International Journal of Applied Environmental Sciences
ISSN 0973-6077 Volume 11, Number 5 (2016), pp. 1199-1212

http://www.ripublication.com

Design and Performance Test of Non Odorous and Low Maintenance (NOL) Composting Bin Prototype

A.S. Yuwono[1*], Y.C. Wirasembada[1], J. Febrita[1], R.A. Sabarina[1], A.D. Sefiani[1]

[1]Dept. of Civil and Environmental Engineering, Bogor Agricultural University (IPB), Indonesia, Campus IPB Darmaga, PO Box 220 Bogor, 16002 Indonesia.

Abstract

Solid waste management usually generate new problems, not only environmental concerns, but also social concerns as well. Until the present time, IPB (Bogor Agricultural University) as one of the biggest academic institutions in Indonesia is against these problems, especially in odorous impacts which are generated from open dumping. Solid waste management practices in IPB are still limited to merely collection (without any separation for its composition), transport and disposal (open dumping). The objectives of this research were to quantify waste generation in IPB Dramaga Campus, to design and develop a non-odorous and low maintenance (NOL) composting bin prototype based on the generated waste, to carry out performance test of the composting bin and to test the compliance of the resulted compost. The average of waste generation in IPB Dramaga was 0.04 kg/capita/day, where the average of waste density was 106.3 kg/m^3. The main fractions of waste composition are plastic (32%), paper (28%), and food scrap (23%). Temperature monitoring, odour emission test and compost performance test in three models of composting bins (CB1, CB2 and CB3), indicated that CB3 was the most suitable composting bin to be implemented due to its great performance test. Composting bin was designed using natural static pile composting system, where the volume of composting bin was 7.5 m^3 per batch with minimum area of 64.5 m^2.

Keywords: composting, non odorous composting bin, performance test, waste generation

1. INTRODUCTION

Bogor Agricultural University (IPB) campus is one of the big academic institutions in Indonesia. Solid waste management practices in IPB are still limited to merely collection, transport and disposal. Solid waste is collected without any separation for its composition, such as plastic, aluminium, wood, paper, etc. Transportation vehicles of solid waste are not provided by separating room for each composition of solid waste. Disposal in IPB is categorised as low technology, which is being approached for open dumping that poses a serious threat to groundwater resources and soil [1].

Solid waste is produced by every unit in IPB Dramaga Campus, such as classrooms, laboratories, cafeteria, open spaces, department offices and dormitories. Solid waste generation has been measured without using a proper SNI standard, which leads inaccurate results of solid waste generation data in IPB. Many researchers agree that a waste generation and waste characterization study is the first critical step in successful waste management planning [2; 3; 4].

According to Kaplowitz et al. [5] higher education, such as IPB, may be well suited to take the lead on environmental protection for solid waste programs. Higher education may teach and demonstrate principles of awareness and stewardship of the natural world and increase societies environmental sustainability [2]. Teaching and demonstrating solid waste in IPB could be done by providing a facility for solid waste management. Based on the Regulation of Public Work Minister of Indonesia [6], one of the implementations for solid waste treatment is by composting.

Compost installation is a low technology, however, in Southeast Asia, composting is not a common practice due to high operation and maintenance costs, the high cost of the final product with respect to commercial fertilizers [7], as well as poor performance and inefficient performances [8]. Compost installation causes an odour because of the decomposition process of organic material and it can be handled by using some technologies, such as absorption, adsorption and biofilter [9].

The objectives of this research were as follows:

1. To quantify waste generation in IPB Dramaga Campus according to the national standard (SNI No. 19-3964-1994) [10].
2. To design and develop a non-odorous and low maintenance (NOL) composting bin prototype based on the generated waste.
3. To carry out performance test of the composting bin and to test the compliance of the resulted compost according to the national standard (SNI No. 19-7030-2004) [11].

2. RESEARCH METHODS

Waste generation and waste composition were collected in several areas at IPB Dramaga Campus. The design of the composting bin was carried out in the Laboratory of Environmental Engineering, Dept. of Civil and Environmental Engineering (SIL), Bogor Agricultural University (IPB), Indonesia.

Tools used in this research included balance (capacity 5 kg and 100 kg), a wooden box for volume measurement (40 cm length, 50 cm width, 30 cm height), trash bag for taking samples (volume 40 litre), gloves, masks, thermometer, measuring tape, computer, Microsoft Office 2016, AutoCAD 2016 and Sketch Up. Materials used in this research were compostable solid wastes and goat manure as organic activators.

The measurements were taken place at 7 buildings at IPB Dramaga Campus, i.e. Andi Hakim Nasoetion building (AHN), Postgraduate School (PASCA), female student dormitories (ASTRI), male student dormitories (ASTRA), Faculty of Agricultural Engineering and Technology (FATETA), Faculty of Forestry (FAHUTAN) and Faculty of Veterinary Medicine (FKH). Seven buildings were chosen based on the characteristic of occupants in IPB Dramaga Campus.

