Appendix D

Evaluation of Landfill Gas Collection Efficiency

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A. Introduction

This appendix provides a brief overview of the methodology used to estimate the expected collection efficiency that can be reasonably achieved by a well-controlled landfill subject to the proposed regulation to reduce methane emissions from municipal solid waste landfills. As discussed in this staff report, the proposed regulation will provide enhanced control of methane emissions from municipal solid waste landfills by requiring the installation of gas collection and control systems at smaller and other uncontrolled landfills. The control measure also includes requirements for all affected landfills to ensure that gas collection and control systems are operating optimally and that fugitive emissions are minimized.

In order to better understand the proposed regulation's impact on collection efficiency, ARB staff evaluated the collection efficiency values for a well-controlled landfill in Palos Verdes, California by performing air dispersion modeling coupled with actual landfill surface gas measurements conducted by District staff. This landfill is owned and operated by the Los Angeles County Sanitation District (District). The District had previously evaluated the gas collection efficiency at this same landfill using actual surface gas measurements and U.S. EPA's air dispersion model – Industrial Source Complex (ISCST3). However, since U.S. EPA phased out the use of the ISCST3 model in 2006, ARB staff conducted the air dispersion modeling using U.S. EPA's new approved replacement model - AERMOD. Below a brief overview of the approach used to determine the landfill collection efficiency using AERMOD modeling and the previously collected landfill gas measurements at the Palos Verdes landfill.

B. Methodology

1. <u>Data Processing</u>

The following data were obtained from the District:

- Methane (CH_4) concentration measurements from the Palos Verdes landfill surface in irregular time periods, in parts per million (ppm)
- Landfill gas emission rate (as estimated from the collection system)
- Various modeling parameters (area dimension, emission rates, etc.)

ARB staff evaluated the data sets to ensure there were no outliers. Because the measurements were not taken continuously over a one-hour period, staff used the average of any measurements that occurred within the same hour, date, and month and to represent the entire hour for that specific day.

2. AERMET Modeling

The AERMOD model requires meteorological parameters to characterize air dispersion dynamics in the atmosphere. These parameters are estimated by AERMOD's supporting meteorological processing model, AERMET. The meteorological data used in the model were selected on the basis of representativeness and availability. Representativeness is determined primarily on whether the wind speed/direction distributions and atmospheric stability estimates generated through the use of a particular meteorological station (or set of stations) are expected to mimic those actually occurring at a location where such data are not available. Typically, the key factors for determining representativeness are proximity of the meteorological station and the presence or absence of nearby terrain features that might alter airflow patterns. For this study, 2003 meteorological data from the Los Angeles International Airport (LAX) was used. LAX is about one mile away from the Palos Verdes landfill. For the upper air conditions, San Diego-Miramar and Oakland International Airport are two full-time and reliable stations in California. As the Miramar station is much closer to the landfill, it was used in this study. After running AERMET, the hourly meteorological data for the full year of 2003 were created. The processed meteorological data, including surface and upper air, were filtered to retain only hours corresponding to times of the measurements. The filtered meteorological files were rearranged into a time period with consecutive hours.

3. AERMOD Modeling

The recently U.S. EPA approved air dispersion model - AERMOD, rather than ISCST3 (phased out on November 9, 2006), was used to estimate the CH_4 hourly concentrations within the landfill in the same time series order as the measurements. Key model parameters are as follows:

Model:	AERMOD
Run Mode:	hourly concentrations (in $\mu g/m^3$)
Model Option:	area source (polygons)
Dispersion Coefficients:	Urban and Rural
Modeling Domain:	800 m x 800 m
Modeling Resolution:	50 m x 50 m for 256 receptors
Receptor Setting:	Placing on center of each area source (1.5 in)
Meteorological Data:	Surface station - LAX (2003), Upper air - San Diego-Miramar (2003)

