ARB Emissions Inventory Methodology for Composting Facilities

3/2/2015

This Composting Methodology was developed with the assistance and review from the following Air Pollution Control Districts (APCD) or Air Quality Management Districts (AQMD): Bay Area AQMD, Butte County AQMD, Imperial County APCD, Sacramento Metro AQMD, San Joaquin Valley APCD, San Luis Obispo County APCD, Santa Barbara County APCD, Shasta County AQMD, South Coast AQMD, Ventura County APCD, and Yolo-Solano AQMD.

I. Background and Applicability

The purpose of this document is to describe a methodology for estimating emissions from California composting facilities. The methodology provides procedures for estimating volatile organic compound (VOC) and ammonia (NH_3) emissions from composting operations. Composting facilities are also sources of greenhouse gases such as methane, nitrous oxide, and carbon dioxide; however, a separate methodology that evaluates the complete lifecycle emissions for GHG emissions is warranted and is not included in this document.

These facilities are typically subject to the regulations of the California Department of Resources, Recycling & Recovery (CalRecycle), the State Water Resource Control Board, and the local air districts. CalRecycle permits the facility siting, pathogen destruction, and general operation standards for composting facilities. The State Water Resource Control Board ensures compliance with state water protection requirements to ensure that wastewater from composting facilities is properly handled onsite. The local air districts permit composting facilities under New Source Review and in some cases have source specific regulations. They also receive odor complaints from local residents and refer them to CalRecycle or the delegated local enforcement agency.

This methodology can be used to estimate emissions from compostable material handling operation facilities (compost facility). A composting facility is an operation or facility that processes, transfers, or stores compostable materials for the purposes of controlled biological decomposition. Compostable materials include: grass clippings, woodwaste, manure, biosolids, digestate, and food waste. The methodology is applicable to facilities that process organic materials via an open windrow composting or aerated static pile processes. This methodology assumes that material is stockpiled prior to composting for up to 14 days before the active phase initiated. Active composting and curing is assumed to take approximately 8 to 9 weeks. Emissions from the composting, drying, or land application of organic wastes generated on farms and used to fertilize farm crops, as well as backyard composting and unintentional composting, are not addressed in this methodology.

This emission inventory methodology addresses composting facilities with feedstocks that include greenwaste, co-composting (greenwaste combined with biosolids and/or manure) and foodwaste mixed with greenwaste. This methodology only applies to a compositing mixtures with no more than 15% by weight foodwaste, biosolids (by volume), or manure (by volume) and mixtures with no less than 85% by weight greenwaste.

The emission calculations from this methodology apply to facilities that are identified by the following Category of Emission Source (CES) code and Reconciliation Emission Inventory Code (REIC):

CES	REIC	Description
89490	199-170-0260-0000	Composting Waste Disposal

II. Source Category Description

a. Process Description

Composting is a process that involves the biological break down of organic matter into products that generally can be used in an agricultural application. Compost application to agricultural fields increases soil health while providing multiple co-benefits. Compost application can reduce the amount of synthetic fertilizer needed, reduce the amount of water used, decrease soil erosion, increase soil carbon storage, and reduce the use of herbicides.

Compostable organic waste feedstock can come from many sources including but not limited to the following:

- Biosolids - organic material resulting from the treatment of wastewater or sewage sludge.
- Animal waste (manure) - non-human animal excretions and waste, including, but not limited to, dried solids and urine from cows or swine.
- Poultry litter - poultry excretions and waste, including, but not limited to, dried solids and urine from chickens, turkeys, geese, or ducks.
- Greenwaste - leaves, grass clippings, plants, tree prunings, branches, and woody material such as large trees and stumps, arising from domestic, agricultural, commercial or municipal activities.
- Pomace - the solid remains of grapes, olives, or other fruit after pressing for juice or oil. It contains the skins, pulp, seeds, and stems of the fruit
- Foodwaste - any food scraps collected from the food service industry, grocery stores, or residential food scrap collection. Foodwaste also includes food material that is chipped and ground. Food packaging material may be included with the foodwaste and depending on the material will need to be separated or ground into the composting pile.
- Liquid waste – some facilities use liquid waste from various sources which may include: brewery waste, soda waste, restaurant wastewater, or wastewater residue.

The following descriptions provide a general overview of the composting process at a facility and common types of composting processes that are currently being used.

