Effect of different intermediate amendments on pH and ammonia emissions of composted poultry mortalities

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Primary Audience: Environmental Engineers, Environmental Scientists, Air Quality Scientists, Agricultural Scientists

SUMMARY

The study of ammonia emissions from composting poultry mortalities has been a topic of interest due to concerns about air quality effects from agricultural facilities. In previous poultry mortality composting research, it was reported that ammonia emissions are strongly affected by increasing the pH of the compost pile above 8. To verify these findings, a project was initiated to examine composting poultry mortalities while using different amendments within the pile and observing the effects on the gaseous emissions. Each pile was constructed using 2 layers of spent hen carcasses, with one layer below and one layer above the intermediate amendment. Each pile design was constructed in triplicate to assist in data verification and statistical analysis. All piles were constructed using fresh woodchips for the base and cap material. The intermediate amendments were chosen based on their availability, applicability for mortality composting, and pH buffering. The control pile had woodchips as the intermediate amendment, as it had a pH closest to neutral (7.4). The 2 additional pile designs consisted of intermediate amendment layers with either poultry compost, a lower pH material of 5.5, or poultry litter, a slightly higher pH material of 7.5. Air samples were collected using a dynamic flux chamber drawing fresh air across the pile face at a known volumetric flow rate of approximately 370 m^3/h. Based on the results of this experiment, using poultry litter for composting may not be an appropriate best management practice if the objective is to minimize ammonia emissions.

Key words: poultry mortality, compost, ammonia, pH

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DESCRIPTION OF PROBLEM

Ammonia emissions from agriculture have been monitored from a variety of sources, such as manure composting sites and animal housing facilities. To humans, ammonia is an irritant to the respiratory system at concentrations in the range of 0.6 to 53 ppm [1]. The detection threshold of ammonia is 0.037 ppm and the recognition threshold is 47 ppm [2]. Because ammonia disperses easily in the atmosphere, as it is 60% the density of air, it is usually detected more readily near the source. However, if present in high concentrations for long periods of time, it

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can pose problems for neighboring residents or businesses. Ammonia typically has a residence time on the order of hours in the atmosphere and, due to its high solubility, is readily removed during rain events. This can cause an increase in the nitrogen concentrations in water systems, which can lead to eutrophication in lakes, making water ways toxic to fish and contaminating surface and ground water systems [3, 4]. Several factors contribute to the effects of ammonia in the air and water, such as temperature, moisture content, and pH [3]. In addition, ammonia is one of the major inorganic alkaline gases in the atmosphere and contributes to the formation of secondary inorganic aerosols. These aerosols are typically found in the fine fraction of the particulate matter and have their own health effects, visibility issues, and are precursors to urban smog formation.

As a farm management practice, composting poultry mortalities is becoming an increasingly attractive option, as it cuts costs for mortality removal and provides a source of nutrients when matured and applied on land. However, the ammonia emissions generated during the composting process are still being assessed to fully understand the environmental effects of composting. Loss of ammonia during composting generates undesirable odors and results in the loss of nitrogen from the finished compost. By reducing ammonia emissions, the final compost product should have higher nitrogen content and, therefore, provide more nutrients to the land upon application. Previous research indicated that altering the pH of the compost, such that it remains below 8, could effectively reduce the amount of ammonia emitted from the pile [5].

The pH within the compost pile matrix can affect the microbial populations during the composting process and, hence, the temperature of the piles and ammonia volatilization. As temperature and pH increase in the compost pile, the ammonia concentrations also increase and have the potential to be lost from the pile [6]. Thermophilic temperatures during composting trials were found to reach a maximum when the pH was within a range of 7.5 to 8.5 [7]. The concentration balance of ammonia (NH_3) and ammonium (NH_4^+) ions in an acidic environment will cause the gaseous ammonia to remain in the aqueous ammonium ion form resulting in lower ammonia emissions to the atmosphere [8].

Correlations between pH and ammonia emissions have been well documented for composting animal manures. In research trials, it was demonstrated that, at a pH below 6.6, nitrogen lost as ammonia was significantly less than when the pH was above 8.0 [9]. This was obtained during the composting of poultry litter with short paper fiber plus pH controlling additives, such as alum [9]. Similar studies adjusting the pH of compost pile using animal mortalities have not been conducted in great detail.

The objectives of this project were to (1) alter the pH of the poultry mortality composting piles using different intermediate amendment materials readily available on farms, one being above neutral (more basic), one below neutral (more acidic), and a control material being close to neutral; (2) quantify ammonia emissions from compost piles and compare them to the pH of the piles; (3) design compost piles for proper comparison in data analysis including replicating designs; and (4) analyze pH, moisture content, and temperature of piles as they mature.

MATERIALS AND METHODS

Pile Design and Construction

The initial design of the compost piles and experimentation was based on previous work conducted at the University of Guelph, which illustrated the strong link between the pH of the pile and ammonia emissions and the need to repeat the pile design to provide statistical validity to the results [5, 10]. The basic pile design was limited to the size and number of bins within the composting facility, which had 10 bins available, each being 2.4 × 2.4 × 2.4 m^3 (8 × 8 × 8 ft^3) in volume. To maximize use of the available bins, 3 different design options to alter the pH of the pile with 3 replicates of each was selected, thus requiring 9 bins. The last bin was required for turning events.

