Technical **Memorandum**

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SUBJECT: Methane and Carbon Dioxide Emissions from Greenwaste Composting

Overview

The methane and carbon dioxide emissions from greenwaste composting were calculated using source test data from two greenwaste sites located in Central California. The source test was for VOC using the South Coast Air Quality Management District (SCAQMD) Method 25.3. This method reports both carbon dioxide and methane concentrations as part of the VOC assessment. The ambient carbon dioxide concentration was found to be too high at greenwaste compost sites to get an accurate carbon dioxide value. The carbon dioxide emitted by the neighboring windrow appeared to be drawn in to the test windrow and produced values exceeding the mass balance values. Therefore carbon dioxide was calculated using a mass balance.

Background

The USEPA Surface Emission Isolation Flux Chamber was used to quantify air emissions from two greenwaste compost facilities using the SCAQMD Rule 1133.2 Sampling Protocol. Photo 1 shows the flux chamber during the test. These composting sites used mechanically mixed windrows to compost typical greenwaste (lawn trimmings, landscape waste, brush, etc.). However, the type of feedstock received at these facilities can vary widely and have a dramatic effect on the compost process and compost emissions. The data from Site 1 represents the most accurate sampling data because it is the most recent data. The flux chamber has been continually modified to improve its performance in assessing compost emissions. The Site 1 data reflects the current state-of-the-art in flux chamber testing technology. The critical issue for compost emissions testing is the measurement of the total flow through the chamber, since the windrows are well ventilated. A helium tracer is introduced with the flux chamber sweep air to measure this flow. The mixing of this tracer at high flow rates is the most challenging aspect of the testing technology. The Site 1 test used an advanced mixing system in the flux chamber to assure that the tracer is completely mixed with the sample gas stream.

Photo 1. Flux Chamber Sampling on Compost Windrows.

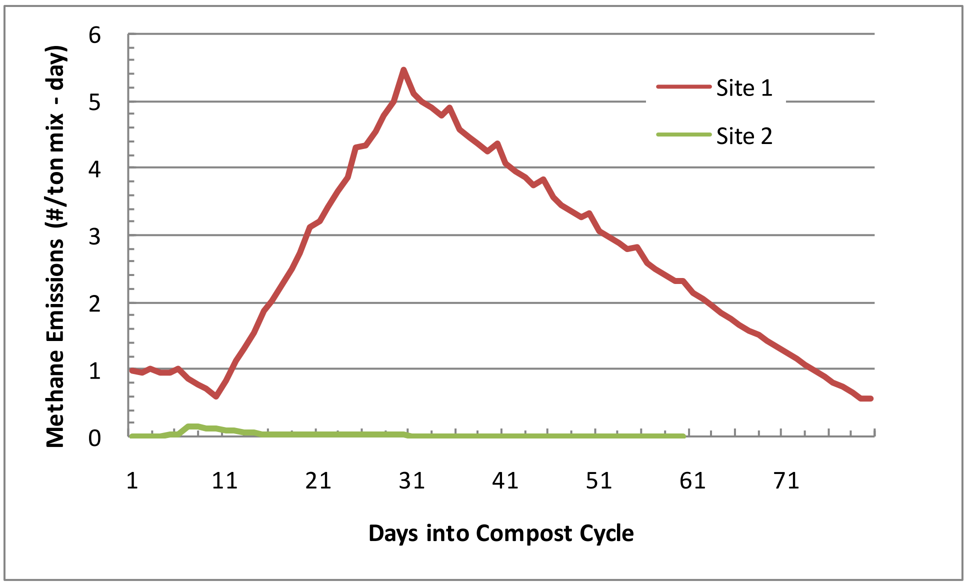
Results

Table 1 shows the results of this analysis. Site 1 had significantly more methane than Site 2. Methane emissions are normally attributed to anaerobic activity so it suggests that Site 1 had more anaerobic activity than Site 2. Figure 1 shows that the methane emissions for Site 2 peaked at the end of the normal compost cycle (30 days) and then gradually decreased during the cure cycle (second 30 days).

Table 1. – Greenhouse Gas Emissions from Greenwaste Composting (# per ton of wet feed).

Constituent	Site 1	Site 2
Methane	206	1.4
Carbon Dioxide	1,087	1,537

Figure 1. – Methane Emissions from Greenwaste Composting (# per ton of wet feed).



Calculation Methodology

Emissions were measured from compost windrows on selected days of the full compost cycle. Site 1 was on an 80 day cycle and Site 2 was on a 60 day cycle. The methane emissions from the test days were then interpolated to daily emissions from each site. The windrows were mixed on three to five day schedules and the emissions during the mixing events was measured. The full profile emissions curves show those mixing events as little bumps on the curve. The total methane emissions were calculated based on the individual daily methane emissions.

