SWAG Project Farm (09478)

Date: 12/10/202

New Jersey Department of Environmental Protection
Reason for Application

Permit Being Modified

Permit Class: **Number:** 0

Description of Modifications: Urban Agriculture Cooperative (UAC) is seeking this permit as part of its efforts to begin a pilot program for composting at community gardens in New Jersey. The site in question is referred to as the SWAG Project Farm; it is a community garden operated on a property leased from the City of Newark. It is expected that the composting program will receive no more than 200 gallons per week of food waste (other than meat, fats, oils, grease, bones, whole eggs, milk or other dairy products, or any other waste that may cause a public health risk or create nuisance conditions) from members of the community. The composting operations will utilize three wood pallet bins (each of 4 ft by ft by 4 ft) as well as an aeration system powered by a 1 hp blower. The blower will operate for approximately 10 seconds every hour. The compost pile will also be covered following incorproation of new materials with a layer of wood chips or finished compost. While the using a blower and covering the pile with non-putrescible materials has been shown to reduce emmissions significantly, due to the difficulty in modelling such reductions and the limited emmissions involved, the emmissions calculations contained herein do not account for such reductions.

New Jersey Department of Environmental Protection
Facility Profile (General)

Facility Name (AIMS): SWAG Project Farm

Facility ID (AIMS): 09478

Street Address: SWAG PROJECT FARM
438-441 PESHINE AVE
NEWARK, NJ 07112

Mailing Address: URBAN AGRICULTURE COOPERTIVE
58 CRAWFORD ST
Attn: Emilio Panasci
NEWARK, NJ 07102

State Plane Coordinates:

X-Coordinate:

Y-Coordinate:

Units:

Datum:

Source Org.:

Source Type:

County: Essex

Location Description:

Industry:

Primary SIC:

Secondary SIC:

NAICS: 111219

New Jersey Department of Environmental Protection
Facility Profile (General)

Contact Type: **Air Permit Information Contact**

Organization: Urban Agriculture Cooperative
Org. Type: Nonprofit
Name: Emilio Panasci
NJ EIN:
Title: Executive Director
Phone: (908) 208-7244 x
Mailing Address: 58 Crawford St Newark, NJ 07102
Fax: ( ) - x
Other: ( ) - x
Type:
Email: epanasci@gmail.com

Contact Type: **Fees/Billing Contact**

Organization: Urban Agriculture Cooperative
Org. Type: Nonprofit
Name: Emilio Panasci
NJ EIN:
Title: Executive Director
Phone: (908) 208-7244 x
Mailing Address: 58 Crawford St Newark, NJ 07102
Fax: ( ) - x
Other: ( ) - x
Type:
Email: epanasci@gmail.com

Contact Type: **General Contact**

Organization: Urban Agriculture Cooperative
Org. Type: Nonprofit
Name: Emilio Panasci
NJ EIN:
Title: Executive Director
Phone: (908) 208-7244 x
Mailing Address: 58 Crawford St Newark, NJ 07102
Fax: ( ) - x
Other: ( ) - x
Type:
Email: epanasci@gmail.com

New Jersey Department of Environmental Protection
Facility Profile (General)

Contact Type: **Responsible Official**

Organization: Urban Agriculture Cooperative

Org. Type: Nonprofit

Name: Emilio Panasci

NJ EIN:

Title: Executive Director

Phone: (908) 208-7244 x

Mailing Address: 58 Crawford St
Newark, NJ 07102

Fax: ( ) - x

Other: ( ) - x

Type:

Email: epanasci@gmail.com

New Jersey Department of Environmental Protection
Facility Profile (Permitting)

1. Is this facility classified as a small business by the USEPA?	No
2. Is this facility subject to N.J.A.C. 7:27-22?	No
3. Are you voluntarily subjecting this facility to the requirements of Subchapter 22?	No
4. Has a copy of this application been sent to the USEPA?	No
5. If not, has the EPA waived the requirement?	No
6. Are you claiming any portion of this application to be confidential?	No
7. Is the facility an existing major facility?	No
8. Have you submitted a netting analysis?	No
9. Are emissions of any pollutant above the SOTA threshold?	No
10. Have you submitted a SOTA analysis?	No
11. If you answered "Yes" to Question 9 and "No" to Question 10, explain why a SOTA analysis was not required	
12. Have you provided, or are you planning to provide air contaminant modeling?	No

New Jersey Department of Environmental Protection
Equipment Inventory

Equip. NJID	Facility's Designation	Equipment Description	Equipment Type	Certificate Number	Install Date	Grand-Fathered	Last Mod. (Since 1968)	Equip. Set ID
E1	Compost Bin	A covered wood bin that is 4 ft by 4 ft by 4 ft and is attached to two other bins; the three bin system is aerated by 1 hp blower. Install estimated.	Manufacturing and Materials Handling Equipment		12/15/2020			
E2	Compost Bin	A covered wood bin that is 4 ft by 4 ft by 4 ft and is attached to two other bins; the three bin system is aerated by 1 hp blower. Install estimated.	Manufacturing and Materials Handling Equipment		12/15/2020			
E3	Compost Bin	A covered wood bin that is 4 ft by 4 ft by 4 ft and is attached to two other bins; the three bin system is aerated by 1 hp blower. Install estimated.	Manufacturing and Materials Handling Equipment					

SWAG Project Farm (09478)

Date: 12/10/2020

New Jersey Department of Environmental Protection
Emission Points Inventory

PT NJID	Facility's Designation	Description	Config.	Equiv. Diam. (in.)	Height (ft.)	Dist. to Prop. Line (ft)	Exhaust Temp. (deg. F)			Exhaust Vol. (acfm)			Discharge Direction	PT Set ID
							Avg.	Min.	Max.	Avg.	Min.	Max.		
PT1	Bins	The bins are covered, but perforations in the sides will allow emissions to escape, similar to an open surface operation.												

SWAG Project Farm (09478)

Date: 12/10/2020

New Jersey Department of Environmental Protection
Emission Unit/Batch Process Inventory

U 1 Compost Bins Emissions resulting from the three on-site compost bins.

UOS NJID	Facility's Designation	UOS Description	Operation Type	Signif. Equip.	Control Device(s)	Emission Point(s)	SCC(s)	Annual Oper. Hours Min.	Annual Oper. Hours Max.	VOC Range	Flow (acfm) Min.	Flow (acfm) Max.	Temp. (deg F) Min.	Temp. (deg F) Max.
OS1	Compost Bins	Emissions from E1	Normal - Steady State	E1				0.0	8,760.0					
OS2	Compost Bins	Emissions from E2	Normal - Steady State	E2				0.0	8,760.0					
OS3	Compost Bins	Emissions from E3	Normal - Steady State	E3				0.0	8,760.0					

09478 SWAG Project Farm Date: 12/10/2020

New Jersey Department of Environmental Protection
Potential to Emit

Subject Item: **U1 Compost Bins**

Operating Scenario: **OS0 Summary**

Step:

Air Contaminant Category (HAPS)	Fugitive Emissions	Emissions Before Controls	Emissions After Controls	Total Emissions	Units	Alt. Em. Limit
VOC (Total)				0.28504320	tons/yr	No

Subject Item: **U1 Compost Bins**

Operating Scenario: **OS1**

Step:

Air Contaminant Category (HAPS)	Fugitive Emissions	Emissions Before Controls	Emissions After Controls	Total Emissions	Units	Alt. Em. Limit
VOC (Total)				0.02169300	lb/hr	No

Subject Item: **U1 Compost Bins**

Operating Scenario: **OS2**

Step:

Air Contaminant Category (HAPS)	Fugitive Emissions	Emissions Before Controls	Emissions After Controls	Total Emissions	Units	Alt. Em. Limit
VOC (Total)				0.02169300	lb/hr	No

Subject Item: **U1 Compost Bins**

Operating Scenario: **OS3**

Step:

Air Contaminant Category (HAPS)	Fugitive Emissions	Emissions Before Controls	Emissions After Controls	Total Emissions	Units	Alt. Em. Limit
VOC (Total)				0.02169300	lb/hr	No

000000 E1 (Manufacturing and Materials Handling Equipment)
Print Date: 12/10/2020

Make:	N/A
Manufacturer:	N/A
Model:	N/A
Type of Manufacturing and Materials Handling Equipment:	Composting Equiment
Capacity:	6.40E+01
Units:	ft^3
Description (if other):	
Have you attached a diagram showing the location and/or the configuration of this equipment?	No
Have you attached any manuf.'s data or specifications to aid the Dept. in its review of this application?	No
Comments:	A covered wood pallet bin that is 4 ft by 4 ft by 4 ft in size and is attached to two other bins; the three bin system is aerated by a 1 hp blower.

000000 E2 (Manufacturing and Materials Handling Equipment)
Print Date: 12/10/2020

Make:	N/A
Manufacturer:	N/A
Model:	N/A
Type of Manufacturing and Materials Handling Equipment:	Composting Equiment
Capacity:	6.40E+01
Units:	ft^3
Description (if other):	
Have you attached a diagram showing the location and/or the configuration of this equipment?	No
Have you attached any manuf.'s data or specifications to aid the Dept. in its review of this application?	No
Comments:	A covered wood pallet bin that is 4 ft by 4 ft by 4 ft in size and is attached to two other bins; the three bin system is aerated by a 1 hp blower.

000000 E3 (Manufacturing and Materials Handling Equipment)
Print Date: 12/10/2020

Make:	N/A
Manufacturer:	N/A
Model:	N/A
Type of Manufacturing and Materials Handling Equipment:	Composting Equiment
Capacity:	6.40E+01
Units:	ft^3
Description (if other):	
Have you attached a diagram showing the location and/or the configuration of this equipment?	No
Have you attached any manuf.'s data or specifications to aid the Dept. in its review of this application?	No
Comments:	A covered wood pallet bin that is 4 ft by 4 ft by 4 ft in size and is attached to two other bins; the three bin system is aerated by a 1 hp blower.

San Joaquin Valley
AIR POLLUTION CONTROL DISTRICT

Compost VOC Emission Factors

September 15, 2010

Reviewers:
Jim Swaney, P.E., Permit Services Manager
Sheraz Gill, Supervising Air Quality Engineer

Authors:
Brian Clements, Senior Air Quality Engineer
Ramon Norman, Air Quality Engineer II
Kai Chan, Air Quality Engineer II

I. Introduction

This report provides the basis for the District's organic material composting volatile organic compound (VOC) emission factors (EFs). The organic material composting EFs contain the following categories: green waste, food waste, and grape pomace. However, the focus will be on green waste, since the San Joaquin Valley's inventory of organic material compost is primarily green waste. The EFs will be used for Rule 4566 (*Organic Material Management*) development and permitting applications in the San Joaquin Valley. These organic material composting EFs are not applicable to biosolids, animal manure, or poultry litter, which have been attributed a separate EF.

Accurate emission factors are required for the proper implementation of applicable air quality regulations and also for the evaluation of appropriate technologies and practices to reduce emissions. The VOC EFs proposed in this report are based on a detailed review of the available science. As would be the case with EFs for other sources, the District's EF should reflect the best scientific information that is currently available.

The District composting EFs are summarized below.

Table 1: Summary of District Composting EFs.

Compost Type	Stockpile (lb-VOC/wet ton/day)	Windrow EF Per composting cycle (lb-VOC/wet ton)
Green Waste, Food Waste, Grape Pomace	1.063	5.71
Co-Composting Biosolids, Animal Manure, Poultry Litter	-	1.78

II. Background

A. Air Quality

The San Joaquin Valley air basin has an inland Mediterranean climate characterized by hot, dry summers and cool, foggy winters. The San Joaquin Valley is surrounded by mountains on the east, west, and south sides. This creates stagnant air patterns that trap pollution, particularly in the south of the San Joaquin Valley. Additionally, the sunshine and hot weather, which are prevalent in the summer, lead to the formation of ozone (photochemical smog). Because of the San Joaquin Valley's geographic and meteorological conditions, it is extremely sensitive to increases in emissions and experiences some of the worst air quality in the nation.

The San Joaquin Valley Air Basin is now classified as an extreme non-attainment area for the health-based, Federal eight-hour ozone standard because of the inability to reach attainment of the standard by the earlier serious and severe

classification attainment dates. The air basin is also classified as a non-attainment area for the Federal PM-2.5 (ultra-fine particulate matter) standard.

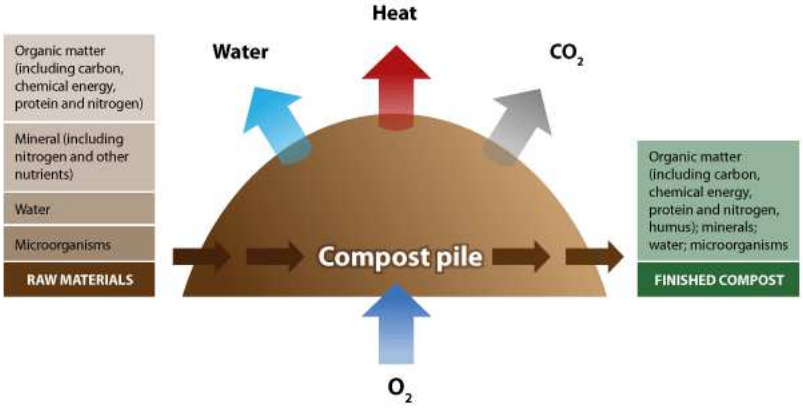
B. Composting

Compost operations can be sources of smog-forming VOCs, fine particulate matter, ammonia (NH_3), and greenhouse gases such as carbon dioxide (CO_2) and methane (CH_4). The emissions are directly emitted from the decomposition of organic material in the San Joaquin Valley. Composting is a process that involves the biological break down of organic matter, typically into marketable products (soil amendments, animal bedding, and alternative daily cover at landfills). Composting uses wastes from a wide-variety of sources, such as curb-side green waste, landscaping, agricultural processing, crop harvesting, food consumption, and forest management.

There are two general categories of composting, aerobic and anaerobic:

Aerobic composting is the decomposition of organic material by microbiological organisms (microbes) in the presence of oxygen (O_2). This oxidation process theoretically results in CO_2, water (H_2O), and organic matter, including nitrates, sulphates and other minerals. Figure 1 below is a visual presentation of theoretic aerobic composting:

Figure 1: Aerobic Compost. [1]



Anaerobic composting is the decomposition of organic matter by microbes in the absence of O_2. During this digestion process, a gas primarily composed of CH_4 and CO_2, known as biogas, waste gas or digester gas is produced. Biogas also consists of nitrogen (N_2), O_2, NH_3, hydrogen sulfide (H_2S), and various VOCs. However, these additional products are generated in relatively small amounts when compared to the amount of CH_4 and CO_2 produced.

[1] http://www.londonfoodrecycling.co.uk

C. Purpose of the San Joaquin Valley Air Pollution Control District

The San Joaquin Valley Air District is a public health agency whose mission is to improve the health and quality of life for all Valley residents through efficient, effective and entrepreneurial air quality management strategies. To protect the health of Valley residents, the District works toward achieving attainment with health-based ambient air quality standards as required under State and Federal law. To achieve this goal, the District develops and adopts air quality attainment plans that include control measures aimed at further reducing emissions from a broad range of sources, commercial, industrial, and agricultural.

As mandated by Federal Law, the San Joaquin Valley Air District adopted its 8-hr ozone attainment plan to demonstrate how the Valley would reach attainment with the Federal eight-hour ozone standard. In developing the ozone attainment plan every feasible measure to reduce emissions of ozone precursors (VOC and NOx) was explored. Green waste composting was a control measured identified in the ozone plan. As such, plans to develop Rule 4566 (*Organic Material Management*) are in place. However, even though the District will be requiring every practical VOC and NOx control, and will be relying on the state and federal governments to significantly reduce emissions from mobile sources of pollution, the San Joaquin Valley will still need the development and adoption of future, not-yet-developed, clean air technologies to reach attainment by the 2023 deadline. Achieving the goal of attainment with air quality standards will require continued contributions from all industries, businesses, and individuals in the San Joaquin Valley.

D. Permitting Requirements

A critical tool that the air districts use to limit increases in emissions of air pollutants and to assure compliance with air quality regulations is the issuance of conditional construction and operating permits to commercial, industrial, and agricultural sources of air pollution. Since the 1970s, the San Joaquin Valley Air Pollution Control District and its predecessors have issued tens of thousands of conditional permits that are being used to assure compliance with air pollution control requirements throughout the Valley. District permits address the requirements of federal standards, state regulations, and District rules that specifically apply to a source of air pollution. New and modified sources of air pollution are also subject to the more protective requirements of “New Source Review”, which are determined on a case-by-case basis and are also included in the permit. Permit holders, District Inspectors, and others use these District permits, rather than directly reference the complex and voluminous underlying regulations, to verify compliance with applicable air quality requirements.

For new sources, the District begins permitting them as we become aware of their emissions. The permitting threshold for these types of operations is 2 lb-pollutant/day. Currently the District quantifies VOC and NH_3 emissions to composting operations. Therefore, any organic material composting operation

which has the potential to emit more than 2 lbs of either VOC or NH_3 per day is subject to District permitting.

III. EF Determination Analysis

Many factors, which are related, affect the composting process that makes it difficult to scientifically analyze composting from an air emissions standpoint. The major factors affecting compost are oxygen, moisture, seasonal temperature fluctuation, temperature increases resulting from microbial respiration, nutrients (especially carbon and nitrogen), feedstock variability and pH. As such, the District will rely heavily on actual test data for this emission factor determination.

A. Green Waste Composting EFs

The chosen EFs are based on the available source test data for organic material composting sites. The District contracted a review of this data to Charles E. Schmidt with the goal of establishing green waste EFs for rule making purposes. The report was intended to identify the tests that utilized appropriate sampling and analytical methods and that were statistically relevant. As a result, the following report was prepared: "Organic Material Composting and Drying focusing on Greenwaste Compost Air Emissions Data Review", by Thomas R. Card and Charles E. Schmidt, June 2008 (see the Appendix A for the full report). This report will be referred to as the "green waste report" hereafter within this document.

The tests were based on the concept of flux emissions escaping the green waste piles. In this context, flux means the rate of mass flow of fluid gases through a given surface area. For example, the flux emissions may be measured in units of mg-VOC/min-m^2. Knowing the total composting period of time, surface pile area, and pile mass, the flux emission factors may be converted to typical EFs used for permitting and rule making, such as in units of lb-VOC/ton. The flux emissions were primarily sampled using the SCAQMD Modified USEPA surface emission isolation flux chamber method, and analyzed using SCAQMD Method 25.3 for total VOCs.

Table 5.1 of the green waste report summarizes the most relevant green waste composting data. The relevant test locations identified in Table 5.1 are Site X, CIWMB Modesto, NorCal, CIWMB Tierra Verde, and two at SCAQMD Inland. Since the compilation of the green waste report, another relevant test was performed at the Northern Recycling Zamora Compost Facility. This test was also conducted by Card and Schmidt. The summary is contained in Tables 2 and 3 below.

1.) Green Waste Stockpile EF

The green waste EFs shown in the Table 2 below are based on a one day stockpile period. While a one day stockpiling period may not be how every facility in the SJV operates, the EF can be applied on a case-by-case basis when stockpiling time periods are known. Also of note, the source test reports do not show the Table 2 numbers directly. The source tests each reported the stockpile EF based on their own site-specific stockpile period. For example, the Northern Recycling Zamora stockpile test assumed the EF for a 90-day stockpile time. The Northern Recycling Zamora stockpile sampling was performed on days 1 and 7, which is representative of normal SJV stockpiling. To arrive at the 90-day stockpile EF, it was assumed the average rates measured on days 1 and 7 were emitted for 90 days. The District reduced the EF to a one-day basis for this EF report. Each of the other stockpile EFs were normalized to a one day basis as well.

Table 2: Green Waste Stockpile VOC EF

Site	Sampling Age of Material	Season Samples Taken	EF (lb-VOC/wet ton/day)
Northern Recycling Zamora	Day 1 & Day 7	Spring	0.126
NorCal Jepson Prairie (Vacaville)	Day 1	Summer	0.422
SCAQMD Inland	Day 2	Fall	0.907
SCAQMD Inland	Day 2	Fall	2.798
Average			1.063

The District surveyed the green waste composting facilities in the San Joaquin Valley. The result of the survey indicates an average stockpile time of 3.85 days, and ranged from 0-21 days. The Site X stockpile EF was based on sampling at day 45, and is not representative of stockpiling in the San Joaquin Valley. As such, the Site X stockpile test was not included in the stockpile EF. The test at CIWMB (Modesto) contained no stockpile data and does not factor into the green waste stockpile EF. The test at CIWMB Tierra Verde contained no uncontrolled stockpile data and does not factor into the green waste stockpile EF.

2.) Green Waste Windrow EF

Table 3: Green Waste Windrow VOC EF

Site	Sampling Age of Material	Season Samples Taken	EF (lb-VOC/wet ton/day)
CIWMB (Modesto)	Over the Active + Curing Phase (days not sampled were interpolated)	Spring	0.85*
Site X		Summer	6.30
NorCal Jepson Prairie (Vacaville)		Fall	5.65
Northern Recycling (Zamora)		Fall	10.03
Average			5.71

*1.54 was identified in the green waste report after a recalculation to better represent other sites; however, 0.85 was the actual value reported from this test site and will be used in the EF determination.

The test results for CIWMB Tierra Verde indicate the testing was performed for other management strategies, not a typical baseline facility; therefore, does not factor into the green waste windrow EF. The two test results for SCAQMD Inland indicate the windrows tested were extremely small; therefore, does not factor into the green waste windrow EF.

Please note, the values are based on the input material (as wet tons), not finished material. The green waste windrow composting EF is based on a typical active + curing phase composting life cycle (minimum 60 days). The active-phase has been defined at a minimum 22 days for District purposes. The District has also examined the VOC profile split over the course of a windrow cycle. The results are summarized below.

Table 4: Green Waste Windrow VOC EF Active-Phase vs Curing-Phase.

Windrow Phase	Overall EF Active + Curing (lb-VOC/wet ton)	VOC Profile Split (%)	Phase EF (lb-VOC/wet ton)
Active-Phase	5.71	90%	5.14
Curing-Phase		10%	0.57

B. Food Waste Composting EFs

The District has not been able to identify an emission factor for uncontrolled food waste composting. Source tests from controlled composting operations have yielded emission factors ranging from 3.4 lb VOC per ton food waste composted

(micropore cover) to 37.1 lb VOC per ton food waste composted (Ag Bag). In addition to the wide range of values observed, it is also unlikely that emissions from a covered system would accurately represent emissions from the open windrow commonly used by facilities in the District. This is because covered systems offer many process control advantages including weather protection and water retention.

Source testing was conducted at the City of Modesto compost facility as a field test study for the California Integrated Waste Management Board (CIWMB). Two goals of this test were to determine VOC emissions from green waste composting and food waste composting. The food waste composting windrows contained approximately 15% food waste (from local food processing plants (e.g. peppers, tomatoes, peaches, and syrup) and 85% ground green waste. The resulting EFs were 0.85 lb-VOC/ton and 1.95 lb-VOC/ton for green waste and food waste respectively. As predicted, the food waste EF was higher than the green waste EF, 2.3 times higher for this test site. Since the average green waste EF has been established at 5.71 lb-VOC/ton, the District considers the food waste EF to be too low to be usable as a stand-alone food waste composting EF since it would be lower than the green waste EF. However, if more data were to become available for food waste composting, the food waste EF from the City of Modesto test site may be used in combination with the new data.

For these reasons, the District will use the green waste composting emission factor to represent this feed stock until a more representative emission factor can be identified.

C. Grape Pomace Composting EFs

The District has not been able to identify an emission factor for grape pomace composting. Therefore, the District will use the green waste composting emission factor to represent this feed stock until a more data is available.

D. Biosolids, Animal Manure, Poultry Litter Composting EFs

Biosolids and animal manure composting emission factors were taken from source tests conducted by the South Coast Air Quality Management District (SCAQMD) in support of their Rule 1133 (Emission Reductions from Composting and Related Operations). These emission factors were calculated as an average of emissions from three co-composting facilities (SCAQMD, 2002) as presented in the Table below.

The District has not been able to identify an emission factor for poultry litter composting. The District will use the biosolids composting emission factor to represent this feed stock until a more representative emission factor can be identified.

Table 5: Biosolids, Animal Manure, and Poultry Litter EFs.

Summary of Co-Composting Emission Factors Developed by SCAQMD		
Location	Emission Factors (lb/wet-ton)	
	VOC	NH_3
RECYC Inc	0.53	2.70
EKO Systems	1.70	3.28
San Joaquin Composting	3.12	2.81
Average	1.78	2.93

Summary

The District composting EFs are summarized below.

Table 6: Summary of District Composting EFs.

Compost Type	Stockpile (lb-VOC/wet ton/day)	Windrow EF Per composting cycle (lb-VOC/wet ton)
Green Waste, Food Waste, Grape Pomace	1.063	5.71
Co-Composting Biosolids, Animal Manure, Poultry Litter	-	1.78

Appendices

Appendix A: "Organic Material Composting and Drying focusing on Greenwaste Compost Air Emissions Data Review", by Thomas R. Card and Charles E. Schmidt, June 2008

Appendix B: Comments and Responses to the "Organic Material Composting and Drying focusing on Greenwaste Compost Air Emissions Data Review"

Appendix C: "Northern Recycling Zamora Compost Facility Air Emissions Source Test", by Thomas R. Card and Charles E. Schmidt, May 2009

Appendix A

"Organic Material Composting and Drying focusing on Greenwaste Compost Air Emissions Data Review", by Thomas R. Card and Charles E. Schmidt, June 2008

San Joaquin Valley
Air Pollution Control District

Organic Material Composting and Drying
focusing on

Greenwaste Compost

Air Emissions Data Review

Report

June 2008

Prepared by

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

Charles E. Schmidt, PhD
19200 Live Oak Road, Red Bluff, CA 96080
530-529-4256 Fax:530-529-4878

Contents

Executive Summary **1**

1.0 Introduction **5**

2.0 Background **5**

3.0 Data Evaluation Methodology **7**

Target Species *7*

Sample Collection Methods *7*

Analytical Methods *7*

4.0 Emission Factor Development **8**

4.1 Compost Pile Configuration *8*

4.2 Full Compost Cycle Simulation *9*

4.5 Emissions from Feedstock and Product Storage *9*

5.0 Most Relevant Green Waste Compost Data **9**

5.1 Confidential Site (Site X) *10*

5.2 California Integrated Waste Management Board (CIWMB) Modesto *10*

5.3 NorCal Waste Systems *11*

5.4 CIWMB Tierra Verde *11*

5.5 SCAQMD Data *11*

5.6 Discussion *11*

6.0 Most Relevant Food Waste Compost Data **12**

7.0 Most Relevant Biosolids Compost Data **13**

8.0 References **14**

Tables

Table ES 1 Summary of greenwaste composting full site VOC emission data (#/ton of feedstock).
Table 5.1 Summary of most relevant green waste composting data.
Table 5.2 Summary of greenwaste VOC emission factors (#/ton feedstock).
Table 6.1 Summary of most relevant food waste composting data.

Figures

Figure ES 1 VOC emission profile for each of the three complete data sets (#VOC/ton feedstock per compost day).
Figure ES 2 The effect of pile temperature on VOC emissions (from 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).
Figure 4.1 Compost Windrow Configuration.
Figure 4.2 Range of area to volume ratios for typical windrow cross-section dimensions.
Figure 5.1 Daily VOC emissions profile from Site X, CIWMB Modesto, and NorCal.

Appendices

A SJVAPCD Reference Table and Complete Report Reviews
B Technical Memorandum – Recalculating CIWMB Modesto Emissions
C Confidential Site X Emissions Report

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.

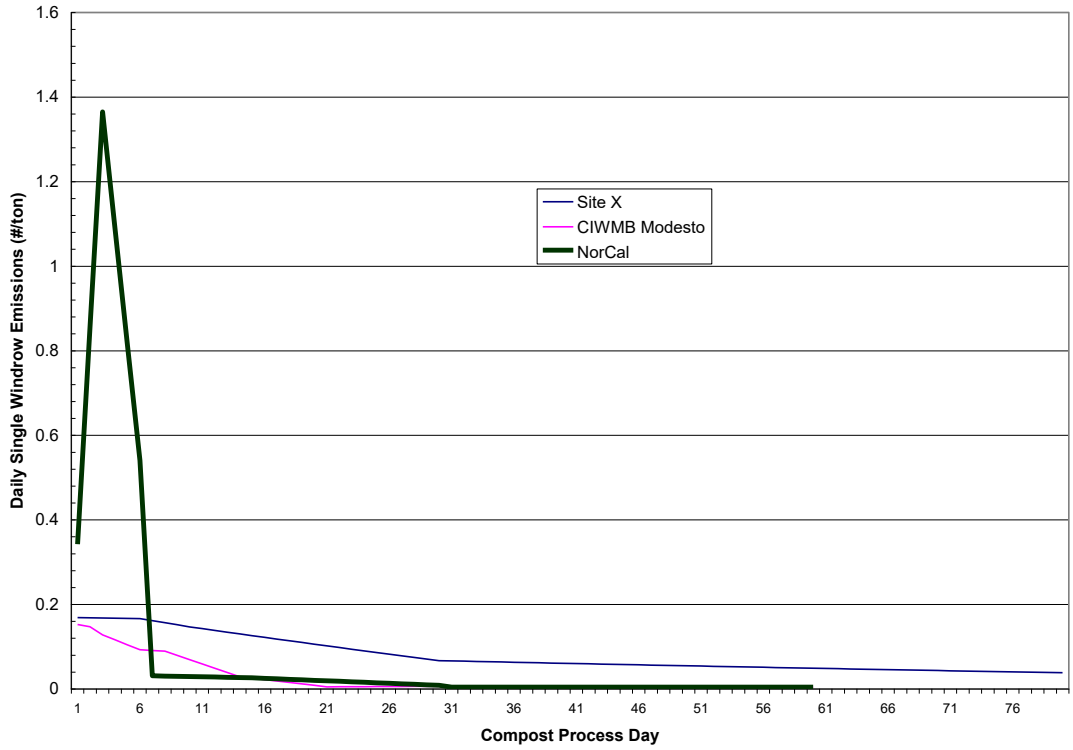
Table ES 1 Summary of greenwaste composting full site VOC emission data (#/ton of feedstock).

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.

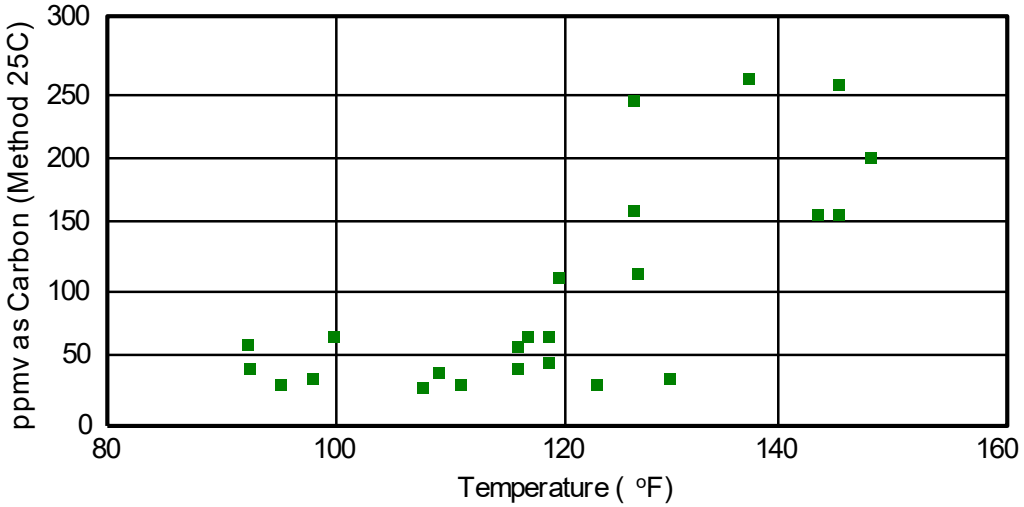
There is some discussion in this report as to why there is a large variability of emissions found in the compost industry. There are several reasons for this:

- 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).