A control pile design was needed for referencing emission measurements. As the primary material for composting at this facility was woodchips, the base, intermediate amendment, and cap layers were constructed with woodchips. The woodchips had a pH of 7.4, were of mixed wood types, and uniform in chip size of approximately 3 to 5 cm in length and 2 to 3 cm in width.

The remaining 2 pile designs had differing intermediate amendments based on their pH, availability, and applicability for composting. The first amendment chosen was previously composted poultry carcasses (**PC**) with woodchips already located at the research barn and having an initial pH of 5.5. This material provided the required acidic buffering capacity that would theoretically reduce ammonia emissions. The second and less acidic amendment selected was poultry litter (**PL**). Litter was chosen because it is readily available on broiler farms and is also widely used for this purpose. The initial pH of the litter was found to be 7.5. Ideally, a more basic intermediate material should been selected for use, however, due to the predominance of litter used in poultry composting, it was deemed necessary to assess the emissions using this material.

Controlling the amount of amendment added to each pile was based on the density of the material with the woodchips, poultry compost, and poultry litter having densities of approximately 283, 194, and 689 kg/m^3, respectively. Compost piles were then constructed using a tractor equipped with a front-end loader bucket. The number of bucket loads of material was kept the same for each pile to maintain consistency.

The poultry mortality composting piles were constructed based on previously established mortality composting guidelines [11]. The base layer of the piles was 60 cm (2 ft) deep to act as an absorption pad for any leachate formed. Two layers of birds were then placed in each pile, each layer having 216 birds and a depth of approximately 15 cm (0.5 ft). In between the 2 bird layers was a 30-cm (1-ft) layer of amendment material. The piles were capped with woodchips to a thickness of ~30 cm (1 ft). After the control piles were constructed, the remaining 6 piles were constructed similarly but using the different intermediate amendment materials. A 40-d lag between the construction of the control piles and the remaining 6 piles occurred to obtain a sufficient quantity of spent laying hens to complete these last 6 piles simultaneously.

During pile construction, 3 type K thermocouples were placed near the bottom, in the middle, and near the top of all the piles. These thermocouples were connected to a Campbell Scientific CR23X data logger [12] that recorded hourly average temperatures for each pile. Ambient barn temperature, relative humidity, and barometric pressure were also recorded in the instrument trailer located inside the composting facility.

Initial Pile Information

The initial properties of the composting materials used in the pile designs are outlined in Table 1, whereas Table 2 summarizes the initial pile characteristics. Average bird weights were used to construct the piles, which resulted in the final mass for each pile being variable based on the bird count.

The carbon and nitrogen content of composting materials are important factors to consider before beginning the composting process and also important to monitor during the process. Having a carbon-to-nitrogen ratio (**C:N**) between 20:1 and 30:1 is optimal for maintaining a microbial environment that is effective for composting [7, 13]. Having a lower C:N indicates an excess of nitrogen and can lead to nitrogen loss

Table 1. Initial compost material properties

Material	pH	Moisture (%)	Carbon[1] (%)	Nitrogen[1] (%)
Woodchips	7.4	72.0	47.2	0.854
Poultry carcasses[2]	NA[3]	65.0	45.0	7.50
Poultry compost	5.5	39.5	44.1	0.048
Poultry litter	7.5	46.0	37.0	1.10

[1]Carbon and nitrogen content was obtained from laboratory results at the University of Guelph for all materials except poultry mortalities.

[2]Initial carbon and nitrogen content, pH, and moisture percentage per mortality from [11].

[3]NA = not available.

Table 2. Initial pile properties

Pile name[1]	Date constructed	Mass of birds (kg)	Mass of intermediate amendment (kg)	Initial C:N[2]
Control 1	August 12, 2009	810	640	16.1
Control 2	August 12, 2009	760	640	16.7
Control 3	August 12, 2009	780	640	16.5
PC 1	September 21, 2009	691	440	20.1
PC 2	September 21, 2009	691	440	20.1
PC 3	September 21, 2009	691	440	20.1
PL 1[3]	September 21, 2009	702	780	18.0
PL 2	September 21, 2009	739	1,560	19.9
PL 3	September 21, 2009	720	1,560	20.1

[1]PC = poultry compost; PL = poultry litter.
[2]Initial carbon-to-nitrogen ratio uses information on poultry mortalities from [11] for carbon and nitrogen content per carcass.
[3]For mass of intermediate amendment, PL 1 only had half the material added due to supply shortage.

through ammonia volatilization. A C:N below 20 is considered low, and ammonia emissions are expected [7]. Based on the above information for the experimental piles, nitrogen was in slight excess for the current study, especially in the control piles.

Pile Turning

Table 3 outlines the turning events that occurred, giving both the calendar date as well as the corresponding composting day in relation to pile creation. Previous studies on mortality composting at the Elora Research Station used a guideline that the piles were turned once the pile temperatures dropped below 50°C. However, due to cold ambient conditions in the winter, turning did not happen as frequently as the guideline suggested.

