San Joaquin Valley
**Air Pollution Control District**

Organic Material Composting and Drying
focusing on

# Greenwaste Compost

## Air Emissions Data Review

# Report

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# Executive Summary

Useful information regarding air emissions from compost sites can be obtained by assessing the flux (mass transfer from the test surface) of hydrocarbon compounds and other compounds such as ammonia, and then expressing these data as emission factors. An emission factor is obtained by taking representative flux data for an operable unit at a compost site, such as a greenwaste in windrow, multiplying the average flux from the windrow by the surface area of the windrow, and generating an emission factor (mass emitted per time per source). These data can be expressed on a per ton basis, and the site air emissions can be obtained by summing the emission per operable unit, which are obtained by multiplying the mass or surface area of each unit by the respective emission factor. As such, the goal of any air pathway analysis intended to assess air emissions from a compost facility, is to obtain representative emission factor data.

The focus of this research effort is to provide to the District a report of relevant and useful emission factors that can be used in the regulatory process to assess air emissions from a variety of compost facilities. Compost emission factor data from 14 reports were reviewed and prioritized for data quality and completeness. These data consisted of emissions test data from greenwaste, biosolids-greenwaste co-composting, and food waste. All the reports were summarized and critiqued with the individual critiques attached in this report's appendix. A summary table was prepared by San Joaquin Valley Air Pollution Control District (SJVAPCD) staff and is provided in the same attachment.

This report is focused on total VOC emissions as measured by South Coast Air Quality Management District (SCAQMD) Method 25.3. This method is a comprehensive total VOC method and is generally not comparable to other total VOC methods including USEPA Method 25 series and USEPA Method TO-12. Ammonia and some methane data is reported as well, but in general is not discussed further. All VOC data reported here, unless otherwise noted, is VOC per SCAQMD Method 25.3.

The green waste composting data was looked at specifically for data that would be both complete and accurate enough to provide a rule making basis. Three data sets were found to be both complete enough and used the appropriate sampling an analytical methods to generate full site emissions. However, one of the data sets did not have stockpile emissions.

The data from these greenwaste composting sites is summarized below in Table ES 1. The data are averaged for reference only with no implication that the average is representative of green waste compost emissions for the SJVAPCD jurisdiction. The California Integrated Waste Management Board's (CIWMB) values are from their Modesto report and were recalculated to be more comparative to the other data (see attached Technical Memorandum). The emission factor was calculated by taking the total process emissions and dividing that by the mass of material that was in the compost process. For most situations, a facility can estimate their annual emissions using these factors by multiplying the factor times the total annual throughput (compost substrate and amendment). All mass values are for input, not output. There is normally significant mass loss during the composting process.

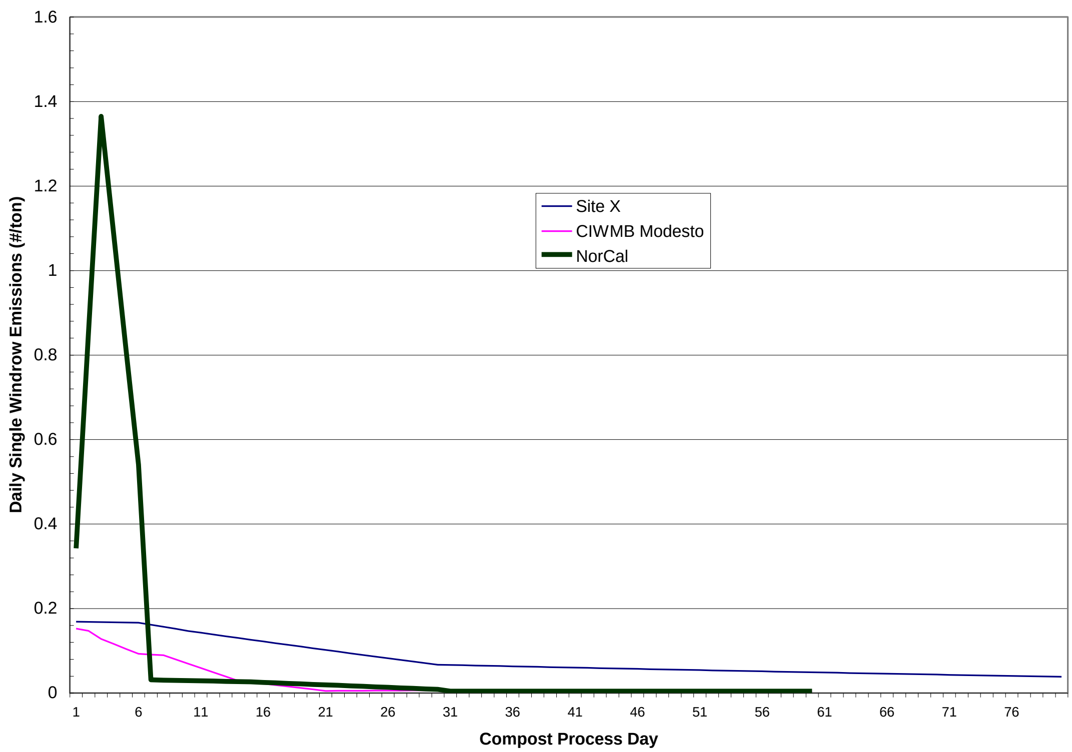
**Table ES 1 Summary of greenwaste composting full site VOC emission data (#/ton of feedstock).**

| Source | Site X | CIWMB | NorCal | Average |
|---|---|---|---|---|
| Stockpile | 7.76 | | 2.95 | 5.36 |
| Windrow | 6.30 | 1.54 | 5.65 | 4.50 |
| Total | 14.06 | | 8.60 | 9.85 |

These data are even more diverse than this table may indicate. Figure ES-1 shows the daily compost windrow emissions for each of these data sets. The NorCal profile particularly shows a unique characteristic initial cycle VOC spike.

There were other important data sets. The CIWMB Tierra Verde data shows the likely range of unit flux values that will be encountered in California green waste composting facilities. These values bracket the data from the three complete sites suggesting that the complete sites may represent the likely working range of emissions from these types of sites.

**Figure ES 1 VOC emission profile for each of the three complete data sets (#VOC/ton feedstock per compost day).**



SCAQMD emission factors, currently the only official regulatory values, are briefly discussed noting that they mostly represent stockpile emissions and not compost emissions. The compost emissions from their data appear unrealistically low and are significantly outside the bounds of all the other data sets.

The most relevant food waste composting data was from only one site and provided emissions for various covered compost technologies. The food waste compost technologies were Ag-Bag®, Compostex®, and micropore covers. These cover technologies are described in more detail in the report text. Food waste windrow emission factors ranged from 1.7 to 36.7 pounds VOC per ton of throughput. Food waste stockpile emission factors ranged from 0.42 to 1.8 pounds VOC per ton of throughput.

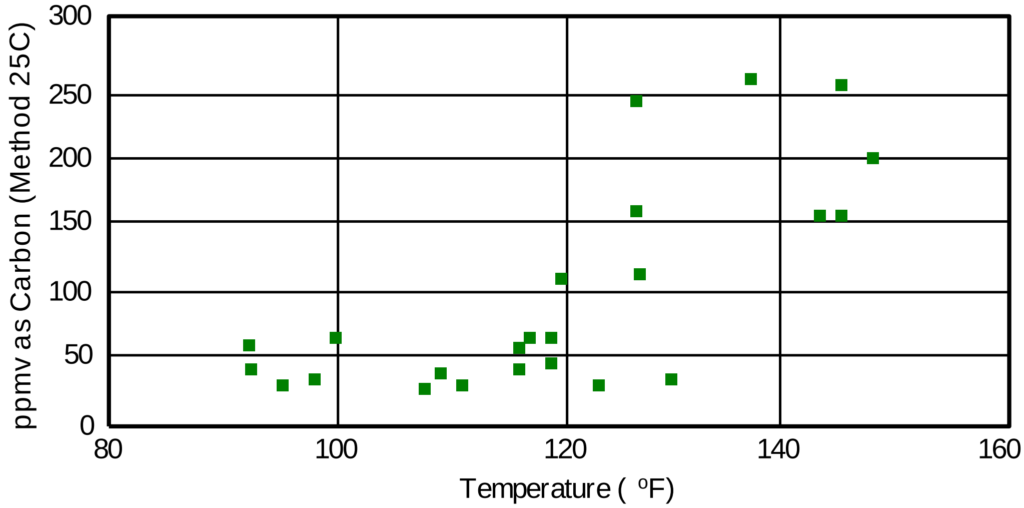
The most relevant biosolids composting data came from two sites. A third site (Las Virgenes) was reported but did not present complete system emissions. One of the sites (LACSD) reported data from both on top of, and underneath, a micropore cover system. The under the cover measured emissions are likely not representative of a normal uncovered process because the affect that the cover has temperature and moisture. In addition, this was a pilot scale facility. The other site was a compliance test for a very large aerated static pile biosolids facility near Bakersfield. The biosolids composting emission factors ranged from 0.2 to 3.7 pounds VOC per ton of total (biosolids plus amendment) throughput.

There is some discussion in this report as to why there is a large variability of emissions found in the compost industry. There are several reasons for this:

- Regional differences is feed stock materials processed at compost facilities
- Seasonal differences in feed stock materials
- Seasonal metrological differences
- Differences in operating procedures and facility management practices
- Size and age of feedstock piles
- Size, shape and orientation of windrows to dominant wind direction
- Solid waste handling equipment
- Control of parameters in the composting process such as aeration or mixing, water content, and temperature
- Compost composition, specifically ratio of carbon-to-nitrogen

The most significant sources of variability in emission factors is likely mostly due to windrow size, feedstock characteristics, waste pile and windrow temperature, and operating characteristics. There was not sufficient data to determine the magnitude of most of these variables, including seasonal emissions variability. Said another way, it is not possible to generate seasonal emission factors for these sources. Seasonal variability likely has both a temperature and feedstock component, which further complicates the determination of emission factor as a function of variable. There has been some previous work showing that the carbon–nitrogen ratio significantly affects air emissions, but again, insufficient information is available to define this effect. Temperature has been studied and there are some data available showing increased air emissions or greater emission factors with increased compost temperature as shown below. This figure shows how temperature affected VOC emissions from an aerated static pile composting biosolids in Philadelphia (Hentz *et al* 1996).

**Figure ES 2 The effect of pile temperature on VOC emissions (from Hentz et al 1996).**




The data set can not at this time be used to assess the impact of these variable on emission factors or compost site air emissions expressed on an annual basis. However, these limited data do justify the range of emission factors reported herein.

In summary, this report serves to:

1) Present the status quo of the industry air emission data base for the Central Valley;
2) Define the range of emission factors measured;
3) Define the key variables that effect air emissions from compost facilities;
4) Describe current and recommended testing protocols used to assess air emissions at compost facilities;
5) Provide an annotated bibliography of the relevant research with commentary on testing protocols, frequency of sample collection, analytical method, and emission factor generation; and
6) Present the emission factors supported by the data base.

# 1.0 Introduction

This report provides a comprehensive review of greenwaste composting air emissions data with focus on total hydrocarbon and ammonia emissions. Methane emissions are also presented to a limited extent. The report also presents some limited data on composting biosolids and food waste.

All raw data and original data reports were provided by San Joaquin Valley Air Pollution Control District (SJVAPCD) Staff. Since the method of analysis of total hydrocarbon is regulatory important, and SJVAPCD has adopted South Coast Air Quality Management District (SCAQMD) Method 25.3 as their standard, data is limited to recently tested California sources.

# 2.0 Background

The air emissions assessment of composting operations is both complicated and resource intensive. Composting can take place either in windrows or in aerated static piles (ASP). Windrows are naturally ventilated and normally mechanically turned on a process schedule. Typical compost windrow dimensions are 3 to 7 feet high, 8 to 20 feet wide, and 50 to 500 feet long. ASP's are large piles that are 8 to 16 feet high with plan form areas of 2,500 to 25,000 $ft^2$. They are normally underlain with an air distribution system that provides air by either suction or pressure. There also are some hybrid technologies that use a cover on a windrow that also have forced air ventilation systems. Most, if not all, greenwaste in California is composted in windrows that are mechanically turned.

A normal compost cycle lasts from 45 to 90 days. Most greenwaste is on a 60 day cycle. The first half of the cycle can be designated as composting and the last half as curing.

In addition to the windrows, there are also material stockpiles on composting sites that store feedstock and product. The size of these stockpiles is widely variable and is a significant factor in overall site emissions variability.

The emissions from these facilities are difficult to quantify. The emissions from a windrow change daily over the compost cycle. Testing is conducted using approved area source assessment technologies with the goal of collecting representative flux data (mass per time-area) that can be used to calculate emission factors for sources found on compost sites, or operable units (e.g., feed stock piles, windrows, product piles, etc.) Emission factors from operable units or sources are expressed as emissions per ton of materials received, and these data are used to estimate emissions (mass per time) for the facility on an annual basis.

Figure 2.1 shows a daily emissions profile from windrow greenwaste composting. In order to generate this curve, the windrow has to be sampled on several of the 60 process days. As shown on the curve, this sampling should be more intensive at the start of the compost cycle because most of the emissions occur at the start of the cycle and the daily emissions are the most temporally variable. In windrows that are less well mixed there can be significant spatial variability as well. For each compost day, from 2-to-8 individual samples should be taken to assure that the spatial variability is accommodated.

Emissions from these sources tend to be variable. The likely important factors in variability are seasonal temperatures, feedstock variability (regionally and seasonally), and operating parameters. Not a lot is known about how these factors affect emissions. The only quantitative data available are the affects that pile temperature has on VOC emissions. Figure 2.2 shows how temperature affected VOC emissions from an aerated static pile composting biosolids in Philadelphia (Hentz *et al* 1996).

**Figure 2.1 Example daily emissions from a greenwaste composting windrow (VOC and ammonia).**

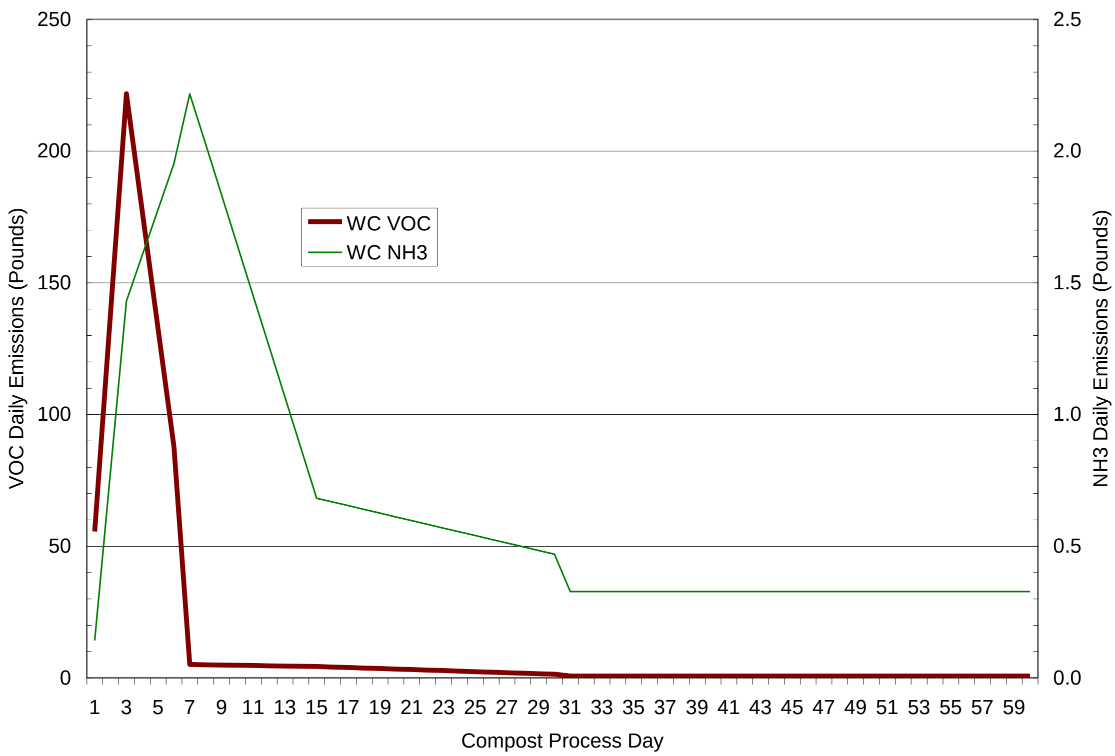
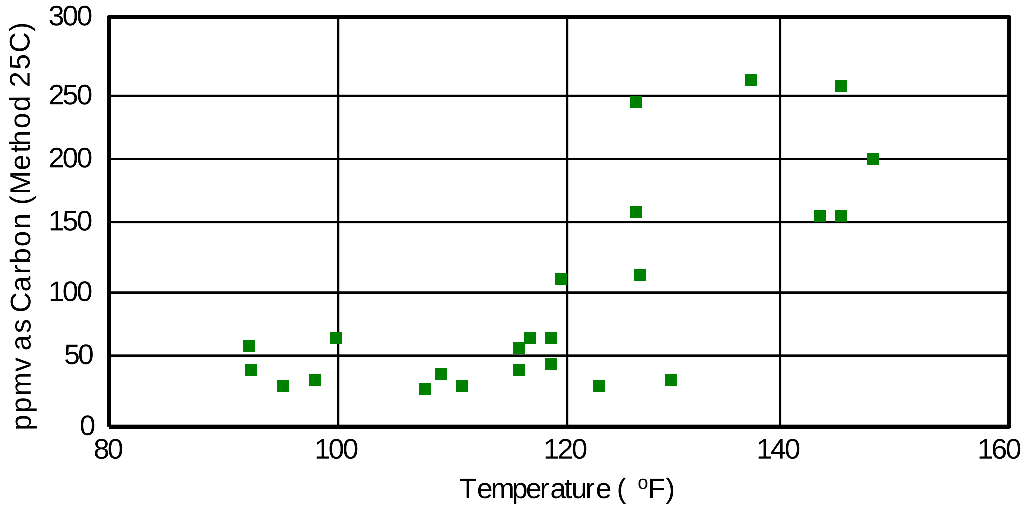


**Figure 2.2 The effect of pile temperature on VOC emissions (from Hentz et al 1996).**




## 3.0 Data Evaluation Methodology

This section covers the methodology for the sampling phase of the air emissions assessment and how the data sets were evaluated.

### *Target Species*

The selection of target species was evaluated as best representing VOC emissions. For compost sites, all work was compared to SCAQMD Method 25.3 since it has been shown that this method is capable of collecting and analyzing for all condensable and volatile hydrocarbon species believed to exist on greenwaste, food waste, and biosolids compost facilities. Data representativeness will be discounted in the review for other methods, including SCAQMD 25.1 and USEPA Method TO-15 as compared to SCAQMD Method 25.3.