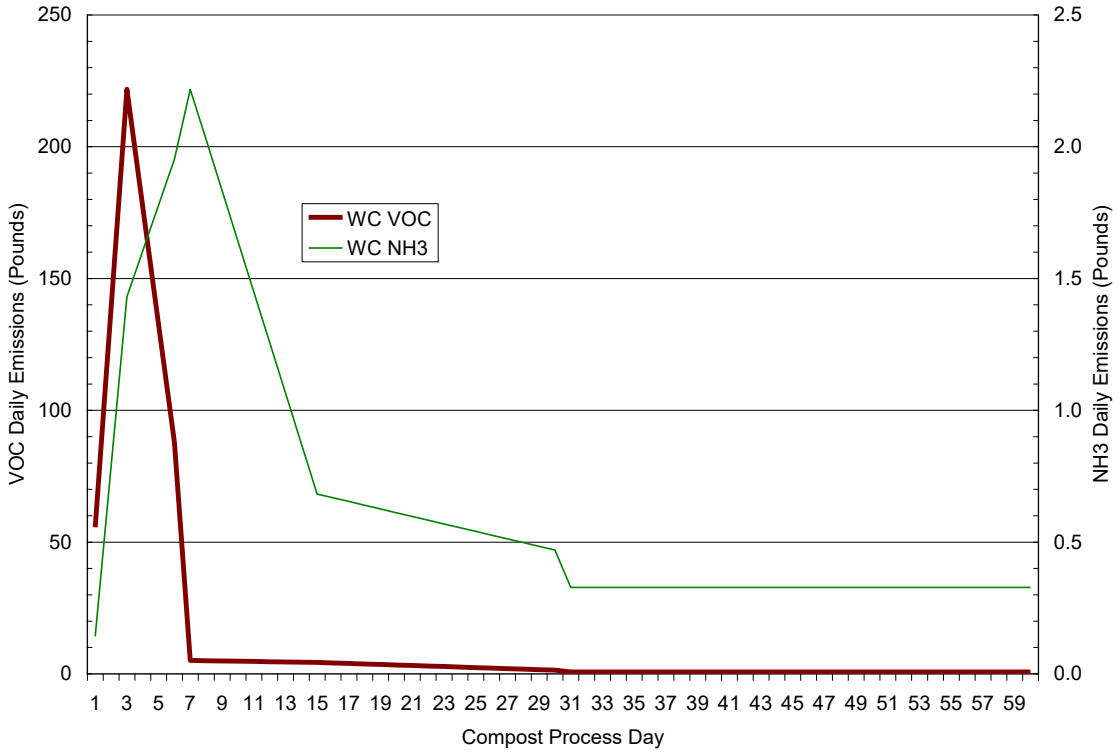
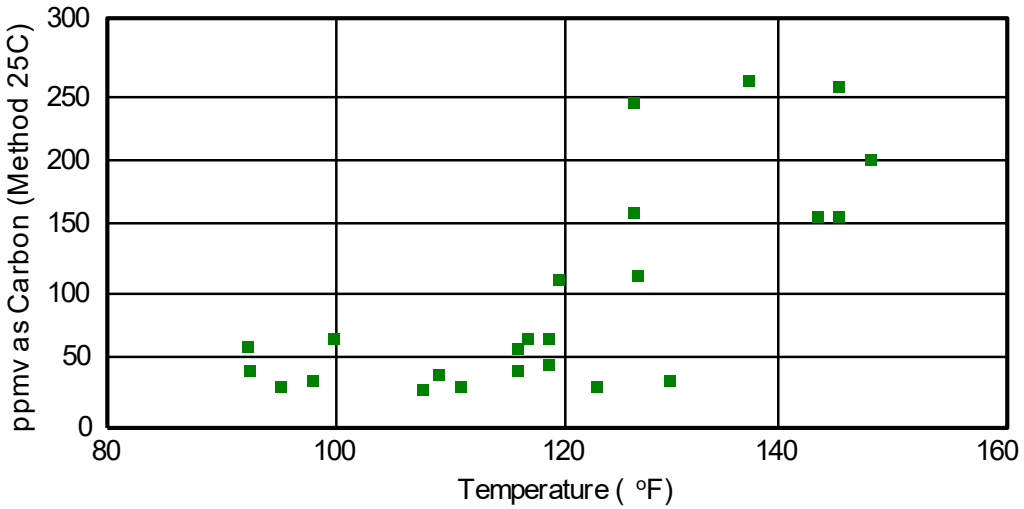


Figure 2.2 The effect of pile temperature on VOC emissions (from Hentz et al 1996).



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.

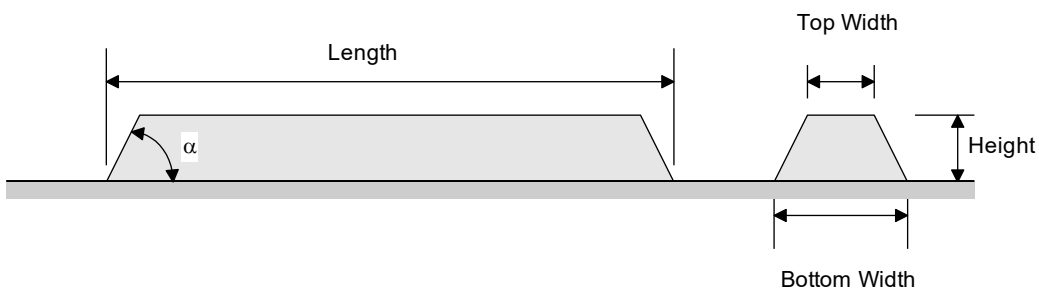
4.0 Emission Factor Development

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

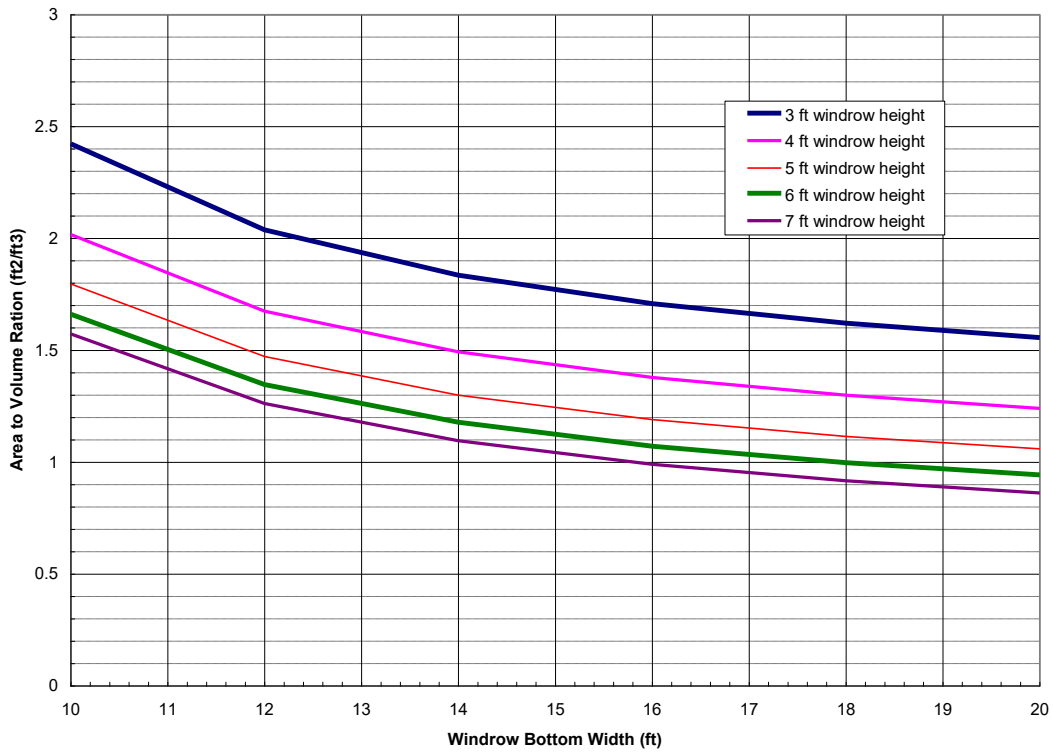
$$S = \frac{p_1 + p_2}{2} s + A_2$$

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

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

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

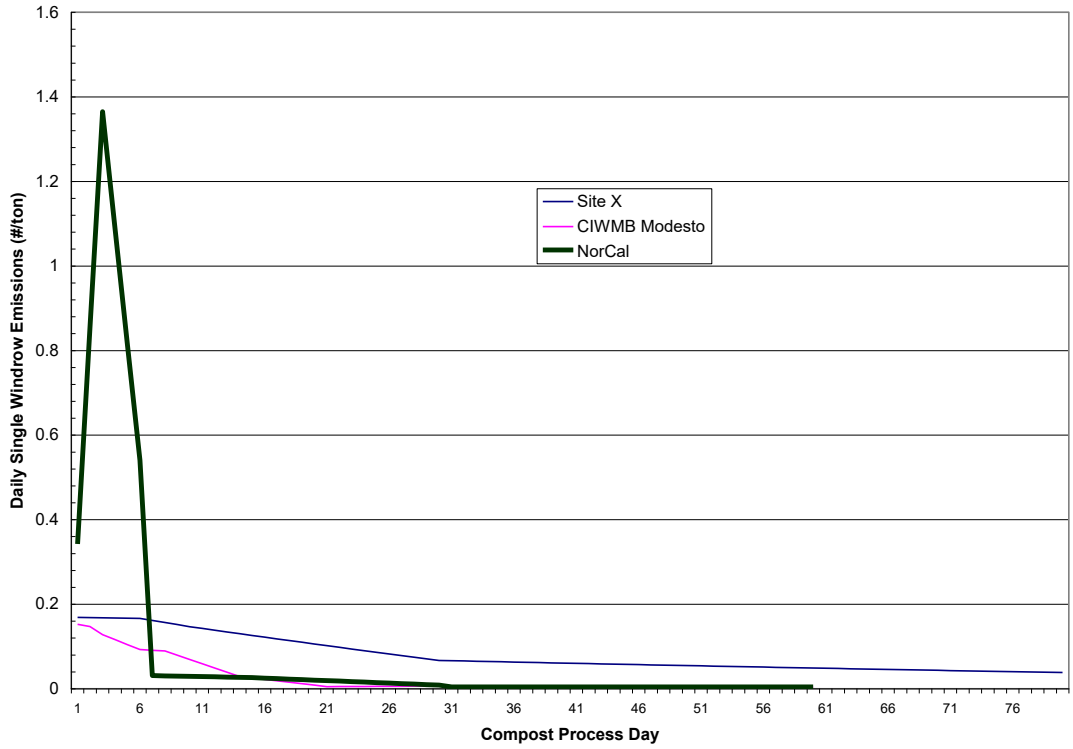


Figure 5.1 Daily VOC emissions profile from Site X, CIWMB Modesto, and NorCal.

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, CO2, 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 SF6.

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, CO2, 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 SF6.

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, 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 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, CO2, O2, 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#NH3/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.

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 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, 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:
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

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: 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

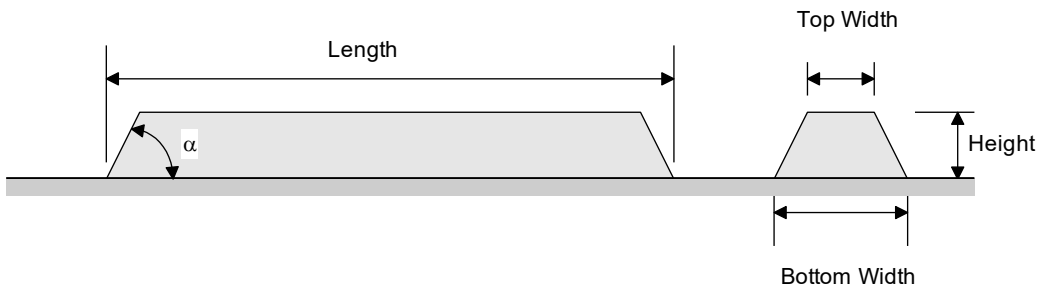
VOC Species

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, α = 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).

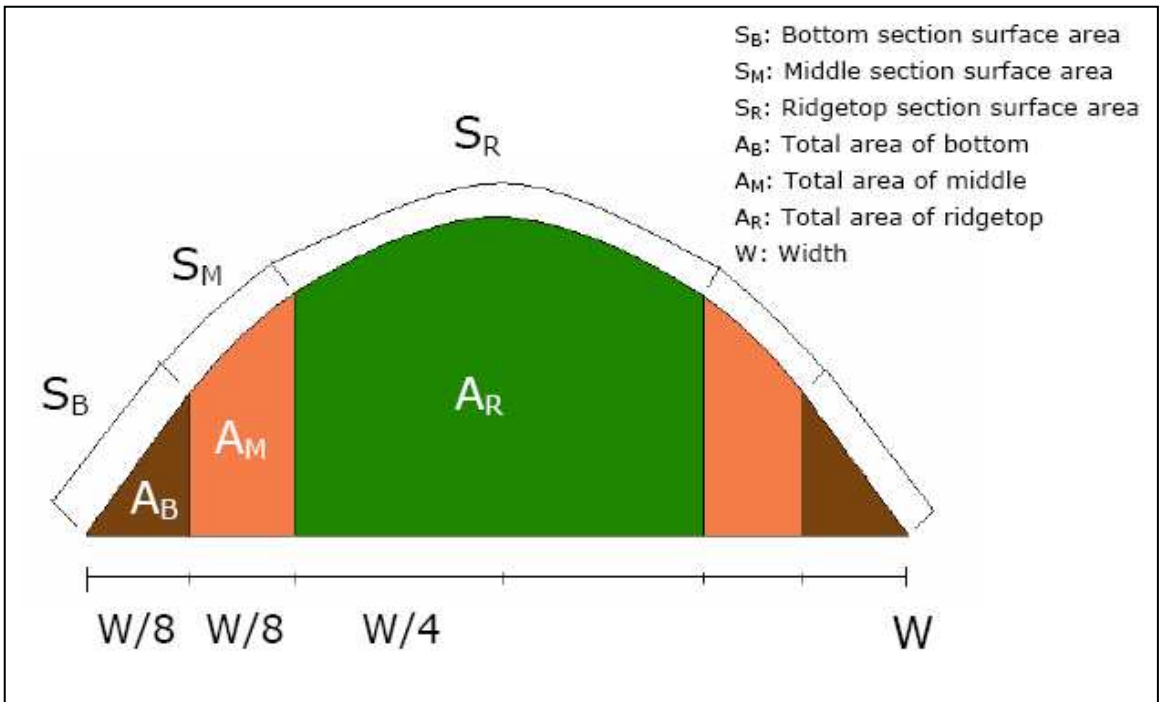


Figure 1. Sampling Segments of Windrows

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

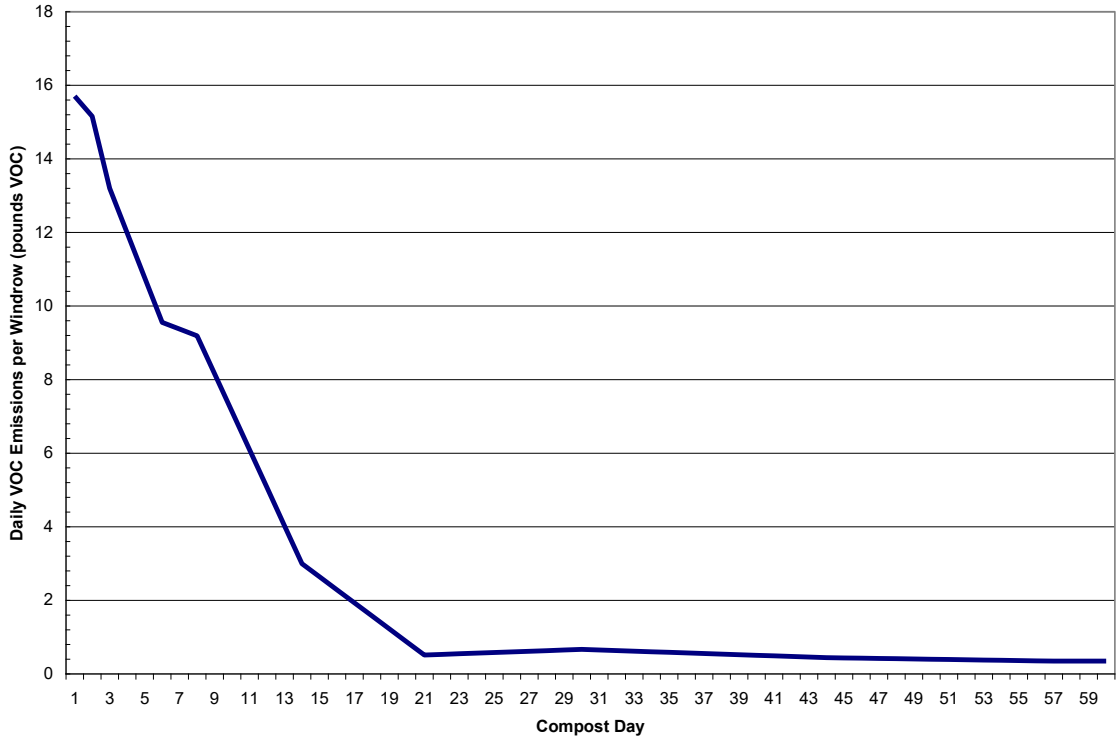
Emission Factor Calculation

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

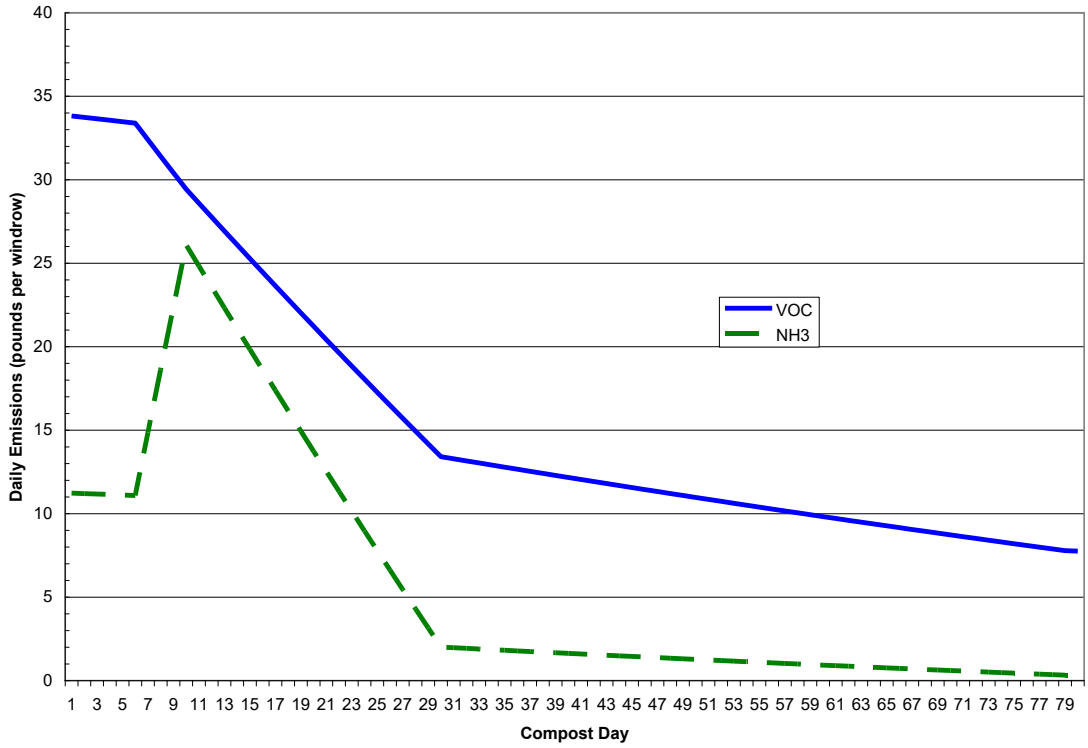


Table 3. Key Assumptions

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
Environmental Management Consulting
41125 278th Way SE
Enumclaw, WA 98022

Dr. C.E. Schmidt
Environmental Consultant
19200 Live Oak Road
Red Bluff, California 96080

May 7, 2008

CE Schmidt, Ph.D.
Environmental Consultant

TABLE OF CONTENTS

		Page
Executive Summary		ii
I.	Introduction	1
II.	Test Methodology	2
III.	Quality Control	4
IV.	Results and Discussions	6
V.	Summary	7

Attachments

A- Emissions Measurement Data Sheets
B- Chain of Custody
C- Lab Reports

References

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	SF6 UHP	SF6 Detect	Methane	TNMNEO	NH3	SOURCE	TEST LOCATION	COMPOST	COMMENT
%	(m3/min)	(ppbv)	(ppbv)	Flux	Flux	Flux			DAY	
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

CE Schmidt, Ph.D.
Environmental Consultant

ATTACHMENT A

EMISSION MEASUREMENT DATA SHEETS

CE Schmidt, Ph.D.
Environmental Consultant

ATTACHMENT B

CHAIN OF CUSTODY

CE Schmidt, Ph.D.
Environmental Consultant

ATTACHMENT C

LABORATORY REPORTS

Appendix B

Comments and Responses to the "Organic Material Composting and Drying focusing on Greenwaste Compost Air Emissions Data Review"

Responses to Comments on the document entitled "Organic Material Composting and Drying focusing on Greenwaste Compost Air Emissions Data Review", by Thomas R. Card and Charles E. Schmidt, June 2008. This report will be referred to as the "green waste report" hereafter within this document.

Summary of comments from Center on Race, Poverty and the Environment (CRPE) / Committee for a Better Arvin:

CRPE 1: The CIWMB Modesto Study should be excluded from consideration because it did not include emissions from the stockpiles.

Response: The green waste report included separate VOC emission factors for the windrows and the stockpiles. The report averaged the measurement results for each of these two processes separately. The CIWMB Modesto Study measurement was used only in developing the windrow VOC emission factor. The lack of a stockpile emission factor from this study does not affect the VOC emission factor for the windrows.

CRPE 2: The CIWMB Modesto Study should be excluded from consideration because the results are not replicable.

Response: This comment is based on Schmidt's recalculation of the results, and his conclusion that the published results of the Modesto Study are incorrect. The District has reviewed Dr. Schmidt's recalculation, and has determined that there is not enough justification within the analysis to support the recalculation of previously published study results. Therefore, the District will use the originally published emission factor of 0.8 to 0.9 lb-VOC/ton.

CRPE 3: The CIWMB Modesto Study should be excluded from consideration because it did not account for the effect of wind on emissions.

Response: The studies that were chosen for inclusion in the green waste report were the studies that were found to be the most complete and valid for the purpose of generating VOC emission factors for composting operations. Conditions during emission measurements at each of the study sites were representative of conditions during actual operations. It is not possible to determine if wind is expected to have a significant effect on the VOC emission rates or adjust measured emission rates without full speciation of the compounds measured. The studies that were determined to be the most valid, including the CIWMB Modesto Study, used total VOC methods without speciation because total VOC methods have been found to capture a higher proportion of the total VOC emissions when compared to other methods. Additionally, there are currently no validated procedures to adjust the measured rates for differing wind velocities. In conclusion, the District is using the most complete scientific data available to update the composting emission factor. As with other emission factors, the proposed composting VOC emission factor will be periodically updated to incorporate if new scientific information indicates that revisions may be necessary.

CRPE 4: None of the three studies relied upon were conducted during the hotter months in the Central Valley. The Modesto report was conducted between October and December, some of the coldest months of the year in the Central Valley. The studies may underestimate emissions because they did not account for the high summer temperatures common in the Central Valley.

Response: As stated above, the studies that were chosen were the studies that were found to be the most complete and valid for the purpose of generating emission factors.

In regards to the comment that the testing for the Modesto report was conducted in the coldest part of the year, records indicate that the coldest months in the Central Valley are December-February and that the average temperature for October is actually higher than both March and April. It must also be noted that the NorCal study was conducted during August in Vacaville, CA, and records indicate that the average summer temperatures in Vacaville are very similar to summer temperatures found in the Central Valley.

The annual compost VOC emission factor developed from the studies are intended to be representative of average annual emissions rather than peak daily emissions. The studies that were determined to be suitable for developing VOC emission factors are actually very representative of seasonal variation throughout the year with testing performed in the spring (Site X testing in March), autumn to early winter (CIWMB, Modesto testing in October - December), and summer (NorCal testing in August).

Summary of Comments from ERM on behalf of Norcal Waste Systems, Inc. Note that this letter includes comments on both the emission factor report and the rulemaking process. Only those comments on the emission factor report are presented here:

ERM 1: The data is limited.

Response: The District agrees that the data is limited, but the purpose of this report was to find all studies that were robust enough to be considered useful in determining an emission factor. The resulting emission factor is based on the best science available at the time.

ERM 2: Limited duration of testing. Site X only one day of testing. Also, Modesto study was recalculated, and did not include stockpiles.

Response: Regarding the one day of testing at Site X: While all sampling was conducted on one day, piles of different ages were sampled in order to obtain flux measurements throughout the life of a pile. Regarding the recalculation of the Modesto Study and lack of stockpile emissions – see responses to CPRE comments 2 and 1, above.

ERM 3: The emissions data are extremely variable. There appeared to be no attempt to account for temporal variations throughout the composting cycle in deriving "average"

emission factors. There is insufficient documentation provided to allow for independent analysis of temporal or spatial factors as they relate to the reported flux rates.

Response: The District agrees that there were limited data available that were complete and valid for developing emission factors given the variability of the source. However, the resulting emission factor is based on the best science available at the time. Each individual study used in the report accounted for the variation throughout the composting process. The individual emission factors from each study referenced in the report were developed from emission measurements for different stages throughout complete composting cycle at each site. Additional information on the time and location of emission measurements is available in the original study reports referenced.

ERM 4: The data from the green waste report should not be averaged for the purpose of developing emission factors for regulatory purposes.

Response: The average emission factors are based on the best science available at the time for calculating VOC emissions from composting.

ERM 5: The data from the green waste report should not be averaged for the purpose of calculating annual emissions. There is insufficient documentation provided in the report to allow for an independent analysis of the data relative to the type of composting operation, throughput, size of piles, and length of composting cycle.

Response: See response to ERM comment 4, above. Additional information on each composting operation is available in the original study reports referenced.

ERM 6: The impact of compost process temperature on emissions should be considered. It is ERM's professional judgment that temperature variations relate more to the time in the composting cycle than seasonal variation in ambient temperature. No information was given in the green waste report as to the location of temperature measurements.

Response: The individual emission factors from each study referenced in the report were developed from emission measurements at different stages throughout the composting cycle at each site, which accounts for temperature variation of the piles during the composting process. Additional information on temperature measurements may be available in the original study reports referenced.

ERM 7: The emissions released during turning of windrows were not addressed in the green waste report.

Response: The District is not aware of any studies that measured emissions released during turning of windrows. If additional information becomes available on emissions released during turning of composting windrows, the District will review this information and incorporate it if appropriate. Based on discussions with Dr. Schmidt, elevated emissions have been measured from windrows immediately after turning but only for a

few hours, at most, and would not be significant over the life cycle of well-managed composting operations.

ERM 8: Data presented for Site X as well as the South Coast Air Quality Management District (SCAQMD) data yielded higher emissions from stockpiles than from the windrows, which ERM considers unlikely.

Response: The District surveyed the green waste composting facilities in the San Joaquin Valley. The result of the survey indicates an average stockpile time of 3.85 days, and ranged from 0-21 days. The Site X stockpile EF was based on sampling at day 45, and is not representative of stockpiling in the San Joaquin Valley. The Site X stockpile test will not be included in the stockpile EF since it is not representative of SJV stockpiling. The SCAQMD stockpile data is considered as some of the most relevant green waste composting data available according to the green waste report. The SCAQMD samples were taken on a very representative day 2 stockpile. These emission measurements were conducted under conditions that were representative of conditions found during actual operations and are considered representative of emissions from these operations.

ERM 9: The green waste report states that the Norcal data exhibits a VOC "spike" in emissions during the first few days of composting. It is ERM's experience from green waste compost testing that this is very representative of the typical windrow composting emissions cycle. Source test documentation should be made available and analyzed systematically to ensure proper review of the test data and a statistical analysis of all test data should be performed.

Response: The District agrees that the measured emissions spike may be characteristic of some types of composting operations. Additional source test documentation may be available in the original study reports and from agencies that performed the studies.

ERM 10: The green waste report's conclusions are based on highly variable and extremely limited data. The green waste report only considered data that were measured using SCAQMD Method 25.3. Data collected by other methods may provide useful relative contributions from the different unit processes and temporal variability. A peer review of the NorCal report prior to issuance may have provided the opportunity to address some of the comments in this letter.

Response: The District agrees that there were limited data available for developing emission factors given the variability of the source. However, the resulting emission factor is based on the best science available at the time. SCAQMD Method 25.3 has been found to capture a higher proportion of the total VOC emissions than the other methods mentioned; therefore, this method was the most appropriate for development of VOC emissions factors. The District acknowledges that data collected by other methods may still be valuable for uses other than development of emission factors. The District agrees that peer review of reports can be valuable and is generally desirable

when time and resource constraints allow. However, the NorCal report was created for another District, the Yolo-Solano APCD, and District source tests are typically not peer reviewed.

Summary of Comments from California Integrated Waste Management Board (CIWMB), now know as Department of Resources Recycling and Recovery (CalRecycle):

CIWMB 1: The green waste report states that the emission factors from each study are averaged for reference only with no implication that the average is representative of green waste compost emissions in the San Joaquin Valley. If the average is not representative of green waste compost emissions, it should not be displayed.

Response: The report does not state that the average emission factors are not representative of green waste compost emissions, but is based on a limited data set from studies suitable for developing emission factors. The average emission factors are presented for reference purposes, per District request, and are based on the best science available at the time to calculate annual emissions from green waste composting. The District will base the final EF on the average of valid, representative test data. As more relevant data becomes available, the EF should be adjusted accordingly.

CIWMB 2: The weighted average of the three studies based on number of samples presents a better starting point for negotiations of the green waste composting emissions factors.

Response: Each study at the different composting sites was found to have sufficient measurements for the purpose of generating valid emission factors; therefore, each study is weighted equally to capture the variability of composting operations. The District used the best scientific information available to develop the green waste composting emission factor and is willing to evaluate and discuss any additional scientific information presented related to the emission factor.

CIWMB 3: The report states "The data are even more diverse than this table may indicate." A reasonable interpretation of this comment and the one above is that there is too little data to formulate an emissions factor applicable to composting facilities in the San Joaquin Valley.

Response: The District understands this comment to refer to the variation in daily emissions throughout the composting cycle, which is not clearly evident when presenting the single overall emission factors for each site. This interpretation is supported by the fact that immediately after this comment the report refers to a figure showing daily compost windrow emissions. Also see responses to ERM comment 1, above.

CIWMB 4: The spike in VOC emissions at the NorCal site may be an outlier since it is based on one flux sample. The District and Dr. Schmidt should review the Day 3 NorCal sampling event to determine whether there are other confounding circumstances.

Response: Other composting studies have also shown an initial increase in emissions during the composting cycle (see referenced report on Tierra Verde Industries composting operation and ERM comment 7, above). There is no indication in the report that the measured emission point was an outlier and comparatively high emissions were also measured on day 6 of the composting operation.

CIWMB 5: Is Figure 2.1 based on actual measured data or is it figurative?

Response: Figure 2.1 of the report is based on actual data from the NorCal composting site.

