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Assessment of Compost from Waste Treatment Unit as Biocover Material for Cipayung Landfill at City of Depok

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***Abstract*—The application of compost as biocover is not only mitigate the greenhouse gasses generated from inside of the landfill itself, but also to reduce the operational cost to supply cover soil and utilize compost that does not have a market. This research investigated the characteristics of compost produced by waste treatment unit (WTU) in City of Depok and its potential as biocover material to reduce methane emission. In this batch experiment, four columns used and utilized two variations of height, which are 40 cm and 80 cm and two sources of compost. Based on the assessment, the quality of compost mostly meets the requirements. Therefore, all compost can be utilized as biocover material as well as daily biocover or final cap for Cipayung landfill since they could show good performance in removing methane. Pre-treatment or curing phase is necessary to improve its quality before using it as biocover material.**

***Keywords*—biocover, compost, methane oxidation, WTU**

I. Introduction

The City of Depok is one of the fast growing cities in Indonesia. Its population is approximately 1.7 million based on the last census at 2010. City of Depok has experienced problems due to the increasing of waste generation. Each people in City of Depok estimate to generate waste approximately 2.5 liters/day and it becomes more than 4,000 m^3/day waste coming from all of its population. However, only 50% waste generated can take to Cipayung landfill site due to the lack of transportation facilities.

During the last five years, City of Depok has already built 40 units of waste treatment unit (WTU) as one of the solid waste management components. WTU is an intermediate treatment facility that takes a place before landfilling. Upon of this numbers, 19 WTUs have been operating until now. The capacity of each WTU is 30 m^3/day and treatments that are conducted in WTU are sorting, shredding, and composting. Nowadays, all of the WTU produce compost in considerable amounts. As if estimated 20% of the incoming waste to each WTU become compost, then compost will be produced in range of 6m^3/day. Unfortunately, compost from WTU cannot put into the market related to its poor quality. Furthermore, this compost also did not meet with Indonesian standard for matured compost and also market criteria. As the result, this compost continues to accumulate and needs large space in WTU to store it. It certainly reduces working space in WTU and may disrupt WTU operational.

Many previous studies found out that compost could not only use as organic fertilizer, but also possible as biocover for landfill. The application of compost as biocover is not only mitigate the greenhouse gasses generated from inside of the landfill itself, but also to reduce the operational cost to supply cover soil. Based on the above description, compost has a potential and a good alternative for daily and final cover soil in landfill. Moreover, compost from WTU that do not have market can utilize for further use. This research investigated the characteristics of compost produced by WTU in City of Depok and its potential as biocover material to reduce methane emission by enhancing its oxidation on landfill.

II. Material and Methods

A. *Compost Characterization*

As methane oxidation layer, characteristics of compost material is important to find out. It should feature beneficial and provide favorable condition for microorganism growth. In this respect, compost should have high surface area as a place for microbes to attach. The larger its surface area, the more microbes can be attached. It combines with other characteristics such as porosity and suitable texture for gas exchange, higher moisture content, and air-filled pore volume. In addition, compost should be fully matured and well texture otherwise; it may produce methane rather than oxidize it [1]. The characteristics of compost that suitable for biocover media will be determined into some parameters that can be seen in Table 1. Compost that is utilized in this research came from two WTUs, which are WTU Hangar 4 at Cipayung Landfill and WTU Jl. Jawa.

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B. *Column Experimental Set Up*

The impact of methane emission reduction in the presence of compost biocover will examine through batch experiment. In this experiment, four columns used and utilized two variations of height. The compost height set up at 40cm (C1 and C2) and 80 cm (C3 and C4). These compost heights based on the appropriate height for cover soil in Indonesian standard. All columns were made of acrylic tube with diameter approximately 20 cm and height of 100 cm.

Methane gas will introduce through the bottom of column (up-flow mode) to separate the clean gas output from the leachate outlet at the bottom of column. The up-flow mode should also prevent the accumulation of methane gas in the headspace of column [2]. Gas load will be set up about 10 ml/minute. The feed gas controlled by rotameter (Dwyer series RM). Artificial methane gas that utilized contained approximately 50vol% each for methane and carbon dioxide gas, which followed the landfill gas content. Air injected into column by compressor provided sufficient oxygen supply throughout the biocover and ensure methane concentration 50% below its lower explosive limit during experiment [3]. The gas and air moisturized first before introduce into the column bed by using washing bottle that is filled with water.

Additional air is blown in above media at the top of column to allow oxygen penetrate into the substrate similar to natural landfill conditions. Airflow rate is adjusted approximately 25 ml/minute, which is followed methane to oxygen ration 1:2.5 [4]. Meanwhile, pressure drop allowance is between 200-3,000 Pa/m-filter bed [5]. The surface loading rate is defined as the volume of the gas per unit area or filter material per unit time [6], which approximately 9.545 $l/m^2.h$.

