
SOURCE TEST REPORT

96-0007/96-0008/96-0009

CONDUCTED AT

San Joaquin Composting, Inc.
Holloway Road
Lost Hills, CA.

CHARACTERIZATION OF AMMONIA, TOTAL AMINE, ORGANIC SULFUR COMPOUND, AND TOTAL NON-METHANE ORGANIC COMPOUND (TGNMOC) EMISSIONS FROM COMPOSTING OPERATIONS

TESTED: February 15, 1996
March 1 & 11, 1996

ISSUED:

REPORTED BY: Carey Willoughby
Air Quality Engineer I

REVIEWED BY:

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Michael Garibay
Air Quality Engineer II

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Arun Roy Chowdhury
Supervising Air Quality Engineer

SOURCE TESTING AND ENGINEERING BRANCH

APPLIED SCIENCE AND TECHNOLOGY

SUMMARY

a.	Firm and Mailing Address	San Joaquin Composting, Inc. 525 N. Shafter Avenue Shafter, CA, 93263-1505
b.	Site Location	Holloway Road Lost Hills, Ca.
c.	Unit Tested	Windrow Piles with 3, 45, & 57 day mixes
d.	Test Requested by	Julia Lester, Planning, (909) 396-3162
e.	Reason for Test Request	Information for the AQMP
f.	Date of Test	February 15, & March 1 & 11, 1996
g.	Source Test Performed by	Ken Sanchez, David Carrillo, Mike Garibay, C. Willoughby, Paul Williamson
h.	Test Arrangements Made Through	J. Deatherage, General Manager, (805) 746-6723
h.	Test Observed by	T. L. Allard, Site Manager, (805) 797-2914

RESULTS

3 Day Pile Average Emission Summary

Contaminant	Emissions per Windrow Pile	Emissions per hour per ton of Compost Mix	Emissions per hour per 1000 ft^2 of Compost
Ammonia (pre turning)	1.54 lb/hr	3.09E-03 lb/hr-ton mix	0.155 lb/hr-1000ft^2
Ammonia (post turning)	1.37 lb/hr	2.75E-03 lb/hr-ton mix	0.138 lb/hr-1000ft^2
Ammonia (wtd. avg)	1.54 lb/hr	3.09E-03 lb/hr-ton mix	0.155 lb/hr-1000ft^2
Amines	0.13 lb/hr	2.59E-04 lb/hr-ton mix	1.30E-02 lb/hr-1000ft^2
Total Sulfur Compounds	0.08 lb/hr	1.68E-04 lb/hr-ton mix	8.41E-03 lb/hr-1000ft^2
Methane	36.46 lb/hr	7.29E-02 lb/hr-ton mix	3.65 lb/hr-1000ft^2
TGNMOC	3.29 lb/hr	6.58E-03 lb/hr-ton mix	0.329 lb/hr-1000ft^2

45 Day Pile Average Emission Summary

Contaminant	Emissions per Windrow Pile	Emissions per hour per ton of Compost Mix	Emissions per hour per 1000 ft^2 of Compost
Ammonia (pre turning)	1.41 lb/hr	2.82E-03 lb/hr-ton mix	0.146 lb/hr-1000ft^2
Ammonia (post turning)	1.56 lb/hr	3.11E-03 lb/hr-ton mix	0.162 lb/hr-1000ft^2
Ammonia (wtd. avg.)	1.41 lb/hr	2.83E-03 lb/hr-ton mix	0.146 lb/hr-1000ft^2
Amines	0.04 lb/hr	8.67E-05 lb/hr-ton mix	4.50E-03 lb/hr-1000ft^2
Methane	0.11 lb/hr	2.20E-04 lb/hr-ton mix	1.14E-02 lb/hr-1000ft^2
TGNMOC	0.12 lb/hr	2.36E-04 lb/hr-ton mix	1.23E-02 lb/hr-1000ft^2

57 Day Pile Average Emission Summary

Contaminant	Emissions per Windrow Pile	Emissions per hour per ton of Compost Mix	Emissions per hour per 1000 ft^2 of Compost
Ammonia (pre turning)	0.13 lb/hr	2.66E-04 lb/hr-ton mix	1.42E-02 lb/hr-1000ft^2
Ammonia (post turning)	2.48 lb/hr	4.97E-03 lb/hr-ton mix	2.65E-01 lb/hr-1000ft^2
Ammonia (wtd. avg.)	0.18 lb/hr	3.68E-04 lb/hr-ton mix	1.97E-02 lb/hr-1000ft^2
Amines	<0.003 lb/hr	<6.58E-06 lb/hr-ton mix	<3.51E-04 lb/hr-1000ft^2
Total Sulfur Compounds	0.08 lb/hr	1.58E-04 lb/hr-ton mix	8.43E-03 lb/hr-1000ft^2
Methane	<0.13 lb/hr	<2.67E-04 lb/hr-ton mix	<1.43E-02 lb/hr-1000ft^2
TGNMOC	<0.12 lb/hr	<2.39E-04 lb/hr-ton mix	<1.27E-02 lb/hr-1000ft^2

Average of 3-day, 45-day, & 57-day piles

Contaminant	Emissions per ton of Compost Mix	Emissions per 1000 ft^2 of Compost Surface Area	Emission per hour - ton of Compost Mix
Ammonia	2.81 lb/ton mix	0.107 lb/hr-1000ft^2	2.07E-03 lb/hr-ton
Amines	0.19 lb/ton mix	6.0E-03 lb/hr-1000ft^2	1.17E-04 lb/hr-ton
Total Sulfur Comp.	0.22 lb/ton mix	8.42E-03 lb/hr-1000ft^2	1.63E-04 lb/hr-ton
Methane	33.49 lb/ton mix	1.23 lb/hr-1000ft^2	2.4E-02 lb/hr-ton
TGNMOC	3.12 lb/ton mix	0.11 lb/hr-1000ft^2	2.28E-03 lb/hr-ton

Notes: Total sulfur compounds based on 3-day and 57-day piles only.
Results do not include emissions from curing piles or emissions during actual turning.
Ton of compost mix refers to original mass as measured by Lost Hills before composting.