CIWMB 6: Figure 2.2 appears to be identical to Figure ES 2 on page 4.

Response: The District agrees.

CIWMB 7: We question whether there is enough data to support the contention that smaller windrows increase emissions. It seems more reasonable that emissions will correlate with the amount of materials in the windrow and operational factors and this is the rationale for having an emissions factor. Assuming that similar materials have similar potential emissions, a smaller windrow might have higher emissions earlier in the process but these emissions should trail off more rapidly.

Response: The report states that "For the same unit surface flux rate, the smaller row will have twice the emissions on a per ton input basis." This is true. As long as the surface flux rates remain the same, smaller windrows will have greater emissions on a per ton basis. However, the District agrees that the flux rate for the smaller windrow would likely decline more rapidly resulting in similar emissions on a per ton basis.

CIWMB 8: We believe we can identify Site X and believe the site receives overflow green waste from San Francisco and the East Bay and may include some food waste. Therefore, it is possible that the Site X data is more representative of food waste composting than green waste composting.

Response: The technical memorandum for the study performed at Site X did not indicate that the composting piles that were tested at the site included food waste. The District's understanding is that the piles at Site X that were tested did not include food waste. The District but will evaluate any evidence that conclusively demonstrates that this was not the case at the time of testing.

CIWMB 9: The report states that the CIWMB Modesto study consisted of 36 measurements. The CIWMB Modesto data set consists of 100 flux chamber samples and 9 quality control samples.

Response: The District agrees that the complete CIWMB Modesto data set consists of 100 flux chamber samples, including emission measurements from green waste composting, food waste composting, composting with a pseudo-biofilter cover, and composting with chemical additives. Only the 36 emission measurements from uncontrolled green waste composting were considered in this section of the report since the purpose was to evaluate emissions studies for use in developing an emission factor for uncontrolled green waste composting.

CIWMB 10: The report states that there is no baseline data for food waste composting. The CIWMB Modesto study includes an emissions profile for an uncontrolled windrow of 85% green waste and 15% food waste.

Response: The District agrees that the CIWMB Modesto study may provide useful information on VOC emissions from composting operations that include some food waste.

CIWMB 11: We question the assumptions and procedures used to recalculate the emissions reported in the CIWMB Modesto study report.

Response: See response to CPRE comment 2, above.

CIWMB 12: Have the results of the emissions study test at Site X been finalized?

Response: These results have been finalized.

CIWMB 13: What is Site Z and why is that data blacked out?

Response: Site Z is a composting operation in California. The Green waste report only included data that was provided to the District. Site Z was not evaluated in the report because this information was not included in the composting emission studies provided to the District from the responsible government agency. Additionally, the report authors indicated that the emissions information was from an older study and this operation was not considered to be representative of current composting practices.

CIWMB 14: What is the basis for the daily throughput number for Site X? This number appears to be less than we expect.

Response: The basis of this number is information reported from the facility.

CIWMB 15: Table 3 in the report for Site X indicates that the average age of the feedstock piles is 45 days. We believe that this feedstock pile is anaerobic. If anaerobic materials are used to create windrows, initial emissions may be expected to be higher.

Response: While this may be the case, the resulting windrow VOC EF at Site X, 6.30 lb/ton, is very close to the NorCal windrow VOC EF of 5.65 lb/ton, and less than the

Zamora windrow VOC EF of 10.03 lb/ton. As such, the emission measurements at Site X are considered representative of emissions from green waste windrows.

CIWMB 16: We believe the emissions factors developed from the studies at Site X and NorCal are skewed high because of high wind speed, low sample count, inclusion of food waste, and small windrow piles.

Response: See responses to CIWMB comments 7, 8, and 15 and ERM comments 1 and 2, above.

Appendix C

"Northern Recycling Zamora Compost Facility Air Emissions Source Test", by Thomas R. Card and Charles E. Schmidt, May 2009

Northern Recycling
Zamora Compost Facility

Baseline Air Emissions Assessment

Air Emissions Source Test

Evaluation of Complete Compost Cycle VOC and Ammonia Emissions

Report

Revision 2

May 2009

Prepared by

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

Charles E. Schmidt, PhD
19200 Live Oak Road, Red Bluff, CA 96080
530-529-4256 Fax:530-529-4878

Contents

EXECUTIVE SUMMARY **1**

1.0 INTRODUCTION **4**

2.0 PROCESS DESCRIPTION AND SAMPLING **4**

3.0 SAMPLING RESULTS **6**

4.0 EMISSIONS CALCULATIONS **9**

4.1 COMPOST PILE CONFIGURATION 9
4.2 FULL COMPOST CYCLE SIMULATION 11
4.4 SIMULATED EMISSIONS PROFILE 11
4.5 EMISSIONS FROM FEEDSTOCK AND PRODUCT STORAGE 13

Appendices

A Full Cycle Simulation Table
B Photographs
C Data Validation Technical Memorandum

Tables

Table ES-1a. Calculated VOC and NH3 emissions from the feedstock storage, compost cycle, and finished product storage (with winery waste).
Table ES-1b. Calculated VOC and NH3 emissions from the feedstock storage, compost cycle, and finished product storage (without winery waste).
Table ES-2. Comparative greenwaste compost emissions (from SJVAPCD).
Table 2.1 Amount of Material Assumed to be on Site for Baseline Emissions Estimate
Table 3.1a Summary of Event 1 sampling results (compost with winery waste).
Table 3.1b Summary of Event 2 sampling results (compost without winery waste).
Table 4.1. Compost Windrow Dimensions and Calculations.
Table 4.2a. Event 1 Feedstock emission calculations (with winery waste).
Table 4.2b. Event 2 Feedstock emission calculations (without winery waste).
Table 4.3. Finished product storage emission calculations.

Figures

Figure 1.1 Site Vicinity Map
Figure 4.1 Compost Windrow Configuration.
Figure 4.2 Simulated VOC Emissions Profile (per windrow).
Figure 4.3 Simulated NH3 Emissions Profile (per windrow).

Executive Summary

This report documents the completed project of assessing baseline air emissions for the new Northern Recycling greenwaste composting facility located near Zamora, California. This report contains the results of two sampling events. The first event was completed in October 2008 and included winery waste in the compost mix. The second event was completed in April 2009 with no winery waste present. USEPA flux chamber samples were taken from actual compost operations to provide unit emissions data that were used to complete the calculation of full scale annual emissions for VOC and ammonia. All sampling and analysis were completed in compliance with the source test protocol document previously submitted to Yolo-Solano APCD.

Emissions were calculated based on a simulation of a full 80 day compost cycle by sampling key process days and interpolating the emissions between those days. Three mixing cycle events were sampled during the first event and mixing was found to be a significant contributor to emissions.

Table ES-1a and ES-1b summarizes the results of this baseline emissions assessment. The measured compost emission factor for compost with winery waste of 16.55 # VOC per ton of composting material is substantially higher than the most comparable previously measured values (5.65 # and 6.3 # VOC per ton compost mix) reported by the San Joaquin Valley APCD (see Table ES-2). The factor without winery waste was 10.03 # VOC per ton of compost mix.

Total site emissions for VOC were 3,030 tons per year with about two thirds of that attributed to the emissions from the feedstock stockpile for compost with winery waste. Total site emissions for VOC were 1,070 tons per year with about one half of that attributed to the emissions from the feedstock stockpile for compost without winery waste. The annual emissions calculations were based on 100,000 tons per year of throughput. No attempt was made in this report to prorate actual annual emissions based on the presence or absence of winery waste.

A concern about this data set are the extremely low ammonia emissions from Event 1 when winery waste was present. The emissions on this site are over an order of magnitude lower than comparable facilities. Most of the ammonia samples were below the method detection limit. The method detection limit for ammonia for this project was typically between 0.2 and 0.4 mg/m3. These are very low detection limits, about a factor of three lower than most SCAQMD Method 207.1 method detection limits. No other comments or explanations are offered for this with the exception that the ammonia sampling and analysis was in full compliance with the QA/QC program and the laboratory samples agreed with the field screening samples. The ammonia emissions without winery waste, however, were essentially the same as other greenwaste compost facilities.

Table ES-1a. – Calculated VOC and NH3 emissions from the feedstock storage, compost cycle, and finished product storage (with winery waste).

		VOC		Ammonia	
Source	**Mass on Site (tons)**	**Emission Factor (pounds/ton)**	**Total Emissions (Tons/year)**	**Emission Factor (pounds/ton)**	**Total Emissions (Tons/year)**
Feedstock Storage	27,000	44.03	2,201	0.017	0.94
Composting	20,000	16.55	828	0.011	0.573
Product Storage	3,000	0.02	1.2	0.0004	0.014
Total	50,000		3,030		1.52
Overall Emission Factor (#/ton)		60.61		0.030	

Table ES-1b. – Calculated VOC and NH3 emissions from the feedstock storage, compost cycle, and finished product storage (without winery waste).

		VOC		Ammonia	
Source	**Mass on Site (tons)**	**Emission Factor (pounds/ton)**	**Total Emissions (Tons/year)**	**Emission Factor (pounds/ton)**	**Total Emissions (Tons/year)**
Feedstock Storage	27,000	11.34	567	1.643	89.93
Composting	20,000	10.03	502	0.445	22.236
Product Storage	3,000	0.02	1.2	0.0004	0.014
Total	50,000		1,070		112.18
Overall Emission Factor (#/ton)		21.40		2.244	

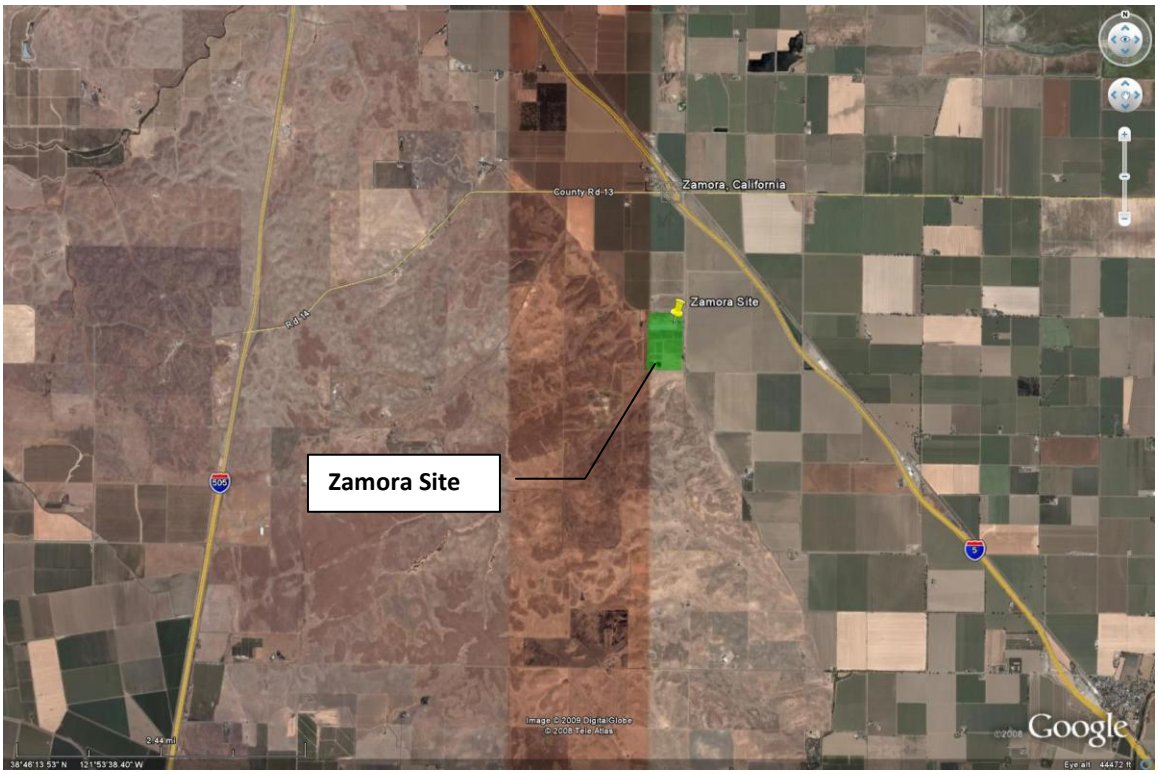
Table ES-2. – Comparative greenwaste compost emissions (from SJVAPCD).

			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						

1.0 Introduction

This project directly measured the VOC and ammonia air emissions from greenwaste composting to develop a baseline air emissions value for a full compost/cure cycle plus feedstock and product storage. All compost operations were located at the Northern Recycling Compost Facility in Zamora, CA as shown in Figure 1.1.

Figure 1.1 Site Vicinity Map



2.0 Process Description and Sampling

This is a new compost facility that composts greenwaste material into a high value landscaping material. Compost is received in a stockpile. The stockpiled material is then ground and placed into windrows. The windrows are mechanically mixed approximately 20 times during an 80 day composting cycle. The windrows are then broken down and screened into the final product. The site is permitted to have a total of 50,000 tons of material on site. Table 2.1 shows the amount of material assumed to be on site for the baseline emissions assessment.

Table 2.1 Amount of Material Assumed to be on Site for Baseline Emissions Estimate

Material	Total Tons on Site
Feedstock Storage	27,000
Composting	20,000
Product Storage	3,000
Total Tons	50,000

The sampling and analysis was conducted in compliance with the document entitled PROTOCOL FOR FLUX CHAMBER SOURCE TESTING OF FUGITIVE AIR EMISSIONS FROM THE NORTHERN RECYCLING COMPOST (NRC) ZAMORA FACILITY, plus a supplemental protocol for the second event, that was previously submitted to the Yolo-Solano APCD.

All sampling took place between October 28 and 30, 2008 for the first event (compost with winery waste) and on April 12, 2009 (compost without winery waste). All surface samples were taken using USEPA Surface Isolation Emission Flux Chamber technology per the source test protocol. Total VOC was analyzed per SCAQMD Method 25.3 and ammonia was measured per SCAQMD Method 207.1. The technical memorandum in Appendix C presents a summary of data validation, project documentation, and laboratory methods used for this project.

The following compost operations were sampled:

Event 1

1. Incoming feedstock (12 samples)
2. Compost Day 1 (4 samples)
3. Compost Day 3 (4 samples)
4. Compost Day 3 Mixing Event (4 samples)
5. Compost Day 7 (4 samples)
6. Compost Day 15 (4 samples)
7. Compost Day 15 Mixing Event (4 samples)
8. Compost Day 29 (4 samples)
9. Compost Day 29 Mixing Event (4 samples)
10. Compost Day 63 (4 samples)
11. Finished product (4 samples)

Event 2

1. Incoming feedstock (4 samples)
2. Compost Day 1 (2 samples)
3. Compost Day 5 (4 samples)
4. Compost Day 8 (2 samples)
5. Compost Day 16 (2 samples)
6. Compost Day 31 (2 samples)

3.0 Sampling Results

Figure 3.1a presents of a summary of sampling results for Event 1. The appendix contains complete sampling data. Note that the vast majority of the ammonia data points had no ammonia detected. The typical ammonia detection limit for this project was between 0.2 and 0.4 mg/m^3.

Figure 3.1b presents a summary of sampling results for Event 2. This data was typical or previous greenwaste compost sampling events at other facilities.

Table 3.1a Summary of Event 1 sampling results (compost with winery waste).

SOURCE	TEST CONDITION	VOC Flux	NH3 Flux	COMMENT
Windrow- Day 1	T1	282	0.0131	**Windrow- Day 1**
Windrow- Day 1	T2	79.2	0.0130	
Windrow- Day 1	S1	136	0.0157	
Windrow- Day 1	Replicate	33.5	0.0174	Replicate
Windrow- Day 1	S2	11.2	0.0104	
Windrow- Day 3	T1	453	0.0219	**Windrow- Day 3**
Windrow- Day 3	T2	36.9	0.0227	
Windrow- Day 3	S1	16.1	0.0179	
Windrow- Day 3	S2	35.8	0.0232	
Windrow- Day 3	Post Mix, T1- Hour 0	1631	0.0232	Post Mix, T1- Hour 0
Windrow- Day 3	Post Mix, S1- Hour 0	742	0.0171	Post Mix, S1- Hour 0
Windrow- Day 3	Post Mix, T1- Hour 4	724	0.0187	Post Mix, T1- Hour 4
Windrow- Day 3	Post Mix, S1- Hour 4	254	0.0231	Post Mix, S1- Hour 4
Windrow- Day 7	T1	148	0.108	**Windrow- Day 7**
Windrow- Day 7	T2	764	0.0233	
Windrow- Day 7	S1	4.52	0.0418	
Windrow- Day 7	S2	1.81	0.0245	
Windrow- Day 15	T1	5.72	0.0332	**Windrow- Day 15**
Windrow- Day 15	T2	26.5	0.0401	
Windrow- Day 15	S1	2.36	0.0266	
Windrow- Day 15	S2	2.65	0.0236	
Windrow- Day 15	Replicate	1.30	0.0257	Replicate
Windrow- Day 15	Post Mix, T2- Hour 0	56.0	0.0244	Post Mix, T2- Hour 0
Windrow- Day 15	Post Mix, S2- Hour 0	6.82	0.0250	Post Mix, S2- Hour 0
Windrow- Day 15	Replicate	9.46	0.0246	Replicate
Windrow- Day 15	Post Mix, T2- Hour 4	40.1	0.0252	Post Mix, T2- Hour 4
Windrow- Day 15	Post Mix, S2- Hour 4	6.29	0.0222	Post Mix, S2- Hour 4
Windrow- Day 29	T1	0.454	0.0155	**Windrow- Day 29**
Windrow- Day 29	T2	1.10	0.0192	
Windrow- Day 29	S1	0.645	0.0151	
Windrow- Day 29	S2	0.381	0.00782	
Windrow- Day 29	Post Mix, T2- Hour 0	27.4	0.0301	Post Mix, T2- Hour 0
Windrow- Day 29	Post Mix, S1- Hour 0	4.39	0.0216	Post Mix, S1- Hour 0
Windrow- Day 29	Post Mix, T2- Hour 4	15.4	0.0369	Post Mix, T2- Hour 4
Windrow- Day 29	Post Mix, S1- Hour 4	3.95	0.0245	Post Mix, S1- Hour 4
Windrow- Day 63	T1	0.955	0.0141	**Windrow- Day 63**
Windrow- Day 63	T2	0.671	0.00994	
Windrow- Day 63	S1	0.223	0.0108	
Windrow- Day 63	S2	0.507	0.0137	
Tipping- Old	T1	6.91	0.0290	**Tipping- Old**
Tipping- Old	T2	1.33	0.0229	
Tipping- Old	T3	7.10	0.0241	
Tipping- Old	T4	7.54	0.0204	
Tipping- Middle Age	T1	3.82	0.0387	**Tipping- Middle Age**
Tipping- Middle Age	T2	6.97	0.529	
Tipping- Middle Age	T3	3.13	0.0702	
Tipping- Middle Age	Replicate	2.61	0.0718	Replicate
Tipping- Middle Age	T4	2.40	0.272	**Tipping- New**
Tipping- New	T1	308	0.0399	
Tipping- New	T2	153	0.0452	
Tipping- New	T3	882	0.0202	
Tipping- New	Replicate	848	0.0302	Replicate
Tipping- New	T4	743	0.0293	
Fresh Product- Day 1	T1	1.13	0.0123	**Fresh Product- Day 1**
Fresh Product- Day 1	T2	1.48	0.00687	
Aged Product- Day 60	S1	0.220	0.00876	**Aged Product- Day 60**
Aged Product- Day 60	S2	2.83	0.0400	
QC	Blank	0.139	0.00342	**QC- Blank**
QC	Blank	0.137	0.00342	
QC	Blank	0.112	0.00440	
QC	Blank	0.0929	0.00440	
QC	Blank	0.0736	0.00440	

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 calculation purposes

Table 3.1b Summary of Event 2 sampling results (compost without winery waste).

SOURCE	TEST CONDITION	VOC Flux	NH3 Flux	COMMENT
Tipping	Day 1, T1	**166**	**16**	Tipping Pile, Day 1
Tipping	Day 1, S1	**14**	**6.7**	Tipping Pile, Day 1
Tipping	Day 7, T1	**17**	**5.7**	Tipping Pile, Day 7
Tipping	Day 7, S1	**7.8**	**4.3**	Tipping Pile, Day 7
Tipping	Replicate	**7.7**	**4.1**	Replicate Sample
Compost	Day 1, S1	**83**	**1.6**	Day 1
Compost	Day 1, T1	**27**	**0.26**	Day 1
Compost	Day 5, S1	**15**	**1.9**	Day 5
Compost	Day 5, T1	**242**	**13**	Day 5
Compost	Day 8, S1	**2.4**	**0.078**	Day 8
Compost	Day 8, T1	**157**	**2.5**	Day 8
Compost	Day 8, S2	**1.5**	**0.26**	Day 8
Compost	Day 8, T2	**131**	**5.0**	Day 8
Compost	Day 16, S1	**1.3**	**0.15**	Day 16
Compost	Day 16, T1	**9.4**	**2.56**	Day 16
Compost	Day 31, S1	**3.0**	**0.17**	Day 31
Compost	Day 31, T1	**1.0**	**0.17**	Day 31
QC	Blank	**0.025**	**0.0031**	99.4% Recovery of helium tracer

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

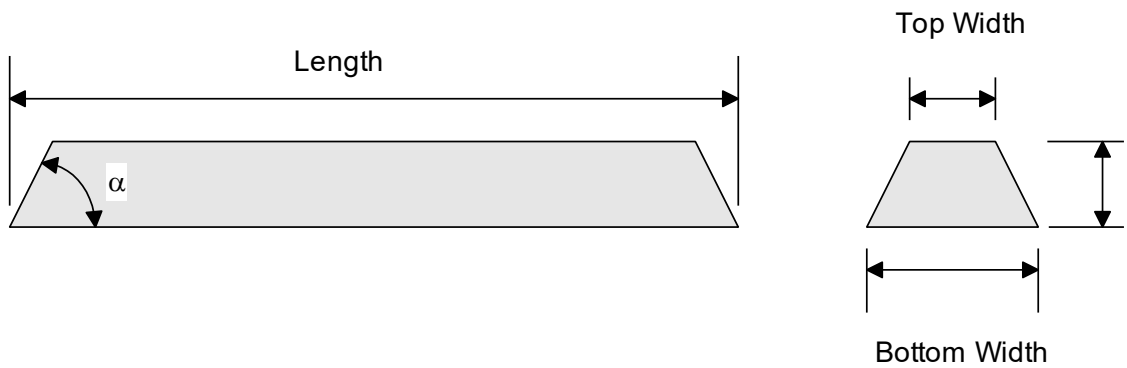
Note 5- MDL value used for ND or non-detect for calculation purposes

4.0 Emissions Calculations

4.1 Compost Pile Configuration

The windrow compost operation consisted of placing ground greenwaste feedstock in a windrow for 80 days. Figure 4.1 shows the typical windrow cross-section for windrow composting as well as the formulas used to compute volume and exposed surface area. Each windrow initially contained about 320 tons of material. Table 4.1 provides the windrow dimensions and calculations.

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

Table 4.1. – Compost Windrow Dimensions and Calculations.

Property	Units	Value
Length	ft	455
Height	ft	4.5
Bottom Width	ft	14
Top Width	ft	7.0
Top Length	ft	448
alpha	R	0.91
	o	52
Top Perimeter	ft	910
Top Area	ft2	3,136
Bottom Perimeter	ft	938
Bottom Area	ft2	6,370
Slant height	ft	5.7
Surface Area	ft2	8,404
	m2	785
Volume	ft3	20,963
	yd3	776
Conversion Factors	ft2/m2	10.7
	ft3/yd3	27
Top Area Ratio		0.373173
Density	#/yd3	823
	#/ft3	30.5
Mass	#	638,990
	ton	319

4.2 Full Compost Cycle Simulation

The unit emission data was extended to estimate emissions from the full compost cycle using linear interpolation and averaging, as noted in Section 2, above.

Full cycle emissions for each day of the compost process, are then added and the sum of the individual daily emissions are totalized. Consistent with the approved protocol, the emission factor consists of the full total (in pounds) cycle emissions divided by the incoming feedstock weight (in tons). The full site emissions are then calculated be multiplying the annual throughput of material by this calculated emission factor. The simulation data tables are provided in the Appendix.

4.4 Simulated Emissions Profile

Figure 4.2 and 4.3 presents the full cycle emissions profile developed for VOC and ammonia. These emissions profiles were developed using a combination of data averaging and linear interpolation between the data points. The spikes on the graphs are due to mixing events. Three mixing events were measured and mixing was found to be a significant contributor to emissions.

Figure 4.2 Simulated VOC Emissions Profile (per windrow).

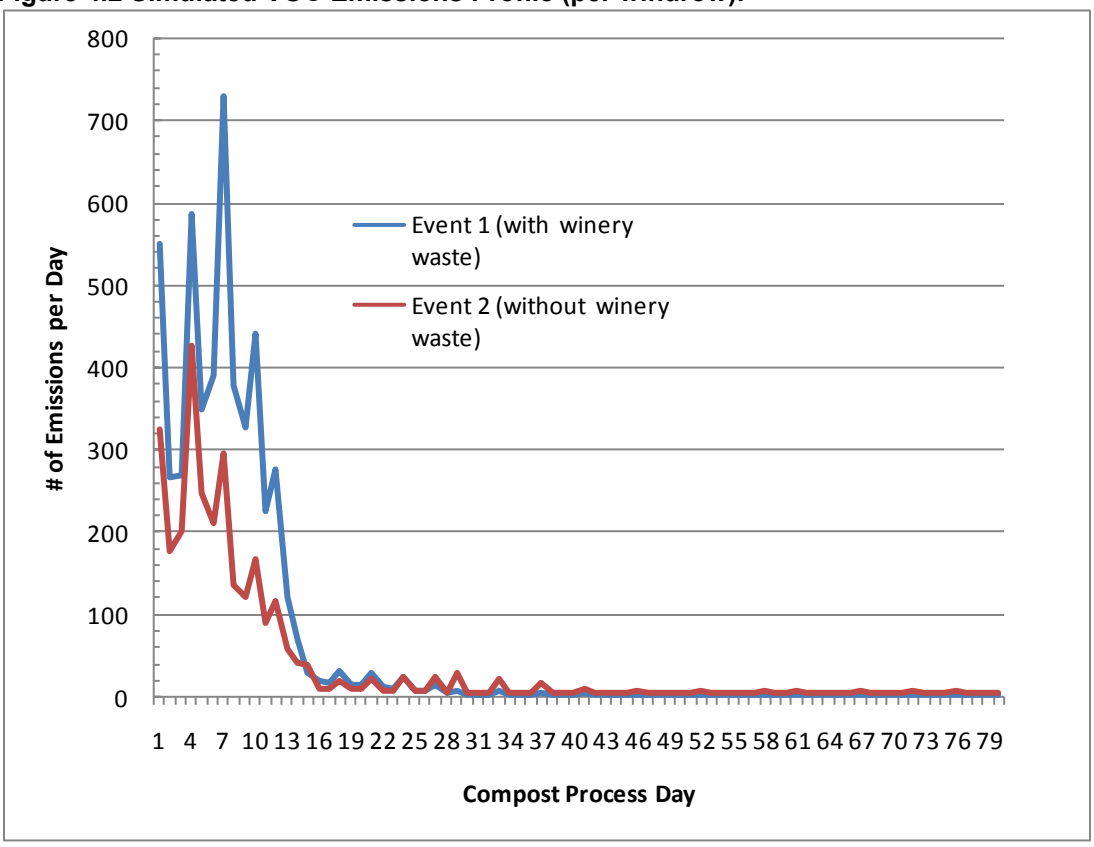
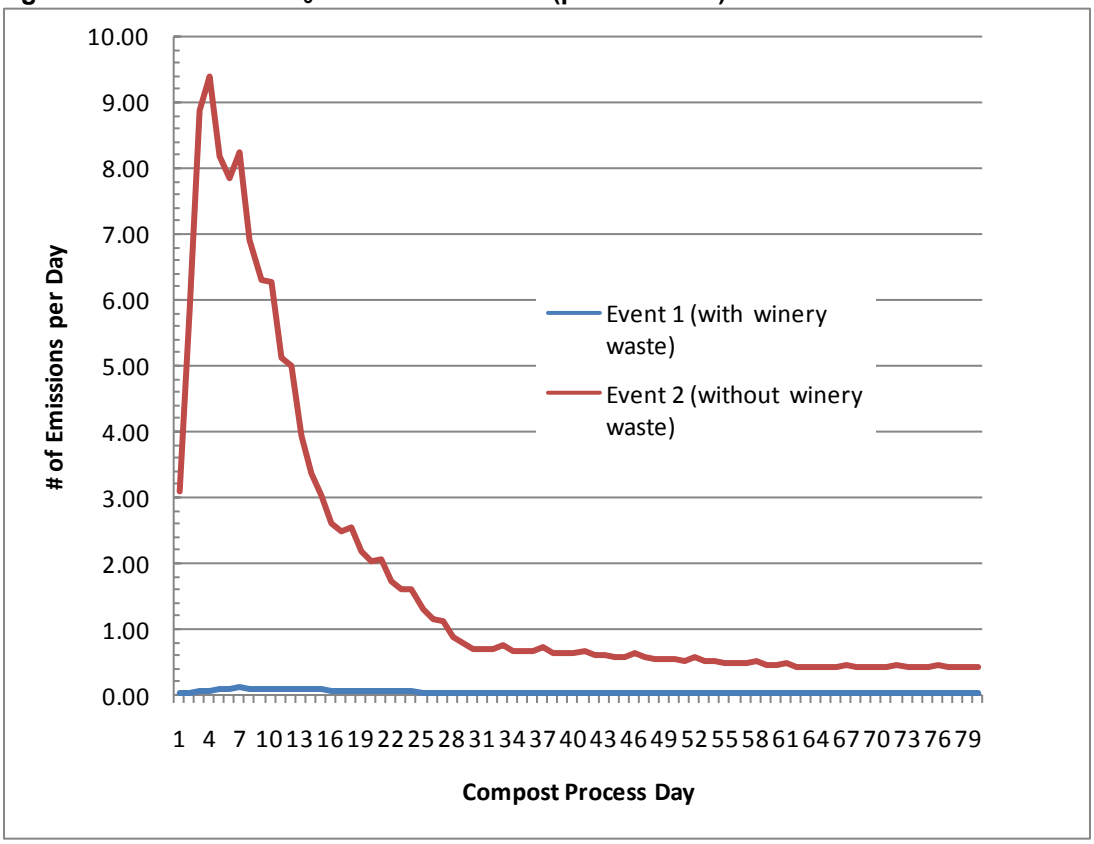


Figure 4.3 Simulated NH_3 Emissions Profile (per windrow).



4.5 Emissions from Feedstock and Product Storage

Table 4.2a, 4.2b, and 4.3 present the VOC and ammonia emission calculations while feedstock is being stored prior to windrowing and from finished compost product storage. The product emissions were assumed to be the same for the winery waste and non-winery waste compost product.

Table 4.2a. – Event 1 Feedstock emission calculations (with winery waste).

Mass	300	tons/day
Density	443	#/yd3
	16.4	#/ft3
Storage Duration	90	day
Total Tons Stored	27,000	tons
Pile Volume	121,896	yd3
	3,291,196	ft3
Pile shape	Frustrum	
Pile Height	20	feet
Pile Length	577	
Pile Width	300	
Pile Area	173,208	feet
Slant Height	28	
Pile Area	204,560	ft2
	19,118	m2

	VOC	**NH3**	
Unit Emissions	198.74	0.084	mg/min-m2
Total Emissions	5,471,153	2,326	gms/day
	12,063	5.1	pounds/day
	2,201	0.9	tons/year
Emission Factor	44.03	0.01709	pounds/ton

Table 4.2b. – Event 2 Feedstock emission calculations (without winery waste).

