Kalmar ECO-TECH '05 and
The Second Baltic Symposium on Environmental Chemistry
KALMAR, SWEDEN, November 28-30, 2005

A PRACTICAL APPLICATION FOR MONITORING METHANE IN AMBIENT AIR AT WASTE DISPOSAL FACILLITIES USING A PORTABLE OPEN PATH ANALYZER

Noboru Tanikawa
Toru Furuichi
Kazuei Ishii
Kohji Matsuo
Hokkaido University, Japan

ABSTRACT

It is well known that methane (CH_4) is a greenhouse gas, and one of the main gases emitted from landfills. CH_4 is also emitted from biogasification facilities and composting facilities. A new method to monitor CH_4 in ambient air has been developed using a portable open path methane analyzer (POMA) that is retailed as an urban gas leak detector. In this study, we have investigated a practical application of a POMA in the field, and the characteristics of CH_4 emissions at landfill sites, biogasification facilities, and a composting facility.

It is clear that this new method is convenient, and can be used to monitor the average concentration of CH_4 in ambient air at a waste disposal facility, such as a landfill site, a composting facility, or a biogasification facility. The concentration of CH_4 in ambient air at landfill sites, a composting facility, and biogasification facilities were found to be 2–30, 2–13, and 3–13 ppm, respectively.

KEYWORDS

Methane; Open path type analyzer; Landfill site; Biogasification; Composting

1 INTRODUCTION

Methane (CH_4) is known to be a major greenhouse gas emitted from landfill sites. It is necessary to measure the volume of methane emitted from landfill sites to judge the stability of a landfill site, and to examine its contribution to global warming. However, it is very difficult to measure the total representative volume of landfill gas from a landfill site, because various landfill gases are heterogeneously emitted from gas venting tubes, and also from the surface of the landfill site. It is also well known that CH_4 is heterogeneously emitted from waste treatment facilities, such as composting facilities and biogasification facilities.

To obtain a representative emission of CH_4 from a landfill site and a waste treatment facility (waste disposal facility), it is necessary to obtain many samples from the gas venting tubes and the ambient air at the landfill site and waste disposal facility, and then analyze the collected

https://doi.org/10.15626/Eco-Tech.2005.060

samples. This is very laborious, time consuming, and costly, and there are hopes that a new and simple method for monitoring CH_4 in ambient air can be developed to provide the desired information in a cost-effective manner.

We have investigated the use of a portable open path-type analyzer for monitoring representative values of CH_4 at waste disposal sites that is quicker and easier to use than conventional analyzers [1, 2]. We reported on a method for using these portable open path-type methane analyzers that was convenient and usable for monitoring the average concentration of CH_4 in ambient air at a landfill site [1]. In this study, we have investigated a practical application for monitoring CH_4 in ambient air at a waste disposal facility using a portable open path-type methane analyzer, and have examined the characteristics of CH_4.

2 MATERIALS AND METHODS

2.1 Instrument and its principle of operation

Figure 1 shows a photograph of a portable open path methane analyzer (POMA) that is retailed as an urban gas leak detector. The POMA consists of an electronics unit, an optics unit, and a connecting tube. It has an InGaAsP distributed-feedback laser light source in the electronics unit. The wavelength of the laser is stabilized at an absorption line of methane (the 1,640–1,700 nm band of the R(3) line (λ = 1.65372 μm)) that is free from interference from atmospheric gases. The laser light is coupled to a single–mode optical fiber in the connecting tube and guided to the optics unit. *Table 1* shows the specifications and performance of the POMA.

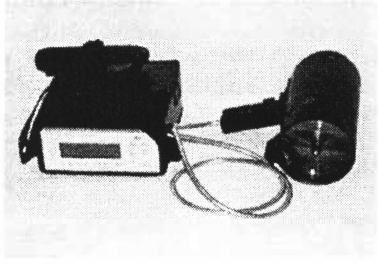

Figure 1. The portable open path methane analyzer used

A schematic method for monitoring the concentration of CH_4 using the POMA is shown in *Figure 2*. The optics unit transmits the laser beam to the special reflector, and part of the backscattered light is condensed onto a photodetector. The photodetector output is fed