For emissions of individual sulfur compounds, refer to calculations section.
TGNMOC may be subject to change upon receipt of modified method 25.1 results.

INTRODUCTION

On February 15, 1996, and March 1 & 11, 1996, personnel from the South Coast Air Quality Management District (SCAQMD), conducted source tests at San Joaquin Composting, Inc. The tests are intended to measure the emission profile of the operation over its composting cycle. The tests were conducted on compost piles consisting of a mixture of dewatered sewage sludge and green waste. The ages of the piles were 3 days, 45 days, & 57 days. These compost ages were chosen as beginning and end compost where activity is theoretically beginning and ending, and at peak temperature (45 days) when activity is expected to be greatest. The results presented in this report represent windrow emissions only since sampling for curing pile emissions was not performed.

Since the composting process is specifically designed to optimize agitation for maximum aerobic content verses internal heat and activity, it was imperative that the process be tested in place and undisturbed. The piles are generally turned once to three times per week depending on workload constraints. The tests were scheduled to coincide with the pile turning, so a pile was tested for ammonia emissions before and after turning, and for the remaining pollutants, before turning only. Sampling was not conducted during turning, however, due to sampling difficulties under turning conditions. Previous testing has shown that the emission remain at the elevated emission rate for approximately 90 minutes after turning, after which emissions return to baseline levels. The "before turning" condition is considered as representing baseline emissions.

The test was requested by the SCAQMD Planning Division in order to inventory emissions from sludge composting operations in the South Coast District and evaluate the impact for possible inclusion to the Air Quality Management Plan (AQMP). San Joaquin Composting has volunteered the use of its Lost Hills facility for purposes of testing emissions to the atmosphere

The following is a summary of operating conditions during the tests:
Average Row Height - 5’ (3 Day), 4.5’ (45 Day), 4’ (57 Day)
Average Row Width at Base - 18’
Average Row Width at Top - 8’
Average Row Length - 450’
Compost Temperature - See Table on page 20
Average Pile Surface Area - 9,990 ft^2 (2 Day), 9,630 ft^2 (20 Day), 9,360 ft^2 (50 Day)
Average Pile Compost Volume - 29,250 ft^3 (3 Day), 26,325 ft^3 (45 Day), 23,400 ft^3 (57 Day)
Compost Composition - 50% sludge, 50% green waste (by initial weight)
Total Number of Windrow Piles - 120 - 130
Total Number of Curing Piles - 30 - 40

EQUIPMENT AND PROCESS DESCRIPTION

A variety of wastes can be utilized as compost materials including manure, dewatered sewage sludge, wood chips, agricultural (or other) "green" wastes, and stable wastes. The materials are transported to the compost facilities where they can be mixed with organic bulking agents in order to improve porosity for the aerobic composting process. Bulking agents can be made up of a variety of organic or green wastes. The compost composition is thought to have an impact on emissions since the process is dependent on micro-biological activity and oxygen availability.

During the composting process, bacteria are allowed to decompose the mixture in a combination of aerobic and anaerobic activity. The dominating airborne by-product of aerobic activity is carbon dioxide. Airborne by-products of the anaerobic activity which are largely reduced compounds include relatively large amounts of methane and ammonia, and relatively smaller amounts of amines, hydrogen sulfide, other reduced sulfur compounds, and other hydrocarbons. The anaerobic activity is less desirable due to emissions of toxic and odor-causing compounds. Fugitive dust can be a direct source of PM-10 emissions, particularly during periods of high temperatures, high wind and low humidity.

The heat generated by the exothermic reactions raises the compost's internal temperature to 120-150°F. The heat also serves the purpose of reducing pathogenic activity. For composting, the mixture can be shaped into various configurations. Pile dimensions may vary greatly depending on application. The piles can also be aerated by a number of means.

At the Lost Hills facility, the compost is typically initially composed of 50% digested sewage sludge and 50% green waste by weight. The compost materials are generated predominantly from the Los Angeles area. The green waste is typically composed of municipal tree and shrub trimmings along with backyard waste from curbside recycling. For composting, the mixture is shaped into several windrow piles of a length of 500 ft and a trapezoidal cross-sectional area. The piles shrink in size as they proceed through the composting period due to the bacterial consumption of the organic material. The piles are turned over every one to three times per week using a diesel driven machine known appropriately as a Scarab. The Scarab straddles a pile as it mixes in air with large rotating till type blades as it travels down the length of the pile. The Scarab uses an adjustable hood to reshape the piles into the trapezoidal shape as it makes its 20-45 minute journey down the pile's length. This process continues typically for 57 days depending on space constraints. For space saving purposes the compost is then relocated to larger curing piles of approximately 20 ft height. Aeration is achieved in the curing piles by turning over with a back-hoe. The composting continues to a lesser degree in the curing piles until the desired consistency is achieved for up to six months and is shipped out as product demand dictates.

SAMPLING AND ANALYTICAL PROCEDURES

Compost Composition

A sample of the compost mix was analyzed for nitrate, ammonia, phosphate, minerals, salts, moisture, and bulk density. This analysis was performed by Soil and Plant Laboratory Inc., who performs analyses for the composting industry. Refer to the attached laboratory report for the results of the compost analysis. This analysis may prove useful in emissions evaluations with respect to compost composition.