Mass	300	tons/day
Density	443	#/yd3
	16.4	#/ft3
Storage Duration	90	day
Total Tons Stored	27,000	tons
Pile Volume	121,896	yd3
	3,291,196	ft3
Pile shape	Frustrum	
Pile Height	20	feet
Pile Length	577	
Pile Width	300	
Pile Area	173,208	feet
Slant Height	28	
Pile Area	204,560	ft2
	19,118	m2

	VOC	**NH3**	
Unit Emissions	51.19	8.118	mg/min-m2
Total Emissions	1,409,351	223,497	gms/day
	3,107	492.8	pounds/day
	567	89.9	tons/year
Emission Factor	11.34	1.64254	pounds/ton

Table 4.3. – Finished product storage emission calculations (used for both winery and non-winery waste containing compost).

Mass	200	tons/day
Density	1123	#/yd3
	41.6	#/ft3
Storage Duration	15	day
Total Tons Stored	3000	tons
Pile Volume	5,343	yd3
	144,256	ft3
Pile shape	Frustrum	
Pile Height	20	feet
Pile Length	90	
Pile Width	100	
Pile Area	8,977	feet
Slant Height	28	
Pile Area	15,186	ft2
	1,419	m2

	VOC	**NH3**	
Unit Emissions	1.42	0.017	mg/min-m2
Total Emissions	2,894	35	gms/day
	6	0.08	pounds/day
	1	0.014	tons/year
Emission Factor	0.02	0.00038	pounds/ton

Appendix A

Full Cycle Simulation Table

Table A1a VOC Cycle Simulation Calculations for Event 1

Compost Day	Unit Flux (mg/min-m2) Top	Side	Total	Mix	UF (mg/m-m2)	Area (m2)	Daily Emissions (mg)	(#)
1	181	60	105	2.1	221	785	249,958,006	551
2	213	43	107	1	107	785	120,450,583	266
3	245	26	108	1	108	785	121,873,545	269
4	298	20	124	1.9	235	785	266,173,572	587
5	351	15	140	1	140	785	158,309,162	349
6	403	9	156	1	156	785	176,526,971	389
7	456	3	172	1.7	293	785	331,066,126	730
8	401	3	152	1	152	785	171,472,778	378
9	346	3	131	1	131	785	148,200,776	327
10	291	3	110	1.6	177	785	199,886,039	441
11	236	3	90	1	90	785	101,656,773	224
12	181	3	69	1.6	111	785	125,415,633	277
13	126	3	49	1	49	785	55,112,769	122
14	71	3	28	1	28	785	31,840,767	70
15	16	3	8	1.5	11	785	12,853,148	28
16	15	2	7	1	7	785	8,006,131	18
17	14	2	7	1	7	785	7,443,497	16
18	13	2	6	2	12	785	13,761,725	30
19	12	2	6	1	6	785	6,318,228	14
20	11	2	5	1	5	785	5,755,594	13
21	10	2	5	2.5	11	785	12,982,399	29
22	8	2	4	1	4.1	785	4,630,326	10
23	7	1	4	1	3.6	785	4,067,691	9
24	6	1	3	3	9.3	785	10,515,171	23
25	5	1	3	1	2.6	785	2,942,423	6
26	4	1	2	1	2.1	785	2,379,789	5
27	3	1	2	3.5	5.6	785	6,360,040	14
28	2	1	1	1	1.1	785	1,254,520	2.8
29	0.8	0.5	1	4.7	2.9	785	3,251,863	7.2
30	0.78	0.51	0.61	1	0.6	785	689,246	1.5
31	0.78	0.50	0.61	1	0.6	785	686,606	1.5
32	0.78	0.50	0.60	1	0.6	785	683,967	1.5
33	0.78	0.50	0.60	4	2.4	785	2,725,308	6.0
34	0.78	0.49	0.60	1	0.6	785	678,687	1.5
35	0.78	0.49	0.60	1	0.6	785	676,048	1.5
36	0.78	0.48	0.60	1	0.6	785	673,408	1.5
37	0.79	0.48	0.59	3	1.8	785	2,012,305	4.4
38	0.79	0.47	0.59	1	0.6	785	668,129	1.5
39	0.79	0.47	0.59	1	0.6	785	665,489	1.5
40	0.79	0.47	0.59	1	0.6	785	662,849	1.5
41	0.79	0.46	0.58	2	1.2	785	1,320,419	2.9
42	0.79	0.46	0.58	1	0.6	785	657,570	1.4
43	0.79	0.45	0.58	1	0.6	785	654,930	1.4
44	0.79	0.45	0.58	1	0.6	785	652,290	1.4
45	0.79	0.44	0.57	1	0.6	785	649,651	1.4
46	0.80	0.44	0.57	1.5	0.9	785	970,517	2.1
47	0.80	0.43	0.57	1	0.6	785	644,371	1.4
48	0.80	0.43	0.57	1	0.6	785	641,732	1.4
49	0.80	0.43	0.57	1	0.6	785	639,092	1.4
50	0.80	0.42	0.56	1	0.6	785	636,452	1.4
51	0.80	0.42	0.56	1	0.6	785	633,813	1.4
52	0.80	0.41	0.56	1.5	0.8	785	946,759	2.1
53	0.80	0.41	0.56	1	0.6	785	628,533	1.4
54	0.80	0.40	0.55	1	0.6	785	625,894	1.4
55	0.80	0.40	0.55	1	0.6	785	623,254	1.4
56	0.81	0.40	0.55	1	0.5	785	620,614	1.4
57	0.81	0.39	0.55	1	0.5	785	617,974	1.4
58	0.81	0.39	0.54	1.5	0.8	785	923,002	2.0
59	0.81	0.38	0.54	1	0.5	785	612,695	1.4
60	0.81	0.38	0.54	1	0.5	785	610,055	1.3
61	0.81	0.37	0.54	1.5	0.8	785	911,124	2.0
62	0.81	0.37	0.53	1	0.5	785	604,776	1.3
63	0.8	0.4	0.53	1	0.5	785	602,136	1.3
64	0.81	0.37	0.53	1	0.5	785	602,136	1.3
65	0.81	0.37	0.53	1	0.5	785	602,136	1.3
66	0.81	0.37	0.53	1	0.5	785	602,136	1.3
67	0.81	0.37	0.53	1.5	0.8	785	903,205	2.0
68	0.81	0.37	0.53	1	0.5	785	602,136	1.3
69	0.81	0.37	0.53	1	0.5	785	602,136	1.3
70	0.81	0.37	0.53	1	0.5	785	602,136	1.3
71	0.81	0.37	0.53	1	0.5	785	602,136	1.3
72	0.81	0.37	0.53	1.5	0.8	785	903,205	2.0
73	0.81	0.37	0.53	1	0.5	785	602,136	1.3
74	0.81	0.37	0.53	1	0.5	785	602,136	1.3
75	0.81	0.37	0.53	1	0.5	785	602,136	1.3
76	0.81	0.37	0.53	1.5	0.8	785	903,205	2.0
77	0.81	0.37	0.53	1	0.5	785	602,136	1.3
78	0.81	0.37	0.53	1	0.5	785	602,136	1.3
79	0.81	0.37	0.53	1	0.5	785	602,136	1.3
80	0.81	0.37	0.53	1	0.5	785	602,136	1.3
							Total Emissions	5,289
								16.55 #/Ton

Table A1a NH3 Cycle Simulation Calculations for Event 1

Compost Day	Unit Flux (mg/min-m2) Top	Side	Total	Mix	UF (mg/m-m2)	Area (m2)	Daily Emissions (mg)	(#)
1	0.01	0.01	0.01	1.1	0.02	785	17,391	0.04
2	0.02	0.02	0.02	1	0.02	785	19,897	0.04
3	0.02	0.02	0.02	1	0.02	785	23,985	0.05
4	0.03	0.02	0.03	1.1	0.03	785	33,880	0.07
5	0.04	0.03	0.03	1	0.03	785	37,615	0.08
6	0.05	0.03	0.04	1	0.04	785	44,431	0.10
7	0.07	0.03	0.05	1.1	0.05	785	56,370	0.12
8	0.06	0.03	0.04	1	0.04	785	48,999	0.11
9	0.06	0.03	0.04	1	0.04	785	46,752	0.10
10	0.05	0.03	0.04	1.1	0.04	785	48,956	0.11
11	0.05	0.03	0.04	1	0.04	785	42,258	0.09
12	0.05	0.03	0.04	1.1	0.04	785	44,013	0.10
13	0.04	0.03	0.03	1	0.03	785	37,765	0.08
14	0.04	0.03	0.03	1	0.03	785	35,518	0.08
15	0.04	0.03	0.03	1.1	0.03	785	36,598	0.08
16	0.04	0.02	0.03	1	0.03	785	31,996	0.07
17	0.03	0.02	0.03	1	0.03	785	30,720	0.07
18	0.03	0.02	0.03	1.1	0.03	785	32,390	0.07
19	0.03	0.02	0.02	1	0.02	785	28,170	0.06
20	0.03	0.02	0.02	1	0.02	785	26,894	0.06
21	0.03	0.02	0.02	1.1	0.02	785	28,181	0.06
22	0.03	0.02	0.02	1	0.02	785	24,344	0.05
23	0.03	0.02	0.02	1	0.02	785	23,069	0.05
24	0.02	0.02	0.02	1.1	0.02	785	23,973	0.05
25	0.02	0.02	0.02	1	0.02	785	20,518	0.05
26	0.02	0.01	0.02	1	0.02	785	19,243	0.04
27	0.02	0.01	0.02	1.1	0.02	785	19,764	0.04
28	0.02	0.01	0.01	1	0.01	785	16,692	0.04
29	0.02	0.01	0.01	1.1	0.01	785	16,958	0.04
30	0.02	0.01	0.01	1	0.01	785	15,367	0.03
31	0.02	0.01	0.01	1	0.01	785	15,318	0.03
32	0.02	0.01	0.01	1	0.01	785	15,269	0.03
33	0.02	0.01	0.01	1.1	0.01	785	16,742	0.04
34	0.02	0.01	0.01	1	0.01	785	15,171	0.03
35	0.02	0.01	0.01	1	0.01	785	15,122	0.03
36	0.02	0.01	0.01	1	0.01	785	15,072	0.03
37	0.02	0.01	0.01	1.1	0.01	785	16,525	0.04
38	0.02	0.01	0.01	1	0.01	785	14,974	0.03
39	0.02	0.01	0.01	1	0.01	785	14,925	0.03
40	0.02	0.01	0.01	1	0.01	785	14,876	0.03
41	0.02	0.01	0.01	1.1	0.01	785	16,309	0.04
42	0.02	0.01	0.01	1	0.01	785	14,777	0.03
43	0.02	0.01	0.01	1	0.01	785	14,728	0.03
44	0.01	0.01	0.01	1	0.01	785	14,679	0.03
45	0.01	0.01	0.01	1	0.01	785	14,630	0.03
46	0.01	0.01	0.01	1.1	0.01	785	16,038	0.04
47	0.01	0.01	0.01	1	0.01	785	14,531	0.03
48	0.01	0.01	0.01	1	0.01	785	14,482	0.03
49	0.01	0.01	0.01	1	0.01	785	14,433	0.03
50	0.01	0.01	0.01	1	0.01	785	14,384	0.03
51	0.01	0.01	0.01	1	0.01	785	14,334	0.03
52	0.01	0.01	0.01	1.1	0.01	785	15,714	0.03
53	0.01	0.01	0.01	1	0.01	785	14,236	0.03
54	0.01	0.01	0.01	1	0.01	785	14,187	0.03
55	0.01	0.01	0.01	1	0.01	785	14,138	0.03
56	0.01	0.01	0.01	1	0.01	785	14,089	0.03
57	0.01	0.01	0.01	1	0.01	785	14,039	0.03
58	0.01	0.01	0.01	1.1	0.01	785	15,389	0.03
59	0.01	0.01	0.01	1	0.01	785	13,941	0.03
60	0.01	0.01	0.01	1	0.01	785	13,892	0.03
61	0.01	0.01	0.01	1.1	0.01	785	15,227	0.03
62	0.01	0.01	0.01	1	0.01	785	13,793	0.03
63	0.0	0.0	0.01	1	0.01	785	13,744	0.03
64	0.01	0.01	0.01	1	0.01	785	13,744	0.03
65	0.01	0.01	0.01	1	0.01	785	13,744	0.03
66	0.01	0.01	0.01	1	0.01	785	13,744	0.03
67	0.01	0.01	0.01	1.1	0.01	785	15,119	0.03
68	0.01	0.01	0.01	1	0.01	785	13,744	0.03
69	0.01	0.01	0.01	1	0.01	785	13,744	0.03
70	0.01	0.01	0.01	1	0.01	785	13,744	0.03
71	0.01	0.01	0.01	1	0.01	785	13,744	0.03
72	0.01	0.01	0.01	1.1	0.01	785	15,119	0.03
73	0.01	0.01	0.01	1	0.01	785	13,744	0.03
74	0.01	0.01	0.01	1	0.01	785	13,744	0.03
75	0.01	0.01	0.01	1	0.01	785	13,744	0.03
76	0.01	0.01	0.01	1.1	0.01	785	15,119	0.03
77	0.01	0.01	0.01	1	0.01	785	13,744	0.03
78	0.01	0.01	0.01	1	0.01	785	13,744	0.03
79	0.01	0.01	0.01	1	0.01	785	13,744	0.03
80	0.01	0.01	0.01	1	0.01	785	13,744	0.03
							Total Emissions	4
								0.011 #/Ton

Table A1b VOC Cycle Simulation Calculations for Event 2

Compost Day	Unit Flux (mg/min-m2) Top	Side	Total	Mix	UF (mg/m-m2)	Area (m2)	Daily Emissions (mg)	(#)
1	27	83	62	2.1	131	785	147,843,960	326
2	81	66	72	1	72	785	80,987,316	179
3	135	49	81	1	81	785	91,572,747	202
4	188	32	90	1.9	172	785	194,100,537	428
5	242	15	100	1	100	785	112,743,608	249
6	210	11	85	1	85	785	95,912,037	211
7	177	6	70	1.7	119	785	134,436,791	296
8	144	2	55	1	55	785	62,248,894	137
9	127	2	49	1	49	785	55,076,966	121
10	111	2	42	1.6	68	785	76,648,060	169
11	94	2	36	1	36	785	40,733,109	90
12	77	2	30	1.6	47	785	53,697,889	118
13	60	2	23	1	23	785	26,389,252	58
14	43	1	17	1	17	785	19,217,324	42
15	26	1	11	1.5	16	785	18,068,093	40
16	9	1	4	1	4	785	4,873,467	11
17	9	1	4	1	4	785	4,717,702	10
18	8	2	4	2	8	785	9,123,874	20
19	8	2	4	1	4	785	4,406,173	10
20	7	2	4	1	4	785	4,250,408	9
21	7	2	4	2.5	9	785	10,236,608	23
22	6	2	3	1	3.5	785	3,938,879	9
23	5	2	3	1	3.3	785	3,783,114	8
24	5	2	3	3	9.6	785	10,882,048	24
25	4	2	3	1	3.1	785	3,471,585	8
26	4	2	3	1	2.9	785	3,315,820	7
27	3	3	3	3.5	9.8	785	11,060,193	24
28	3	3	3	1	2.7	785	3,004,291	6.6
29	2	3	3	4.7	11.8	785	13,388,072	29.5
30	2	3	2	1	2.4	785	2,692,761	5.9
31	1.04	2.96	2	1	2.2	785	2,536,997	5.6
32	1.04	2.96	2.24	1	2.2	785	2,536,997	5.6
33	1.04	2.96	2.24	4	9.0	785	10,147,986	22.4
34	1.04	2.96	2.24	1	2.2	785	2,536,997	5.6
35	1.04	2.96	2.24	1	2.2	785	2,536,997	5.6
36	1.04	2.96	2.24	1	2.2	785	2,536,997	5.6
37	1.04	2.96	2.24	3	6.7	785	7,610,990	16.8
38	1.04	2.96	2.24	1	2.2	785	2,536,997	5.6
39	1.04	2.96	2.24	1	2.2	785	2,536,997	5.6
40	1.04	2.96	2.24	1	2.2	785	2,536,997	5.6
41	1.04	2.96	2.24	2	4.5	785	5,073,993	11.2
42	1.04	2.96	2.24	1	2.2	785	2,536,997	5.6
43	1.04	2.96	2.24	1	2.2	785	2,536,997	5.6
44	1.04	2.96	2.24	1	2.2	785	2,536,997	5.6
45	1.04	2.96	2.24	1	2.2	785	2,536,997	5.6
46	1.04	2.96	2.24	1.5	3.4	785	3,805,495	8.4
47	1.04	2.96	2.24	1	2.2	785	2,536,997	5.6
48	1.04	2.96	2.24	1	2.2	785	2,536,997	5.6
49	1.04	2.96	2.24	1	2.2	785	2,536,997	5.6
50	1.04	2.96	2.24	1	2.2	785	2,536,997	5.6
51	1.04	2.96	2.24	1	2.2	785	2,536,997	5.6
52	1.04	2.96	2.24	1.5	3.4	785	3,805,495	8.4
53	1.04	2.96	2.24	1	2.2	785	2,536,997	5.6
54	1.04	2.96	2.24	1	2.2	785	2,536,997	5.6
55	1.04	2.96	2.24	1	2.2	785	2,536,997	5.6
56	1.04	2.96	2.24	1	2.2	785	2,536,997	5.6
57	1.04	2.96	2.24	1	2.2	785	2,536,997	5.6
58	1.04	2.96	2.24	1.5	3.4	785	3,805,495	8.4
59	1.04	2.96	2.24	1	2.2	785	2,536,997	5.6
60	1.04	2.96	2.24	1	2.2	785	2,536,997	5.6
61	1.04	2.96	2.24	1.5	3.4	785	3,805,495	8.4
62	1.04	2.96	2.24	1	2.2	785	2,536,997	5.6
63	1.04	2.96	2.24	1	2.2	785	2,536,997	5.6
64	1.04	2.96	2.24	1	2.2	785	2,536,997	5.6
65	1.04	2.96	2.24	1	2.2	785	2,536,997	5.6
66	1.04	2.96	2.24	1	2.2	785	2,536,997	5.6
67	1.04	2.96	2.24	1.5	3.4	785	3,805,495	8.4
68	1.04	2.96	2.24	1	2.2	785	2,536,997	5.6
69	1.04	2.96	2.24	1	2.2	785	2,536,997	5.6
70	1.04	2.96	2.24	1	2.2	785	2,536,997	5.6
71	1.04	2.96	2.24	1	2.2	785	2,536,997	5.6
72	1.04	2.96	2.24	1.5	3.4	785	3,805,495	8.4
73	1.04	2.96	2.24	1	2.2	785	2,536,997	5.6
74	1.04	2.96	2.24	1	2.2	785	2,536,997	5.6
75	1.04	2.96	2.24	1	2.2	785	2,536,997	5.6
76	1.04	2.96	2.24	1.5	3.4	785	3,805,495	8.4
77	1.04	2.96	2.24	1	2.2	785	2,536,997	5.6
78	1.04	2.96	2.24	1	2.2	785	2,536,997	5.6
79	1.04	2.96	2.24	1	2.2	785	2,536,997	5.6
80	1.04	2.96	2.24	1	2.2	785	2,536,997	5.6
							Total Emissions	3,205
								10.03 #/Ton

Table A1b NH3 Cycle Simulation Calculations for Event 2

Compost Day	Unit Flux (mg/min-m2) Top	Side	Total	Mix	UF (mg/m-m2)	Area (m2)	Daily Emissions (mg)	(#)
1	0	2	1.13	1.1	1.24	785	1,406,757	3.10
2	3	2	2.35	1	2.35	785	2,657,139	5.86
3	7	2	3.57	1	3.57	785	4,035,408	8.90
4	10	2	3.43	1.1	3.77	785	4,263,343	9.40
5	13	2	3.29	1	3.29	785	3,716,125	8.19
6	10	1	3.14	1	3.14	785	3,556,483	7.84
7	7	1	3.00	1.1	3.30	785	3,736,525	8.24
8	4	0	2.77	1	2.77	785	3,128,743	6.90
9	4	0	2.53	1	2.53	785	2,860,644	6.31
10	3	0	2.29	1.1	2.52	785	2,851,800	6.29
11	3	0	2.06	1	2.06	785	2,324,447	5.12
12	3	0	1.82	1.1	2.00	785	2,261,983	4.99
13	3	0	1.58	1	1.58	785	1,788,249	3.94
14	3	0	1.34	1	1.34	785	1,520,151	3.35
15	3	0	1.11	1.1	1.22	785	1,377,257	3.04
16	3	0	1.05	1	1.05	785	1,185,635	2.61
17	2	0	0.99	1	0.99	785	1,119,218	2.47
18	2	0	0.93	1.1	1.02	785	1,158,081	2.55
19	2	0	0.87	1	0.87	785	986,384	2.17
20	2	0	0.81	1	0.81	785	919,967	2.03
21	2	0	0.75	1.1	0.83	785	938,905	2.07
22	2	0	0.70	1	0.70	785	787,133	1.74
23	1	0	0.64	1	0.64	785	720,715	1.59
24	1	0	0.58	1.1	0.64	785	719,728	1.59
25	1	0	0.52	1	0.52	785	587,881	1.30
26	1	0	0.46	1	0.46	785	521,464	1.15
27	1	0	0.40	1.1	0.44	785	500,552	1.10
28	1	0	0.34	1	0.34	785	388,630	0.86
29	0	0	0.28	1.1	0.31	785	354,434	0.78
30	0	0	0.28	1	0.28	785	318,295	0.70
31	0.17	0.17	0.28	1	0.28	785	314,376	0.69
32	0.17	0.17	0.27	1	0.27	785	310,458	0.68
33	0.17	0.17	0.27	1.1	0.30	785	337,194	0.74
34	0.17	0.17	0.27	1	0.27	785	302,621	0.67
35	0.17	0.17	0.26	1	0.26	785	298,703	0.66
36	0.17	0.17	0.26	1	0.26	785	294,785	0.65
37	0.17	0.17	0.26	1.1	0.28	785	319,953	0.71
38	0.17	0.17	0.25	1	0.25	785	286,948	0.63
39	0.17	0.17	0.25	1	0.25	785	283,030	0.62
40	0.17	0.17	0.25	1	0.25	785	279,111	0.62
41	0.17	0.17	0.24	1.1	0.27	785	302,712	0.67
42	0.17	0.17	0.24	1	0.24	785	271,275	0.60
43	0.17	0.17	0.24	1	0.24	785	267,356	0.59
44	0.17	0.17	0.23	1	0.23	785	263,438	0.58
45	0.17	0.17	0.23	1	0.23	785	259,520	0.57
46	0.17	0.17	0.23	1.1	0.25	785	281,162	0.62
47	0.17	0.17	0.22	1	0.22	785	251,683	0.55
48	0.17	0.17	0.22	1	0.22	785	247,765	0.55
49	0.17	0.17	0.22	1	0.22	785	243,847	0.54
50	0.17	0.17	0.21	1	0.21	785	239,928	0.53
51	0.17	0.17	0.21	1	0.21	785	236,010	0.52
52	0.17	0.17	0.21	1.1	0.23	785	255,301	0.56
53	0.17	0.17	0.20	1	0.20	785	228,173	0.50
54	0.17	0.17	0.20	1	0.20	785	224,255	0.49
55	0.17	0.17	0.19	1	0.19	785	220,337	0.49
56	0.17	0.17	0.19	1	0.19	785	216,418	0.48
57	0.17	0.17	0.19	1	0.19	785	212,500	0.47
58	0.17	0.17	0.18	1.1	0.20	785	229,440	0.51
59	0.17	0.17	0.18	1	0.18	785	204,663	0.45
60	0.17	0.17	0.18	1	0.18	785	200,745	0.44
61	0.17	0.17	0.17	1.1	0.19	785	216,509	0.48
62	0.17	0.17	0.17	1	0.17	785	192,908	0.43
63	0.17	0.17	0.17	1	0.17	785	188,990	0.42
64	0.17	0.17	0.17	1	0.17	785	188,990	0.42
65	0.17	0.17	0.17	1	0.17	785	188,990	0.42
66	0.17	0.17	0.17	1	0.17	785	188,990	0.42
67	0.17	0.17	0.17	1.1	0.18	785	207,889	0.46
68	0.17	0.17	0.17	1	0.17	785	188,990	0.42
69	0.17	0.17	0.17	1	0.17	785	188,990	0.42
70	0.17	0.17	0.17	1	0.17	785	188,990	0.42
71	0.17	0.17	0.17	1	0.17	785	188,990	0.42
72	0.17	0.17	0.17	1.1	0.18	785	207,889	0.46
73	0.17	0.17	0.17	1	0.17	785	188,990	0.42
74	0.17	0.17	0.17	1	0.17	785	188,990	0.42
75	0.17	0.17	0.17	1	0.17	785	188,990	0.42
76	0.17	0.17	0.17	1.1	0.18	785	207,889	0.46
77	0.17	0.17	0.17	1	0.17	785	188,990	0.42
78	0.17	0.17	0.17	1	0.17	785	188,990	0.42
79	0.17	0.17	0.17	1	0.17	785	188,990	0.42
80	0.17	0.17	0.17	1	0.17	785	188,990	0.42
							Total Emissions	142
								0.445 #/Ton

Appendix B
Photographs

Appendix C
Data Validation Technical Memorandum

NEW JERSEY DEPARTMENT OF ENVIRONMENTAL PROTECTION

SCIENCE ADVISORY BOARD

FINAL REPORT

OUTDOOR FOOD WASTE COMPOSTING

Prepared for:

Commissioner Catherine R. McCabe

Prepared by:

Ad Hoc Work Group

Approved by:

NJDEP SCIENCE ADVISORY BOARD

Judith Weis, Ph.D. (Chairperson)
Clinton J. Andrews, Ph.D., P.E.
Lisa Axe, Ph.D.
Michel Boufadel, Ph.D., P.E.
Anthony Broccoli, Ph.D.
Tinchu Chu, Ph.D.
John E. Dyksen, M.S., P.E.
John T. Gannon, Ph.D.
Michael Gochfeld, M.D., Ph.D.
Charles R. Harman, M.A.
Richard H. Kropp, M.S., P.E.
Robert J. Laumbach, M.D., MPH
Peter Lederman, Ph.D., P.E.
Robert J. Lippencott, Ph.D.
Tavit O. Najarian, Sc.D.
Nancy C. Rothman, Ph.D.

April 22, 2020

Members of the Ad Hoc Work Group and their Standing Committee affiliations:

Peter Strom, Ph.D., Chairperson (Water Quality and Quantity)
Joann Held, M.S. (Climate and Atmospheric Sciences)
Howard Kipen, M.D., M.P.H. (Public Health)
Uta Krogmann, Ph.D.[1]

[1] Dr. Krogmann, a non-SAB member, is a Professor and Solid Waste Extension Specialist at the School of Biological and Environmental Sciences and the NJ Agricultural Experiment Station, at Rutgers University.

Table of Contents

Preface 2
1. Background 1
2. New Jersey Current Regulatory Framework.....2
3. Charge Questions and Responses.....3
4. Work Group Recommendations.....4
5. Nature of Food Waste, Composting, and Composting "Recipes" 6
5.1 Definitions of food waste 6
5.2 Challenges with food waste composting.....7
5.3 Composting "recipes" or best practices 8
5.4 Composting of meat products.....10
6. Outdoor Composting Methods.....11
6.1 Outdoor versus enclosed composting 11
6.2 Windrow composting.....13
6.3 Static pile composting.....14
6.4 Composting using synthetic covers 16
6.5 Management 17
7. Compost Product Testing Requirements 18
8. Leachate 24
8.1 Leachate characterization.....25
8.2 Leachate quantity.....26
8.3 Effect of composting method 27
8.4 Site factors.....27
8.5 Leachate control 27
9. Air Emissions 30
9.1 Pollutants emitted to the air during composting operations.....30
9.2 Emission rates.....31
9.3 Control technologies and best management practices (BMPs) to reduce emissions....32
9.3.1 Volatile organic compounds.....32

9.3.2 Particulate matter 32
9.3.3 Odors 32
9.4 Air permitting requirements 35
10. Potential Human Health Effects 36
10.1 Exposures 37
10.2 Health outcomes 37
10.3 Occupational health 38
10.4 Community health 39
10.5 Odors 40
10.6 Conclusions 40
11. Buffer Zones 40
12. Size of Composting Facilities 41
13. References 44
Appendix 1. Food composting project overview prepared by the SRWMP 56
Appendix 2: Revised Program Information Needs 57

Preface

The New Jersey Department of Environmental Protection Agency's (NJDEP) Site Remediation and Waste Management Program (SRWMP) has asked the Science Advisory Board (SAB) to provide scientifically based information that could be used to inform the implementation of regulatory changes needed to facilitate outdoor food waste composting in New Jersey. In doing so, the SRWMP posed to the SAB a series of charge questions (see Section 1) and information needs (Appendix 1). In response, the SAB formed a Work Group to deliberate on this request. This report addresses the charge questions and needs by providing relevant background as well as more detailed scientific information.

1. Background

Based on 2017 data (USEPA, 2019b), food waste is the second largest component (15.2%), after paper, of municipal solid waste (MSW) in the USA (Table 1-1). Unlike with paper, which is 65.9% recycled, only limited recycling of food waste has been achieved (6.3% composted). In contrast, 69.4% of yard trimmings is composted.

Table 1-1. Municipal solid waste (MSW) generation and management in the USA, 2017. (Based on USEPA, 2019b.)

Material	Generated		% of generation managed by:			
	millions of tons	%	Recycling	Composting	Combustion	Landfilling
Paper	67.0	25.0	65.9	-	6.7	27.4
Glass	11.4	4.2	26.6	-	13.0	60.4
Metals	25.1	9.4	33.3	-	11.7	55.1
Plastics	35.4	13.2	8.4	-	15.8	75.8
Rubber and leather	9.1	3.4	18.3	-	27.3	54.3
Textiles	16.9	6.3	15.2	-	18.8	66.0
Wood	18.0	6.7	16.7	-	15.8	67.5
Other materials	5.1	1.9	28.4	-	13.1	58.4
Food, other*	40.7	15.2	-	6.3	18.4	75.3
Yard trimmings	35.2	13.1	-	69.4	6.0	24.6
Misc. inorganic wastes	4.0	1.5	-	-	19.6	80.5
Total MSW	**267.8**	100	**25.1**	**10.1**	**12.7**	**52.1**

* Includes collection of other MSW organics for composting.

The State of New Jersey has expressed interest in reduction and improved management of food waste. For example, P.L.2017, Chapter 136, approved July 21, 2017 (NJ Senate Bill 3027) "Establishes [a] State food waste reduction goal of 50 percent by 2030." NJ Assembly Bill 2371, which requires large food waste generators to separate and recycle food waste, has just become law in April 2020.

While there is a desire to encourage food waste composting as an environmentally beneficial, sustainable waste management/recycling process, there is a need to prevent environmental problems from arising. A set of regulatory requirements is needed to guide composting activities; these should be based on the best available scientific research. This would

encourage composting by implementing the least restrictive regulatory requirements possible while still protecting public health and the environment.

Currently, source separated food waste is a Class C recyclable material in New Jersey, and thus composting of food waste requires a Class C recycling general approval. In the past, there have been a handful of food waste composting facilities in the state, but they have closed due to operational problems such as odor nuisances and leachate issues. As of January 2020, there are no operating Class C food waste composting facilities in the state. However, there is one Research, Development, and Demonstration (RD&D) facility in operation; a second has been permitted by the Division of Solid and Hazardous Waste (DSHW) but is awaiting permits from other Programs in NJDEP. Because of past environmental issues, such facilities have had difficulties in complying with environmental rules for air (odor) and water (surface/groundwater).

