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 (IS CST3). 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. Data Processing

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 µg/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),
4. **Calculations of CH\textsubscript{4} Gas Collection Efficiency Based on AERMOD**

The modeled CH\textsubscript{4} concentration by AERMOD can be regarded as an equivalent concentration reduction in the landfill surface achieved by gas collection (CH\textsubscript{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\textsubscript{4} (CH\textsubscript{m}) due to emissions. Gas collection efficiency is then calculated by Equation 1:

\[
E = \frac{CH_r}{CH_r + CH_m}
\]

(1)

5. **Conversion of Mass Concentration to Volume Concentration**

The outputs from AERMOD are reported as mass concentrations for CH\textsubscript{4} (in µg/m\textsuperscript{3}), while the measured CH\textsubscript{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\textsubscript{4}:

\[
C_{mass} = \frac{1.95 \times 10^5}{T} \times C_{ppm}
\]

(2)

where \(C_{mass}\) is the CH\textsubscript{4} mass concentration (in µg/m\textsuperscript{3}), \(C_{ppm}\) is the CH\textsubscript{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\textsubscript{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\textsubscript{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\textsubscript{4} and “corrected collection efficiency” represents the results after removing any hours that had negative CH\textsubscript{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

<table>
<thead>
<tr>
<th></th>
<th>CH4 Conc (ppm)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Urban</td>
</tr>
<tr>
<td>Measured LF Surface</td>
<td>2.498</td>
</tr>
<tr>
<td>Bias Correction</td>
<td>0.059</td>
</tr>
<tr>
<td>Actual LF Surface</td>
<td>2.557</td>
</tr>
<tr>
<td>Air Background</td>
<td>1.835</td>
</tr>
<tr>
<td>LF Conc (CHm)</td>
<td>0.722</td>
</tr>
<tr>
<td>Corrected LF Conc (CHm)*</td>
<td>0.879</td>
</tr>
<tr>
<td>Modeled Conc (CHi)**</td>
<td>4.873</td>
</tr>
<tr>
<td>Total Conc (CHr+CHm)</td>
<td>5.595</td>
</tr>
<tr>
<td>Corrected Total Conc (CHr+CHm)</td>
<td>5.752</td>
</tr>
<tr>
<td>Collection Efficiency</td>
<td>87.10%</td>
</tr>
<tr>
<td>Corrected Collection Efficiency</td>
<td>84.72%</td>
</tr>
</tbody>
</table>

**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.

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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).
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.
4. Distribution of Methane Concentrations over Receptor Heights

To see how the modeled CH\textsubscript{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