4. Calculations of CH_4 Gas Collection Efficiency Based on AERMOD

The modeled CH_4 concentration by AERMOD can be regarded as an equivalent concentration reduction in the landfill surface achieved by gas collection (CH_r) where the model estimates the emissions that are captured through the landfill extraction wells. Gas generation is expressed as the sum of the modeled reduction at the surface due to collection and the measured surface CH_4 (CH_m) due to emissions. Gas collection efficiency is then calculated by Equation 1:

$$E = \frac{CH_r}{CH_r + CH_m} \qquad (1)$$

5. Conversion of Mass Concentration to Volume Concentration

The outputs from AERMOD are reported as mass concentrations for CH_4 (in µg/m^3), while the measured CH_4 were reported as volume concentrations (in ppm). The conversion of mass concentration into volume concentration can be made by Equation 2 at a standard air pressure of one atm condition for CH_4:

$$C_{mass} = \frac{1.95 * 10^5}{T} x C_{ppm} \qquad (2)$$

where C_{mass} is the CH_4 mass concentration (in µg/m^3), C_{ppm} is the CH_4 volume concentration (in ppm), and T is the atmospheric air temperature (in Kevin). Note that all terms are also a function of time.

C. Results

1. Gas Collection Efficiency Derived from AERMOD Modeling

Table 1 presents the gas collection efficiency determined following Equation 1 and using the AERMOD modeled outputs and CH_4 measurements as inputs to the equation. Any hour with modeled zero concentration was not included in the analysis and the corresponding measurement during that hour was also not included. In addition, because there were hours in which there resulted negative CH_4 concentrations after subtracting the background concentration and being corrected for instrument bias, two sets of collection efficiency values are reported in Table 1 - the “collection efficiency” and the “corrected collection efficiency.” “Collection efficiency” represents the results without removing any hours that had negative concentrations of CH_4 and “corrected collection efficiency” represents the results after removing any hours that had negative CH_4 concentrations. As shown in Table 1, the results demonstrate a collection efficiency of about 85 percent for the gas collection system in the Palos Verdes landfill.

Table 1. Gas Collection Efficiency Derived from AERMOD Modeling

	CH4 Conc (ppm)	
	Urban	**Rural**
Measured LF Surface	2.498	2.498
Bias Correction	0.059	0.059
Actual LF Surface	2.557	2.557
Air Background	1.835	1.835
LF Conc (CHm)	0.722	0.722
Corrected LF Conc (CHm)*	**0.879**	**0.879**
Modeled Conc (CHr)**	4.873	4.748
Total Conc (CHr+CHm)	5.595	5.470
Corrected Total Conc (CHr+CHm)	**5.752**	**5.627**
Collection Efficiency	87.10%	86.80%
Corrected Collection Efficiency	**84.72%**	**84.38%**

Note:
1. The hours with measurements being less than the background were excluded for the analysis;
2. The hours with modeled zero concentrations were excluded for the analysis.

2. Distribution of Methane Concentrations over the Landfill

Figure 1 shows the spatial distribution of the modeled CH_4 concentrations over the landfill. The concentrations are averaged over the monitoring time period or all monitoring hours. The distribution is nearly uniform except near the landfill boundaries. This implies that the results are not sensitive to the locations of receptors within the landfill, and that the gas collection efficiency approach presented above based on the overall average measurements and average modeled concentrations is reasonable. In fact, a grid-by-grid analysis versus the overall average analysis showed a difference of about 1 percent (analysis not shown).

