# Estimates of Methane Emissions from Three California Landfills using Two Measurement Approaches

**Extended Abstract # 89**

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## INTRODUCTION

Estimates of methane emissions from municipal solid waste (MSW) landfills have been typically derived from models of methane generation (based on the amount of organic waste deposited and climatic conditions), 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.[1] There are several logical 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 a relatively small number of comprehensive field studies that have been made 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.[2]

As the focus on GHG emissions inventorying and reporting moves from the international or national level to the facility level, understanding the accuracy of applying the modeling approach to individual facilities becomes increasing important. Recently, several studies have been undertaken to evaluate methods of measuring or modeling site specific methane emissions in order to develop methane budgets or inventories.[3,4,5,6]

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. In

2006 WM began using two measurement techniques to quantify methane emissions at 12 of its 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).[6] For this study, methane flux measurements were made using the vertical radial plume mapping (VRPM) approach with tunable diode lasers. This paper discusses the results of field measurements made during 2007 and 2008 using these two methods at three WM landfills located in California.

# METHODS

## Landfill Study Sites

Two week long field studies of methane emissions were made at the 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 landfills may be categorized as a typical large-scale MSW landfill that is currently receiving waste and has an active landfill gas collection system (LFGCS). The Lancaster landfill is located in an arid desert area, while the TriCities and Kirby Canyon sites are located in a more moderate or Mediterranean climate.

**Table 1.** Landfill Study Sites Detail

| Site | City | Coordinates | Study Dates |
|---|---|---|---|
| Lancaster | Lancaster | 34°44'52"N 118°07'13"W | 09/10/2007–09/14/2007<br>01/15/2008–01/18/2008 |
| TriCities | Fremont | 37°29'42"N 121°59'23"W | 02/12/2008–02/14/2008<br>06/23/2008–06/27/2008 |
| Kirby Canyon | Morgan Hill | 37°11'07"N 121°39'58"W | 01/29/2008–01/31/2008<br>06/09/2008–06/13/2008 |

## 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.[7] The summary flux results and

statistics presented here are based the arithmetic mean of all measurements. Chambers were placed in a systematic grid within the area being measured by the VRPM method to facilitate comparison.

## 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.

### *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.[8]

Recently, a simplified model for approximating the area contributing to flux based on the tracer release experiments has been proposed.[9] 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.

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

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

In determining unit flux rates, mass flux data were rejected if they were obtained 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 static chamber and 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 three MSW landfills in using static flux chambers and the VRPM approach are summarized in Table 2. In general the methane flux results determined by static chambers were with one exception lower than the VRPM flux determinations. There was remarkable agreement between static chamber and VRPM flux results for the September 2007 field campaign at Lancaster and the June 2008 testing at TriCities. Conversely, VRPM flux estimates were substantially higher than the chamber results for the Kirby Canyon landfill. One potential explanation may be that a majority of the emissions detected at the Kirby Canyon site by the VRPM method were released from above the surface of the landfill or outside of the four corner configuration area that was covered by the chamber grid.

The average methane collection 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 84%. These values are consistent other recent reports in the literature.[4] There was also relatively good agreement within measurements for each landfill. These values may reflect the more stringent emissions requirements in place in California as well as the lower emission potential of a drier climate. Similarly, the methane control efficiency values were also high ranging from 81 to 92% illustrating the importance of adequately accounting for methane oxidation.

| 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 (%) |
|---|---|---|---|---|---|---|---|
| Lancaster 9/07 | 1.111 | 1.08 | 4361 | 36 | 0 | 92 | 92 |
| Lancaster 1/08 | 0.017 | 4.70 | 7333 | 36 | 0 | 81 | 81 |
| TriCities 2/2008 | 1.396 | 10.73 | 31821 | 47 | 24 | 86 | 88 |
| TriCities 6/2008 | 4.810 | 7.81 | 25909 | 47 | 29 | 88 | 90 |
| Kirby Canyon 1/2008 | -0.001 | 23.13 | 22886 | 18 | 21 | 84 | 87 |
| Kirby Canyon 6/2008 | 0.056 | 41.53 | 19777 | 18 | 62 | 72 | 84 |


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