. Moreover, composting reduces the yard waste volume by 50% to 70% (Wilson & Feucht 2011). Composting is the most economical and sustainable option for waste management because it is easy to operate and can be conducted in a confined space provided it is managed properly to produce a high quality product (Jaya *et al*. 2006).

A variety of composting processes exists and can be adapted to any scale of organic waste management. These systems range from simple to sophisticated technologies. Passive piles, windrows, aerated static piles and in-vessel composting systems are being used worldwide to treat different types of organic waste. The passive composting pile method involves forming mixtures of raw material into a pile. Passive aerated windrows are windrows that are not turned. Aeration is accomplished with the passive movement of air through the pile. Minimal labor and equipment is needed with passive composting; therefore, it is the least expensive large-scale composting method (Mohee 2007). In the windrow composting method, organic waste is placed into elongated rows that are turned regularly to maintain aerobic composting conditions. Windrows can be located outdoors. The advantages of windrow composting include low facility investment, high environmental-friendliness, easy operation and low failure rate (Hua-Shan Tsai *et al*., 2006). Aerated static piles or forced aeration windrows are a relatively high technology approach that can be used to compost yard waste and municipal solid waste. The in-vessel system is a high technology method in which composting is conducted within a fully enclosed system under mechanical control. However, this system is rarely used to compost yard waste because it is expensive to maintain this degree of control (USEPA 1994).

The mix ratio of leaves, grass and brush entering a composting facility depends on many factors including climate, geographical region, land-use mix, season and collection restrictions (Michel *et al*. 1995). The mix ratio of composting reported in the literature varies. In yard waste composting, some of the materials need to be processed prior to composting. Woody materials need to be ground to provide the proper size and surface area for microorganisms to decompose. Generally, leaves do not need to be ground, although grinding does accelerate the digestion process (Rogoff *et al*. 1994). When materials such as leaves and grass clippings are composted, a microbial process converts them to a more usable organic material (Bass *et al*. 2011). The microorganisms that break down yard wastes require favorable temperatures, moisture and oxygen (Wilson & Feucht 2011). Turning frequency is commonly believed to be a factor that affects the rate of compost production and the compost quality. However, turning results in the release of compost odors (Michel *et al*. 1995). Once composting materials have been composted, they should be cured to stabilize the compost. The finished compost should not have an unpleasant odor (USEPA 1994). Compost is known to be nutrient-rich (Candinas *et al*. 1999) and the generally high application rates imply a considerable import of nutrients into the soil (Nevens & Reheul 2003).

2.0 CURRENT MANAGEMENT OF UKM'S YARD WASTE

Presently, the yard waste at UKM is collected by 10 registered contractors that are appointed and monitored by the Department of Management and Maintenance (JPP) UKM. JPP has one landscape lorry under the Unit of Landscape. They collect the yard waste twice a day based on the zone assigned to them. The yard waste collected is then be disposed of by the contractor. Table 1 shows the dedicated zone and location for collecting yard waste by the 10 different contractors. The zone is labeled as A, B, C, D, E and F. The locations listed cover all the green areas on the UKM campus.

Table 1 The zone and location for the collection of yard waste by 10 different contractors