### *Sample Collection Methods*

As demonstrated by the SCAQMD and indicated in Rule 1133, the preferred method for sample collection or assessment of compound emissions from sources at compost sites is the SCAQMD Modified USEPA surface emission isolation flux chamber technology. All the research reviewed used this technology except one, and this work (Hanaford Compost Site) was discounted as non-applicable and non-representative. On occasion, the USEPA technology was used without the SCAQMD modification, in which case a bias in emission may have been encountered.

### *Analytical Methods*

The appropriate analytical methods for this research are SCAQMD Method 25.3 for VOCs (or total non-methane non-ethane organic compounds) and SCAQMD Method 207.1 for ammonia. Other methods fall short and are identified as such.

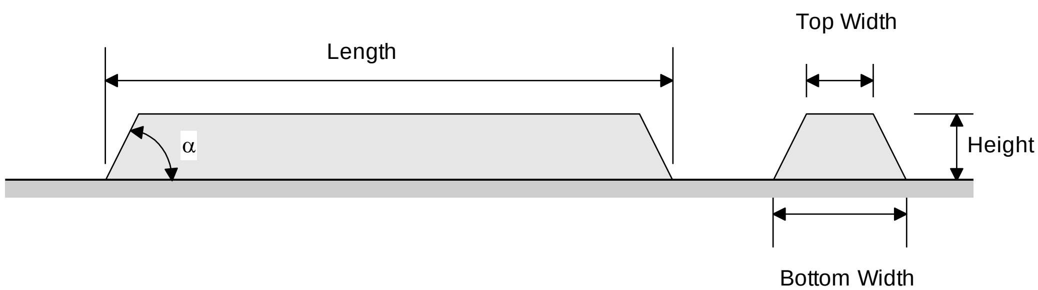
# 4.0 Emission Factor Development

Once the unit flux data has been obtained, the full cycle emissions are then estimated by the following procedures.

## *4.1 Compost Pile Configuration*

Compost pile dimensions have a high degree of variability. However, they all match the shape shown in Figure 4.1. The key property for the configuration is the surface area to volume ratio. Figure 4.2 shows how this varies for different cross sections. There is over a factor of two difference in surface area to volume ratio between shallow and deep windrows. For the same unit surface flux rate, the smaller row will have twice the emissions on a per ton input basis.

**Figure 4.1. – Compost Windrow Configuration.**




**Mensuration formulas**

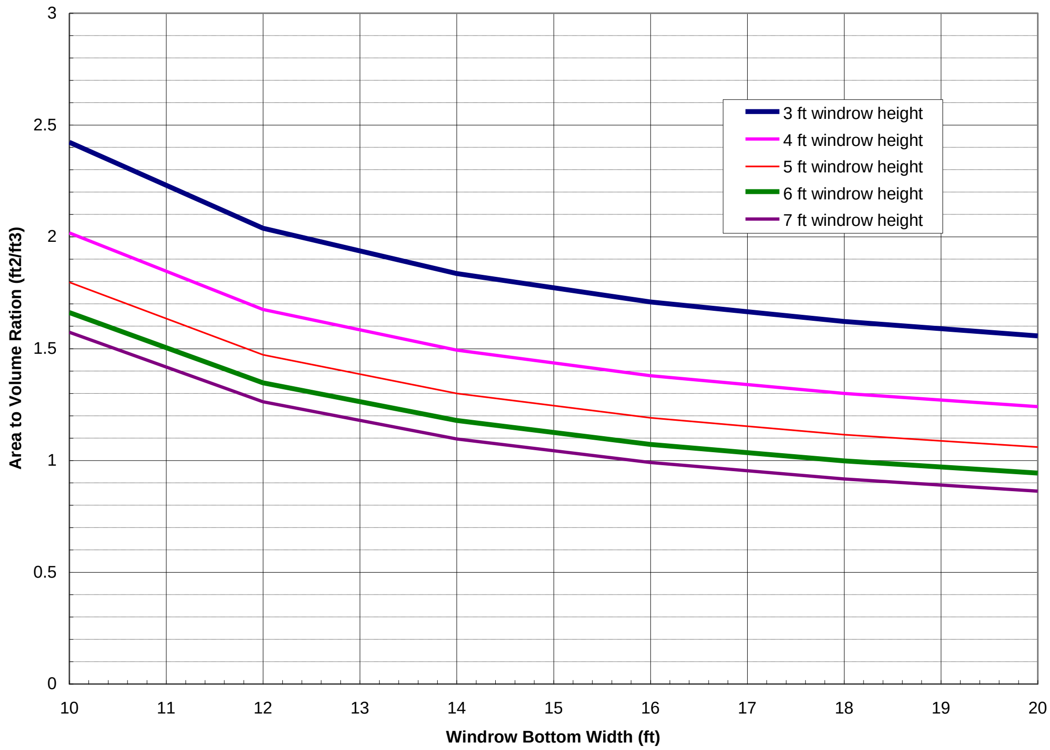
$$S = \frac{p_1 + p_2}{2} s + A_2$$

$$V = \frac{h(A_1 + A_2 + \sqrt{A_1 A_2})}{3}$$

$$s = \sqrt{h^2 + ((W_B - W_T)/2)^2}$$

where S = total surface area, $p_1$ = bottom perimeter, $p_2$ = top perimeter, s = slant height, V=volume, h=vertical height, $A_1$ = bottom area, $A_2$ = top area, α = bottom angle

**Figure 4.2. – Range of area to volume ratios for typical windrow cross-section dimensions.**




### *4.2 Full Compost Cycle Simulation*

The unit emission data should be extended to estimate emissions from the full compost cycle using linear interpolation and averaging. Full cycle emissions for each day of the compost process, should then added and the sum of the individual daily emissions should be totalized. The emission factor consists of the full total cycle emissions (in pounds) divided by the incoming feedstock weight (in tons).

### *4.5 Emissions from Feedstock and Product Storage*

The emissions from feedstock and product storage typically are calculated by taking unit flux data (apportioned to different types of materials) and multiplying by the average annual storage surface area. For some data sets, there was more area in storage than in windrows.

## 5.0 Most Relevant Green Waste Compost Data

This section presents the data found to be most relevant in characterizing greenwaste emissions in the State of California. Table 5.1 presents a summary of this data in both an emission factor and unit emission rate form. The paragraphs below discuss the data points in detail.

**Table 5.1 Summary of most relevant green waste composting data.**

| | | | VOC | | | | | | | NH3 | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | EF | Unit Flux (mg/min-m2) | | | Unit Flux (#/hr-1,000ft2) | | | EF | Unit Flux (mg/min-m2) | | | Unit Flux (#/hr-1,000ft2) | | |
| **Location** | **Material** | **Activity** | **(#/ton)** | **Peak** | **Avg** | **Min** | **Peak** | **Avg** | **Min** | **(#/ton)** | **Peak** | **Avg** | **Min** | **Peak** | **Avg** | **Min** |
| Site X | Landscape | Stockpiles | 7.76 | 186 | 111 | 37 | 2.30 | 1.38 | 0.46 | 0.03 | 0.62 | 0.39 | 0.16 | 0.01 | 0.00 | 0.002 |
| | Waste | Windrows | 6.30 | 23 | 11 | 3 | 0.29 | 0.13 | 0.04 | 2.34 | 26.56 | 12.07 | 0.20 | 0.33 | 0.15 | 0.003 |
| | | Total | 14.06 | | | | | | | 2.37 | | | | | | |
| CIWMB Modesto | | Windrows | 1.54 | 42 | 9 | 0.1 | 0.51 | 0.11 | 0.001 | | | | | | | |
| NorCal | | Stockpiles | 2.95 | 110 | 54 | 4 | 1.36 | 0.66 | 0.046 | 0.08 | 2.1 | 1.21 | 0.61 | 0.03 | 0.01 | 0.008 |
| | | Windrows | 5.65 | 376 | 73 | 1 | 4.65 | 0.90 | 0.010 | 0.54 | 7.29 | 1.68 | 0.22 | 0.09 | 0.02 | 0.003 |
| | | Total | 8.60 | | | | | | | 0.62 | | | | | | |
| CIWMB TV | | Mix HCN | | 124 | 42 | 2 | 1.53 | 0.52 | 0.02 | | | | | | | |
| | | Mix LCN | | 443 | 110 | 1 | 5.48 | 1.36 | 0.02 | | | | | | | |
| | | UnMix HCN | | 23 | 6 | 1 | 0.28 | 0.07 | 0.01 | | | | | | | |
| | | UnMix LCN | | 38 | 10 | 1 | 0.47 | 0.13 | 0.01 | | | | | | | |
| SCAQMD Inland Summer | | Stockpiles | 4.75 | | 24 | | | 0.30 | | 0.01 | | 6.55 | | | 0.081 | |
| | | Windrows | 0.3 | | 6 | | | 0.08 | | 1.31 | | 0.32 | | | 0.004 | |
| | | Total | 5.05 | | | | | | | 1.32 | | | | | | |
| SCAQMD Inland Winter | | Stockpiles | 1.96 | | 20 | | | 0.25 | | 0.29 | | 2.67 | | | 0.033 | |
| | | Windrows | 0.5 | | 6 | | | 0.08 | | 0.03 | | 0.32 | | | 0.004 | |
| | | Total | 2.47 | | | | | | | 0.32 | | | | | | |

## 5.1 Confidential Site (Site X)

This is the most recent data set, taken in the Spring of 2008. This is a confidential source composting greenwaste in the SJVAPCD. The data set consists of about 20 measurements, all collected with the newly modified SCAQMD flux method and acceptable laboratory method and practice. This site had large stockpiles with about one half the emissions coming from the stockpiles. The stockpiles had about 50% of the surface area as the windrows. The windrow emissions from this site were about an order of magnitude (10 times) the emissions measured by the SCAQMD in 2001, but were not the highest measured of this data group. The site was very well operated with significant attention to process control. This site uses very small windrows with a high surface area to volume ratio.

## 5.2 California Integrated Waste Management Board (CIWMB) Modesto

This data set was taken in 2006 using the current state of the art methods for that time. The emission factor in this table (1.5 # VOC per ton) was recalculated to better represent the other projects and is about twice the factor presented in their report (see attached TM). Note that the average unit flux value is the same as Site X (about 10 mg/min-$m^2$), but the emissions are a factor of 4 lower. This is due to a combination of the larger windrows used on this site and the rapid fall off of emissions after initial composting. This was also a well run site. The data set consisted of 36 measurements.

## 5.3 NorCal Waste Systems

This site is located near Vacaville, CA. The data was taken in 2006. It is a well operated site with larger windrows. The data set consisted of a total of 12 measurements, which is a small number for use in estimating life-cycle emissions. This site had VOC emissions that were about four times greater than the CIWMB Modesto report. The average flux rate was about eight times higher.

## 5.4 CIWMB Tierra Verde

This data was not sufficient to develop a full site emission factor. What it does provide is a range of unit flux rates for the various process management strategies tested, including carbon/nitrogen ratio and mixing. These average unit flux values, ranging from 6 to 100 mg/min-$m^2$, completely bracket the previous data sets and appear to provide a valid range of emission rates for the greenwaste composting process. However, the data are insufficient to draw specific conclusions about mixing because there could be high emissions from either handling or stockpiling compost from the non-mixed process.

## 5.5 SCAQMD Data

The SCAQMD data are provided purely for reference. However, it should be noted that the windrow emissions are extremely small (5 times lower than CIWMB Modesto) and most of the emission factor is from stockpiles. The windrow data is derived from a total of four measurements.

## 5.6 Discussion

Figure 5.1 presents the daily emission profile for VOC for the three sites that had complete data. Note that the NorCal emissions are dominated by a severe emissions peak that occurred early in the process followed by lower emissions that the other sources immediately after the peak.

Table 5.2 presents a summary of the valid data points with the average value shown. This does not imply that the average value is representative, is only shown for reference.

**Table 5.2 Summary of greenwaste VOC emission factors (#/ton feedstock).**

| Source | Site X | CIWMB | NorCal | Average |
|---|---|---|---|---|
| Stockpile | 7.76 | | 2.95 | 5.36 |
| Windrow | 6.30 | 1.54 | 5.65 | 4.50 |
| Total | 14.06 | | 8.60 | 9.85 |

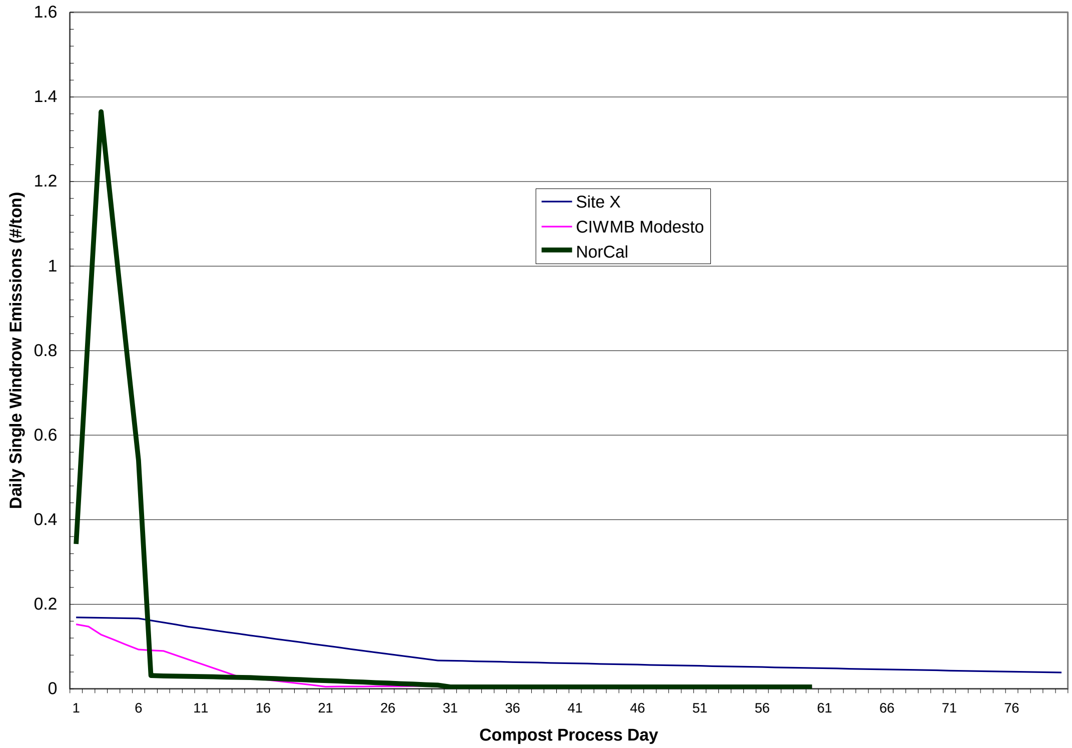



**Figure 5.1 Daily VOC emissions profile from Site X, CIWMB Modesto, and NorCal.**

# 6.0 Most Relevant Food Waste Compost Data

This section presents the data found to be most relevant in characterizing food waste emissions in the State of California. Table 6.1 presents a summary of this data in both an emission factor and unit emission rate form. The paragraphs below discuss the data points in detail.

All the food waste data was taken from the NorCal site near Vacaville, CA. The emissions data consists of very comprehensive tests on four food waste composting technologies. All the data utilized SCAQMD Method 25.3 and used the current state of the art flux chamber techniques at the time of the sampling.

The first technology tested was the use of the AgBag® vessel reactor. This consists of a polyethylene bag encapsulated compost windrow that has a small amount of forced air (100 – 300 cfm) into it. The bag is vented by small (5 cm dia) port placed every 20 feet along the bags length on each side. The compost cycle consists of 30 days in the bag and then 30 days of curing out of the bag. During the cure phase, the windrow is mixed every three days using the standard Rotoshredder/Scarab windrow mixer.

The second technology used was the Compostex cover technology. This consists of a standard windrow that is placed and mixed, then covered with the Compostex®

polypropylene cover. The cover is very porous, but does supply insulation and some water retention.

**Table 6.1 Summary of most relevant food waste composting data.**

| | | | VOC | | | | | | | NH3 | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | EF | Unit Flux (mg/min-m2) | | | Unit Flux (#/hr-1,000ft2) | | | EF | Unit Flux (mg/min-m2) | | | Unit Flux (#/hr-1,000ft2) | | |
| **Location** | **Technology** | **Activity** | **(#/ton)** | **Peak** | **Avg** | **Min** | **Peak** | **Avg** | **Min** | **(#/ton)** | **Peak** | **Avg** | **Min** | **Peak** | **Avg** | **Min** |
| NorCal | AgBag | Stockpile | 0.42 | 9 | 4 | 0.5 | 0.12 | 0.06 | 0.01 | 0.02 | 1.05 | 0.39 | 0.03 | 0.01 | 0.01 | 0.000 |
| | | Windrow | 36.7 | 9,603 | 1,729 | 1 | 119 | 21.38 | 0.01 | 0.7 | 98.84 | 13.82 | 0.01 | 1.22 | 0.17 | 0.000 |
| | | Total | 37.1 | | | | | | | 0.7 | | | | | | |
| | Compostex | Stockpile | 1.5 | 31 | 12 | 0.33 | 0.38 | 0.15 | 0.00 | 0.002 | 0.02 | 0.01 | 0.01 | 0.000 | 0.000 | 0.000 |
| | | Windrow | 25.4 | 899 | 143 | 0.4 | 11.11 | 1.76 | 0.01 | 8.1 | 173 | 12 | 0.01 | 2.14 | 0.15 | 0.000 |
| | | Total | 26.9 | | | | | | | 8.1 | | | | | | |
| | Micropore 30 | Stockpile | 1.8 | 27 | 13 | 8 | 0.34 | 0.17 | 0.10 | 0.1 | 6.48 | 1.45 | 0.10 | 0.08 | 0.02 | 0.001 |
| | | Windrow | 9.0 | 195 | 32 | 0.1 | 2.41 | 0.39 | 0.00 | 14.1 | 370 | 21.3 | 0.00 | 4.57 | 0.26 | 0.000 |
| | | Total | 10.8 | | | | | | | 14.2 | | | | | | |
| | Micropore 45 | Stockpile | 1.7 | 27 | 13 | 8 | 0.34 | 0.17 | 0.10 | 0.1 | 6 | 1 | 0.1 | 0.08 | 0.02 | 0.001 |
| | | Windrow | 1.7 | 622 | 33 | 0.1 | 7.70 | 0.40 | 0.00 | 1.3 | 56.4 | 2.87 | 0.00 | 0.70 | 0.04 | 0.000 |
| | | Total | 3.4 | | | | | | | 1.4 | | | | | | |

The last two technologies were micropore covers. These covers are expanded polytetrafluoroethylene (PTFE) membranes encased in a polyester protective covering. The pore size of the PTFE membrane is controlled to maximize oxygen transfer while minimizing water vapor loss. This pore size is a barrier to most non-methane hydrocarbons but not in general to ammonia. The cover provides an opportunity for superior process control due to weather protection and moisture control. The covering system is substantially more costly than the Compostex® system. For the micropore cover system, two cases were evaluated. The first case was for covering the windrow for 30 days, followed by a 30 day uncovered cure period. The second case was for covering the windrow for 45 days, followed by a 15 day cure period. Both cure periods had mechanical mixing every three days. While covered, the micropore windrow received about 300 cfm of forced air on a 10 minute on/20 minute off cycle.

