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Application of portable gas detector in point and scanning method to estimate spatial distribution of methane emission in landfill

Asiyanthi Tabran Lando [a,c,*], Hirofumi Nakayama [b], Takayuki Shimaoka [b]

[a] Department of Urban and Environmental Engineering, Graduate School of Engineering, Kyushu University, 744 Motooka, Nishi-ku, Fukuoka 819-0395, Japan
[b] Department of Urban and Environmental Engineering, Faculty of Engineering, Kyushu University, 744 Motooka, Nishi-ku, Fukuoka 819-0395, Japan
[c] Department of Civil and Environmental Engineering, Faculty of Engineering, Hasanuddin University, Jl. Poros Malino Km.6 Gowa, 92172 South Sulawesi, Indonesia

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ABSTRACT

Methane from landfills contributes to global warming and can pose an explosion hazard. To minimize these effects emissions must be monitored. This study proposed application of portable gas detector (PGD) in point and scanning measurements to estimate spatial distribution of methane emissions in landfills. The aims of this study were to discover the advantages and disadvantages of point and scanning methods in measuring methane concentrations, discover spatial distribution of methane emissions, cognize the correlation between ambient methane concentration and methane flux, and estimate methane flux and emissions in landfills. This study was carried out in Tamangapa landfill, Makassar city-Indonesia. Measurement areas were divided into basic and expanded area. In the point method, PGD was held one meter above the landfill surface, whereas scanning method used a PGD with a data logger mounted on a wire drawn between two poles. Point method was efficient in time, only needed one person and eight minutes in measuring 400 m^2 areas, whereas scanning method could capture a lot of hot spots location and needed 20 min. The results from basic area showed that ambient methane concentration and flux had a significant ($p < 0.01$) positive correlation with $R^2 = 0.7109$ and $y = 0.1544$ x. This correlation equation was used to describe spatial distribution of methane emissions in the expanded area by using Kriging method. The average of estimated flux from scanning method was 71.2 $g\ m^{-2}\ d^{-1}$ higher than 38.3 $g\ m^{-2}\ d^{-1}$ from point method. Further, scanning method could capture the lower and higher value, which could be useful to evaluate and estimate the possible effects of the uncontrolled emissions in landfill.

1. Introduction

One of the biggest parts of the anthropogenic source of emissions comes from landfills. Landfill sites produced landfill gas (LFG) which containing with decomposable organic waste. The major components of LFG are methane and carbon dioxide, which are by products of the biological decomposition of organic material. Despite methane component of LFG is a potential energy resource, it has a potential to create explosion hazard, and is accepted as a greenhouse gas (GHG) contributing to global warming (Conestoga-Rovers, 2010). Emissions show large spatial variation due to the biogenic origin of these emissions and inhomogeneous characteristics of landfills and their cover soil. Therefore, development of efficient and cost-effective methods for measurements of these emissions is an important assignment and a challenge to the scientific community (Galle et al., 2001).

In developing countries, the acceleration of national development has produced not only the prosperity but also an environmental impact of municipal solid waste (MSW) management and industrial waste treatment. Indonesia, as a representation of developing country, has a common problem in terms of disposal facility that the operated landfill for refuse disposal is open dumping system and only a few is controlled landfill system. All of the existing open dumping landfill systems, the gaseous collection and recovery facilities are not provided. The generated landfill gas (biogas) contains mostly methane and carbon dioxide as a result of biodegradation process of organic matter in landfill, which has not been recovered or even measured (Kardono and Purwanta, 2007).

Conducting the field measurements of methane emissions at landfills is a challenging task. Landfills can spread over tens to hundreds of acres and surface area emissions vary substantially due to differences in topography, type of waste disposed, types, extent,

* Corresponding author at: Department of Civil and Environmental Engineering, Faculty of Engineering, Hasanuddin University, Jl. Poros Malino Km.6 Gowa, 92172 South Sulawesi, Indonesia. Tel.: +62-411-581585, +62-81243633179.

E-mail addresses: lando-a@doc.kyushu-u.ac.jp, asiyanthi@gmail.com (A.T. Lando).

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and condition of cover systems (daily, intermediate, final), and the in-place LFG management systems, if any. From a regulatory perspective, landfills are considered an "area" source (versus point source) where emissions vary spatial and temporally (Jeremy, 2012).

The main difficulty in measuring methane emission from landfills is the spatial variability of emissions, in combination with the sheer size of a modern landfill. Various researchers have reported the spatial variability of methane emissions. Several researchers illustrated the high spatial variation in emissions, caused by the high heterogeneity of waste. Emissions at one spot can be 1000 fold of emissions from a spot a located a few meters away (Oonk, 2010). According to Czepiel et al. (1996) there is no correlation between emission at a spot at the landfill and the emission six meters away. They estimate that 50% of emissions are released at 5% of the landfill surface; Bergamaschi et al. (1998) estimate that 70% of methane emissions are released through short cuts. Nozhevnikova et al., 1993, gives a typical distribution of distributions of methane emissions at a landfill and similar patterns, but similar distribution are reported by Oonk (2010) and Mackie and Cooper (2009). Rachor et al. (2009) studied variation in emissions within the square meter and even at this small scale emissions proved to be highly heterogeneous.