According to SNI [10], waste was separated based on its composition, such as food scrap, papers, glass, plastic, foliage and others. The weight and volume for every fraction was measured. The measurement series were carried out within 8 days. The number of people occupying each building was also identified. Waste generation data was expressed in kilogram/capita/day, whereas waste composition data was expressed in percent. Waste generation and waste composition data was then used to plan a waste treatment facility in IPB Dramaga Campus. All of the research procedures are depicted schematically in Figure 1.

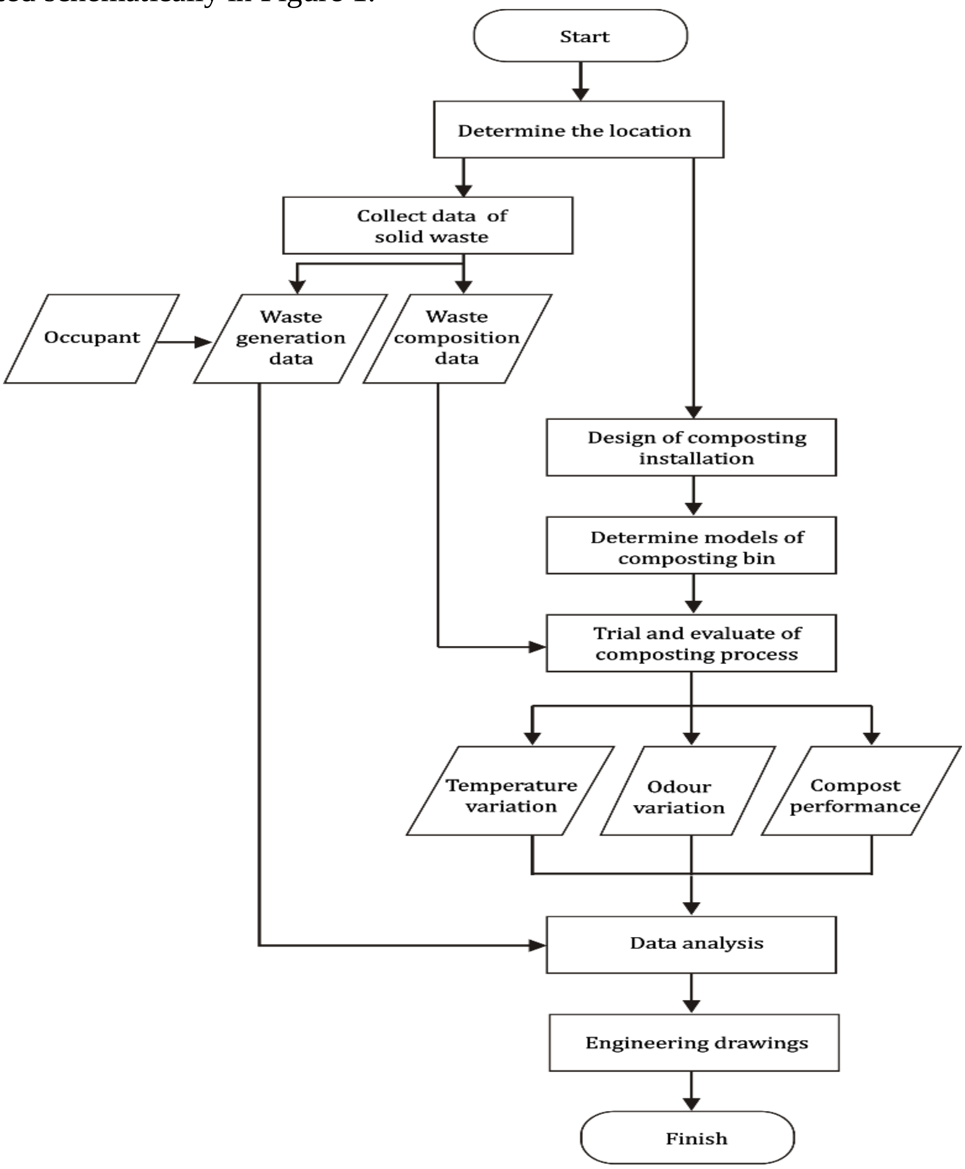


Figure 1: Research procedure

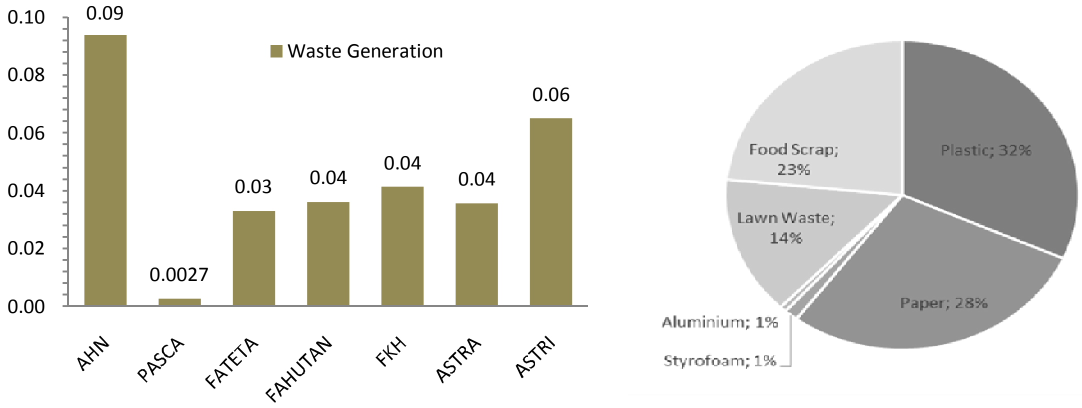
Design of composting installation was carried out by determining various models of composting bin. Each model of composting bin was tested to perform its composting process of organic waste from IPB Dramaga Campus. Compostable wastes consisted mainly of food scrap and foliage. Goat manure was used as an extra addition which had a function as an activator.

