Estimation of Methane Emissions in a Landfill using Pole Method

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From the previous study, a chamber method was used in measuring methane emission. However, these methods have some disadvantages: the time needed to measure emissions at entire landfill site; there is a big chance that hot-spots of methane emissions are missed, resulting in an underestimation of emissions; and scattered "hot-spots" which have extremely high emission intensity.

In this paper, we proposed a latter method, named pole method. Pole method is a scanning surface method with LMD (Laser Methane Detector) mounted between two poles to measure ambient methane concentration in a landfill. Our aim was to estimate methane missions in a landfill with the pole method, since it could cover spatial distribution and variability of ambient methane concentration, allowing measurement across an area of 400 m^2 in only 20 min, in contrast to the much slower chamber method.

We have discovered that methane flux from chamber method and ambient methane concentrations from pole method has a correlation, a moderately positive correlation with $r^2 = 0.6126$. Methane emission in a landfill was estimated from this correlation and compared its result with the methane emission from chamber method and with IPCC default method, and the results are: 33.4 Gg/yr, 8.61 Gg/yr, and 15.72 Gg/yr, respectively. These results show that methane emission from pole method is higher than other estimation, and we can conclude that pole emission can be used for estimate methane emission in a landfill site.

Key Words: *methane emission, pole method, methane flux, ambient methane concentration*

1. INTRODUCTION

One of the most serious environmental problems associated with the landfilling of municipal waste is emission of methane. Methane is an effective greenhouse gas with a Global Warming Potential (GWP) 23 times as high as that of carbon dioxide in a 100-year time horizon. More than 10% originates from landfill of the global anthropogenic methane emission [1) 2)].

In practice, the only way to obtain landfill-level information on the landfill gas (LFG) effluxes and, for example, on the gas recovery efficiency is to measure the emission directly. However, direct measurements are scarce, which is at least partly explained by the problems in the LFG measurement methodologies [3)].

Several methods are used to measure landfill methane emissions. The flux chamber method is most commonly used to quantify methane fluxes from landfill cover soil [4) 5) 6)]. Static flux chambers are relatively inexpensive, simple to set up and operate, and highly sensitive. However, they can be deployed for only short periods without disturbing the measured surface, so no flux measurements are available between chamber deployments [6) 7) 8)]. The high spatial variability of emissions necessitates a large number of chamber measurements to quantify whole-site emissions, making the flux chamber approach time consuming and labour intensive. Further, specific geostatistical techniques must be applied to flux chamber results for accurate determination of whole-landfill emissions [8) 9)]. For these reasons, chamber measurements are not well suited to whole-site assessments, but certainly can be valuable for localized studies. Point measurement

of subsurface gas concentrations and of pressure gradients with calculation of diffusive and pressure-driven flux face similar problems due to high spatial variability [5) 9)].

Instead, we proposed a latter method, named pole method, in measuring ambient methane concentrations in a landfill. Pole method is a scanning surface method with Laser Methane Detector (LMD) mounted between two poles to measure ambient methane concentration. Our aim was to estimate methane emissions in a landfill with the pole method, since it could cover spatial distribution and variability of ambient methane concentration. The pole method uses an LMD with a data logger mounted on a wire drawn between two poles, allowing measurement across an area of 400 m^2 in only 20 min, in contrast to the much slower chamber method.

We have discovered that methane flux from chamber method and ambient methane concentrations from pole method has a correlation, a moderately positive correlation with r^2 = 0.6126. Simple linear regression was used in representing relationship between methane flux and ambient methane concentration because there was only one explanatory (independent or predictor) variable. Methane emission in a landfill was estimated from this relationship and compared its result with the methane emission from chamber method and with IPCC default method.

2. INVESTIGATION AREA

We carried out the investigation in Tamangapa Landfill, Makassar City, South-Sulawesi Province, Indonesia. The landfill of Tamangapa was established in 1993 situated on the incline of an escarpment, this landfill is open dump disposal site. This landfill has an allocation 14.3 hectares of land with depths ranging from approximately 4 to 20 meters, make a steep slope in this landfill (>45°). Since its opening, an estimated 1.240.000 tonne of MSW has been disposed of to this landfill with a current waste volume of approximately 1.800.000 m^3 [10)].

