FLUX MEASUREMENTS OF GREENHOUSE GASES FROM AN ABANDONED OPEN DUMPING SITE OF SOLID WASTE IN SRI LANKA

M. Nagamori[1], T. Koide[2], N.K. Wijewardane[3], Y. Watanabe[1], Y. Isobe[1], M.I.M. Mowjood[4], T. Ishigaki[5], K. Kawamoto[2,6]
[1]Center for Environmental Science in Saitama
Telephone: +81-480-73-8371; Fax: +81-480-70-2031
E-mail: nagamori.masanao@pref.saitama.lg.jp
[2]Institute for Environmental Science and Technology, Saitama University
[3]Postgraduate Institute of Agriculture, University of Peradeniya
[4]Department of Agric. Engineering, University of Peradeniya
[5]National Institute for Environmental Studies
[6]Graduate School of Science and Engineering, Saitama University

Abstract

The investigation of greenhouse gas emission from a waste dumping site in Sri Lanka was conducted. The investigated site in this study is an abandoned waste dump site located at a hilly river bank in the Central Province of Sri Lanka (N 7º 09', E 80º 35'), consisting of two different sections with waste ages of around 0.5 year (New-section) and 7 years (Old-section). A simplified method for determination of methane gas flux using laser methane detector was considered to be effective to grasp the magnitude of methane flux. It was shown that the points those exhibited high value of methane gas flux also showed low EC-value compared with those of the other surround points. Furthermore, the low hardness of these points indicated that large amount of methane gas flux was caused by high permeability of surface as some stumps had been grown or as boundary between buried waste and ground line had been loosened. Measured fluxes for methane, carbon dioxide, and nitrous oxide in New-section ranged in <0.04-1800, 4.9-1800, and <0.0001-0.35 mL m^{-2} min^{-1}, respectively. Little amount of methane gas was emitted from surface in Old-section. Relatively high fluxes of nitrous oxide were observed in some plots at middle and bottom for both sections, suggesting that nitrification was stimulated by aerobic condition due to the penetration of air from the slope of dumped waste.

Keywords: Landfill gas, Gas flux, Open dump, Sri Lanka, Closed-chamber method

1. Introduction

The contribution of emissions of greenhouse gases (GHGs) to global climate change has gained intensive public acceptance. Methane is one of the most important GHGs because its global warming potential (GWP) value is estimated to be more than 20 times that of carbon dioxide. Although waste landfill has been recognized as a large source of anthropogenic methane emission, those inventory has been estimated only using national statics on waste landfilling and the methane generation rate according to IPCC guideline (IPCC 2006). On the other hand, estimations of methane emission from whole waste landfill have been performed by field measurement. The sparse literature on actual field measurements of landfill methane emissions indicates wide range spanning roughly eight order magnitude (0.0014 – 50,000 g m^{-2} day^{-1}, 0.0035 – 54,000 mL m^{-2} min^{-1}) (Giani at. al. 2002; Ishigaki et al. 2005; Abichou et al. 2011; Goldsmith et al. 2012). Moreover, parallel emissions of not only methane but also nitrous oxide, whose global warming potential is estimated to be more than 300 times that of carbon dioxide, have been previously reported (Boerjesson at. al. 1997; Bogner et al. 1999; Mcbain et al. 2005; Houhu et al. 2009), its range is from Minimum Determination Limit to 0.094 g m^{-2} day^{-1} (0.037 mL m^{-2} min^{-1}). The measurement of gas flux at landfill surface is problematic due to the sprawling areal extent and heterogeneous nature of most landfill sites.

The objective of this study is to observe typical landfill gas fluxes such as methane, carbon dioxide and nitrous oxide at two sections those have different ages of the buried waste inside each other of an abandoned waste dump site in Sri Lanka. Simplified tests to measure methane gas flux, ground temperature and soil-EC were conducted at each grid point for two sections. Additionally, three major gas fluxes were measured using a closed static chamber technique mainly on points of high methane gas flux obtained from simplified test. The relationships between each gas flux and other items were determined.