Stockpile

Organic waste is generally transported by truck for processing at composting facilities. The material is dumped in piles to wait for incorporation into an active composting pile. Material may be held in these pre-processing stockpiles for a few hours up to several days. During the stockpile phase, the composting process may begin and create emissions that are uncontrolled.

Grinding and Screening

In most cases, the materials in the stockpile will be ground and screened before they are placed in the windrows. An electric or diesel powered grinder is generally used for this purpose. The material may also be sent through a screening plant to sort out debris and garbage from the process.

Once the materials have been processed through the grinding and screening phase, it is then placed in piles or windrows to start the active and curing phases of the composting process. Brief descriptions of common composting methods used in California are listed below.

Static Piles

Static piles are the simplest form of composting and require little management and equipment. Once established, it is very difficult to adjust moisture, and static piles tend to go anaerobic in the center. Aerobic conditions can be achieved if the initial pile porosity is high (>60%) and there is a high proportion of bulking materials to keep pores open for air exchange. In general, product is kept on site for at least 15 days prior to sale to meet CalRecycle's pathogen reduction requirements and is only turned if temperature warrants. Currently this composting method is not addressed by the air district rules and is not addressed in this methodology. Upon further analysis and additional data availability, emissions from static piles may be addressed at a later date.

Windrow Composting

Windrow is the general term for an elongated pile of stacked raw materials. Piles need to be small (3-6') and porous enough for air to pass through them over a long period of time. A turned windrow is one that is mechanically turned using a bucket loader, manure spreader or a windrow turner. Turning the windrow remixes the materials, allowing all the raw materials to be colonized by microorganisms in the warmer, more active internal part of the compost pile. Turning reintroduces oxygen and allows heat, water vapor, and gases to escape. The most important reason for turning the pile is to reestablish porosity allowing air to get into the pile.

Passively aerated windrow system (PAWS)

PAWS includes perforated pipes placed at the base of each windrow to promote convective airflow throughout the pile. The key to this system is thorough premixing of feedstocks before placing over the perforated pipes. Also, passively aerated windrows need to be insulated with finished compost to ensure that temperatures at the outer edges of the windrow are sufficient for pathogen destruction.

Forced Aerated Static Piles

Forced aerated static piles are similar to PAWS piles, but blowers are installed at the ends of perforated pipes or air ducts. Air flow can be adjusted by changing the frequency and duration of the blower. Usually, blowers are set to turn on when the compost reaches a maximum temperature (e.g., 150F). Aerated static piles can be either positively or negatively aerated. (UW, 2002)

b. Emissions from Composting Windrows (VOCs, NH_3,)

This emissions methodology addresses VOC and NH3 emissions resulting from composting of organic materials. A brief description for each of these is presented below.

VOCs: Volatile organic compounds are emitted when organic waste is composted. VOCs are emitted as a result of decomposition of organic material within the composting windrow and also directly from the feedstock. Whether the waste organic materials are composted or handled otherwise, they continue to emit a variety of VOCs. These VOCs are biogenic in origin; thus, they are biodegradable. Since these are biogenic and biodegradable compounds, any measure that would promote active biological processes will decrease their emissions. The key factors that need to be controlled to optimize the biological process of composting are oxygen content, moisture content, pH, and carbon:nitrogen (C:N) ratio. Furthermore, since the VOC compounds emitted are biodegradable, water soluble (to some extent), and have adsorptive potential, there are an array of mitigation alternatives including pseudo-biofilter cap available to control their emissions. (SJV, 2010)

CalRecycle and UC Davis conducted a study in 2011 to determine what VOCs are emitted from composting piles and the reactivity of the VOCs detected. More than 100 VOCs were detected and quantified in this study, including aliphatic alkanes, alkenes, aromatic hydrocarbons, biogenic organics, aldehydes, ketones, alcohols, furans, acids, esters, ether, halogenated hydrocarbons and dimethyl disulfide (DMDS). Alcohols were found to be the dominating VOC in the emissions from a compost pile regardless of age, with the highest emissions coming from the younger composting windrows. (CalRecycle, 2011)

NH_3: The presence of excess nitrogen in the form of ammonium carbonate or ammonia can be traced to the microbial metabolism of protein or other sources of nitrogen. If the C:N ratio is too low, the energy source (carbon or carbohydrates) may be less than that required for converting all the available nitrogen into microbial cells. In such an event, the organisms make full use of available carbon and the excess nitrogen combines with hydrogen and is emitted as ammonia. If excess nitrogen in a decomposing mass is too great, ammonia may be formed in amounts sufficient to be toxic to the microbial population in the compost and will be emitted into the atmosphere as well.

c. Available Emissions Test Data

Emissions test data available for developing emission factors used in this methodology are presented in Tables II-1 through II-3 below. The emissions test data was compiled to determine emission factors for greenwaste (including foodwaste up to 15% of feedstock) and biosolids/manure co-composting. A more detailed summary of the available emission factor sources can be found in the attached Appendix A.