Sampling Procedure

A dynamic flux chamber, shown in Figure 1, was constructed specifically for the bins such that it fit over the composting bins and created a seal around the perimeter. At the back of the bins, a 10.2-cm diameter hole was drilled through the concrete wall to allow outside ambient air to be drawn in and over the piles during sampling. A fan, located on the exterior ducting of the flux chamber, was used to draw ambient air over the pile face. The flow rate was controlled using an adjustable 15.24-cm IRIS damper [14] located behind the fan. Typically, the flow rate was set at approximately 370 m^3/h to match previously conducted studies [5]. Samples of the exhaust stream were obtained via a stainless steel sampling port positioned in the exhaust duct. Samples were drawn through the port and delivered to the ammonia analyzer via a 30.5-m heated sample line.

Ammonia concentrations were measured using a chemiluminescence ammonia and oxides of nitrogen analyzer [15]. Each bin was sampled for a period of 1 h. The first 20 min of a sample were discarded from the data analysis, as the sampling system required time to purge the air from previous measurements and the instruments required time to adjust to the concentration change [10]. The last portion of the hour sample was then used to determine an overall average concentration from the pile for the giv-

Table 3. Pile-turning dates

Turning event	Control piles		Poultry compost piles		Poultry litter piles	
	Date	Compost day	Date	Compost day	Date	Compost day
1	October 21, 2009	70	December 2, 2009	72	December 9, 2009	79
2	January 19, 2010	160	January 19, 2010	120	January 21, 2010	122
3	April 21, 2010	252	April 21, 2010	212	April 21, 2010	212

Figure 1. The dynamic flux chamber constructed to fit over the composting bins and seal the perimeter [14].

en sampling day and converted into a mass per volume concentration using the ideal gas law with measured ambient pressures and temperatures at the composting facility. A weekly sampling schedule was established to capture trends in the data.

The emissions were calculated based on an equation presented in [16]

$$E = (C_P - C_A)\,Q, \quad (1)$$

where E is the emission rate (g/h); C_P is the ammonia concentration above the pile (g/m^3); C_A is the ambient ammonia concentration (g/m^3); and Q is the flushing flow rate of approximately 370 m^3/h. The exact flow rate was calculated for each sampling event for use in the data analysis, as it varied slightly from 370 m^3/h due to changes in pressure across the IRIS damper.

Grab samples of the compost, which began after the second turning event, were collected from each pile on a weekly basis using a soil-coring probe. The samples were collected from the top of the pile in 5 separate locations at a depth of approximately 0.5 m to provide a composite sample. Moisture was determined from gravimetric analysis of a 150 to 225 g of wet sample placed in an oven for 24 h at 100°C. The pH was determined using an EcoTester pH2 Waterproof Pocket Tester pH meter [17]. Approximately 50 g of compost was ground so that pieces were about 2 mm in size and then placed in a 500-mL Nalgene sample bottle [18]. The bottle was filled to the top with deionized water and shaken gently with a mechanical shaker for 15 min. Once the shaking was complete, the calibrated pH meter was inserted into the sample until the reading had stabilized.

RESULTS AND DISCUSSION

General Observations

The initial observation made from the composting piles was that, by the second turning event, the poultry carcasses were decomposed to a point where they were no longer distinguishable as chickens. Bones and feathers were evident, whereas soft tissue was only found in clumps typically located near the bottom portion of the piles. The PL 3 pile was the least decomposed of all 9 piles, as there were still several clumps of carcasses with flesh still visible. Ammonia and other odors were much stronger coming from PL 3 as compared with the other 8 bins. These odors were also encountered a couple times toward the end of the sampling campaign from the same pile.

Pile Temperatures

Pile temperatures were monitored throughout the composting process. The temperatures presented in Figure 2 are for the middle of the pile. This temperature location better illustrates what was occurring within the core of the pile, as the other 2 (upper and lower) thermocouples were influenced more by ambient conditions. Turning events, as given in Table 3, are readily identifiable by the dips in the temperature profiles of the various piles.

The thermophilic temperature range that promotes microbial activity in composting piles is defined as being between 45 and 75°C [19]. Whereas all piles experienced some time when their temperatures were below the thermophilic range, the PL piles were below this temperature for a larger portion of the sampling period. Therefore, the composting process may not have been ideal. As expected, peak temperatures were encountered after a turning event, which reintroduced oxygen into the pile and allowed for the redistribution of moisture to enable accelerated microbial growth.

Moisture Content

Moisture content was sampled once a week from each pile after the second turning event; results are presented in Figure 3. As with temperature, moisture content is a vital parameter necessary to enable the microbial community to carry out the composting process. Water is lost via microbial activity and evaporation and decreases as the pile matures. The optimum moisture level is between 50 and 60% [7]. After the second turning event, the observed moisture content in all piles was slightly above the ideal range, with the moisture content typically dropping to within the desired range by the end of the sampling period.