2. Materials and methods

2.1 Description of field site

The investigated site in this study is an abandoned waste dump site located at a hilly river bank in the Central Province of Sri Lanka (N 7º 09', E 80º 35'). The average annual rainfall is above 2000 mm with an average annual temperature of 24.5 ºC (Department of Meteorology, 2012). From the site, two different sections with waste ages of around 0.5 and 7 years (hereinafter, “New-section” and “Old-section”) as shown in figure 1 were selected to measure surface gas fluxes. Height of waste between top and bottom is approximately 35-m. Although majority of landfilled waste was domestic garbage, construction and demolition waste also was contained. Old-section was almost covered with loam thinly and was overgrown with weeds. New-section was covered partially with loam and weeds.

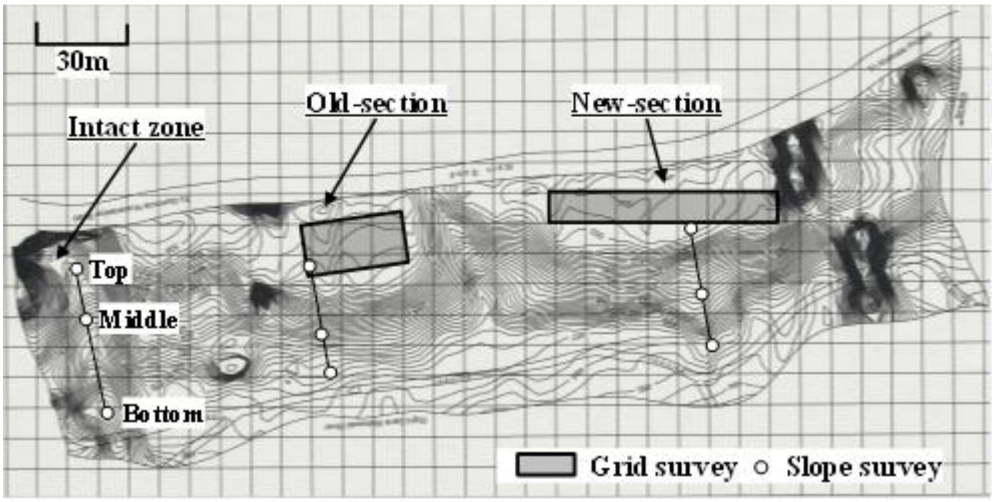

Figure 1: Land survey map and sampling points along the slope

2.2 Field methods and gas analysis

The present study was conducted consecutively, "slope survey", "grid survey", "hot spot survey". "Slope survey" and "grid survey" were conducted between 16th and 19th March 2012. The samples were taken from three marked plots along the slope (Top, Middle, and Bottom) each inside the dump and non-waste dumping / intact zone (Figure 1).

In the "grid survey", the measurement points were arranged in a 5×5 m grid at the surface area (including top of slope survey) of 450-m^2 for "Old-section" and 750-m^2 for "New-section" (Figure 2). The ground temperature at the depth of 0.5 m and soil-EC value at the depth of 5 cm were measured using TR-81 thermometer (T&D Co., Ltd., Nagano, Japan) and ECTester11+ soil conductivity meter (Eutech instruments, Ayer Rajah Crescent, Singapore) at each point. And simplified method of methane gas flux was performed using LMD-SA3C31B Laser Methane Detector (Tokyo Gas Engineering Co., Ltd., Tokyo, Japan) at each point. The infrared ray laser directed at ground surface from the device after 1 min from setting of a hollow cylinder which has 5 cm of internal diameter and 20 cm of length. The device receives the reflected beam from ground surface and calculates the concentration of methane gas in the cylinder. It is assumed that methane gas flux (LMD-flux) obtained above-described concentration using LMD from 0 ppm for duration of 1 minute.

The gas fluxes were measured at bottom, middle and four grid points for each section using a closed static chamber technique (Klute 1986). The gas flux of top of Intact-zone was also measured to know the background condition. A round chamber, whose form was truncated cone; diameter of base and top were 282 mm and 214 mm, height was 88 mm tall, was placed on the ground surface. Soil was packed into a mound around the interface between the chamber and the surface of the ground and wetted to form an adequate seal. The chamber surface area and volume were 620 cm^2 and 4.3 L, respectively. An enclosed headspace sample was collected from the chamber and placed in an air-tight aluminium bag after 0, 2, 4, 6 and 8 min of the closure of the chamber for sampling by MP-15CF air sampling pump (Shibata Scientific Technology, Ltd., Tokyo, Japan) at about 1 L min^{-1}. The samples were taken to the laboratory for analysis. The concentration of oxygen, nitrogen, methane, carbon dioxide and hydrogen in the samples were analysed using gas chromatography (GC) equipped with Thermal Conductivity Detector (GC-14A, Shimadzu Cooperation, Kyoto, Japan and 6890 series, Agilent Technologies, Santa Clara, USA). Nitrous oxide was analysed using GC equipped with Electron Capture Detector (GC-14B, Shimadzu Cooperation, Kyoto, Japan).

