Final Report

Odor, hydrogen sulfide, and ammonia emissions from the composting of caged layer manure

To

Broiler and Egg Association of Minnesota
2380 Wycliff Street
St. Paul, MN 55114

Principal Investigator: David Schmidt, Extension Engineer
Department of Biosystems and Agricultural Engineering
1390 Eckles Avenue
St. Paul, MN 55108
Phone: 612-625-4262

Organization: University of Minnesota

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Project Objective:
Document changes in odor, hydrogen sulfide, and ammonia emission from an existing compost operation in response to changes in the initial compost mixture.

Background:
In 1998, the Department of Biosystems and Agricultural Engineering studied the impact of composted layer hen manure on fly breeding potential and quantified the odor, ammonia, and hydrogen sulfide emission rate during the compost process. This research was done at a full-scale layer hen manure composting site in Clay County Minnesota. Research results and anecdotal evidence suggest that composting reduced the fly breeding potential of fresh manure. However, odor emissions were thought to be higher than desirable based on farm management observations and neighbor complaints.

Project Description:
This project was designed to determine if changes in the initial compost mixture affect odor and gas emissions during composting. It is believed that increasing the carbon:nitrogen ratio, decreasing the moisture content, and increasing the porosity of the initial composting mixture reduces odor, hydrogen sulfide, and ammonia emissions.

This research was conducted at the same site in Clay County Minnesota that was monitored in 1998. At this site, manure from 250,000 laying hens (approximately 180 tons) is collected each week from the pits below a naturally ventilated caged-layer operation. This manure is mixed with sunflower hulls and composted in a windrow approximately 4.5 meters wide and 80 meters long on a large clay pad (60 x 100 meters) near the barns. Typically, four to six windrows, in various stages of composting, are located on the clay pad. After four to six weeks of composting, the compost is moved offsite to a curing pad or applied on agricultural fields.

On July 13, 1999 an 80 meter windrow was constructed in four, 20-meter, sections. Each 20 meter section was constructed with a different mix ratio of sunflower hulls to manure on a volume basis (1:1, 2:1, 2.5:1, 3:1). Samples of fresh manure, sunflower hulls, and initial compost mixture were collected on July 13, 1999. Samples of compost from each of the four sections were collected on July 26 and August 10, 1999. All samples were frozen and sent to the Soils Testing Laboratory at the University of Minnesota for evaluation of total carbon, total nitrogen, phosphorus, potassium, percent moisture, and percent ash (Table 2). Bulk density and porosity measurements of the initial materials and the mixed compost were made in the field.

Air samples were collected on July 15, July 26, and August 10, 1999 using a portable wind tunnel (Figure 1) and evaluated for odor, hydrogen sulfide, and ammonia. Compost temperatures were taken at approximately the midpoint of the cross sectional area of the windrow using a thermocouple probe.

The compost was mixed daily during the first week and once weekly during the next three weeks of composting. This was the standard management practice at the composting site during 1999.

