GAS EMISSIONS INVENTORY OF METHANE (CH4) WITH FIRST ORDER DECAY (FOD) METHOD IN TPA PIYUNGAN, BANTUL, DIY

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GAS EMISSIONS INVENTORY OF METHANE (CH_4) WITH FIRST ORDER DECAY (FOD) METHOD IN TPA PIYUNGAN, BANTUL, DIY

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ABSTRACT: TPA Piyungan is an endpoint landfill disposal of waste that generated from three citizens (Yogyakarta , Sleman and Bantul). The amount volume of waste that goes on everyday and the volume of waste that has been buried in landfill, has huge potential of methane. The purpose of this paper is to inventory emissions of methane (CH_4) in TPA Piyungan with First Order Decay (FOD) method and analyze the alternative utilization technologies of methane (CH_4) in accordance with the conditions of TPA Piyungan. From the results obtained by the First Order Decay (FOD) method, emissions of methane (CH_4) is equal to 6.186 Gg or 6186 tons. The use of alternative methane (CH_4) utilization technologies are such as Landfill Gas (LFG) Flaring, Fuel Cell, and Convert Methane Gas to Methanol. From the three alternative technologies, Landfill Gas (LFG) Flaring is the technology that can be most applied in accordance with the TPA conditions.

KEYWORDS: Methane gas emissions, tpa piyungan, first order decay method, landfill gas (lfg) flaring

1. INTRODUCTION

TPA Piyungan is an endpoint landfill disposal of waste that generated from three citizens (Yogyakarta , Sleman and Bantul), which in a day can receive waste as much as 300 to 400 tons. TPA Piyungan is administered through the SEKBER KARTAMANTUL which facilitates city of Yogyakarta, Sleman and Bantul in coordinating and determining the policy to be taken in the management of waste in the TPA Piyungan. Moreover, the age of TPA Piyungan operations that have expired and the capacity of the waste that has narrowed.

One of waste management agenda in TPA Piyungan is methane (CH_4) gas management activities that has yet to be implemented properly. The amount volume of waste that goes on everyday and the volume of waste that had been buried in landfill has huge potential of methane gas, so we need a technology that can accommodate gas production that can be used either for TPA Piyungan or society around the landfill.

There are two methods for determination emissions of methane (CH_4) from landfill : Mass Balance Method and First Order Decay (FOD) Method. Based on the IPCC 2006 GL, the level of greenhouse gas emissions from the landfill are advised to be calculated using the first order decay (FOD) method, because FOD has more accurate on annual emissions calculation results.

Inventory of methane gas in TPA Piyungan with the FOD method also been done before, but was limited to the amount of potential methane results without any further management. Based on previous research, derived emissions of methane (CH_4) in TPA Piyungan reaches 1,13 Piyungan Gg (gigagram) on 1996 and reached its peak in 2010 of 6,39 Gg then decreased in 2011 with the emission 6,35 Gg. Therefore this paper aims to inventory the methane gas emissions with FOD method based on primary and secondary data in the field

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and proposes an alternative methane utilization technology in accordance with the conditions of TPA Piyungan, so it can be used as a reference for the formulation of policies related to waste management in the future.

2. METHODOLOGY

2.1. CLASSIFICATION OF WASTE COMPONENTS

Waste component is a parameter that indicates the fraction of wet or dry weight of waste components. In this paper, waste components expressed in fractions (percent) wet weight of waste components. Referring to the implementation of the standard waste composition survey, based on the IPCC 2006 GL, classified into 11 components: food waste, garden and park waste, wood, paper and cardboard, textiles, nappies, rubber and leather, plastic, metal, glass (ceramic and pottery) , and others (ash, dust, waste electronics, etc.)

2.2. DETERMINATION OF WASTE COMPOSITION

Determination of waste composition is based on 1m^3 of waste samples that represent the entire composition of waste dumped in TPA. Waste composition is determined on the weighing sample components which sorted from 1 m^3 of waste samples. This method refers to the IPCC 2006 GL.

2.3. IMPLEMENTATION OF WASTE SAMPLING

Waste sampling was conducted for 8 consecutive days beginning on Tuesday, April 8, 2014 until Tuesday, April 15, 2014 at 09.00 until 12.00 pm (rush hour operations in TPA Piyungan).