This landfill has nine zones: zone A (1.779 ha), B (2.242 ha), C_1 (1.112 ha), C_2 (0.502 ha), C_3, D (2.665 ha), E_1 (1.915 ha), E_2 (2.115 ha), and F (0.950 ha). The investigation was carried out only in five zones (B, C_1, C_2, E_2, and F), because the remains zones already closed.

Makassar city's residential population in 2012 was approximately 1.612.413 people [11)]. The city, like many others in Indonesia, suffers from inability to cope with waste generation and disposal. Municipal solid waste (MSW) generation is estimated at around 500 tonne / day in 2012 [12)].

Fig.1. Satellite Image of Tamangapa Landfill

3. METHODOLOGY

We carried out two methods in this investigation, chamber method to measure methane flux and pole method to measure ambient methane concentration in Tamangapa landfill. Then, we compared these results with methane emission from IPCC Default Method.

(1) Measurement of methane flux by chamber method

We measured methane flux by the chamber method, using the LMD mounted on a small chamber (Fig. 2). We measured the flux in the 20-m × 20-m quadrat (16 cells). The flux methane in each cell was measured once for 5 min.

We converted methane concentration (ppm) as measured by LMD in the chamber to methane flux (g m^{-2} h^{-1}) according to the following equation:

$$F = \rho \times \frac{V}{A} \times \frac{\Delta C}{\Delta t} \times \frac{273}{(273+T)} \times 10^{-6} \times 3600 \quad (1)$$

with F is methane flux [g m^{-2} h^{-1}]; ρ is gas density [g m^{-3}], for methane = 714 g m^{-3}, V is volume of chamber [m^3]; A is area of chamber base [m^2]; $\Delta C/\Delta t$ is slope of change in methane concentration [ppm] over time [h]; T is average of temperature in chamber [°C].

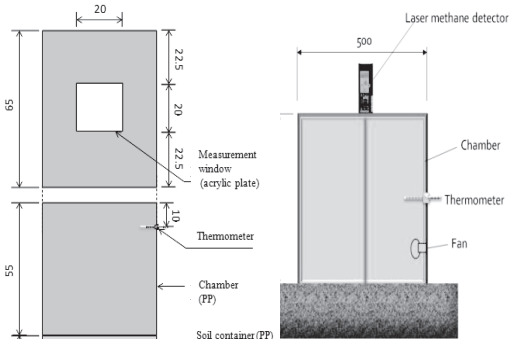

Fig.2. Chamber dimensions and methane flux measurement

(2) Measurement of ambient methane concentrations by pole method

The pole method uses an LMD with a data logger mounted on a wire strung between two poles (Fig. 3).

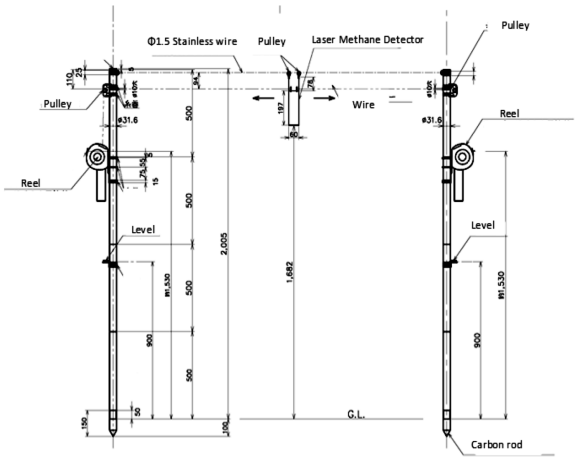

Fig.3. Scheme of pole

Fig. 4. Measurement of ambient methane concentration by pole method.

The poles were placed initially at two corners of the quadrat in a north–south orientation. The wire between the poles was held taut by two people, who drew the LMD alternately towards themselves with a reel that each held (Fig.4). The LMD was held at about 1.7 m above the surface. The data logger recorded the ambient methane concentration every 0.1 s. The poles were then moved 1 m across and the measurement was repeated. It took about 20 min to cover the entire quadrat.

These contours (Fig.5) are the results from pole method which show the high variation of spatial distribution of ambient methane concentration.