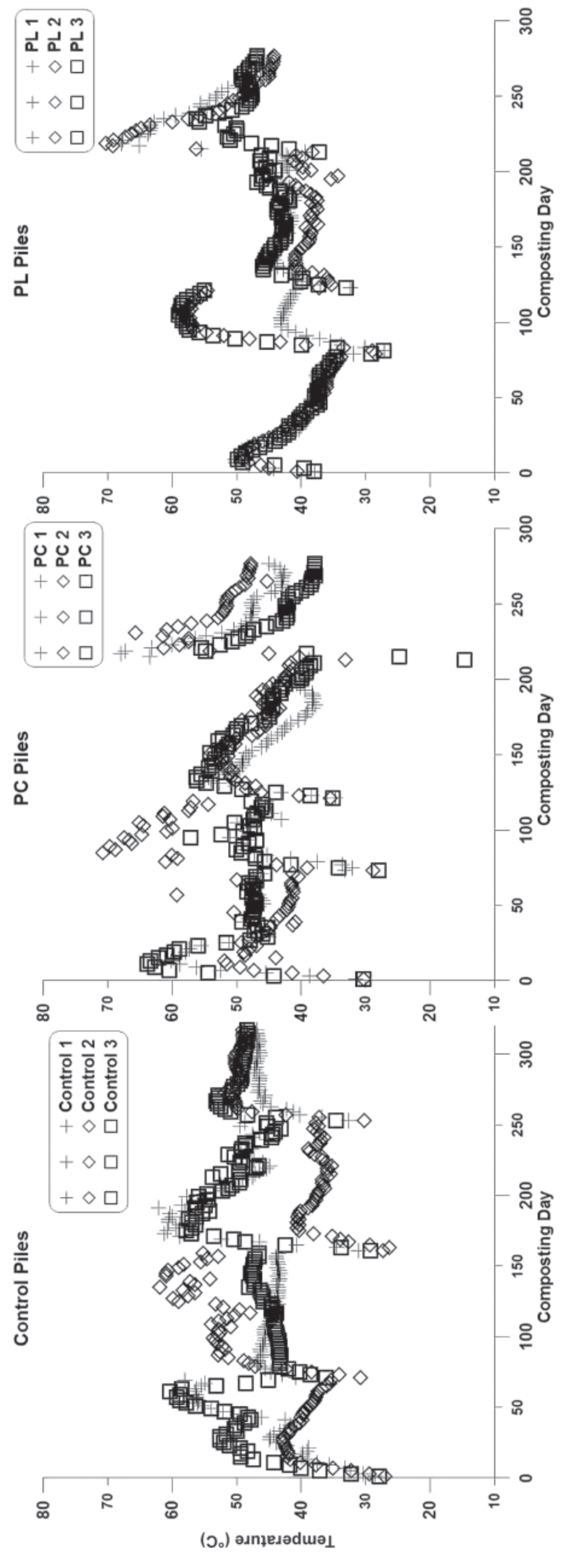

Figure 2. Pile temperatures from the middle of the compost pile. PC = poultry compost; PL = poultry litter.

Pile pH

Pile pH was analyzed on a weekly basis after the second turning event; results are presented in Figure 4. Both the control and PC piles had pH levels around 8, which peaked in pH within the first 30 d of the pile turning and then decreased below 8 as the piles matured. The PL piles, whose litter pH was initially 7.5, had the highest pH after turning, reaching in excess of 9 for PL 3. The control and PC piles' pH decreased to around 6 at the end of the sampling period, whereas only PL 1 followed a similar trend. This was the pile with the reduced amount of litter used as the intermediate amendment as compared with PL 2 and PL 3. The pH for PL 2 and PL 3 stayed within the 7.5 to 9 range throughout the sampling time.

Ammonia Emissions

Ambient ammonia concentrations were measured over 3 d, to determine a representative outdoor ammonia concentration, which was then subtracted from the concentration measured above each pile. The average ambient concentration was estimated to be 0.017 ppm or 1.27E-05 g/m^3.

Ammonia emissions measured from all 9 piles are given in Figure 5, with measurements commencing after the initial pile construction. The first noticeable observation from Figure 5 is that PL piles behaved differently than control and PC piles with regard to ammonia emissions. The PL piles, especially PL 2 and PL 3, had much higher ammonia emissions than the control and PC designs. The highest emissions were generated by PL 3 and reached a maximum of 2.6 g/h before the second turning event. Although PL 1 had lower emissions than its 2 counterparts, its emissions are still greater than that observed for the control or PC piles. Half the litter amendment was used in the construction of PL 1 compared with PL 2 and 3, which could explain the initially lower ammonia emissions as compared with the other 2 PL piles.

Ammonia Versus pH Data

For days with simultaneous measurements of ammonia emissions and pH, the ammonia emissions were plotted as a function of compost pH, as given in Figure 6. For the control and PC piles, compost pH rarely went above 8.0 and resulted in fairly low ammonia emissions. The PL piles, in comparison, had a noticeably higher compost pile pH and ammonia emissions, with the ammonia emissions increasing with increasing pH.