Besides, not only measurements at the grid point but the gas fluxes were also measured at some hot spots detected by the LMD ("Hot spot survey"). "Hot spot survey" was conducted 10th July 2012. A round chamber, whose form was truncated cone; diameter of base and top were 324 mm and 280 mm, height was 145 mm tall.

3. Results and discussion

3.1 Grid and slope survey by simplified test

Figure 2 shows the contouring maps of measured LMD-flux, ground temperature, soil-EC value and rough sketch of landfill surface. Measured LMD-flux for Old-section, New-section, and Intact-zone ranged in 2-820, 5-1,200, and 5 ppm-m, respectively. Measured ground temperature for Old-section, New-section, and Intact-zone ranged in 27.6-52.2, 28.1-39.3, and 26.6 degrees, respectively. Measured soil-EC value for Old-section, New-section, and Intact-zone ranged in 0.03-0.60, 0.06-0.81, and 0.09 mS/m, respectively.

LMD-flux at landfill surface appeared to be an irregular disorganized pattern and existed locally high. It is well known that the temperature in a waste layer will rise by chemical reaction and/or biodegradation. But there was no correlation between LMD-flux and ground temperature. It may be suspected that ground temperature at the depth of 0.5 m was influenced by high ambient temperature. Nagamori et al. (2002) suggested that large methane flux was observed from the portion around the area of high soil-EC value. Although the most of detected LMD-fluxes were within the error for Old-section, a high value of 820 mL m^{-2} min^{-1} was denoted at only one point; B5 ("B" and "5" mean vertical and horizontal line illustrated by Figure 2.). Actually EC-value of this point (0.11 mS/m) was small compared with those of the other surround points. These findings are not consistent with Nagamori et al. (2002). The high LMD-fluxes at B5 may be because of some physical condition of this point which allowed the landfill gas passed through. On the New-section, LMD-flux of B40 and C75 were relatively high. Especially, LMD-flux of C75 for New-section was extremely high in this study. Hardness of surface that we did not investigate in this study should greatly influence the gas flux. This idea may be examined by the rough sketch (Figure 2) which illustrates a stump near C75 point.