EPA Emission Isolation Flux Chamber

The procedure for measuring emissions from the compost pile surfaces is a modified form of the procedures found in the US Environmental Protection Agency's (EPA) *Measurement of Gaseous Emission Rates from Land Surfaces Using an Emission Isolation Flux Chamber User's Guide.*

Under the EPA procedures, gaseous emissions from surface migration are collected from an isolated surface area with an enclosure device called an emission isolation flux chamber. Clean, dry sweep air or nitrogen is introduced to the flux chamber at a fixed, controlled rate (5.0 lit/min recommended) as a carrier where it mixes with the contaminants from the surface migration. The flux chamber encompasses a fixed surface area (1.4 ft^2), and is designed to isolate the surface from phenomena that can influence the air surface interface such as wind speed, other meteorological conditions, or properties of the waste itself. The flux chamber is sunk to a depth of one inch into the surface in order to create a seal between the flux chamber and the surface. The flux chamber and sweep air system is designed such that the contents are well mixed and no internal stratification exists. A probe is located in the flux chamber to extract a gaseous sample for subsequent analysis. The probe is of such a design that the sample represents a composite of various altitudes from within the flux chamber. Sampling is conducted at a rate of lesser than or equal to the sweep air rate. The remainder of the flux chamber contents are allowed to vent through a small opening located strategically on the flux chamber dome. For measuring flux chamber internal temperature, a thermocouple is also located within the flux chamber. Refer to Figure 1 for specifications and exact dimensions of the flux chamber design.

Modifications to the Flux Chamber Method

The Flux Chamber procedure is intended primarily for surface migration from landfills, hazardous waste treatment facilities, and hazardous spill remediation covered under the RCRA and CERCLA acts. The procedure assumes that gaseous emissions from the surface within the chamber area are much less than that of the sweep air rate. Under this assumption, mass emissions of a given contaminant is a product of the measured sample concentration and sweep air rate and reported per unit of surface area. Upon field evaluation of the flux chamber, it was discovered that the surface flux migration rate was more appreciable in the composting operation and could not be ignored as compared to the sweep air rate. The calculation of mass emissions of a given contaminant thus becomes a product of the measured sample concentration, sweep air rate, and surface migration rate. Furthermore this migration rate could not be directly measured due to the discovery that any attempt to employ a measuring device resulted in an impedance of the surface migration.

As an amendment to the EPA procedure, the surface migration rate must be determined. A procedure for calculating surface migration employs a material balance and concentrations taken from the sample analysis of an inert known component initially mixed into the sweep gas (refer to material balance section). For this reason, the sweep gas is composed of 10% helium (balance ultra-pure grade air) as a component to perform the analysis and material balance.

For the purposes of this test, the flux chamber's shell and sample path was constructed entirely of non reactive materials. Since sulfur compounds were measured, this also meant that metals of any kind could not be used in its construction to avoid catalytic decomposition. The following sampling specifications were used during testing:

Sweep Air Type:	10% Helium, 90% Air (99.999 % purity)
Sweep Air Rate:	5.0 lit/min
Bag Sampling Rate:	1.0 lit/min
Ammonia Sampling Rate:	1.0 lit/min
Amines Sampling Rate:	1.0 lit/min

Each sampling run was integrated over several points to insure representativeness. In order to account for general spatial variabilities, the flux chamber samples were drawn and integrated over several points

Modifications to the Flux Chamber Method (Con't.)

along the pile length for an averaging effect. This is also known as composite sampling. A evaluation of methane migration was conducted using a portable Flame Ionization Detector (FID) to determine spatial variations in emissions from the compost (Refer to page 20). The FID was also used to determine flux chamber period of equilibration with surface emissions for each sampling point. Equilibration was indicated by a steady plateau in the methane readings.

A small mixing fan is mounted within the flux chamber to ensure complete mixing within the flux chamber and allow for a homogeneous sample. The fan speed was set at approximately 110 rpm during all sampling and equilibration periods. A bench-top smoke study revealed that at 110 rpm, the fan can perform adequate mixing without affecting vertical surface migration.

Results are reported as concentration (ppm) in the flux chamber and emission rates are calculated in lb/hr-ft^2 of surface area. Final mass emission rates are reported on a per pile and per unit of compost basis using the pile dimensions within the facility. The number of sampling points used in each run and real time FID readings at each sampling point are presented on page 20 as well for statistical considerations. The FID readings are to be used primarily to indicate steady state and degree of point to point variability. For quantification purposes, the FID readings are considered to be less accurate than the sampling methods shown below.

Ammonia Sampling

An ammonia sample was collected during each sampling run from the flux chamber sample line using Draft SCAQMD Method 207.1. The midget sampling train consisted of two midget impingers each filled with 15 ml of 0.1N Sulfuric Acid, an empty bubbler, and a bubbler filled with tared silica gel, as shown in Figure 2. A minimal amount of condensation was observed in the sample line leading to the ammonia train. The impingers and bubblers were contained in an ice bath to condense ammonia, water vapor, and other condensable matter present in the sample stream.

Ammonia Sampling (Con't.)

The samples from the 3 day pile were collected for a period of 18 minutes over six sampling points before turning and 12 minutes over four sampling points after turning at a sampling rate of 1.0 lit/min. The samples taken from the 45 and 57 days piles were each collected for approximately 24 minutes over eight sampling points before turning and 15 minutes over five sampling points after turning at a sampling rate of 1.0 lit/min.

The SCAQMD laboratory analyzed for ammonia deposited in the impingers as ammonium by ion chromatography. Moisture gain was determined volumetrically in the impingers, and gravimetrically in the silica gel. Ammonia concentration in the flux chamber was determined using the ammonia content collected in the impingers, along with the sampling rate and net elapsed sampling time.

A blank field sample train from each of the three sampling days was analyzed in a manner consistent with the above analysis for quality control purposes.

Amines Sampling

An amines sample was collected during each "before turning" sampling run from the flux chamber sample line using the Ninhydrin Method. This method will detect primary and secondary but not tertiary amines which are not expected to be significant. The sampling train consists of two midget impingers, each filled with 10 ml of acidified isopropanol, an empty bubbler, and a bubbler filled with tared silica gel. The silica gel impinger is connected to the vacuum side of a leak-free sample pump and a calibrated rotameter, as shown in Figure 3. The impingers and bubblers were contained in an ice bath to condense amines, water vapor, and other condensable matter present in the sample stream.