Based on the initial pH of the composting materials, the ammonia emissions from the control piles would have been expected to be closer to those of the PL piles, as the woodchips had a starting pH of 7.4 and the poultry litter was 7.5. What the initial pH of the amendment material does not account for is the availability of the carbon and nitrogen for the microbes to metabolize in each of the amendments, as the pH of the control piles quickly emulated that found in the PC piles (Figure 4). This similarity in the behavior of the pile pH between the control piles and PC piles also resulted in similar ammonia emissions as time progressed. Nitrogen found in manure is more readily available for microbial consumption than the nitrogen that is bound in woody materials. When nitrogen is more easily consumed, more is metabolized, with the end result being that more ammonia is generated. Similar to other composting studies and based on the results presented here, as the pH increased above 8.0 and the piles became more basic, ammonia concentrations also increased.

Statistical Analysis

Statistical analyses were conducted on the ammonia emissions for all pile designs looking at pile temperature, age, moisture, and pH as variables. The statistical analyses, using SPLUS 8.0 [20], used aggregate data for each pile design. Data collected between the second and third turning events were used, as they were the most consistent and complete.

Linear multivariate regression models were run for the ammonia emissions coming from each pile design against all of the explanatory variables (time, pH, temperature, and moisture content). The results of these models and the associated *P*-values that test against a null hypothesis of a zero slope are presented in Table 4.

Based on the information provided in Table 4, it is evident that the explanatory variables all

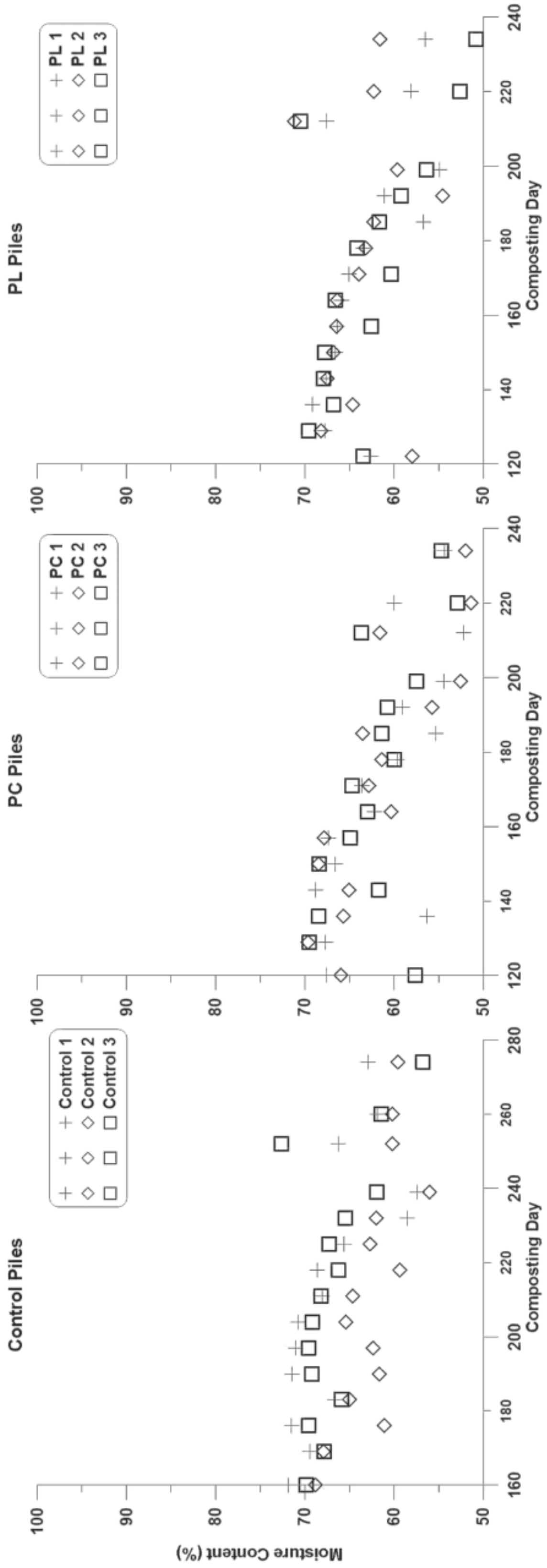

Figure 3. Moisture content from each compost pile. PC = poultry compost; PL = poultry litter.