This report considers outdoor composting, which might be the least expensive (and therefore most economically viable) approach. While not considered here, the potential roles of enclosed composting and the use of food waste as animal feed, in producing renewable energy (e.g., anaerobic digestion at water pollution control plants or in stand-alone facilities) and other forms of recycling and reuse should not be ignored.

2. New Jersey Current Regulatory Framework

All regulated recycling activities in NJ are governed by the New Jersey Administrative Code, Title 7, Chapter 26A. These regulations were promulgated pursuant to the Solid Waste Management Act, N.J.S.A. 13:1E-1 et seq., particularly the New Jersey Statewide Mandatory Source Separation and Recycling Act, N.J.S.A. 13:1E-99.11.

As provided at N.J.A.C. 7:26A-1 et seq., source separated food waste is considered a "Class C recyclable material." The current regulations only allow food waste composting operations to be conducted in fully enclosed structures with complete walls and roof that include an air management system capable of removing odors and noxious compounds permitted by the Department pursuant to N.J.A.C. 7:27. The building is required to have a minimum setback of 50 feet from the property line of the recycling center.

However, provisions of the regulation also allow a recycling center to operate a Research, Development, and Demonstration (RD&D) project pursuant to N.J.A.C. 7:26-1.7(f) to demonstrate that the specific materials received do not require full enclosure to prevent leachate problems and off-site impacts such as odors from typical food wastes. Based on the results of the RD&D project the Department may issue a general approval to allow other forms of structures or other measures that would be adequate to prevent on and off-site impacts.

When these regulations were promulgated, the provisions appear to have envisioned large-scale compost facilities. No specific provisions were made for micro-scale, small-scale, or medium scale food waste compost facilities that may have lesser impacts to the environment and human health than large, or very large facilities.

3. Charge Questions and Responses

The SRWMP posed the three following charge questions for the Work Group to address. Brief responses from the Work Group are provided here for each charge question. These are intended to be distillations of more in-depth information presented in various sections of this report, to which the reader is also directed.

Charge Question 1: What are the potential impacts to groundwater and air from outdoor food waste composting?

Response

Leachate and runoff from outdoor food waste composting potentially can contain high concentrations of organic matter, nutrients, and other contaminants. Discharge to surface water must be prevented, and depending on the composting material, operations, and site factors, discharge to groundwater may lead to non-compliance with groundwater quality standards. Best management practices (BMPs) have been developed to prevent or mitigate these concerns. Leachate issues are addressed mainly in Section 8.

Potential air impacts from outdoor food waste composting operations include particulate matter, volatile organic compounds, and greenhouse gases (especially methane and perhaps nitrous oxide), but most concern focuses on odors and bioaerosols. Mitigation of these concerns usually involves both BMPs and buffer zones. Air issues are addressed mainly in Section 9, and buffer zones in Section 11. Human health concerns for both workers and nearby residents mainly center on air emissions, particularly of bioaerosols; these are discussed in Section 10.

Both water and air impacts may depend on the materials being composted (addressed in Section 5), composting methods used (Section 6), and the size of the facility or amount of material being handled (Section 12).

Compost product quality is of importance for several reasons, including with respect to potential health concerns, measures of process effectiveness, and as indicators of potential water and air impacts. Testing requirements are discussed in Section 7.

Charge Question 2: What is the best recipe for composting of food waste?

Response

In order to provide for rapid and effective composting while minimizing odors and other problems, it is necessary to adequately satisfy the needs of the microbial community that is responsible for this activity. This requires the balancing of a number of factors, including maintenance of a suitable temperature range, oxygen levels, moisture content, pH, carbon to nitrogen ratio (C/N), and other nutrient concentrations. Mixing various wastes together in appropriate proportions and mixing food wastes with bulking agents can be helpful or necessary in achieving some of these objectives. This is discussed in Section 5.

Charge Question 3: What buffer do you need around these facilities?

Response

Buffer zones around food composting operations may be desirable to mitigate a number of environmental issues, but for this report the focus was on odors and bioaerosols. Some of the related issues are noted above in the response to Charge Question 1, while buffer zones are addressed specifically in Section 11.

4. Work Group Recommendations

a. Although this report focused on outdoor composting, the potential roles of enclosed composting and the use of food waste as animal feed, in producing renewable energy (e.g., anaerobic digestion at water pollution control plants with digesters or in stand-alone facilities), and other forms of recycling and reuse should not be ignored.

b. Composting is a proven technology for conversion of many organic wastes to a useful and environmentally beneficial product. However, composting sites may also be a source of environmental problems, especially water contamination and odors. For this reason, any proposed facilities should thoroughly document how these issues will be minimized as part of the approval process.

c. Although food waste is a very variable feedstock, in many cases it is too wet. Therefore, a composting facility needs to store sufficient amounts of dry bulking agent (see Section 5).

d. Even though food waste is source-separated, the separation is not 100% efficient and pre- and post-processing measures need to be in place to remove waste materials (Section 5).

e. Outdoor food waste composting operations are likely to generate leachate. Both the amount produced and the concentrations of contaminants present may vary widely depending on the starting materials, processing methods, and site itself. A variety of best management practices must be employed to prevent discharge to surface waters, and to ensure that any discharge to groundwater does not lead to violation of groundwater quality standards (Section 8).

f. Food waste and food waste composting are prone to odor generation. This depends on many factors related to the starting materials, processing methods, and site itself. A suite of best management practices must be employed by a facility to minimize odor problems (Section 9).

g. Based on both dispersion models and experience, recommended buffer zones for medium to large outdoor food waste composting facilities, based on odors and *Aspergillus fumigatus* bioaerosols, may be 1000-2000 feet or more. While it is possible that best management practices may reduce these distances for some sites, this is an indication of why future large-scale food waste composting facilities in most parts of New Jersey will need to be enclosed (Section 11).

h. Very small composting operations pose much less risk of odor, leachate, and other environmental problems, and offending materials are more easily removed if necessary. This warrants application of reduced permitting conditions, including the possibility of exemption from most requirements, as is practiced in some other states (Section 12).

i. The two outdoor composting methods with a long history are windrowing and aerated static pile (ASP). Windrowing has the operational advantage of simplicity and provides more frequent turning. ASP is usually expected to produce less leachate, can be operated in a way to generate less odor, and may emit fewer bioaerosols due to the decreased turning; however, the control of an ASP is more complex. Some newer approaches provide full or partial covering of the composting material, which may reduce leachate and odor release. To promote innovation, it is recommended that none of these types of operations be prohibited at this time, but rather that all proposals be required to document how they will meet the environmental requirements of the site (Section 6).

j. If finished compost is to be used off-site, some product testing is recommended. Since the analytical testing methods of the US Composting Council are well accepted in the composting community, it is suggested they form the basis of the analyses to be used (Section 7).

k. The intended use of the compost should be clearly defined prior to the selection of the technology to be chosen. Early input from compost users will help to produce a marketable product where that is a goal.

l. To date, the human health risk associated with exposure to composting of organic wastes seems to be low for most people, and no serious outcomes have been reported associated with food waste composting. However, it is logical to anticipate an increased risk of infection in immunocompromised individuals, and the pros and cons of active or passive surveillance or some type of public notification can be considered. For worker protection, keeping materials moist will reduce production of bioaerosols and thus mitigate risk of respiratory and dermal conditions. Measures to inform or exclude from the workplace those who are immunocompromised can be considered. Best management practices and buffer zones are needed to protect individuals at higher risk. The threat to people who have any degree of immunosuppression needs further exploration (Section 10).

m. Although Work Group members may not be aware of all of the steps that will be part of the formal rule-making process in this case, we applaud previous DEP efforts to involve stakeholders, and also the inclusion of training requirements for facility operators.

n. Because food waste is so variable, and because some aspects of composting can be very material and situation specific, there is likely to be little peer-reviewed scientific literature available that is directly applicable for consideration of a proposed operation, especially for small-scale outdoor composting. In Europe, composting of source separated food and yard waste, mostly at medium and large scale, has been practiced for several decades and this experience can inform implementation of food waste composting in New Jersey. Much of the information included in this report is based on reasonable inference from similar composting practices, and some is from the gray literature. Thus there will continue to be a need for research on food waste composting in New Jersey, and it is recommended that NJDEP considers conducting or sponsoring such research. Topics identified include:

    1) Monitoring of environmental impacts of small-scale composting sites.
    2) Odor and bioaerosol dispersion modeling that can be implemented at New Jersey composting sites.
    3) Human health impacts of composting on immunocompromised residents.
    4) Connecting leachate generation forecasting models from composting operations with surface and groundwater quality models.
    5) Establishing pathogen, parasite, and weed seed destruction efficiencies and bioaerosol emission rates for food waste composting operations.

5. Nature of Food Waste, Composting, and Composting "Recipes"

5.1 Definitions of food waste

Defining food waste can be challenging, as there is no universally accepted definition. Does it include materials on-farm, during storage and processing, in transport, and/or from

supermarkets, restaurants, institutions or households? The United Nations Environment Program (UNEP) defines food waste as "food that completes the food supply chain up to a final product, of good quality and fit for consumption, but still doesn't get consumed because it is discarded, whether or not after it is left to spoil or expire. Food waste typically (but not exclusively) takes place at retail and consumption stages in the food supply chain" (UNEP, 2019). Based on this definition the following stages of the food supply chain are included in this report: final part of the manufacturing/processing stage, distribution, wholesale, retail, out-of-home consumption (e.g., restaurants, schools, hospitals) and home consumption. On-farm wastes, handling and storage and the major portion of the manufacturing/processing stage are outside this scope.

The UNEP definition excludes the inedible portion of the food such as peels or rinds, chicken bones or corncobs. For the purpose of this report, the definition is expanded and includes the inedible portion. This seems more appropriate for this report as edible and inedible portions of food products are typically disposed of and composted together. This also follows the United States Environmental Protection Agency's (USEPA) definition of food waste as "food such as plate waste (i.e., food that has been served but not eaten), spoiled food, or peels and rinds considered inedible that is sent to feed animals, to be composted or anaerobically digested, or to be landfilled or combusted with energy recovery" (USEPA 2019a). Solid food waste discharged to the sewer via the garbage disposal in the kitchen sink is included in the scope of this report, if collected for composting.

Food waste to be composted might also be mixed with other compostable products (e.g., paper plates, napkins). If compostable products are collected together with the food waste, it needs to be ensured they do not negatively affect pre-processing in the composting facility and are decomposed while at the composting facility. The inclusion of biodegradable plastic products also needs to be assessed carefully, because they are difficult to distinguish from non-degradable plastics during pre-processing and because they might not degrade in smaller composting facilities that are the size of small-scale backyard composters (Körner et al., 2005, Greene and Tonjes, 2014), nor degrade at a sufficient rate to be eliminated during processing.

5.2 Challenges with food waste composting

Food waste is a challenging composting feedstock because it is "a highly heterogeneous material with a high moisture content, high organic to ash ratio, and an amorphous physical structure" (Cerda et al., 2018). The variability is such that generalizations about it are difficult. For example, individual food wastes may have a high (e.g., carbohydrate or fatty materials) or low (e.g., proteinaceous materials) carbon to nitrogen ratio (C/N); be relatively stable or highly putrescible; be very acidic (naturally containing acids or because they have fermented) or neutral or even alkaline. They are usually wet, or very wet, but could also be too dry. One concern with highly putrescible wastes, such as some food wastes, is that they may be highly odorous already when they arrive at a site. They might have fermented at the source or in the collection bin,

which can cause a lag phase during composting delaying the decomposition (Sundberg et al., 2013).

In addition, as source-separation is not 100% efficient, food waste can be contaminated with other waste materials. To separate these the facility needs to be equipped with the appropriate pre-processing equipment (see for example, Chiumenti et al., 2005 or Krogmann et al., 2010).

Leaf composting may typically be done under suboptimal conditions, allowing the extra time required (months) in exchange for reduced processing costs (Strom et al., 1980; Strom et al., 1986; Strom and Finstein, 1994). However, with more putrescible wastes, such as most food wastes, it is usually desirable to provide more nearly optimized conditions in order to achieve a higher biodegradation rate during the composting process so as to quickly destroy the problematic substances, reduce odor generation, and decrease the time the material remains on site (Finstein et al., 1986a, b and 1987a, b, c, d). A primary factor that can interfere with rapid composting is excessive temperatures, which can inhibit or even kill the microorganisms responsible for biodegradation (especially at 150 °F or higher); thus one goal of process control in active composting is preventing such temperatures from occurring. On the other hand, low temperatures, such as can occur in very small piles, can interfere with rapid composting and with achieving pathogen kill and destruction of weed seeds.

5.3 Composting "recipes" or best practices

Moisture content, C/N, and the material structure/substrate porosity are typically adjusted in the initial feedstock, often by mixing different food wastes, or food waste with other materials (often referred to as bulking agents) such as yard waste or woodchips. Various wastes also may be mixed to adjust the pH of food waste (e.g., cranberry fruit with horse manure, Ramirez-Perez et al., 2007).

The optimum moisture content for composting is feedstock specific and varies between 40-70%, with higher optimum moisture contents for feedstocks that are coarser and have higher water holding capacities. If the moisture is too low, decomposition is slowed. Moisture contents above optimum reduce the availability of oxygen, which then favors slower anaerobic degradation accompanied by the formation of odorous gases. During composting, the maximum tolerable moisture content (Bidlingmaier, 1983) of coarser feedstocks (e.g., wood and bark 74-90%) exceeds the tolerable moisture content of feedstocks with less material structure (e.g., paper, 55-65%; food waste and grass, 50-55%). In many cases, food waste is too wet (Table 5-1). The addition of a dry bulking agent such as woodchips, shredded bark, sawdust, or recycled compost is a common practice to lower the initial moisture content. However, this can increase the composting mass substantially.

With the exception of nitrogen, composting feedstocks generally contain enough other nutrients (e.g., phosphorus, potassium, sulfur, calcium, iron, magnesium), including trace

nutrients, to sustain the composting process. Very uniform feedstock can create exceptions (e.g., paper is low in phosphorus). Therefore, generally only the C/N is adjusted.

Assuming a C/N of microbial cells of 5/1 (Vaccari et al., 2006) and assuming 20% of the carbon is used for the biomass and 80% for energy, the initial C/N of the composting feedstock should be 5 * (80+20)/20 = 25. Of great importance is the actual availability of the carbon and nitrogen. With the exception of keratin (structural protein, for example in hair) and a few similarly resistant components, nitrogen is considered available. However, carbon in lignin, some aromatics and cellulose embedded in lignin is resistant to degradation. Therefore, a suitable C/N at the beginning of the composting process is between 25 and 30 for most wastes. For woody feedstocks containing a considerable portion of lignin, a C/N of 35-40 is considered optimum (Golueke, 1977). Wastes with lower and higher C/N can be composted, but a too high C/N slows microbial degradation while a too low C/N results in the release of nitrogen as ammonia, to the air and/or in leachate. Especially if anaerobic conditions develop (with attendant low pH from production of organic acids via fermentation), low C/N can also lead to the release of amines, some of which have especially unpleasant odors (e.g., putrescine, cadaverine). The C/N of food waste is more often too low (Table 5-1), requiring the addition of a carbon source (typically as the bulking agent).

Regardless of the feedstock or the selected technology, a minimum free pore space of 20-30% (Haug, 1993) to 35-50% (Chiumenti et al., 2005) is recommended. The free air space is needed to ensure sufficient supply of oxygen to the waste. Particle sizes and particle size distributions, as well as the structural strength of the material, determine the free air space. Large, firm and irregular shaped particles lead to more free-air space. Food waste typically has a poor material strength causing free air space to collapse under the pressure of the overlying material. Typically, a bulking agent reducing the moisture content also increases the free air space. Lambert and Neubauer (2015) additionally note that sufficient supply of oxygen is important to reduce methane emissions, and recommended that source-separated food and yard waste from urban areas in Austria be mixed with the same volume of bulking agent (i.e., about 50% by volume, which is about 25% bulking agent by mass of the final mixture).

The addition of a bulking agent and/or recycled compost can help to adjust the pH. Adjusting the pH with lime (granulated limestone) should be performed with care, because it can result in increased ammonia emissions (Amlinger et al., 2005) for low C/N wastes.

Table 5-1. Moisture, N, C/N, and material structure of various food wastes and bulking agents

	Moisture (% wet weight)	N (% dry weight)	C/N	Material structure[1]	Reference
Food wastes					
Food waste	76	1.9	22	Poor	Krogmann et al. (2010)
Source-separated food and yard waste - downtown (no yards) - single-family homes	 64-77 57-71	 1.2-2.3 1.1-2.0	 17-27 15-23	 Poor Good to Poor	Krogmann et al. (2010)
Corn cobs	9-18	0.4-0.8	56-123	Good	Rynk (1992)
Fruit wastes	62-88	0.9-2.6	20-49	Poor	Rynk (1992)
Vegetable produce	87	2.7	19	Poor	Rynk (1992)
Vegetable wastes		2.5-4	11-13	Poor	Rynk (1992)
Vegetable food processing wastes	86-91	2.8-7.0	7-14	Poor	Rogers et al. (2001)
Coffee grounds	6.2	1.4	32		Rogers et al. (2001)
Tomato skins and seeds	86	1.7	31		Rogers et al. (2001)
Cranberry skins and rice hulls	53-61	1.1-1.2	44-52		Rogers et al. (2001)
Fish waste (gurry, racks and so on)	50-81	6.5-14.2	3-5	Poor	Rynk (1992)
Mixed slaughterhouse waste		7-10	2-4	Poor	Rynk (1992)
Bulking agents					
Wood (e.g., chips, shavings) - softwood - hardwood		 0.04-0.23 0.06-0.11	 212-1313 451-819	 Good Good	Rynk (1992)
Straw	4-7	0.3-1.1	48-150	Good	Rynk (1992)

[1] Based on Bidlingmaier (1983) or best professional judgement.

5.4 Composting of meat products

Composting of meat products, which can be very wet, high in nitrogen, and highly putrescible, is of concern because of the potential for attraction of pests, production of odors, and presence of pathogens. There is more of an issue if meat by-products from meat processing plants are composted compared to predominantly plant based waste containing some meat products. Small-scale backyard composters do not reach high enough temperatures throughout the composting material to ensure sufficient pathogen reduction (Storino et al., 2016). However,

this could be different at large-scale facilities. Frank-Whittle and Insam (2013) reviewed treatment alternatives for slaughterhouse wastes, including composting, and the inactivation of pathogens. They concluded that under stringent management, composting of slaughterhouse wastes would not be expected to pose a risk to human and animal health; however, some pathogens, such as prions (e.g., the infectious agent for mad cow disease) and some spore-forming bacteria might survive composting. Open facilities for meat by-products require special considerations (Vidussi and Rynk, 2001). Some guidance can be based on experience with composting of animal mortalities on farms (Berge et al., 2009).

6. Outdoor Composting Methods

The objective of a composting facility is the production of high-quality compost under controlled conditions, with minimal adverse effects on the environment, at reasonable costs. A composting facility for food waste consists of areas for tipping the food waste; pre-processing of the incoming waste; post-processing of the compost; storage of bulking agents, final compost and disposal residues; and for composting itself, including the active stage and potentially a slower "curing" stage. While this report focuses on the composting portion of the facility, all areas can contribute to environmental impacts to varying degrees, and therefore, need to be considered when designing and operating a composting facility.

There are two ways of minimizing environmental impacts, such as odorous emissions, from the composting area: 1) control of the microbial degradation, and 2) installation of technical control measures. To enhance the composting process, independently of the feedstock, the rate of microbial decomposition is usually increased by at least partial optimization of the composting process. The main influencing parameters are typically controlled based on an understanding of the growth conditions of the decomposing microorganisms. The parameters considered, as indicated above, include:

- Biodegradability
- Moisture content
- Oxygen content, material structure, particle size, and aeration
- Temperature
- Nutrients (mainly C/N)
- pH

6.1 Outdoor versus enclosed composting

There are open (outdoor), enclosed (in-vessel) and partially enclosed composting facilities. Enclosed and partially enclosed facilities are generally superior with regard to odorous emissions and leachate/runoff control but are more complex, costly, and energy intensive, and are not covered here. However, summaries can be found in Chiumenti et al. (2005) and

Krogmann et al. (2010). In enclosed facilities the compost is not exposed to precipitation, although condensate might be produced in condensers or on colder building surfaces such as roofs and walls. The semi-enclosed facility in Cloppenburg-Stapelfeld, Germany, demonstrated that a semi-enclosed composting facility can be operated without discharges of leachate and runoff through partial enclosure, a roof over the curing area and use of condensates in the process (Krogmann et al., 2010). Regarding the release of the greenhouse gasses CH_4 and N_2O, Lampert and Neubauer (2015) suggested that process optimization is more important than enclosure.

In open systems the gaseous emissions of the composting process escape, in most cases without control, to the surrounding environment. Layers of finished compost acting as a biofilter or synthetic covers can provide some degree of control of gaseous emissions. A distinction among open systems is if the compost is moved periodically after placement or not. In static systems the compost is not moved, while in agitated systems the compost is at rest most of the time, but is moved or turned at intervals for homogenization, fluffing and to a lesser extent for aeration and perhaps some control of temperature. Open composting technologies include windrows, aerated static piles with compost covers, and aerated static piles with synthetic covers (e.g., plastic bag/sleeve, semi-permeable sheeting, or "compost fleece"). The synthetic covers provide essentially a temporary mobile enclosure for the composting area.

Another concern with composting in general, and perhaps food waste composting in particular, is the attraction of vermin, including disease vectors. The range of possible examples include rats, mosquitos (in ponded water), and seagulls. In some cases these may be more difficult to control with outdoor composting.

A comparison of different open composting systems is provided in Table 6-1. The following subsections look at each type in more detail.

Table 6-1. Comparison of various open composting systems (best professional judgement if not stated otherwise[a])

	Windrows	Aerated static piles (compost cover)	Aerated static piles (membrane cover)
Land area [acre/ton] (Kranert, 2000)	0.000269-0.00056	0.000224-0.000493[b] (0.00009-0.000179)[c]	0.000224-0.000493[b] (0.00009-0.000179)[c]
Odor control	Size of pile, compost fleece, turning when favorable wind direction	Compost cover providing some odor control	Membrane providing some odor control
Leachate control	No, some control with compost fleece	Some control due to higher evaporation	Membrane provides some control
Oxygen control	No, some control through pile size	Included in temperature control	Yes
Temperature control	No, some control through pile size	Yes	No
Complexity	Low	Moderate	Moderate
Main composting / curing time [weeks] Krogmann et al. (2010)	12-20	3 / 6-8[d]	8 / 4-12
Montgomery County (2018)	16-20 / 2-4	8-10 / 4-6	8-10 / 4-6
Goldstein (2015)			8 / 10-12
Costs (Montgomery County, 2018)	Lowest capital costs, medium operating costs	Medium capital, low to medium operating costs	Low to medium capital, medium operating costs

[a] Based on best professional judgement, because not found in the literature. More documentation of actual designs and case studies is needed.

[b] Composting with process control, 13,000 ton/yr.

[c] Composting with process control, 55,000 ton/yr.

[d] Biosolids.

6.2 Windrow composting

Windrows, which are elongated piles, can be used for the entire composting process or for curing only. Windrowing varies in terms of pile size, turning equipment, and turning frequency, but at larger-scale usually requires frequent turning by specialized equipment. Windrows are naturally ventilated by diffusion and convection. A simple, but not very effective turner is the front-end loader, which is often used in small-scale facilities.

Agitation speeds up microbial activity by breaking up particles, thereby exposing fresh surface area to microbial attack, and the mixing brings microorganisms into contact with undegraded substrates. The effect of turning on the oxygen supply of the windrow is not very

substantial unless the pile is turned almost constantly. In general, turning also provides poor control over temperature. The heat released from the increased microbial activity after turning causes a rapid increase in temperature, often surpassing the temperature prior to turning, and also quickly depletes oxygen (Miller et al., 1989). If temperatures increase above 65-70ºC, decomposition is slowed down, and if temperatures increase to 80ºC, it nearly stops (Miller et al., 1989) and especially odorous compounds (e.g., pyridine and pyrazine) can be released due to chemical, non-biological reactions (Mayer, 1990). Smaller pile sizes can increase oxygen levels and decrease temperatures to some degree (Strom et al., 1980).

The turning frequency is decreased from a maximum during the initial phase, which has the highest rates of degradation and emission, and during which most pathogen reduction takes place, to less often as the material becomes stabilized. During curing turning is often omitted, although Amlinger et al. (2005) also recommended turning during curing to ensure low odor emissions. In most cases, higher turning frequencies lead to a decrease in processing time but also to an increase in operating costs. Amlinger et al. (2005) recommended an initial turning frequency of every 3-4 days to lower methane emissions. However, frequent turning can increase ammonia and nitrous oxide losses (Amlinger et al., 2009). To achieve pathogen reduction goals for unrestricted compost use, state regulations generally follow 40 CFR Part 503 (USEPA, 2018) pathogen reduction requirements for biosolids (for windrow composting, 5 turnings during 15 days with temperatures above 55 ºC).

The turning equipment and the aeration type (natural versus active) determine the windrow dimensions such as cross-sectional shape (e.g., triangle or trapezoid), height, and width. For example (Kern, 1991), the base of a naturally ventilated, triangular windrow of source-separated food and yard waste can vary from 3.0 – 4.0 m (10-13 ft) and the height between 1.0 – 2.5 m (3-8 ft). Amlinger et al. (2005) recommended an initial pile height of 1.5 m to lower odor emissions. A cover with a layer of compost or wood chips or a compost fleece can reduce odor emissions further, although the authors indicated that there are few studies assessing the effectiveness of this measure and therefore no final recommendation was given (see also discussion on synthetic covers below). For frequently turned, naturally ventilated windrows of source-separated food and yard waste, processing times of 12-20 weeks were reported (Kern, 1991). If turned very frequently (7 times per week initially decreasing to 2 times per week) processing times can be less than 12 weeks (Amlinger et al., 2005). Less often, windrows are aerated by forced or vacuum-induced aeration similar to aerated static piles (see discussion on active aeration below). With active aeration 2.5 – 3.0 m (8-10 ft) pile heights are feasible. Strom and Finstein (1994) emphasized that even for leaves-only composting, pile height should not exceed 6 feet to avoid overheating and excessive odors.

6.3 Static pile composting

The lack of agitation in static pile composting requires the maintenance of adequate porosity over an extended period even more so than in windrows. In most cases, the static pile

has the shape of a truncated pyramid. As a modification, the feedstock can be stacked in open composting cells; to compensate for vertical moisture and temperature gradients in the piles, the composting material in this system is moved from one cell to another. Chiumenti et al. (2005) pointed out that an unaerated static pile in the shape of a truncated pyramid is not aerated as well as a windrow.

In the United States, the aerated static pile is one of the most common biosolids (treated sewage sludge) composting technologies and is also implemented in food waste composting. Typical dimensions are between 12 m and 15 m (39-49 ft) at the base with a height of 3 m (10 ft). The technology was developed in 1970 in Beltsville, MD, by the Agricultural Research Service of the U.S. Department of Agriculture. Piles were covered with a layer of finished compost to prevent heat loss from the upper layer and provide a minimum-level of odor treatment of gaseous emissions (USEPA, 1981). The timer-controlled blowers maintained an oxygen level of 5-15%. However, unfavorable temperatures (180 °F) in the static pile resulted in the development of the Rutgers process (Finstein et al., 1986a), which adopted temperature-controlled blowers (in most cases the temperature is below 60ºC in the pile). In the initial and final composting phases, the temperature feedback needs to be overridden by a timer to ensure minimum aeration if the temperatures in the pile are below the set point (Lenton and Stentiford, 1990). The aeration of the initial process in Beltsville was vacuum induced while the Rutgers process used forced aeration once it was realized that temperature control could not be achieved in vacuum mode. Discussions of ventilation direction are available in Finstein et al. (1986a and 1987a, b, c, d). Typical processing times for sludge in aerated static piles are 21 days followed by 6-8 weeks of curing in windrows, but shorter times may be feasible (Finstein et al., 1983).

Aerated static piles, if properly controlled using temperature feedback with forced aeration to increase composting rate, provide more rapid decomposition for most wastes. They also decrease leachate generation because temperature feedback control utilizes evaporative cooling to maintain optimal temperatures, and the total aeration demand is 5-10 times higher for cooling than for the stoichiometrically needed oxygen (Krogmann et al., 2010). Due to the moisture gradient established, aerated static piles with forced aeration are on the dry side in the lower part of the pile (see below). It should be noted (Finstein et al., 1983; Finstein et al., 1986a) that temperature feedback is really only effective if positive pressure ventilation (blowing air into the middle of the pile), rather than vacuum (drawing air from the middle of the pile) is used. The idea that vacuum aeration allows for better odor control is a misconception; it is not usually possible to adequately control temperature with the much less efficient vacuum approach, leading to greater odor production and less rapid decomposition of odorous compounds. A better approach is to use forced pressure aeration, but to cover the pile with a thin layer of finished compost that can then serve as a biofilter for odor control (Finstein et al., 1986a). In this biofilter layer, odorous compounds can be partially adsorbed to the compost particles, decomposed, or dissolved in the condensate in the upper cooler compost cover. Other disadvantages of vacuum induced aeration are a higher energy consumption and a wet compost layer at the lower part of

the pile compared to a pile with forced aeration. The wet layer can cause considerable odor emissions when the compost is moved (Amlinger et al., 2005).

One disadvantage of an aerated static pile is that the composting materials are not routinely mixed during this phase of the operation. This allows development of substantial gradients of temperature and moisture, preventing achievement of near optimal conditions uniformly throughout the pile. Due to the moisture gradient, the lower portion of the pile can dry out, extending the processing time. In Austria this was found to be a major pitfall of aerated static piles if they were not controlled carefully (Amlinger et al., 2005). It is also possible for channeling (rather than good distribution) of air to occur. Overall, this usually makes it necessary to control the aeration carefully and incorporate a second, or curing stage.

6.4 Composting using synthetic covers

Synthetic covers include plastic bags/sleeves such as EcoPOD® and EURO bagging technologies, semi-permeable sheeting such as GORE-TEX®, and compost fleeces such as ComposTex®. These covers can overcome or mitigate some of the disadvantages of open composting methods (odors, run-off, leachate). However, they also may add to the cost of an operation, and there may be limited peer-reviewed literature available for a specific proprietary product.

Compost fleece (e.g., ComposTex®, a UV resistant gas permeable polypropylene fabric) is used as a temporary measure to reduce odor emissions and keep compost dry, especially later in the composting process during times of lower evaporation. Amlinger et al. (2009) summarized the functions of compost fleeces as conservation of moisture in the windrows due to condensation, diversion of precipitation, and prevention of dry windrow surfaces, while still allowing gas exchange, resulting in more homogenous composting. In Austria, compost fleeces or roofs are recommended during heavy rain events if the annual precipitation exceeds 1000 mm (39.4 in – all parts of New Jersey typically receive more than this) and the windrows are not positively aerated, to avoid increased odor emissions caused by high moisture levels (Amlinger et al., 2009). Paré et al. (2000) confirmed leachate reduction during the composting of crucifer and carrot residues mixed with sawdust and straw in Quebec, Canada, when covered with a ComposTex® fleece. Automatic compost fleece winding equipment attached to the turning machine is recommended for larger facilities.