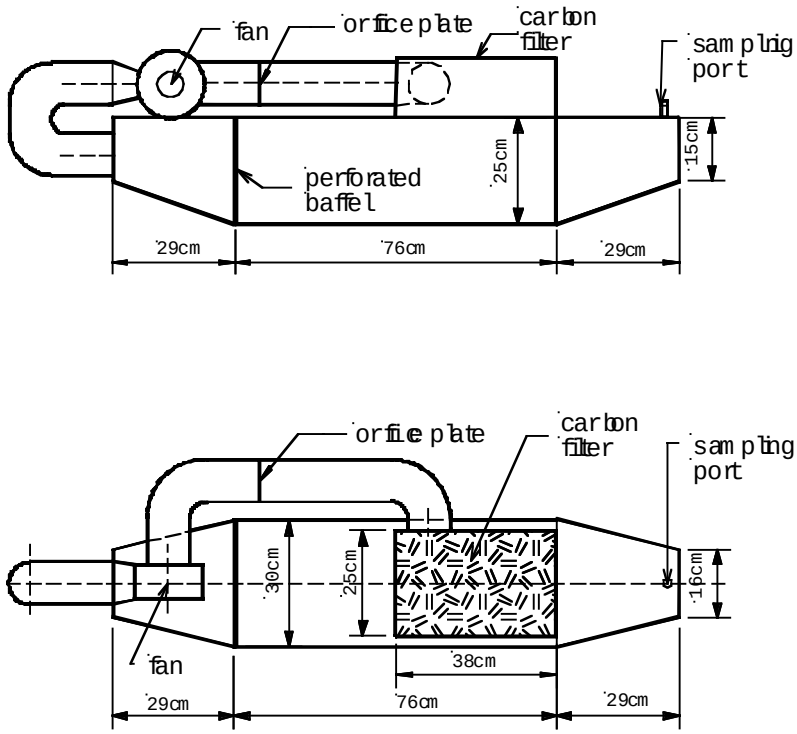

Figure 1. Top and side view diagram of portable wind tunnel (Schmidt et al., 1999)

Results

Compost Mixture

Testing of the physical and chemical parameters of the compost suggest that the volume ratio of sunflower hulls to manure resulted in a slightly higher carbon:nitrogen ratio, but had a much greater impact on the moisture content and porosity of the compost (Table 1). Moisture content of all of the compost mixtures decreased throughout the composting period while C:N ratio increased slightly.

Odor and Hydrogen Sulfide Emissions

Odor and hydrogen sulfide emissions decreased over time for all compost mixtures but were not significantly different from each other (Table 2). Initial odor emission rates were between 205 and 289 ou-m^3/s-m^2 and day 28 were between 33 and 39 ou-m^3/s-m^2. Initial hydrogen sulfide emission rates were between 215 and 411 µg/s/m^2 with the highest emissions occurring in the windrow with the 2:1 mix ratio. The lowest hydrogen sulfide emissions recorded was from the 3:1 compost mixture on day 13. After day 3 no significant difference in hydrogen sulfide emissions was measured except on the 3:1 compost mixture on day 13 where the hydrogen sulfide emission was 19 µg/s/m^2.

Table 1. Composition of manure, sunflower hulls and compost during 1999.

Substrate	Volume Ratio[1]	Moisture (%)	Density kg/m^3	Porosity %	Ash % db[2]	Carbon % db[2]	Nitrogen % db[2]	C•N ratio
Initial mix, day 1	1:1	65.4	897	10	29.4	37.2	2.61	14.3
	2:1	68.3	647	38	24.7	37.4	2.49	15.0
	2.5:1	•	533	•	•	•	•	•
	3:1	59.2	442	55	15.0	43.2	2.49	17.3
Compost, day 13	1:1	60.6	534	•	31.6	37.2	1.91	19.5
	2:1	48.4	374.	•	9.9	36.1	1.78	20.3
	2.5:1	43.9	307	•	31.1	37.1	1.79	20.7
	3:1	55.3	307	•	27.9	38.4	1.94	19.8
Compost, day 28	1:1	49.3	488	•	34.2	35.2	1.92	18.3
	2:1	45.7	274	•	29.5	36.8	2.03	18.1
	2.5:1	35.0	317	•	34.8	32.6	1.72	19.0
	3:1	39.5	307	•	27.7	38.1	1.92	19.8
Fresh manure	n/a	74.1	1010	•	34.5	34.0	3.06	11.1
Sunflower hulls	n/a	8.6	170	•	2.4	44.9	0.75	59.9
Finished comp.	2:1	22.9	•	•	30.9	37.0	1.79	20.7

[1]Estimate based on counting the number of filled loader buckets of each material in the initial mix.
[2]db = dry basis

Table 2. Odor and hydrogen sulfide emissions and temperature as influenced by compost mixture.