There is really no baseline/no control data for food waste. All the data consists of some level of control technology. The micropore cover system provides the highest level of control at the highest cost. From a regulatory standpoint at NorCal, the AgBag technology was considered baseline. Note that for food waste, better process control that lowers VOC emissions may actually increase ammonia emissions.

# 7.0 Most Relevant Biosolids Compost Data

This section presents the data found to be most relevant in characterizing biosolids composting emissions in the State of California. Table 7.1 presents a summary of this data in both an emission factor and unit emission rate form. The paragraphs below discuss the data points in detail.

**Table7.1 Summary of most relevant biosolids composting data.**

| | | | VOC | | | | | | | NH3 | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | EF | Unit Flux (mg/min-m2) | | | Unit Flux (#/hr-1,000ft2) | | | EF | Unit Flux (mg/min-m2) | | | Unit Flux (#/hr-1,000ft2) | | |
| Location | Technology | Activity | (#/ton) | Peak | Avg | Min | Peak | Avg | Min | (#/ton) | Peak | Avg | Min | Peak | Avg | Min |
| LACSD/ Cedar Grove | Uncovered | ASP | 3.7 | 74 | 15 | 0.3 | 0.92 | 0.46 | 0.00 | 4.6 | 200 | 27.94 | 1.56 | 2.47 | 1.24 | 0.019 |
| | Micropore | ASP | 0.2 | 21 | 2.9 | 0.3 | 0.26 | 0.13 | 0.003 | 1.8 | 279 | 17.72 | 1.40 | 3.44 | 1.73 | 0.02 |
| SKIC | ASP/Biofilter | Whole Site | 0.2 | 3.0 | 0.8 | 0.2 | 0.04 | 0.010 | 0.002 | 0.1 | 5 | 1.81 | 0.18 | 0.06 | 0.02 | 0.002 |
| SCAQMD Las Virgenes | | Biofilter In | 0.8 | | 3.1 | | | 0.04 | | 0.7 | | 2.9 | | | 0.04 | |

There were only four biosolids data sets that utilized a VOC test method (SCAQMD 25.1/25.3) that would provide meaningful regulatory data for SJVAPCD. All biosolids composting utilizes some bulking agent or amendment that is almost always greenwaste. So essentially almost all biosolids composting is co-composting with greenwaste.

Three data sets do not really represent baseline/uncontrolled emissions. The Cedar Grove data set utilized an under-the-cover measurement to establish control efficiency for a micropore cover system. The micropore cover does influence the entire compost process so even the under the cover measurement is likely lower in emissions than an uncovered pile or windrow. The Las Virgenes data is from a compost structure, so it represents the uncontrolled emissions from composting in a building, not outdoor composting.

The SKIC data set is from a compliance test at the South Kern Industrial Complex near Bakersfield. The facility was a very large aerated static pile (ASP) facility that had induced air flow controlled by biofilters.

The Cedar Grove data is from the test of a micropore cover for Los Angeles County Sanitation District's biosolids from the Joint Water Pollution Control Plant in Carson, CA. The actual test occurred in Everett, Washington at a facility that was designed to compost greenwaste under micropore covers. As mentioned earlier, under the cover measurements were utilized to estimate cover control efficiency. However, it is unlikely that an uncovered system would perform even as well as the under the cover micropore system. This is because the micropore system offers many process control advantages including weather protection and water retention.

# 8.0 References

Hentz Jr, L. H., W. E. Toffey, and C. E. Schmidt. 1996. **Understanding the Synergy Between Composting and Air Emissions.** BioCycle. 37(3):67-75.

# Appendix A
# SJVAPCD Literature Table
# and
# Individual Report Summaries

# *TECHNICAL MEMORANDUM*

Date: May 9 2008
To: SJAQMD Staff
From: CE Schmidt

RE: Annotated Bibliography in Support of the SJVAPCD Greenwaste Baseline Composting Document

The core documents collected and reviewed by the SJVAPCD staff supporting the baseline document preparation as foundational to the proposed Rule 4566 have been reviewed with a focus on: project objective, sample collection technology, analytical methodology, and representativeness of the reported and tabulated flux or emission rate data. Each of the research reports has been reviewed, and an annotated bibliography has been prepared, and is contained herein.

The purpose of this effort was to provide council to the SJVAPCD staff with regard to using the available information regarding the compost industry in rule making. A companion document has been prepared in a similar vein with regard to the flux data use in these documents, emission calculation algorithm and assumptions used in the process, and the overall usability of the emission rate data. These two documents, constitutes the contracted support to the SJVAPCD staff for the purpose of rule making.

The annotated bibliographies are provided as an attachment to this memorandum.

Note that three studies have been added to the reference list for your review.

CE Schmidt

SUMMARY OF ANNOTATED BIBLIOGRAPHY ATTACHMENTS

**SITE:** Cedar Grove Composting, Everett, WA;
**TITLE:** "Full Scale Evaluation of Gore Technology On LACSD Biosolids at Cedar Grove Composting, Everett, WA"

**SITE:** Inland Composting and Organic Recycling Facility, Colton, CA; City of LA Anchorage Green Material Facility, San Pedro, CA; City of LA Van Norman Green Material Mulching Facility, San Fernando Valley, CA, and Scholl Canyon Landfill Site (alternative daily cover application)
**TITLE:** "Air Emissions Tests Conducted at Green Material Processing Facilities"

**SITE:** Jepson Prairie Organics Compost Facility, Vacaville, CA
**TITLE:** "Air Emissions Source Test- Emissions Evaluation of Complete Compost Cycle VOC and Ammonia Emissions"

**SITE:** City of Modesto Compost Facility, Modesto, CA
**TITLE:** "Emissions Testing of Volatile Organic Compounds from Greenwaste Composting at the Modesto Compost Facility in the San Joaquin Valley"

**SITE:** Inland Empire Composting, Colton, CA
**TITLE:** "Ammonia and Volatile Organic Compound (VOC) Emissions From A Greenwaste Composting Facility "

**SITE:** Westlake Farms Co-Composting Facility, Stratford, CA
**TITLE:** "Assessment of Volatile Organic Compound and Ammonia Emissions from a Bulking Agent Stockpile"

**SITE:** Intravia Rock and Sand, Inc. Upland, CA
**TITLE:** "Ammonia and Volatile Organic Compound (VOC) Emissions From A Non-Curbside Greenwaste Chipping and Grinding Facility "

**SITE:** Rancho Las Virgenes Municipal Water District, Calabasas, CA
**TITLE:** "Characterization of Ammonia, Total Amine, Organic Sulfur Compound, and Total Non-Methane Organic Compound Emissions from Composting Operations "

**SITE:** Little Hanaford Farms, Centralaia, WA
**TITLE:** "Technical Support Document Little Hanaford Farms"

**SITE:** EKO Systems, Corona, CA
**TITLE:** "Characterization of Ammonia, Total Amine, Organic Sulfur Compound, and Total Non-Methane Organic Compound (TGNMOC) Emissions From Composting Operations "

**SITE:** San Joaquin Composting, Inc, Lost Hills, CA
**TITLE:** "Characterization of Ammonia, Total Amine, Organic Sulfur Compound, and Total Non-Methane Organic Compound (TGNMOC) Emissions From Composting Operations "

**SITE:** Tierra Verde Industries, Irvine, CA
**TITLE:** "Technical Report- Best Management Practices for Greenwaste Composting Operations: Air Emissions Tests vs. Feedstock Controls and Aeration Techniques"

**SITE:** Jepson Prairie Organics Compost Facility, Vacaville, CA
**TITLE:** "Jepson Prairie Organics Facility Compostex Cover System- Air Emissions Report"

**SITE:** Jepson Prairie Organics Compost Facility, Vacaville, CA
**TITLE:** "Jepson Prairie Organics Facility Micropore Cover System- Air Emissions Report"

**SITE:** South Kern Industrial Complex (SKIC) LLC, Taft, CA
**TITLE:** "SKIC Air Emissions Compliance Report"

# ***SJVAPCD ANNOTATED BIBLIOGRAPHY FACT SHEET***

## COMPOST TYPE: Biosolids

**SITE:** Cedar Grove Composting, Everett, WA

**PAPER TITLE:** "Full Scale Evaluation of Gore Technology On LACSD Biosolids at Cedar Grove Composting, Everett, WA"

**AUTHORS:** Tom Card, CE Schmidt

**DATE:** August, 2007 (testing conducted 01/07 to 03/07)

## PROJECT OBJECTIVE:
Evaluate VOC and ammonia emissions for biosolids composting using the Gore micropore/ASP cover system, and to determine the control efficiency for the cover system.

## FACILITY OPERATIONS:
Cedar Grove composting utilizes a three-phase compost operation with a 28 day active phase (covered), a 13 day maturation phase (covered ) and a 14 day cure phase (uncovered).

## TARGET SPECIES:
Methane, ethane, $CO_2$, CO, Total non-methane organic carbon (condensable and volatile), and ammonia.

## SAMPLE COLLECTION METHODS:
SCAQMD Modified (6" port, tracer) USEPA surface emission isolation flux chamber.

## ANALYTICAL METHODS:
SCQAMD Method 25.3, SCAQMD Method 207.1, and USEPA Method TO-14/GC-ECD for the tracer $SF_6$.

## SCOPE OF WORK:
Over 100 flux measurements conducted over a 43-day time period. Test locations were selected to represent side and top of pile with test locations, and top and side under the cover test locations. Testing was conducted on head space under the cover, from flux chambers under the cover, on the cover (top and side locations), during phase transitions and mixed compost, on cover seams, and repeat testing on different portions of the covered compost.,

Phase 1, Day 2- three flux tests on cover per round per day, two rounds, two buried flux
Phase 1, Day 4- Same, plus full replicate tests

Phase 1, Day 7- Same
Phase1, Day 14- Same
Phase 1,Day 28- Same
Transition P1/P2- breakdown compost, mixed compost, covered compost tests; multiple
Phase 2, Day 1- Same as covered
Phase 2, Day 13- Same as covered
Phase 3, Day 1- Same as covered

## QC DATA:

Work plan was prepared and is available.
Adequate frequency of blank, replicate, and repeat samples are reported.
QC data indicated overall acceptable method performance.

## FINDINGS:

Biosolids Uncontrolled test pile)- 1.8 #VOC/ton and 4.0 #NH3/ton

Fugitive Emissions with Gore Cover- 0.2 #VOC/ton and 1.8 #NH3/ton

Note- Uncontrolled emissions, as well as the control efficiency estimate reference measurements taken from two flux chambers under the cover during the life-cycle testing effort.

## CONCLUSIONS:

The appropriate sample collection and analytical techniques were employed, with the exception that recent SCAQMD Modified USEPA flux chamber techniques were not used (redesigned sweep air inlet system and stack testing in extended stack), although the flow rates were probably low enough so that the sample collection technique was not biased.

## COMMENTS:

Climatic conditions may have influenced the composting operations, in particular the beginning of the cycle. The LACSCD biosolids arrived in a semi-frozen state, and this may have hampered complete mixing of the biosolids with bulking agent, and delayed the starting of the composting process. The cool winter weather with light precipitation for the area probably had little effect on the composting operations. The testing effort was not hampered by the weather.

## *SJVAPCD ANNOTATED BIBLIOGRAPHY FACT SHEET*

**COMPOST TYPE: Greenwaste**

**SITE:** Inland Composting and Organic Recycling Facility, Colton, CA; City of LA Anchorage Green Material Facility, San Pedro, CA; City of LA Van Norman Green Material Mulching Facility, San Fernando Valley, CA, and Scholl Canyon Landfill Site (alternative daily cover application)

**PAPER TITLE:** "Air Emissions Tests Conducted at Green Material Processing Facilities"

**AUTHORS:** CIWMB Brenda Smyth, CE Schmidt

**DATE:** February 22, 2002 (testing conducted 12/03/01, 12/06/01, and 12/07/01)

**PROJECT OBJECTIVE:**
Evaluate baseline VOC and ammonia emissions for greenwaste composting operations in the SCAQMD.

**FACILITY OPERATIONS:**
All three compost facilities receive, grind, static pile compost, and screen product in similar fashion. The landfill uses greenwaste mulch as alternative daily cover.

**TARGET SPECIES:**
Methane, ethane, CO2, CO, and Total non-methane organic carbon (condensable and volatile), and ammonia.

**SAMPLE COLLECTION METHODS:**
USEPA surface emission isolation flux chamber, standard chamber. Side-by-side open path optical remote sensing by SCAQMD at the Inland Empire

**ANALYTICAL METHODS:**
NMAM 6015 for ammonia, EPA Method 25C for methane and TNMHC, Method TO-15 for VOC species, and SCQAMD Method 25.3 for condensable and non-condensable organic compounds (by SCAQMD Lab).

**SCOPE OF WORK:**
Inland Composting and Organics Recycling Facility
14 Flux chamber tests: raw greenwaste, Day 17 compost, Day 45 compost, Day 90 overs material, screened product fines.
Anchorage Facility
18 Flux chamber tests: Day 1 compost, Day 3 compost, and Day 7 compost, Day 14 compost, Day 28 compost, Day 80 compost, Day 90 overs.

Van Norman Facility
24 Flux chamber tests: Day 1 compost, Day 3 compost, Day 5 compost (raw, coarse mulch, fine mulch, superfine mulch)

## QC DATA:

Work plan was prepared and is available.
Adequate frequency of blank samples reported; no replicate samples.
QC data indicated overall acceptable method performance.

## FINDINGS:

Greenwaste- 0.186 #VOC/hr-1000ft2 and 0.002 #NH3/hr-1,000ft2 (mean values for the collective data set).

Note- The frequency of testing is limited in that there are many different area sources in a compost cycle and life cycle emission estimates must include operational considerations, spatial variability, and time-dependent emissions per source. 54 data points collected at three different facilities does not constitute a robust program.

## CONCLUSIONS:

The appropriate sample collection and analytical techniques were employed, with the exception that recent SCAQMD Modified USEPA flux chamber techniques were not used (redesigned sweep air inlet system and stack testing in extended stack), although the flow rates were probably low enough so that the sample collection technique was not biased. The use of the flux data, estimate of surface area, and representativeness of the emissions estimate should be reviewed.

## COMMENTS:

The results of these test show much lower ammonia emissions and lower VOC emissions from facilities located in the SCAQMD area compared the SCAQMD published values of 0.224 #VOC/hr-1,000ft2 and 0.091 #NH3/hr-1,000ft2 from the Inland Empire site. This is suggested to be related to the difference in seasonal flux and the analytical methods: higher emissions in the summer and more compound detection with SCAQMD Method 25.3 as compared to Method 25C.

# *SJVAPCD ANNOTATED BIBLIOGRAPHY FACT SHEET*

## COMPOST TYPE: Food Waste with Ag Bag Cover and Greenwaste

**SITE:** Jepson Prairie Organics Compost Facility, Vacaville, CA

**PAPER TITLE:** "Air Emissions Source Test- Emissions Evaluation of Complete Compost Cycle VOC and Ammonia Emissions"

**AUTHORS:** Tom Card, CE Schmidt

**DATE:** May, 2006 (testing conducted 08/23/05 to 08/25/05)

## PROJECT OBJECTIVE:
Evaluate VOC and ammonia site wide baseline emissions for food waste composting using the Ag Bag cover system and the static greenwaste windrow compost system.

## FACILITY OPERATIONS:
Jepson Prairie Organics Compost facility utilizes a two-phase compost operation with a 30-day active phase (food waste in the Ag Bag, covered) and ASP system, and a 30 day cure phase (uncovered).

## TARGET SPECIES:
Methane, ethane, $CO_2$, CO, Total non-methane organic carbon (condensable and volatile), and ammonia.

## SAMPLE COLLECTION METHODS:
SCAQMD Modified (6" port, tracer) USEPA surface emission isolation flux chamber.

## ANALYTICAL METHODS:
SCQAMD Method 25.3, SCAQMD Method 207.1, and USEPA Method TO-14/GC-ECD for the tracer $SF_6$.

## SCOPE OF WORK:
Over 46 flux measurements conducted over a 3-day time period.  Test locations were selected to represent Ag Bag ports, and the side and top of curing or greenwaste piles. Receiving and finish was also tested.

Food Waste/Ag Bag
Phase 1 Compost, Day 1- Two flux tests on bag ports
Phase 1, Compost, Day 4- Same
Phase 1, Compost, Day 5- Same
Phase 1, Compost, Day 8- Same
Phase 1, Compost, Day 10- Same

Phase 1, Compost, Day 22- Same
Phase 1, Compost, Day 30- Same
Phase 2, Cure, Day 0 unmixed, one flux test
Phase 2, Cure, Day 3, unmixed and mixed- three flux tests
Phase 2, Cure, Day 7- unmixed, one flux test
Phase 2, Cure, Day 10, unmixed and mixed- two flux tests
Phase 2, Cure, Day 13- one flux test
Phase 2, Cure, Day 19, unmixed and mixed- two flux tests
Phase 2, Cure, Day 25- one flux test
Phase 2, Cure, Day 31, unmixed and mixed- two flux tests
Finish- three flux tests

Greenwaste Static Pile
Phase 1, Compost, Day 3- one flux test
Phase 1, Compost, Day 6- Same
Phase 1, Compost, Day 7- three flux tests
Phase 1, Compost, Day 15- one flux test
Phase 1, Compost, Day 30- Same
Phase 2, Cure, Day 50 unmixed, one flux test
Finish- three flux tests

Phase 3, Day 1- Same as covered

## QC DATA:

Work plan was prepared and is available.
Adequate frequency of blank, replicate, and repeat samples are reported.
QC data indicated overall acceptable method performance.

## FINDINGS:

Food Waste in Ag Bag- 37 #VOC/ton and 0.7 #NH3/ton

Static Pile Greenwaste Composting- 14 #VOC/ton and 0.5 #NH3/ton

## CONCLUSIONS:

The appropriate sample collection and analytical techniques were employed, with the exception that recent SCAQMD Modified USEPA flux chamber techniques were not used (redesigned sweep air inlet system and stack testing in extended stack), although the flow rates were probably low enough so that the sample collection technique was not biased.

## COMMENTS:

The Ag Bag showed very low emissions during the in-vessel phase with little emissions from the open ports and little effect by the blower fans. Most of the emissions occurred during the curing phase. The greenwaste static pile was occasionally watered and mixed.