The sample was collected for the same time period as the “before turning” ammonia samples at a sampling rate of 1.0 lit/min.

The contents of the impingers were reacted with a 0.2% Ninhydrin (1,2,3 tri-ketohydrindene) in isopropanol reagent to produce "Ruhemann's purple." The SCAQMD laboratory then analyzed for primary and secondary amines using a spectrophotometer and Beer's law. Moisture gain was determined volumetrically in the impingers, and gravimetrically in the silica gel for quality control purposes. Amines concentration in the flux chamber was determined using the amines content collected in the impingers, along with the sampling rate and net elapsed sampling time. The results are reported as n-butyl amine. A blank field sample reagent was analyzed in a manner consistent with the above analysis for quality control purposes.

Integrated Gas Sampling

An integrated gas sample was collected during each "before turning" sampling run from the flux chamber sample line using the vacuum side of a leak-free sample pump and a calibrated rotameter. These samples were collected in Tedlar bags as shown in Figure 4. The contents of the Tedlar bags were analyzed for organic sulfur compounds. Due to the reactivity of the sulfur compounds, that analysis was performed within 4 hours of sampling. The gases were separated by gas chromatography. Selected toxic sulfur compounds were analyzed using a flame photo-ionization detector.

Modified Method 25.1 - Non-Methane Organics

An integrated gas sample was collected during each "before turning" sampling run from the flux chamber using a modified 25.1 sampling apparatus. The apparatus consists of small Teflon impinger containing 5 ml of HPLC grade water connected to a six liter summa polished canister as shown in Figure 5. This method has recently been recognized in the source testing community as the method of choice for low concentration organics. This is the only currently known method of detecting both condensable and gaseous organic emissions with acceptable precision at low concentration. This method is used for non-methane organics concentration below 25 ppm.

Results were reported as Total Gaseous Non-Methane Organic Compounds (TGNMOC). The liquid within the impinges was analyzed with an infrared total carbon analyzer. The contents of the canister were analyzed using the gaseous analytical procedure of existing SCAQMD Method 25.1 by the total combustion analysis (TCA) technique using a flame ionization detector (FID). Since it was discovered after analysis that the concentrations of non-methane organics were all above 25 ppm, the results of the Modified Method 25.1 were discarded in favor of the standard Method 25.1 results (see next section).

Method 25.1 - Non-Methane Organics

Integrated gas samples were taken during each "before turning" sampling run from the flux chamber using SCAQMD Method No. 25.1. Duplicate gas samples were collected in dry ice cooled condensate traps and in nine liter evacuated tanks (Figure 6). This method is used for non-methane organics concentration above 25 ppm.

The contents of the traps and the tanks were analyzed at the SCAQMD laboratory for CO, CO_2, O_2, CH_4 and total gaseous non-methane organic compounds (TGNMOC). CO, CH_4 and TGNMOC concentrations were analyzed by the total combustion analysis (TCA) technique using a flame ionization detector (FID); SCAQMD Method No. 25.1. The O_2 and CO_2 concentrations were determined by gas chromatography (GC) using a thermal conductivity detector (TCD).

Compost Internal Temperature

The compost was monitored with a type “K” thermocouple at various depths in the compost at each of the locations the sampling took place. Results were reported as an average temperature encountered at each location. The results are reported on page 20.

TEST CRITIQUE

The test was conducted under normal operating conditions on a pre-arranged basis.

Refer to “Soil and Plant Laboratory, Inc.” Analysis sheet for compost composition.

Sulfur compounds were not analyzed for the 45 day pile due to staffing difficulties within the SCAQMD laboratory on that day. Results are reported without the contribution of the 45 day pile sulfur compounds.

The "after-turning" sampling does not include emissions while turning but those a few minutes after turning. Emissions during turning were not determined due to difficulties in obtaining representative samples under the turning conditions. The turning process has been observed to cause a strong but short burst of emissions based on the observation of a steam plume and strong odors. Because of this, the estimations developed in the report are assumed to underestimate actual emissions by an unknown amount.

Other factors such as EPA reported potential 20% low bias in the flux chamber method and possible condensation in the sampling lines can also be responsible for a low bias. It should be noted that for

TEST CRITIQUE (Con't)

purposes of establishing emissions baseline estimates and subsequent emissions reduction estimates that a low bias will always occur.

A heavy rain event occurred one or two days before the 3 day pile sampling. This had the effect of increasing both compost mass and moisture content over the original compost mixture, and over the 45 and 57 day piles which were sampled during dryer periods. Higher TGNMOC and methane emissions from the 3 day pile supports the theory that compost moisture has a great effect on emissions and anaerobic activity.

During the March 11 sampling event, some of the material in the green waste stockpile area in the facility was observed to be spontaneously combusting. The "smoldering" effect, according to the facility, was caused by dry high winds from the previous night. This phenomena was observed to generate an indeterminable amount of white smoke which may result in a potential source of direct PM-10 emissions. The effect did not occur on the windrow compost that was sampled.