Table II-1: Summary of Available Active Composting Greenwaste Emissions Test Data

Site	VOC (lbs VOC/wet ton)	Ammonia (lbs NH3/wet ton)
SCAQMD Inland	1.56	0.26
SCAQMD Inland	2.25	0.63
CIWMB (Modesto)	0.85	N/A
CIWMB (Modesto)*	1.95	N/A
Site X	6.30	2.34
Jepson Prairie	5.65	0.24
Northern Recycling (Zamora)	10.03	0.45
City of Modesto	1.50	N/A
City of Modesto*	2.20	N/A
Average	**3.58**	**0.78**

*Source test contained 15% by weight foodwaste

Table II-2: Summary of Available Active Co-Composting Greenwaste with Biosolids/Manure Emissions Test Data

Site	VOC (lbs VOC/wet ton)	Ammonia (lbs NH3/wet ton)
Recyc Inc.	0.53	2.7
EKO System	1.7	3.28
San Joaquin Composting, Inc.	3.12	2.81
Average	**1.78**	**2.93**

Table II-3: VOC Stockpile Greenwaste Emissions Test Data

Site	VOC EF (lb-VOC/wet ton-day)
Northern Recycling Zamora	0.13
NorCal Jepson Prairie (Vacaville)	0.42
SCAQMD Inland	0.10
SCAQMD Inland	0.13
Average	**0.20**

d. VOC and Ammonia Emission Control Techniques

A number of control techniques are available to facilities to control the emissions from composting activities. These control techniques reduce both VOCs and ammonia emissions. The first technique is aerated static piles (ASP). In aerated static pile composting, organic waste is mixed together in one large pile instead of rows. To aerate the pile, layers of loosely piled bulking agents (e.g., wood chips, shredded newspaper) are added so that air can pass from the bottom to the top of the pile. The piles also can be placed over a network of pipes that deliver air into or draw air out of the pile. Often air blowers are activated by a timer or a temperature sensor. The air is run through a biofilter to control the emissions from the windrow. ASP systems can incorporate covers over the windrow to increase the capture efficiency. Examples of these types of systems include the Gore cover, Engineered Compost System (ECS), or AgBag.

Finished compost can be used as a pseudo-biofilter. Finished compost can be applied in a thick layer over the surface of the windrow. Facilities may apply the finished compost for differing durations of time to reduce emissions. 90% of the VOC emissions happen in the active phase of composting and as a result compost covers are most effective during this active phase. (SJV, 2010) SJVAPCD and SCAQMD's regulations are designed to get the most reductions early on in the active phase and require a 22-day compost cover (60% reduction of VOCs) and 15-day compost cover (40% reduction of VOCs), respectively.

Finally, one of the most effective ways to reduce emissions is to operate at an indoor facility or use a fully enclosed system. Indoor facilities are generally located in large warehouses and the indoor air is ducted through a biofilter. Fully enclosed systems may use drums, silos, or other types of sealed containers to capture the air and direct it through a biofilter. Facilities can achieve 80% or more emissions reductions using these types of emission control devices.

e. Emission Control Demonstrations

A number of studies have analyzed the use of emission control devices on composting windrows. The most common types in California involve the use of compost as a cover for the windrows or an aerated static pile that passes the exhaust gas through a biofilter. Table II-4 shows the most common emission control devices with their respective aeration types (positive or negative), emission control methods (compost cap, biofilter, etc.), and cover material (biofilter, membrane, plastic, etc.). Detailed summaries of the sources can be found in the attached Appendix A.