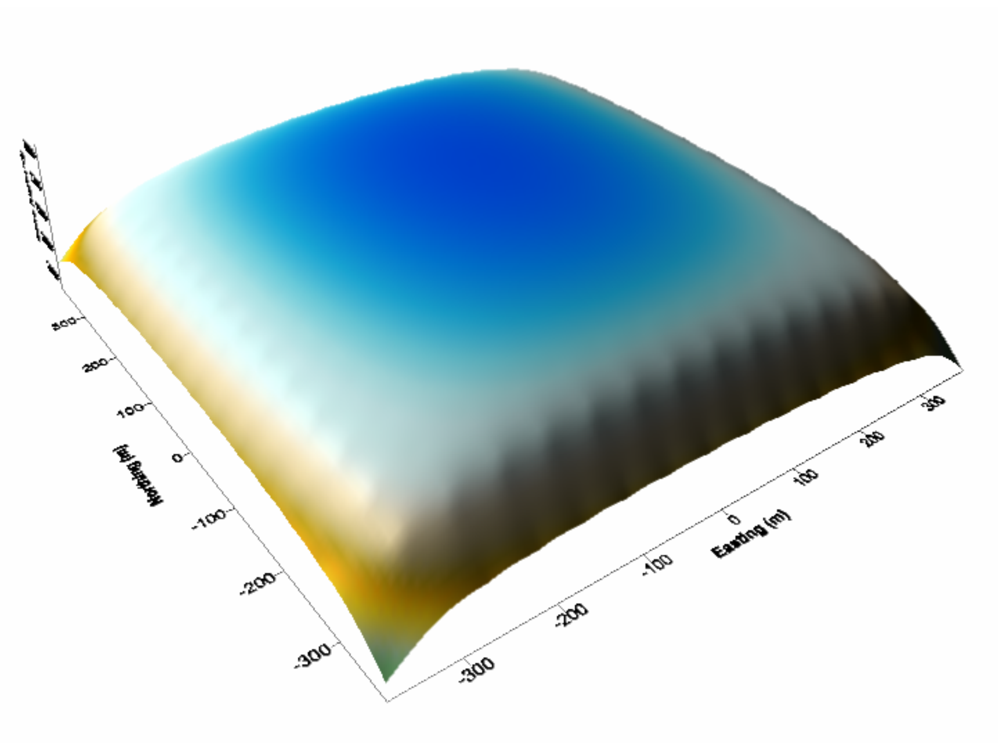

Figure 1. Spatial Distribution of the
Modeled CH_4 Concentration over the Landfill Surface

3. Distribution of Methane Concentrations Beyond the Landfill

To investigate how the CH_4 concentrations change with downwind distance outside of the landfill, a modeling run was conducted by placing the receptors along the central line of the domain in the predominate wind direction at distances of 0, 1, 5, 10, and 20 m from the landfill boundary. The modeled CH_4 concentrations are normalized to those that are located on the boundary and on the center of the modeling domain, respectively. The results are summarized in Figure 2. As shown in Figure 2, the CH_4 concentrations decrease with the downwind distance rapidly. At 10 meters, the CH_4 concentrations have decreased by about 40 percent and at 20 meters by about 60 percent compared with those at the boundary.