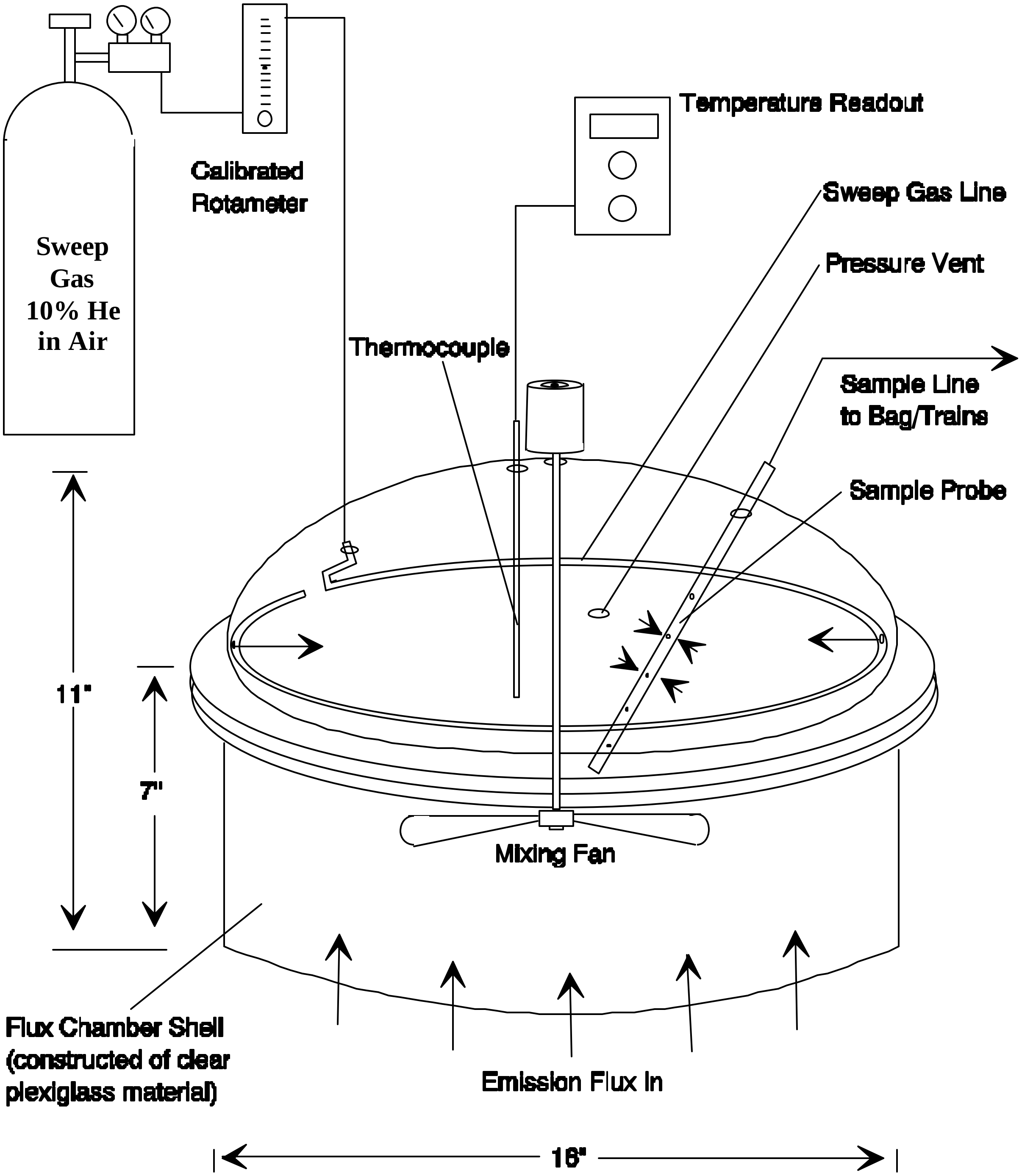


Figure 1 Emission Isolation Flux Chamber

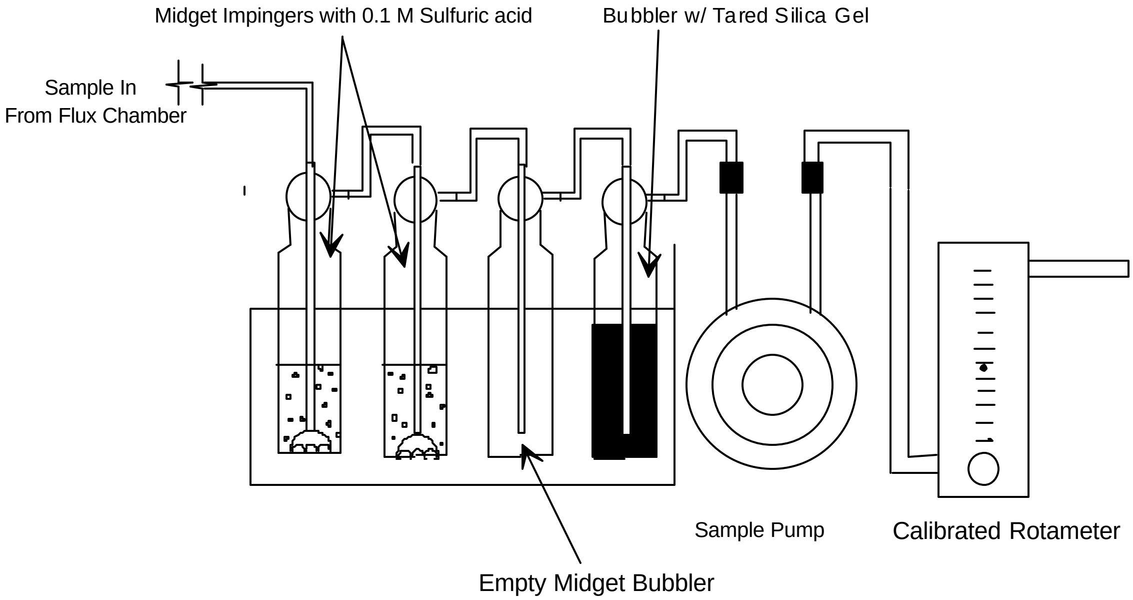


Figure 2 Ammonia Midget Sampling Train

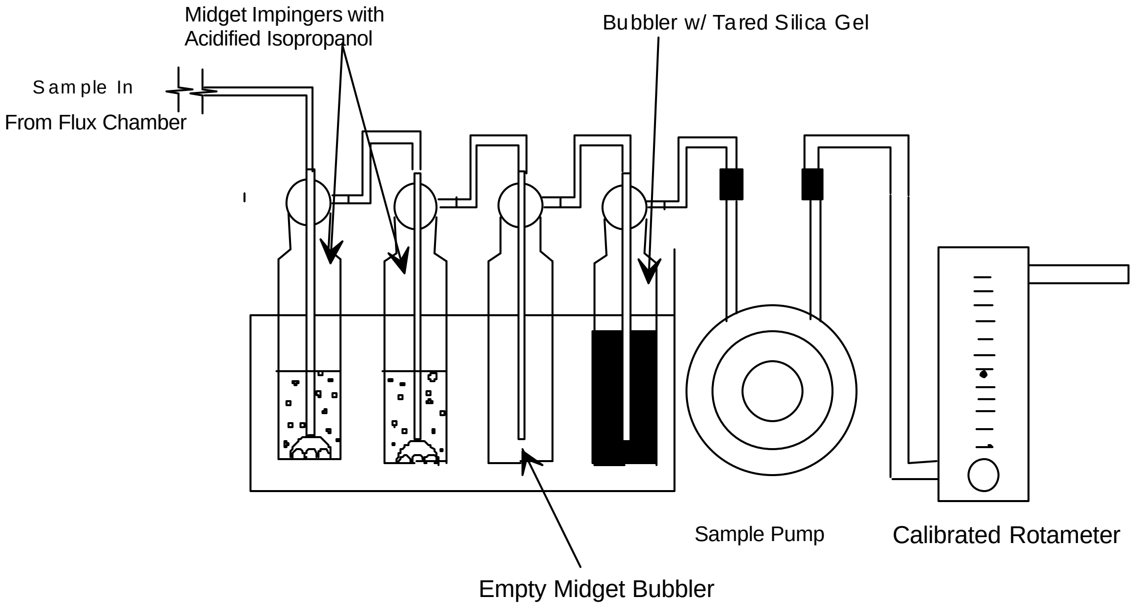


Figure 3 Amines Midget Sampling Train

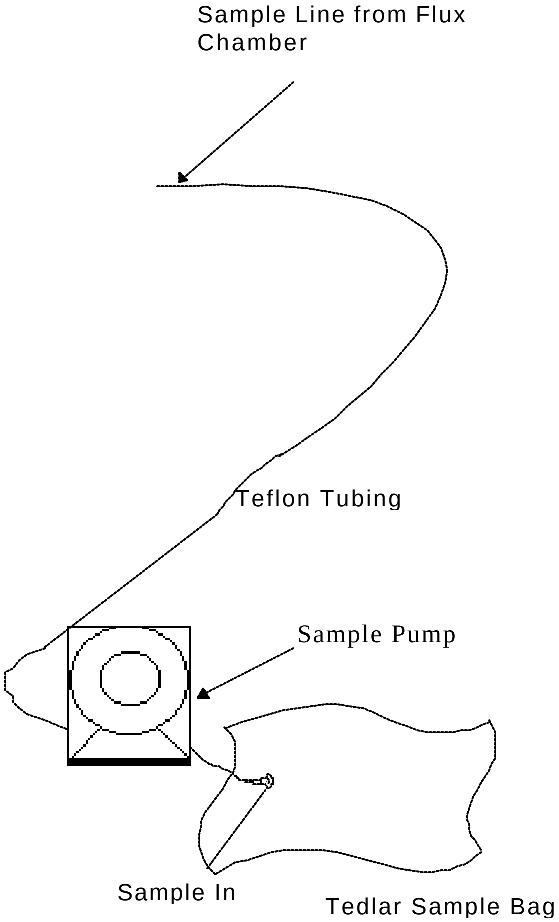


Figure 4 Integrated Gas Sampling Apparatus

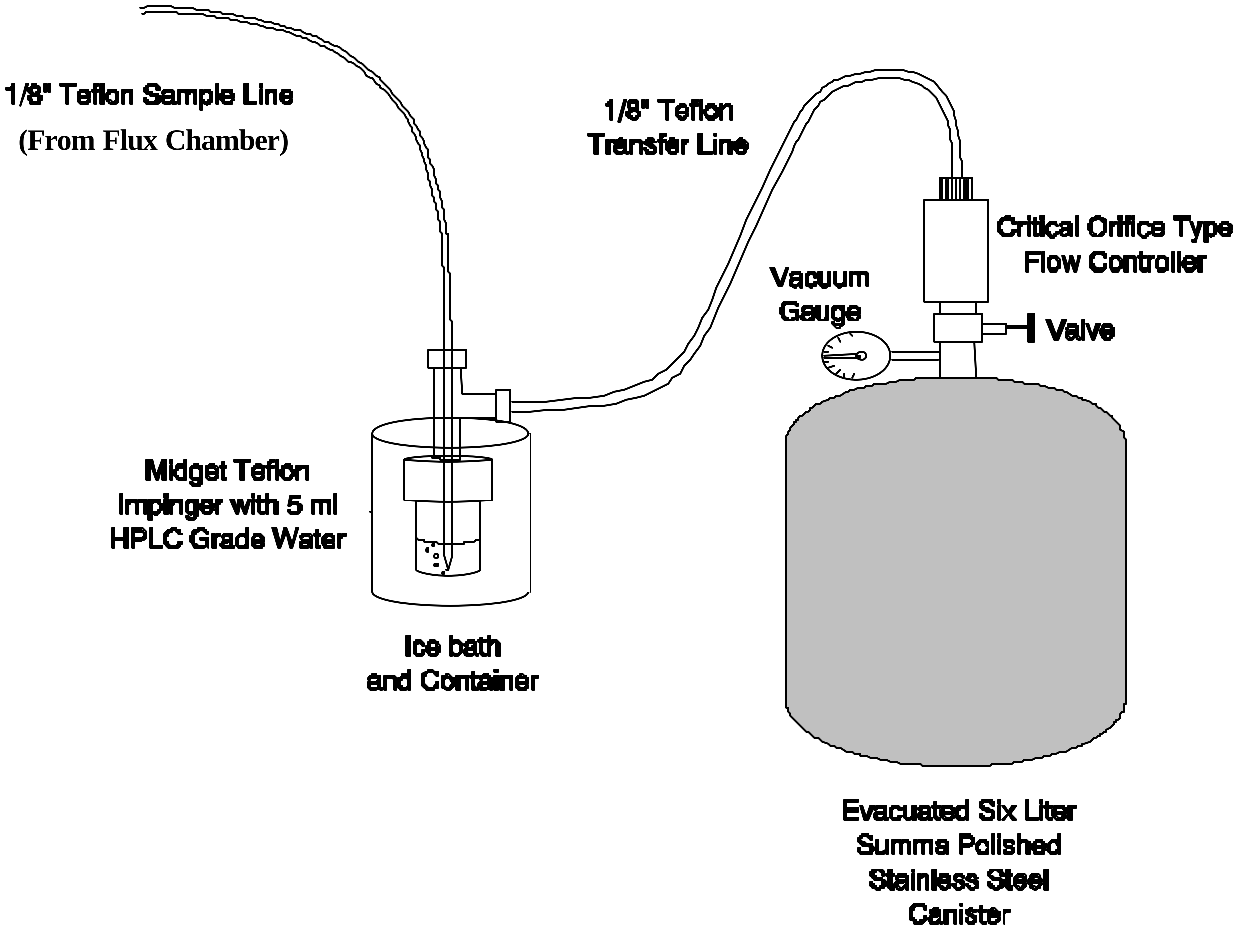


Figure 5 Modified 25.1 Sampling Apparatus