2.4. DETERMINATION OF THE DRY MATTER CONTENT

- Sampling Methods

  Samples were taken for determination of dry matter is samples that used in the determination of waste composition. Base the determination of dry matter content is per type of waste component where not all components have water content. Based on the IPCC 2006 GL, the determination of the dry matter content just applied for waste components that contribute to the formation of methane gas.

  Weight of samples for determination of dry matter content of a waste component is ± 5 kg samples were taken from the determination of waste composition by weight reduction of the sample. Reduction of the sample weight for each waste component is done with a 'quartering' procedures, such as those in Figure 1 below:

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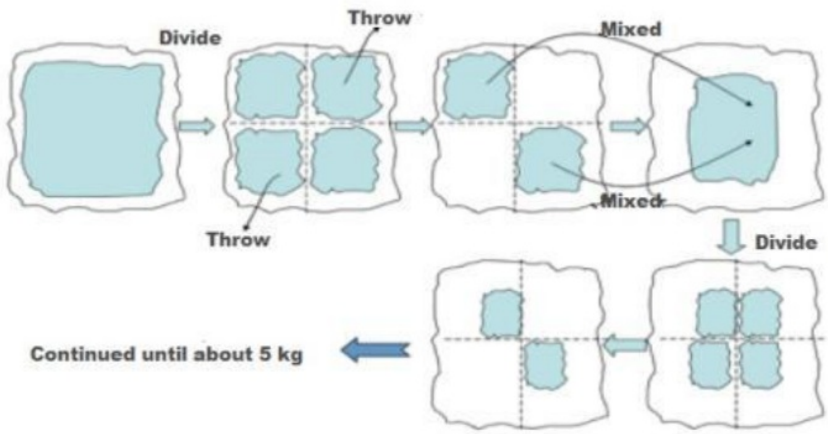

Figure 1. Quartering procedures in sample weight reduction

- Dry Matter Content Determination Method

Determination of dry matter content (dry matter content) is done with a gravimetric approach, that is through the weighing of a representative sample.

- The water content in waste component is calculated by the equation :

$$\textbf{\% water content} = (B - C) / (B - A) \times 100\ \% \qquad (1)$$

Explanation :
A : Weight empty tray
B : Weight tray containing sample
C : Weight tray containing sample which has been dried for 2 hours and cooled for ± 15 minutes in a desiccator

- The dry matter content in waste component is calculated by the equation :

$$\textbf{dry matter content} = (100\ \% - \%\ \text{water content}) \qquad (2)$$

3. DATA ANALYSIS

The data obtained will be analyzed using the First Order Decay (FOD). The phases in the processing of FOD method is as follows:

- Calculation of DDOCm

At first order reaction, the amount of product is proportional to the amount of material that reacts. In the degradation process of waste organic material in the landfill, CH_4 formation reaction rate is proportional to the rate of reduction of mass organic carbon decomposes in anaerobic conditions (DDOCm). That means, the year in which the waste deposited / piled in a landfill is not relevant to the amount of CH_4 formed each year as there are only a total mass of material that decomposes in the landfill.

When the amount of material that decomposes in the landfill in the first year is known, then every year the number could be considered as the first year on the method of estimation of CH_4 formation. The calculation of the basic order can be done using two simple equations by

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decomposition reactions begin to occur on January 1 in the year after the deposition of waste.

FOD Simple Spreadsheet Model (using the Template or Software IPCC 2006)

To estimate CH_4 emissions from all landfills in the country / region, the emissions of waste dumped in landfill each year is modeled as a separate row in the spreadsheet. In the IPCC Waste Model, the formation of CH_4 is calculated separately for each year of waste disposal, and the total CH_4 formed is obtained by summing CH_4 formed at the end of each year.