During composting process, temperature change and odour variation were monitored in each composting bin model. Temperature change was monitored daily during 60 days. Odour variation for each model of composting bin was evaluated periodically by using odour judge panel method. Odour was scored by [-4 up to +4] range indicating that "-4" is for bad or unpleasant odour, whereas "+4" is intended for good or pleasant odour.

The odour judge panellist consisted of six members and odour was evaluated every week for one month. At the end of the composting process, compost product from each composting bin was analysed in the laboratory, based on the parameters as stated in the national compost standard [11]. Temperature variation, odour variation and compost performance were then analysed to choose the best composting bin.
Calculating size of composting bin was carried out by using waste generation data. Besides composting bin, other composting installation parts, such as sieving tool and compost packing corner were also considered as parts of the composting facility. Design of composting installation was drawn by using AutoCAD and Sketch-Up.

3. RESULTS AND DISCUSSIONS

Waste generation was measured based on waste collecting habit in sampling areas where solid waste is normally collected from top floor towards down floor. Figure 2 shows variation of waste generation in each sampling site. AHN shows the highest amount of waste generation. Waste generation amount was affected by income, social economy, consumption patterns, and season [4; 7; 12; 13]. It was different in other sampling sites which were fulfilled by students who had a low number of waste generations due to their low income. The average of waste generation at IPB Dramaga Campus was 0.04 kg/capita/day. The average of waste density at IPB Dramaga Campus was 106.3 kg/m^3. The main fraction of waste composition is shown in Figure 2, where the main fractions are plastic (32%), paper (28%), and food scrap (23%).



(a) **(b)**

Figure 2: Waste generation in each sampling site (a) and waste composition at IPB Dramaga Campus (b).

3.1. Potency for Composting

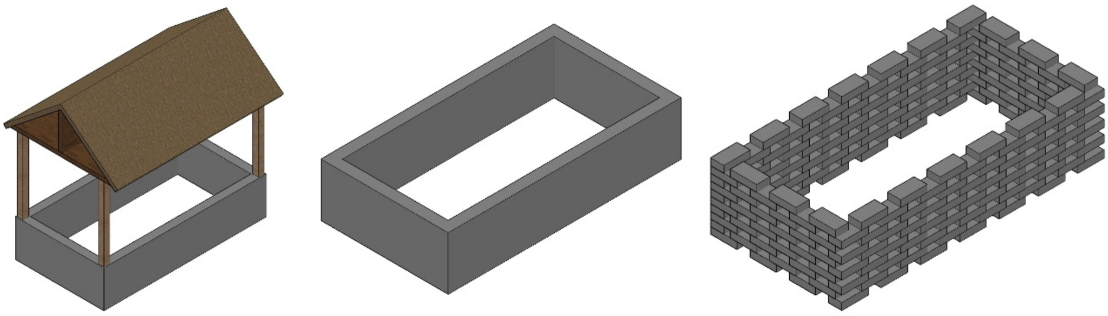
Knowledge of waste generation and composition is useful for facilitating the preparation of an effective and economical long-term plan for waste management [2; 4]. Waste generation data and waste composition data will determine the potency of waste for composting. Some sites are not feasible to implement compost installation due to low potency, i.e. less than 0.10 m^3/day or under 20% of organic fraction, such as PASCA, ASTRA and ASTRI. The rest of sampling sites were feasible to implement composting installation.

3.2. Aeration System in Composting Bin

According to Kumar [14], there are three main systems of aeration in composting system, namely aerated-static pile system, enclosed system and the windrow system. According to Nasir [15], there is easier method which does not need aeration; it is called the natural static pile. Natural static pile composting system was chosen to keep low maintenance. According to Genaille [16], there are rules to achieve low maintenance composting installation, i.e. no moisture manually added and no frequent turning.

3.3. Experiments in Composting Bin

In determining a suitable composting installation, three different models of composting bin (CB) were applied. The name was CB1, CB2, and CB3. CB1 and CB2 were rectangular composting bin, where aeration entered from the top of composting bin. The different between CB1 and CB2 was the roof coverage for CB1, whilst CB2 had no coverage at all. CB3 was equipped with an aeration hole in each side of the composting bin and was not covered by roof. Figure 3 shows layout of three different types of the composting bin.



(a) (b) (c)

Figure 3: Layout of composting bin: (a) CB1, (b) CB2, and (c) CB3.

3.4. Change of Temperature

Temperature is the most important indicator of the efficiency of the composting process [17] and factor to be monitored during composting [14]. Temperature within the range of 45-55°C ensures the best degradation of composting mass, whereas temperature above 55°C results in pathogen destruction [14]. After that, the temperature was generally decreased, due to more stabilized organic matter [18]. The temperature was continually monitored on-site for 60 days.