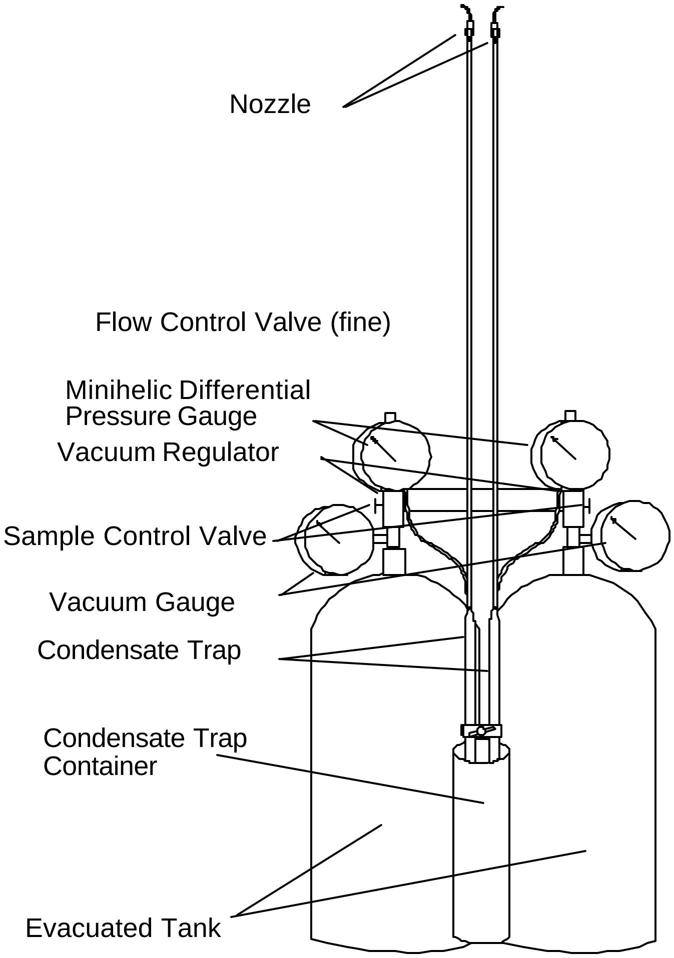


Figure 6 Method 25.1 Sampling Apparatus

Number of Sampling Points, Compost Temp. and FID Readings at Each Sampling Point

Before Turning

3 Day Pile

Sampling Point Zone #	FID Reading (ppm)	Internal Temp. (^{o} F)
1	45	120
2	110	120
3	4,500	99
4	7,000	104
5	2,900	94
6	500	114
7	N/A	N/A
8	N/A	N/A
9	N/A	N/A

45 Day Pile

Sampling Point Zone #	FID Reading (ppm)	Internal Temp. (^{o} F)