- Calculation of DDOCm deposited on year T, Gg

Data input of dumped waste in landfill into a spreadsheet can be bulk data or based on composition. On the basis of composition, waste is separated into paper, cardboard, food, etc. (11 components). DOCf parameter is the fraction of the real DOCm degraded in landfill sites. DOCm decomposition process (DDOCm) entering the landfill is calculated with the following equation:

$$DDOCm = W \times DOC \times DOCf \times MCF \quad (3)$$

Explanation:

W	=	Amount deposited (Gg)
DOC	=	Degradable organic carbon
DOCf	=	Fraction of DOC decomposing under anaerobic conditions
MCF	=	Methane correction factor (based on the IPCC 2006 GL, TPA in Indonesia is categorized unmanaged - deep (>5m waste) and/or high water table by the value of MCF = 0,8) (IPCC, 2006)

- Calculation of DDOCm rem, DDOCm dec, DDOCm a, and DDOCm decomp

The method of calculating CH_4 emissions from landfill which has been described previously using the assumption that the anaerobic decomposition from DDOCm to CH_4 be starting to happen January 1 in the year after the waste accumulation (with an average delay of 6 months before the decomposition reaction starts). If anaerobic decomposition occurs earlier, that is in the year of accumulation, separate calculations must be made to the accumulation. DDOCm can be calculated with the following equation:

- Calculation of DDOCm rem

  Decomposable DOC (DDOCm rem) Not Reacted is mass of deposited DDOCm which not decomposed at the end of the year of sampling (2014). The calculation DDOCm rem are as follows:

$$DDOCm\ rem = DDOCm \times exp2 \quad (4)$$

Explanation :

DDOCm	= Mass of organic components in the waste that degraded and decomposed (Gg)
k	= Rate of reaction constants
M	= Month of reaction starts (= delay time +7)
exp2	= $exp^{[(-k\ (13-M))/12]}$ (IPCC, 2006)

- Calculation of DDOCm dec

  Decomposable DOC (DDOCm dec) decomposed is mass of deposited DDOCm which decomposes in the year of sampling (2014). The calculation DDOCm dec are as follows:

$$DDOCm\ dec = DDOCm\ rem \times (1 - exp2) \quad (5)$$

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Explanation :

DDOCm rem = Mass of deposited DDOCm which not decomposed at the end of the year (Gg)

exp2 = $exp^{[(-k (13-M))/12]}$ (IPCC, 2006)

- Calculation of DDOCm a

  Decomposable DOC (DDOCm a) Accumulated in SWDS End of Year is mass of accumulated DDOCm in the landfill at the end of the year of sampling (2014). The calculation DDOCm a are as follows:

$$\text{DDOCm a} = \text{DDOCm rem} + [\ \text{DDOCm a (T-1)} \times \text{exp1}] \quad (6)$$

Explanation :

DDOCm rem = Mass of deposited DDOCm which not decomposed at the end of the year (Gg)

DDOCm a (T-1) = Mass of accumulated DDOCm in the landfill in the previous year

k = Rate of reaction constants

exp1 = $exp^{[-k]}$ (IPCC, 2006)

- Calculation of DDOCm decomp

  Decomposable DOC (DDOCm decomp) decomposed is mass of DDOCm in the landfill decomposes in the year of sampling (2014). The DDOCm decomp calculation is as follows:

$$\text{DDOCm decomp} = \text{DDOCm dec} + [\text{DDOCm a (T-1)}] \times (1- \text{exp1}) \quad (7)$$

Explanation :

DDOCm dec = mass of deposited DDOCm which decomposes in the deposit year (2014)

DDOCm a (T-1) = Mass of accumulated DDOCm in the landfill in the previous year`

k = Rate of reaction constants

exp1 = $exp^{[-k]}$ (IPCC, 2006)

- Calculation of Methane (CH_4) Generated from TPA

Methane generated is mass formed of methane in the year of sampling (2014) decomposition of organic components stored in the waste. The calculation of CH_4 generated is as follows :

$$CH_4 \text{ generated} = \text{DDOCm decomp} \times (16/12) \times F \quad (8)$$

Where :

DDOCm decomp (2014) = Mass of DDOCm in the landfill decomposes in the year of sampling

(16/12) = Molecular weight ratio of CH_4 / C

F = Fraction of CH4 by volume in generated landfill gas (0,5) (IPCC, 2006)