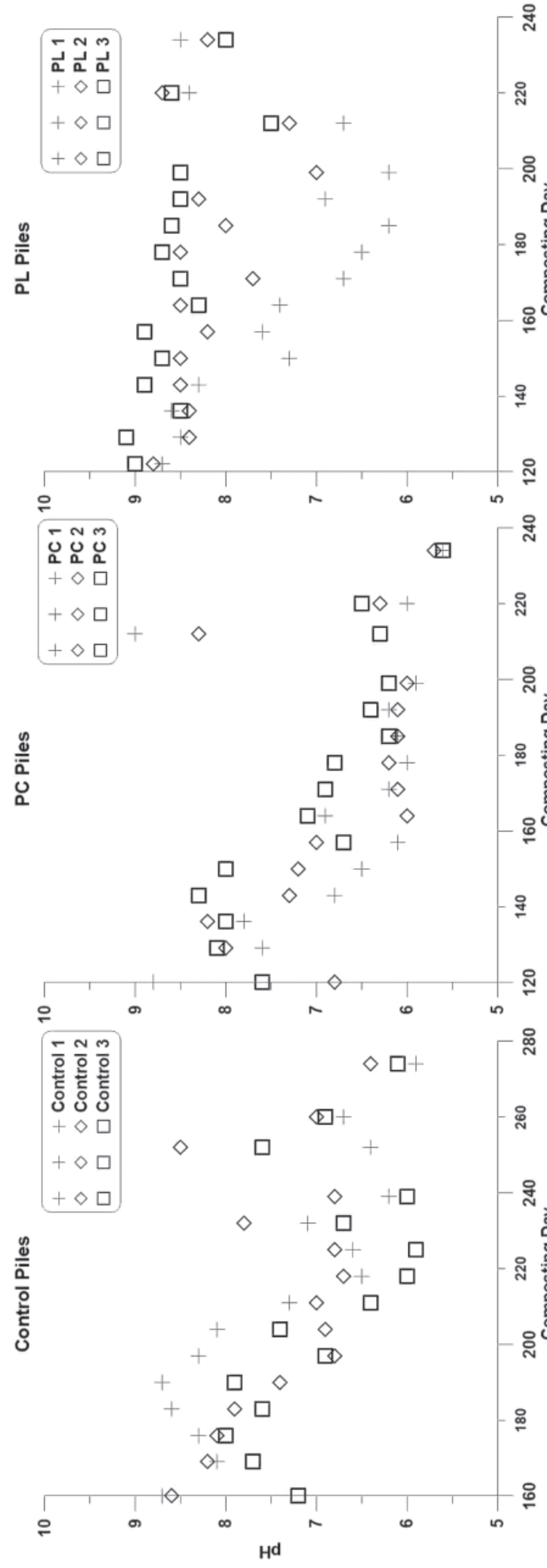

Figure 4. Results of pH tests from compost piles. PC = poultry compost; PL = poultry litter.

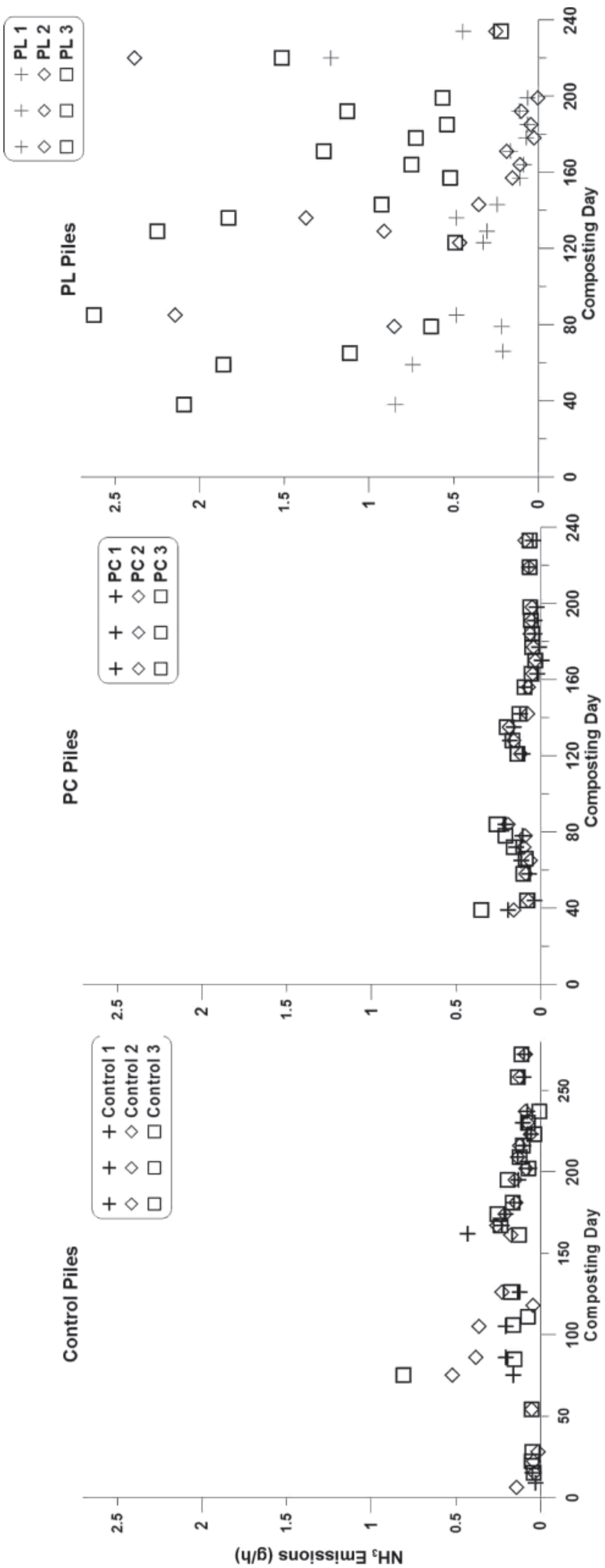

Figure 5. Ammonia emissions from compost piles. PC = poultry compost; PL = poultry litter.