Carbon dioxide emissions were calculated using a mass balance. It was assumed that the average mass reduction in greenwaste composting was 35%. The assumed reaction[1] for carbon dioxide production was as follows:

$2\ C_{27}H_{38}O_{16}N + 57\ O_2 \rightarrow 54\ CO_2 + 38\ H_2O + 2\ NH_3$

Mw → *1,264* *1,936*

This means that for every pound of substrate reduction, either 0.684 pounds of methane are produced or 1.53 pounds of carbon dioxide are produced. Therefore the equation to calculate carbon dioxide emissions from methane emissions is:

$$M_{CO2} = \left((F_R * 2000) - \frac{M_{CH4}}{0.684} \right) * 1.53$$

Where F_R is the mass fraction substrate reduced during the composting process (35%), M_{CH4} the mass of methane emissions, and M_{CO2} is the mass of carbon dioxide emissions.

Discussion

The variability of these two measurements was greater than desired. The Site 1 data should be the most accurate, but it is likely that the Site 2 data is valid as well. The most likely cause of the variability was the operation of the compost facility, and particularly the type of feedstock that the facility was composting at the time. Both facilities produce a high quality product, but a feedstock that rapidly depletes oxygen levels will likely produce more methane due to the higher level of anaerobic activity. Emissions measurement technology differences are highly unlikely to be the sole cause of the variable methane emissions.

References

1. Kayhanian, M and G. Tchobanoglous. Computation of C/N Ratios for Various Organic Fractions. BioCycle 33(5) May 1992.

Attachment 1 – Tabular Daily Emissions.

	Methane Emisions (#/day-ton mix)	
Compost Day	Site 1	Site 2
1	0.96	0.00
2	0.96	0.00
3	1.00	0.01
4	0.95	0.01
5	0.95	0.02
6	0.99	0.02
7	0.86	0.14
8	0.77	0.13
9	0.71	0.11
10	0.59	0.10
11	0.83	0.09
12	1.12	0.07
13	1.31	0.06
14	1.55	0.04
15	1.88	0.03
16	2.03	0.03
17	2.26	0.03
18	2.50	0.03
19	2.73	0.03
20	3.11	0.03
21	3.19	0.03
22	3.42	0.03
23	3.65	0.03
24	3.87	0.02
25	4.30	0.02
26	4.32	0.02
27	4.55	0.02
28	4.77	0.02
29	4.99	0.02
30	5.47	0.02
31	5.10	0.01
32	4.99	0.01
33	4.89	0.01
34	4.78	0.01
35	4.91	0.01
36	4.57	0.01
37	4.47	0.01
38	4.36	0.01
39	4.26	0.01
40	4.36	0.01
41	4.05	0.01
42	3.95	0.01
43	3.85	0.01
44	3.75	0.01
45	3.83	0.01
46	3.55	0.01
47	3.45	0.01
48	3.36	0.01
49	3.26	0.01
50	3.32	0.01
51	3.06	0.01
52	2.97	0.01
53	2.87	0.01
54	2.78	0.01
55	2.81	0.01
56	2.59	0.01
57	2.49	0.01
58	2.40	0.01
59	2.31	0.01
60	2.32	0.01
61	2.12	
62	2.03	
63	1.94	
64	1.85	
65	1.76	
66	1.67	
67	1.58	
68	1.49	
69	1.41	
70	1.32	
71	1.23	
72	1.15	
73	1.06	
74	0.98	
75	0.89	
76	0.81	
77	0.72	
78	0.64	
79	0.56	
80	0.56	
Total CH4	206	1.4
CO2 =	610	1,068

Attachment 2 – Tabular Raw Data for Site 1.