ZONE	LOCATION	COMPANY
A	Keris Mas College, UKM Consultancy Sdn., Bangunan Wawasan, Centre for Research and Instrumentation Management, Academic Development Center, Puri Pujangga	Perniagaan P. Redan
B	Dectar, Canselori, Faculty of Social Sciences and Humanities, Pusanika, Tun Sri Lanang Library, Faculty of Economics and Management, Faculty of Science and Technology, Faculty of Islamic Studies, Institute of the Malay World and Civilization Mosque, Health Centre, Department of Development and Maintenance, Centre For General Studies, UKM Press, School of Language Studies and Linguistics, Information Technology Center, Tun Abdullah Mohd Salleh Hall Complex, Faculty of Education, Faculty of Engineering and Built Environment, Zaaba College, Faculty of Law, Wisma Kayu, Wisma Aman, Solar Energy Research Institute, Komuter Parking, Transport Unit, PALAPES, Bursar's Office, Bukit Puteri Residential Area, Animal House, Plant House, Institute of Systems Biology, Aminuddin Baki College, Ibrahim Yaakub College, Ungku Omar College, Burhanuddin Helmi College Dectar, Canselori	Zainab Enterprise, Wawasan Teguh Enterprise, Luxda Enterprise, DMA Services Sdn. Bhd & JN Prestij
C	Field UKM	Saujana Scape & Greens Sdn Bhd
D	Dato' Onn College, Tun Hussein Onn College	Semangat Murni Sembilan Puluh Sembilan
E	Mosque, Health Centre, Department of Development and Maintenance, Centre For General Studies, UKM Press, School of Language Studies and Linguistics, Information Technology Center, Tun Abdullah Mohd Salleh Hall Complex, Faculty of Education, Faculty of Engineering and Built Environment, Zaaba College, Faculty of Law, Wisma Kayu	Tasek Bersih Enterprise
F	Ibu Zain College, Rahim Kajai College, Idris Al-Marbawi College	MS Enterprise

2.1 Yard Waste Collection

The yard waste generated at UKM is year-round and was estimated at 2.36 tonne/day which comprises of leaves, branches and miscellaneous fruit and grass. All the yard waste collected are from trees and bushes trimming, grass cutting and fallen leaves. The collection area for the yard waste is divided into 6 zones and is collected by 10 different contractors each day (Table 1). Table 2 provides the composition of yard waste by weight. The weighing activity was conducted over a period of 10 days from 13 June 2011 to 24 June 2011. The data collected includes material from 6 zones surrounding the UKM campus. The total yard waste collected over 10 days was 23.60 tonne. By weight composition, leaves generated 1.86 tonne/day, whereas grass/fruit and branches generated 0.28 tonne/day and 0.22 tonne/day, respectively. It shows that the majority of the yard waste consisted of leaves, 78.89%, followed by miscellaneous fruit and grass, 11.68%. Only 9.43% of the yard waste consisted of branches/tree stems.

Table 2 Materials generated in yard waste by weight in 10 days

Yard waste (tonne/day)	2.36
Leaves (tonne/day)	1.86
Grass/ fruit (tonne/day)	0.28
Branches (tonne/day)	0.22