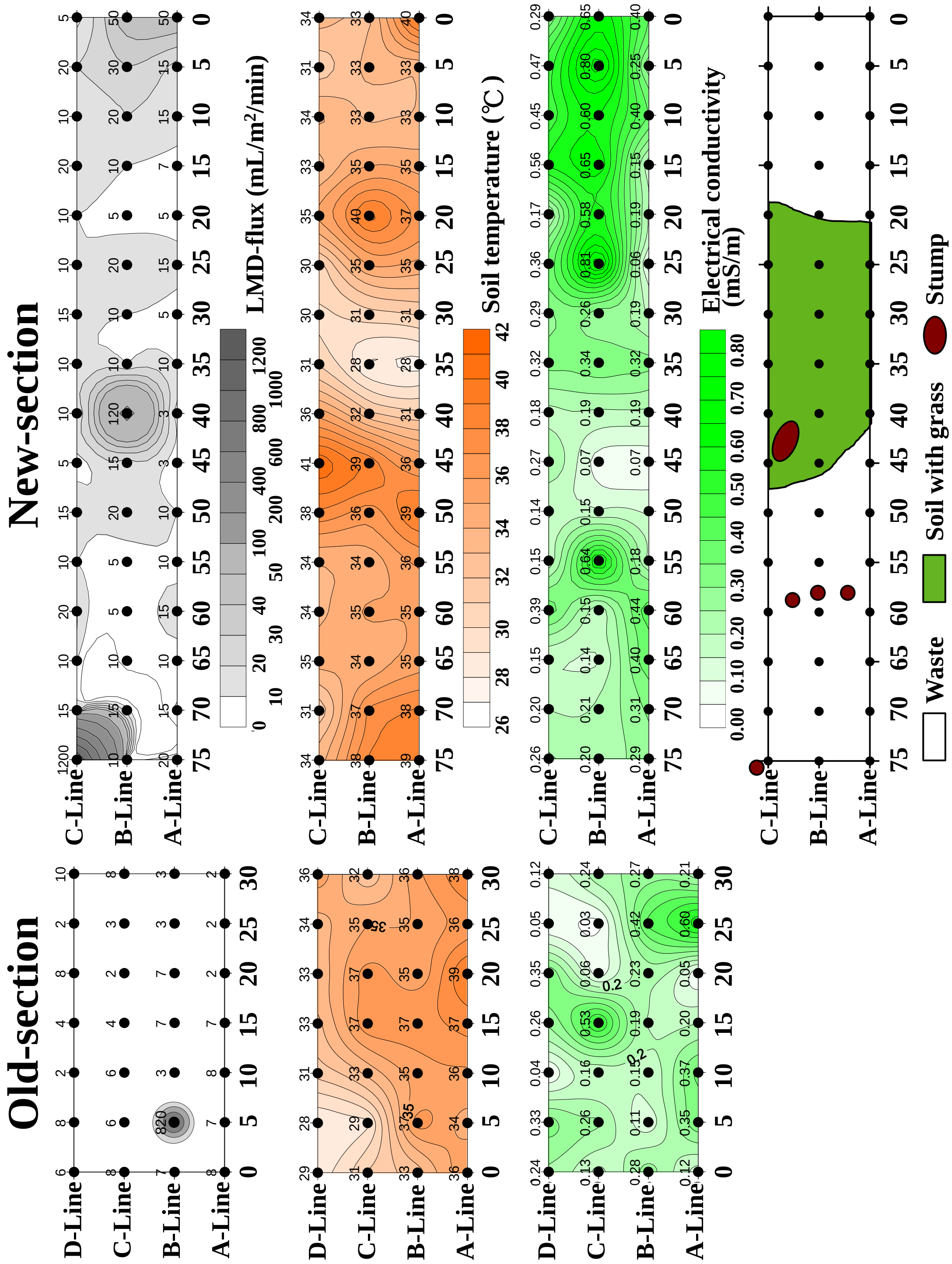

Figure 2: Contouring maps (LMD-flux, soil temperature, soil EC) and rough sketch of landfill surface (New-section)

3.2 Gas flux on the landfill surface

Measured methane gas fluxes for Old-section, New-section, and Intact-zone ranged in <0.04-840, <0.04-87, and <0.04 mL m^{-2} min^{-1}, respectively. Measured carbon dioxide gas fluxes for Old-section, New-section, and Intact-zone ranged in 6.1-920, 19-76, and 8.4 mL m^{-2} min^{-1}, respectively. Measured nitrous oxide gas fluxes for Old-section, New-section, and Intact-zone ranged in <0.0001-0.030, 0.00057-0.060, and 0.00056 mL m^{-2} min^{-1}, respectively. Since emission of carbon dioxide from landfill site derived from organic matter is disregarded as carbon neutral, there are almost no reports of their emission. Although other fluxes were not far from results of previous studies, it seems that the gas flux from present site was lower than those in low-latitude regions. Even though New-section had passed only less than one year from the end of reclamation, the methane gas flux (87 mL m^{-2} min^{-1}) is comparably small to other researches.

Figure 3 shows the relationship between LMD-flux and methane flux (r^2=0.50). This simplified method was found not to be useful for estimating methane gas flux, due to LMD-flux often overestimated the value obtained closed statics chamber method. This might be due to a large margin of error for this device. It is more useful that the closed flux chamber technique using LMD shown by Komsilp et al. (2009) than the present simplified method.