SOURCE	MPO	TEST LOCAT	25.3	207.1	CO2	Methane	Ethan	TNMNE	NMNEO	NMNEO	NH3	NH3 Vol	NH3	Helium	Trace	Total Flo	SF6 U	SF6 D	CO2	Methane	TNMNEO	NH3	SOURCE
	DAY		ID	ID	(ppmv)	(ppmv)	(ppmv	(ppmv)	(ppmv)	(ppmv)	(mg)	(m3)	(mg/m3	%	%	(m3/min)	(ppbv)	(ppbv)	Flux	Flux	Flux	Flux	
Windrow Compost	10	Top- T1	G-101	A-101	3912	27.4	ND	12.2	6.06	6.12	0.365	0.0295	12.4	10.31	0.20	0.2578	N/A	N/A	13,651	35.47	16	25	Windrow Compost
Windrow Compost	10	Top-T2	G-102	A-102	3790	16.7	ND	11.8	11.2	1.0	0.489	0.0268	18.2	10.22	0.27	0.1893	N/A	N/A	9,711	15.88	11	27	Windrow Compost
Windrow Compost	10	Side- S1	G-103	A-103	6000	93	ND	21.0	20.1	1.0	0.278	0.0282	9.9	10.20	0.23	0.2217	N/A	N/A	18,012	103.58	23	17	Windrow Compost
Windrow Compost	10	Side- S2	G-104	A-104	4000	17.2	ND	4.25	3.58	1.0	0.055	0.0248	2.2	10.33	0.19	0.2718	N/A	N/A	14,721	23.49	5.8	4.6	Windrow Compost
Windrow Compost	6	Top- T1	G-105	A-105	3554	10	ND	17.7	17.2	1.0	0.505	0.0311	16.2	10.33	0.27	0.1913	N/A	N/A	9,204	9.49	17	24	Windrow Compost
Windrow Compost	6	Side- S1	G-106	A-106	5000	65	ND	9.94	9.37	1.0	0.029	0.0303	0.96	10.31	0.16	0.3222	N/A	N/A	21,810	105.52	16	2.4	Windrow Compost
Windrow Compost- Post Mix Hr-1	10	Top- T1	G-107	A-107	5000	14.9	ND	5.62	4.89	1.0	0.113	0.0295	3.8	10.20	0.15	0.3400	N/A	N/A	23,015	25.45	9.6	10	Windrow Compost- Post Mix Hr-1
Windrow Compost- Post Mix Hr-1	10	Side- S1	G-108	A-108	9000	65.7	ND	10.6	9.45	1.14	0.239	0.0332	7.2	10.22	0.19	0.2689	N/A	N/A	32,770	88.76	14	15	Windrow Compost- Post Mix Hr-1
Windrow Compost- Post Mix Hr-3	10	Top- T1	G-111	A-111	3207	11.5	ND	5.77	5.23	1.0	0.123	0.0271	4.5	10.20	0.12	0.4250	N/A	N/A	18,453	24.55	12	15	Windrow Compost- Post Mix Hr-3
Windrow Compost- Post Mix Hr-3	10	Side- S2	G-112	A-112	7000	48.7	ND	7.15	5.65	1.49	0.202	0.0254	8.0	10.22	0.16	0.3194	N/A	N/A	30,267	78.13	11	20	Windrow Compost- Post Mix Hr-3
Windrow Compost	30	Top- T1	G-109	A-109	3004	58.3	ND	5.97	5.57	1.0	0.050	0.0130	3.8	10.33	0.28	0.1845	N/A	N/A	7,502	54.02	5.5	5.5	Windrow Compost
Windrow Compost	30	Side- S1	G-110	A-110	5000	574	ND	6.65	5.82	1.0	0.002	0.0103	0.19	10.31	0.24	0.2148	N/A	N/A	14,540	619.30	7.2	0.32	Windrow Compost
Windrow Compost- Post Mix Hr-5	10	Top- T1	G-113	A-113	3219	19.3	ND	3.91	3.34	1.0	0.089	0.0231	3.9	10.20	0.12	0.4250	N/A	N/A	18,522	41.20	8.3	13	Windrow Compost- Post Mix Hr-5
Windrow Compost- Post Mix Hr-5	10	Side-2	G-114	A-114	5000	42.0	ND	5.19	4.14		0.163	0.0219	7.4	10.22	0.18	0.2839	N/A	N/A	19,217	59.89	7.4	16	Windrow Compost- Post Mix Hr-5
Windrow Compost	79	Top- T1	G-115	A-115	14000	100	ND	5.41	2.91		0.011	0.0587	0.19	10.31	0.47	0.1097	N/A	N/A	20,789	55.09	3.0	0.16	Windrow Compost
Windrow Compost	79	Side- S2	G-116	A-116	8000	79.60	ND	5.70	4.27		0.009	0.0588	0.15	10.33	0.30	0.1722	N/A	N/A	18,647	68.84	4.9	0.20	Windrow Compost
Windrow Compost- Prep Pile	0	Top- T1	G-117	A-117	2291	2.13	ND	27.6	27.6	1.0	0.004	0.0509	0.08	10.20	0.19	0.2684	N/A	N/A	8,326	2.87	37	0.16	Windrow Compost- Prep Pile
Windrow Compost- Prep Pile	0	Side- S1	G-118	A-118	5000	47.20	ND	116	115	1.0	0.013	0.0512	0.25	10.20	0.16	0.3188	N/A	N/A	21,577	75.57	186	0.62	Windrow Compost- Prep Pile
Sample Replicate	0	Side- S1	G-119	A-119	5000	46.70	ND	106	105	1.0	0.013	0.0605	0.21	10.20	0.16	0.3188	N/A	N/A	21,577	74.77	170	0.53	Sample Replicate
Media Blank	N/A	N/A	G-120	A-120	1.57	1.0	ND	1.0	1.0	1.0	0.004	0.0540	0.074	10.20	10.7	0.005	N/A	N/A	0	0.025	0.025	0.0028	Media Blank

Attachment 3 – Tabular Raw Data for Site 2.