Sampling port provided on the top of the column is used to determine exhaust gas volume and methane concentrations after passing through compost bed. Exhaust gas captured by using flex foil gasbag (SKC # 262-05). Methane concentrations in the exhaust gas assessed by Gas Chromatography (GC-Shimadzu – 8A). Thermometer and moisture probe located on the side of column at a height 25 and 35 from the bottom of column C1 and C2. Meanwhile, thermometer and moisture probe at column C3 and C4 located at the height of 25, 45 and 65 cm. The column batch set sketch for this experimental lab-scale can be seen in Fig. 1 below.

C. *Methane Removal Efficiency*

The removal efficiency (RE) is the fraction of the methane removed by the biocover [6]. This RE expressed as a percentage as follow:

$$RE = \{(C_i - C_o)/ C_i\} \times 100. \quad (1)$$

Where C_i and C_o is methane fraction at inlet and outlet of the column, respectively.

III. Results and Discussion

A. *Compost Quality for Methane Oxidation*

At the beginning, compost that is taken from both WTU did not meet the quality that has been determined previously on Table 1. Therefore, this compost need to further treatment before utilizing it as media in this experiment. Pretreatment conducted as a curing phase to improve its quality and meet the requirement by giving additional air and water. In addition, manual turning performed every day to make air distributed evenly throughout the compost pile. After pre-treatment, compost then sieved to get uniform particle size, which is between 0.5-2.0 mm. These composts further analyzed in the lab to determine its physical, chemical, and biological characteristics. The results can be seen on Table I.

The result shows that two physical and two chemical parameters did not meet the requirement based on Indonesia standard for matured compost and reference value for biocover media. Both compost shows having bulk density lower than expected. Bulk density is a measure of the mass of material within a given volume and having influences at certain physical properties, which are porosity, strength, and compactibility [7]. Higher value of bulk density indicates that compost has less pore space and more compact [8]. The bulk density value is small because the particle size of the compost that utilized is also small, which is 0.5-2.0 mm. Compost has been sieved to get this appropriate size. According to [1], finely sieved compost made from municipal solid waste with particle size less than 20 mm showed initial high respiration activity. Therefore, we expected to acquire high methane oxidation during this experiment with this size.

Moisture content is important parameter to support microbial activity in order to enhance methane oxidation in biocover. Moisture content value both compost is about 51%, slightly higher than 50%. Theoretically, ideal moisture content should approach 100% to diminish moisture limitation during biological decomposition but excess moisture content caused compacting and reduced void space [9]. Therefore, 1% difference does not significantly affect compost as biocover media.

Electrical conductivity both composts did not meet the requirements, which is less than four. Compost from WTU Jl. Jawa has a higher value (12.43 µS/cm) than compost from WTU Hangar 4 Cipayung Landfill (9.8 µS/cm). Conductivity is a measure of soluble salt content [10]. Compost originating from food waste typically has a high value of conductivity. Both compost shows having higher conductivity than expected because of its origin from household waste that is mostly contain food waste. This parameter provides scarce information on the suitability of a substrate for methane oxidation as in [1]. Nevertheless, higher value of conductivity is harm to germinating seed due to osmotic effect and microbial activity can be disrupted. On the other hand, higher

TABLE I: COMPOST QUALITY BASED ON LAB ANALYSIS

Parameters	Unit	Reference values for biocover media [3]	Indonesia Standard - SNI No. 19-7030-2004	Compost from Hangar 4	Compost from WTU Jl. Jawa
Physical					
Bulk density	kg/l	0.8-1.1		0.6197	0.6240
Moisture content	%w/w	30-50	50	51.69	51.01
Water holding capacity (WHC)	%DM	50-130	58	86.4	95.2
Air-filled pore volume	%v/v	>25		43.07	42.68
Pore Volume	Cc/g			4.736×10^{-2}	1.419
Particle size	Mm		0.5-25	0.5-2.0	0.5-2.0
Temperature	^{o}C		< 30	28	28
Color			Dark brown	Dark brown	Dark brown
Odor			Earthy smell	Earthy smell	Earthy smell
Chemical					
Electrical conductivity	µS/cm	< 4		9.8	12.42
pH-value	-	6.5-8.5	6.8-7.49	7.8	7.8
N_{total} – Kjedahl	%DM	> 0.5	0.4	1.93	1.82
PO_4-P	%DM	> 0.3	>0.1	0.42	0.19
Loss of ignition	%DM	> 15		17.9	16.38
Total organic carbon (TOC)	%DM	> 7		6.4	6.6
C/N ratio		(17-25):1	(10-20):1	22	18.6
Biological					
Respiration Activity 4 days (AT-4)	mg O_2/g DM			2.43	1.85