Table II-4: Control Techniques for Composting Operations

Control Type	Aeration	Control Method	Cover Material
Windrow			
Static Pile – No Biofilter	Passive	None	None
Managed Windrow – No Biofilter	Passive	None	None
Water Management Requirements[1]	Passive	Watering	None
Static Pile/Passively Aerated Windrow covered 15 days with a biofilter[2]	Passive	At least 6 inches of Compost Cover	Finished Compost or Compost Overs
Static Pile/Passively Aerated Windrow covered 22 days with a biofilter[1]	Passive	At least 6 inches of Compost Cover	Finished Compost or Compost Overs
Aerated Static Pile (ASP)			
Negative ASP with Biofilter (classic)[3]	Forced, Negative Air	At least 6 inches of Compost Cover (optional), Biofilter Bed	Finished Compost or Compost Overs
Positive ASP with Biofilter Cover	Forced, Positive Air	At least 6 inches of Compost Cover	Finished Compost or Compost Overs
Enclosed Aerated Static Pile			
Enclosed, Negative ASP with Biofilter (e.g., ECS)	Forced, Negative Air	Biofilter Bed	Engineered Cover Tarp
Negative ASP with Biofilter (indoor)[3]	Forced, Negative Air	Biofilter Bed	Building
Enclosed, Positive ASP (e.g., GORE Cover)	Forced, Positive Air	None	Engineered Cover Membranes
Ag Bag	Forced, Positive Air	None	Thick Mill Plastic Bag
General Enclosed Pile vented through a Biofilter	Forced	Vented through biofilter	Finished Compost or Compost Overs

[1]Requires compliance with pile management and/or watering requirements in SJVAPCD's rule 4566.
[2]Requires compliance with pile management and/or watering requirements in SCAQMD's rule 1133.3.
[3]These composting types can be conducted at the indoor setting venting indoor air to a biofiltration control system.

(SC, 2011a) (NRAES, 1992) (Paul & Geesing, 2009)

III. Recommended Emission Estimation Approaches

This methodology describes two approaches for estimating emissions. The first is based on actual emission testing and the second approach relies on industry averaged data emission factors from composting facilities. These two approaches are described below.

a. Facility Specific Data (Emission Testing)

Conducting on-site emissions testing to determine site specific emission factors is one approach for estimating emissions from a given facility. It is recommended to use the testing methods listed in the South Coast Air Quality Management District (SCAQMD) or San Joaquin Valley Air Pollution Control District (SJVAPCD) composting rules. SCAQMD lists their testing requirements and protocols in SCAQMD Rule 1133.3(e). SJVAPCD lists their testing requirements in SJVAPCD Rule 4566(6.4). This data can be combined with the facility throughput, control technology factors etc. as described in b. below to estimate the annual emissions for the facility.

b. Composting Emission Factor

An alternative approach is to use emission factors developed based on the results of emission tests or studies performed at one or more facilities. This approach is described below. Use of the following emission factors are subject to the approval of the local air districts who permit the composting facilities.[1] Additional testing may be necessary to demonstrate emission control efficiency factors or emissions from a composting facility.

i. Data Requirements

For each facility, the following information would be needed to calculate the emissions for the facility using a recommended emission factor:

- Facility throughput (wet tons)
  - o Annual amount of organics processed at the facility. Wet tons is defined as the mass of greenwaste, co-composting, and foodwaste that is processed at the facility, excluding any screen waste that does not go through the composting process.
- Feedstock Composition (e.g. greenwaste, foodwaste, co-composting)
  - o This emission factor is appropriate for greenwaste only or a mixture of greenwaste with foodwaste or co-composting up to 15% by weight of total.
- Control Technology Efficiency (ASP, biofilter)
  - o It is necessary to determine the control technology emission reduction efficiency. This can be done with source testing or using the standard recommended values in Table III-3.
- Average Stockpile Time

[1] The local air pollution control districts or air quality management districts may have established emission factors and/or regulation approved for use in their corresponding air basin. Contact the local air district for more information.

- It is necessary to average the time that the incoming organics are stockpiled before incorporation into the composting piles.

ii. Estimating Emissions from a Facility

Total Annual Emissions = (CPEF x (1-CE) x TP) + (SEF x SD X TP);

- Where
  - CPEF = Composting Process Emission Factor (lbs/wet-ton)
  - SEF = Stockpile Emission Factor (lbs/wet ton-day)
  - SD = Average number of days material is stockpiled (days)
  - CE = Control Efficiency (Percentage)
  - TP = Total annual facility throughput (wet-tons)

Table III-1: Recommended Emission Factors for Greenwaste and Foodwaste[1]

Pollutant	Stockpile (lbs/wet ton-day)	Composting Process (lbs/wet ton)
VOC	0.20	3.58
NH3	N/A	0.78

Table III-2: Recommended Emission Factors for Greenwaste Mixed with Animal Manure, Biosolids, or Poultry Litter (Co-Composting[1])

Pollutant	Co-Composting Process (lbs/wet ton)
VOC	1.78
NH3	2.93

[1] Foodwaste, biosolids, and manure can be a maximum of 15% by weight of the total mixture with greenwaste.