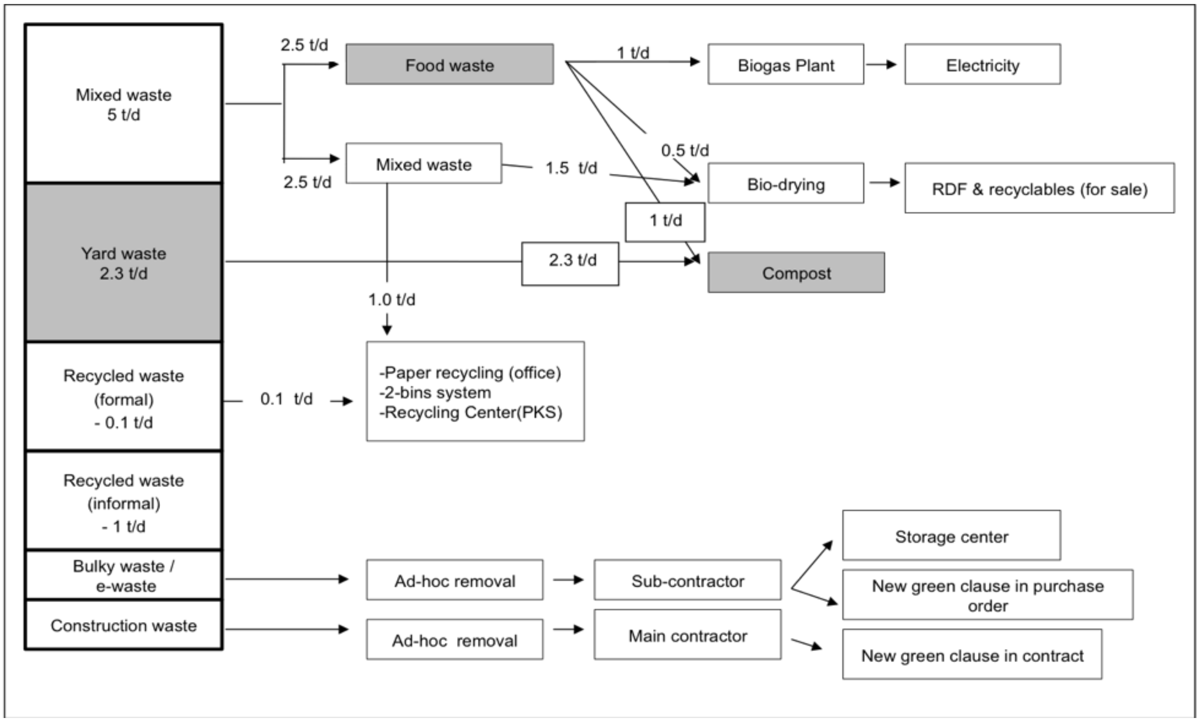


Figure 1 Flow chart of future waste treatment at UKM

Figure 1 is a flow chart of future waste treatment at UKM which include the future management of yard waste. This flow chart is a fundamental concept to streamline waste treatment, inspired by the Head of Zero Waste Campus Group. Currently, UKM generates 5 tonne of mixed waste every day and 50% of the total mixed waste is food waste, while the other half is from the non-organic waste. In the future, the food waste will be treated using three different treatment systems: biogas plant, bio-drying and composting. All the three technologies will be used in treating food waste because UKM wants to treat our internal waste without sending it to landfill. From the 2.5 tonne of food waste per day from cafeterias, 1 tonne of it will be mixed with 2.36 tonne of yard waste to produce compost. The method of composting that will be adopted is based on practicality and cost-effectiveness. Other wastes such as recycled waste, bulky waste, electronic waste and construction waste will be recycled or disposed of in a green manner.

2.2 Analysis of Total Yard Waste Generated

The data gathered during the 2-week study was compiled and analyzed. Figure 2 and Figure 3 show the average total yard waste generated in each zone. The highest collection of yard waste for week 1 (W1) and 2 (W2) is from Zone B with 8855 kg, while the lowest yard waste generated is from Zone C with 504.5 kg. Zone B generated the most yard waste collection because it catered to a majority of the locations on campus, whereas Zone C only catered to one location, the UKM field. Figure 3 illustrates the yard waste generated every day by each zone. Wednesday is the highest collection day with average collection of 453.2 kg, whereas Friday is the lowest collection day with average collection of 318.3 kg.