Table 1. The specifications and performance of the the portable open path type methane analyzer

Detection principle	Wavelength-modulation spectroscopy for infrared absorption
Light source	InGaAsP distributed-feedback laser
Wavelength (nm)	1653.7
Response time (s)	0.1
Detection distance (m)	< 30
Lower detection limit (ppm•m)	50
Upper detection limit (ppm•m)	6000
Weight (kg)	4.4 in total (Electronics unit : 3.2, Optics unit : 0.9, Connecting tube : 0.3)
Dimensions (mm)	Electronics unit : W 195, D 260, H88 Optics unit : W 114, D 244, H206
Battery	Nickel-metal hydrate battery(12 V)

into the electronics unit, and this is converted into the absorption factor of the laser light. The POMA measures the path-integrated methane concentration (in units of ppm·m) between the optical unit and the special reflector. The concentration of CH_4 is calculated using *Equation 1*

$$CH_4 \text{ (in ppm)} = M/X \quad (1)$$

where M = the path-integrated methane concentration (in units of ppm·m) and X = the distance (in m).

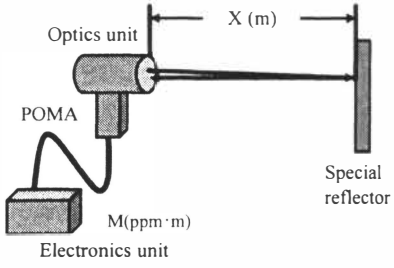

Figure 2. A schematic drawing of the method for monitoring the concentration of CH_4 using the POMA

2.2 Method

The concentration of CH_4 in ambient air measured by varying the distance between the POMA and the special reflector, at two landfill sites (Landfill sites A and B) is shown in Table 2, at three kitchen waste biogasification facilities (Facilities C, D, and E) in *Table 3*, and at a composting facility (Facility F) in *Table 4*.

Landfill site A was a controllable closed system disposal facility (CSDF), which is increasingly being used in Japan. A CSDF has a barrier, such as a roof or an artificial foundation that can prevent rainfall from infiltrating the waste. The physical conditions (e.g., temperature and water content) within the waste layers can be controlled, depending on the quality of the landfilled waste, without imposing any impact on the environment. Landfilled waste is pulverized incombustible waste, plastics, and ash. It is estimated that these have a low content of easily biodegradable organic matter. The POMA and the special reflector were positioned at a height of 7 m above the landfill surface at opposite ends of the landfill site, spaced about 38 m apart, and the concentration of CH4 between them was periodically measured. For comparison, the air at the midpoint between the optical unit and the special reflector (Point G) was sampled using a plastic tube, and the sample gas was introduced into the continuous CH_4 analyzer. Its specifications are shown in *Table 5*. The air at Point H, Point I, and Point J,

Table 2. Outline of landfill site tested

	Landfill site A	Landfill site B
Duration of reclamation	2002-	1979-
Reclamation area (m2)	1000	101,500
Landfilled solid waste	Pulverized incombustible waste and plastics, Ash	Domestic waste

Table 3. Outline of kitchen waste biogasification facilities tested

	Facility C	Facility D	Facility E
Fermentation temperature (°C)	55	35	55
Treatment capacity of kitchen waste (t/d)	22	55	16
Population in communities	41,000	94,000	42,000

Table 4. Outline of composting facility (Facility F)

Raw material	Livestock excreta, kitchen waste, and pulverized wood waste
Treatment capacity	26 (t/d)
Method	Open type automatic rotary mixing

shown in *Figure 3*, was intermittently sampled into plastic bags through a plastic tube and the concentration of CH_4 was measured using the continuous CH_4 analyzer.

Landfill site B was divided into four sections. Domestic waste, including kitchen garbage, was sent to direct landfill. It is estimated that much organic matter was present at Landfill site B. The concentration of CH_4 was measured in each section at a height of about 1.5 m using the POMA.