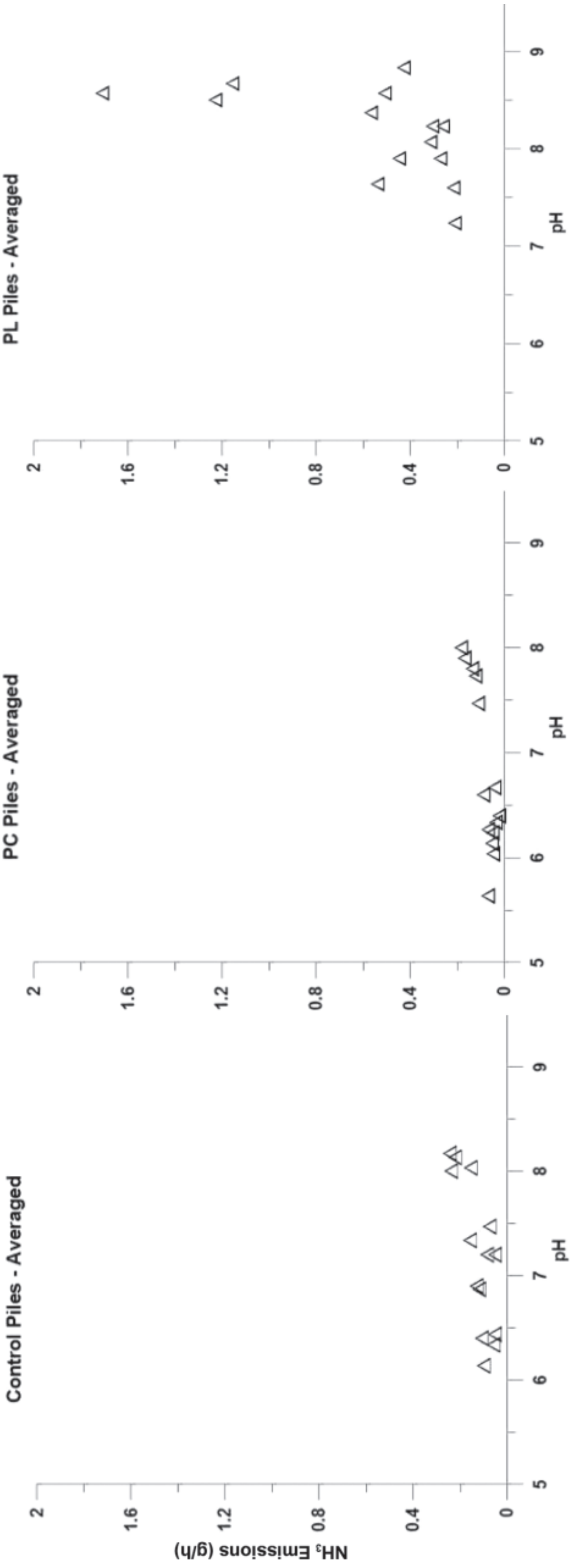

Figure 6. Relationship between ammonia emissions and pH. PC = poultry compost; PL = poultry litter.

Table 4. Linear multivariate regression models

Data comparison[1]	Equation	*P*-value	R^2 (%)
Control pile	$\hat{U} = 1.384 - 0.003\ (t) - 0.011\ (pH) - 0.001\ (T) - 0.007\ (M)$	t = 0.025 pH = 0.742 T = 0.620 M = 0.251	89.6
Poultry compost piles	$\hat{U} = -1.176 + 0.002\ (t) + 0.117\ (pH) + 0.003\ (M)$	t = 0.352 pH = 0.053 T = 0.950 M = 0.619	88.9
Poultry litter piles	$\hat{U} = 4.992 - 0.022\ (t) - 0.383\ (pH) + 0.080\ (T) - 0.018\ (M)$	t = 0.163 pH = 0.517 T = 0.180 M = 0.704	59.9

[1]All comparisons are NH_3 versus time (t), pH, temperature (T), and moisture (M).

have differing effects on emissions. Apparently, the multivariate analysis was not appropriate for the data sets in spite of having large R^2 values. Only the time variable for the control piles showed a *P*-value of significance.

To further the analysis, linear models were run using one explanatory variable. These results are given in Table 5, with the significant models being highlighted. The data collected from the control and PC piles generated linear regressions models that appear to be a good fit based on the statistical results. However, for both the control and PC piles, the relationships between NH_3 versus temperature did not generate models with statistical significance. In general, as the *P*-values increased, the R^2 value decreased, thus reflecting the unaccounted for variability in the models.

In addition, there is an inverse relationship between emissions versus time and a proportional relationship between emissions versus pH. As time progressed, the emissions decreased, and as pH increased so did the emissions. The PL piles did not generate linear regression models that were as good a fit as those of the control and PC piles.