## ***SJVAPCD ANNOTATED BIBLIOGRAPHY FACT SHEET***

**COMPOST TYPE: Greenwaste and Greenwaste with Food Waste**

**SITE:** City of Modesto Compost Facility, Modesto, CA

**PAPER TITLE:** "Emissions Testing of Volatile Organic Compounds from Greenwaste Composting at the Modesto Compost Facility in the San Joaquin Valley"

**AUTHORS:** Brenda Smyth, Fatih Buksonamez, CE Schmidt

**DATE:** October 31, 2007 (testing conducted 10/19/06 to 12/14/06)

### PROJECT OBJECTIVE:
Evaluate baseline VOC emissions during greenwaste composting and greenwaste that includes food waste, and to assess VOC emissions reduction potential of Best Management Practices (BMP) including application of a finished compost blanket on top of the greenwaste windrow and application of two chemical additives to greenwaste windrow.

### FACILITY OPERATIONS:
City of Modesto- 250 to 300 tons of greenwaste per day, some paper and residential food waste; 30 acre site with maximum 500 tons per day capacity. Greenwaste source is residential, landscape business, and municipal pruning. The process is static composting in windrows: greenwaste is tipped on a concrete pad, processed in a grinder, shaped in windrows, and mixed by Scarab-type turner approx. once per week with infrequent watering.

### TARGET SPECIES:
Methane, ethane, CO2, CO, and Total non-methane organic carbon (condensable and volatile) with CO used as a tracer species.

### SAMPLE COLLECTION METHODS:
SCAQMD Modified (6" port, tracer) USEPA surface emission isolation flux chamber.

### ANALYTICAL METHODS:
SCQAMD Method 25.3.

### SCOPE OF WORK:
Over 100 flux measurements conducted over a 57-day time period. Test locations were selected to represent bottom, middle and top of pile with test locations selected by real time instrument data.

Greenwaste (control test pile)

Day 1- Three-to-four flux tests per pile per day
Day 2- Same
Day 3- Same
Day 6- Same
Day 8- Same
Day 14- Same
Day 21- Same
Day 30- Same
Day 44- Same
Day 57- Same
Greenwaste with 15% food waste- Same

Greenwaste capped with finished compost blanket- Same

Greenwaste inoculated with two chemical additives- Same

## QC DATA:

Work plan was prepared and is available.
Adequate frequency of blank samples reported; no replicate samples.
QC data indicated overall acceptable method performance.

## FINDINGS:

Greenwaste (control test pile)- 0.8 to 0.9 #VOC/ton

Greenwaste with 15% food waste- 1.3 to 2.6 #VOC/ton

Greenwaste capped with finished compost blanket- 0.1 to 0.4 #VOC/ton

Greenwaste inoculated with two chemical additives- 0.5 to 0.6 #VOC/ton

Note- surface area of vented sources estimated at 10% for all piles except biofilter finish-covered pile, which was estimated by screening to be 1% to 2%. Fall season and frequent site watering my have influenced the flux data.

## CONCLUSIONS:

The appropriate sample collection and analytical techniques were employed, with the exception that recent SCAQMD Modified USEPA flux chamber techniques were not used (redesigned sweep air inlet system and stack testing in extended stack), although the flow rates were probably low enough so that the sample collection technique was not biased. The use of the flux data, estimate of surface area, and representativeness of the emissions estimate should be reviewed.

## COMMENTS:

None.

# ***SJVAPCD ANNOTATED BIBLIOGRAPHY FACT SHEET***

## COMPOST TYPE: Greenwaste

**SITE:** Inland Empire Composting, Colton, CA

**PAPER TITLE:** "Ammonia and Volatile Organic Compound (VOC) Emissions From A Greenwaste Composting Facility "

**AUTHORS:** SCAQMD, Wayne Stredwick

**DATE:** Testing conducted 09/27/01 and 10/04/01)

## PROJECT OBJECTIVE:
Evaluate VOC and ammonia emissions during greenwaste composting including: tipping pile, static piles, and windrows.

## FACILITY OPERATIONS:
The site processes 350 tons of greenwaste per day. The waste is received and stored up to two days, stored in a static pile after grinding for up to 14 days, placed in windrow for up to 45 days and screened. The process is static composting in windrows: greenwaste is tipped on a concrete pad, processed in a grinder, shaped in windrows, and mixed by Scarab-type turner approx. once per week with infrequent watering.

## TARGET SPECIES:
Methane, ethane, $CO_2$, CO, and Total non-methane organic carbon (condensable and volatile) with helium used as a tracer species and ammonia.

## SAMPLE COLLECTION METHODS:
SCAQMD Modified (6" port, 10% helium tracer) USEPA surface emission isolation flux chamber.

## ANALYTICAL METHODS:
SCQAMD Method 25.3 and SCAQMD Method 207.1.

## SCOPE OF WORK:
Over 30 flux measurements conducted over a two-day time period.
Tipping pile- 10 tests; 0-2 day old tested.
Static piles- 10 tests; 7 day old tested.
Windrow- 10 tests; day 7 and day 30 tested.

## QC DATA:
It is not known if a work plan was prepared or is available.

Blank samples and replicate sample data were not reported or commented on, with the exception of problems encountered. Note that all 25.3 samples were taken in duplicate as per the method.

## FINDINGS:

| | **Ammonia** | **Methane** | **TNMNEOC** |
|---|---|---|---|
| | (lb/hr-1000ft2) | (lb/hr-1000ft2) | (lb/hr-1000ft2) |
| Tipping Pile | 0.091 | 0.079 | 0.368 |
| Static, Fines and ADC Pile | 0.071 | 0.024 | 0.226 |
| Windrow | 0.004 | 0.005 | 0.079 |
| Site Total (lb/ton) | 1.32 #/ton | 0.83 #/ton | 5.05 #/ton |

## CONCLUSIONS:

The appropriate sample collection and analytical techniques were employed including the SCAQMD Modified USEPA flux chamber technique. No discussion was provided about specific surface area testing, designation of sub area per type of source, and no QC data was provided. The use of the flux data, estimate of surface area, and representativeness of the emissions estimate should be reviewed.

## COMMENTS:

None.

# ***SJVAPCD ANNOTATED BIBLIOGRAPHY FACT SHEET***

## COMPOST TYPE: Bulking Agent Stockpile

**SITE:** Westlake Farms Co-Composting Facility, Stratford, CA

**PAPER TITLE:** "Assessment of Volatile Organic Compound and Ammonia Emissions from a Bulking Agent Stockpile"

**AUTHORS:** LACSD, CH2MHill, Tom Card, CE Schmidt

**DATE:** April 27, 2005 (testing conducted 03/24/ 2005)

## PROJECT OBJECTIVE:
Evaluate VOC and ammonia emissions for the Westlake Farms Co-Composting site bulking agent, shredded almond wood waste (orchard waste).

## FACILITY OPERATIONS:
The Westlake Farms Co-Composting facility ATC includes utilizing orchard waste as a bulking agent for a negative ASP/biofilter biosolids composting operation. The emissions from the bulking agent are part of the site emissions estimate.

## TARGET SPECIES:
Methane, ethane, CO2, CO, Total non-methane organic carbon (condensable and volatile), ammonia, and total hydrocarbon species.

## SAMPLE COLLECTION METHODS:
USEPA surface emission isolation flux chamber (standard chamber design- no significant advective flow from the source) and tracer recovery (CO).

## ANALYTICAL METHODS:
SCQAMD Method 25.3, SCAQMD Method 207.1, and USEPA Method TO-12. Real time instrument data was used to select sample collection from test locations (FID/PID) and CO tracer recovery.

## SCOPE OF WORK:
Eight flux measurements were conducted over a 1-day time period, where four of the eight locations were selected for sample collection by Methods 25.3 and 207.1. All screening data was similar, and based on field screening data the two highest flux and the two lowest flux locations were selected for testing.

## QC DATA:
Work plan was prepared and is available.
Adequate frequency of blank, replicate, and repeat samples are reported.

QC data indicated overall acceptable method performance.

## FINDINGS:

Static Pile Flux- 0.00000073 #VOC/hr,ft-1 and 0.0000000079 #NH3/hr,ft-1

Advective flow was calibrated based on a field test that generated recovery of CO tracer (36%) from a thin layer of wood chips divorced from the static pile (not composting).

## CONCLUSIONS:

The appropriate sample collection and analytical techniques were employed. The SCAQMD Modified USEPA flux chamber techniques were not used given that advective flow was not anticipated. All data were at or below MDL for the methods and the emissions could potentially overestimate the emissions from the source based on demonstrated adsorption of the CO tracer species. The non-detect TO-14 results supported the very low/non-detect Method 25.3 results.

## COMMENTS:

The flux from the orchard waste showed very low VOC and even lower ammonia emissions.

# ***SJVAPCD ANNOTATED BIBLIOGRAPHY FACT SHEET***

## COMPOST TYPE: Greenwaste

**SITE:** Intravia Rock and Sand, Inc. Upland, CA

**PAPER TITLE:** "Ammonia and Volatile Organic Compound (VOC) Emissions From A Non-Curbside Greenwaste Chipping and Grinding Facility "

**AUTHORS:** SCAQMD, Mei Wang

**DATE:** Testing conducted 07/12/02)

**PROJECT OBJECTIVE:**
Evaluate VOC and ammonia emissions during greenwaste composting including: tipping pile, static piles, and windrows.

**FACILITY OPERATIONS:**
The site receives non-curbside greenwaste, stores the wastes, grinds the waste, and ships the waste off site. Composting is not conducted on site. The material stays on site for about 30 days. Little information was available regarding the site operations.

**TARGET SPECIES:**
Methane, ethane, CO2, CO, and Total non-methane organic carbon (condensable and volatile) with helium used as a tracer species and ammonia.

**SAMPLE COLLECTION METHODS:**
SCAQMD Modified (6" port, 10% helium tracer) USEPA surface emission isolation flux chamber.

**ANALYTICAL METHODS:**
SCQAMD Method 25.3 and SCAQMD Method 207.1.

**SCOPE OF WORK:**
Over 20 flux measurements conducted over a one-day time period.
Tipping pile- 10 tests.
Ground material pile- 10 tests.

**QC DATA:**
It is not known if a work plan was prepared or is available.
Blank samples and replicate sample data were not reported or commented on. Note that all 25.3 samples were taken in duplicate as per the method.

**FINDINGS:**

| | **Ammonia** | **Methane** | **TNMNEOC** |
|---|---|---|---|
| | (lb/hr-1000ft2) | (lb/hr-1000ft2) | (lb/hr-1000ft2) |
| Tipping Pile | 0.0030 | 0.0029 | 0.228 |
| Ground Piles | 0.0006 | 0.0097 | 0.153 |
| Site Total (lb/ton) | 0.017 #/ton | 0.058 #/ton | 1.5 #/ton |

## CONCLUSIONS:

The appropriate sample collection and analytical techniques were employed including the SCAQMD Modified USEPA flux chamber technique. No discussion was provided about specific surface area testing, designation of sub area per type of source, and no QC data was provided. The use of the flux data, estimate of surface area, and representativeness of the emissions estimate should be reviewed.

## COMMENTS:

None.

# *SJVAPCD ANNOTATED BIBLIOGRAPHY FACT SHEET*

## COMPOST TYPE: Biosolids Bulked with Wood Chips

**SITE:** Rancho Las Virgenes Municipal Water District, Calabasas, CA

**PAPER TITLE:** "Characterization of Ammonia, Total Amine, Organic Sulfur Compound, and Total Non-Methane Organic Compound Emissions from Composting Operations "

**AUTHORS:** SCAQMD, Carey Willoughby

**DATE:** Testing conducted 12/19/95 and 12/20/95)

### PROJECT OBJECTIVE:
Verify the flux chamber sampling method for assessing emission from compost operations, and evaluate air emissions from the biosolids compost operations.
Method verification was accomplished by flux testing on the compost in an enclosed building, then comparing those emissions to the mass loading on the biofilter inlet line from the enclosure.

### FACILITY OPERATIONS:
The site receives dewatered biosolids, mixes the biosolid waste with wood chips, constructs windrows on subsurface vents in an enclosure structure, supplies positive air flow to the piles for 45 days, and collects the enclosure air and runs the air through a biofiltration system.

### TARGET SPECIES:
Methane, Total non-methane organic carbon (condensable and volatile) with helium used as a tracer species and ammonia, $CO_2$, $O_2$, amines, and organic sulfur compounds.

### SAMPLE COLLECTION METHODS:
SCAQMD Modified (6" port, 10% helium tracer) USEPA surface emission isolation flux chamber.

### ANALYTICAL METHODS:
SCQAMD Method 25.1, SCAQMD Method 207.1, and non-specified methods for total amines and organic sulfur.

### SCOPE OF WORK:
Over 34 flux measurements conducted over a two-day time period.
Flux chamber testing on compost windrows in one cell or area, 17 locations per day, two days.
Simultaneous biofilter (replicate) inlet testing for the facility.

## QC DATA:

It is not known if a work plan was prepared or is available.
Blank samples and replicate sample data were not reported or commented on.

## FINDINGS:

| **Source** | **Ammonia** | **Methane** | **TNMOC** | **CS** |
|---|---|---|---|---|
| | (lb/hr-1000ft2) | (lb/hr-1000ft2) | (lb/hr-1000ft2) | (lb/hr-1000ft2) |
| Inlet Sampling | 0.036 | 0.025 | 0.038 | 0.038 |
| Flux Chamber on Compost | 0.012 | NA | NA | NA |
| Site Total (lb/ton) | 0.70 #/ton | 0.50 #/ton | 0.76 #/ton | 0.69 |

## CONCLUSIONS:

The appropriate sample collection and analytical techniques were employed including the SCAQMD Modified USEPA flux chamber technique. No discussion was provided about specific surface area testing, designation of sub area per type of source, and no QC data was provided. The use of the flux data, estimate of surface area, and representativeness of the emissions estimate should be reviewed.

The conclusion from the technical team indicated that the USEPA flux chamber method, for a variety of reasons, was 'the preferred method' for estimating and comparing emissions from compost sites.

## COMMENTS:

None.

## *SJVAPCD ANNOTATED BIBLIOGRAPHY FACT SHEET*

### COMPOST TYPE: Waste material- not specified

**SITE:** Little Hanaford Farms, Centralaia, WA

**PAPER TITLE:** "Technical Support Document Little Hanaford Farms"

**AUTHORS:** Clint Lamoreaux, Southwest Clean Air Agency

**DATE:** April, 2005 (testing conducted 08/04)

### PROJECT OBJECTIVE:
Comply with permit requirements.

### FACILITY OPERATIONS:
75,000 Ton per year static pile windrow composting operation that receives solid waste of unspecified type and origin and produces compost and soil amendments.

### TARGET SPECIES:
Eight amines plus ammonia, two sulfur compounds, and eight oxygenated compounds are listed. No total VOC.

### SAMPLE COLLECTION METHODS:
None specified.

### ANALYTICAL METHODS:
None specified.

### SCOPE OF WORK:
None provided. Emission rate data provided as final number for amines, two sulfur compounds, ammonia, and a short list of oxygenated compounds. Sample collection technique not specified. Sample count and sampling strategy not specified. Analytical method not specified.

### QC DATA:
None provided.

### FINDINGS:
VOC Emissions factor- 0.10 #VOC/ton and 0.062#$NH_3$/ton

Note- No method information, scope of work or test data was provided. These findings provide no useful information. Discount this reference.

## CONCLUSIONS:

No useful information is provided.  Discount this reference.

## COMMENTS:

You have to be kidding me!

# ***SJVAPCD ANNOTATED BIBLIOGRAPHY FACT SHEET***

## COMPOST TYPE: Biosolids (20%) and Manure (80%)

**SITE:** EKO Systems, Corona, CA

**PAPER TITLE:** "Characterization of Ammonia, Total Amine, Organic Sulfur Compound, and Total Non-Methane Organic Compound (TGNMOC) Emissions From Composting Operations "

**AUTHORS:** SCAQMD, Carey Willoughby

**DATE:** Testing conducted 11/16/95, 01/24, and 01/26/96

### PROJECT OBJECTIVE:
Evaluate VOC and ammonia emissions during greenwaste composting by testing three different ages of compost; Day 2, Day 20 and Day 50. Based in temperature, the peak emission was expected on Day 20.

### FACILITY OPERATIONS:
The site receives biosolids and manure and produces compost by static pile windrow (50 day compost cycle) and a non-specified curing phase in larger piles. No mention was made regarding bulking agent, although it is likely that bedding or fiber was present in the manure.

### TARGET SPECIES:
Methane, O2, CO2, CO, and Total non-methane organic carbon (condensable and volatile) with helium used as a tracer species, total sulfur compounds, ammonia and amines.

### SAMPLE COLLECTION METHODS:
SCAQMD Modified (6" port, 10% helium tracer, mixing fan) USEPA surface emission isolation flux chamber.

### ANALYTICAL METHODS:
SCQAMD Method 25.1, Amines, Sulfur Compounds, and SCAQMD Method 207.1.

### SCOPE OF WORK:
Nine sampling points per source (Day 2, 20, 50) prior to turning and five sampling points post turning per source. Note- number of samples is not specified, and the SCAQMD often collects composite samples. It is possible that only six composite samples were collected per these 42 flux tests (9 x 3 plus 5 x 3).

## QC DATA:
It is not known if a work plan was prepared or is available.
Blank samples and replicate sample data were not reported or commented on. Note that all 25.3 samples were taken in duplicate as per the method.

## FINDINGS:

| **Compounds** | **Emission Factor** |
|---|---|
| | (lb/ton) |
| Ammonia | 3.28 |
| Amines | <0.0003 |
| Methane | 2.23 |
| TGNMOC | 1.7 |
| Total Sulfur Compounds | 0.015 |
| | |

## CONCLUSIONS:
The appropriate sample collection and analytical techniques were employed including the SCAQMD Modified USEPA flux chamber technique. No discussion was provided about specific surface area testing, designation of sub area per type of source, and no QC data was provided. The use of the flux data, estimate of surface area, and representativeness of the emissions estimate should be reviewed.

## COMMENTS:
None.

## *SJVAPCD ANNOTATED BIBLIOGRAPHY FACT SHEET*

### COMPOST TYPE: Biosolids (50%) and Greenwaste (50%)

**SITE:** San Joaquin Composting, Inc, Lost Hills, CA

**PAPER TITLE:** "Characterization of Ammonia, Total Amine, Organic Sulfur Compound, and Total Non-Methane Organic Compound (TGNMOC) Emissions From Composting Operations "

**AUTHORS:** SCAQMD, Carey Willoughby

**DATE:** Testing conducted 02/15/96, 03/01/96, and 03/11/96

### PROJECT OBJECTIVE:
Evaluate VOC and ammonia emissions during greenwaste composting by testing three different ages of compost; Day3, Day 45 and Day 57. Based in temperature, the peak emission was expected on Day 45.

### FACILITY OPERATIONS:
The site receives biosolids and manure and produces compost by static pile windrow (50 day compost cycle) and a non-specified curing phase in larger piles. No mention was made regarding bulking agent, although it is likely that bedding or fiber was present in the manure.