SOURCE	PID (pmv)	FID (pmv)	NH3 (ppmv)	25.3 ID	Methane (ppmvC)	Ethane (ppmvC)	TNMNEO (ppmvC)	NMNEO Trap (ppmvC)	NMNEO Tank (ppmvC)	NH3 ID	NH3 (mg)	NH3 Vol (m3)	NH3 (mg/m3)	Odor (D/T)
Windrow Composting; Day 1, Pile G5	240	1100	0.2	G/L-116	2.15	ND	913	785	128	A-116	0.08	0.0595	1.3	
Windrow Composting; Day 3, Pile G5	NA	NA	3	G/L-302	18.2	ND	2,316	1,082	1,234	A-302	0.53	0.0616	8.6	
Windrow Composting; Day 6, Pile G3	NA	NA	10	G/L-110	64.0	2.33	1441	1441	2.33	A-110	0.10	0.0614	1.6	
Windrow Composting; Day 7, Pile G3, Top of windr	NA	NA	100	G/L-202	618	ND	90.8	63.4	27.4	A-202	1.3	0.0645	20	
Windrow Composting; Day 7, Pile G3, Middle heigh	NA	NA	20	G/L-205	6.14	ND	21.0	11.4	9.60	A-205	0.40	0.0485	8.2	
Windrow Composting; Day 7, Pile G3, Bottom of wi	NA	NA	8	G/L-206	18.9	ND	7.98	7.11	<2	A-206	0.19	0.0641	3.0	
Windrow Composting; Day 15, Pile G24	1.1%	11	4	G/L-115	9.48	ND	6.81	4.73	2.08	A-115	0.03	0.0481	0.62	
Windrow Composting; Day 30, Pile G10	9500	120	10	G/L-114	91.6	ND	29.8	13.8	16.0	A-114	0.36	0.0618	5.8	
Windrow Composting; Day 50, Pile G4	NA	NA	27	G/L-111	18.7	ND	10.2	9.28	<2	A-111	Broken	0.0541	N/A	
Windrow Composting Pile; Unspecified age, Top lo	NA	NA		G/L-211	5009	ND	308	166	142	A-211	0.41	0.0466	8.8	
Windrow Composting Pile; Unspecified age, Side lo	NA	NA	2	G/L-210	2.03	ND	9.07	7.65	<2	A-210	0.06	0.0630	0.95	
Windrow Composting Pile; Unspecified age, Side lo	NA	NA	1	G/L-120	39.9	ND	1,018	711	307	A-120	0.35	0.0643	5.4	

SOURCE	SF6 Trace (ppbv)	SF6 (ppbv)	Total Flow (lpm)	Total Flow (m3/min)	Methane Flux	TNMNEO Flux	Odor Flux	NH3 Flux	Ports	Area (m2)	CH4 mg/min	VOC (mg/min)	NH3 (mg/min)
Windrow Composting; Day 1, Pile G5	104	25	20.8	0.021	0.21	94	N/A	0.22		403	84	37,992	87
Windrow Composting; Day 3, Pile G5	105	16	32.81	0.033	2.8	376	N/A	2.2		403	1,116	151,445	879
Windrow Composting; Day 6, Pile G3	104	25	20.8	0.021	6.2	149	N/A	0.26		403	2,497	59,963	106
Windrow Composting; Day 7, Pile G3, Top of windr	104	11	47.27	0.047	134	21	N/A	7.3		403	53,959	8,456	2,933
Windrow Composting; Day 7, Pile G3, Middle heigh	105	14	37.5	0.038	1.1	4	N/A	2.4		403	433	1,581	970
Windrow Composting; Day 7, Pile G3, Bottom of wi	104	26	20	0.02	1.7	1	N/A	0.46		403	702	316	184
Windrow Composting; Day 15, Pile G24	104	2.4	216.7	0.217	9.5	7	N/A	1.0		403	3,822	2,928	419
Windrow Composting; Day 30, Pile G10	104	32	16.25	0.016	6.8	2	N/A	0.72		403	2,723	945	289
Windrow Composting; Day 50, Pile G4	104	22	23.64	0.024	2.1	1	N/A	0.500		403	834	485	201
Windrow Composting Pile; Unspecified age, Top lo	104	17	30.59	0.031	717	47	N/A	2.1		403	288,461	18,920	844
Windrow Composting Pile; Unspecified age, Side lo	105	6.3	83.33	0.083	0.78	4	N/A	0.61		403	313	1,492	245
Windrow Composting Pile; Unspecified age, Side lo	104	24	21.67	0.022	4.1	110	N/A	0.92		403	1,631	44,379	371