Therefore, point and scanning method are proposed to estimate methane emissions in a landfill by using portable gas detector (PGD). This gas detector was named Laser Methane Detector (LMD) and manufactured by Tokyo Gas Engineering Co., Ltd., Japan. The measurement principle of this PGD relies on the characteristics of methane gas, which absorbs the laser beam (infrared rays) of specific wavelength. The laser beam directed at targets/reflectors such as gas piping, ceiling etc. will reflect back a diffused beam from the target. This device will receive the reflected beam and will measure the absorption of the beam, which will then be calculated into column density (ppm-m), concentration (ppm) multiplied by the thickness (m) of laser beam from PGD to the targets. (Source: TGE's website). Therefore, methane concentration could be derived by divided column density with measurement height (m). The specification of this PGD is shown in Table 1.

Lab scale study was carried out to evolve and examine the PGD in estimating methane emissions prior to measure ambient methane concentrations in landfill by point and scanning methods. These methods measured ambient methane concentrations then combined with methane flux to estimate methane emissions by correlation equation. The objectives in this study are to discover the advantage and disadvantage of point and scanning method in measuring methane concentrations, to discover spatial distribution of methane emissions, to cognize the correlation between ambient methane concentration and methane flux, and to estimate methane flux and emissions in landfills.

Table 1
Specification of the laser methane detector.

Items	Specification
Target gas	Methane (CH_4) and methane-containing gas
Detection limits	1–50,000 ppm m
Measuring speed	0.1 s
Accuracy of detection	±10%
Detection distance	0.5–30 m (0.5–100 m using an optional reflect sheet)
Dimensions	0.07 (W) × 0.179 (D) × 0.042 (H) m
Calibration	Self calibrating with integrated reference cell
Operating temperature	−10 °C to 50 °C
Application	Indoor and outdoors under strong sunshine
Connection	Bluetooth and Internet Access (Android)
Area of use	Non-explosion proof area

Source: Tokyo Gas Engineering Co., Ltd.

2. Material and methods

2.1. Application of portable gas detector to estimate methane emissions in lab scale study

This study was undertaken in the lab room to prevent outside interference. The model of landfill was made from box tub with square base size $75 \times 55\,cm^2$ at height of 30 cm (Fig. 1). The box tub was filled by soil which had same properties with the landfill surface. The soil has similar type with cover soil in Indonesian landfill. The density and porosity of this soil were $0.713\,g\,cm^{-3}$ and 0.32, respectively. Further, methane source was derived from methane tank which was connected with the flow meter. The methane tank as methane supplier in this study contains 100% methane gas. A flexible plastic tube was placed on the base of tub with spiral shaped. This plastic tube was connected with plastic tube from methane tank and flow meter. Previously, the tube, which was placed in base of tub, was perforated by using auger. Holes were made along the tube which allows methane to flow through it. A cover of PGD and two sides of wall in Fig. 1 were utilized to avoid wind influence and any other interference from outside. In the bottom of cover, a transparent sheet was used to allow the laser from PGD through it.

This measurement used a PGD with data logger mounted on a rod between two poles and was hanged at 50 cm from surface (Fig. 1). The surface was divided into four grids and methane concentrations were measured once for 1 min on the center of each grid. These four grids were named position #1, #2, #3, and #4. This measurement was undertaken in four main conditions: variations of methane flow rates (1, 2, 3, 4, 5, and $6\,L\,min^{-1}$), wind speed (0, 2, 4, and $6\,m\,s^{-1}$), position of PGD (#1, #2, #3, and #4), and cover utilization (no and with cover) measurement. Fig. 2 shows methane flux measurement by chamber method using the PGD mounted on a small chamber. Four grids were made on the surface and flux on the center of each grid was measured for 3 min.

The heights in no and with cover measurement were 50 cm and 10 cm, respectively. These heights are used in measuring ambient methane concentration in laboratory scale study because the wind source (fan) had a height of 30 cm from the tub surface. Therefore, measurements will be full and half affected by wind, in 10 cm (with cover) and 50 cm (no cover), respectively.

2.2. Application of portable gas detector to estimate spatial distribution of methane emissions in landfill

2.2.1. Field study site

The field study area located in Tamangapa landfill, lies 15 km from Makassar City, South Sulawesi Province, Indonesia. It is owned and operated by Parks and Sanitation Agency, Municipal Government of Makassar City. This landfill was established in 1993, an open dump disposal site, no daily cover soil, bumpy surface, no vegetation, and now the waste having reached a depth of 20 m. This landfill has an allocation 14.3 ha of land with depths ranging from approximately 4–20 m, make a steep slope in this landfill. Since its opening, an estimated 1.4 million ton of MSW has been disposed of to this landfill with a current waste volume of approximately 1.800.000 m^3 (World Bank, 2007), with designed capacity is 2.15 million ton of waste. In addition, Makassar city's residential population in 2012 was approximately 1.6 million people (Komisi Pemilihan Umum, 2013). 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 ton day^{-1} in 2012 (Dinas Pertamanan dan Kebersihan