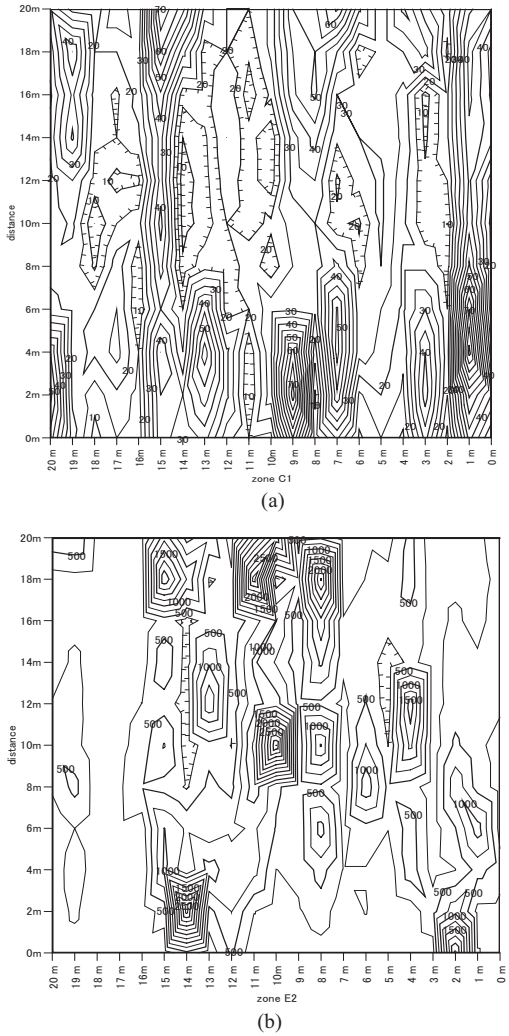

Fig. 5. Contours of ambient methane concentration from pole method investigation at zone C_1 (a) and zone E_2 (b).

(3). IPCC Default Method to estimate methane emission in a landfill

The default methodology from IPCC is a mass balance approach that involves estimating the degradable organic carbon (DOC) content of the solid waste. i.e., the organic carbon that is accessible to biochemical decomposition, and using this estimate to calculate the amount of methane that can be generated by the waste [13].

The default methodology allows for the calculation of methane emission based on [14]:

a) The amount of waste deposited in the different categories of solid waste disposal sites
b) The fraction of degradable organic carbon and the amount which actually degrades
c) The fraction of methane in landfill gas

The determination of annual methane emissions for each country or region can be calculated from this equation (Eq.2):

$$ME = \left(MSW_T \times MSW_F \times MCF \times DOC \times DOC_F \times F \times \frac{16}{12} - R\right) \times (1 - OX)$$

Where :
ME = Methane Emission (Gg/yr)
MSW_T = total MSW generated (Gg/yr)
MSW_F = fraction of MSW disposed to solid waste disposal sites
MCF = methane correction factor (fraction)
DOC = degradable organic carbon (fraction)
DOC_F = fraction DOC dissimilated
F = fraction of methane in landfill gas
16/12 = conversion of Carbon to Methane
R = recovered methane (Gg/yr)
OX = oxidation factor (fraction)

The IPCC Guidelines introduce various specific default values and recommendation, particularly for use in countries with lack of solid waste statistics. In most developing countries there is no gas extraction and recovery; hence the only figure needed in the calculation is the number of inhabitants in the country, with clear focus on the urban population [13) 14)].

4. RESULT AND DISCUSSION

From data processing by using Excel®, we have found that the ambient methane concentration and methane flux has a correlation, a moderately positive correlation with $r^2 = 0.6126$ (Fig.5).

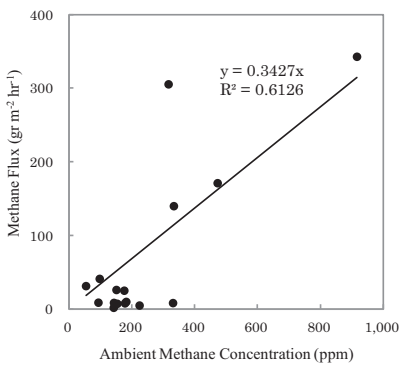

Fig.5. Relationship between ambient methane concentration and methane flux.

This moderately correlation due to differences in the way they measure the methane flux and ambient methane concentration. Chamber method is an investigation of point method (point by point), whereas the pole method is a scanning surface method in a landfill. However, methane emission can be estimated from this correlation.