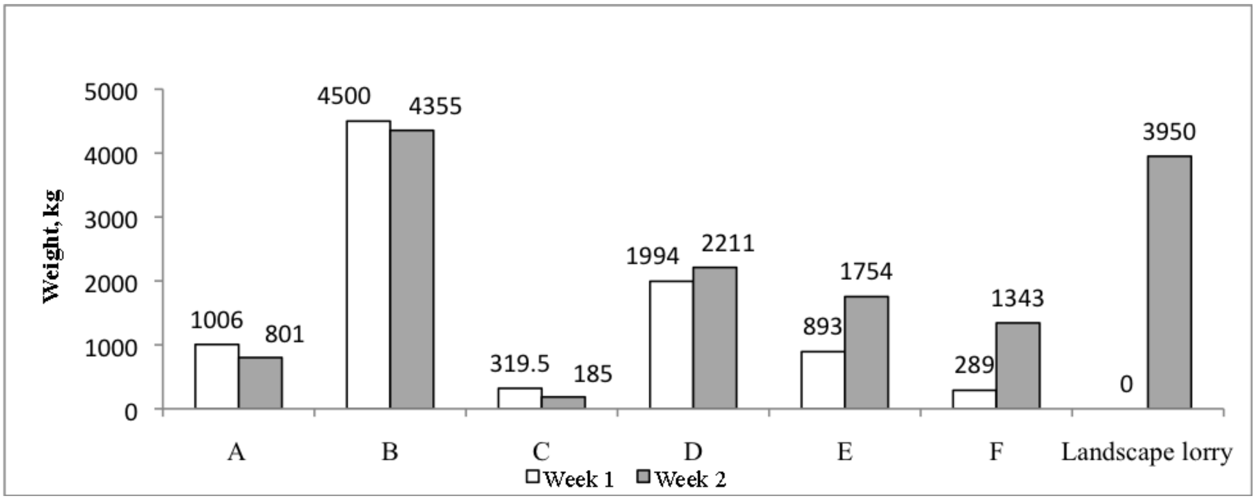
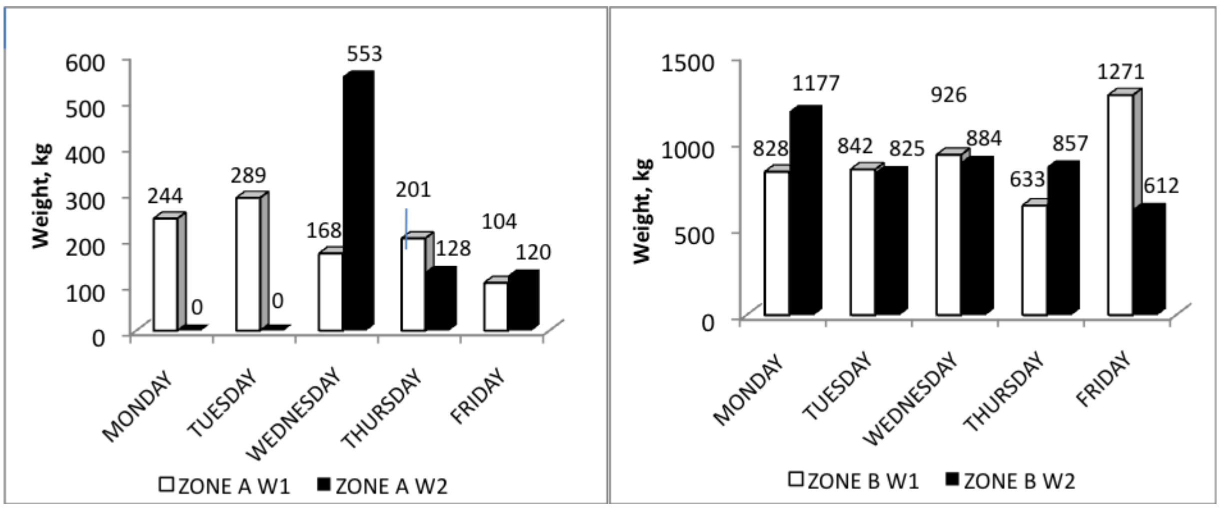