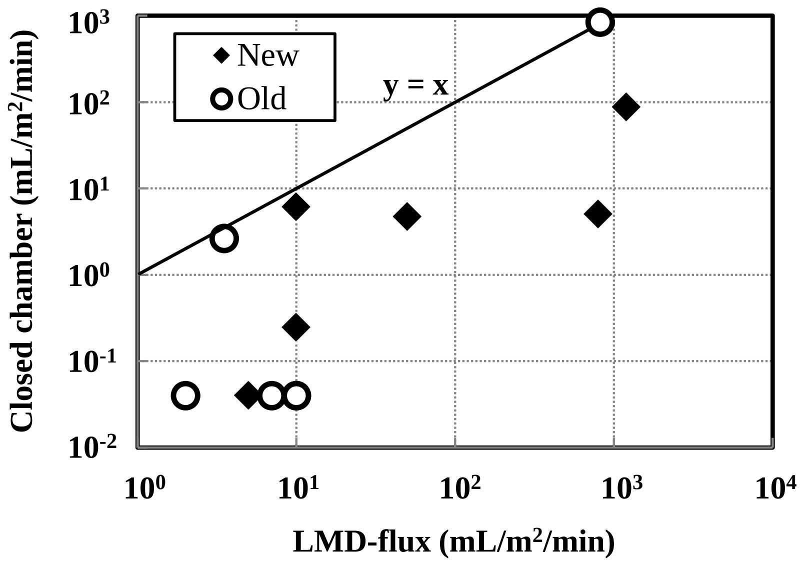

Figure 3: Relationship of methane gas flux between simplified method and closed chamber method

Figure 4 shows the relationship between gas flux of nitrous oxide and methane. A negative correlation was found with methane gas flux for nitrous oxide gas flux, and low correlation coefficient (r^2) between these values for Old-section, and New-section were 0.49 and 0.29, respectively. Besides, (r^2) excluding middle and bottom points for Old-section, and New-section were up to 0.93 and 0.40, respectively. The results showed that higher methane flux for obligatory anaerobic condition had a tendency to have lower flux of nitrous oxide. High gas fluxes of nitrous oxide over 0.01 mL m^{-2} min^{-1} were observed in some plots at middle and bottom for both sections as shown in Figure 4, suggesting that nitrification was stimulated due to aerobic condition on the slope of dumping waste.

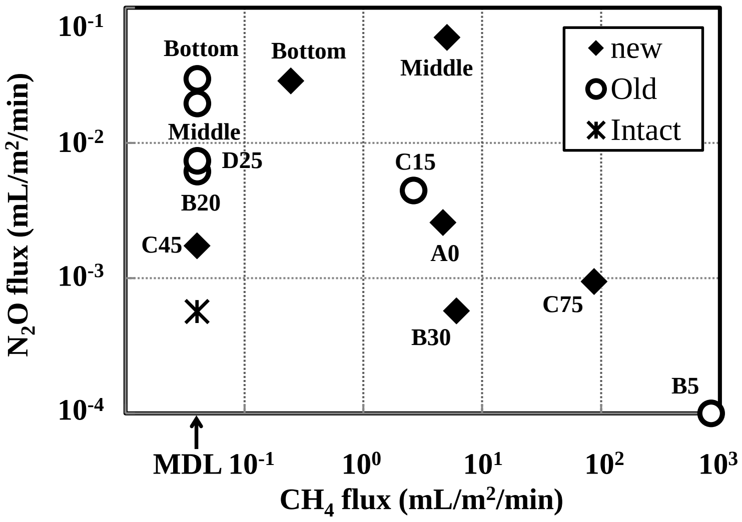

Figure 4: Relationship between gas flux of nitrous oxide and methane (MDL: Minimum Determination Limit)

3.3 Hot spot survey

Hot spots were detected at three points for Old-section and five points for New-section by “Hot spot survey” at top-surface using the LMD. No significant difference was observed in Old-section, and most of the hot spot for New-section were placed near the boundary between buried waste and ground line.

Figure 5(a) shows the measured gas flux of methane, carbon dioxide and nitrous oxide for each point. This investigation exhibited different trend of gas emission. No methane flux at hot spot was observed in Old-section, and these carbon dioxide fluxes were close to flux of circumferential environment (Intact-zone). On the other hand, measured gas fluxes of hot spot in New-section for methane, carbon dioxide, and nitrous oxide ranged in 0.97-1800, 4.9-1800, and 0.014-0.35 mL m^{-2} min^{-1}, respectively. In particular, fluxes of methane and carbon dioxide at Hot-N1, -N3 and -N4, were relatively higher than the other spots in New-section. These results were the biggest gas flux from top surface in the present site. However, there were fewer spots emitted of large amount of gases as a young landfill.

Using the IPCC GWP values of 21 for methane and 310 for nitrous oxide (IPCC 2006), the equivalent carbon dioxide emissions of each point were determined as shown in the Figure

5(b). First, it is understood the gas flux surveys were conducted March and July as the reasons why nitrous oxide gas fluxes from the hot spots were relatively higher than other points at the top. Seasonal variation in gas emissions from present dump site has to be investigated further. Moreover, since the spot of gas emission in Old-section was very local and few, it appeared that emissions amount of GHGs originating from buried waste in this site had been decreasing for 7 years. In New-section, methane gas flux as the equivalent carbon dioxide was different in more than one or two digit from carbon dioxide or nitrous oxide, respectively. The ratio of methane to nitrous oxide in New-section was almost the same as the data shown by Mcbain et al. (2005) and Houhu et al. (2009).