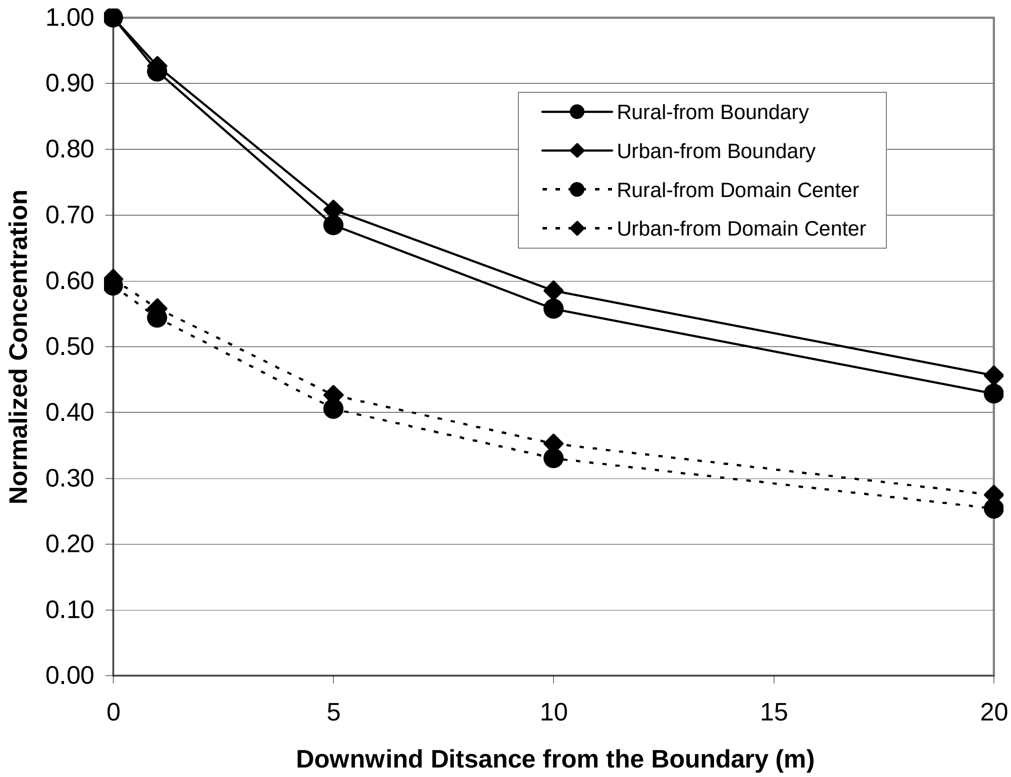

Figure 2. Normalized CH_4 Concentrations vs. Downwind Distances

4. <u>Distribution of Methane Concentrations over Receptor Heights</u>

To see how the modeled CH_4 concentrations change with receptor heights, we conducted a sensitivity study using AERMOD by placing receptors on the center of the modeling domain with different heights – 0, 0.5, 1, 2.5, 5, and 10 meters above the landfill surface. The results are normalized and presented in Figure 3. It is apparent that the setting of receptor heights plays an important role in determining the gas collection efficiency. For this study, the height of all receptors was placed in a height of 1.5 inches which was identical to the measurement height.

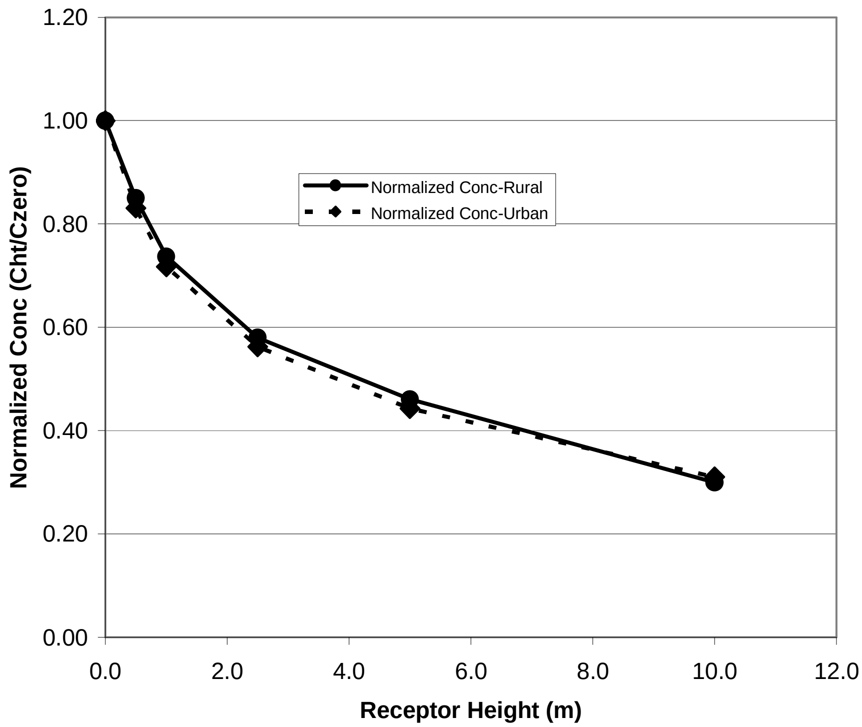

Figure 3. Normalized CH_4 Concentrations vs. Receptor Heights