### TARGET SPECIES:
Methane, O2, CO2, CO, and Total non-methane organic carbon (condensable and volatile) with helium used as a tracer species, total sulfur compounds, ammonia and amines.

### SAMPLE COLLECTION METHODS:
SCAQMD Modified (6" port, 10% helium tracer, mixing fan) USEPA surface emission isolation flux chamber.

### ANALYTICAL METHODS:
SCQAMD Method 25.1, Amines, Sulfur Compounds, and SCAQMD Method 207.1.

### SCOPE OF WORK:
Nine sampling points per source (Day 3, 45, 57) prior to turning and five sampling points post turning per source. Note- number of samples is not specified, and the SCAQMD often collects composite samples. It is possible that only six composite samples were collected per these 42 flux tests (9 x 3 plus 5 x 3). These locations were screened with an FID and these field data may have been used to select locations for sample collection, either composite or discrete samples.

## QC DATA:

It is not known if a work plan was prepared or is available.
Blank samples and replicate sample data were not reported or commented on.

## FINDINGS:

| **Compounds** | **Emission Factor** |
|---|---|
| | (lb/ton) |
| Ammonia | 2.81 |
| Amines | 0.19 |
| Methane | 33.49 |
| TGNMOC | 3.1 |
| Total Sulfur Compounds | 0.22 |
| | |

## CONCLUSIONS:

The appropriate sample collection and analytical techniques were employed including the SCAQMD Modified USEPA flux chamber technique.  No discussion was provided about specific surface area testing, designation of sub area per type of source, and no QC data was provided.  The use of the flux data, estimate of surface area, and representativeness of the emissions estimate should be reviewed.

## COMMENTS:

The compost site had experienced heavy rain prior the Day 3 testing resulting in higher emissions as per the authors.  The greenwaste stockpile combusted during the 03/11/96 testing event.

# ***SJVAPCD ANNOTATED BIBLIOGRAPHY FACT SHEET***

## COMPOST TYPE: Greenwaste Engineering Evaluation (Not Life Cycle)

**SITE:** Tierra Verde Industries, Irvine, CA

**PAPER TITLE:** "Technical Report- Best Management Practices for Greenwaste Composting Operations: Air Emissions Tests vs. Feedstock Controls and Aeration Techniques"

**AUTHORS:** Brenda Smyth, CE Schmidt

**DATE:** July 29, 2003 (testing conducted 10/29-30/02, 11/06-07/02, and 02/04-05/03)

## PROJECT OBJECTIVE:
Evaluate baseline air emissions from feedstock blends (C:N) and aeration techniques and to determine how changing these variables affects air emissions from the compost.

## FACILITY OPERATIONS:
Engineering evaluations were performed on four, custom-made windrow piles. Two piles were made with higher C:N and two with lower C:N. One of each type of blends were mechanically aerated while the others were not mixed at all. The resulting matrix was as follows: low C:N aerated and low C:N non-aerated; and high C:N aerated and high C:N non-aerated. Aeration was facilitated by turning three times per week. Of the 100 day cycle, testing was conduced on Day 3 and 4, and Day 11 and 12, and Day 101 and 102.

## TARGET SPECIES:
Methane, ethane, CO2, CO, and Total non-methane organic carbon (condensable and volatile) with CO used as a tracer species.

## SAMPLE COLLECTION METHODS:
Standard USEPA Flux Chamber (bottom and sides) and SCAQMD Modified (6" port, CO tracer) USEPA surface emission isolation flux chamber.

## ANALYTICAL METHODS:
SCQAMD Method 25.3, SCAQMD 207.1, and ASTM Odor.

## SCOPE OF WORK:
52 Flux measurements conducted over a 103-day time period. Test locations were selected to represent bottom, middle and top of pile with the top test location typically replicated.

## QC DATA:

Work plan was prepared and is available.
Adequate frequency of blank samples and replicate samples reported in Tech Memo. QC data indicated overall acceptable method performance.

## FINDINGS:

Ammonia emissions were generally below method detection limit.

VOC emissions by Method 25.3:

| Test Pile | #VOC per day/ton |
|---|---|
| Static, Low C:N | 0.055 |
| Turned, Low C:N | 0.848 |
| Static, High C:N | 0.038 |
| Turned, High C:N | 0.240 |
| | |
| Total | 0.247 |

## CONCLUSIONS:

VOC emissions decreased with increasing C:N. Higher VOC emissions were observed for turned versus non-turned piles. VOC emissions peaked during the first week. It was not possible to determine if static verses turned piles were higher or lower VOC emitters. Life cycle for turned compost is shorter that static compost.

## COMMENTS:

The engineering evaluation of C:N ratio and aeration provide useful operational information, but life-cycle emission factor data is difficult to extract from these data. Note that only one 6” diameter exhaust port chamber was used (top location) and a standard chamber was used for the middle and bottom-side locations. Although a tracer gas was used (CO), a bias in sampling could have resulted from back pressure in the standard chamber as related to advective flow.

***<u>SJVAPCD ANNOTATED BIBLIOGRAPHY FACT SHEET</u>***

## COMPOST TYPE: Food Waste with Compostex Cover

**SITE:** Jepson Prairie Organics Compost Facility, Vacaville, CA

**PAPER TITLE:** "Jepson Prairie Organics Facility Compostex Cover System- Air Emissions Report"

**AUTHORS:** Tom Card, CE Schmidt

**DATE:** April 2008, (testing conducted 02/05-07/08)

**PROJECT OBJECTIVE:**
Evaluate VOC and ammonia site wide baseline emissions for food waste composting using the Compostex Cover System.

**FACILITY OPERATIONS:**
Jepson Prairie Organics Compost facility utilizes the Compostex cover system. The compost operation includes food waste grinding, mixing with a greenwaste bulking agent, a 45-day active compost phase (food waste covered) and a cure phase (uncovered).

**TARGET SPECIES:**
Methane, ethane, CO2, CO, Total non-methane organic carbon (condensable and volatile), and ammonia.

**SAMPLE COLLECTION METHODS:**
SCAQMD Modified (6" port, 10% helium tracer with modified air introduction system and stack testing approach and mixer) USEPA surface emission isolation flux chamber.

**ANALYTICAL METHODS:**
SCQAMD Method 25.3, SCAQMD Method 207.1, and USEPA Method TO-14/GC-ECD for the tracer SF6 (verification on tracer study).

**SCOPE OF WORK:**
Over 71 flux measurements conducted over a 3-day time period. Test locations were selected to represent the life-cycle emissions from the operations including uncovering, mixing, and time-dependent emissions post mixing. Receiving and finish was also tested.

| | |
|---|---|
| Feedstock as received and aged | 2 Flux tests- fresh and 24 hours old |
| Compost Day 1, covered | 4 Flux tests, (T1, T2, S1, S2) |
| Compost Day 3, covered | 4 Flux tests, (T1, T2, S1, S2) |
| Compost Day 7, covered | 4 Flux tests, (T1, T2, S1, S2) |

| | |
|---|---|
| Variability Test, Day 7 | 4 Flux tests, (T1, T2, S1, S2) |
| Compost Day 15, covered | 4 Flux tests, (T1, T2, S1, S2) |
| Compost Day 28, covered | 4 Flux tests, (T1, T2, S1, S2) |
| Compost Day 28, uncovered and unmixed | 4 Flux tests, (T1, T2, S1, S2) |
| Compost Day 28, Mix Decay (hr 1, hr 4) | 4 Flux tests, (T1, S1, T1, S1) |
| Curing Day 45, uncovered and unmixed | 4 Flux tests, (T1, T2, S1, S2) |
| Variability Test, Day 45 | 4 Flux tests, (T1, T2, S1, S2) |
| Curing Day 55, uncovered and unmixed | 4 Flux tests, (T1, T2, S1, S2) |
| Curing Day 55, Mix Decay (hr 1, hr 4) | 4 Flux tests, (T1, S1, T1, S1) |
| Finish Product- post screening | 4 Flux tests- 2 fresh, 2 aged |
| Blank testing | 9 Flux tests |
| Replicate testing | 8 Flux tests |
| TOTAL | 71 Flux tests |

## QC DATA:

Work plan was prepared and is available.
Adequate frequency of blank, replicate, and repeat samples are reported.
QC data indicated overall acceptable method performance.

## FINDINGS:

Food Waste with Compostex- 27 #VOC/ton and 8.1 #NH3/ton

## CONCLUSIONS:

The appropriate sample collection and analytical techniques were employed, including the recent, validated modifications to the SCAQMD Rule 1133 recommended procedure (6" port, 10% helium tracer). The modifications included the redesigned sweep air inlet system and stack testing in extended stack, backup tracer, and internal mixer. Data was collected without an adverse affect from high winds.

## COMMENTS:

The Compostex cover system showed a reduced air emissions for VOC (27 #VOC/ton versus 37 #VOC/ton) as compared to the historic Ag Bag compost system, but higher ammonia emissions (8.1 #NH3/ton versus 1.0 #NH#/ton). The robust assessment produced representative life-cycle emissions from the Compostex cover system on food waste at this site.

# *SJVAPCD ANNOTATED BIBLIOGRAPHY FACT SHEET*

## COMPOST TYPE: Food Waste with Compostex Cover

**SITE:** Jepson Prairie Organics Compost Facility, Vacaville, CA

**PAPER TITLE:** "Jepson Prairie Organics Facility Micropore Cover System- Air Emissions Report"

**AUTHORS:** Tom Card, CE Schmidt

**DATE:** April 2008, (testing conducted 01/17/08 – 02/15/08)

## PROJECT OBJECTIVE:
Evaluate VOC and ammonia site wide baseline emissions for food waste composting using the Micropore Cover System; 30 day and 45 day covered operations

## FACILITY OPERATIONS:
Jepson Prairie Organics Compost facility typically utilizes the Compostex cover system, and a test was conducted using micropore fabric with forced air (Mor and GE covers). The micropore test used a compost operation that included food waste grinding, mixing with a greenwaste bulking agent, a 30-day and a 45-day active compost phase (food waste covered with micropore) and a cure phase (uncovered).

## TARGET SPECIES:
Methane, ethane, $CO_2$, CO, Total non-methane organic carbon (condensable and volatile), and ammonia.

## SAMPLE COLLECTION METHODS:
SCAQMD Modified (6" port, 10% helium tracer with modified air introduction system and stack testing approach and mixer) USEPA surface emission isolation flux chamber.

## ANALYTICAL METHODS:
SCQAMD Method 25.3, SCAQMD Method 207.1, and USEPA Method TO-14/GC-ECD for the tracer $SF_6$ (verification on tracer study).

## SCOPE OF WORK:
95 Flux measurements were conducted over multiple field trips. Test locations were selected to represent the life-cycle emissions from the operations including uncovering, mixing, and time-dependent emissions post mixing. Receiving and finish was also tested.

| | |
|---|---|
| Feedstock as received and aged | 2 Flux tests- fresh and 24 hours old |

| | |
|---|---|
| Compost Day 1, covered | 4 Flux tests, (T1, T2, S1, S2) |
| Variability Test, Day 1, covered | 4 Flux tests, (T1, T2, S1, S2) |
| Compost Day 8, covered | 4 Flux tests, (T1, T2, S1, S2) |
| Compost Day 18, covered | 4 Flux tests, (T1, T2, S1, S2) |
| Compost Day 31, covered | 4 Flux tests, (T1, T2, S1, S2) |
| Compost Day 31, uncovered and unmixed | 4 Flux tests, (T1, T2, S1, S2) |
| Compost Day 32, Mix Decay (hr 1, hr 4) | 4 Flux tests, (T1, S1; T1, S1) |
| Compost Day 45, covered | 4 Flux tests, (T1, T2, S1, S2) |
| Compost Day 45, uncovered and unmixed | 4 Flux tests, (T1, T2, S1, S2) |
| Compost Day 45, Mix Decay (hr 1, hr 4) | 4 Flux tests, (T1, S1, T1, S1) |
| Compost Day 46, uncovered and unmixed | 4 Flux tests, (T1, T2, S1, S2) |
| Compost Day 46, Mix Decay (hr 1, hr 4) | 4 Flux tests, (T1, S1, T1, S1) |
| Compost Day 55, Mix Decay (hr 1, hr 4) | 4 Flux tests, (T1, S1, T1, S1) |
| Compost Day 58, covered | 4 Flux tests, (T1, T2, S1, S2) |
| Compost Day 58, Mix Decay (hr 1, hr 4) | 4 Flux tests, (T1, S1, T1, S1) |
| Compost Day 60, covered | 4 Flux tests, (T1, T2, S1, S2) |
| Variability Test, Day 60, covered | 4 Flux tests, (T1, T2, S1, S2) |
| Compost Day 60, Mix Decay (hr 1, hr 4) | 4 Flux tests, (T1, T2, S1, S2) |
| Finish Product- post screening | 4 Flux tests- 2 fresh, 2 aged |
| Blank testing | 9 Flux tests |
| Replicate testing | 8 Flux tests |
| TOTAL | 95 Flux tests |

## QC DATA:

Work plan was prepared and is available.
Adequate frequency of blank, replicate, and repeat samples are reported.
QC data indicated overall acceptable method performance.

## FINDINGS:

Food Waste with 30-Day Micropore Cover- 11 #VOC/ton and 14 #NH3/ton
Food Waste with 45-Day Micropore Cover- 3.4 #VOC/ton and 114 #NH3/ton

## CONCLUSIONS:

The appropriate sample collection and analytical techniques were employed, including the recent, validated modifications to the SCAQMD Rule 1133 recommended procedure (6" port, 10% helium tracer). The modifications included the redesigned sweep air inlet system and stack testing in extended stack, backup tracer, and internal mixer. Data was collected without an adverse affect from high winds.

## COMMENTS:

The 30-Day Micropore cover system showed a reduced air emissions for VOCs (11 #VOC/ton versus 27 #VOC/ton) as compared to the baseline Compostex cover system, but higher ammonia emissions (14 #NH3/ton versus 8.1 #NH#/ton). And, the 30-Day Micropore cover system showed a reduced air emissions for VOCs (3.4 #VOC/ton versus 11 #VOC/ton) as compared to the 30-Day Micropore cover system, and also lower ammonia emissions (1.4 #NH3/ton versus 14 #NH#/ton). The robust assessment produced representative life-cycle emissions from the Micropore cover system on food waste at this site.

# *SJVAPCD ANNOTATED BIBLIOGRAPHY FACT SHEET*

## COMPOST TYPE: Biosolids

**SITE:** South Kern Industrial Complex (SKIC) LLC, Taft, CA

**PAPER TITLE:** "SKIC Air Emissions Compliance Report"

**AUTHORS:** Tom Card, CE Schmidt

**DATE:** January 2008, (testing conducted 08/08-12/07 and 12/04-06/08)

## PROJECT OBJECTIVE:
Determine the air emissions of VOCs and ammonia from the primary and secondary ASPs and the biofilters (mixing building, primary, and secondary biofilters); and determine the control efficiency of the biofilters for both VOCs and ammonia.

## FACILITY OPERATIONS:
SKIC operates a co-composting facility that uses aerated static pile and biofilters. The biosolids are received in a building, mixed with greenwaste bulking agent, heap piled, placed in primary composting under negative aeration via subsurface ventilation and covered with a layer of finish biosolids (30 days), broke-down and transported to secondary curing which is also under negative aeration via subsurface ventilation but not covered with finish, screened, and sold as product. Gases collected from the mixing building, primary and secondary are routed though separate biofiltration consisting of wood chip media maintained by irrigation.

## TARGET SPECIES:
Methane, ethane, CO2, CO, Total non-methane organic carbon (condensable and volatile), and ammonia.

## SAMPLE COLLECTION METHODS:
SCAQMD Modified (6" port, 10% helium tracer with modified air introduction system and stack testing approach and mixer) USEPA surface emission isolation flux chamber.

## ANALYTICAL METHODS:
SCQAMD Method 25.3, SCAQMD Method 207.1, and USEPA Method TO-14/GC-ECD for the tracer SF6 (verification on tracer study).

## SCOPE OF WORK:
Approximately 103flux or stack measurements were conducted over two field trips. The primary composting and biofilter was tested in August and the secondary and biofilter along with the mixing building biofilter was tested in December. Test locations were selected to represent the life-cycle emissions from the operations. Biofilter inlet testing

included triplicate stack testing in order to establish inlet concentrations and flow rates into the biofilters for destruction efficiency determinations.

| **Process** | **Stack Tests** | **Flux Locations** |
|---|---|---|
| | | |
| **Primary Composting** | | |
| Compost Surface- Day 5, 11, 16 | None | 9 |
| | | |
| **Secondary Composting** | | |
| Compost Surface- Day 22, 28, 36 | None | 9 |
| | | |
| **Mixing Building Biofilter** | | |
| Biofilter In | 3 + 3 | None |
| Biofilter Surface- 16 cell grid | None | 16 |
| | | |
| **Primary Biofilter** | | |
| Biofilter In | 3 | None |
| Biofilter Surface- 16 cell grid | None | 16 |
| | | |
| **Secondary Biofilter** | | |
| Biofilter In | 3 | None |
| Biofilter Surface- 16 cell grid | None | 16 |

## QC DATA:

Work plan was prepared and is available.
Adequate frequency of blank, replicate, and repeat samples are reported.
QC data indicated overall acceptable method performance.

## FINDINGS:

Facility Emissions- 0.31 #VOC/ton and 0.14 #NH3/ton

Biofilter Destruction Efficiency; VOCs- 88% to 97%, NH3- 81% to 97%

## CONCLUSIONS:

The appropriate sample collection and analytical techniques were employed, including the recent, validated modifications to the SCAQMD Rule 1133 recommended procedure (6” port, 10% helium tracer). The modifications included the redesigned sweep air inlet system and stack testing in extended stack, backup tracer, and internal mixer. Data was collected without an adverse affect from high winds.

## COMMENTS:

The ASP composting system complete with biofilter blanket on primary composting, negative aeration and biofilter control, and secondary curing negative aeration and biofilter control shows low emissions of VOCs and ammonia. Destruction efficiencies for both VOCs and ammonia from maintained wood chip biofiltration range from 81% to 97% or these species. The robust assessment produced representative life-cycle emissions from the negative ASP system and biofiltration control.

# Appendix B
# Technical Memorandum
# CIWMB Modesto Data Recalculation

41125 278th Way SE, Enumclaw, WA 98022 USA
Phone: 360-802-5540 Fax: 360-802-5541
E-Mail: trcard@earthlink.net

**TO:** Chuck Schmidt

**FROM:** Tom Card

**DATE:** June 19, 2008

**SUBJECT:** CIWMB Modesto Composting Report Analysis

An analysis has been made of the California Integrated Waste Management Board's (CIWMB) report entitled **Emissions Testing of Volatile Organic Compounds from Greenwaste Composting at the Modesto Compost Facility in the San Joaquin Valley**. It was not possible to reproduce the calculations in the report to verify their accuracy. Instead, the emissions are recalculated using the quantitative and written descriptions of the site and the testing procedures. There can be many reasons why this calculation is different than the report's calculation. Those differences are discussed in detail below.