Days of composting	Volume mix ratio	Number of air samples	Hydrogen Sulfide µg/m^2-s Mean (s.d)	Odor (ou-m^3/m^2-s) Geomean (s.d. in $\log_{10}$)	Windrow Temperature ˚C
3	1:1	3	342 (24)	213 (0.30)	45
	2:1	3	411 (97)	289 (0.12)	62
	2.5:1	2	288 (212)	262 (0.02)	56
	3:1	3	215 (104)	205 (0.44)	34
13	1:1	3	186 (66)	70 (0.23)	67
	2:1	3	170 (62)	71 (0.11)	68
	2.5:1	3	170 (55)	54 (0.37)	68
	3:1	2	19 (0)	38 (0.46)	70
28	1:1	3	103 (63)	39 (0.81)	68
	2:1	2	152 (12)	34 (0.55)	60
	2.5:1	3	147 (56)	33 (0.26)	57
	3:1	2	127 (12)	38 (0.22)	65

ou=odor unit, m=meter, s=second, µg= microgram, s.d.=standard deviation)

Odor and hydrogen sulfide emission data from 1998 and 1999 can also be compared (Figure 2 and Figure 3). This comparison shows much higher emissions were recorded in 1999 than in 1998 for all compost mixtures. This increase in measured emissions seems to run contrary to the experience of the farm management and the number of nuisance complaints registered by those living close to the site. Changes in compost management between the two years may contribute to this difference between perceived and measured emissions. In 1998, the windrows were turned daily. Since the turning of compost generally increases emissions significantly, the frequent turning in 1998 may have contributed to more odors emissions and subsequent complaints from neighbors. Secondly, less frequent turning in1999 resulted in a crust formation on the sides of the windrows. This crust may reduce emissions from this pile—similar to a straw cover on a liquid manure storage. Also, this crust may force the gas emissions through the top of the pile thus increasing emissions in the area where the air samples were collected. This would account for the higher measured emissions in 1999.

To evaluate the difference in emissions from the top area of the pile and emissions from the total pile area, a separate study was conducted. On September 23, 1999, two air samples were collected from each of three compost windrows. One sample was collected using the portable wind tunnel and a second sample was collected using a larger wind tunnel that completely enclosed three meters of a compost windrow (Figure 4). Each windrow sampled had similar initial mix ratios (approximately 2:1) and had been constructed 15, 22, and 29 days prior to sampling. Windrows had been turned daily for the first week after construction and weekly thereafter.

For the compost windrows 15 and 29 days old, the measured emissions of odor and hydrogen sulfide with the large wind tunnel were much lower (64% lower for odor, 85%-91% lower for hydrogen sulfide) than that measured with the small wind tunnel (Table 3). These measurements fit well with the hypothesis that the windrow emissions measured from only the top venting area of the pile are much greater than the actual pile emissions. It is unclear why this relationship was not seen for measurements taken on the windrow 22 days old.

Table 3. Odor and hydrogen sulfide emissions from two different wind tunnel sizes.

Compost age	Odor emissions $ou\text{-}m^3/s\text{-}m^2$		Hydrogen sulfide emissions $\mu g/s\text{-}m^2$	
	Small Tunnel	Large Tunnel	Small Tunnel	Large Tunnel
15	62	23	118	18
22	19	23	27	19
29	52	19	184	15