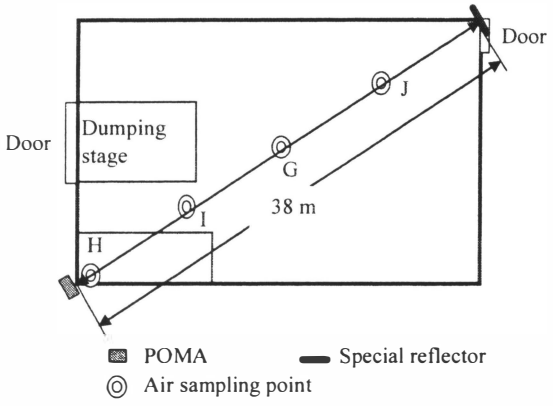

Figure. 3 An outline of the monitoring of the concentration of CH_4 at Landfill site

The main equipments were located in rooms at the kitchen waste biogasification facilities. The concentration of CH_4 in ambient air in the main rooms, where CH_4 might leak, was measured. The concentration of CH_4 in ambient air at a composting facility was also measured.

Table 5. The specifications of the conventional CH_4 analyzer

Measurement principle	Range (ppm)	Sample flow (ml/min)
Flame ionization detector method	0 - 10	900

3 RESULTS AND DISCUSSION

3.1 Landfill sites

At Landfill site A, the concentration of CH_4 varied over the range 2–4 ppm. This is higher than the level in the outside air, because it contains a contribution from the landfill gas. Examples of the change in CH_4 concentration measured by the POMA and the continuous CH_4 analyzer at Point G are shown in Figure 4. When essential works (for example, dumping or bulldozing of the waste) is carried out at Landfill site A, the door of the landfill site is opened, and the air ventilators are operated. As illustrated in *Figure 4*, measurements were recorded for a period of 18 min, and then the door was opened, and the air charging system was

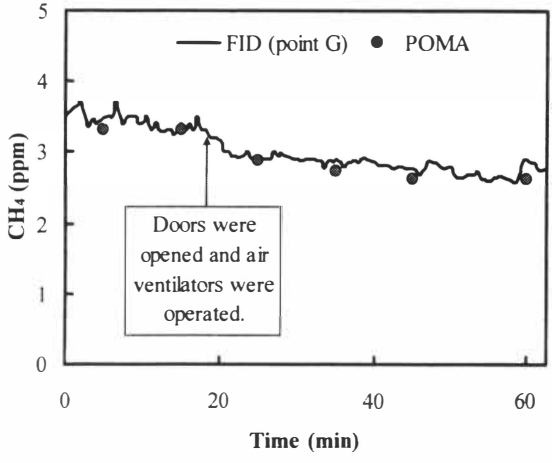

Figure 4. An example of the change in concentration of CH_4 at Landfill site A

operated. During the initial 18 min, the concentration of CH_4 measured by the POMA was approximately equal to that measured by the continuous CH_4 analyzer. After 18 min, the concentration of CH_4 measured by the POMA and the continuous CH_4 analyzer decreased gradually as the outside air entered and diluted the methane-rich air inside. The concentration of CH_4 measured by the POMA was also approximately equal to that measured by the continuous CH_4 analyzer.

An example of the change in CH_4 concentration measured by the POMA and that at Points G, H, I, J using the continuous CH_4 analyzer is shown in Figure 5. During the initial 18 min, there were differences in the concentration of CH_4 at Points G, H, I, J, and the mean CH_4 concentration at Points G, H, I, J were approximately equal to those measured by the POMA. After 18 min, the outside air entered and mixed with the inside air. After this had occurred, there was little difference between the CH_4 concentration at Points G, H, I, J, and that from the POMA. Namely, it was clear that the POMA can monitor representative values of CH_4 concentration in the landfill site where CH_4 is heterogeneously emitted.

The results of CH_4 in ambient air at Landfill site B are shown in *Table 6.* Domestic waste, including kitchen waste, is sent to landfill at Sections 3 and 4. It seems that large volumes of landfill gas are emitted at Sections 3 and 4, as the organic matter contained in the waste is actively degrading. More than 20 years have passed since Section 1 was completed, and more than 10 years have passed since Section 2 was completed. The peak activity of the organic degradation in each section is considered to have passed, and the volume of landfill gas produced has reduced. The concentration of CH_4 in ambient air at Sections 3 and 4 was higher than at Sections 1 and 2. The maximum reading observed was 30 ppm. The concentration of CH_4 in ambient air at Sections 1 and 2 sometimes increased when the wind blew in from Sections 3 and 4.