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4. RESULTS AND DISCUSSION

4.1. DETERMINATION WEIGHT OF WET WASTE IN TPA PIYUNGAN

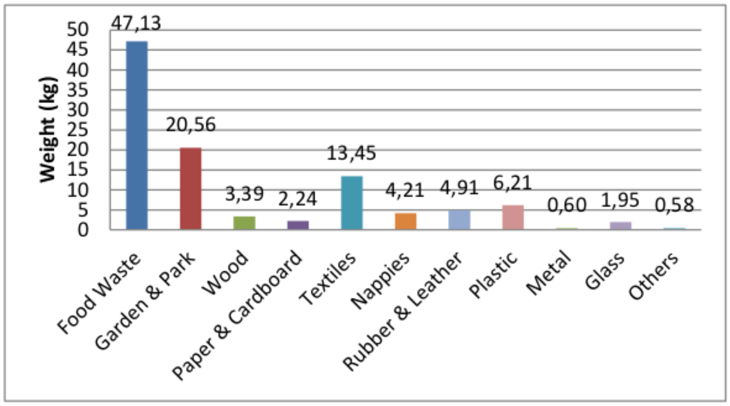

Figure 2. Wet weight per composition (kg)

It can be seen from Figure 2 above, earned the biggest weight of wet waste is derived from food waste which is equal to 47.13 kg equal to 44.82% wet weight. This suggests that the characteristics of the waste that went into TPA Piyungan everyday dominated by food waste so that the results of the weighing of wet waste, food waste is the most severe among other components.

4.2. CALCULATION OF DOC (DEGRADABLE ORGANIC COMPOUND)

DOC (Degradable Organic Compound) is one of the waste characteristics that determine the emission rate amount of formation methane gas. The calculation results are shown in Figure 3 below :

Table 1. The results of the calculation of DOC components trash

No.	Components	Wet Weight (%)	Dry Matter Content (%)	DOC i (% dry matter)	DOC
		A	B	C	D = A x B x C
1	Food waste	44,82	56,93	38	0,097
2	Garden & Park	19,59	70,56	49	0,068
3	Wood	3,24	40,45	50	0,007
4	Rubber & Leather	2,08	53,80	44	0,005
5	Textiles	12,72	51,55	30	0,020
6	Nappies	3,99	32,74	60	0,008

The result from Table 1 above, the highest DOC result is food waste component that is equal to 0.097. This suggests that food waste is a component that became the greatest contributor for the rate formation of methane emissions among other components.

4.3. CALCULATION ANALYSIS OF METHANE GAS EMISSIONS USING FIRST ORDER DECAY (FOD) METHOD

Based on the calculation of methane emissions with first order decay method, the results of CH_4 Generated are shown in Table 2 below :

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Table 2. Total emissions of methane

No.	Waste Components	CH_4 Generated	
		Gg	Ton
1	Food waste	4	4000
2	Garden & Park	2	2000
3	Wood	0,054	54
4	Rubber & Leather	0,053	53
5	Textiles	0,045	45
6	Nappies	0,034	34
	Total	6,186	6186

Table 2 shows the total CH_4 Generated by 6.186 Gg is equal to 6186 tons. From these results, it can be seen from the six waste components, food waste is the largest contributor to emissions of methane which is equal to 4 Gg or 4000 tons. This is consistent with the composition of waste that goes to TPA Piyungan which are mostly derived from food waste.

From previous research, decreased methane emissions in 2011 is equal to 6.35 Gg. The results of methane emissions that researchers gain is decreased from 2011 that is equal to 6.186 Gg. This is due to a decreasing the volume of waste that goes to TPA Piyungan since 2009. Indications decrease the volume of waste is evidenced by the many people who have succeeded in carrying out the management of organic waste by using communal composter. Waste management based on data from previous research, indicate that the number of composting reach until 0.3% in 2011.

4.4. SCALE ASSESSMENT OF ALTERNATIVE METHANE (CH_4) GAS UTILIZATION TECHNOLOGY

Scale assessment that used for the selection of alternative technology is ranking procedure method, where there are several factors that serve as parameters along with the scale in units of numbers. The assessment of these parameters can be seen in the Table 3 below :

Table 3. Scale assessment of alternative methane gas utilization technologies

No.	Aspect	Parameters	Scale*	Alternative Tecnologies		
				LFG	Fuel Cell	Methanol Conversion
1	Technical	▪ The installation compatibility with the environment conditions in TPA	10	8	6	7
		▪ The installation compatibility with the climatic conditions in TPA	5	5	5	5
		▪ The installation compatibility with the geographical conditions (region)	5	5	5	5
		▪ Availability of supporting infrastructures	6	6	4	6
		▪ Capability of human resources for operational technology	8	7	6	6
		▪ Health and Safety	9	8	8	8
2	Potential Utilization	▪ Potential absorptivity for the community around the landfill	6	3	4	4
		▪ Potential absorptivity for the landfill operations	5	5	5	5
		▪ The level of energy efficiency	3	3	2	3
		▪ Environmentally friendly	4	3	4	4