Plastic bags/sleeves and semi-permeable sheeting technologies have the same benefits as compost fleeces, but also allow the control of temperature and oxygen levels in the covered piles. Semi-permeable sheeting consists of three layers, a semi-permeable polytretrafluoroethylene (PTFE) membrane sandwiched between two UV-stable polyester fabric layers (Kühner, 2001). The membrane is gas and water vapor permeable, but impermeable to liquid water because of the larger size of the rain drops. Water vapor also condenses on the inside of the sheeting and odorous compounds are partially dissolved in the condensed water, which drips back onto the

composting material. Oxygen and temperature are measured, and the process is controlled based on oxygen levels. Some of the temperatures seem to be above 75ºC for long periods of time (Anon. 2017). A study investigating the detrimental effect of the high temperatures in this case was not found, but such temperatures are known to be problematic (e.g., Finstein et al., 1987a). One of the scarce studies investigating semi-permeable membranes (Kühner, 2001) showed a reduction in odor emissions of 97% compared to open windrow systems. The odor emissions were measured by an olfactometer (measuring the dilution of odorous air with odorless air at which 50% of panelists smell something and 50% do not). However, the author pointed out that additional simple measures to reduce odors during curing such as smaller piles are needed to maintain the benefit of reduced odor emissions during composting under covers.

While the semi-permeable covers help reduce odor emissions and leachate/runoff, they do not guarantee problem-free operation of a composting facility, if not operated correctly, as proven by the closing of the Peninsula operation in Delaware (BioCycle, 2014; Seldman, 2014). Among other issues, the facility did not use sufficient amounts of bulking agents, nearby neighbors were affected by odor emissions, and the compost contained visible contaminants.

A modification of coverage with sheeting is an aerated pile in a patented plastic bag system. Plastic bags/sleeves (e.g., Avidov et al., 2018) allow the collection and treatment of gaseous emissions, although external treatment in a biofilter is generally not implemented. These polyethylene bags/sleeves were originally used as silage bags and are modified for composting application. Composting in the bags for 8 weeks is followed by 1-3 months of curing (Chiumenti et al., 2005). There is much less experience with bag composting. Avidov et al. (2018) noted the likelihood that use of polyethylene sleeves would reduce leachate, although no rain occurred during their trial.

6.5 Management

No matter the scale and technology, proper management and quality control is key for a well-operated composting facility. This includes pre- and post-processing equipment to remove waste materials and the availability of sufficient amounts of bulking agents. The most suitable technology for a given situation depends on the location and the capacity of the facility as well as the waste material. All-weather operation needs to be possible; leachate and air emissions need to be handled. While aerated static piles and covered aerated static piles might reduce odors and leachate, there are still emissions as material needs to be moved, there are gaseous emissions from the aerated static piles, and the operation of aerated static piles and covered aerated piles is more complex (e.g., the aeration can dry out the unfinished composting material). Best management practices and guidelines on how to operate composting facilities and control odor emissions can be found in Coker (2016) and Müsken (2001). While there are comparisons between outdoor and in-vessel systems in Europe, side-by-side comparisons of various open composting systems are limited.

After composting is completed, the material is screened for particle size and contaminants, and may be bagged. Screening may be a major source of bioaerosols and/or dust. With sludge composting, woodchips added as a bulking agent are typically recovered for reuse during screening; this is a major source of *Aspergillus fumigatus* spores (Millner et al., 1977) that may or may not be relevant for specific food waste composting operations.

7. Compost Product Testing Requirements

There are no national testing requirements for composts from source-separated food wastes in the US, which is different from many other countries (Brinton, 2000; Harrison, 2003; Bernal et al., 2017); instead, testing requirements vary by state. Bernal et al. (2009) define compost as a "stabilised and sanitised product of composting, which has undergone an initial, rapid stage of decomposition, is beneficial to plant growth and has certain humic characteristics". Based on this definition testing requirements include plant nutrient concentrations and indicators of organic matter humification, pathogen reduction, and maturity (Bernal et al., 2017). To address environmental and safety issues, testing requirements include visual contaminants and chemical pollutants. Further testing requirements depend on the intended use of the compost such as available nutrients for agricultural fields or water holding capacity for growth medium mixes (Bernal et al., 2017).

The US Composting Council's Seal of Testing Assurance Program (STA) certifies composts and requires the analysis of the following parameters (US Composting Council, 2019):

pH
soluble salts
nutrient content (total N, P_2O_5, K_2O, Ca, Mg)
moisture content
organic matter content
bioassay (maturity)
stability (respirometry)
particle size (report only)
pathogen indicator (Fecal Coliform or *Salmonella*)
trace metals (Part 503 regulated metals)

As an example of state regulations, New York requirements are given in Table 7-1 (NYSDEC, 2019a, b). These are similar to the analyses required for the US Composting Council's STA certification.

Table 7-1. New York State testing requirements (NYSDEC, 2019a, b):

Parameters for Analysis,*and Limits, where specified (mg/kg dry weight)	
Total Kjeldahl Nitrogen	Arsenic (As ≤ 41)
Ammonia	Cadmium (Cd ≤ 10)
Nitrate	Chromium (total) (Cr ≤ 1000)
Total Phosphorus	Copper (Cu ≤ 1500)
Total Potassium	Lead (Pb ≤ 300)
pH	Mercury (Hg ≤ 10)
Total Solids	Molybdenum (Mo ≤ 40)
Total Volatile Solids	Nickel (Ni ≤ 200)
	Selenium (Se ≤ 100)
Fecal coliform or *Salmonella* sp. bacteria	Zinc (Zn ≤ 2500)

* Analyses to be done 2-12 times/yr, depending on size of facility (2 times if < 5 yd^3/d).

In New York State, the number of parameters to be analyzed can be reduced after two years. Compared to the US Composting Council's STA requirements, no maturity test is specified, but how maturity is determined needs to be outlined. Pathogen and vector attraction reduction requirements need to be met as well. There are also limits for visible contaminants. No dilution with bulking agents is allowed and an analysis of the bulking agents might also be necessary. Furthermore, information about compost uses needs to be provided.

As another example, Washington State also specifies testing and includes limits (WAC, 2018a). As can be seen in Table 7-2, these are very similar to the ones from New York State. They omit chromium, and do not include the fertilizer (NPK) tests, but do add plastic and sharps as contaminants of concern. Several of the limits are also set at lower values. Although total solids is not included, it must be determined in order to report the other test results on a dry weight basis.

Table 7-2. Washington State testing for compost (Source: WAC, 2018a).

Parameters	**Limit** mg/kg dry weight (unless noted)
Arsenic	20
Cadmium	10
Copper	750
Lead	150
Mercury	8
Molybdenum	9
Nickel	210
Selenium	18
Zinc	1400
Physical contaminants[1]	1% by weight total, not to exceed 0.25% film
Sharps	0
pH	5 - 10 (range)
Biological stability[2]	Moderately unstable to very stable
Fecal coliform OR *Salmonella*[3]	< 1,000 MPN/g dry solids < 3 MPN/4 g dry solids

[1]A label or information sheet must be provided with compost that exceeds 0.1% film plastic. See WAC 173-350-220 (6)(f)(iii)(D)(I).

[2] Tests for biological stability must be done as outlined in the United States Composting Council Test Methods for the Examination of Composting and Compost unless otherwise approved by the jurisdictional health department.

[3] Test for either fecal coliform or *Salmonella* (MPN = most probable number).

For comparison, the compost certification system in Germany has several requirements regarding pathogen reduction. First, the chosen composting system needs to be one of about 30 approved and tested composting systems (BGK, 2010); second, monitoring needs to ensure certain time – temperature requirements (at least a certain temperature for at least a specified amount of time) are met; and third, *Salmonella* and weed germination thresholds need to be met (BGK, 2017).

The European Composting Network (ECN, 2018) has developed a certification program for compost that includes a "minimum set of compost properties for declaration" and "precautionary limits", as shown in Tables 7-3 and 7-4. The limits on potential toxic elements in this document are based on Amlinger et al. (2004).

Table 7-3. ECN (2018) minimum set of compost properties for declaration.

Quality criteria	Parameter	Dimension	Appraisal
Soil improvement	Organic matter	[% DM]	≥ 15 %, declaration
	Liming value (CaO)	[% DM]	declaration
Fertilizing properties	Nitrogen (N) total	[% DM]	declaration
	Phosphorus (P) total	[% DM]	declaration
	Potassium (K) total	[% DM]	declaration
	Magnesium (Mg) total	[% DM]	declaration
Material properties	Maximum particle size	[mm]	declaration
	Bulk density	[g/l FM]	declaration
	Dry matter	[% FM]	declaration
	Salinity / El. conductivity	[mS/m]	declaration
	pH value		declaration
Biological parameters	Aerobic biological activity		declaration
	Plant response[1)]		declaration

[1)] The declaration of plant response is only necessary if the compost is used as mixing compound in growing media.

Table 7-4. ECN (2018) precautionary limit values.

Precautionary quality criteria	Parameter	Limit value
Hygiene	Salmonellae	Absent in 25 g dry matter
Undesired ingredients and properties	Impurities (content)	≤ 0,5 % dry matter
	Weed seeds	≤ 2 seeds per liter
Inorganic pollutants	Lead (Pb)	130 mg kg^{-1} dry matter
	Cadmium (Cd)	1.3 mg kg^{-1} dry matter
	Chromium (Cr)	60 mg kg^{-1} dry matter
	Copper (Cu)[1)]	300 mg kg^{-1} dry matter[2)]
	Nickel (Ni)	40 mg kg^{-1} dry matter
	Mercury (Hg)	0.45 mg kg^{-1} dry matter
	Zinc (Zn)[1)]	600 mg kg^{-1} dry matter[2)]

[1)] Copper (Cu) and Zinc (Zn) are also considered as trace elements. Values exceeding 110 mg Cu kg^{-1} dry matter and 400 mg Zn kg^{-1} dry matter must be declared.

[2)] These values represent orientation thresholds.

It may be noted that some of the limits (e.g., for cadmium) differ substantially among different jurisdictions. This is also clear in a table from Boldrin et al. (2011), as shown in Table 7-5. European limits are seen to differ from country to country, but in general are much more restrictive than those for Texas (sometimes by an order of magnitude or more), as a representative of the USA. Our Work Group is reporting these various values without making a specific recommendation as to which are more appropriate for New Jersey because this exceeds the scope of this document. However, we do note that food waste compost in Europe typically meets their stricter standards (Boldin et al., 2011). Also, the regulations in the USA tend to be based on the 1985 recommendations for sewage sludge/biosolids. Although they were risk-based, concerns have been expressed, considering newer information, about their applicability for all soils and situations in New Jersey (Krogmann et al., 2001; Harrison and Krogmann, 2007). It is recommended that these values be revisited if food waste composting becomes a more common practice in the State.

Table 7-5. Comparison of heavy metal limits in compost (Boldrin et al., 2011).

Table 9.3.7 *Heavy metals limits for some compost standards (mg/kg dm), from Hogg* et al. *(2002). Hogg, D., Barth, J., Favoino, E., Centemero, M., Caimi, V., Amlinger, F., Devliegher, W., Brinton, W. and Antler S. (2002): Comparison of compost standards within the EU, North America and Australasia. Waste and Resources Action Programme, WRAP, Banbury, UK.*

Country	Regulation	Cd	Cr_{tot}	Cr(VI)	Cu	Hg	Ni	Pb	Zn	As
Austria	Compost ordinance: Quality Class A+ (organic farming)	0.7	70	—	70	0.4	25	45	200	—
	Compost ordinance: Quality Class A (agriculture; hobby gardening)	1	70	—	150	0.7	60	120	500	—
	Compost ordinance: Quality Class B (landscaping; reclaimed land) limit value	3	250	—	500	3	100	200	1800	—
	Compost ordinance: Quality Class B (landscaping; reclaimed land) guide value	—	—	—	400	—	—	—	1200	—
Germany	Bio waste ordinance (I)	1	70	—	70	0.7	35	100	300	—
	Bio waste ordinance (II)	1.5	100	—	100	1	50	150	400	—
Netherlands	Compost	1	50	—	60	0.3	20	100	200	15
	Compost (very clean)	0.7	50	—	25	0.2	10	65	75	5
EC	Draft W.D. biological treatment of biowaste (class 1)	0.7	100		100	0.5	50	100	200	
	Draft W.D. biological treatment of biowaste (class 2)	1.5	150		150	1	75	150	400	
	2092/91 EC – 1488/98 EC (organic farming)	0.7	70	0	70	0.4	25	45	200	—
UK	UKROFS 'Composted household waste'	0.7	70	—	70	0.4	25	45	200	—
	Composting association quality label	1.5	150		200	1	50	150	400	
USA	Texas TNRCC Grade 1 compost	16	180	—	1020	11	160	300	2190	10
	Texas TNRCC Grade 2 compost	39	1200	—	1500	17	420	300	2800	41

The fecal coliform analysis is probably not an appropriate indicator for pathogen levels in food waste compost (Doyle and Erickson, 2006). *Salmonella* is only a good indicator if it is known that the food waste contained *Salmonella* (Brinton et al., 2009). Brinton et al. (2009) suggested that maybe *Escherichia coli*, *E. coli* O157:H7, fecal streptococci, *Listeria* spp., and *Clostridium perfringens* might be better for compost made from manure and food waste. They also found correlations between *E. coli* and fecal coliforms and the sum of the other indicators and recommended further investigations are needed.

It may be reasonable to assume that with regard to pathogens, composting of food waste represents no greater hazard than composting of sewage sludge (biosolids). Thus the relevant Federal 40 CFR 503 regulations for sewage sludge (USEPA, 2018) have been adopted in many cases for composts produced from a wide variety of other waste materials (Gurtler et al., 2018). Tetra Tech, Inc. (2002) considered use of these regulations appropriate for food wastes, and

examined fecal coliform and *Salmonella* spp. indicator reductions, time-temperature protocols, and vector attraction reduction requirements; all were found to be achievable with low level technology. While coliforms and *Salmonella* spp. may not be especially appropriate indicators for food waste, the time-temperature relationships were developed based on work by Burge et al. (1981) and are applicable for virtually all pathogens (one possible exception is prions). They also would be appropriate for other animal and plant pathogens and weed seeds.

Stability indicates that the compost is resistant to further microbial activity, while maturity means that it is ready for its specific end use (Wichuk and McCartney, 2010), which often refers to a lack of phytotoxicity. The California Compost Quality Council (2001) conducted a study comparing various maturity and stability tests. To determine the level of maturity and stability the study recommends testing of the C/N ratio of the compost, which should be < 25, one test from a list of stability tests, and one test from a list of maturity tests. The Solvita® test by Woodsend Laboratory combines two tests, one from each list.

The testing methods of the US Composting Council are well accepted in the composting community. Therefore, it is suggested to base the sampling and analytical methods on the "Test Methods for the Examination of Composting and Compost" (TMECC, 2002).

8. Leachate

Outdoor composting poses concerns for leachate generation, potentially leading to discharges to surface or groundwater. As is true with the other environmental considerations for outdoor food waste composting, the risk depends on the types and quantities of materials being composted, the composting methods and practices being used, and the site itself. Leachate ponding may also promote mosquito breeding and odor production.

The differences in food wastes being composted in turn may lead to leachates with very different properties. For example, high C/N wastes may produce leachates in which the major concern is biochemical and chemical oxygen demand (BOD and COD), while low C/N wastes may leach high concentrations of nitrogen, probably much of it in the form of ammonium. (Nitrate may also be released, once the material has cooled and nitrification has occurred, as may be the case during curing or storage.) In the past there has been perhaps some expectation that yard waste, in the absence of low C/N, might pose little risk to groundwater, but that belief may need reevaluation (e.g., Tonjes et al., 2018). Also, the presence of substances of concern in the raw materials (such as metals) may lead not only to their presence in the final compost (e.g., requiring the product testing in the previous section), but also in leachate. Other important factors for leachate generation include initial moisture content, wetting practices, and water holding capacity of the material. The extent to which leachate becomes run-off or percolates into the soil will depend on site factors such as impermeable surfaces and slope.

8.1 Leachate characterization

Krogmann and Woyczechowski, (2000) sampled leachate at two full-scale biogenic (source separated food and yard) waste facilities in Germany, as well as performing lab-scale experiments on various biogenic waste components individually. Although there was considerable variability, food waste composting leachate often had a higher BOD and COD than any of the other constituents tested (branches, grass, leaves, hedge cuttings, and miscellaneous yard waste), although grass clippings gave higher nitrogen concentrations. They also provided a table (reproduced here as Table 8-1) comparing their results to some from the literature, which further emphasized the high degree of variation encountered. Some of the leachate pollutant concentrations were very high – up to 45,000 mg/L BOD, 100,000 mg/L COD, 1600 mg/L total Kjeldahl nitrogen, and 150 mg/L total phosphorus.

Table 8-1. Table 7 from Krogmann and Woyczechowski (2000).

Table 7. Comparison of chemical and physical characteristics of liquid products from composting facilities from previous studies

		Leachate				Condensate			Runoff	
Composting method	Mixture This study	Ulén 1997 Covered windrows	Not covered windrows	Cole 1994 Not covered windrows	Loll 1994 Various	This study 85-L reactor	115-L reactor	Loll 1994 Various	This study Not covered windrows	Loll 1994 Various
Waste type‡	B	B	B	Y	B, Y	B, F	B,Y	B, Y	B	B, Y
pH		7.6	7.9	8.35–9.2	5.8–8.6	3.09–8.93	3.08–9.36	8.0–8.6	6.62–8.47	7.0–8.1
Conductivity	9.37–27.94	5.9	6.0	3.89–6.4	4.1–14.7	0.03–16.54	0.00–38.60	1.8–2.5	–	1.3–8.8
BOD_5	8–11, 571	–	–	–	10 000–45 000	< 1–2797	1–41 840	100–1000	< 2–513	100–1200
COD	2434–31 812	–	–	–	20 000–100 000	5–12, 208	3–77, 159	500–2000	56–1768	500–2500
TOC	–	920	610	–	5000–18 000	–	–	< 50–500	–	< 50–500
VFA	118–9535	–	–	–	–	–	–	–	–	–
NH_4^+-N	98–558	–	–	5.1–10.5*	50–800	< 0.1–3286	0.03–5960	< 5–100	2.0–46.0	15–300
NO_3^--N	–	–	–	3.6–5.8†	< 5–190	–	–	< 1	< 0.1–96.4	< 5–150
NO_2^--N	–	–	–	–	–	–			< 0.1–0.80	–
TKN	250–1602	–	–	–	–	< 0.1–3442	< 1–9482	–	–	–
Total N	–	240	420	–	–	–	–	–	–	–
Total P	–	28	16	–	50–150	–	–	< 1	–	< 1–50
K^+	–	620	1170	1629–2323	1075–7280	–	–	–	–	–
Ca^{2+}	–	340	280	386–462	–	–	–	–	–	–
Mg^{2+}	–	110	110	213–290	–	–	–	–	–	–
Na^+	–		430	640	–	–	–	–	–	–
Mn	–	–	–		1.5–3.5	–	–	–	–	–
Fe	–	–	–		16–52	–	–	–	–	–
S	–		60	60	–	–	–	–	–	–
Cl^-	1514–5254	780	1150	–	2 000–10 000	–	–	–	106–445	30–500
As	–	–	–	–	–	–	–	–	0.001–0.044	–
Cr	–	0.16	0.10	0.02–0.06	–	–	–	–	–	–
Ni	–	0.21	0.13	–	0.07–2.6	–	–	< 0.04	–	< 0.05–1
Cu	–	0.31	0.19	0.25–0.38	–	–	–	–	–	–
Co	–	–	–	–	0.01–0.2	–	–	< 0.05	–	< 0.05–0.2
Zn	–	0.79	0.30	–	1–8	–	–	0.2–1.6	0.011–2.4	< 1–2
Cd	–	0.01	– n.d.	< 0.1	0.01–0.2	–	–	< 0.02	< 0.001–0.172	< 0.05–0.2
Hg	–	–	–	–	–	–	–	< 0.0005	–	–
Pb	–	0.03	– n.d.	< 0.25	0.01–0.2	–	–	< 0.1	< 0.001–0.500	< 0.1–0.2

pH unitless, conductivity in mS cm^{-1}, other parameters in mg l^{-1}; * . NH_4; †. NO_3; ‡. B – biogenic waste; Y – yard waste; F – food waste; n.d. – not detected.

Elements of concern, such as lead, arsenic, cadmium, and mercury, are to be expected in the leachate only to the extent that they were present in the original materials (including bulking agent). Additionally, compost is often considered a good medium for immobilizing a variety of toxic constituents; however, the presence of high concentrations of colloidal and dissolved organic compounds may also mobilize some compost and soil constituents (Chatterjee et al., 2013.). Likewise, the reducing conditions induced by the presence of high concentrations of organic material in groundwater may solubilize some otherwise immobile soil constituents (USGS, undated). Harmful microorganisms may be present initially, or potentially grow if the conditions are suitable. Many toxic organic compounds, if present initially, are likely to be biodegraded during composting, but it is also possible for some degradation products to show toxicity.

Coker (2008a, b) also has discussed a number of the issues with stormwater runoff from composting facilities. In a recent report (Coker 2017) he applied some of his findings for a proposed facility in New Jersey. Coker (2008b) notes that the increasing requirements for water quality management, as well as odor control and air emissions, are important reasons to consider in-vessel composting and enclosure of operations within buildings.

8.2 Leachate quantity

Leachate often mixes with rainwater, which dilutes it. An important question is how much of the precipitation deposited on a site ends up as runoff, how much is temporarily retained by the composting material, and how much is permanently lost through evaporation (and/or percolation, for unpaved sites). Wilson et al. (2004) found that for nearly saturated composted cow manure in a laboratory physical model, with water applied as 4 relatively heavy simulated 20 minute "storms" (22, 30, 37, and 44 mm) over an 8 day period, very little leachate was generated immediately, but on average 68% of the applied water leached out over the 24 hours following each event. Likewise, at a full-scale facility composting sewage sludge with woodchips, in which the very wet (65% moisture content) material occupied 68% of the pad, again 68% of the rainfall over a one-month period was collected in the site's stormwater detention pond. Based on their results, the authors suggested that 68% was the maximum likely volumetric runoff coefficient for composting material, and that the material substantially delayed the release of runoff. Krogmann and Woyczechowski (2000) gave a more detailed analysis based on types of materials and facilities, and indicated leachate could be a little as 0% for covered materials; however, for open piles on paved surfaces, some runoff was unavoidable.

Kalaba et al. (2007) developed a stormwater runoff model for predicting the quantity of runoff for open windrows. They found a weighted runoff coefficient for the entire pad should be used, based on individual coefficients of 0.85 for the asphalt and 0.5 to 0.6 for the composting material. However, they noted the complexity of the hydrology resulting from the presence of the organic material, and the fact that its runoff coefficient might vary considerably based on the feedstock and the time it had been composting.

8.3 Effect of composting method

With respect to the effect of composting method on leachate generation, some limited information is available, and is summarized below.

Windrowing varies in terms of pile size, turning equipment, and turning frequency. No research on the effects of these factors on leachate quantity or quality was found for inclusion in this review. Based on field observations (U. Krogmann and P.F. Strom, independently), a dry outer layer often forms on windrows between turnings (unless it rains or snows heavily, in which case there may be a wet layer). This may act to absorb new rainfall in some cases, or it may act to shed some of the rainwater before it percolates through the pile. Where piles are inadequately moist initially and turned infrequently, a substantial dry inner mass has been observed. However, leachate has still been observed in all of these situations.

It seems generally agreed that aerated static piles are likely to generate less leachate, as they evaporate considerable amounts of water. Some of this water may form condensate, which may also need to be managed, as it can be highly contaminated, potentially even containing higher nitrogen concentrations than leachate (Table 8-1; Krogmann and Woyczechowski, 2000). Additionally, it seems likely that if decomposition occurs more rapidly, so that piles may be removed sooner, the amount of exposure to precipitation and hence the amount of leachate produced will be decreased. However, the need for a curing stage may reduce this potential advantage.

As discussed in Section 6 above, the use of synthetic covers (including plastic bags/sleeves such as EcoPOD® and EURO bagging technologies), semi-permeable sheeting (e.g., GORE-TEX®, and compost fleeces such as ComposTex®) and "biofilter" covers of finished compost will reduce leachate production. Placing a roof over the composting material may entirely eliminate leachate.

8.4 Site factors

Important site factors for leachate include proximity to surface water, depth to ground water, surface and soil permeability, and slope. Composting on an impervious surface facilitates collection of leachate for on-site treatment or discharge to a sanitary sewer, and may be necessary where compliance with groundwater quality standards is required.

It has been recommended (Strom and Finstein, 1994) that piles be oriented up and down, rather than across, slopes at the site. This helps minimize ponding of runoff in contact with the piles, which would otherwise increase the opportunity for additional leaching of contaminants.

8.5 Leachate control

Kennedy/Jenks Consulting (2007) provided a report for the Oregon Department of Environmental Quality that summarized 15 studies on leachate and runoff with the intent of

providing guidance on the need for groundwater protection. They concluded that unless an area received low precipitation (does not apply in New Jersey), "the use of improved or impervious surfaces may be the most prudent method of protecting water resources…."

Coker (2008b) notes that "composting facilities must plan for control and management of storm water through a combination of both structural and nonstructural management techniques." He recommends "reduce, reuse, recycle." Reduction includes enclosing facilities, conducting activities under a roof, and segregating different runoff flows, so that lightly contaminated flows can be managed separately from more heavily contaminated ones (such as pile leachate). He also recommends stormwater pollution prevention plans (SWPPPs) with an objective to "implement and maintain best management practices (BMPs) that identify, reduce, eliminate, and/or prevent the discharge of stormwater pollutants" (WDEQ, 2004).

Wetting the composting material with collected stormwater is one method of reuse (Coker, 2008b). Of course, care must be taken to prevent this water from producing new leachate and runoff, but many composting piles dry during processing, and re-wetting may be needed. Recycling of the runoff for crop irrigation may be possible at some sites. Stormwater storage would be needed for both of these options.

A variety of best management practices (BMPs) are available for runoff treatment. CH2MHill (2004) ranked 27 stormwater BMPs for composting sites (for the Oregon Dept. of Environmental Quality) in 6 categories: space efficiency, odor control, cost, level of complexity, number of benchmark constituents potentially controlled, and usefulness for bacterial indicator, lead, and/or nitrate control. The resulting matrix is provided here in Table 8-2. The report recommends that "If technically and economically feasible, each site should employ some type of each of the BMP categories."

Table 8-2. BMP Ranking Matrix (Table 3-3 from CH2MHill, 2004).

BMP Number	BMP (By Type)	Space Efficiency	Odor Control	Cost[1]	Level of Complexity	Number of Benchmark Constituents Controlled[2]	E. Coli, Lead, and Nitrate Control (EC Pb NO3)
Oil and Grease							
1	Oil Water Separator	HIGH	N/A	LOW	LOW	7	Pb ONLY
Erosion, Sediment Control, and Debris Control							
2	Grading Facility Areas	N/A	YES	LOW	LOW	5	N/A
3	Appropriate Site Vegetation	MED	N/A	LOW	MED	5	YES
4	Graveling or Paving	N/A	YES	MED	LOW	5	N/A
5	Sediment Basins, or Traps	HIGH	YES	MED	LOW	5	YES
6	Bioswale or Grassy Swale	LOW	YES	LOW	MED	12	YES
7	Soil filter	MED	YES	LOW	MED	12	YES
8	Wetland	LOW	YES	LOW	MED	12	YES
9	Holding pond or detention facility	LOW	N/A	MED	MED	4	Pb NO3 ONLY
10	Sediment Control with Compost Filter Berms, Wattles, Bales, or Fences	MED	YES	LOW	HIGH	5	Pb ONLY
11	Sediment Control with Centrifugal Devices, Weirs, or Baffles	HIGH	YES	LOW	MED	5	Pb ONLY
12	Granular Filtration Tanks	HIGH	YES	LOW	HIGH	12	EC Pb ONLY
13	Soil and Plant Systems	MED	YES	LOW	HIGH	12	YES
14	Chemical Treatment	LOW	YES	HIGH	HIGH	12	YES
15	Coagulation and Sedimentation	LOW	N/A	HIGH	HIGH	12	YES
16	Aeration and Ozonation	LOW	YES	HIGH	MED	12	N/A
17	Underground Injection with Pretreatment	LOW	YES	HIGH	HIGH	9	N/A
Stormwater and Composte Leachate Diversion							
2	Grading Facility Areas	N/A	YES	LOW	LOW	5	N/A
3	Paving	N/A	YES	MED	LOW	5	N/A
18	Diversion with Containment Barriers, Curbing, Berms, Gutters	HIGH	YES	HIGH	LOW	5	N/A
19	Liner systems	N/A	N/A	MED	LOW	5	N/A
20	Collection and Reuse of Stormwater, Compost Leachate, or Washwater	LOW	N/A	MED	HIGH	12	N/A
21	Minimize Runoff by Practicing Specific Operating Procedures	N/A	YES	LOW	LOW	12	YES
Covering Activities							
22	Roof Structure	HIGH	YES	MED	LOW	12	YES
23	Membrane, Tarp, or Cover	HIGH	YES	MED	MED	12	YES
24	Indoor Operations	HIGH	YES	HIGH	HIGH	12	YES
Housekeeping							
25	Elimination of Standing Surface Water	N/A	YES	LOW	LOW	8	YES
26	Prompt Processing of Incoming Compost Feedstocks	N/A	YES	LOW	LOW	4	N/A
27	Shaping of Piles	HIGH	YES	LOW	LOW	6	YES

Notes:
1. See Table 3-2, Costs Associated with BMPs for details on cost. For ranking, cost is computed as capital cost/1000 + operating cost/100 and cost breakpoints are at 60 and 600.
2. See Table 3-1 for the list of specific constituents controlled and Table 5-2 for the list of benchmark constituents.

In some cases, it may be necessary to consider hauling collected leachate to off-site treatment facilities (Coker, 2008b), such as wastewater treatment plants. Discharge to a sanitary sewer may also be an option in some cases.

While many of the best management practices described are intended to prevent untreated or inadequately treated discharges to surface water, discharge to groundwater is also of potential concern. While controlled infiltration may be acceptable in some cases (e.g., as has been successfully practiced with properly designed and maintained septic systems in low density residential areas), current practice discourages this for composting operations. Food waste composting facilities that are small enough to potentially use this approach are likely also small enough that they can prevent or collect the leachate they generate.

Thus, surface and groundwater pollution at food waste composting sites should be avoided by employing the combination of best management practices selected as most appropriate for the particular material, operation, and site. These BMPs may include methods for the prevention of leachate/runoff production (e.g., by covering the site), collection of the flow, storage, treatment, reuse, and/or removal. Although a paved and/or lined operational area may increase total runoff produced, it is usually necessary to limit mud and other operational issues, and to minimize odors from ponded water that might otherwise accumulate in contact with the composting materials.

9. Air Emissions

9.1. Pollutants emitted to the air during composting operations

A wide range of pollutants may be emitted to the air during composting operations including particulate matter, volatile organic compounds (VOCs), odorous substances (including ammonia), greenhouse gases (particularly methane and nitrous oxide), and bioaerosols (discussed in Section 10). There are also air pollution emissions (especially particulate matter, VOCs and nitrogen oxides) from trucks delivering organic waste and transporting finished product, but those are not discussed here since that traffic would be evaluated separately as part of the County Solid Waste Management Plan.

Particulate matter emissions are likely to be generated by many activities including handling of feedstocks and amendments, turning of piles, movement of compost between processing areas, screening, bagging or loading for bulk transport of finished compost, wood grinding, and trucks travelling on unpaved roads. The most common particulate matter concern is classified as visible dust emissions.

VOC emissions are mostly generated as a by-product of the decomposition of the food waste and amendments. The individual VOCs are not of particular concern at the level at which they are likely to be emitted, but as a group they are important as precursors to tropospheric ozone. This group of pollutants is highly regulated in New Jersey because of the difficulty the State has had in meeting the National Ambient Air Quality Standard for Ozone.

The decomposition of food waste also generates odorous pollutants that normally are below thresholds set to protect public health, but can be above the level detectable by human noses. Thus odors are generally (but not always – see Section 10 below) considered a quality of life issue rather than a concern for human health. The level at which odors become a problem is subjective. Because of this, the emission rates and air concentrations of odorous substances often are not quantified. These emissions are usually addressed by implementation of best operating practices and then regulated in response to complaints from neighbors. It should be

kept in mind that for composting sites in general, odors are the most common source of complaints and it is recommended that they be managed before they result in objections.