Figure 4, 5 and 6 show temperature variation of the compost pile and ambient air during composting process. Daily temperature was recorded in 21.8-25.8 °C. Three types of composting bin temperature had reached its peak during the first week, where for CB1 was 50°C, whereas for CB2 and CB3 were 47°C. Research conducted by Abbassi et al. [18] indicated that temperature of the composting process was rapidly increased from ambient temperature during the first six days of the process. At the end of the composting process, the temperature of composting bin with roof was 34°C and the temperature of composting bin without roof was 27-31°C. CB2 and CB3 resulted in lower temperature than CB1 that could be affected by direct rainfall which raised moisture in composting process. Temperature variation in CB3 was more stable than the other composting bins due to high addition of moisture and oxygen. According to Adhikari [19], the microbial activity is mainly affected by moisture and oxygen.

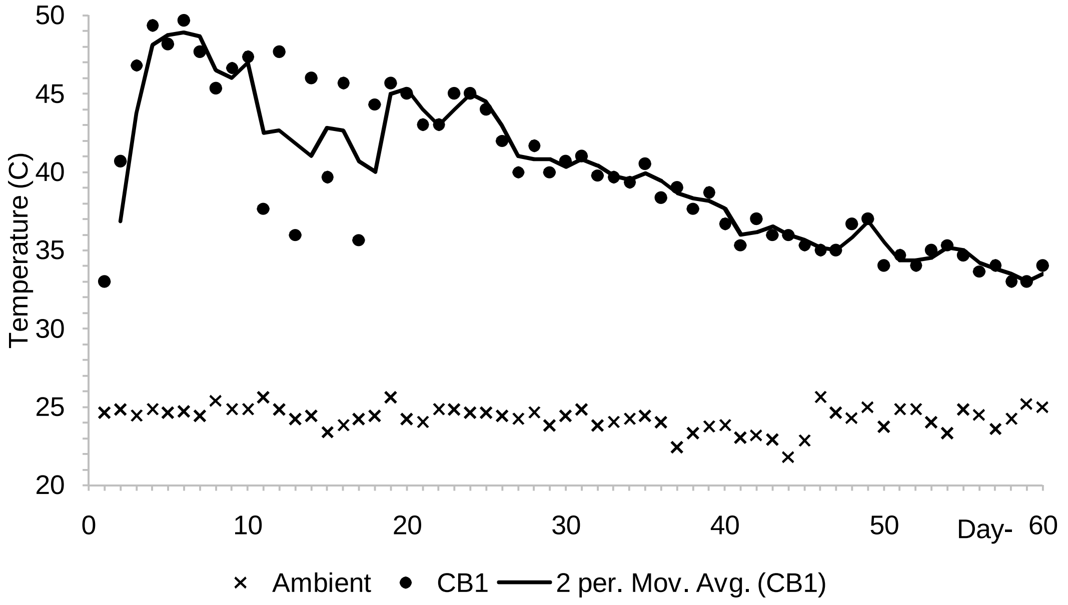


Figure 4: Temperature variations in CB1

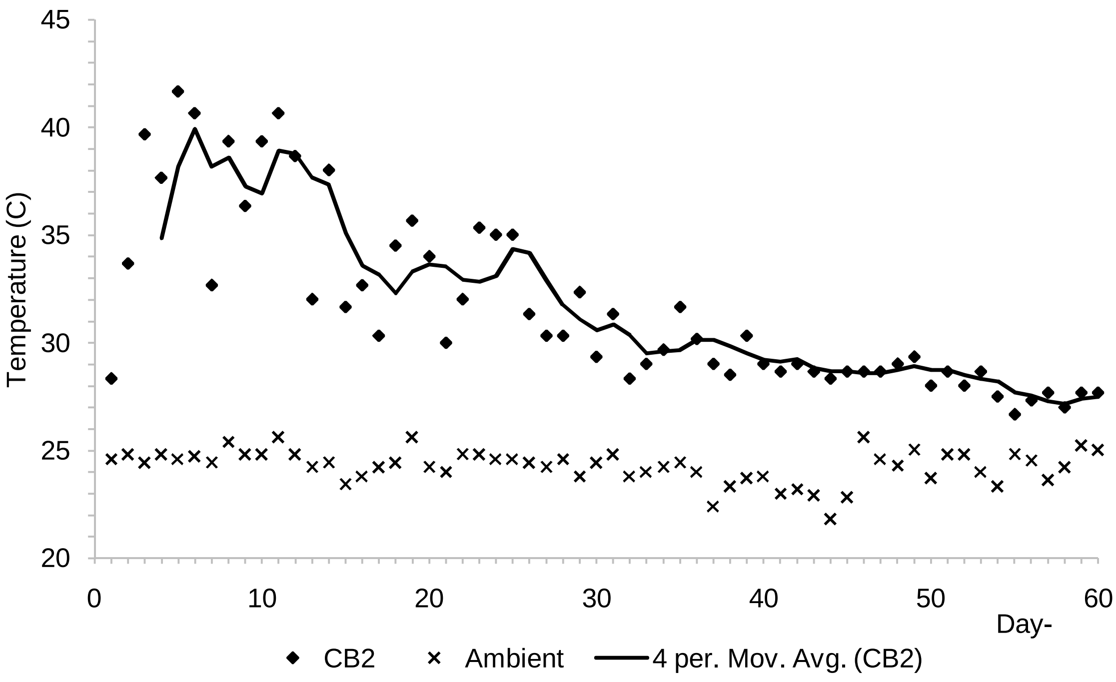


Figure 5: Temperature variations in CB2

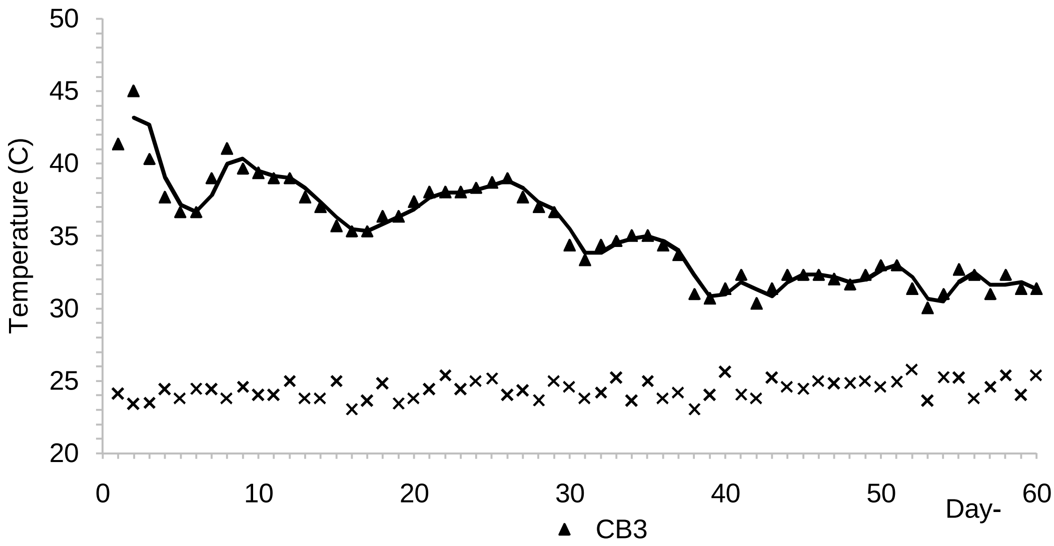


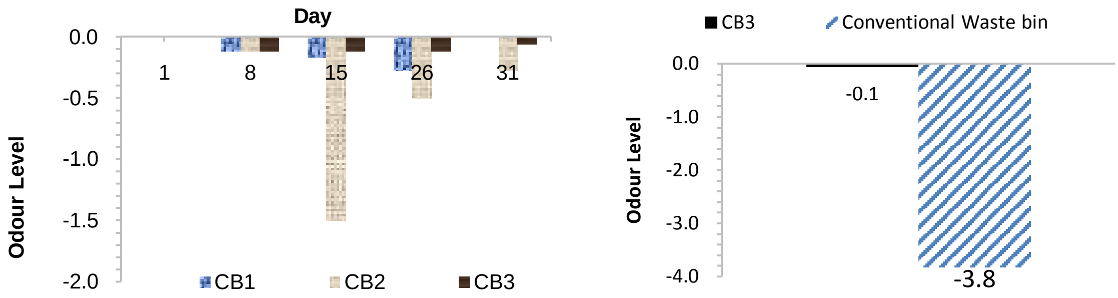
Figure 6: Temperature variations in CB3

3.5. Evaluation of Odour Emission