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3	Economic **	▪ Investment cost	10	8	5	4
		▪ Operational dan maintenance	8	6	4	4
		▪ Payback duration	7	4	3	3

*) The scale value is 1-10, where the larger the number, the greater the importance of these parameters.
**) For the economic aspect (alternative technologies column), the smaller the number shows the more expensive its cost.

Having conducted an assessment of each alternative technology, the next step is to calculate the total value of each technology. Technology with the largest total value indicates that the technology is the most possible to be applied. The total value is multiply the scale of each parameter with the scale of each technology. Calculation of the total value can be seen in Table 4 below :

Table 4. The total value of alternative methane gas utilization technologies

Aspect	Scale / Paramaeters	Alternative Tecnologies		
		LFG	Fuel Cell	Methanol Conversion
Technical	▪ The installation compatibility with the environment conditions in TPA	80	60	70
	▪ The installation compatibility with the climatic conditions in TPA	25	25	25
	▪ The installation compatibility with the geographical conditions (region)	25	25	25
	▪ Availability of supporting infrastructures	36	24	36
	▪ Capability of human resources for operational technology	56	48	48
	▪ Health and Safety	72	72	72
Potential Utilization	▪ Potential absorptivity for the community around the landfill	18	24	24
	▪ Potential absorptivity for the landfill operations	25	25	25
	▪ The level of energy efficiency	9	6	9
	▪ Environmentally friendly	12	16	16
Economic **	▪ Investment cost	80	50	40
	▪ Operational dan maintenance	48	32	32
	▪ Payback duration	28	21	21
	The Total Value	**514**	**428**	**443**

From the Table 4 calculation results, can be obtained the highest total value of alternative technologies is Landfill Gas (LFG) Flaring with 514. This suggests that landfill gas (LFG) flaring is the technology that can be most applied in accordance with the TPA Piyungan conditions compared to the fuel cell and the methanol conversion. Also required to consider the assessment of the social and political aspects that influence the decisions of technology selection. In this paper, social and political aspects are not discussed in detail (more into the technical, the potential utilization and the economic aspects) of each alternative technology.

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5. CONCLUSIONS AND RECOMMENDATIONS

5.1. CONCLUSIONS

Based on the research that has been conducted, was determined as follows:

1. Based on a waste sampling in TPA Piyungan, can be obtained by the composition of the waste wet weight (kg) and (%). From these data, the composition of the waste that has the greatest wet weight is food waste that is equal to 47,13 kg equal to 44,82% wet weight. This suggests that the characteristics of the waste that went into TPA Piyungan everyday dominated by food waste.
2. DOC calculations from each waste component can be obtained after analyzing the dry matter content. Based on these calculations, food waste is a component with the largest DOC value is 0,097. This suggests that food waste is a component that became the greatest contributor for the rate formation of methane emissions among other components.
3. From the analysis of methane (CH_4) emissions calculation using the first order decay (FOD) method, can be obtained the total emissions of methane (CH_4 generated) is 6,186 Gg or 6186 tons.
4. Decreasing of methane (CH_4) emissions since 2011 due to the decrease in the volume of waste that goes to TPA Piyungan since 2009. Indications decrease the volume of waste is evidenced by the many people who have succeeded in carrying out the management of organic waste by using communal composter.
5. According to the calculation results of the scale assessment, it can be concluded that the Landfill Gas (LFG) Flaring is a technology that can be most applied in accordance with the TPA Piyungan conditions.

5.2. RECOMMENDATIONS

1. Necessary infrastructure in the form of a layer or geomembrane landfill cover that aims to support the Landfill Gas (LFG) Flaring technology.
2. Supervise required to sterile the location of landfill from scavengers and all forms of activity that is not in accordance with the operational procedures of Landfill Gas (LFG) Flaring technology.
3. Central and local governments should provide clear regulations and procedures related to the procurement of installation and operation of Landfill Gas (LFG) Flaring technology.

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