Table III-3: Control Techniques for Composting Operations

Control Type	Aeration	VOC Control Efficiency	NH3 Control Efficiency
Windrow			
Static Pile – No Biofilter	Passive	0%	0%
Managed Windrow – No Biofilter	Passive	0%	0%
Water Management Requirements[1]	Passive	19%	19%
Static Pile/Passively Aerated Windrow covered 15 days with a biofilter[2]	Passive	40%	20%
Static Pile/Passively Aerated Windrow covered 22 days with a biofilter[1]	Passive	60%	20%
Aerated Static Pile (ASP)			
Negative ASP with Biofilter (classic)	Forced, Negative Air	26%	23%
Positive ASP with Biofilter Cover	Forced, Positive Air	80%-98%	53%
Enclosed Aerated Static Pile			
Enclosed, Negative ASP with Biofilter (e.g., ECS)	Forced, Negative Air	80%-98%	70%-78%
Negative ASP with Biofilter (indoor)	Forced, Negative Air	80%-98%	80%-99%
Enclosed, Positive ASP (e.g., GORE Cover)	Forced, Positive Air	80%	70%
Ag Bag	Forced, Positive Air	80%	70%
General Enclosed Pile vented through a Biofilter	Forced	80%	70%

[1]Requires compliance with pile management and/or watering requirements in SJVAPCD's rule 4566.
[2]Requires compliance with pile management and/or watering requirements in SCAQMD's rule 1133.3.

Data Sources

(CalRecycle, 2011) Volatile organic compound emissions from green waste composting: Characterization and ozone formation

(CalRecycle, 2013) Greenwaste Compost Site Emissions Reductions from Solar-powered Aeration and Biofilter Layer

(Colorado, 2012) Composting: VOC Emissions & Best Management Practices, Colorado Department of Public Health and Environment

(Elsevier, 2009) *A methodology to determine gaseous emissions in a composting plant,* Composting Research Group, Department of Chemical Engineering, Barcelona, Spain

(NRAES, 1992) NRAES, On-Farm Composting Handbook, June 1992.

(Paul & Geesing, 2009) John Paul and Dieter Geesing, Compost Facility Operator Manual, 2009.

(SC, 2011) RULE 1133.3 EMISSION REDUCTIONS FROM GREENWASTE COMPOSTING OPERATIONS

(SC, 2011a) SCAQMD, Final Staff Report for Proposed Amended Rule 1133.1 and Proposed Rule 1133.3, July 2011.

(SDSU, 2012) *Full-Scale VOC Emissions from Green And Food Waste Windrow Composting*, Fatih Büyüksönmez, Department of Civil, Construction and Environmental Engineering, San Diego State University

(SJV, 2011) RULE 4566 ORGANIC MATERIAL COMPOSTING OPERATIONS, SJVAPCD

(SJV, 2010) Compost VOC Emission Factors, SJVAPCD

(UW, 2002) The Art and Science of Composting, Leslie Cooperband, University of Wisconsin-Madison

(Yolo, 2012) ECS AC Composter Pilot Facility, Air Emissions Source Test, Thomas R. Card, P.E., Charles E. Schmidt, PhD.

Appendix A to ARB Recommended Emissions Inventory Methodology for Composting Facilities

A. Overview

This appendix provides a summary of available California facility composting emissions data and an overview of a recent study conducted on effectiveness of emission control systems.

B. California Air District Emission Factors

Two sets of emission factors have been adopted by local air quality management districts. The San Joaquin Air Pollution Control District (SJVAPCD) published their emission factor in 2010. SJVAPCD adopted Rule 4565: Biosolids, Animal Manure, and Poultry Litter and Rule 4566: Organic Material Composting Operations for composting facilities in March of 2007 and August of 2011, respectively. The South Coast Air Quality Management District (SCAQMD) adopted their Rule 1133.2: Emission Reductions from Co-Composting Operations in January 2003 and Rule 1333.3: Emission Reductions from Greenwaste Composting Operations in July 2011. SCAQMD published the following emission factors as part of the 2011 rulemaking process. Table A-1 list the factors for each district. As can be seen, SJVAPCD has an emission factor for VOC emissions and SCAQMD has emission factors for both VOCs and ammonia. The following Tables A-2 through A-5 present the underlying emissions source test data that were used in developing the approved emission factors for each district.