Odour emission is the biggest problem caused by any compost installation. It causes vapour and gases directly emitted to the environment [7; 8; 9; 20; 21; 22; 23]. The odour generated during composting can be eliminated by using various methods, such as water flushing, burning, chemicals, air dilution and biofilter [9]. In this research odour was avoided by modifying composting bins. Figure 6 abovementioned different models of composting bins. These three types of composting bins affected the release of odour.

Figure 7 shows each composting bin that has different odour characteristics. On the first day, average odour score was merely zero, which showed that compostable waste had not decomposed and emitted no odour in the ambient air. Afterwards, average odour score was -0.1 during first eight days of composting in CB1 and CB2. At day 18 for CB2, odour score was -1.5 which reflected odour nuisance to the environment. In CB3, however, odour score was merely -0.1 from day 2 until day 30, which reflected minimum odour nuisance to the environment.

Odour emission is minimized when there is adequate oxygen [24]. CB3 ensured the availability of oxygen which caused lower odour generation compared to conventional waste bins that emitted odour with score of -4. This indicated that CB3 emitted odour in minimum level caused almost without any nuisance to the environment. Figure 7 (b) shows comparison of the odour scales between CB3 and conventional waste bin.



(a) **(b)**

Figure 7: Odour emissions during composting process for each composting bin (a) and Comparison between CB3 and conventional waste bin (b).