Table 1 summarizes the results of this analysis compared to the report's findings. The South Coast Air Quality Management District (SCAQMD) emission factor is presented for comparative purposes.

**Table 1. Preliminary Results**

| Source | VOC (#/ton mix) |
|---|---|
| Recalculation of CIWMB Results | 1.5 |
| CIWMB Report | 0.6 - 0.7 |
| SCAQMD Emssion Factor | 3.8 |

# Basis of Recalculation

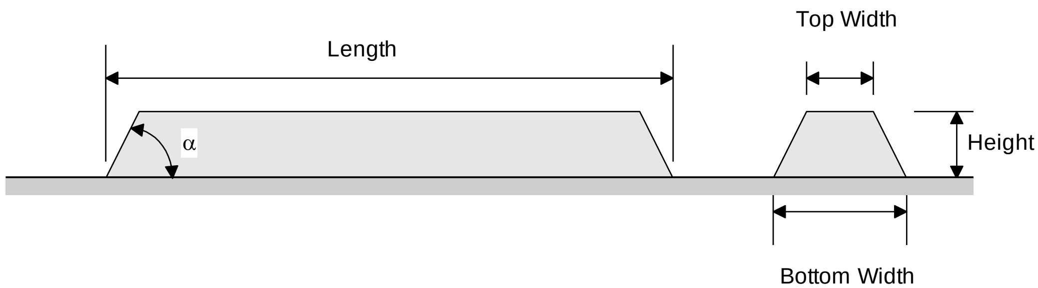
## *VOC Species*

This report calculated VOC emissions as methane with no method bias factor applied. The SCAQMD presents VOC emissions as hexane carbon and includes a method bias factor. This report did not present the VOC data in this manner since most jurisdictions report VOC as methane with no method bias factor.

## *Compost Process*

The compost process tested was greenwaste in windrows. The compost was placed in the windrow and mixed eleven times over a 60 day cycle. No attempt was made in the CIWMB report to quantify immediate mixing emissions. Previous work has shown that mixing emissions are irrelevant in well mixed aerobic windrows, but mixing emissions dominate in poorly mixed and poorly vented windrows. Based on the descriptions and data in the report, this windrow likely trends to the former condition. Figure 1 presents the windrow configuration that this report assumed along with the mensuration formulas used. Table 2 presents the windrow calculated data.

**Figure 1. Assumed Windrow Configuration and Mensuration Formulas**




**Mensuration formulas**

$$S = \frac{p_1 + p_2}{2} s + A_2$$

$$V = \frac{h(A_1 + A_2 + \sqrt{A_1 A_2})}{3}$$

$$s = \sqrt{h^2 + ((W_B - W_T)/2)^2}$$

where S = total surface area, $p_1$ = bottom perimeter, $p_2$ = top perimeter, s = slant height, V=volume, h=vertical height, $A_1$ = bottom area, $A_2$ = top area, $\alpha$ = bottom angle

The CIWMB reported the surface area as 206.4 $m^2$. This report calculates the surface area as 212 $m^2$. The CIWMB reports the initial bulk density as 360 $kg/m^3$. This report calculates the density as 510 $kg/m^3$. The density difference is significant and could be one of the primary causes of the differences in results. The CIWMB number is significantly lower than any density value for greenwaste compost seen by this author. The compost windrow normally shrinks during the cycle. This shrinkage was not incorporated in this calculation, but based on the emissions profile (late cycle emissions go to essentially zero) this should not have significant impact.

The compost windrow was sampled typically at two locations on the top of the windrow, on the middle of the side and at the bottom of the side. Figure 2 is taken directly out of the CIWMB report to show the portions of the windrow that these samples represent. Table 3 shows this report's allocation of the surface areas compared to the CIWMB allocation of surface areas. It was not possible to determine how the CIWMB calculated their area ratios.

## *Compost Venting*

Compost often cracks and develops vent channels so that a large portion of the vent air goes through few channels. The CIWMB report discussed the phenomena extensively. However, the data suggest that the vent channels had no more emissions than the rest of the top surface. Many of the non-vented top surfaces had emissions exceeding the vented surfaces, which suggests that for the added volumetric flow even the field instrument screening data are not good indicators of VOC flux or emissions. Therefore, for this report all top surface values are averaged

**Table 2. Windrow Dimensions and Capacities**

| Property | Units | Value |
|---|---|---|
| Length | ft | 102.0 |
| Height | ft | 6.8 |
| Bottom Width | ft | 14.4 |
| Top Width | ft | 5.6 |
| Top Length | ft | 93 |
| alpha | R | 1.00 |
| | o | 57 |
| Top Perimeter | ft | 198 |
| Top Area | ft2 | 522 |
| Bottom Perimeter | ft | 233 |
| Bottom Area | ft2 | 1,469 |
| Slant height | ft | 8.1 |
| Surface Area | ft2 | 2,265 |
| | m2 | 212 |
| Volume | ft3 | 6,497 |
| | yd3 | 241 |
| | m3 | 184 |
| Conversion Factors | ft2/m2 | 10.7 |
| | ft3/yd3 | 27 |
| | ft3/m3 | 35.31 |
| Top Area Ratio | | 0.230 |
| Mass | Tons | 103 |
| Density | *#/yd3* | 856 |
| | kg/m3 | 509 |

**Figure 2. CIWMB Windrow Cross Section (Figure 1. from the CIWMB report).**

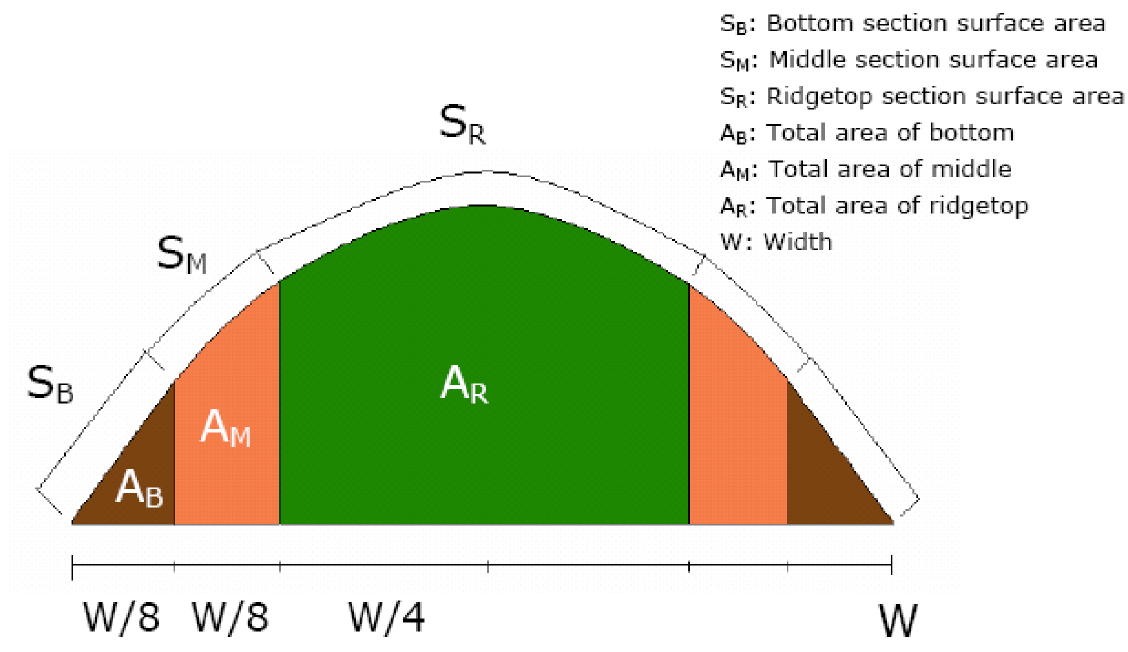



Figure 1. Sampling Segments of Windrows

**Table 3. Comparison of Surface Area Allocations.**

| Source | Top | Middle | Side |
|---|---|---|---|
| This Report | 0.5 | 0.25 | 0.25 |
| CIWMB Report | 0.26 | 0.37 | 0.37 |

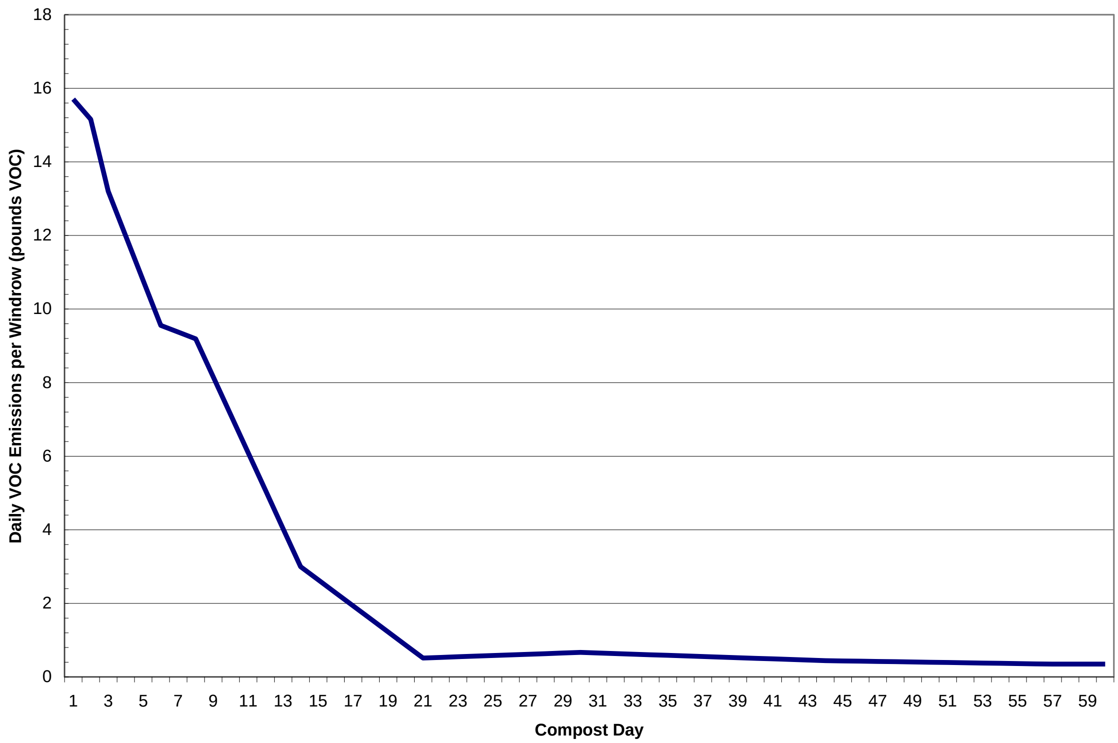
## *Emission Factor Calculation*

Table 4. presents a simulated full 60 day compost cycle emissions based on the CIWMB data. The highlighted values are measured unit emissions, the rest of the data is linearly interpolated from the measured data. Figure 3 shows the daily emissions profile.

**Table 4. Simulated VOC Emissions Profile.**

| Compost Day | Weighting Factors RH | RL | Mid | Bot | Total | Unit Flux (mg/min-m2) RH | RL | Mid | Bot | Total | Surface Area (m2) | Emissions VOC (#) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.25 | 0.25 | 0.25 | 0.25 | 1.00 | 19.05 | 34.78 | 2.71 | 36.93 | 23.4 | 212 | 15.7 |
| 2 | 0.25 | 0.25 | 0.25 | 0.25 | 1.00 | 30.16 | 38.95 | 1.96 | 19.13 | 22.5 | 212 | 15.2 |
| 3 | 0.25 | 0.25 | 0.25 | 0.25 | 1.00 | 34.44 | 41.58 | 1.21 | 1.34 | 19.6 | 212 | 13.2 |
| 4 | 0.25 | 0.25 | 0.25 | 0.25 | 1.00 | 31.23 | 38.12 | 0.94 | 1.04 | 17.8 | 212 | 12.0 |
| 5 | 0.25 | 0.25 | 0.25 | 0.25 | 1.00 | 28.01 | 34.66 | 0.68 | 0.75 | 16.0 | 212 | 10.8 |
| 6 | 0.25 | 0.25 | 0.25 | 0.25 | 1.00 | 24.80 | 31.20 | 0.41 | 0.46 | 14.2 | 212 | 9.6 |
| 7 | 0.25 | 0.25 | 0.25 | 0.25 | 1.00 | 22.76 | 27.74 | 3.49 | 1.79 | 13.9 | 212 | 9.4 |
| 8 | 0.25 | 0.25 | 0.25 | 0.25 | 1.00 | 20.71 | 24.28 | 6.57 | 3.13 | 13.7 | 212 | 9.2 |
| 9 | 0.25 | 0.25 | 0.25 | 0.25 | 1.00 | 19.52 | 20.83 | 5.54 | 2.67 | 12.1 | 212 | 8.2 |
| 10 | 0.25 | 0.25 | 0.25 | 0.25 | 1.00 | 18.33 | 17.37 | 4.51 | 2.20 | 10.6 | 212 | 7.1 |
| 11 | 0.25 | 0.25 | 0.25 | 0.25 | 1.00 | 17.14 | 13.91 | 3.48 | 1.73 | 9.1 | 212 | 6.1 |
| 12 | 0.25 | 0.25 | 0.25 | 0.25 | 1.00 | 15.95 | 10.45 | 2.45 | 1.27 | 7.5 | 212 | 5.1 |
| 13 | 0.25 | 0.25 | 0.25 | 0.25 | 1.00 | 14.76 | 6.99 | 1.42 | 0.80 | 6.0 | 212 | 4.0 |
| 14 | 0.25 | 0.25 | 0.25 | 0.25 | 1.00 | 13.57 | 3.53 | 0.39 | 0.34 | 4.5 | 212 | 3.0 |
| 15 | 0.25 | 0.25 | 0.25 | 0.25 | 1.00 | 11.83 | 3.21 | 0.35 | 0.33 | 3.9 | 212 | 2.6 |
| 16 | 0.25 | 0.25 | 0.25 | 0.25 | 1.00 | 10.10 | 2.89 | 0.30 | 0.32 | 3.4 | 212 | 2.3 |
| 17 | 0.25 | 0.25 | 0.25 | 0.25 | 1.00 | 8.36 | 2.57 | 0.26 | 0.30 | 2.9 | 212 | 1.9 |
| 18 | 0.25 | 0.25 | 0.25 | 0.25 | 1.00 | 6.63 | 2.25 | 0.22 | 0.29 | 2.3 | 212 | 1.6 |
| 19 | 0.25 | 0.25 | 0.25 | 0.25 | 1.00 | 4.89 | 1.93 | 0.18 | 0.28 | 1.8 | 212 | 1.2 |
| 20 | 0.25 | 0.25 | 0.25 | 0.25 | 1.00 | 3.15 | 1.60 | 0.14 | 0.27 | 1.3 | 212 | 0.9 |
| 21 | 0.25 | 0.25 | 0.25 | 0.25 | 1.00 | 1.42 | 1.28 | 0.10 | 0.26 | 0.8 | 212 | 0.5 |
| 22 | 0.25 | 0.25 | 0.25 | 0.25 | 1.00 | 1.44 | 1.38 | 0.09 | 0.24 | 0.8 | 212 | 0.5 |
| 23 | 0.25 | 0.25 | 0.25 | 0.25 | 1.00 | 1.46 | 1.48 | 0.09 | 0.22 | 0.8 | 212 | 0.5 |
| 24 | 0.25 | 0.25 | 0.25 | 0.25 | 1.00 | 1.48 | 1.58 | 0.09 | 0.20 | 0.8 | 212 | 0.6 |
| 25 | 0.25 | 0.25 | 0.25 | 0.25 | 1.00 | 1.51 | 1.68 | 0.09 | 0.19 | 0.9 | 212 | 0.6 |
| 26 | 0.25 | 0.25 | 0.25 | 0.25 | 1.00 | 1.53 | 1.77 | 0.09 | 0.17 | 0.9 | 212 | 0.6 |
| 27 | 0.25 | 0.25 | 0.25 | 0.25 | 1.00 | 1.55 | 1.87 | 0.09 | 0.15 | 0.9 | 212 | 0.6 |
| 28 | 0.25 | 0.25 | 0.25 | 0.25 | 1.00 | 1.57 | 1.97 | 0.09 | 0.13 | 0.9 | 212 | 0.6 |
| 29 | 0.25 | 0.25 | 0.25 | 0.25 | 1.00 | 1.59 | 2.07 | 0.09 | 0.11 | 1.0 | 212 | 0.6 |
| 30 | 0.25 | 0.25 | 0.25 | 0.25 | 1.00 | 1.62 | 2.17 | 0.09 | 0.10 | 1.0 | 212 | 0.7 |
| 31 | 0.25 | 0.25 | 0.25 | 0.25 | 1.00 | 1.62 | 2.05 | 0.10 | 0.10 | 1.0 | 212 | 0.6 |
| 32 | 0.25 | 0.25 | 0.25 | 0.25 | 1.00 | 1.63 | 1.92 | 0.11 | 0.10 | 0.9 | 212 | 0.6 |
| 33 | 0.25 | 0.25 | 0.25 | 0.25 | 1.00 | 1.64 | 1.80 | 0.13 | 0.10 | 0.9 | 212 | 0.6 |
| 34 | 0.25 | 0.25 | 0.25 | 0.25 | 1.00 | 1.65 | 1.68 | 0.14 | 0.11 | 0.9 | 212 | 0.6 |
| 35 | 0.25 | 0.25 | 0.25 | 0.25 | 1.00 | 1.66 | 1.56 | 0.15 | 0.11 | 0.9 | 212 | 0.6 |
| 36 | 0.25 | 0.25 | 0.25 | 0.25 | 1.00 | 1.67 | 1.44 | 0.17 | 0.11 | 0.8 | 212 | 0.6 |
| 37 | 0.25 | 0.25 | 0.25 | 0.25 | 1.00 | 1.68 | 1.32 | 0.18 | 0.11 | 0.8 | 212 | 0.6 |
| 38 | 0.25 | 0.25 | 0.25 | 0.25 | 1.00 | 1.69 | 1.20 | 0.20 | 0.12 | 0.8 | 212 | 0.5 |
| 39 | 0.25 | 0.25 | 0.25 | 0.25 | 1.00 | 1.70 | 1.08 | 0.21 | 0.12 | 0.8 | 212 | 0.5 |
| 40 | 0.25 | 0.25 | 0.25 | 0.25 | 1.00 | 1.71 | 0.96 | 0.22 | 0.12 | 0.8 | 212 | 0.5 |
| 41 | 0.25 | 0.25 | 0.25 | 0.25 | 1.00 | 1.72 | 0.84 | 0.24 | 0.12 | 0.7 | 212 | 0.5 |
| 42 | 0.25 | 0.25 | 0.25 | 0.25 | 1.00 | 1.73 | 0.72 | 0.25 | 0.12 | 0.7 | 212 | 0.5 |
| 43 | 0.25 | 0.25 | 0.25 | 0.25 | 1.00 | 1.73 | 0.60 | 0.26 | 0.13 | 0.7 | 212 | 0.5 |
| 44 | 0.25 | 0.25 | 0.25 | 0.25 | 1.00 | 1.74 | 0.48 | 0.28 | 0.13 | 0.7 | 212 | 0.4 |
| 45 | 0.25 | 0.25 | 0.25 | 0.25 | 1.00 | 1.64 | 0.55 | 0.27 | 0.13 | 0.6 | 212 | 0.4 |
| 46 | 0.25 | 0.25 | 0.25 | 0.25 | 1.00 | 1.54 | 0.62 | 0.26 | 0.13 | 0.6 | 212 | 0.4 |
| 47 | 0.25 | 0.25 | 0.25 | 0.25 | 1.00 | 1.43 | 0.68 | 0.25 | 0.14 | 0.6 | 212 | 0.4 |
| 48 | 0.25 | 0.25 | 0.25 | 0.25 | 1.00 | 1.33 | 0.75 | 0.24 | 0.14 | 0.6 | 212 | 0.4 |
| 49 | 0.25 | 0.25 | 0.25 | 0.25 | 1.00 | 1.22 | 0.82 | 0.23 | 0.14 | 0.6 | 212 | 0.4 |
| 50 | 0.25 | 0.25 | 0.25 | 0.25 | 1.00 | 1.12 | 0.89 | 0.22 | 0.14 | 0.6 | 212 | 0.4 |
| 51 | 0.25 | 0.25 | 0.25 | 0.25 | 1.00 | 1.01 | 0.96 | 0.21 | 0.14 | 0.6 | 212 | 0.4 |
| 52 | 0.25 | 0.25 | 0.25 | 0.25 | 1.00 | 0.91 | 1.02 | 0.20 | 0.15 | 0.6 | 212 | 0.4 |
| 53 | 0.25 | 0.25 | 0.25 | 0.25 | 1.00 | 0.81 | 1.09 | 0.19 | 0.15 | 0.6 | 212 | 0.4 |
| 54 | 0.25 | 0.25 | 0.25 | 0.25 | 1.00 | 0.70 | 1.16 | 0.18 | 0.15 | 0.5 | 212 | 0.4 |
| 55 | 0.25 | 0.25 | 0.25 | 0.25 | 1.00 | 0.60 | 1.23 | 0.18 | 0.15 | 0.5 | 212 | 0.4 |
| 56 | 0.25 | 0.25 | 0.25 | 0.25 | 1.00 | 0.49 | 1.30 | 0.17 | 0.15 | 0.5 | 212 | 0.4 |
| 57 | 0.25 | 0.25 | 0.25 | 0.25 | 1.00 | 0.39 | 1.37 | 0.16 | 0.16 | 0.5 | 212 | 0.3 |
| 58 | 0.25 | 0.25 | 0.25 | 0.25 | 1.00 | 0.39 | 1.37 | 0.16 | 0.16 | 0.5 | 212 | 0.3 |
| 59 | 0.25 | 0.25 | 0.25 | 0.25 | 1.00 | 0.39 | 1.37 | 0.16 | 0.16 | 0.5 | 212 | 0.3 |
| 60 | 0.25 | 0.25 | 0.25 | 0.25 | 1.00 | 0.39 | 1.37 | 0.16 | 0.16 | 0.5 | 212 | 0.3 |
| | | | | | | | | | | | | 159 |
| | | | | | | | | | | | Emission Factor (#/ton) | 1.5 |