Table A-1: Summary of Composting Emission Factors Approved by SJVAPCD & SCAQMD

Compost Type	Stockpile (lb-VOC/wet-ton-day)		Windrow EF Per Composting Cycle (lb-VOC/wet ton)		Windrow EF (lb NH3/wet ton)
	SJVAPCD	SCAQMD	SCAQMD	SCAQMD	SCAQMD
Greenwaste, Foodwaste, Grape Pomace	0.2	N/A	5.71	4.67	0.71
Co-Composting	N/A	N/A	1.78	1.78	2.93

Table A-2: SJVAPCD VOC Stockpile Greenwaste Emissions Testing Data

Site	Length of Time the Material Stays in the Stockpiles (day)	Season Samples Taken	EF (lb-VOC/wet ton-day)
Northern Recycling Zamora	90	Spring	0.126
NorCal Jepson Prairie (Vacaville)	7	Summer	0.422
SCAQMD Inland	9	Winter	0.101
SCAQMD Inland	21	Fall	0.133
Average			0.196

Table A-3: SJVAPCD VOC Windrow Greenwaste Emissions Testing Data

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

Table A-4: SCAQMD Greenwaste VOC & Ammonia Emissions Testing Data

Site	Sampling age of material	Season samples were taken	Throughput (tons/day)	VOC (lbs/wet ton)	Ammonia (lbs/wet ton)
Inland	Over the static and windrow phase	Winter	307	1.56	0.26
Inland		Fall	350	2.25	0.63
Modesto	Over the active and curing phase (days were not sampled were interpolated)	Fall	103	0.85	N/A
Site X		Spring	200	6.30	2.34
JPO		Summer	163	5.65	0.24
Zamora		Spring	319	10.03	0.445
Weighted average emission factors				**4.67**	**0.66**

Table A-5: SCAQMD & SJVAPCD Co-Composting Uncontrolled VOC & Ammonia Emissions Testing Data

Facilities	VOC E.F. (lb/ton mix)	NH3 E.F. (lb/ton mix)
RECYC Inc. (Corona, 1995)	0.53	2.7
EKO System (Corona, 1995)	1.7	3.28
San Joaquin Composting, Inc. (Lost Hills, 1996)	3.12	2.81
Average	1.78	2.93

As shown in Table A-4, SCAQMD used the same emission source data as SJVAPCD. However, they included two additional source tests from the Inland facility in the calculation to determine the emissions factor. This caused the weighted emission factor to decrease by approximately 1 lb/wet ton. At the time of the SJVAPCD's emission factor development, SJVAPCD chose not to use these source tests because they believed that the facility was small and did not accurately reflect the size of the facilities in their district. Because there is a limited subset of data, we have included the Inland source test information. While the data may not be representative of the sites in SJVAPCD, it is representative of many sites throughout the state and is included in this methodology.

C. *Composting Facility Emissions Test Data*

a. *Modesto Composting Facility*

CalRecycle sponsored a study in 2012 by San Diego State University. The study was conducted at the Modesto Composting Facility operated by the City of Modesto. Samples were collected with United States Environmental Protection Agency (U.S. EPA) isolation flux chambers for 59 days and analyzed according to the SCAQMD Method 25.3. Two separate composting windrows were tested in this study. The first windrow was comprised of greenwaste only and the second windrow was a mixture of 85% greenwaste and 15% foodwaste. Emission factors were determined to be 1.4 g/kg-dry-weight (dw) (1.5 lbs VOC/wet ton[1]) and 2.2 g/kg-dw (2.2 lbs VOC/wet ton[1]) for greenwaste and greenwaste combined with foodwaste composting, respectively. (SDSU, 2012)

b. *Composting Outside of California*

The Colorado Department of Public Health and Environment published a memo titled "*Composting: VOC Emissions & Best Management Practices*" in 2012. In the memo, they cited the SJVAPCD emission factor as "the most robust and technically sound study currently available." However, they did not use the stockpile emission factor as they assumed that the climate differences would impact the emissions from the stockpile. This was not a concern for the active composting emission factor as the

[1] Conversion to wet tons was done using the initial blend moisture content.

moisture content, temperature, and turning requirements should create a windrow with similar characteristics. (Colorado, 2012)

D. *Summary of Composting Emission Sources*

The following tables A-6 through A-7 present a summary of the available source testing results for composting facilities whose test results were used to develop the emission factors in the proposed composting emission inventory methodology.