Polynomial models using one explanatory variable were also generated to determine whether any significant nonlinear relationships existed in the data. Results of the runs are given in Table 6. The nonlinear analysis was based on a polynomial equation, as it appeared as though it may fit some of the trends with respect to time and pH. The only statistically significant nonlinear models occurred for the PC piles with both NH3 versus pH and temperature.

To try and explain the remaining gaps in the data, covariate analyses were performed for all the gaseous compounds versus time, pH, moisture, and temperature. However, results of the covariate analyses did not provide any further insights toward the relationships of the data.

As a result of this analysis, it was determined that there are definable linear relationships between ammonia emissions and each of time, pH and, to a lesser extent, moisture content for the control and PC piles. The PL piles did not produce defined relationships due to the sporadic nature of the data. Reasons for this were linked back to the characteristics of the intermediate amendment, poultry litter, and its effect on the

Table 5. Linear regression models

Data comparison	Equation	*P*-value – slope	R^2 (%)
Control Piles			
NH_3 vs. time	$\hat{U} = 0.647 - 0.003X$	0.000	86.2
NH_3 vs. pH	$\hat{U} = -0.453 + 0.081X$	0.002	67.8
NH_3 vs. temperature	$\hat{U} = 0.268 - 0.003X$	0.452	6.43
NH_3 vs. moisture	$\hat{U} = -0.819 + 0.015X$	0.024	45.2
Poultry compost piles			
NH_3 vs. time	$\hat{U} = 0.363 - 0.002X$	0.002	67.7
NH_3 vs. pH	$\hat{U} = -0.372 + 0.066X$	0.000	84.3
NH_3 vs. temperature	$\hat{U} = -0.128 + 0.005X$	0.168	20.0
NH_3 vs. moisture	$\hat{U} = -0.453 + 0.009X$	0.046	37.3
Poultry litter piles			
NH_3 vs. time	$\hat{U} = 1.912 - 0.009X$	0.036	40.2
NH_3 vs. pH	$\hat{U} = -2.701 + 0.396X$	0.066	32.6
NH_3 vs. temperature	$\hat{U} = 0.257 - 0.004X$	0.547	4.16
NH_3 vs. moisture	$\hat{U} = -2.923 + 0.054X$	0.059	34.1

overall composting process. The results of the statistical analysis indicate the complex nature of the composting process, even under controlled conditions.

CONCLUSIONS AND APPLICATIONS

1. Amendments conformed to the desired pH requirements: control piles used woodchips that had a pH of 7.4, acidic spent PC amendment with a pH of 5.5, and the slightly basic PL at a pH of 7.5.
2. Based on the average temperatures, the control and PC piles were within the thermophilic temperature range during the majority of the composting trials.
3. The average temperature for the PL piles was typically below the thermophilic temperature range; therefore, the composting process was not ideal for these piles.
4. Moisture content came within the range of 50 to 60% during the second and third turning events for all 9 piles.
5. Emissions of ammonia from the control and PC piles were fairly similar in both trend and magnitude.
6. The PL 2 and PL 3 piles emitted more ammonia than PL 1 due, in part, to PL 1 having half the amendment and, thus, providing less nitrogen to the pile.
7. The ammonia emissions and pH of the compost piles were correlated, but the

Table 6. Polynomial regression models

Data comparison	Equation	*P*-value (X^2)	R^2 (%)
Control piles			
NH_3 vs. time	$\hat{U} = 1.492 - 0.011X$	0.205	88.9
NH_3 vs. pH	$\hat{U} = 2.094 - 0.628X + 0.049X^2$	0.221	73.8
NH_3 vs. temperature	$\hat{U} = 1.512 - 0.065X + 0.001X^2$	0.062	41.1
NH_3 vs. moisture	$\hat{U} = 5.280 - 0.176X + 0.001X^2$	0.339	51.4
Poultry compost piles			
NH_3 vs. time	$\hat{U} = 0.951 - 0.009X$	0.238	73.2
NH_3 vs. pH	$\hat{U} = 1.775 - 0.552X + 0.044X^2$	0.051	91.0
NH_3 vs. temperature	$\hat{U} = 2.265 - 0.103X + 0.001X^2$	0.005	72.0
NH_3 vs. moisture	$\hat{U} = 2.056 - 0.073X + 0.001X^2$	0.437	42.1
Poultry litter piles			
NH_3 vs. time	$\hat{U} = 3.707 - 0.032X$	0.704	41.4
NH_3 vs. pH	$\hat{U} = 1.897 - 0.751X + 0.071X^2$	0.878	32.0
NH_3 vs. temperature	$\hat{U} = 6.450 - 0.308X + 0.004X^2$	0.796	0.893
NH_3 vs. moisture	$\hat{U} = 35.812 - 1.183X + 0.010X^2$	0.231	45.5

correlation was more apparent for the control and PC piles, which were primarily at a pH below 8.0.

8. The pH of the PL piles did go above 8.0 for extended periods of time and resulted in these piles emitting considerably more ammonia than the control and PC piles; therefore, the bioavailability of nitrogen plays a large role in the emission of ammonia during composting.
9. In general, based on these results, the PL piles were more variable and did not promote an ideal composting environment.

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