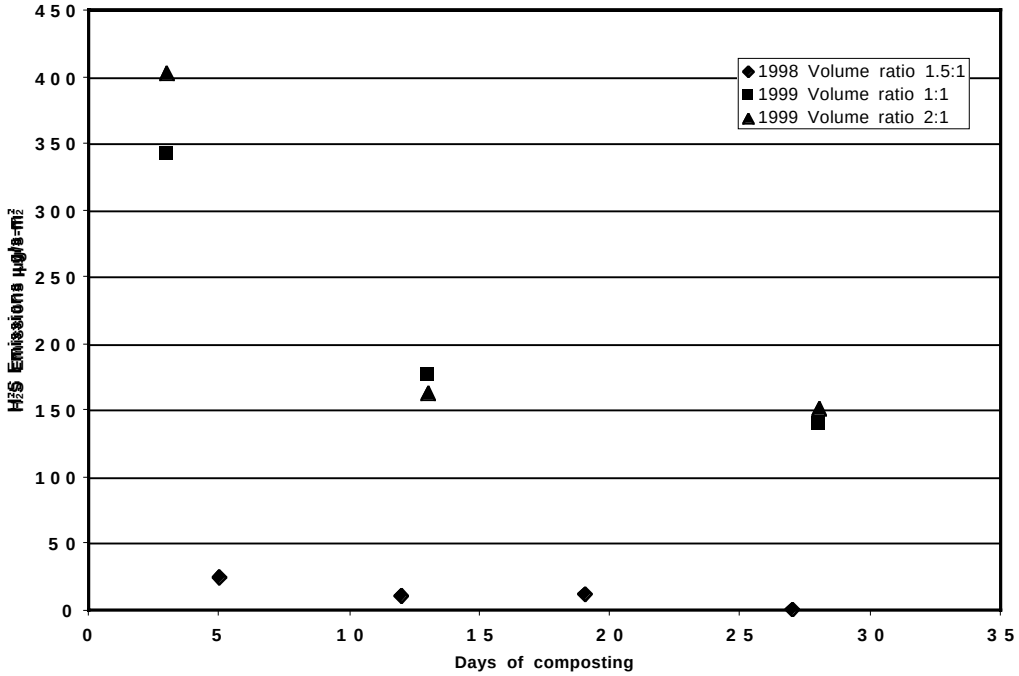

Figure 2. Hydrogen sulfide emissions—A comparison between years and experiments.

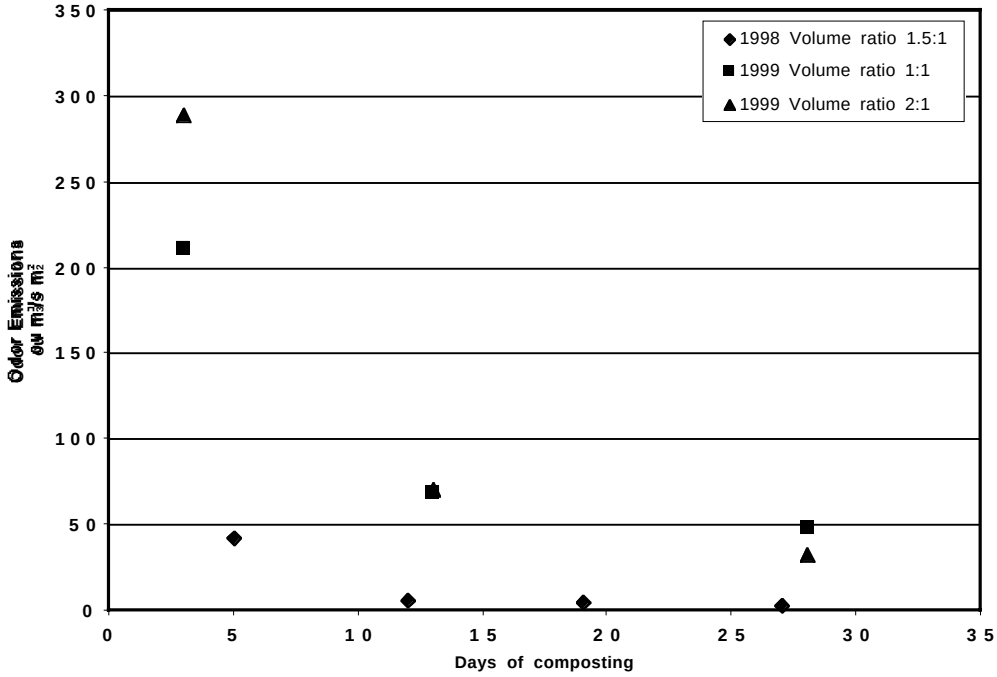

Figure 3 Odor emissions—A comparison between years and experiments.

Figure 4. Photograph of large wind tunnel used in study.

Nitrogen Loss

Nitrogen loss during composting is an issue from both an agronomic and air quality perspective. Nitrogen losses through ammonia emissions are currently regulated in some countries in Europe because of environmental concerns. Ammonia emissions from the compost windrows were measured at the same time odor and hydrogen sulfide emissions were measured. Unfortunately, these measurements often exceeded the upper limits of the measurement equipment used in this experiment of 3500 $\mu g/s/m^2$. Ammonia emissions ranged from 700 to 3500 $\mu g/s/m^2$ with most of the emissions meeting or exceeding the 3500 $\mu g/s/m^2$ measurement limit.

