ESTIMATES OF METHANE EMISSIONS FROM WESTERN LANDFILLS USING OTM-10.

Roger B. Green
Waste Management, Inc.
Cincinnati, Ohio

Gary R. Hater
Waste Management, Inc.
Cincinnati, Ohio

C. Douglas Goldsmith
Alternative Natural Technologies, Inc.
Blacksburg, Virginia

Jeffrey P. Chanton
Florida State University
Dept. of Oceanography
Tallahassee, Florida

Nathan Swan
Cygnus Environmental Group
Louisville, Kentucky

ABSTRACT

Waste Management (WM) has undertaken a developmental program with the objective of measuring methane emissions from a number of its landfills in the U.S. Accurate emissions determinations will improve the understanding of the emissions performance of the facilities but should also provide insight on what operational practices will increase emissions performance.

Methane emissions were measured at four municipal solid waste landfills located in California and Colorado. Measurements were made using ground based optical remote sensing (ORS) for large area sources utilizing a tunable diode laser (TDL). The approach used is generally outlined in US EPA Other Test Method 10 (OTM-10). Each of the landfills surveyed had active landfill gas collection systems and intermediate or long-term soil covers. Field measurements were performed over a period of several weeks in 2007 and 2008 with each landfill being measured twice. Methane flux rates were derived using a multiple linear regression approach to determine the landfill surface area contributing measured emissions. Mean methane emission rates determined from TDL measurements ranged from 0.7−15.7 g m^{-2} d^{-1}. Assessments of the efficiency of the landfill gas collection systems based on the emissions measurements and the amount of landfill gas collected during the measurement campaigns ranged from 72-92%. When the amount of methane oxidized was taken into account the overall methane control efficiency ranged from 79-92%.

INTRODUCTION

Estimates of methane emissions from municipal solid waste (MSW) landfills have been typically derived from models of methane generation, an assumption about the efficiency of the landfill gas collection system (typically 75%) and sometimes an assumption of methane oxidation in landfill cover soils (usually 10%). When estimated in this manner, landfill methane emissions have been reported to represent approximately 2% of total annual greenhouse gas (GHG) emissions (IPCC, 2007). There are several good reasons why such an approach has been used for the top down or global estimation of emissions at landfills. First, is the issue of consistency and the fact that national and international inventories of GHG emissions require comparable methods of estimation. Another is that the accurate quantification of methane emissions from landfills has been shown to be technically challenging. There are relatively few comprehensive field studies conducted at operating landfills to develop methane emissions budgets. In these studies a relatively wide range of emission rates have been reported and emissions have been observed to vary both spatially and temporally (IPCC, 2006).

As the focus of GHG emissions inventorying and reporting shifts from the international or national level to the facility level, understanding the accuracy of applying the modeling approach to individual facilities becomes increasing important. Several studies evaluating methods of measuring or modeling landfill emissions to develop site specific methane budgets have recently been reported (Babilotte et al., 2008, 2009; Spokas et al., 2006; Borjesson et al., 2009; Bogner et al., 2009).

In 2006 WM began using two methane measurement techniques to quantify emissions at landfills located in various climates across the U.S. One approach was the use of static chambers to measure surface flux while the other was a method developed by the U.S. EPA, in conjunction with ARCADIS Inc., that uses ground based optical remote sensing (ORS) for large area sources. Additional details on the ORS approach are detailed in a method termed Other Test Method 10 (OTM-10) (USEPA, 2006). The methane flux measurements reported in this paper

Table 1. Landfill Study Sites Detail

Site	City, State	Coordinates	Field Campaign Dates
DADS	Aurora, CO	39°39'40"N 104°42'49"W	05/15/2007–05/18/2007 10/23/2007–10/24/2007
Lancaster	Lancaster, CA	34°44'52"N 118°07'13"W	09/10/2007–09/14/2007 01/15/2008–01/18/2008
TriCities	Fremont, CA	37°29'42"N 121°59'23"W	02/12/2008–02/14/2008 06/23/2008–06/27/2008
Kirby Canyon	Morgan Hill, CA	37°11'07"N 121°39'58"W	01/29/2008–01/31/2008 06/09/2008–06/13/2008

were made with the vertical radial plume mapping (VRPM) approach using tunable diode lasers.