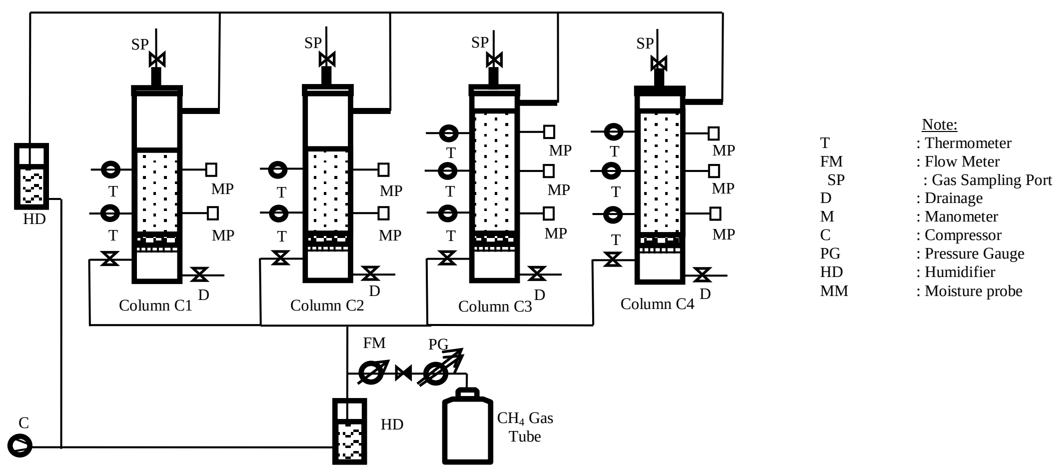

Figure 1. Schematic diagram of the column experimental set up

conductivity means the compost is having many soluble nutrients, which is good for microbial growth. In addition, methanotrophs are rather tolerant to higher conductivity [10].

Total organic carbon (TOC) both compost shows less than seven but loss of ignition (LOI) more than 15. LOI is a parameter that represents organic content in compost. Meanwhile, TOC is also a factor that can substitute of organic content [10]. High value of TOC indicates high biological diversity [11]. The organic carbon provides primary energy source and organic content provides nutrients for the growth of methanotrops bacteria. For that reason, higher organic contents are favorable. Compost that is utilized has organic content more than 15 and expected to support the activity of methanotrops. Furthermore, methane oxidation also will increase in line with high methanotrops activity.

Respiration activity (RA) determined the amount of oxygen per gram dry matter within a certain period in aerobic condition [1]. Low RA indicates high maturity of compost. Based on that fact, both composts can be categorized highly matured due to their low RA value, which are 2.43 and 1.85 mg O_2/DM. This value is much smaller than guiding value by [1], which is approximately <8 mg O_2/gr oDM. Study of [4] shows no significant correlation between basal respiration and methane oxidation rate.

Previous study showed that maturity of compost might have influence in facilitating methane oxidation in landfill biocover as in [4]. It also found that several parameters such as bulk density, organic matter (LOI), TOC, N-total, P-total, and electrical conductivity are having relevant impact on methane oxidation compare with RA [4]. Reference [4] stated that analysis by ANOVA identified bulk density, WHC, electrical conductivity, total nitrogen, and loss of ignition as the main critical factors influencing methane oxidation rate. Nevertheless, those all parameters are interdependent and mutually influence each other. High rate methane oxidation can be achieved by taking into account appropriate parameters that can support methanotrops growth. Therefore, the quality of compost that utilized in this study expected suitable for landfill biocover.

B. *Methane Oxidation Efficiency*

This experiment has conducted over a month under the same indoor temperature that are between (27-29)^{o}C. The methane oxidation means that methane removed from the gas flow and converted into carbon dioxide, water and biomass. The reaction equation can be described as follows [12]:

$$2CH_4 + 3O_2 \rightarrow CO_2 + 3H_2O + biomass. \quad (2)$$

Based on (2), the rate of methane oxidation will be high along with high oxygen availability. Meanwhile, high carbon dioxide produced reduces the occurrence of proliferation of microorganisms, called as biomass in (2) within the compost [12], [13]. The risk of bed clogging inside of the column will be smaller if more carbon dioxide formed than biomass [12], [13].

The rate of methane oxidation efficiencies during experiment calculate by using (1). The results can be seen on Fig. 2 and Fig. 3 below.