(1) Estimation of methane emission in Tamangapa landfill from correlation between ambient methane concentration (pole method) and methane flux (chamber method)

Simple linear regression was used in determine the correlation between ambient methane concentration (pole method) and methane flux (chamber method), with this equation:

$$y = 0.3427\ x \qquad (3)$$

From Eq.3., we can calculate the average of methane flux in each zone subsequently calculate the estimated methane emission with multiply the average of methane flux with the area of each zone, Table 1.

Table 1. Estimation of methane emission from correlation between pole and chamber method

Name of zone	Average of methane flux ($g\ m^{-2}\ h^{-1}$)	Area (m^2)	Estimation of methane emission ($g\ h^{-1}$)
B	1.62	22420	3.62×10^4
C_1	9.34	11120	1.04×10^5
C_2	23.33	5020	1.17×10^5
E_2	158.65	21150	3.36×10^6
F	21.55	9500	2.05×10^5
Total of methane emission			3.82×10^6
Total of methane emission in Gg/yr = 33.4 Gg/yr			

(2) Estimation of methane emission in Tamangapa landfill from methane flux (chamber method) investigation

Methane emission estimation was derived from multiplication the average of methane flux with the area of each zone, Table 2.

Table 2. Estimation of methane emission from methane flux (chamber method) investigation

Name of zone	Average of methane flux ($g\ m^{-2}\ h^{-1}$)	Area (m^2)	Estimation of methane emission ($g\ h^{-1}$)
B	2.15	22420	4.81×10^4
C_1	8.06	11120	8.96×10^4
C_2	8.64	5020	4.34×10^4
E_2	34.72	21150	7.43×10^5
F	6.13	9500	5.83×10^5
Total of methane emission			9.83×10^5
Total of methane emission in Gg/yr = 8.61 Gg/yr			

(3) Estimation of methane emission in Tamangapa landfill from IPCC Default Method

IPCC default method (Eq.2.) gave a result of total methane emission in a year (2013) in Tamangapa landfill = 15.72 Gg/yr (Table 3). This result was obtained by using the spreadsheets from UNFCCC non-Annex I Greenhouse Gas Inventory Software [15].

MSW_T x MSW_F = 300.15 (Table 3) was derived from total residential population in Makassar City, population whose waste goes to solid waste disposal sites (landfill), multiply by MSW disposal rate to solid waste disposal sites (default value from IPCC, 1996).

Estimation of methane emission from correlation between chamber and pole method is the highest result of methane emission, followed by estimation from IPCC default method and from methane flux investigation, Table 4. These results show that pole method can be used to estimate methane emission in a landfill.

Table 3. Estimation of methane emission from IPCC Default Method

Parameter	Value	Note
MSW_T (Gg/Yr)	300.15	Calculated
MSW_F (-)		
MCF (-)	0.6	Default value from IPCC, 1996 [14]
DOC (-)	0.17	Default value from IPCC, 1996 [14]
DOC_F (-)	0.77	Default value from IPCC, 2006 [13]
F (-)	0.5	Default value from IPCC, 2006 [13]
R (-)	-	No data for Indonesia
OX (-)	0	Default value from IPCC, 2006 [13]
Methane Emission (Gg/yr)	**15.72**	Calculated

Table 4. Recapitulation of Methane Emission Estimation

Method of Estimation	Methane Emission (Gg/yr)
Methane emission estimation from correlation between chamber and pole method	33.4
Methane emission estimation from methane flux investigation	8.61
Methane emission estimation from IPCC Default Method	15.72

5. CONCLUSION

1). Pole method is a scanning surface method whereas chamber method is a point method in measuring methane emission in a landfill. The advantages of pole method are: easy to use, fast, effective and efficient, can save much time, could cover wide area, and there is a small chance that hot spots of methane emission are missed.

2). The positive correlation between pole and chamber method shows that pole method can be used to estimate methane emission in a landfill.

3). Methane emission estimation from correlation between pole and chamber method has a highest value (33.4 Gg/yr) than estimation from methane flux (chamber method) investigation (8.61 Gg/yr) and IPCC default method (15.72 Gg/yr). These results show that estimation of methane emission from pole method could capture many hot spots in the landfill surface because of its scanning.

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(Received July 19, 2013)