Figure 2 Total yard waste generated by zones



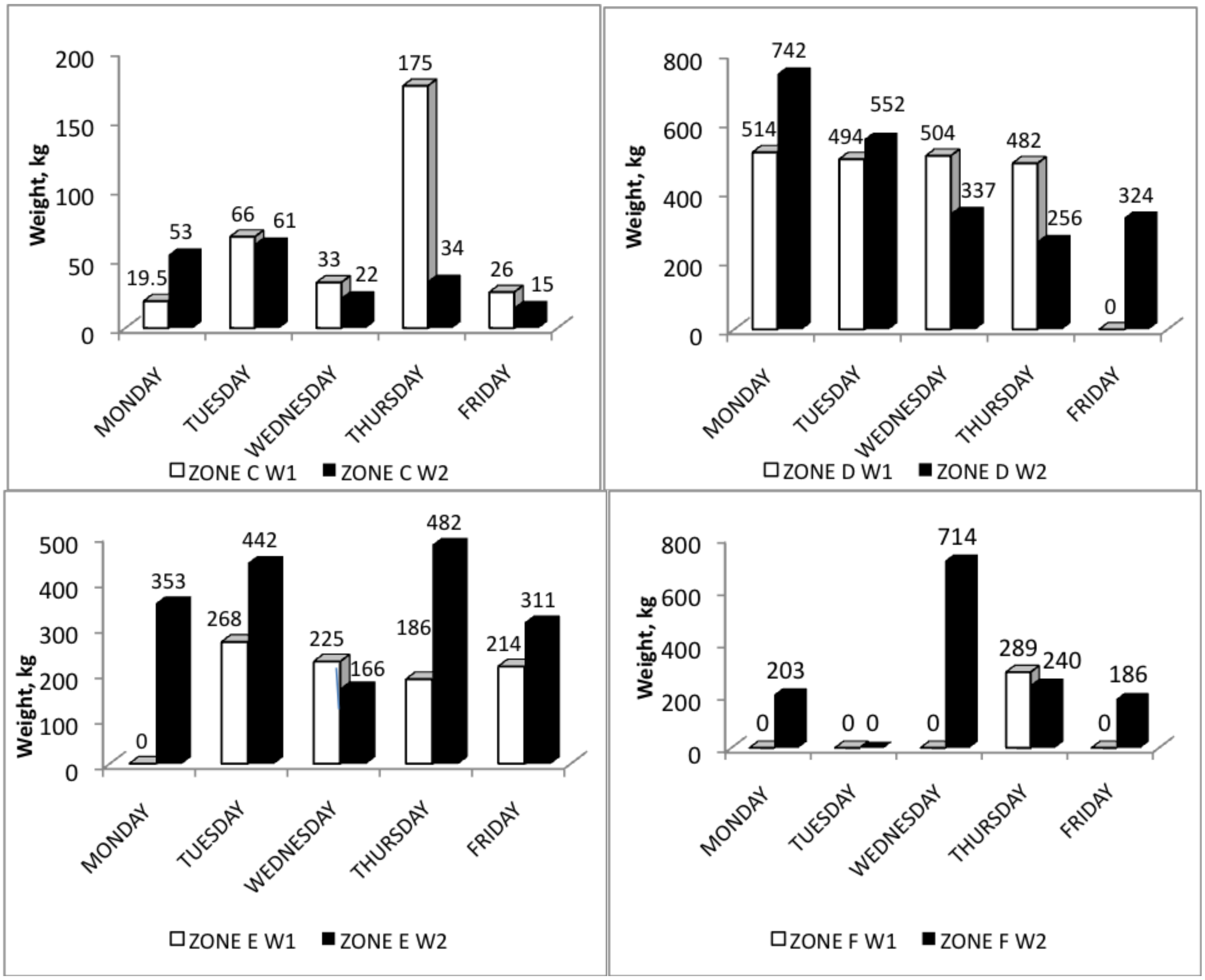


Figure 3 Yard waste generated at UKM by zone for 2 weeks

■3.0 OVERVIEW OF THE YARD WASTE COMPOSTING FACILITY

A dedicated yard waste composting facility is located behind the Faculty of Education. The size of the area is approximately 5016 square meters. It is surrounded naturally with bushes and trees to improve the visual appearance of the composting area.

3.1 Technology Selection of Composting Method

The selection of a specific composting method is based on factors such as capital and operational costs, land availability and operational complexity (Mohee 2007). Table 3 shows a comparison of the composting technology of three different methods which are commonly used when composting large amounts of waste. Each system differs primarily in the method used to aerate the compost. Turned windrows are labor intensive, less costly and more flexible. Aerated static piles and in-vessel systems are capital intensive but provide better control of the composting operation. The aerated static piles and in-vessel systems are high technology approaches because both systems have dedicated equipment to control the composting process, whereas the turned windrow is controlled manually.

Table 3 Comparison of composting technologies

Technology	Product quality	Process	Speed	Capital & operational costs	Process control
Turned windrow	average	simple	short	high	medium
Aerated pile	good	average	shortest	highest	good
In-vessel	good	complex	shortest	highest	excellent

3.2 Potential Costs

When evaluating a proposed composting system, identifying the capital and operating costs is important because these are the main costs. Capital (fixed) costs include the cost of land and equipment and site improvements. Operating costs include labor, maintenance, and utilities (Mohee 2007). Figure 4 shows a comparison of composting technologies in terms of cost and throughput (Leonard 2001). Compost production costs are highest for in-vessel systems and lowest for passive windrows. Aerated static pile composting costs are the highest and passive pile composting costs are the lowest. As the volume of compost materials increases, there is a tendency to increase labor and use more sophisticated composting equipment. Regarding costs, turned windrows are a reasonable option to produce average quality compost.