METHODS

Landfill Study Sites

Two multi-day field studies of methane emissions were made at the DADS landfill, Lancaster Landfill, the TriCities Recycling and Disposal Facility and the Kirby Canyon Recycling and Disposal Facility. Details on the landfills are presented in Table 1. Each of these facilities is an active large-scale MSW landfill that is currently receiving waste and has an active landfill gas collection system (LFGCS). The DADS and Lancaster landfills are located in semi-arid or arid areas, while the TriCities and Kirby Canyon sites are located in a more moderate or Mediterranean climate.

Static Chamber Measurements

Surface methane emissions were determined with a static chamber technique. The principle of the technique is to seal a volume of air above a gas-emitting or consuming surface so that the emitted (or consumed) gas cannot escape and its accumulation in the volume can be monitored. The chambers used in this study were constructed of polished aluminum sheeting with dimensions of 0.63 x 0.63 x 0.2 m which covered a surface area of 0.4 m^2. Each chamber consisted of lid and collar and contained a small fan to circulate air within the chamber. Measurements consisted of sealing the chamber lid to the ground on previously installed collars. Methane samples were collected from the chambers immediately after sealing (time = 0) and every 5 minutes over the next 25 minutes using a 60 mL plastic syringe fitted with plastic valves. Samples were analyzed on a gas chromatograph equipped with a flame ionization detector. Methane flux was determined by plotting methane concentration (C) versus elapsed time (t). The slope of the fitted line (dC/dt) was determined by linear regression and a non-zero flux was reported only if there was a 90% confidence ($p<0.1$) in the correlation between methane concentration and time, otherwise a zero flux was reported (Barlaz et al., 2004). The summary flux results and statistics presented are based the arithmetic mean of all measurements. Chambers were located in a systematic grid established in the area being measured by the VRPM method to facilitate comparison.

Methane oxidation was determined using the isotopic fractionation approach described by Chanton and Liptay, 2000. In this approach, methane emitted through the cover is captured in static chambers and the ratio of $^{13}C/^{12}C$ in the sample is compared a sample collected from an anoxic zone of the landfill such as a gas well.

Vertical Radial Plume Mapping

A vertical radial plume mapping (VRPM) configuration termed the 'four corners' approach was used to calculate methane emissions. The four corners configuration encloses a rectangular area of the landfill with four VRPM planes. Each of the VRPM planes consists of five retro-reflecting mirrors. Two retroreflectors are placed along the surface at 1/3 and 2/3 of the full optical path, while the remaining three are arranged vertically at the end of the optical path with one at the ground suface and the others approximately 6 and 12 m above the ground surface. Two methane specific TDLs (GasFinder 2.0, Boreal Laser) mounted on controllable scanners are established at two opposite corners of the four corners configuration, while two scissor lifts used to mount the vertical retroreflectors are established at the other two corners. The TDLs scan the optical path to each of the five retroreflectors dwelling at each for 15 to 30 seconds during each measurement cycle. Wind speed and vector data are acquired with calibrated meteorological heads (R.M. Young, Model 05103) located approximately 2 m and 14 m above the ground. A schematic illustration of the four-corners VRPM is shown in Figure 1.