3.6. Evaluation of Compost Performance

National standard of compost quality from solid waste [11] was made to protect consumers and prevent environmental pollution. Different model of composting bin implied different result of compost quality. Compost quality from CB1 does not comply with the SNI standard due to high number of carbon, C/N ratio and magnesium. CB2 did not comply neither with SNI standard due to high number of carbon and C/N ratio. Compost resulted from CB3, however, complied with the SNI standard. Table 1 shows compost quality of each composting bin.

Many factors could impact compost quality, such as source of compostable waste. Three models of composting bins were tested using different sources of compostable wastes, which impacted the result of compost performance.

Table 1: Compost quality

Parameter	**Standard***	**Unit**	**Result**		
			CB1	**CB2**	**CB3**
Temperature	Groundwater temperature	°C	34	28	31
Colour	Black	-	Black	Black	Black
Macro elements					
Nitrogen (N)	>0.4	%	1.3	1.2	1.9
Carbon (C)	9.8 – 32	%	42	35	19
C/N	10 – 20	-	32	29	10
P_2O_5	>0.1	%	1.2	1.4	1.4
K_2O	>0.22	%	1.77	0.24	2.60
Micro elements					
Cobalt (Co)	<34	$mg.kg^{-1}$	0.0	0.0	6.3
Zinc (Zn)	<500	$mg.kg^{-1}$	135	142	66
Other elements					
Calcium (Ca)	<25.5	%	0.6	0.5	4.1
Magnesium (Mg)	<0.6	%	0.8	0.6	0.5

Parameter	Standard*	Unit	Result		
			CB1	CB2	CB3
Iron (Fe)	<2.0	%	0.7	1.3	1.3
Manganese (Mn)	<0.1	%	0.07	0.08	0.08

* Indonesia standard of SNI No. 19-7030-2004

3.7. Design of Composting Bin

Composting installation needs raw materials, such as compostable waste and goat manure. Waste generation in IPB Dramaga Campus was 0.04 kg/capita/day with an average of compostable waste of 18.9%. In this composting process, compostable raw material was mixed with goat manure. Goat manure was used as an activator which increases the process of decomposition of organic matter in composting [14]. Goat manure contains 5.06% of N substrate, 0.67% of P substrate, and 3.97% of K substrate [25]. According to Nasir (2013) [15], natural static pile composting system needs 56 days processing time.

All of the variation above was taken into consideration for choosing the most suitable composting bin. Temperature variation reflects about perfection of the process. Odour variation impacts such a nuisance to environment. Compost quality indicates the perfectness of the biodegradation process. Based on these reasons, CB3 was the most suitable composting bin to implement.

The composting bin was designed using natural static pile composting system. The capacity of composting bin was assumed on the largest volume of compostable waste at IPB Dramaga Campus, i.e. 0.25 m^3 per day. Based on the design criteria where composting bin will take time for 60 days, composting bin needs to hold up for 15 m^3 per batch. Composting will be divided into 2 composting bins; each composting bin will hold up to 7.5 m^3 per batch. The reason in dividing composting bins is to minimize area use. Table 2 shows the volume of composting bin.

Table 2: Volume of composting bin

No	Parameter	Quantity	Unit
1	Volume per period	15.0	m^3/period
2	Composting bin	2	bins
3	Volume per bin	7.5	m^3/period

Based on the volume per bin, composting bin has a height for 0.7 m and has a ratio 2:1 for its length and width. This calculation leads the length and width of the composting bin, where the length and width is 4.7 m and 2.3 m, respectively. Light concrete is used as material for composting bin. The dimension of light concrete is 60cm x 20cm x 7cm. Aeration was enabled on the side surface of the composting bins by making holes between the light concrete. The aeration hole is about 3 cm. Detail design of composting bin is presented in Appendix 1.

3.8. Operational and Management

Each of composting bins will decompose organic waste for 60 days, where the numbers of composting bins are three. Every day, compostable waste can be transported and processed into composting bins. During day 1 to 60 compostable wastes will be dumped in composting bin 1. Day 61 to 120 compostable wastes will be dumped in composting bin 2. Day 121 to 180, compostable wastes will be dumped in composting bin 3. After the first 60 days, compostable waste which was decomposed will be treated using sieving tool. Compostable waste which does not decomposed perfectly due to short time of composting process will be dumped into next composting process. Appendix 2 shows 3D models of the composting bin.

4. CONCLUSIONS

Conclusions from this research are as follows:

1. Waste generation and waste composition was not identical for each sampling site. The average waste generation at IPB Dramaga Campus was 0.04 kg/capita/day. The biggest fraction of the generated solid waste was plastic, foliage and food scrap.
2. Performance test showed variations of each composting bin. Based on performance test, compost from CB3 complied with the national standard [SNI 19-7030-2004].
3. CB3 was the most suitable composting bin to be implemented. Composting bin was designed using natural static pile composting system, where the volume of composting bin was 7.5 m^3 per batch. Based on waste generation data, there will be 3 composting bins for each site.

ACKNOWLEDGEMENT

The research was conducted with financial support from The Osaka Gas Foundation, Japan, organized by The Research Centre of Environment, Bogor Agricultural University (PPLH-IPB). Authors wish to thank to Mr. Maulana Ibrahim Rau Hasibuan ST, MSc, research assistants and technicians during field experiments as well as laboratory analysts for their helpful services.