1	11	153
2	6	159
3	7	121
4	3	148
5	80	125
6	4	148
7	2.5	159
8	35	153
9	N/A	N/A

57 Day Pile

Sampling Point Zone #	FID Reading (ppm)	Internal Temp. (o F)
1	2.3	137
2	2.1	129
3	2.2	137
4	2	102
5	4	122
6	4.5	90
7	2.5	104
8	2.1	115
9	N/A	N/A

After Turning

3 Day Pile

1	150	97
2	200	100
3	500	110
4	110	119
5	N/A	N/A

45 Day Pile

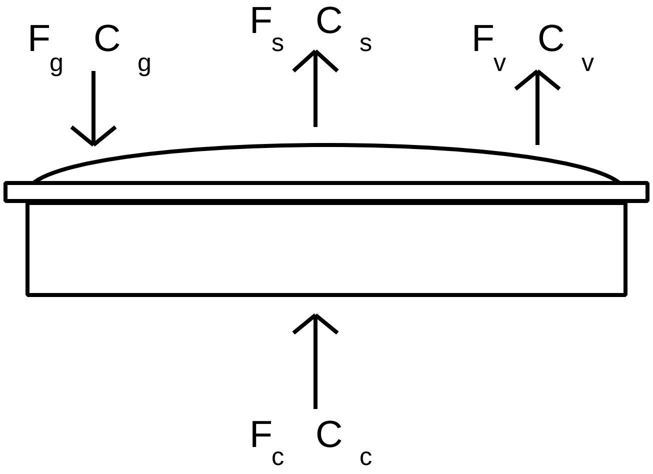
1	20	143
2	110	151
3	18	130
4	11	146
5	5	156