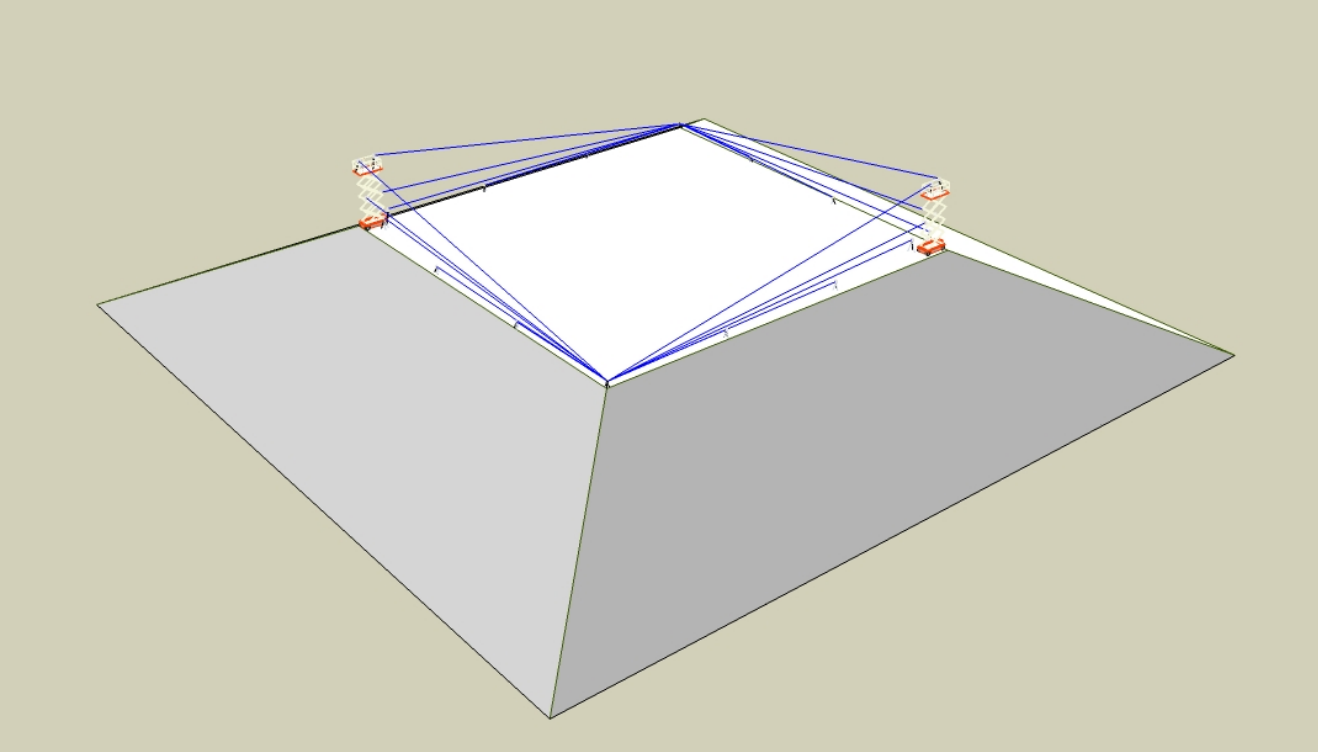

Figure 1. Schematic illustration of the 'four-corners' VRPM configuration.

VRPM Flux Calculations and Area Contributing to Flux: The average methane mass flux (g/s) was calculated for three cycle groupings of VRPM measurements using the VRPM algorithm provided in the Flux Calculator (v. 1.09 beta) software provided by Arcadis Inc. The landfill surface area that contributes to the mass flux as calculated by the VRPM algorithm varies as function of wind direction, wind speed, atmospheric stability and the surface emissions rate. In order to provide an estimate of whole landfill emission rates using the VRPM method, a unit emission rate given in units of methane mass per surface area per time (e.g. g CH_4 m^{-2} d^{-1}) must be determined. In 2008 and 2009 WM, in cooperation with the U.S. EPA and Arcadis, performed a number of controlled acetylene tracer gas release experiments in an effort to determine a method for estimating the upwind surface area contributing to the mass flux measured by a VRPM configuration (Thoma et al., 2008).

Thoma et al, (2009) have recently proposed a simplified model for approximating the area contributing to flux based on tracer release experiments. The model is based on a multiple linear regression fit of tracer collection efficiency data, the wind adjusted release distance of the tracer from the measurement plane and wind speed. In this paper the area contributing to flux (ACF) is determined by the product of the VRPM plane length and one half the wind adjusted release distance (WARD) at which the collection efficiency is equal to zero as determined by the multiple linear regression model shown in equation 1.

$$CEF = 0.732\text{-}3.34 \times 10^{-3} (WARD) + 9.41 \times 10^{-2} (WS) \quad (1)$$

where:

CEF = the normalized collection efficiency factor;

WARD = distance from the release point to the VRPM plane divided by the cosine of the wind angle measured from a vector perpendicular to the VRPM plane;

WS = wind speed

Mass flux data were rejected for determining unit flux rates when the wind speed was < 1 m/s or the wind angle from a vector perpendicular to the observing VRPM plane was > 30º.