REFERENCES

[1] Ali SM, Pervaiz A, Afzal B, Hamid N, Yasmin A. 2013. Open Dumping of Municipal Solid Waste and Its Hazardous Impacts on Soil and Vegetation Diversity at Waste Dumping Sites of Islamabad City. *Journal of King Saud University–Science.* 26(1): 59-65.

[2] Morrissey AJ, Zavodska A. 2004. Achieving Campus Sustainability: the Challenges and Constrains. *Proceedings of the International Conference on Waste Technology and Management.* 469-478.

[3] Smyth SP, Fredeen AL, Booth AL. 2010. Reducing Solid Waste in Higher Education: The First Step Towards 'Greening' a University Campus. *Journal of Resources, Conservation and Recycling.* 54(11): 1007-1016.

[4] Virgen QA, Gonzales PT, Benitez SO. 2012. Seasonal Analysis of the Generation and Composition of Solid Waste: Potential use-A Case Study. *Journal of Environment Monitor Assess*. 185: 4633-4645.

[5] Kaplowitz MD, Yeboah FK, Wilson AM. 2009. Garnering Input for Recycling Communication Strategies at Big Ten University. *Journal of Resources, Conservation and Recycling.* 53(11): 612-623.

[6] [KEMEN PU] Kementerian Pekerjaan Umum. 2013. *Penyelenggaraan Prasarana dan Sarana Persampahan dalam Penanganan Sampah Rumah Tangga dan Sampah Sejenis Rumah Tangga* Nomor 3 tahun 2013. Jakarta: Kementerian Pekerjaan Umum.

[7] Ngunyen NU, Schnitzer H. 2009. Sustainable Solution for Solid Waste Management in Southeast Asian Countries. *Journal of Waste Management.* 29: 1982-1995.

[8] Marmolejo LF, Diaz LF, Torres P, Garcia M. 2012. Perspective for Sustainable Resource Recovery from Municipal Solid Waste in Developing Countries: Applications and Alternatives. *Journal of Waste Management an Integrated Vision.*

[9] Park KJ, Choi MH, Hong JH. 2002. Control of Composting Odour Using Biofiltration. *Compost Science and Utilization.* 10(4): 356-362.

[10] [SNI] Standar Nasional Indonesia (Indonesian National Standard). 1994. *Metode Pengambilan dan Pengukuran Contoh Timbulan Sampah dan Komposisi Sampah Perkotaan (Methods of Sampling and Measuring Composition of Municipal Waste Generation)* SNI No. 19-3964-1994. Jakarta: Badan Standardisasi Nasional (National Standardization Agency of Indonesia).

[11] [SNI] Standar Nasional Indonesia (Indonesian National Standard). 2004. *Spesifikasi Kompos dari Sampah Organik Domestik (Compost Specification from Organic Domestic Waste*) SNI No. 19-7030-2004. Jakarta. Badan Standardisasi Nasional (National Standardization Agency of Indonesia).

[12] Chaerul M, Tanaka M, Shekdar AV. 2007. Municipal Solid Waste Management in Indonesia: Status and the Strategic Actions. *Journal of the Faculty of the Environmental Science and Technology*. 12(1): 41-49.

[13] Babayemi JO, Dauda KT. 2009. Evaluation of Solid Waste Generation, Categories and Disposal Options in Developing Countries: A Case Study of Nigeria. *Journal of Applied Sciences and Environmental Management.* 13(3): 83-88.

[14] Kumar S. 2011. Composting of Municipal Solid Waste. *Critical Review in Biotechnology.* 31(2): 112-136.

[15] Nasir M. 2013. *Karakteristik Pengomposan Limbah Padat Pasar Tradisional dengan Sistem Natural Static Pile*. Bogor (ID): Institut Pertanian Bogor.

[16] Genaille DM. 2006. A Low Maintenance Approach to Composting Cattle Mortalities on The Farm [thesis]. Canada: University of Manitoba.

[17] Karnchanawong S, Suriyanon N. 2011. Household Organic Waste Using Bins with Different Types of Passive Aeration. *Journal of Resources, Conservation and Recycling.* 55(5): 548-553.

[18] Abbassi BE, Abubaker S, Al-Manaseer E, Nassour A, Dababneh B, Shqairat W, Al-Jaar M. 2015. Optimization of Operating Parameters of Windrow Composting of Animal Manures. *Journal of Solid Waste Technology and Management.* 41(1): 60-67.

[19] Adhikari BK. 2011. Onsite Treatment of Urban Organic Waste Using Home Composting Systems [thesis]. Canada: McGill University.

[20] Michael FC, Reddy CA. 1998. Effect of Oxygenation Level on Yard Trimmings Composting Rate, Odour Production and Compost Quality in Bench-Scale Reactors. *Compost Science and Utilization*. 6(4): 6-14.

[21] Sironi S, Botta D. 2001. Biofilter Efficiency in Odour Abatement at Composting Plants. *Compost Science and Utilization.* 9(2): 149-155.