Ammonia may be among the odorous compounds emitted during composting. It has a lower health threshold than many of the other relevant odorous substances. The odor threshold for ammonia is reported to be 5 ppm (ATSDR, 2004). This is near the California 1-hour Reference Concentration of 4.6 ppm (CARB, 2019), but much lower than occupational standards, which are set at 25 ppm by Cal/OSHA, NIOSH and ACGIH (NJDOH 2016). Reports of ammonia exceeding occupational standards (intended for indoor work environments) in outdoor composting operations have not been encountered thus far.

Greenhouse gases are also a component of air emissions during composting, with methane being the most prominent (CARB, 2017). However, further consideration of this pollutant group was beyond the scope of this report.

9.2. Emission rates

Among the air pollutants resulting from composting operations, the emission rates of VOCs are of particular interest and are the focus of this subsection. Particulate matter is of concern if visible dust is observed. As mentioned above, problematic levels of odorous compounds are subjective, but will be obvious to neighbors if they are present at unacceptable concentrations. Odorous emission rates have been determined using olfactometry (Bidlingmaier and Müsken, 2007). Such values might be difficult to use for regulation and enforcement in New Jersey, but may be useful for dispersion modeling and sizing of buffer zones. Little information is available regarding emission rates for ammonia, though Pechan (2004) estimated a rate of 2.81 lb/ton of mixed waste as a good starting point.

Emission rates for VOCs will depend on feedstock composition, composting method, age of the pile, temperature, sunlight, oxygen content, humidity and pH. Although some work has been done in California (see emission factors in Table 9-1) it is difficult to identify a generally applicable emission factor. The two largest air districts in California (South Coast and San Joaquin Valley) have adopted emissions factors for composting operations that average around five pounds of VOC per ton of feedstock (CARB, 2018).

Table 9-1. Emission Factors for VOCs

VOC Emission Factor	Activity	Reference
5.71 lb/ wet ton	Windrows	SJVAPCD (2010)
1.3-2.6 lb/ wet ton of feedstock	Food waste during active composting period	California Integrated Waste Management Board (2007)
3.12 lb/ton	50:50 Biosolids to Green Waste ratio	Pechan (2004)
1.063 lb/wet ton /day	Stockpile for either Green Waste or Food Waste	SJVAPCD (2010)

9.3. Control technologies and best management practices (BMPs) to reduce emissions

9.3.1. Volatile organic compounds

VOCs will be generated regardless of the method that is chosen for composting, so preventing them from entering the air is the principal control method. California researchers have found that the most effective method for reducing emissions from compost piles is a combination of aeration, covering with a breathable fabric or finished compost, and maintaining proper moisture content. Forcing air through the piles, using an aeration system with a blower, maintains aerobic conditions within the piles. Compost caps have also been proven to be especially effective. California Integrated Waste Management Board (2007) has found that a compost cap composed of finished compost placed over the ridgeline of a well-managed windrow reduced VOC emissions by about 75% over the first two weeks of composting.

9.3.2. Particulate matter

Dusty operations such as handling of feedstocks and amendments, movement of compost between processing areas, screening and bagging of finished compost, wood grinding, and trucks travelling on unpaved roads may all be sources of particulate matter emissions at composting facilities. Dust generation can be minimized by maintaining optimal moisture content, including misting of dry materials. Paved roadways and working pads will also reduce dust generation by truck traffic (Environment Canada, 2013).

9.3.3. Odors

Odorous substances can be produced at every stage of the composting process, so a broad array of strategies is needed to control odors. "New Jersey's Manual on Composting Leaves and Management of other Yard Trimmings" (Strom and Finstein, 1994) provides guidance, noting that "The major problem encountered - even at leaf only composing sites - is odor." It outlines odor problems as developing in 4 stages, in which odorous compounds must:

1) be present initially or produced during processing;

2) be released from the pile (meaning they are in a volatile form);

3) travel off-site; and

4) be detected by a sensitive receptor.

While odor problems can be prevented by disrupting any one of the stages, it is generally agreed that it is most desirable to prevent problems at stage 1. This is normally best done by avoiding prolonged and/or extensive anaerobic conditions and by promoting the rapid degradation (through providing beneficial composting conditions for factors such as temperature,

oxygen, and moisture content) of the compounds causing the odors, or of the putrescible compounds that breakdown to release them (Finstein et al., 1987c). In the absence of sufficient oxygen, volatile organic acids (which have vinegary, cheesy, goat-y, and sour odors), alcohols and esters (fruity, floral, alcohol-like), and amines and sulfur compounds (barnyard, fishy, rotten) can be produced. However, it should be noted that with low C/N wastes (high nitrogen content), ammonia odors may be released even under aerobic conditions.

Once odorous compounds are present, their escape (stage 2) can sometimes be prevented by minimizing pile disturbance; absorption, adsorption, and/or biodegradation within a biofilter-like cover; and/or pH adjustment. Some of the odorous compounds (e.g., acetic acid, hydrogen sulfide) are acidic, and will dissociate to an ionic form (and thus be rendered non-volatile) under neutral to alkaline conditions. This means that limestone addition is sometimes beneficial. However, some odorous compounds (ammonia, amines) are bases; their release can be minimized under more acidic conditions, but may be increased if lime is added.

Once odors are released, an effort can be made to minimize their off-site effect by trying to time odor-releasing operations (e.g., turning) to coincide with favorable wind conditions. A windsock or weathervane is useful for determining when wind direction is away from nearby receptors. Additionally, lower wind speeds are associated with worse odors, as they provide less dilution as air passes over the odor-releasing material, and also with less turbulence leading to less vertical mixing. Temperature inversions trap odors near the ground, and thus may represent another important factor to consider.

Morrison Hershfield (2017) includes a comprehensive list of best practices for odor management in their report to Metro Vancouver. The California Code of Regulations (17863.4) provides a regulatory framework for requiring best practices in an odor management plan. In general, well-constructed, properly aerated piles will produce fewer odors, but some type of cover (similar to those chosen for VOC control) will also be necessary. During handling of raw materials, odors can be minimized by moving food waste into composting piles on the same day that they are received. Odors must also be addressed during post-processing of compost and leachate management. Table 9-2 includes a sampling of best practices, including management plans for identifying and addressing odor episodes, found in a variety of sources, but especially well described by Morrison Hershfield (2017). A well-managed composting facility would use almost every one of these BMPs.

Some have advocated the use of anti-odorant sprays to control odor episodes. However, the DEP Division of Air Quality (DAQ) does not allow the use of deodorizing agents as they only mask the smell, which does not solve the problem if the underlying chemical causes health issues. DAQ does allow the use of “neutralizing” agents as they chemically/physically react with the substances that originally caused the odor. However, before use a neutralizing agent must be reviewed by DAQ to confirm that there will be no health risk to receptors beyond the fence line of the facility.

Table 9-2. Best Management Practices (BMPs) for Odor Control*

OPERATION	BMP for Odor Control
Waste Material Storage & Transport	Cover collection/delivery vehicles should be covered and equipped with a leachate containment system.
	Make deliveries to an indoor space equipped with air pollution control equipment (e.g., a biofilter).
	Place waste into composting piles on the day they are received. If incoming feedstock is very odorous or wet, collection frequencies might need to be increased and the feedstock needs to be processed more quickly.
	Develop good housekeeping practices that include removal of spilled feedstock from facility roads and other areas daily, and cleaning of delivery vehicle wheels and loading area before leaving the site.
Pre-processing (e.g., screening, grinding, mixing)	Ensure that sufficient amounts of bulking agent are available to avoid odorous leachate if incoming feedstock is very wet.
	Cover odorous materials left over from screening.
Composting Process	Cover aerated static piles with a membrane or layer of finished compost to contain odors.
	Carefully control aeration rates, temperature, oxygen, and moisture.
	Limit material movements to times when weather conditions are unlikely to carry odorous substances to off-site receptors.
	Ensure sufficient compost stability before compost is moved to post-processing.
Post-Processing (Screening)	Limit screening to times when weather conditions are unlikely to carry odorous substances and dust to off-site receptors.
Leachate Management	Aerate water retention basins to avoid odors. Aeration should be a part of the stormwater management design.
	Avoid ponding of water in contact with organic material.
General Management Tools	Provide training for staff regarding procedures and maintenance that will minimize generation of odors, and regarding plans to address odor incidents expeditiously.
	Plan to regularly note any odorous conditions and immediately address them.
	Plan to respond to odor complaints.
	Lay out procedures for proper maintenance of yard waste and other amendments stockpiles.
	Lay out procedures for proper maintenance of materials left over from screening.
	Ensure that the facility capacity is not exceeded.
	Use on-site meteorological station to measure wind speed and direction is helpful if sensitive receptors are nearby and in a particular direction.

* From several sources, but most are especially well described in Morrison Hershfield (2017), California Code of Regulations (2019), and Cal Recycle (2005).

9.4 Air permitting requirements

The Air Pollution Control Regulations set out at N.J.A.C. 7:27 identify the type of operations that need an Air Permit in the State of New Jersey. In N.J.A.C. 7:27.8.3(a) the Permit Regulation states:

> No person may construct, reconstruct, install, or modify a significant source or control apparatus serving the significant source without first obtaining a preconstruction permit under this subchapter.

N.J.A.C.7:27-8.2 lays out all the different types of operations that may be considered significant. The activities most likely to be found at a composting facility are contained in subsections 8.2(c)10, 11, 16, 17 and 19:

7:27-8.2 Applicability

(c) Any equipment or source operation that may emit one or more air contaminants, except carbon dioxide (CO_2), directly or indirectly into the outdoor air and belongs to one of the categories listed below, is a significant source (and therefore requires a preconstruction permit and an operating certificate), unless it is exempted from being a significant source pursuant to (d) or (e) below:

10. Tanks, reservoirs, containers and bins which have a capacity in excess of 2,000 cubic feet [74 yd^3] and which are used for the storage of solid particles;

11. Stationary material handling equipment using pneumatic, bucket or belt conveying systems from which emissions occur;

16. Equipment that is used for treating waste soils or sludges, including municipal solid wastes, industrial solid wastes, or recycled materials, if the influent to the equipment has a solids content of two percent by weight or greater. Typical operations performed by this type of equipment include, but are not limited to, soil cleaning, composting, pelletizing, grit classifying, drying, and transfer station operations. However an area used as a temporary storage area, such as a concrete pad or a roll-off container, shall not be considered to be equipment used for treating waste soils or sludges, provided that the area is not also used for treatment;

17. Equipment used for the purpose of venting a closed or operating dump, sanitary landfill, hazardous waste landfill, or other solid waste facility, directly or indirectly into the outdoor atmosphere including, but not limited to, any transfer station, recycling facility, or municipal solid waste composting facility;

19. Equipment in which the combined weight of all raw materials used exceeds 50 pounds in any one hour, provided:

i. Such equipment shall not include equipment which is the same type as is included within a category described in (c)1, 2, 4, 5, 6, 7, 8, 9, 10, 12, 15 or 18 above; or in (c)20 below, but which is excluded from the category because it does not meet an applicability threshold set forth in the description of the category. That is, the equipment has a lower capacity, weight of materials processed, vapor pressure, or consumption of BTUs, or otherwise falls outside a parameter that is included in the description of the category;

Regardless of whether a facility needs an Air Permit, it will still be subject to the General Provisions of the Air Pollution Control Rules as stated in 7:27-5.2

(a) Notwithstanding compliance with other subchapters of this chapter, no person shall cause, suffer, allow or permit to be emitted into the outdoor atmosphere substances in quantities which shall result in air pollution as defined herein.

Under this requirement, off-site odors and visible emissions are not permitted. If offsite odors or dust do occur, the DAQ may require an odor or dust control plan even if no air permit is required for any other reason. A dust control plan should address procedures that would minimize dust from handling of feedstocks and amendments, movement of compost between processing areas, screening and bagging of finished compost, wood grinding, and trucks travelling on unpaved roads. An odor control plan should address means to place organic wastes within piles on the same day that they are received; leachate management techniques; and strategies for identifying odor incidents and responding to complaints.

If an operation is very large (emitting more than 25 tons/year of VOC), it also would be subject to Operating Permit requirements in N.J.A.C. 7:27-22. Using the California VOC emission factor of 5 pounds of VOC per ton of feedstock, it would appear that such a facility would have to process about 20,000 cubic yards of compostable material per year to trigger Operating Permit requirements.

10. Potential Human Health Effects

Concern for health effects from composting is not new, although few serious outcomes are documented. There is a substantial dearth of reports in the literature of serious health outcomes in workers or nearby community members. Nevertheless, the risks are real and deserve continued attention using more sophisticated research techniques. Foci of concern generally revolve around risks for serious health outcomes from established pathogens or toxic agents. Although these previously documented outcomes have been associated with different settings or with susceptible populations, the specific agents (mostly microorganisms, with some VOCs) are known to be constituents of, or amplified by, composting processes (e.g., Finstein et al., 1987c). This section will first consider potentially adverse exposures that can be present in

composting operations and then address current evidence for associated health outcomes in both workers and communities. The recent literature has two excellent reviews and one meta-analysis on this topic (Domingo and Nadal, 2009; Robertson et al., 2019; Pearson et al., 2015). Health concerns associated with the product (compost) are discussed above under testing requirements. No literature specific to food waste was identified.

10.1. Exposures

Exposures can be categorized as microbiological or toxic, the latter including metals, polycyclic aromatics, and VOC's. Microbiological exposures are of greatest concern because they can induce acute, life-threatening illness. This is based on two specific disease processes, allergy or infection, and is not as strictly dose related as with toxicant effects. Metals and other inorganic toxicants generally require high and/or prolonged concentrations or doses to induce clinically recognizable toxic effects, e.g., metal poisoning. This contrasts with fungi and other microbes whose effects can be multiplied in the host by allergic or infectious processes. While risks are higher with greater concentrations or doses of bioaerosols, they are not eliminated by moderate or low exposures, which can induce disease in those with appropriate susceptibility such as atopy or immune deficiency. Additionally, some fungal species, such as several in the genus *Aspergillus*, are normally present in substantial concentrations in composting materials and can contribute meaningfully to the composting process.

10.2. Health outcomes

Aspergillus, particularly *A. fumigatus*, is a ubiquitous fungus that grows best under warm, aerobic conditions. An early review, after it was recognized as sometimes abundant at composting facilities, was provided by Marsh et al. (1979). It occurs in most soils and can also be found in homes, offices, and the ambient air. It is well-known to produce a number of characteristic, relatively uncommon, but serious and even fatal outcomes. Most lethal is invasive aspergillosis, a systemic and often difficult to treat infection. Increased concentrations of *Aspergillus* spores apparently contribute to increased risk in the immunosuppressed. This infection is largely confined to those with impaired immunity due either to inherited immunodeficiency, cancer chemotherapy, pharmacologic immunosuppression with steroids or biologics, or inter-current debilitating disease including HIV/AIDS, alcoholism and diabetes. This is of growing concern due to the increasing prevalence of such susceptible individuals in our population. Also, people taking antibiotics may depress their normal bacterial community, increasing the risk of infection by opportunistic fungal pathogens (Clark et al., 1984). Immunocompetent individuals are resistant to *Aspergillus* infection and have negligible concerns in terms of *Aspergillus* infection.

Other serious but less lethal conditions caused by *Aspergillus* species (and other microorganisms such as some thermophilic actinomycetes) include hypersensitivity pneumonitis (extrinsic allergic alveolitis), a type of immune-mediated acute pneumonia, which is mediated by

a characteristic immunological reaction to various inhaled organic antigens. Cases are difficult to diagnose and rare. Farmer's Lung is the classic example of this, due to inhalation of overgrowth of actinomycetes in moldy grains. Similarly, allergic bronchopulmonary aspergillosis, which can also affect the sinuses, is an atopic allergic condition only seen in asthmatics.

A more concentration-dependent outcome is irritation of mucous membranes and the upper respiratory tract by bioaerosols containing bacteria, fungi, mycotoxins, and other microbial constituents as well as VOCs. Not only are bioaerosols potential irritants, but they also convey, particularly in workers, increased risks of atopic upper respiratory sensitization clinically manifest as diagnosable conditions such as pharyngitis, rhinitis, and conjunctivitis, along with lower respiratory conditions such as bronchitis and asthma (Robertson et al., 2019).

Another important biological agent is *Legionella* spp. (the cause of Legionnaire's disease), particularly *L. pneumophila*. Exposure to this organism, which is common in soil and grows in water tanks, whirlpools and similar environments is via inhalation and produces a potentially lethal pneumonia infection. Large outbreaks of over 100 cases from contaminated water sources are documented. While *Legionella* species are found in compost, no composting-associated cases are described in the literature.

10.3. Occupational health

A number of studies of composting workers have been reported as case series (see Domingo and Nadal, 2009; Robertson et al., 2019). Increased rates of mucous membrane symptoms and lower respiratory system symptoms such as bronchitis are well-documented but increases in other lung diagnoses or permanent impairment in pulmonary function has not been described. One new worker at a vegetative waste composting facility in Belgium, who regularly hand-turned composting piles, developed an "extremely rare" case of hypersensitivity pneumonitis, probably complicated by invasive bronchopulmonary aspergillosis; he changed jobs and fully recovered (Vincken and Roels, 1984). Likewise, one worker at a large sewage sludge composting facility that utilized woodchips as a bulking agent developed an *Aspergillus niger* ear infection (Clark et al., 1984). In this overall study Clark et al. (1984) examined four large sewage sludge composting facilities, including one in Camden, NJ, and compared workers with high exposure to composting dust to those with lesser exposure and controls. The group with higher exposure was found to score higher on tests of exposure to *A. fumigatus* and some other measures, but generally not to have higher incidence of disease. While respiratory protection and water suppression of dust are recommended, this seems largely to be based more on precautionary common sense and comfort than on a documented need for avoidance of specific pathogens.

10.4. Community health

One community environmental study from the UK, using an ecological design, examined 34,963 hospital admissions for respiratory conditions within 250-2500 meters of a large open-air composting facility (Douglas et al., 2016). There were no significant associations between admissions and distance of home addresses from composting facilities. Moreover, sensitivity analyses demonstrated no significant associations with subgroups of respiratory infections, asthma or COPD. This study represents an ambitious approach, likely limited by its focus on hospitalized (rather than outpatient) infections, as well as potential exposure misclassification, diluting its power, and an inability to focus on susceptible immunocompromised individuals. Another similar ecological study from the same group, using modeled *Aspergillus fumigatus* concentrations (instead of distance from the plant as a proxy) for 76 composting facilities was also null (Roca-Barcelo et al., 2019). These studies deserve replication with more robust study designs, particularly a consideration of non-hospitalized conditions such as allergic respiratory disease.

A case of allergic bronchopulmonary aspergillosis was documented in a young man living within 250 feet of a large leaf composting facility in suburban New Jersey (Kramer et al., 1989). Wind direction was reported to be from the site towards the home 52% of the time.

A number of European countries have established health relevant levels for bacteria and/or fungi at composting facilities. The U.K. Environment Agency has established acceptable levels above background of 1000 Colony Forming Units (CFU) per m^3 for total bacteria, 300 cfu/$m^3$for gram negative bacteria (source of endotoxin) and 500 CFU for A. *fumigatus* (Pearson et al., 2015). Monitoring for gram negative bacteria is no longer required (U.K. Environment Agency, 2018a, b). Importantly, while employers are provided with guidance on how to protect workers by assessing risk and controlling exposures to as low as reasonably possible, there are no quantitative exposure limits for workers in the U.K. Employing the precautionary principle, the U.K. Environment Agency also has a guidance specifying that composting facilities with sensitive receptors (workplaces and homes) within 250 m of the fence line must complete a risk assessment for that site and monitor bioaerosols (Pearson et al., 2015). Germany has proposed a Technical Control Value of 50,000 CFU per m^3 for mesophilic (growing maximally at ambient temperatures) fungi (Federal Institute for Occupational Safety and Health, 2013 and 2019). The Netherlands has a proposed an occupational standard of 90 endotoxin units (EU) per m^3 over 8 hours (DECOS, 2010). Poland has a limit of 100,000 CFU per m^3 for mesophilic bacteria, 50,000 CFU per m^3 for fungi, and 2,000 EU per m^3 for endotoxin (Gutarowska et al., 2015). Overall one can see that although many agencies are in the same neighborhood with respect to setting buffer boundaries and standards around plants, much work needs to be done.

10.5. Odors

Lastly, the impact of odors associated with composting, particularly when done in the open may be the greatest source and trigger of community concerns (Herr et al., 2003). Although not lethal, odors can substantially diminish quality of life and are also associated with stress, elevated blood pressure, and asthma attacks. It is anticipated that expanding the feed stock to food waste, including meat and dairy, will exacerbate this problem.

10.6. Conclusions

Serious health effects from composting have not yet been shown to be common or even implicated as an important threat to public health. Nevertheless, it is not a well-studied area and the threat to people who have any degree of immunosuppression needs further exploration.

11. Buffer Zones

Buffer zones may be beneficial in minimizing off-site environmental and public health impacts, and are sometimes implemented for surface water, groundwater, bioaerosols, odor, and noise, among other factors. Only bioaerosols and odor will be considered here.

Austria, a country with a long composting history and many small open facilities, has developed best practices for composting facilities (Amlinger et al., 2009). According to these best practices, each site is unique and odor dispersion modeling is considered the state of the art for siting of composting facilities. Although they are inflexible, buffer zones are simple to implement, so practice also includes a list of buffer zone sizes addressing odor nuisances from composting facilities. These zones range between 300 and 1000 m (980 - 3280 ft), and are differentiated by feedstock, throughput, level of enclosure, and type of receptor. In comparison to yard waste composting operations, all facilities processing bio-waste (source-separated food and yard waste) require a detailed odor assessment for a proposed composting site. The assessment outlined in the guidelines includes odor dispersion modeling. If an already operating facility is assessed an on-site investigation can replace the odor dispersion modeling. On a case-by-case basis the detailed odor assessment can be omitted for facilities processing less than 1000 metric tons/yr.

The Austrian guidelines also mention cases where temperature inversions occurred and odor complaints beyond 1000 m were reported. Thus daily operations may be adjusted based on meteorological conditions (Lung, 2003).

With regard to bioaerosols, Amlinger et al. (2009) note that because assessing human health risk is problematic (due to the lack of a clear dose-response relationship), acceptable exposure levels cannot be set. Instead they focus on reducing bioaerosol formation through best management practices (BMPs). In open composting, this includes wetting material before and/or

during turning or moving piles, covering piles, and timing operations based on meteorological conditions. However, they also note that, depending on topography and wind, bioaerosol concentrations normally have dropped to background levels within 150-200 meters downwind. Note that such a buffer zone is much smaller than the one recommended for odor (300-1000 m), and is also much less than those discussed below.

Millner et al. (1980) developed emission estimates and dispersion models for *Aspergillus fumigatus* and other bioaerosols released from biosolids composting facilities during turning with a front-end loader. Under some of their better case scenarios (unstable atmospheric conditions), bioaerosol levels returned to background within 500-600 m, but the emission rates in their tests may have been higher than would be the case with current BMPs in place. They also noted that counts often returned to background levels shortly (minutes) after turning of piles and other disturbances of the material ceased.

Douglas et al. (2017) used dispersion modeling to predict *A. fumigatus* exposure from composting facilities. They concluded that such an approach may be useful, although additional work was needed. It also appears from their work that concentrations could still remain relatively high at 600 m. This would reinforce the suggestion of Amlinger et al. (2009) from above to place an emphasis on BMPs to reduce bioaerosol emissions.

Many government entities have recommended buffer zones around facilities or quantitative exposure regulations or guidelines aimed at preventing adverse health outcomes. One early study demonstrated elevated viable *Aspergillus* and thermophilic actinomycetes detectable at least 500 m downwind of a composting facility (Recer et al., 1991). For New Jersey leaf composting sites, Zwerling and Strom (1992) found *A. fumigatus* counts, during site activities such as turning, to decrease with distance from the site, but to still be elevated above typical background levels at distances of 1250 ft (381 m), the longest distance measured at any site. Counts did decrease quickly after activity ceased.

Williams et al. (2019) used dispersion modeling to predict *A. fumigatus* exposures from British outdoor composting plants. Their projections are meant to be qualitative, and seem to overestimate airborne concentrations. However, the results suggest that a buffer of about 670 m would be needed to reach the current regulatory limit of 500 cfu/m^3 above background, and that the current buffer of 250 m reduces the count only to 1400 cfu/m^3.

12. Size of Composting Facilities

Small quantities of material, such as are typical in residential backyard composting, are unlikely to represent a leachate problem as long as they are not located directly on a stream bank. However, as the amount of material increases, the potential biochemical and chemical oxygen demands (BOD and COD), nutrient (nitrogen and phosphorus), and other contaminant loads

(mass per time) increase, representing possible surface water and groundwater risks. There is no obvious threshold at which these impacts start to occur. Likewise, odors from very small piles are unlikely to pose a problem unless they are located directly next to a sensitive receptor, such as a residence.

Idaho (State of Idaho DEQ, 2013), as an example, has defined 4 levels of management for composting facilities, including those that accept food waste, based on volume and composition. "Below Regulatory Concern" applies to facilities handling up to 300 cubic yards on site at one time, and that accept food waste without meats or animal fats. Tier I facilities may accept the same wastes up to 600 cubic yards. Tier II composting facilities can accept larger volumes of a variety of compostable materials, but the waste must not pose a substantial threat to public health or the environment, while Tier III facilities handle wastes or volumes that do pose such risks. However, no references or other documentation is provided in this document indicating the basis for the particular size or materials limitations; likely it was based on the professional judgment of one or more of the individuals advising the developers of the guidelines or the developers themselves.

Note that 300 cubic yards would be about 50 yards of pile length with a cross-sectional area of 6 square yards (about 6 feet high by 12 feet wide, with a semicircular shape). It is not clear that operations of that size necessarily would be "below regulatory concern" in New Jersey, depending upon the material handled and where it was located.

Other states have likewise recognized a need to streamline requirements for small composting facilities handling less problematic wastes if they wish to encourage composting. According to a summary prepared for Illinois (IFSC 2015), Massachusetts reduced permitting requirements for composting facilities that handle less than 20 cubic yards/day (< 1 compactor truck) of food waste (about 5000 cubic yards/year for a 5 day work week), New York set the limit at 1000 cubic yards/year (currently different; see below), and North Carolina sets the cut-off at 1000 cubic yards of food waste per quarter (4000 cubic yards/year). In Maine, reduced requirements apply for wastes with C/N between 15/1 and 25/1 if the volume is less than 400 cubic yards/month (4800 cubic yards/year). The intent in all cases appears to be minimization of the regulatory burden while still ensuring protection of public health and the environment. The wide range of limits may reflect local conditions and sensibilities, differences in the types of materials managed, or a lack of objective criteria or data upon which to set the levels. Also, of course, the relationship between the amount on site at one time (as used in Idaho) and the amount received per time period (the 4 other states mentioned) will depend on how long material stays on site.

Current New York State regulations (NYSDEC, 2019a, c) define 3 levels of regulatory oversight based on capacity that apply for composting facilities that accept food waste:

1) "exempt" applies if ≤ 1 yd^3/day (also applies to home composting);

2) “registration” applies for ≤5,000 yd^3/yr;

3) “permit” applies for > 5000 yd^3/yr.

Exempt facilities must be “operated in a manner that does not produce vectors, dust or odors that unreasonably impact neighbors of the facility, as determined by the department, and when no waste remains on-site for more than 36 months”. Registration involves notification and operating requirements.

Washington State updated their 2003 composting rules in 2013 in order to grant exemptions for some types of green waste composting under certain conditions (Platt, 2016). The rules (WAC, 2018a) set out five conditional exemptions, but only the first two, for “All organic feedstocks”, potentially apply to food wastes:

(1) ≤ 25 yd^3 of material on-site at any time

(2) ≤ 250 yd^3 of material on-site at any time, and ≤ 1000 yd^3 of material per calendar year

For exemption (1), there are no notification, reporting, or testing requirements. For (2), the state and the local health department must be notified, and if there is distribution of compost off-site, several operational, testing (yearly), and reporting (yearly) requirements must be met. The testing requirements are the same as those included above in Table 7-2. Importantly, regardless of any exemptions, Washington rules also include a performance standard (WAC, 2018b), which specifies that the owner/operator must design, construct, and operate the facility “in a manner that does not pose a threat to human health or the environment.” The conditional exemption is also based on other requirements, including operation to “control nuisance odors to prevent migration beyond property boundaries” and “prevent attraction of flies, rodents, and other vectors.”

There does not seem to be specific published empirical research that can be used to define the size of a food waste composting operation that is “below regulatory concern,” for which no permit requirements are ever needed. However, based on the observations of researchers and practitioners, it does seem likely that, if they do not handle especially problematic materials, many “micro-sites”, such as those that might be incorporated in a small community urban garden, could be operated with only minimal requirements. These might include provisions to prevent leachate from entering surface water or storm sewers, minimize dust (and bioaerosol) production (e.g., by lightly wetting pile surfaces before and/or during turning), and by operating in such a way as to minimize odor release and avoid odor complaints. One caveat could be that the pile will be removed if odors cannot be quickly controlled or if other problems develop.

13. References

Amlinger, F., Pollak, M., and Favoino, E. (2004). Heavy metals and organic compounds from wastes used as organic fertilisers. ENV.A.2./ETU/2001/0024. Final report for Directorate-General for the Environment of the European Commission. https://ec.europa.eu/environment/waste/compost/pdf/hm_finalreport.pdf, accessed 3/11/20.

Amlinger, F., Peyr, S., Hildebrandt, U., Müsken, J., and Cuhls, C. (2005). Stand der Technik der Kompostierung, Grundlagenstudie (State of the Technology of Composting, Baseline Review: in German). Bundesministerium für Land- und Forstwirtschaft, Umwelt und Wasserwirtschaft, Vienna, Austria. (see below).

Amlinger, F., Hildebrandt, U., Müsken, J., and Cuhls, C. (2009). The State of the Art of Composting – A Guide to Good Practice, Austrian Ministry for Agriculture and Forestry, Environment and Water Management, Vienna, Austria. https://www.bmnt.gv.at/umwelt/abfall-ressourcen/behandlung-verwertung/behandlung-biotechnisch/richtlinie_sdt.html, accessed 1/31/20 (includes download links for both original German and English versions, as well as Amlinger et al. 2005 technical report in German immediately above.)

Anon. (2017). Sustainable Generation and GORE® Cover Membrane Covered Positive ASP Composting Technology. W. L. Gore & Associates, Sustainable Generation LLC. Available at http://calgreeneng.com/wp-content/uploads/2018/04/Gore-Cover-Clean-Compost-Technology-March-2017.pdf.

ATSDR (2004). Public Health Statement for Ammonia. Agency for Toxic Substances and Disease Registry. https://www.atsdr.cdc.gov/phs/phs.asp?id=9&tid=2, accessed 3/18/20.

Avidov, R., I. Saadi, A. Krasnovsky, S. Medina, M. Raviv, Y. Chen and Y. Laor. (2018). Using polyethylene sleeves with forced aeration for composting olive mill wastewater pre-absorbed by vegetative waste. *Waste Management*, 78, 969–979.

Berge, A. C. B., Glanville, T. D., Millner, P. D. and Klingborg, D. J. (2009). Methods and microbial risks associated with composting of animal carcasses in the United States. *Journal of the American Veterinary Medical Association*, *234*(1), 47-56.

Bernal, M. P., Sommer, S. G., Chadwick, D., Qing, C., Guoxue, L. and Michel Jr, F. C. (2017). Current approaches and future trends in compost quality criteria for agronomic, environmental, and human health benefits. In *Advances in agronomy* (Vol. 144, pp. 143-233). Academic Press.