57 Day Pile

1	11	135
2	2	140
3	3	145
4	2	138
5	N/A	N/A

Material Balance for Compost Surface Migration Rate

For calculating the compost surface migration rate, a helium material balance was performed around the flux chamber. Helium was the chosen constituent because of inert properties and its ease of accurate analysis. The material balance is derived as follows:



Where:

F_g = Sweep Gas Flow Rate (measured)

C_g = Sweep Gas Helium Concentration (analyzed)

F_s = Sample Flow Rate (measured)

C_s = Sample Helium Concentration (analyzed)

F_v = Vent Flow Rate (unknown)

C_v = Vent Helium Concentration (assume = C_s)

F_c = Compost Surface Migration Flow Rate (unknown)

C_c = Compost Surface Migration Helium Concentration (assumed zero)

Flow Balance:

$$F_v = F_c + F_g - F_s$$

Helium Balance:

$$F_c C_c + F_g C_g = F_s C_s + F_v C_v$$

Material Balance for Compost Surface Migration Rate (continued)

Substitute:

$C_c = 0$

$C_v = C_s$

F_v = Flow Balance

then:

$$F_gC_g = F_sC_s + (F_c + F_g - F_s)C_s$$

$$F_gC_g - F_cC_s = F_sC_s + F_gC_s - F_sC_s$$

$$F_cC_s = F_gC_g - F_gC_s$$

$$F_c = \frac{F_g(C_g - C_s)}{C_s}$$

EMISSION ESTIMATION CALCULATIONS

Windrow emissions are based on the surface area of the windrows and the results of the flux chamber sampling reported per unit of surface area. The weighted average for ammonia assumes that the windrows emit at the elevated "after turning" emission rate for 90 minutes and that the piles are turned 2.5 times per week. Piles emit “after turning” rates 2.2% of the time. The facility wide emissions do not include curing pile emissions and are calculated using the average of the three windrow ages.

The following data was used for the calculations:
Pile Height - 5’ (3 Day), 4.5’ (45 Day), 4’ (57 Day)
Pile Width at Base - 18’
Pile Width at Top - 8’
Pile Length - 450’
Pile Side Length - 7.1’ (3 Day), 6.7’ (45 Day), 6.4’ (57 Day)
Pile Surface Area - 9,990 ft^2 (3 Day), 9,630 ft^2 (45 Day), 9,360 ft^2 (57 Day)
Avg. Pile Surface Area - 9,660 ft^2
Pile Volume - 29,250 ft^3 (3 Day), 26,325 ft^3 (45 Day), 23,400 ft^3 (57 Day)
Density - 1,200 lb/yd^3 (3 Day), 1,014 lb/yd^3 (45 Day), 972 lb/yd^3 (57 Day)
Mass - 650 tons (3 Days),
Original Pile Mass from Losthills scale - 500 tons*
Total Number of Windrow Piles - 125 - 130
Time in Windrow - 57 Days

NH_3 weighted average = (NH_3 before turning $*$ 0.978) + (NH_3 after turning $*$ 0.022)

For 3 - Day

NH_3 Weighted Avg. = (1.54E-04 x 0.978) + (1.38E-04 x 0.022) = 1.54E-04 $lb/hr\text{-}ft^2$

For 45 - Day

NH_3 Weighted Avg. = (1.46E-04 x 0.978) + (1.62E-04 x 0.022) = 1.46E-04 $lb/hr\text{-}ft^2$

For 57 - Day

NH_3 Weighted Avg. = (1.42E-05 x 0.978) + (2.65E-04 x 0.022) = 1.97E-05 $lb/hr\text{-}ft^2$

Avg. of Weighted Average = 1.07E-04 $lb/hr\text{-}ft^2$

** Difference between calculated mass at 3 days and measured mass at 0 days can be attributed to moisture gain due to rain event.*

Averages:*

Contaminant	Annual Emissions	Emissions per ton of Compost Mix	Mass Rate per 1000 ft^2 of Compost	Mass Rate per row	Mass Rate per lb/hr-ton
Ammonia	577 ton/year	2.81 lb/ton mix	0.107 lb/hr-1000ft^2	1.03 lb/hr	2.07E-03 lb/hr-ton
Amines	39 ton/year	0.19 lb/ton mix	6.0E-03 lb/hr-1000 ft^2	0.07 lb/hr	1.17E-04 lb/hr-ton
Methane	6,862 ton/year	33.49 lb/ton mix	1.23 lb/hr-1000ft^2	12.24 lb/hr	2.4E-02 lb/hr-ton
TGNMOC	639 ton/year	3.12 lb/ton mix	0.11 lb/hr-1000ft^2	1.14 lb/hr	2.28E-03 lb/hr-ton
Total Sulfur Compounds	45 ton/year	0.22 lb/ton mix	8.42E-03 lb/hr-1000ft^2	0.081 lb/hr	1.63E-04 lb/hr-ton

Ton/Yr = lb/hr ∗ 128 windrow piles ∗ 24 hr/day ∗ 365 day/yr ∗ ton/2,000 lb

Lb/Ton Compost = lb/hr ∗ pile/500 ton ∗ 24 hr/day ∗ 57 day

Lb/Hr-1000 FT^2 = (Avg. lb/hr-ft^2) ∗ 1,000

Lb/Hr = (Avg. lb/hr-ft^2) ∗ (Avg. Pile Surface Area)

Lb/Hr-Ton = (Avg. lb/hr-ft^2) ∗ (Avg. Pile Surface Area) / Original Pile Mass

* Rain event before 3-day pile test. See test critique.