Table A-6: Summary of Available Active Composting Greenwaste Emissions Test Data

Site	VOC (lbs VOC/wet ton)	Ammonia (lbs NH3/wet ton)
Inland	1.56	0.26
Inland	2.25	0.63
CIWMB (Modesto)	0.85	N/A
CIWMB (Modesto)*	1.95	N/A
Site X	6.30	2.34
Jepson Prairie	5.65	0.24
Northern Recycling (Zamora)	10.03	0.45
City of Modesto	1.50	N/A
City of Modesto*	2.20	N/A
Average	**3.58**	**0.78**

*Source test contained 15% foodwaste

Table A-7: Summary of Available Active Co-Composting Greenwaste with Biosolids/Manure Emissions Test Data

Site	VOC (lbs VOC/wet ton)	Ammonia (lbs NH3/wet ton)
Recyc Inc.	0.53	2.7
EKO System	1.7	3.28
San Joaquin Composting, Inc.	3.12	2.81
Average	**1.78**	**2.93**

F. *Emission Reduction Technology Assessments*

The following section provides a brief overview of the sources that were used to develop the proposed emission reduction (control efficiency) factors in the emission inventory methodology.

a. *CalRecycle: Greenwaste Compost Site Emissions Reductions from Solar-Powered Aeration and Biofilter Layer*

CalRecycle and SJVAPCD sponsored a test project that monitored emissions from a solar powered aerated static pile system (eASP). The eASP utilized ambient air blown into the pile from the bottom; the blowers were powered by photovoltaic panels and associated batteries. The eASP had a biofiltration layer added to the surface as an air pollution control measure. A series of compost windrows were built concurrent with the eASP using the same feedstock. The air emissions from the eASP were compared to the on-site measured air emissions of the current industry standard windrow composting method.

Table A-8 provides a summary of the emissions from the windrow over the 22-day active composting period, as specified by SJVAPCD Rule 4566. VOC reductions of 98.8% were achieved when compared to the control windrows. Reductions in ammonia emissions were 83% using tubes in the field, and 53% from the laboratory, when the eASP was compared to the control windrows. Reductions in emissions of greenhouse gases ranged from 13% for methane up to nearly 89% for N_2O for the eASP system when compared to the controls. (CalRecycle, 2013)

Table A-8: Results of eASP Study (lbs pollutant/wet ton)

		NH3		GHG			
	VOC	Field	Lab	CO2	CH4	N2O	CO2e
Prototype ASP (22 Days)	0.099	0.017	0.007	205.70	5.05	0.010	315
Baseline Windrow (22 days)	8.604	0.099	0.014	731.63	5.81	0.093	883
% reduction from Baseline	**-98.8%**	**-83.2%**	**-53.3%**	**-71.9%**	**-13.0%**	**-88.8%**	**-64.3%**

b. *Colorado Department of Public Health and Environment: Composting: VOC Emissions & Best Management Practices*

Colorado cited the October 31, 2007 report "Emissions Testing of Volatile Organic Compounds from Greenwaste Composting at the Modesto Compost Facility in the San Joaquin Valley" published by the California Integrated Waste Management Board and used 75% control efficiency for biofilter/compost cover that is used for the entire process. They used a 56.25% control efficiency when the biofilter/compost cover is used only in the first two weeks.

Table A-9: Summary of Control Efficiencies from Colorado Department of Public Health and Environment

Control Option	Specific Requirements	VOC Reduction (i.e. control efficiency)
Finished Compost Blanket/pseudo-biofilter	Cover the active compost windrow with a blanket of finished compost. A finished compost blanket must be reapplied following any turning event. The blanket shall be applied such that there are no visible gaps or cracks in the cap.	75%
Finished Compost Blanket/pseudo-biofilter – First two weeks only	Cover the active compost windrow with a blanket of finished compost. A finished compost blanket must be reapplied following any turning event during the first two weeks of composting. The blanket shall be applied such that there are no visible gaps or cracks in the cap.	56.25%

G. Regulatory Requirements for Emission Controls

SJVAPCD and SCAQMD both specify in their regulations the minimum requirements for composting facilities emission control devices. The requirements of the regulations are summarized in the following tables.