**Figure 3. Simulated VOC Emissions Profile.**




## *Summary*

An independent analysis of the Modesto flux data as supplied in the CE Schmidt Technical Memorandum was conducted. The emission estimate reported in the CIWMB report could not be duplicated, and the differences in assumptions, especially those that may be more significant have been identified and discussed. All things considered, the independent recalculation of the Modesto site emission factors are surprisingly similar to the CIWMB emission factors. This recalculation, again considering the differences and the similarity of the independently derived emission factors indicates that:

- Assumptions thought to be significant probably have less of an influence on the emission factor development process;

- The similarity in the emission factor estimates clearly establishes the ‘ball park’ for greenwaste emissions as those representing a site complying with a given site operations plan with regular maintenance and inspection. In other words, these data may represent sites that are capable of maintaining lower VOC emissions while producing an acceptable compost product.

- Given that the accuracy and precision specifications for flux chamber testing with GC analysis is +/- 50%, the data should be viewed as stated below:
    - 0.7 +/- 0.35 Range is 0.35 #/ton to 1.1 #/ton
    - 1.5 +/- 0.75 Range is 0.75 #/ton to 2.3 #/ton

- Note that these ranges overlap indicating no statistical difference in the numbers (0.7 and 1.5)

- Emission factors for the other test piles are not offered at this time.

# Appendix C
# Technical Memorandum
# Site X Emission Report

**Technical MEMORANDUM**

Environmental Management Consulting
41125 278th Way SE, Enumclaw, WA 98022 USA
Phone: 360-802-5540 Fax: 360-802-5541
E-Mail: trcard@earthlink.net

**TO:** [redacted]

**COPY:** Chuck Schmidt

**FROM:** Tom Card

**DATE:** April 24, 2008

**SUBJECT:** Compost Emissions Source Test
Preliminary Results

A preliminary analysis has been made for your site emissions and this memo presents those results. The results are not final yet, but we are not expecting any dramatic changes. However, do not make important decisions regarding these results until they are finalized.

Table 1 summarizes the results for you site and Table 2 provides comparison data (windrow emissions only) from the SCAQMD and a site similar to yours (that must remain confidential). You are about twice the SCAQMD number for VOC and about four times for ammonia. However, you are lower in VOC than a similar tested site. Figure 1 shows the emissions profile for a typical windrow.

One of our concerns regarding the data set is that the flow rate through the flux chambers was about five times higher than we would expect. This is likely due to the wind speed. Unfortunately your site is located in a high wind area and there is not much that can be done to mitigate wind speed.

Table 3 is a list of assumptions made about your operation that have a direct bearing on the emissions estimate. Please review these assumptions and correct them where appropriate.

**Table 1. Preliminary Results**

| | Emissions (pounds per ton received) | |
|---|---|---|
| **Source** | **VOC** | **Ammonia** |
| Receiving Stockpile | 7.76 | 0.03 |
| Windrows | 6.30 | 2.34 |
| Total | 14.06 | 2.37 |

**Table 2. Comparative Results (Windrow only)**

| | Emissions (pounds per ton received) | |
|---|---|---|
| **Source** | **VOC** | **Ammonia** |
| Site X | 6.30 | 2.34 |
| SCAQMD | 3.80 | 0.50 |
| Site Z | [redacted] | |

**Figure 1. Emissions Profile**

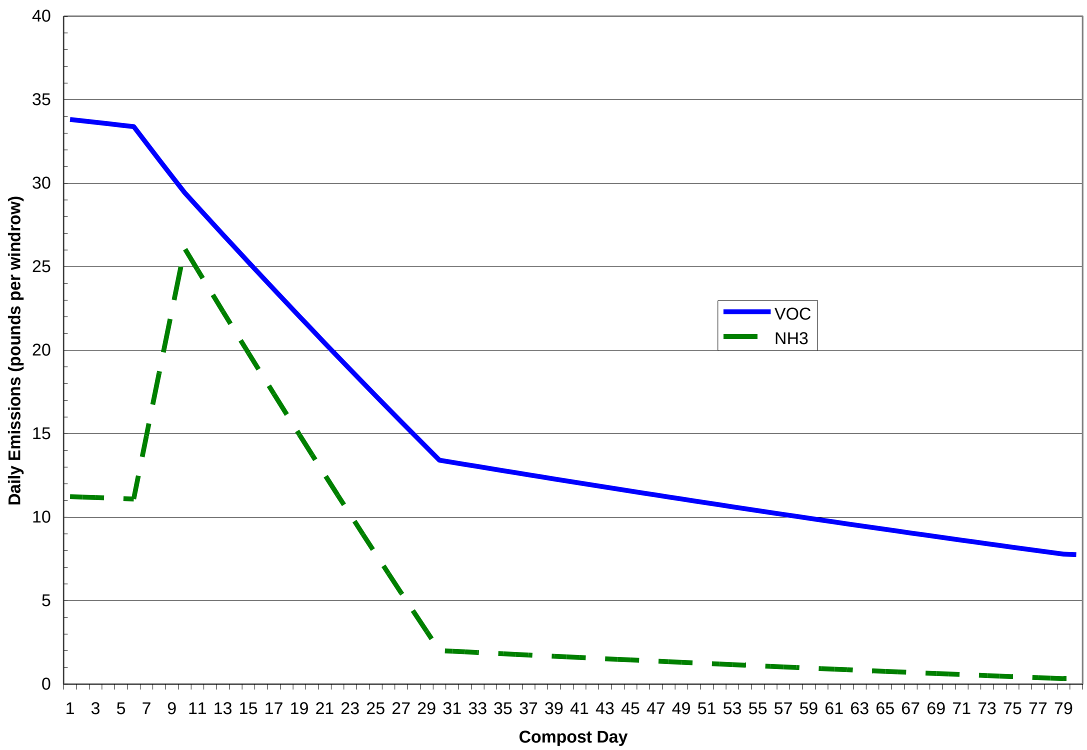



**Table 3. Key Assumptions**

| Item | Value | Units |
|---|---|---|
| Average daily throughput | 356 | Tons |
| Stockpile density | 800 | #/yd3 |
| Average stockpile duration | 45 | days |
| Mass in windrow | 200 | tons |
| Compost cycle duration | 80 | days |

# *TECHNICAL MEMORANDUM*

## FLUX CHAMBER SOURCE TESTING OF FUGITIVE AIR EMISSIONS FROM SITE X COMPOST FACILITY

Prepared By:

Mr. Tom Card
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Enumclaw, WA 98022

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May 7, 2008

***CE Schmidt, Ph.D.***
***Environmental Consultant***

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## EXECUTIVE SUMMARY

Field measurements were conducted at the Site X compost facility located in the California Central Valley. Testing was conducted on the pre-compost windrow and compost windrow area sources on site for the purpose of assessing total volatile organic compound (VOC- expressed as total non-methane non-ethane organic compounds by SCAQMD Method 25.3) emissions and ammonia emissions from the composting of greenwaste on site. Although the scope of work was limited by comparison to a full life-cycle emissions assessment, these data provide a good estimate of process emissions as tested.

The testing was conducted on March 10, 2008; the one-day testing effort was conducted on a day with winds running about 13 mph to 14 mph for the duration of the testing activities. Because most information points toward higher air emissions during windy conditions, it is possible that the measured flux data and thus site emission data were influenced by the higher winds resulting in a higher air emissions estimate.

The data collection approach included using the USEPA-recommended flux chamber modified as per the SCAQMD Rule 1133 as approved by recent method improvements, and standard air sample collection methods for VOCs or reactive organic gases, and ammonia. This approach provided data of high quality (accuracy and precision) representative of air emissions of study compounds from the organic composting process and the greenwaste static pile windrow composting process. The testing was scheduled so that fugitive air emissions could be measured at key times in the composting processes studied. The organic composting system was evaluated by collecting fugitive emission samples from the following area sources:

### *GREENWASTE COMPOSTING OPERATION*

| | |
|---|---|
| Feedstock as received and aged | Not tested |
| Compost Day 0 | 2 Flux tests, (T1, S2) |
| Compost Day 6 | 2 Flux tests, (T1, S1) |
| Compost Day 10 | 4 Flux tests, (T1, T2, S1, S2) |
| Compost Day 10, 1-hr post mixed | 2 Flux tests, (T1, S1) |
| Compost Day 10, 3-hr post mixed | 2 Flux tests, (T1, S1) |
| Compost Day 10, 5-hr post mixed | 2 Flux tests, (T1, S1) |

| | |
|---|---|
| Compost Day 30 | 2 Flux tests, (T1, S1) |
| Compost Day 79 | 2 Flux tests, (T1, S1) |
| Blank testing | 1 Flux test |
| Replicate testing | 1 Flux test |
| TOTAL | 20 Flux tests |

Testing was conducted using the USEPA surface emission isolation flux chamber, real time detection for ammonia (screening-level analysis), SCAQMD Method 25.3 for total VOCs, and SCAQMD Method 207.1 for ammonia. The assessment of the test surfaces included screening using real time detection in the field (colorometric tubes for ammonia), and flow conditions in the flux chamber as a result of advective flow from the area sources tested. Advective flow from the windrow composting (gas production and wind) was quantitatively assessed by using a tracer gas (10% helium) in the flux chamber, gas collection in evacuated stainless steel canisters, and analysis off site by gas chromatography/thermal conductivity detection (GC/TCD). The dilution of helium was used to calculate advective flow, and these data were used in the calculation of compound emissions from the test sources.

Note that the recommended SCAQMD method bias factor correction of 1.086 was not applied to these data. There is no scientific justification for applying a specific bias correction factor generated from one laboratory to another laboratory, since a given analytical method bias is unique to that laboratory and not intrinsic to the method.

The data tables generated and reported in this document describe the fugitive air emission from the sources tested on site. These flux data, combined with engineering data that describes the composting operations, can be used to generate a facility emission factor data base and a facility baseline emission estimate for total VOCs and ammonia. The engineering estimate for VOC and ammonia emissions is reported elsewhere.

***CE Schmidt, Ph.D.***
***Environmental Consultant***

## I. INTRODUCTION

This technical memorandum describes the field testing that was conducted in order to assess air emissions of ammonia, and VOC air emissions from the Site X greenwaste compost facility. Testing was conducted by Dr. C.E. Schmidt , Mr. Tom Card, and Ms. Katie Schmidt on March 10, 2008. Site preparation included arranging for the test piles and providing access to the facility.

The objective of the study was to provide representative, fugitive air emissions of study compounds from the purpose of generating ammonia and VOC emission estimates from the composting of greenwaste at the facility. This was accomplished by selecting representative test locations, and quantitative analysis of air emissions producing representative average air emissions data.

This memorandum includes a discussion of the testing methodology, quality control procedures, results, discussion of the results, and summary statements.

## II. TEST METHODOLOGY

Testing for surface flux was conducted using the USEPA recommended Surface Isolation Flux Chamber (USEPA. Radian Corporation, February 1986). Flux chamber sampling was performed on static windrow piles of greenwaste materials as found on site the day of testing.

The operation of the surface flux chamber is given below:

1) Flux chamber, sweep air, sample collection equipment, and field documents were located on-site.

2) The site information, location information, equipment information, date, and proposed time of testing were documented on the Emissions Measurement Field Data Sheet.

3) The exact test location was selected and placed about 0.25" to 0.5" into compost matrix sealing the chamber for surface testing, or on the agricultural bag positioned to achieve a chamber/interface seal. .

4) The sweep air flow rate (ultra high purity air with a carbon monoxide tracer gas additive) was initiated and the rotometer, which stabilizes the flow rate, was set at 5.0 liters per minute. A constant sweep air flow rate was maintained throughout the measurement for each sampling location.

5) Flux chamber data were recorded every residence interval (6 minutes) for five intervals, or 30 minutes.

6) At steady-state (assumed to be greater than 5 residence intervals), the screening by colorimetric tube and real-time instrument was performed. After screening, sample collection was performed by interfacing the sample container (acid impinger, trap and canister, and tedlar bag (if scheduled) sequentially) to the purged, sample line and filling the container with sample gas or collecting the desired sample following sample collection protocols as per the work plan.

7) After sample collection (impinger solution, trap and evacuated canister, and tedlar bag) all sample media was sealed, labeled, and stored as per protocol, and sample collection information was documented on the data sheet.

8) After sampling, the flux measurement was discontinued by shutting off the sweep air,

removing the chamber, and securing the equipment. The chamber was cleaned by dry wipe with a clean paper towel and the sample lines were purged with UHP air.

9) Sampling locations were recorded on the field data sheet. The equipment was then relocated to the next test location and steps 1) through 8) were repeated.

## III. QUALITY CONTROL

Control procedures that were used to assure that data of sufficient quality resulted from the flux chamber study are listed and described below. The application and frequency of these procedures were developed to meet the program data quality objectives as described in SCAQMD Rule 1133a with some modifications.

Field Documentation -- A field notebook containing data forms, including sample chain-of-custody (COC) forms, was maintained for the testing program. Attachment A contains the Emission Measurement Data Sheets.

Chain-of-Custody -- COC forms were not used for field data collection. Field data were recorded on the Chain-of-Custody forms provided in Attachment B.

***Ammonia Analysis by SCAQMD Method 207.1***

Laboratory Spike Recovery- One laboratory spike sample was performed and the recovery of the spike was 101%. These data indicate acceptable method performance.

Calibration – A five point calibration curve was performed for the ammonia method, and the correlation curve was reported within method specification. These data indicate acceptable method performance.

Trip Blank—One trip blank sample was collected and the level reported was <0.004 mg per sample (MDL 0.004 mg) or below method detection. These data indicate acceptable method performance.

Field Replicate Sample Analysis -- One field sample was collected in replicate and analyzed for the project. The RPD values for sample/replicate pair was 12 (QC criteria 50 RPD). These data indicate acceptable method repeatability and method performance.

***Total Non-Methane and Non-Ethane Organic Compound Analysis by SCAQMD Method 25.3***

Method Quality Control –Method quality control included method blank determinations, and method response to four-point calibration curves. All method QC testing was with method specifications, and these data indicate acceptable method performance.

Field System Blank – One blank samples was analyzed as blind QC sample. TNMNEO levels in the blank sample were less that <1.0 ppmvC for the condensable, volatile and total hydrocarbon analysis (method detection limit 1 ppmvC). These data establish sensitivity for the method (project QC criteria), and indicate acceptable method performance.

Field Replicate Sample – One field sample was collected and analyzed in replicate. In this data set, study compounds detected showed precision within precision criteria for field samples (RPD 50) for the TNMNEO or total VOC concentration. The RPD for the data set was 9.0 indicating acceptable method precision and performance.

***Tracer Helium Analysis by GC/TCD***

Laboratory Control Spike and QC Duplicate Analysis- Laboratory control spike sample data are not available at this time.

Laboratory Precision– Laboratory QC sample data are not available at this time.

Tracer Recovery Sample- One media blank sample was collected in the field by filling a canister for analysis in order to determine tracer recovery apart from the flux measurement technology or the advective flow from sources. The tracer was recovered from the media blank samples with a value of 105% (QC criteria ±50%, or 50% to 150% recovery). These data indicate acceptable method performance.