Landfill Gas Collection and Control Efficiency

The efficiency of the landfill gas collection system was determined from unit area methane flux results from VRPM measurements, the rate of methane recovery via the LFGCS from landfill gas volume and composition measurements made during or within a couple weeks of the flux measurements and the surface area of the landfill.

The collection efficiency of the LFGCS was calculated as the amount of methane collected divided by the amount of methane produced as shown in the following equation:
CH_4 Collection Efficiency (%) = ($CH_{4\ recovered}$ / $CH_{4\ produced}$) x 100

where:

$CH_{4\ produced} = CH_{4\ recovered} + CH_{4\ emitted} + CH_{4\ oxidized}$

An additional calculation showing the methane control efficiency that indicates the overall control of emissions by the combined effect of the amount of methane collected and the amount oxidized in cover soils as estimated by stable isotope techniques using static flux chambers. The control efficiency calculation is as follows:

CH_4 Control Efficiency (%) = ($CH_{4\ recovered} + CH_{4\ oxidized}$ / $CH_{4\ produced}$) x 100

where:

$CH_{4\ produced} = CH_{4\ recovered} + CH_{4\ emitted} + CH_{4\ oxidized}$

RESULTS AND DISCUSSION

The results of methane emission measurements performed at the four MSW landfills in using static flux chambers and the VRPM approach are summarized in Table 2. Chamber measured methane fluxes ranged from -0.001 to 4.810 g m^{-2} d^{-1}, with an average of 0.970 g m^{-2} d^{-1}. VRPM measurements ranged from 1.08 to 41.53 g m^{-2} d^{-1}, with an average of 11.87 g m^{-2} d^{-1}. The methane flux results determined by static chambers were, with one exception, lower than the VRPM flux determinations. There was generally good agreement between static chamber and VRPM flux results for the September 2007 field campaign at Lancaster and the June 2008 testing at TriCities. VRPM flux estimates were substantially higher than the chamber-measured results for the DADS and Kirby Canyon landfills.

Methane oxidation values across the sampling campaigns ranged from 0 to 64% with a mean of 25%. The methane oxidation results reported as zero for the May sampling at DADS and both sampling events at Lancaster are explained by the fact that the amount of methane content in samples was insufficient to perform the analyses.

The average methane collection and control efficiencies calculated from VRPM flux measurements for each of the site campaigns are presented in Table 2. The collection efficiency values ranged from 72 to 92% across the sites averaging 83%. There was also relatively good agreement within measurements for each landfill. The range of the collection efficiency values are consistent other recent reports in the literature (Spokas et al., 2006). The methane control efficiency values were ranged from 79 to 92%, with an average of 85% illustrating the importance of adequately accounting for methane oxidation.

Collection and control efficiencies calculated from chamber measured fluxes are not presented here, however it is clear that they would on average be much higher than those calculated using the VRPM values.

Table 2. Summary Methane Emission and Collection and Control Efficiency Calculations

Site and Study Date	Chamber Flux ($g\ m^{-2}\ d^{-1}$)	VRPM Flux ($g\ m^{-2}\ d^{-1}$)	CH_4 Collected ($kg\ d^{-1}$)	Surface Area (ha.)	CH_4 Oxidation (%)	Collection Efficiency (%)	Control Efficiency (%)
DADS 5/2007	0.317	2.96	11,077	85	0*	82	82
DADS 10/2007	0.055	3.00	9,255	85	64	76	79
Lancaster 9/07	1.111	1.08	4,361	36	0*	92	92
Lancaster 1/08	0.017	4.70	7,333	36	0*	81	81
TriCities 2/2008	1.396	10.73	31,821	47	24	86	88
TriCities 6/2008	4.810	7.81	25,909	47	29	88	90
Kirby Canyon 1/2008	-0.001	23.13	22,886	18	21	84	87
Kirby Canyon 6/2008	0.056	41.53	19,777	18	62	72	84

**Flux results did not contain a sufficient CH4 content to determine methane oxidation.*

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