Table A-10A: SJVAPCD Rule 4565 Co-Composting Emission Control Device Requirements

Facility Size	Emission Control Device	Alternative to Emission Control Device
Less than 20,000 tons/year	Implement at least 3 of the Class One mitigation measures listed in Table 2 ***OR*** implement at least 2 Class One mitigation measures in addition to 1 Class Two mitigation measure for active composting listed in Table A-10B.	
20,000 to 100,000 tons/year	Implement at least 4 of the Class One mitigation measures listed in Table 2 **OR** implement at least 3 Class One mitigation measures in addition to 1 Class Two mitigation measure for active composting listed in Table A-10B.	
Greater than 100,000 tons/year	Implement at least 4 Class One mitigation measures in addition to 1 Class Two mitigation measure for active composting ***OR*** Implement at least 2 Class One mitigation measures, in addition to 1 Class Two mitigation measure for active composting and 1 Class Two mitigation measure for curing composting listed in Table A-10B.	

Table A-10B – SJVAPCD Rule 4565 Co-composting Facility Mitigation Measures

Class One Mitigation Measures	
1.	Scrape or sweep, at least once a day, all areas where compostable material is mixed, screened, or stored such that no compostable material greater than one inch (1") in height is visible in the areas scraped or swept immediately after scraping or sweeping, except for compostable material in process piles or storage piles.
2.	Maintain a minimum oxygen concentration of at least five percent (5%), by volume, in the free air space of every active and curing compost pile.
3.	Maintain the moisture content of every active and curing compost pile between 40% and 70%, by weight.
4.	Manage every active pile such that the initial carbon to nitrogen ratio of every pile is at least twenty (20) to one (1).
5.	Cover all active compost piles within 3 hours of each turning with one of the following: a waterproof covering; at least six (6) inches of finished compost; or at least six (6) inches of soil.
6.	Cover all curing compost piles within 3 hours of each turning with one of the following: a waterproof covering; at least six (6) inches of finished compost; or at least six (6) inches of soil.
7.	Implement an alternative Class One mitigation measure(s) not listed above that demonstrates at least a 10% reduction, by weight, in VOC emissions.
Class Two Mitigation Measures	
8.	Conduct all active composting in aerated static pile(s) vented to a VOC emission control device with a VOC control efficiency of at least 80% by weight.
9.	Conduct all active composting in an in-vessel composting system vented to a VOC emission control device with a VOC control efficiency of at least 80% by weight.
10.	Conduct all curing composting in aerated static pile(s) vented to a VOC emission control device with a VOC control efficiency of at least 80% by weight.
11.	Conduct all curing composting in an in-vessel composting system vented to a VOC emission control device with a VOC control efficiency of at least 80% by weight.
12.	Implement an alternative Class Two mitigation measure(s) not listed above that demonstrates at least 80% reduction, by weight, in VOC emissions.

Table A-11: SJVAPCD Rule 4566 Greenwaste and Foodwaste Emission Control Device Requirements

Facility Size	Emission Control Device	Alternative to Emission Control Device
Less than 200,000 tons/year	Watering System Requirements	19% Reduction of VOC emissions
200,000 to 750,000 tons/year	Watering System Requirements and Finished Compost Cover	60% Reduction of VOC emissions
Greater than 750,000 tons/year	80% Reduction of VOC emissions	80% Reduction of VOC emissions

Table A-12: SCAQMD Rule 1133.2 Co-Composting Emission Control Device Requirements

Facility Size	Emission Control Device	Alternative to Emission Control Device
Any new facility with greater than 20% manure, by volume	Enclosed Emission Control Device with a control efficiency of 80% reduction of VOC and Ammonia Emissions	80% Reduction of VOC and Ammonia emissions

Table A-13: SCAQMD Rule 1133.3 Greenwaste Emission Control Device Requirements

Facility Size	Emission Control Device	Alternative to Emission Control Device
New facility with less than 20% manure or 5,000 tons foodwaste	Cover windrow with finished compost and watering requirements	40% Reduction of VOC emissions and 20% reduction of Ammonia emissions
New facility with greater than 20% manure, by volume, or 5,000 tons and greater than 10% foodwaste, by weight	80% Reduction of VOC and ammonia emissions	80% Reduction of VOC and Ammonia emissions