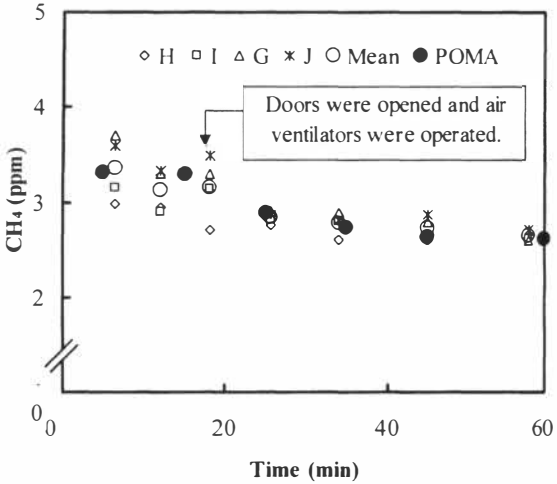

Figure 5. Another example of the change in concentration of CH_4 at Landfill site A

Table 6. CH_4 in ambient air at Landfill site A

	Duration of reclamation	CH_4 (ppm)
Section 1	1979 - 1983	3.3 - 6.0
Section 2	1984 - 1992	1.8 - 5.2
Section 3	1993 -	1.8 - 9.6
Section 4	1999 -	2.9 - 30.0

3.2 Biogasification facilities and composting facility

CH_4 in ambient air in the main rooms of the kitchen waste biogasification facilities could be conveniently and quickly measured by the POMA.

The results are shown in *Table 7*. This data changed, depending on the conditions of the room (e.g., type of operation, volume, sealing, and ventilation), and the values were small and therefore, negligible. Test equipment is available to detect accidental CH_4 leaks, which can measure the concentration of CH_4 at the percent level. The POMA is more useful for a rapid early detection of accidental CH_4 leaks, as it can monitor the concentration of CH_4 at the ppm level.

Table 7. CH_4 in ambient air at kitchen waste biogasification facilities

Room	CH_4 (ppm)		
	Facility C	Facility D	Facility E
Methane fermentation room	2.8 - 3.7	2.0 - 2.8	3.5 - 12.8
Waste water treatment room	4.9 - 5.1	2.0 - 2.7	1.9 - 2.0
Electric generator room	5.2 - 7.5	1.9 - 2.0	-
Solid residual treatment room	2.1 - 2.4	3.1 - 11.4	-

Table 8. CH_4 in ambient air at the composting facility

Height (m)	1	2	3
CH_4 (ppm)	4.6	7.2	12.8

The results measured by the POMA in the central region of the composting facility are shown in *Table 8*. The concentration of CH_4 depended on the measurement height. The concentration of CH_4 at a height of 1 m was lower than that at a height of 3 m. It is presumed that the gases that are emitted by the degradation of organic matter, which includes CH_4, rise, and are diluted as their temperature increases. The concentration of CH_4 at a height of 1 m varied with changes in location, and was in the range 3–6 ppm. This was because of the active degradation area in the composting equipment was limited.

4 CONCLUSIONS

We have developed a practical application for monitoring CH_4 in ambient air at waste disposal facilities using a portable open path-type methane analyzer, and have used it to investigate and characterize the concentration of CH_4 in ambient air. The following conclusions were reached:

- A POMA can conveniently and quickly monitor the concentration of CH_4 in ambient air at landfill sites, kitchen waste biogasification facilities, and composting facilities, where CH_4 may be emitted heterogeneously.
- The concentration of CH_4 varied over the range, 2–4 ppm at the landfill sites where pulverized incombustible waste, plastics, and ash were landfilled.
- The concentration of CH_4 varied over the range, 2–30 ppm at the landfill sites where domestic waste, including kitchen garbage, was directly landfilled.
- The concentration of CH_4 varied over the range, 2–13 ppm at the kitchen waste biogasification facilities.
- The concentration of CH_4 varied over the range, 3–13 ppm at the composting facility.

ACKNOWLEDGEMENT

The Authors wish to thank the Anritsu Co. and Mr. Yukio Kamiegawa for valuable assistance.

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