Field Replicate Sample – One field sample was collected in replicate. The precision (relative percent difference) for the field replicate sample pair was 0.0, which is less than the QC criteria of 50 RPD. These data indicate acceptable method performance.

## IV. RESULTS AND DISCUSSIONS

A summary of the field sample collection for the field testing is shown in Table 1. All field data for the on site surface flux chamber testing (screening for ammonia, temperature), and sample identification information are presented in Table 1. All laboratory data including quality control data are presented in Table 2. These flux data include measured advective flow rate in the flux calculation. Surface flux data are shown in flux units for hydrocarbon emissions (mg/m2,min-1 as methane, ppmvC) and for ammonia (mg/m2,min-1 as ammonia).

Surface flux data for a surface area source are calculated using measured target compound concentrations and flux chamber operating parameter data (sweep air flow rate of 5.0 liters per minute [or 0.005 m3/min] plus advective flow [m3/min], surface area of 0.13 square meters [$m^2$]). The site emissions can be calculated by multiplying the flux by the surface area of the source. The flux is calculated from the sweep air flow rate Q (cubic meters per minute [$m^3$/min]), the species concentration Yi (micrograms per cubic meter [mg/$m^3$)], and exposure to the chamber surface area A (square meters [$m^2$]), as follows:

$$Fi = (Q) (Yi) / (A)$$

Emission rate of from a given static windrow test pile can be calculated by multiplying unit or average flux data per compound by surface area and reported as a function of area source.

Note that the recommended SCAQMD method bias factor correction of 1.086 was not applied to these data. There is no scientific justification for applying a specific bias correction factor generated from one laboratory to another laboratory, since a given analytical method bias is unique to that laboratory and not intrinsic to the method.

## V. SUMMARY

Emission testing was performed on the Site X static windrow, greenwaste compost operations in order to generate an estimate of the facility baseline emissions for VOCs and ammonia. Testing was conducted at key times (compost at different age and under different conditions) in the compost cycle for the purpose of obtaining representative air emissions of ammonia and VOCs from the test piles. The following is a summary of activities and results associated with this objective:

- Surface flux measurements of study compounds were measured on static windrow piles in the compost cycle, from the pre-compost windrow piles to near the end-of-cycle compost (Day 79). Testing was performed using the USEPA recommended surface flux chamber technology as modified by the SCAQMD for advective flow sources at compost sites. This technology quantitatively measures flux at the test surface of study compounds.

- Field and laboratory quality control data indicate acceptable data quality for SCAQMD Method 207.1 (ammonia) and SCAQMD Method 25.3 (organic gases). System blank levels were acceptable, and precision between a sample and replicate field samples was within the RPD criteria of 50. The recovery of the helium tracer QC showed acceptable method performance, and the use of the helium recovery data per sample demonstrated to be a effective and representative approach to assessing volumetric flow from the sources tested.

- Note that the recommended SCAQMD method bias factor correction of 1.086 was not applied to these data. There is no scientific justification for applying a specific bias correction factor generated from one laboratory to another laboratory, since a given analytical method bias is unique to that laboratory and not intrinsic to the method.

- The wind speeds experienced on the day of testing may have affected the emission estimate. It is believed that higher winds generate higher flux and thus air emissions. The winds on the day of testing ranged from 13 mph to 14 mph. This is a high wind area, however, using these test data to represent an annual emissions estimate may result in a bias in the emissions.

- Two samples were collected on a ‘pre-compost’ windrow, meaning that material prepared composting was tested and the pile was not yet included in the life-cycle process. Data from this ‘front-end’ area source, although small in surface area, was used to represent greenwaste material on site prior to entering the composting operations, including the tipping piles, screening piles, and storing piles.

- The flux data can be used to estimate ammonia, and VOC emissions from the test pile surfaces. Emission rate data is obtained by multiplying surface areas of the test piles by the surface area of the test piles.

## REFERENCES

USEPA. 1986. "Measurement of Gaseous Emission Rates From Land Surfaces Using an Emission Isolation Flux Chamber, Users Guide." EPA Environmental Monitoring Systems Laboratory, Las Vegas, Nevada, EPA Contract No. 68-02-3889, Work Assignment No. 18, Radian Corporation, February 1986. NTIS # PB 86-223161.

Table 1. Summary of Test Information.

| DATE | TIME | SOURCE | COMPOST | Section | TEST LOCATION | NH3 | Helium | TRACER | 25.3 | 207.1 | IN SURF | IN AIR | OUT SURF | OUT AIR | WINDS | COMMENT |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | DAY | PILE | | (ppmv) | (%) | SF6 | ID | ID | °F | °F | °F | °F | (mph) | |
| 3/10/2008 | 941 | Windrow Compost | 10 | D-16 | Top- T1 | 10 | 10.31 | 1.046 | G-101 | A-101 | 63 | 83 | 63 | 61 | 13 | Mixed and water added 3 days prior, pile 4.5' tall, 10' base |
| 3/10/2008 | 942 | Windrow Compost | 10 | D-16 | Top-T2 | 12 | 10.22 | 1.049 | G-102 | A-102 | 89 | 95 | 84 | 61 | 13 | Mixed and water added 3 days prior |
| 3/10/2008 | 942 | Windrow Compost | 10 | D-16 | Side- S1 | 12 | 10.20 | 1.058 | G-103 | A-103 | 66 | 92 | 66 | 66 | 13 | Mixed and water added 3 days prior |
| 3/10/2008 | 943 | Windrow Compost | 10 | D-16 | Side- S2 | 4 | 10.33 | 1.042 | G-104 | A-104 | 58 | 75 | 58 | 62 | 13 | Mixed and water added 3 days prior |
| 3/10/2008 | 1136 | Windrow Compost | 6 | D-18 | Top- T1 | 28 | 10.33 | 1.042 | G-105 | A-105 | 64 | 100 | 64 | 68 | 13 | |
| 3/10/2008 | 1139 | Windrow Compost | 6 | D-18 | Side- S1 | 2 | 10.31 | 1.046 | G-106 | A-106 | 62 | 90 | 62 | 68 | 13 | |
| 3/10/2008 | 1144 | Windrow Compost- Post Mix Hr-1 | 10 | D-16 | Top- T1 | 8 | 10.20 | 1.058 | G-107 | A-107 | 66 | 92 | 66 | 70 | 13 | Mixed at 1107 |
| 3/10/2008 | 1148 | Windrow Compost- Post Mix Hr-1 | 10 | D-16 | Side- S1 | 12 | 10.22 | 1.049 | G-108 | A-108 | 125 | 95 | 125 | 68 | 13 | Mixed at 1107 |
| 3/10/2008 | 1250 | Windrow Compost- Post Mix Hr-3 | 10 | D-16 | Top- T1 | 10 | 10.20 | 1.058 | G-111 | A-111 | 65 | 84 | 65 | 76 | 14 | Mixed at 1107 |
| 3/10/2008 | 1343 | Windrow Compost- Post Mix Hr-3 | 10 | D-16 | Side- S2 | 20 | 10.22 | 1.049 | G-112 | A-112 | 60 | 90 | 60 | 77 | 14 | Mixed at 1107 |
| 3/10/2008 | 1351 | Windrow Compost | 30 | E-7 | Top- T1 | 8 | 10.33 | 1.042 | G-109 | A-109 | 60 | 104 | 60 | 76 | ND | Pile 4' tall, 10' wide base |
| 3/10/2008 | 1351 | Windrow Compost | 30 | E-7 | Side- S1 | 6 | 10.31 | 1.046 | G-110 | A-110 | 62 | 92 | 62 | 77 | ND | |
| 3/10/2008 | 1535 | Windrow Compost- Post Mix Hr-5 | 10 | D-16 | Top- T1 | 8 | 10.20 | 1.058 | G-113 | A-113 | 63 | 80 | 63 | 75 | ND | Mixed at 1107 |
| 3/10/2008 | 1537 | Windrow Compost- Post Mix Hr-5 | 10 | D-16 | Side-2 | 16 | 10.22 | 1.049 | G-114 | A-114 | 66 | 86 | 66 | 77 | ND | Mixed at 1107 |
| 3/10/2008 | 1548 | Windrow Compost | 79 | B-10 | Top- T1 | 4 | 10.31 | 1.046 | G-115 | A-115 | 64 | 93 | 64 | 75 | ND | Pile 3.5' tall and 9 ' wide base |
| 3/10/2008 | 1549 | Windrow Compost | 79 | B-10 | Side- S2 | 2 | 10.33 | 1.042 | G-116 | A-116 | 70 | 81 | 70 | 76 | ND | |
| 3/10/2008 | 1707 | Windrow Compost- Prep Pile | 0 | C-12 | Top- T1 | <0.05 | 10.20 | 1.058 | G-117 | A-117 | 72 | 82 | 72 | 78 | ND | |
| 3/10/2008 | 1715 | Windrow Compost- Prep Pile | 0 | C-12 | Side- S1 | 1 | 10.20 | 1.058 | G-118 | A-118 | 74 | 79 | 74 | 78 | ND | |
| 3/10/2008 | 1715 | Sample Replicate | 0 | C-12 | Side- S1 | 1 | 10.20 | 1.058 | G-119 | A-119 | 74 | 79 | 74 | 78 | ND | Sample Replicate |
| 3/10/2008 | 1715 | Media Blank | N/A | N/A | N/A | N/A | 10.20 | 1.058 | G-120 | A-120 | N/A | N/A | N/A | N/A | NA | Reagent Blank |

Table 2.  Summary of Flux Data (mg/m2,min-1).

| SOURCE | COMPOST DAY | TEST LOCATION | 25.3 ID | 207.1 ID | Methane (ppmv) | Ethane (ppmv) | TNMNEO (ppmv) | NMNEO Trap (ppmv) | NMNEO Tank (ppmv) | NH3 (mg) | NH3 Vol (m3) | NH3 (mg/m3) | Helium % |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Windrow Compost | 10 | Top- T1 | G-101 | A-101 | 27.4 | ND | **12.2** | 6.06 | 6.12 | 0.365 | 0.0295 | 12.4 | 10.31 |
| Windrow Compost | 10 | Top-T2 | G-102 | A-102 | 16.7 | ND | **11.8** | 11.2 | 1.0 | 0.489 | 0.0268 | 18.2 | 10.22 |
| Windrow Compost | 10 | Side- S1 | G-103 | A-103 | 93 | ND | **21.0** | 20.1 | 1.0 | 0.278 | 0.0282 | 9.9 | 10.20 |
| Windrow Compost | 10 | Side- S2 | G-104 | A-104 | 17.2 | ND | **4.25** | 3.58 | 1.0 | 0.055 | 0.0248 | 2.2 | 10.33 |
| Windrow Compost | 6 | Top- T1 | G-105 | A-105 | 10 | ND | **17.7** | 17.2 | 1.0 | 0.505 | 0.0311 | 16.2 | 10.33 |
| Windrow Compost | 6 | Side- S1 | G-106 | A-106 | 65 | ND | **9.94** | 9.37 | 1.0 | 0.029 | 0.0303 | 0.96 | 10.31 |
| Windrow Compost- Post Mix Hr-1 | 10 | Top- T1 | G-107 | A-107 | 14.9 | ND | **5.62** | 4.89 | 1.0 | 0.113 | ###### | 3.8 | 10.20 |
| Windrow Compost- Post Mix Hr-1 | 10 | Side- S1 | G-108 | A-108 | 65.7 | ND | **10.6** | 9.45 | 1.14 | 0.239 | 0.0332 | 7.2 | 10.22 |
| Windrow Compost- Post Mix Hr-3 | 10 | Top- T1 | G-111 | A-111 | 11.5 | ND | **5.77** | 5.23 | 1.0 | 0.123 | 0.0271 | 4.5 | 10.20 |
| Windrow Compost- Post Mix Hr-3 | 10 | Side- S2 | G-112 | A-112 | 48.7 | ND | **7.15** | 5.65 | 1.49 | 0.202 | 0.0254 | 8.0 | 10.22 |
| Windrow Compost | 30 | Top- T1 | G-109 | A-109 | 58.3 | ND | **5.97** | 5.57 | 1.0 | 0.050 | 0.0130 | 3.8 | 10.33 |
| Windrow Compost | 30 | Side- S1 | G-110 | A-110 | 574 | ND | **6.65** | 5.82 | 1.0 | 0.002 | 0.0103 | 0.19 | 10.31 |
| Windrow Compost- Post Mix Hr-5 | 10 | Top- T1 | G-113 | A-113 | 19.3 | ND | **3.91** | 3.34 | 1.0 | 0.089 | 0.0231 | 3.9 | 10.20 |
| Windrow Compost- Post Mix Hr-5 | 10 | Side-2 | G-114 | A-114 | 42.0 | ND | **5.19** | 4.14 | | 0.163 | 0.0219 | 7.4 | 10.22 |
| Windrow Compost | 79 | Top- T1 | G-115 | A-115 | 100 | ND | **5.41** | 2.91 | | 0.011 | 0.0587 | 0.19 | 10.31 |
| Windrow Compost | 79 | Side- S2 | G-116 | A-116 | 79.60 | ND | **5.70** | 4.27 | | 0.009 | 0.0588 | 0.15 | 10.33 |
| Windrow Compost- Prep Pile | 0 | Top- T1 | G-117 | A-117 | 2.13 | ND | **27.6** | 27.6 | 1.0 | 0.004 | 0.0509 | 0.08 | 10.20 |
| Windrow Compost- Prep Pile | 0 | Side- S1 | G-118 | A-118 | 47.20 | ND | **116** | 115 | 1.0 | 0.013 | 0.0512 | 0.25 | 10.20 |
| Sample Replicate | 0 | Side- S1 | G-119 | A-119 | 46.70 | ND | **106** | 105 | 1.0 | 0.013 | 0.0605 | 0.21 | 10.20 |
| Media Blank | N/A | N/A | G-120 | A-120 | 1.0 | ND | **1.0** | 1.0 | 1.0 | 0.004 | 0.0540 | 0.074 | 10.20 |

Flux Unit: mg/m2,min-1

Note 1- Methane Flux = (CH4 ppmv)(0.653)(m3/min)/0.13 = mg/m2,min-1 CH4

Note 2- TNMNEO Flux = (TNMNEO ppmv)(0.653)(m3/min)/0.13 = mg/m2,min-1 TNMNEO

Note 3- Ammonia Flux = (NH3 mg/m3)(m3/min)/(0.13 m2) = mg/m2,min-1 NH3

Note 4- Total Flow = (Helium %/Helium % recovered)(0.005 m3/min) = m3/min total flow

Note 5- MDL value used for ND or non-detect for calcuation purposes

Table 2. Summary of Flux Data (mg/m2,min-1).

| Trace % | Total Flow (m3/min) | SF6 UHP (ppbv) | SF6 Detect (ppbv) | Methane Flux | TNMNEO Flux | NH3 Flux | SOURCE | TEST LOCATION | COMPOST DAY | COMMENT |
|---|---|---|---|---|---|---|---|---|---|---|
| 0.20 | 0.2578 | N/A | N/A | 35.47 | **16** | **25** | Windrow Compost | Top- T1 | 10 | |
| 0.27 | 0.1893 | N/A | N/A | 15.88 | **11** | **27** | Windrow Compost | Top-T2 | 10 | |
| 0.23 | 0.2217 | N/A | N/A | 103.58 | **23** | **17** | Windrow Compost | Side- S1 | 10 | |
| 0.19 | 0.2718 | N/A | N/A | 23.49 | **5.8** | **4.6** | Windrow Compost | Side- S2 | 10 | |
| 0.27 | 0.1913 | N/A | N/A | 9.49 | **17** | **24** | Windrow Compost | Top- T1 | 6 | |
| 0.16 | 0.3222 | N/A | N/A | 105.52 | **16** | **2.4** | Windrow Compost | Side- S1 | 6 | |
| 0.15 | 0.3400 | N/A | N/A | 25.45 | **9.6** | **10** | Windrow Compost- Post Mix Hr-1 | Top- T1 | 10 | |
| 0.19 | 0.2689 | N/A | N/A | 88.76 | **14** | **15** | Windrow Compost- Post Mix Hr-1 | Side- S1 | 10 | |
| 0.12 | 0.4250 | N/A | N/A | 24.55 | **12** | **15** | Windrow Compost- Post Mix Hr-3 | Top- T1 | 10 | |
| 0.16 | 0.3194 | N/A | N/A | 78.13 | **11** | **20** | Windrow Compost- Post Mix Hr-3 | Side- S2 | 10 | |
| 0.28 | 0.1845 | N/A | N/A | 54.02 | **5.5** | **5.5** | Windrow Compost | Top- T1 | 30 | |
| 0.24 | 0.2148 | N/A | N/A | 619.30 | **7.2** | **0.32** | Windrow Compost | Side- S1 | 30 | |
| 0.12 | 0.4250 | N/A | N/A | 41.20 | **8.3** | **13** | Windrow Compost- Post Mix Hr-5 | Top- T1 | 10 | |
| 0.18 | 0.2839 | N/A | N/A | 59.89 | **7.4** | **16** | Windrow Compost- Post Mix Hr-5 | Side-2 | 10 | |
| 0.47 | 0.1097 | N/A | N/A | 55.09 | **3.0** | **0.16** | Windrow Compost | Top- T1 | 79 | |
| 0.30 | 0.1722 | N/A | N/A | 68.84 | **4.9** | **0.20** | Windrow Compost | Side- S2 | 79 | |
| 0.19 | 0.2684 | N/A | N/A | 2.87 | **37** | **0.16** | Windrow Compost- Prep Pile | Top- T1 | 0 | Representative of Tipping Pile/Pre Pile |
| 0.16 | 0.3188 | N/A | N/A | 75.57 | **186** | **0.62** | Windrow Compost- Prep Pile | Side- S1 | 0 | |
| 0.16 | 0.3188 | N/A | N/A | 74.77 | **170** | **0.53** | Sample Replicate | Side- S1 | 0 | |
| 10.7 | 0.005 | N/A | N/A | 0.025 | **0.025** | **0.0028** | Media Blank | N/A | N/A | 105 Percent Recovery of He Tracer |
| | | | | | | | | | | |

MDL Value Used

Note 1- Methane Flux = (CH4 ppmv)(0.653)(m3/min)/0.13 = mg/m2,min-1 CH4
Note 2- TNMNEO Flux = (TNMNEO ppmv)(0.653)(m3/min)/0.13 = mg/m2,min-1 TNMNEO
Note 3- Ammonia Flux = (NH3 mg/m3)(m3/min)/(0.13 m2) = mg/m2,min-1 NH3
Note 4- Total Flow = (Helium %/Helium % recovered)(0.005 m3/min) = m3/min total flow
Note 5- MDL value used for ND or non-detect for calcuation purposes

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ATTACHMENT A

EMISSION MEASUREMENT DATA SHEETS

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ATTACHMENT B

CHAIN OF CUSTODY

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ATTACHMENT C

LABORATORY REPORTS

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