Nitrogen losses can also occur from the emissions of other nitrogen gases, such as nitrous oxides or nitrogen gas, or through leaching and runoff from the windrows. (This composting site was designed to prevent leaching and control runoff from the compost windrows.)

Total nitrogen losses during the composting period were estimated by measuring the total nitrogen in the initial and final compost mixtures and comparing these values to the amount of ash or phosphorus in the initial mixture. This technique assumes that the amount of ash or phosphorus remains constant throughout the composting period. Using this method, the compost at 28 days lost 37, 32, and 58% of the original nitrogen based on ash content and 50, 35, and 42% based on phosphorus content, 1:1, 2:1, 3:1 mix ratios,

respectively. It is unclear which method, ash or phosphorus, is a better indicator of true nitrogen loss during composting.

Table 4 shows the actual nutrient content of the compost after 28 days of composting. The nitrogen content of the compost is highest with the 3:1 mix ratio on a per ton basis. However, on a volume basis the nitrogen content is highest in the 1:1 ratio. This is primarily due to the higher moisture content of the 1:1 mix.

It is likely that both the composition of the initial compost mixture and the management of the compost are factors contributing to the loss of nitrogen during composting.

Table 4. Nutrient content of compost at 28 days.

Initial CompostMix ratio[1]	**Moisture %**	**Density lbs/yd^3**	**Nitrogen lbs/ton (lbs/yd^3)**	**Phosphorus lbs/ton (lbs/yd^3)**	**Potassium lbs/ton (lbs/yd^3)**
1:1	49.3	819	19.5 (8.0)	13.6 (5.6)	23.1 (9.5)
2:1	45.7	610	22.0 (6.7)	13.7 (4.2)	29.3 (9.0)
2.5:1	35	575	22.4 (6.4)	13.1 (3.7)	27.2 (7.8)
3:1	39.5	575	23.2 (6.7)	11.1 (3.2)	24.0 (6.9)

[1]Ratio of sunflower hulls to manure on a volume basis.

Conclusions

Four compost piles were constructed and monitored for odor and hydrogen sulfide emissions. Each of the four compost piles had a different volume ratio of sunflower hulls to manure, 1:1, 2:1, 2.5:1, 3:1. These mixtures resulted in different moisture content, porosity, and carbon:nitrogen ratio of the original compost mixtures with the change in mixture having the least impact on carbon:nitrogen ratio. Odor emissions on day 3 of composting were 213, 289, 262, and 205 ou-m^3/s-m^2, for mix ratios of 1:1, 2:1, 2.5:1, 3:1, respectively, and were 4 to 7 times higher than on day 13 or day 28. Hydrogen sulfide emissions were highest on day 3 ranging from 215-411 µg/s-m^2, approximately twice what was measured on day 13 and day 28. Odor and hydrogen sulfide emissions from all the different compost mixtures were greater in 1999 than in 1998. However, the farm management and neighbors complaints indicate that nuisance odors were fewer in 1999. Compost pile management may have contributed to these measured differences and to the seemingly contradictory anecdotal evidence.

The method of air sampling from the compost windrows had a dramatic effect on measured emissions. A wind tunnel constructed to cover the entire surface area of 10 feet of pile length resulted in emissions 1 to 10 times less than measurements made with a small wind tunnel which sampled air from the venting area of the compost windrow. This effect was likely the result of the crust formation on the sides of the windrow and the venting of the gases through the top center of the windrows.

Nitrogen loss during composting was similar for all compost mixtures and ranged from 32 to 58%.

More research is needed to determine the most accurate method of measuring gas emissions from compost piles. Research to determine the other factors involved in conserving nutrients (primarily nitrogen) during composting is also necessary.

A paper was written on this research and will be presented at an American Society of Agricultural Engineering specialty conference October 10, 2000.