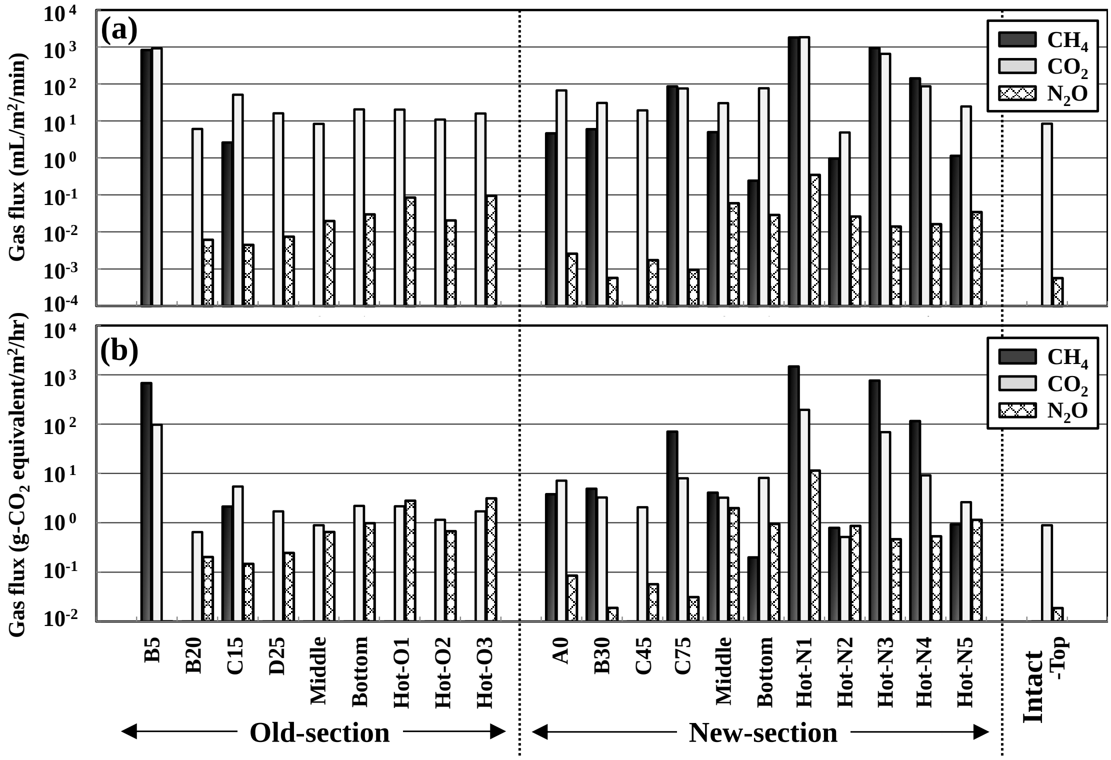

Figure 5: Measured and converted gas flux of methane, carbon dioxide and nitrous oxide; (a) Volumetric gas flux (mL/m^2/min), (b) Gas flux of carbon dioxide equivalent (g-CO_2 equivalent/m^2/hr)

4. Conclusion

The results of the typical landfill gas flux such as methane, carbon dioxide and nitrous oxide in an abandoned open dump located at the Central Province of Sri Lanka are presented in the following s:

1. The simplified test was conducted on methane gas flux using laser methane detector. This survey was shown to be useful in practical application, and succeeded in predicting the area emitted large amount of methane gas quickly.

2. Measured gas fluxes in New-section with waste ages of around 0.5 years for methane, carbon dioxide, and nitrous oxide ranged in <0.04-1800, 4.9-1800, and <0.0001-0.35 mL m^{-2} min^{-1}, respectively.

3. Little methane gas flux from surface in the dumped waste was emitted after only seven years from the end of reclamation (Old-section).

4. Relatively high gas fluxes of nitrous oxide were observed in some plots at middle and bottom for both sections, suggesting that nitrification was stimulated due to aerobic conditioning on the slope of dumping waste.

5. Acknowledgement

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