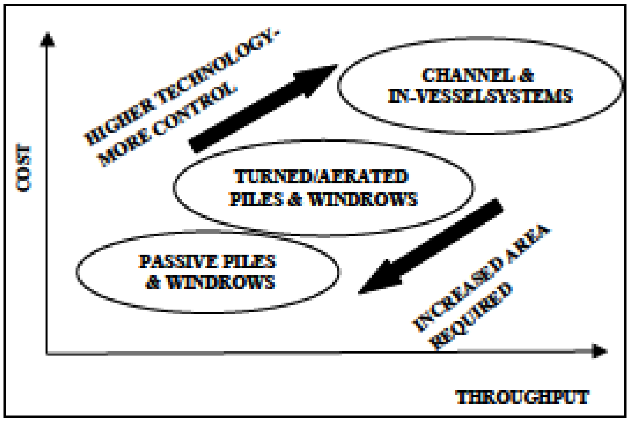


Figure 4 Comparison of composting technologies in terms of cost and throughput. *Source:* Leonard 2001

3.3 Windrow Composting and Requirementsi Designing the Composting Facility

Based on the technologies evaluation which considering the effective costs and operational process, windrow method is found more suitable to be implemented in UKM composting facility. In windrow composting, the wastes are piled in elongated rows and will turned regularly. Raw materials can be added as part of the pile formation. Windrow shapes and sizes vary, depending on the climate, equipment and material used (Mohee 2007). Typically, windrows are 2 to 3 m high, 4 to 5 m wide and 30 to 40 m long, as shown in Figure 5 (British Columbia 1996). Windrow height varies based on the feedstock, the tendency of the composting material to compact and the turning equipment that is used. Careful monitoring of windrow width is unnecessary; however, to ensure that proper oxygen and temperature levels are maintained, windrow height, which determines aeration level to a far greater degree than windrow width, should be monitored. Windrow length has little impact on the composting process (USEPA 1994). Frequent turning of the material provides aeration, mixes the material, helps to control temperatures and redistributes moisture. The turning schedule during composting varies from operation to operation, depending on the pile temperature, season, labor availability and the desired compost quality. The time required to complete the composting process ranges from five to ten weeks, depending on the type of material being composted and the turning frequency (Mohee 2007).

The area required for composting depends on the amount of waste to be received and the amount of bulking agents required (British Columbia 1996). Yard waste has a density ranging from 250 pounds per cubic yard to 500 pounds per cubic yard (Miller 2001). For this composting facility, 2.36 tonne of yard waste and 1 tonne of food waste generated every day will be mixed together for composting material. Generally, one cubic meter of raw composting material will require approximately 0.8 square meters of ground area for windrow setup (British Columbia 1996). The size of the windrow for this composting facility will be 1.5 m high, 42 m long and 3 m wide at the base with a trapezoidal cross section, whereby the volume is 3 m^3 per m length. Based on 3.36 tonne of yard waste and food waste generated per day, it is estimated that 8 windrows each 42-meter long are necessary.