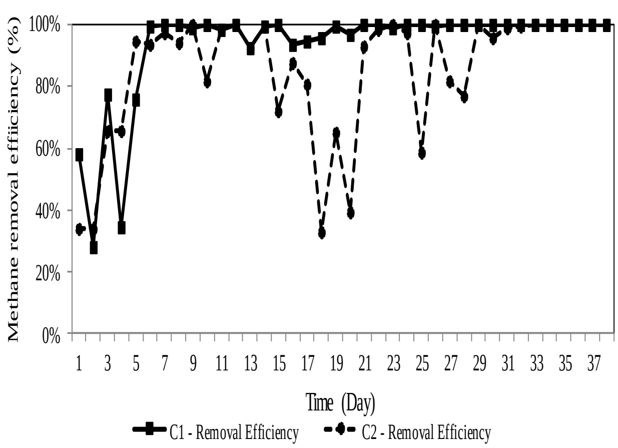

Figure 2. Methane oxidation efficiency on column C1 and C2

Fig. 2 shows that methane removal efficiencies on column C1 increases slowly during the first five days and reaches its stability after day 6. During experiment, column C1 shows well performances that could reach 100% removal efficiency on day 8. Meanwhile, column C2 shows fluctuation of methane removal efficiencies. The fluctuation started at the beginning and continued until day 32. After that, column C2 was stable to remove methane and reached its 100% efficiencies on day 33. Therefore, column C1 considered as having better performance compare with column C2.

Contrary with column C1, column C3 shows more fluctuation and reaches its stability over a month as can be seen on Fig. 3. Even column C3 are having the same source of compost with column C1, it seem could not remove methane as fast as column C1. Its 100% efficiencies achieve on day 12. Meanwhile, column C4 showed a great rebound on third day but it became more stable afterwards. Column C4 reached its 100% removal efficiencies on day 8 and then its efficiencies remain stable. On day 18, rate of removal slightly decreased into 74% but it gradually increases afterwards into 100%.

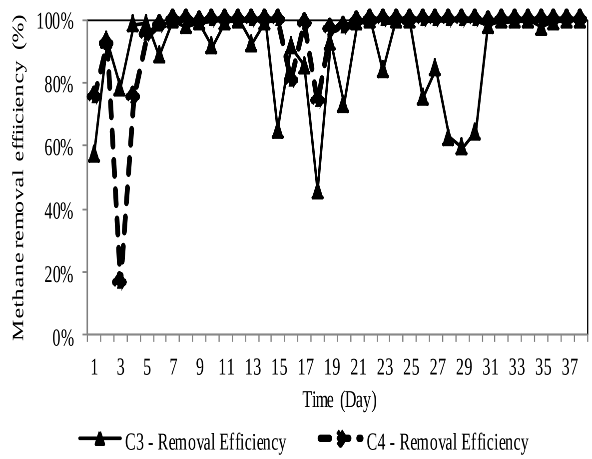

Figure 3. Methane oxidation efficiency on column C3 and C4

Both composts are having different characteristics based on initial lab test, which summarized in Table 1. Therefore, its ability to remove methane also differs. It depends on their ability to support methanotrops growth and provide high oxygen transfer. The availability of oxygen is important as is governed the rate of methane oxidation [13]. Compost from WTU Jl. Jawa has higher pore volume compared with compost from WTU Hangar 4. Therefore, it favored oxygen to transfer into the inner part of biocover. The increasing oxygen concentration, in the range of (3-20) %, will reduce fluctuation of methane conversion rate into less than 10% [13]. On the other hand, a decreased of oxygen concentration from 3% to 1% affects the fall off methane oxidation rate more than 50% as described in [13]. Other research by [2] stated that excess air and higher oxygen concentration lead to exopolymeric substances (EPS) production. EPS associated with methane oxidation and has a potential to make pore clogging and reduced permeability of column medium [14]. During this experiment, EPS is not formed. Reference [2] found that EPS was visible on day 105 in their research. Thereof, this research needs a further investigation to investigate its performance in a long term.

IV. Conclusions

The lab results show that mostly parameters meet with the requirements as in SNI No. 19-7030-2004 and reference values. Bulk density and TOC are having slightly higher value than expected. Meanwhile, electric conductivity is much higher than referred value. On the other hand, all parameters are interdependent and mutually influence each other. High rate methane oxidation can be achieved by taking into account appropriate parameters that can support methanotrophs growth.

It was showed that compost from WTU Jl. Jawa is more efficient to remove methane at the height of 40 cm. Stability of methane removal reaches within six days compare 33 days with compost from WTU Hangar 4. On the other hand, at the media height of 80 cm, compost from WTU Hangar 4 shows better performance compare with compost from WTU Jl. Jawa. Compost from WTU Hangar 4 reaches its stability to reduce methane in 12 days. Meanwhile, compost from WTU Jl. Jawa has an efficiency more fluctuated and needs more than a month to get its stability in removing of methane. Therefore, all these compost can be utilized as biocover material as well as daily biocover or final cap for Cipayung landfill since their methane removal efficiency could reach 100%. Pre-treatment is necessary to improve compost quality before utilizing it as biocover media. However, this research is need a further assessment related of their performance in long term.

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