BGK (2010). Hygiene Baumuster-Prüfsystem (HBPS): Kompostierungsanlagen, Vergärungsanlagen; 4. ergänzte und überarbeitete Auflage (Hygiene Type Test System (HBPS): Composting plants, Fermentation plants; 4. Supplemented and revised edition.

https://www.kompost.de/fileadmin/user_upload/Dateien/Guetesicherung/Dokumente_Kompost/HBPS.pdf (accessed 4/21/20).

BGK (2017). Gütesicherung Kompost (Compost Quality Assurance). https://www.kompost.de/guetesicherung/guetesicherung-kompost/ (accessed 7/10/19)

Bidlingmaier, W. (1983). Das Wesen der Kompostierung von Siedlungsabfällen (Basics of MSW composting: in German). In: Hösel, G., Bilitewski, B., Schenkel, W. and Schnurer, H. (eds.) *Müll-Handbuch*, vol. 5 KZ 5305. Erich Schmidt Verlag, Berlin, Germany.

Bidlingmaier, W., and Müsken, J. (2007). Odor emissions from composting plants. In Waste Management Series (Vol. 8, pp. 215-324). Elsevier.

BioCycle (2014). State orders closure of Peninsula compost facility. https://www.biocycle.net/2014/10/23/state-orders-closure-of-peninsula-compost-facility/ (accessed 7/10/19).

Boldrin, A., Christensen, T.H., Körner, I., and Krogmann, U. (2011). Composting: mass balances and quality. In Solid Waste Management and Technology, Volume 2, T.H. Christensen (Ed.), John Wiley and Sons, Ltd., Chichester, U.K, pp. 569-582.

Brinton, W. F. (2000). Compost quality standards and guidelines. Final Report by Woods End Research Laboratories for the New York State Association of Recyclers.

Brinton Jr, W. F., Storms, P., and Blewett, T. C. (2009). Occurrence and levels of fecal indicators and pathogenic bacteria in market-ready recycled organic matter composts. *Journal of Food Protection*, 72(2), 332-339.

Burge, W.D., Colacicco, D., and Cramer, W.N. (1981). Criteria for Achieving Pathogen Reduction during Composting. J. Water Pollution Control Fed. 53: 1683-1690.

California Code of Regulations (2019). 14 CCR Section 17863.4 Odor impact minimization plan, https://govt.westlaw.com/calregs/Document/I31D188B73FF04F7599512C43DAE2E0B1?viewType=FullText&originationContext=documenttoc&transitionType=CategoryPageItem&contextData=(sc.Default), accessed 1/10/20.

California Compost Quality Council (CCQC). (2001). Compost maturity index. California Compost Quality Council, Nevada City, CA.

California Integrated Waste Management Board (2007). Emissions testing of volatile organic compounds from greenwaste compost at the Modesto Compost Facility in the San Joaquin Valley. Publication No. 442-2007-0009, https://www2.calrecycle.ca.gov/Publications/Details/1263, accessed 1/10/20.

Cal Recycle (2005). Odor impact minimization plan. https://www.calrecycle.ca.gov/swfacilities/compostables/odor/oimp, accessed 3/18/20.

CARB (California Air Resources Board) (2017). Final draft method for estimating greenhouse gas emission reductions from diversion of organic waste from landfills to compost facilities, https://www.arb.ca.gov/cc/waste/cerffinal.pdf, accessed 1/10/20.

CARB (2018). Composting in California: addressing air quality permitting and regulatory issues for expanding infrastructure, http://californiacompostcoalition.org/wp-content/uploads/2018/11/FINALC1-1.pdf, accessed 1/10/20.

CARB (2019). Consolidated Table of OEHHA / CARB approved risk assessment health values. https://ww2.arb.ca.gov/resources/documents/consolidated-table-oehha-carb-approved-risk-assessment-health-values, accessed 3/18/20.

Cerda, A., Artola, A., Font, X., Barrena, R., Gea, T. and Sánchez, A. (2018). Composting of food wastes: status and challenges. *Bioresource Technology*, *248*, 57-67.

Chatterjee, N., Flury, M., Hinman, C., and Cogger, C.G. (2013). Chemical and physical characteristics of compost leachates: A review. A report prepared for the Washington State Department of Transportation, https://www.wsdot.wa.gov/research/reports/fullreports/819.1.pdf, accessed 1/10/20.

CH2MHill. (2004). Commercial composting water quality permit development. Oregon Department of Environmental Quality, Contract No. 044-04.

Chiumenti, A., Chiumenti, R., Diaz, L.F., Savage, G.F., Eggerth, L.L. and Goldstein, N. (2005). *Modern composting technologies*. J.G. Press, Emmaus, PA.

Clark, C.S., Bjornson, H.S., Schwartz-Fulton J., Holland, J.W., and Gartside, P.S. (1984). Biological health risks associated with the composting of wastewater treatment plant sludge. J. Water Pollution Control Fed. 56:1269-1276.

Coker, C. (2008a). Managing storm water. *BioCycle*, 49(2), 28-34.

Coker, C. (2008b). Storm water treatment. *BioCycle*, 49(4), 29-36.

Coker, C. (2016). Controlling composting odors. *BioCycle*, 57(2), 18.

Coker, C. (2017). Water management for proposed Pittsgrove Twp. ASP composting facility. Report prepared for South Jersey Agricultural Products, Elmer, NJ, by Coker Composting and Consulting, Troutville, VA.

DECOS (2010). Endotoxins: Health-Based Recommended Occupational Exposure Limit. Dutch Expert Committee on Occupational Safety, Health Council of the Netherlands (DECOS)

in Cooperation with the Nordic Expert Group for Criteria Documentation of Health Risks from Chemicals. Publication no. 2010/04OSH. https://www.healthcouncil.nl/documents/advisory-reports/2010/07/15/endotoxins-health-based-recommended-occupational-exposure-limit, accessed 1/9/20.

Domingo JL and Nadal M. (2009). Domestic waste composting facilities: A review of human health risks. Environment International 35(2):382-9.

Douglas, P., Bakolis, I., Fecht, D., Pearson, C., Leal Sanchez, M., Kinnersley, R., de Hoogh, K., and Hansell, A.L.. (2016). Respiratory hospital admission risk near large composting facilities. Int J Hyg Envir Heal. 219(4):372-9.

Douglas, P, Tyrrel, S.F., Kinnersley, R.P., Whelan, M., Longhurst, P.J., Hansell, A.L., Walsh, K., Pollard, S.J.T., and Drew, G.H. (2017) Predicting *Aspergillus fumigatus* exposure from composting facilities using a dispersion model: A conditional calibration and validation. International Journal of Hygiene and Environmental Health 220 (2017) 17–28.

Doyle, M. P. and Erickson, M. C. (2006). Closing the door on the fecal coliform assay. *Microbe*, 1(4), 162-163.

Environment Canada (2013). Technical document on municipal solid waste organics processing. Cat. no.: En14-83/2013E, https://www.ec.gc.ca/gdd-mw/3E8CF6C7-F214-4BA2-A1A3-163978EE9D6E/13-047-ID-458-PDF_accessible_ANG_R2-reduced%20size.pdf, accessed 1/10/20.

Federal Institute for Occupational Safety and Health. (2013) http://www.baua.de/de/Themen-von-A-Z/Biologische-Arbeitsstoffe/TRBA/TRBA-405.html BAuA. Technische Regel für Biologische Arbeitsstoffe 214 (Technical Rules for Biological Agents 214). Bundesanstalt für Arbeitsschutz und Arbeitsmedizin (Federal Institute for Occupational Safety and Health) accessed January 8, 2015.

Federal Institute for Occupational Safety and Health (2019) Technischen Regeln für Biologische Arbeitsstoffe (Technical Rules for Biological Agents) Das technische Regelwerk im Rahmen der Biostoffverordnung (The technical rulebook under the Biomaterials Regulation, in German.) https://www.abfallmanager-medizin.de/recht/technische-regeln-fuer-biologische-arbeitsstoffe-trba-das-technische-regelwerk-im-rahmen-der-biostoffverordnung/, accessed 07/03/19.

Finstein, M.S., Miller, F.C., Strom, P.F., MacGregor, S.T., and Psarianos, K.M. (1983). Composting Ecosystem Management for Waste Treatment. Bio/Technol. 1:347-53.

Finstein, M.S., Miller, F.C. and Strom, P.F. (1986a). Waste treatment composting as controlled system. In: Rehm, H.-J. and Reed, G. (eds.) *Biotechnology*, vol. 8, pp. 363-398. VCH Verlagsgesellschaft, Weinheim, Germany.

Finstein, M.S., Miller, F.C. and Strom, P.F. (1986b). Monitoring and Evaluating Composting Process Performance. J. Water Pollution Control Fed. 58:272-278.

Finstein, M.S., Miller, F.C., Hogan, J.A., and Strom, P.F.. (1987a, b, c, d). Analysis of EPA Guidance on Composting Sludge: Part I - Biological Heat Generation and Temperature, BioCycle 28(1):20-26; Part II - Biological Process Control, BioCycle 28(2):42-47; Part III - Oxygen, Moisture, Odor, Pathogens, BioCycle 28(3):38-44; and Part IV - Decomposition Rate and Facility Design and Operation, BioCycle 28(4):56-61.

Franke-Whittle, I. H. and Insam, H. (2013). Treatment alternatives of slaughterhouse wastes, and their effect on the inactivation of different pathogens: a review. *Critical Reviews in Microbiology*, 39,139–151.

Goldstein, N. (2015). Food scraps composting at yard trimmings site. *BioCycle*, 56(4), 21-22.

Golueke, C.G. (1977). *Biological reclamation of solid waste*. Rodale Press, Emmaus, PA.

Greene, K. L. and Tonjes, D. J. (2014). Degradable plastics and their potential for affecting solid waste systems. *WIT Transactions on Ecology and the Environment*, 180, 91-102.

Gurtler, J. B., Doyle, M. P., Erickson, M. C., Jiang, X., Millner, P., and Sharma, M. (2018). Composting to inactivate foodborne pathogens for crop soil application: A review. *Journal of Food Protection*, 81(11), 1821-1837.

Gutarowska, B, Skora, J., Stepien, L., Szponar B., Otlewska, A., and Pielech-Przybylska, K. (2015) Assessment of microbial contamination within working environments of different types of composting plants. J. Air Waste Manag. Assoc., 65, 466-478.

Harrison, E. Z. (2003). Compost Marketing and Labeling Project. Final report prepared to the New York State Energy Research and Development Authority. NYSERDA Report 6593. Cornell Waste Management Institute, Ithaca, NY.

Harrison, E.Z. and Krogmann, U. (2007). Guidelines for Application of Sewage Biosolids to Agricultural Lands in the Northeastern U.S. Rutgers NJ Agricultural Experiment Station, Bulletin E317. https://njaes.rutgers.edu/pubs/publication.php?pid=E317 , accessed 3/23/20.

Haug, R.T. (1993). *The practical handbook of compost engineering*. CRC Press, Inc., Boca Raton, FL.

Herr, C. E. W., zur Nieden, A., Bodeker, R. H., Gieler, U., and Eikmann, T. F. (2003). Ranking and frequency of somatic symptoms in residents near composting sites with odor annoyance. *Int. J. Hyg. Environ. Health*. 206:61–64.

Idaho Department of Environmental Quality. (2013). Processing (Composting) Facility Guidance and Checklists for Tier II and Tier III Processing Facilities. Retrieved from https://www.deq.idaho.gov/media/1078589-composting_guidance.pdf, accessed 1/9/20.

IFSC (Seven Generations Ahead & Illinois Food Scrap Coalition) (2015). Food Scrap Composting Challenges and Solutions in Illinois Report. Retrieved from https://sevengenerationsahead.org/images/work/zerowaste/IFSC-FoodScrapReportFINAL-Jan2015.pdf, accessed 9/1/19.

Kalaba, L., Wilson, B.G., and Haralampides, K. (2007) A stormwater runoff model for open windrow composting sites. Compost Science & Utilization 15(3): 142-150.

Kennedy/Jenks Consulting (2007). Compost leachate research. Report prepared for the Oregon Department of Environmental Quality, Land Quality Division.

Kern, M. (1991). Untersuchungen zur vergleichenden Beurteilung von Kompostierungsverfahren: Technik – Umweltrelevanz – Kosten. (Comparative evaluation of composting systems: technology – environmental relevance – costs: in German). In: Wiemer, K. and Kern, M. (eds.): Abfallwirtschaft: Bioabfallkompostierung – flächendeckende Einführung, pp. 235-278. Baeza Verlag, Witzenhausen, Germany.

Körner, I., Redemann, K. and Stegmann, R. (2005). Behaviour of biodegradable plastics in composting facilities. *Waste Management*, 25(4), 409-415.

Kramer, M. N., Kurup, V.P., and Fink, J.N. (1989). Allergic Bronchopulmonary Aspergillosis from a Contaminated Dump Site. Am. Rev. Respir. Dis. 140:1086-1088.

Kranert, M. (2000). Aerobe Verfahren (Kompostierung) Aerobic Systems (Composting). In: *Biologische Abfallverwertung (Biological Waste Treatment)*, Bidlingmaier, W. (ed.), pp. 56-119. Eugen Ulmer GmbH & Co., Stuttgart, Germany.

Krogmann, U., and Woyczechowski, H. (2000). Selected characteristics of leachate, condensate and runoff released during composting of biogenic waste. Waste Management & Research, 18(3), 235–248. doi: http://dx.doi.org/10.1177/0734242X0001800305

Krogmann, U., Boyles, L.S. and Heckman, J. (2001). Guidelines for the Land Application of Sewage Sludge for New Jersey Agriculture. Biosolids Working Group, Rutgers Cooperative Extension, Bulletin E228. https://njaes.rutgers.edu/pubs/publication.php?pid=E228, accessed 3/23/20.

Krogmann, U., Körner, I. and Diaz, L.F. (2010). Composting: Technology. In: *Solid Waste Technology and Management*, Christensen, T.H. (ed.), pp. 533-568. John Wiley & Sons, Chichester, UK.

Kühner, M. (2001). Planenkompostierung – Kompostierung unter semipermeablen Planenabdeckungen (Composting with covers – Composting under semipermeable covers: in German). In: Bioabfallkompostierung – Neue Entwicklungen and Lösungsmöglichkeiten zur Reduzierung von Geruchsemissionen. Hessisches Landesamt für Umwelt and Geologie, Wiesbaden, Germany.

Lampert, C. and Neubauer, C. (2015). Praxis grosser Kompostierungsanlagen und wesentliche Anforderungen an einen emissionsfreien Betrieb (Management practices of large composting facilities and main requirements for a low emission operation). Report REP-0501, Umweltbundesamt, Vienna, Austria.

Lenton, T.G. and Stentiford, E.I. (1990). Control of aeration in static pile composting. *Waste Management and Research*, 8, 299-306.

Lung, T. (2003). Ausbreitungsrechnungen und computergesteuerte Anlagenführung. (Dispersion calculations and computer-controlled plant management; in German). In: Microorganisms in the vicinity of waste treatment plants, Hessian State Office for the Environment and Geology, Wiesbaden. pp. 11-18. https://ip-lung.de/wp-content/uploads/2018/06/HLUG-03.pdf, accessed 1/31/20.

Marsh, P.B., Millner, P.D. and Kla, J.M. (1979). A guide to the recent literature on aspergillosis as caused by *Aspergillus fumigatus*, a fungus frequently found in self-heating organic matter. Mycopathologia 60: 67-81.

Mayer, J. (1990). Geruchsstoffe bei der Heißrotte von Hausmüll (Odorous compounds during composting of MSW at high temperatures). Ph.D. dissertation of the Department of Chemistry and Pharmacy at the Eberhard Karls Unversität Tübingen, Germany.

Miller, F.C., Harper, E.R. and Macauley, B.J. (1989). Field examination of temperature and oxygen relationships in mushroom composting stacks – consideration of stack oxygenation based on utilization and supply. *Australian Journal of Experimental Agriculture*, 29(5), 741-750.

Millner, P.D., Marsh, P.B., Snowden, R.B., and Parr, J.F. (1977). Occurrence of *Aspergillus fumigatus* during composting of sewage sludge. Applied and Environmental Microbiology 34: 765-772.

Millner, P.D., Bassett, D.A., and Marsh, P.B. (1980). Dispersal of Aspergillus fumigatus from Sewage Sludge Compost Piles Subjected to Mechanical Agitation in Open Air. Applied and Environmental Microbiology, 39:1000-1009.

Montgomery County (2018). Strategic Plan to Advance Composting, Compost Use, and Food Scrap Diversion in Montgomery County, Maryland. Montgomery County, Department of Environmental Protection, Division of Solid Waste Services, Rockville, MD.

Morrison Hershfield (2017). Best odour management practices at composting facilities, prepared for Metro Vancouver, http://www.metrovancouver.org/services/solid-waste/SolidWastePublications/Composting_Best_Practices_Study_Final_Report.pdf, accessed 1/10/20.

Müsken, J. (2001). Einfluß der Betriebsführung auf die Emissionscharakteristik einer Kompostierungsanlage (Effect of the Operation on the Emission Characteristic of a Composting Facility: in German). In: Bioabfallkompostierung – Neue Entwicklungen and Lösungsmöglichkeiten zur Reduzierung von Geruchsemissionen. Hessisches Landesamt für Umwelt and Geologie, Wiesbaden, Germany.

NJDOH (2016). Hazardous Substance Fact Sheet: Ammonia. NJ Department of Health. https://nj.gov/health/eoh/rtkweb/documents/fs/0084.pdf, accessed 3/18/20.

NYSDEC (2019a). Composting facilities. New York State Department of Environmental Conservation, 6 CRR-NY 361-3.2 https://govt.westlaw.com/nycrr/Document/Id4d62f22dfe911e7aa6b9b71698a280b?viewType=FullText&originationContext=documenttoc&transitionType=CategoryPageItem&contextData=(sc.Default)&bhcp=1 (accessed 7/10/19)

NYSDEC (2019b). Tables. New York State Department of Environmental Conservation, 6 CRR-NY 361-3.9 https://govt.westlaw.com/nycrr/Document/Id4d62f37dfe911e7aa6b9b71698a280b?viewType=FullText&originationContext=documenttoc&transitionType=CategoryPageItem&contextData=(sc.Default) (accessed 2/4/20)

NYSDEC (2019c). Regulations for Organic Recycling Facilities: brief summaries. New York State Department of Environmental Conservation, https://www.dec.ny.gov/chemical/97488.html#Composting (accessed 2/4/20)

Paré, M., Paulitz, T. C. and Stewart, K. A. (2000). Composting of crucifer wastes using geotextile covers. *Compost Science & Utilization*, 8(1), 36-45.

Pearson, C., Littlewood, E., Douglas, P., Robertson, S., Gan,t T.W., and Hansell, A.L. (2015). Exposures and health outcomes in relation to bioaerosol emissions from composting facilities: a systematic review of occupational and community studies. Journal of Toxicology and Environmental Health, Part B Crit. Rev. 18(1):43-69.

Pechan, E.H. (2004). Technical memorandum: MANE-VU 2002 ammonia emissions inventory for miscellaneous sources, final, prepared for the Mid-Atlantic Regional Air Management Association by E.H. Pechan & Associates, Inc. https://www.marama.org/visibility/Ammonia/Final_Tech_Memo.pdf, accessed 1/10/20.

Platt, B. (2016). Washington – Composting Rules. Institute for Local Self-Reliance. https://ilsr.org/rule/on-farm-composting/washington-3/, accessed 1/30/20.

Ramirez-Perez, J.C., Strom, P.F. and Krogmann, U. (2007). Horse Manure and Cranberry Fruit Composting Kinetics and Measures of Stability. *Compost Science & Utilization*, 15 200-214.

Recer, G.M., Browne, M.L., Horn, E.G., Hill, K.M., Boehler, W.F. (2001) Ambient air levels of Aspergillus fumigatus and thermophilic actinomycetes in a residential neighborhood near a yard-waste composting facility. *Aerobiologia* 17: 99–108.

Robertson S, Douglas P, Jarvis D, and Marczyloa E. (2019). Bioaerosol exposure from composting facilities and health outcomes in workers and in the community: A systematic review update. Int J Hyg Envir Heal. 222(3):364-86.

Roca-Barcelo, A., Douglas, P., Fecht, D., Sterrantino, A.F., Williams, B., Blangiardo, M., Gulliver, J., Hayes, E.T., and Hansell, A.L. (2019). Estimating *Aspergillus fumigatus* exposure from outdoor composting activities in England between 2005 and 14. Environ Res. [Nov 30: Epub ahead of print].

Rogers, B.F., Krogmann, U. and Boyles, L.S. (2001). Nitrogen mineralization of non-traditional organic wastes. *Soil Science,* 166(5), 353-363.

Rynk, R. (ed.) (1992). *On-Farm Composting Handbook*. Northeast Regional Agricultural Engineering Service, Ithaca, NY.

Seldman, N. (2014). Failure of the Wilmington composting facility underscores need for a locally based diverse composting infrastructure. https://ilsr.org/failure-wilmington-compost-facility-underscores-locally-based-diverse-composting-infrastructure/. Institute for Local Self-Reliance, Washington, DC.

Seven Generations Ahead & Illinois Food Scrap Coalition (IFSC). 2015. Food Scrap Composting Challenges and Solutions in Illinois Report. Retrieved from https://sevengenerationsahead.org/images/work/zerowaste/IFSC-FoodScrapReportFINAL-Jan2015.pdf, accessed 9/1/19.

SJVAPCD (San Joaquin Valley Air Pollution Control District) (2010). Compost VOC emission factors. September 15, 2010, https://www.valleyair.org/busind/pto/emission_factors/Criteria/Criteria/Composting/Compost%20EF.pdf, accessed 1/10/20.

Storino, F., Arizmendiarrieta, J. S., Irigoyen, I., Muro, J. and Aparicio-Tejo, P. M. (2016). Meat waste as feedstock for home composting: Effects on the process and quality of compost. *Waste Management*, 56, 53-62.

Strom, P.F., Morris,, M.L., and Finstein, M.S. (1980). Leaf Composting through Appropriate, Low-Level Technology. Compost Sci. 21(6):44-8.

Strom, P.F., Flower, F.B., Liu, M.H.P., and Finstein, M.S. (1986). Municipal Leaf Composting: Recommended Methods. BioCycle 27(9):48-52.

Strom, P.F. and Finstein, M.S. (1994). New Jersey's Manual on Composting Leaves and Management of other Yard Trimmings. New Jersey Department of Environmental Protection, 81pp. http://www.nj.gov/dep/dshw/rrtp/compost/cptitle.htm

Sundberg, C., Yu, D., Franke-Whittle, I., Kauppi, S., Smårs, S., Insam, H., Romantschuk, M. and Jönsson, H. (2013). Effects of pH and microbial composition on odour in food waste composting. *Waste Management* 33(1), 204-211.

Tetra Tech, Inc. (2002). Commercial Food Waste Composting Study. Project report prepared for Oregon Department of Environmental Quality, Land Quality Division, Solid Waste Program.

Tonjes, D.J., Rapiejko, A., and Norgard, J. (2018). When compost does bad things to groundwater. Conference Proceedings, The Federation of New York Solid Waste Associations (https://nyfederation.org/2018-proceedings/), https://nyfederation.org/wp-content/uploads/2018/pdf2018/69%20TonjesD.pdf, accessed 2/5/20.

TMECC (2002). Test Methods for the Examination of Composting and Compost. U.S. Composting Council, Bethesda, MD.

U.K. Environment Agency (2018a). Bioaerosol Monitoring at Regulated Facilities - Use of M9: RPS 209. https://www.gov.uk/government/publications/bioaerosol-monitoring-at-regulated-facilities-use-of-m9-rps-209/bioaerosol-monitoring-at-regulated-facilities-use-of-m9-rps-209, accessed 1/9/20.

U.K. Environment Agency (2018b). Environmental Monitoring of Bioaerosols at Regulated Facilities. Technical Guidance Note (Monitoring) M9. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/730226/M9_Environmental_monitoring_of_bioaerosols_at_regulated_facilities.pdf, accessed 1/9/20.

United Nations Environment Programme (UNEP) (2019). (https://www.unenvironment.org/thinkeatsave/about/definition-food-loss-and-waste)

US Composting Council (2019). Compost STA. https://www.compostingcouncil.org/page/CertifiedCompostSTA (accessed 11/23/19).

USEPA (1981). *Composting processes to stabilize and disinfect municipal sewage sludge*. EPA 430/9-81-011. Office of Water Program Operations, United States Environmental Protection Agency, Cincinnati, OH.

USEPA (2018). Title 40, Code of Federal Regulations, Part 503: Standards for the Use or Disposal of Sewage Sludge. https://www.govinfo.gov/content/pkg/CFR-2018-title40-vol32/pdf/CFR-2018-title40-vol32.pdf.

USEPA (2019a). Sustainable Management of Food. https://www.epa.gov/sustainable-management-food/sustainable-management-food-basics#targetText=Food%20waste%20refers%20to%20food,%20or%20combusted%20with%20energy%20recovery. United States Environmental Protection Agency, accessed 1/9/20.

USEPA (2019b). Advancing Sustainable Materials Management: 2017 Fact Sheet. United States Environmental Protection Agency, EPA 530-F-19-007. https://www.epa.gov/sites/production/files/2019-11/documents/2017_facts_and_figures_fact_sheet_final.pdf, accessed 1/9/20.

USGS (undated). Oxidation/reduction (redox). Water Resources, US Geological Survey. https://www.usgs.gov/mission-areas/water-resources/science/oxidationreduction-redox?qt-science_center_objects=0#qt-science_center_objects, accessed 3/19/20.

Vaccari, D.A., Strom, P.F. and Alleman, J.A. (2006). *Environmental biology for engineers and scientists.* John Wiley & Sons, Inc., Hoboken, NJ.

Vidussi, F. and Rynk, R. (2001). Meat byproducts as composting feedstocks. *BioCycle,* March, 71-74.

Vincken, W., and Roels, P. (1984). Hypersensitivity pneumonitis due to *Aspergillus fumigatus* in compost. Thorax. 39:74-75.

WAC (2018a). Composting Facilities. Washington Administrative Code 173-350-220. https://apps.leg.wa.gov/wac/default.aspx?cite=173-350-220, accessed 1/30/20.

WAC (2018b). Performance Standards. Washington Administrative Code 173-350-040. https://apps.leg.wa.gov/wac/default.aspx?cite=173-350-040, accessed 1/30/20.

WDEQ (2004). "Guidance Manual for Preparing/Updating a Stormwater Pollution Prevention Plan for Industrial Facilities, Washington Department of Ecology, Publication Number 04-10-030.

Wichuk, K.M. and McCartney, D. (2010). Compost stability and maturity evaluation – a literature review. Can. J. Civ. Eng. 37: 1505–1523.

Williams, B, Douglas, P, Roca-Barcelo, A, Hansell, A.L., and Hayes, E. (2019). Estimating *Aspergillus fumigatus* exposure from outdoor composting activities in England between 2005 and 14. Waste Manag. 84: 235-244.

Wilson, B.G., Haralampides, K., and Levesque, S. (2004). Stormwater runoff from open windrow composting facilities. J. Environ. Eng. Sci. 3: 537-540.

Zwerling, E. and Strom, P.F. (1992). Viable *Aspergillus fumigatus* spores aerosolized from yard waste composting. Report submitted to NJDEP, Office of Recycling and Planning, Trenton, NJ

Appendix 1. Food composting project overview prepared by the SRWMP

ISSUE: Outdoor Food Waste Compost Operations. What are the Potential Impacts to groundwater and air from outdoor food waste composting? What is the best recipe for composting of food waste? What buffer do you need around these facilities?

BACKGROUND:

- Source separated food waste is a Class C recyclable material. Composting of food waste requires a Class C recycling general approval.
- In the past, there was a handful of food waste compost facilities in NJ, but all of them closed due to operational problems. Some created odor nuisance as well as leachate problems.
- Currently there are no operating Class C food waste compost facilities in NJ, only one Research, Development, and Demonstration (RD&D) facility operating (a second was permitted by DSHW but is awaiting permits from other Programs in DEP).
- Because of past contamination issues, Air permitting (odor) and Water permitting (surface/groundwater) have become major hurdles for such facilities.

INFORMATION NEEDED*:

a. Need scientific data based on research and studies to determine potential adverse impact on human health and the environment from odors and leachates.
    i. Need recommended recipe (C:N ratio) including addition of dairy/meat products and other practices to enhance composting process and minimize odor.
b. Need recommended liner (if any) material for the compost bed including leachate control to minimize impacts on surface/groundwater.
c. Need comparative study for various compost methods (traditional windrows, static/forced aeration, etc.) and recommended method for outdoor food waste composting.
d. Need appropriate tests to determine nutrients and contaminants in the final compost product.

JUSTIFICATION: See background.

*These are the original program needs provided at the initiation of the project. During the course of the work, these needs were modified/expanded in response to the developing information. The revised needs are presented in Appendix 2.

Appendix 2: Revised Program Information Needs

In addition to the above charge questions, the SRWP requested that the Work Group provide a scientific basis for the following information needs. Although information needs (Appendix 1) were presented at the onset of the Work Group's deliberation, modified/expanded needs became apparent during the course of this project. Corresponding scientific information for each numbered bullet can be found throughout the report.

1) Recommended recipes (e.g., carbon to nitrogen ratio, C/N) including addition of dairy/meat products and other practices to enhance the composting process and minimize odor (discussed in Section 5).
2) Comparisons of various composting methods (e.g., traditional windrows, static piles with forced aeration) and recommended methods for outdoor food waste composting (Section 6).
3) Appropriate tests to determine nutrients and contaminants in the final compost product (Section 7).
4) Scientific data on potential adverse impacts on human health and the environment from leachate and runoff, and recommended leachate control practices (including liner, if any), to minimize impacts on surface and groundwater (Section 8).
5) Scientific data on potential adverse impacts on human health and the environment from air emissions, including odors and biological aerosols (Sections 9 and 10).
6) Comparative studies of impacts associated with various **types** of food waste that are composted (Section 5).
7) Comparative studies of various **sizes** of composting facilities to determine relative environmental risks from each (Section 12).
8) Recommended tiers based on size and type of composting materials based on (6) and (7) above. An ultimate objective would be to provide an exemption from permitting or reduce permitting requirements for smaller facilities treating less problematic materials (Section 12).

UAC SWAG PROJECT FARM - PTE CALCULATIONS

200	Gallons/WK SSO (Source Seperated Organics)
40	Gallons/CY SSO (Conversion Factor)
768	Lbs/CY SSO (Conversion Factor)
5	CY/WK SSO
3840	LBS/WK SSO
1.92	TNS/WK SSO
99.84	TNS/YR SSO
5.71	VOC Emission Factor - See Note 1
570.0864	LBS VOC/YR
0.065078356	LBS VOC/HR
0.2850432	TNS VOC/YR
0.021692785	LBS VOC/HR FOR EACH INDIVIDUAL BIN

Notes

1 Except where specified, the VOC emissions noted above are for the entire three-bin system to be operated at the property.

2 The VOC Emission Factor is based on the report titled "Compost VOC Emission Factors" prepared by the San Joaquin Valley Air Pollution Control Discrict dated September 15, 2010. (https://www.valleyair.org/businid/pto/emission_factors/Criteria/Criteria/Composting/Compost%20EF.pdf) The NJDEP Science Advisory Board cited to this VOC Emission Factor in its report titled "Final Report Outdoor Food Waste Composting" dated April 22, 2020.

3 All other emmissions are expected to be de minimis, and, therefore, have not been modeled. See the NJDEP Science Advisory Board report titled "Final Report Outdoor Food Waste Composting" dated April 22, 2020. (https://www.nj.gov/dep/sab/sab_food_composting.pdf)