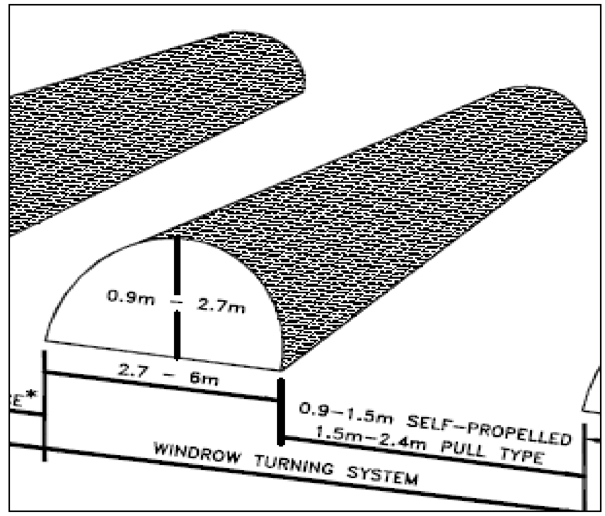


Figure 5 Dimensions and spacing for windrows. *Source:* British Columbia 1996

A roof over the compost windrow is required. Excessive rain may slow the composting process by causing anaerobic zones to develop (British Columbia 1996). The roof is applied for all the required spaces as listed in Table 4. The floor is designed in such a way that the liquid leachate from the compost can flow freely to a central point for collection, which is applied to the windrow when the windrow becomes too dry (British Columbia 1996). Sprinklers will be installed to spread water evenly over the composting mass. The sprinkler connected to a water storage and rainwater-harvesting tank. The roof of the composting shed specially designed to collect rainwater from the rooftops. Beams should be built along the composting shed to control runoff and leachate migration (Mohee 2007). Figure 6 is a pilot plant of composting project in UKM whereby this facility is being set up to test the windrows method before its being implemented as an actual composting system in the campus.

Figure 6 Pilot plant of windrow composting

Table 4 Required spaces for a composting plant processing three tons of waste per day

No.	Type	Required area
	Area A (composting area)	
1	Unloading area for yard waste and shredding area	20 m x 10 m
2	Unloading area for food waste	10 m x 5 m
3	Shredding area	10 m x 10 m
4	Composting pad 1 (windrow)	42 m x 16 m
5	Composting pad 2 (windrow)	42 m x 16 m
6	Water storage and rainwater harvesting tank	Standard tank size
	Area B (additional space requirements)	
7	Curing area	40 m x 15 m
8	Compost storage area	20 m x 15 m
9	Mini composting systems; bin and rotary drum	5 m x 5 m
10	Garden	20 m x 10 m
11	Shed for workers	5 m x 5 m

3.4 Operation and Logistic of the Composting Area

The total area of the composting facility is approximately 5016 m^2. This area divided into two different areas: A and B. Area A is for compost processing, whereas area B is for additional spaces including a small garden for planting using compost product as fertiliser. During operation, lorries unload all of the yard wastes or food wastes to dedicated areas. The yard waste such as leaves and branches were shredded using yard waste shredder prior to Windrow 1 and continue to Windrow 2. At the same process, the food waste mixed directly to yard waste at Windrow 1. Other composting systems such as rotary drum and composter bins will be used as separate systems to compost the yard waste in small quantities.

Figure 7 illustrates the procedure to compost yard and food wastes. JPP workers will turn the piles every day. It is estimated that the piles require 6 to 8 weeks to be composted (Nur Fatin *et al*. 2012). Plant waste contains relatively large amounts of cellulose and lignin, and the concentrations of saccharides, amino acids, proteins, and carbohydrates within this waste are relatively low. Therefore, the incubation time required for plant waste is longer than that for other compost materials (Hua-Shan Tsai *et al*., 2007). The finished compost will be dark brown in color with an earthy smell. The JPP is responsible for storing the finished compost. Some of the finished compost will be used for landscaping and the rest will be sold to a third party.

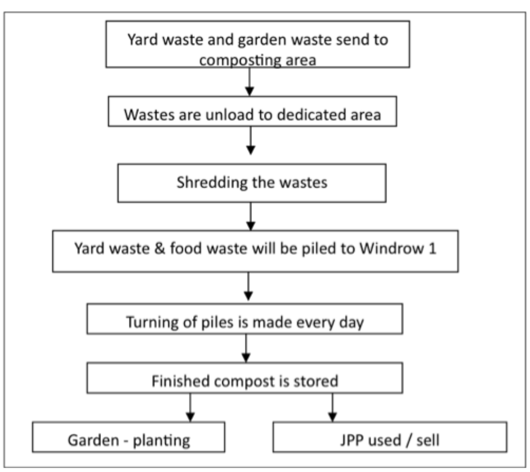


Figure 7 Flow chart of the composting procedure

4.0 CONCLUSION

The 3.36 tonne of yard and food waste generated per day will require an estimated 8 windrows that are 1.5 m high, 42 m long and 3 m wide at the base with a trapezoidal cross section. One windrow is expected to complete the composting process over 4 weeks. The composting of yard waste with food waste is a good method to reduce the amount of waste generated at UKM. By planning and proposing a yard waste composting facility that considers the technology of each method, this facility will successfully process the waste efficiently in a sustainable manner.

Acknowledgement

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