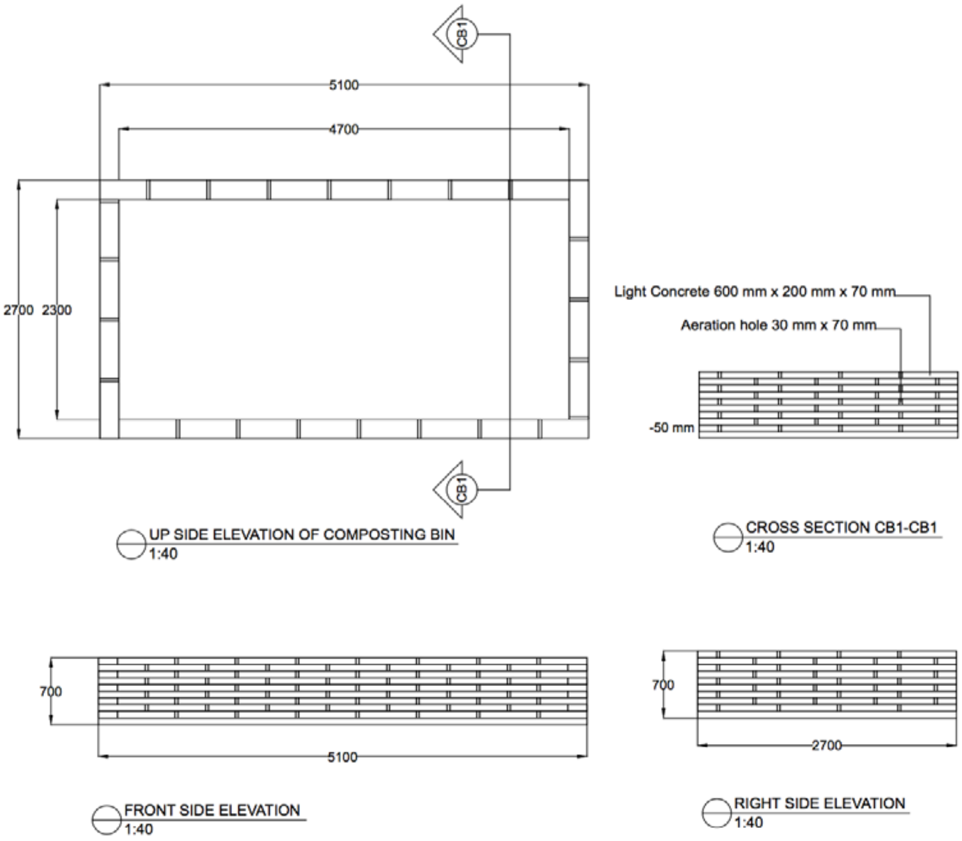
[22] Smidt E, Meissl K, Tintner J, Binner E. 2009. Resource Recovery by Composting – Materials, Techniques and Quality Assessment. In: Pereira J C, Bolin J L, editor. *Composting: Processing, Materials and Approaches*. New York: Nova Science Publisher. 1-30.

[23] Yuwono, AS and Schulze Lammers, P. 2004. Overview paper: Odour pollution in the environment and the detection instrumentation. Agricultural Engineering International: The CIGR Journal of Scientific Research and Development. Invited Overview Paper. Vol. VI. July, 2004

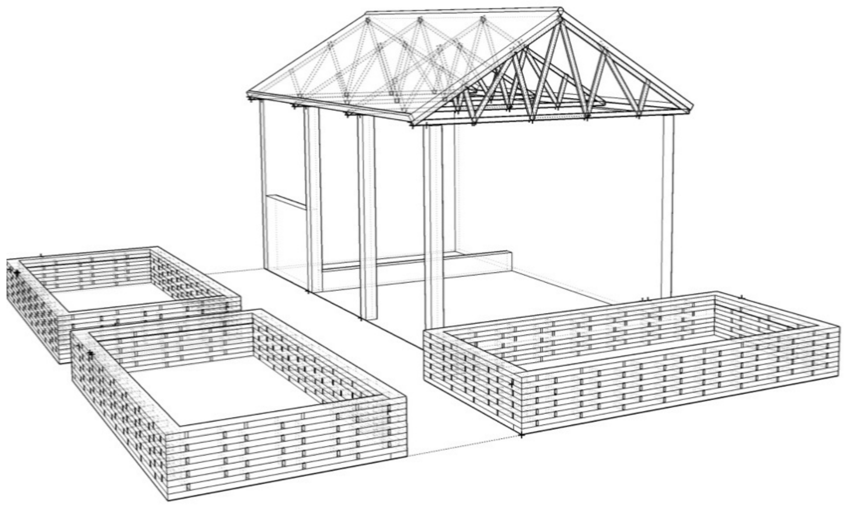
[24] Harrison EZ. 2007. Compost Facilities: Off-Site Air Emissions and Health.

[25] Novien A. 2004. *Pengaruh Beberapa Jenis Aktivator terhadap Kecepatan Proses Pengomposan dan Mutu Kompos dari Sampah Pasar dan Pengaruhnya terhadap Pertumbuhan dan Produksi Tanaman Caisim (Brassica juncea L) dan Jagung Semi (Zea Mays L)* [Skripsi]. Bogor (ID): Institut Pertanian Bogor.

APPENDIX



Appendix 1. Detail of Composting Bin



Appendix 2. 3D Models of Composting Bin