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Determination of Ammonia Emission Factors for Land Application of Poultry Manure

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Abstract

Ammonia (NH_3) emissions from farm operations have been identified by the National Agri-Environmental Health Analysis and Reporting Program (NAHARP) as one of the quantitative indicators of agricultural environmental performance in Canada. Based on current estimates, about 6% of all Canadian emissions can be attributed to land application of poultry manure. The Fraser Valley of B.C. generates large quantities (approximately 280,000 tonnes) of poultry manure each year. While land application of poultry litter can provide essential plant nutrients for crop production, improper manure management can lead to ammonia volatilization from the litter, and it can be detrimental to the environment.

Ammonia emission is affected by atmospheric conditions such as wind speed and air temperature in the period following land application, and the effect depends on the relative emissions over the succeeding days. The principle objective of this project is to monitor ammonia emissions over time from land application of poultry manure, in order to develop effective emission factors for the British Columbia ammonia indicator/inventory.

This paper will present the results obtained from field experiments (involving different types of manure and grass heights) conducted at the PARC Agassiz Research Station of Agriculture and Agri-Food Canada in 2005, using wind tunnels, acid traps and flow injection analyzer for the determination of ammonia emission.

INTRODUCTION

The Government of Canada and the provincial and territorial governments have signed an agreement on the Agricultural Policy Framework (APF). The APF includes the development of national environmental standards to support producers in taking steps that will help in the achievement of measurable progress towards these environmental goals. Under a Memorandum of Understanding between Agriculture and Agri-Food Canada (AAFC) and Environment Canada (EC), a National Agri-Environmental Standards Initiative (NAESI), program was launched. The overall objective of NAESI is to deliver environmental standards that will significantly advance conservation and protection goals in the priority areas. In the first year of NAESI program, the emphasis was on problem assessment and priority setting. A scoping study was also conducted during this period to help meet this NAESI requirement. Subsequently, in addition to the above, field work involving improvement of emission factors from land application of poultry manure from different classes of poultry for Canadian conditions was initiated at the University of British Columbia to match up to latest population estimates and activity data for the poultry sector.

Ammonia (NH_3) emissions, being next to sulfur dioxide (SO_2) and nitrogen oxides (NO_x), are important contributors to eutrophication and acidification of natural ecosystems. Its contribution to the formation of fine particulate matter and smog has also received increasing attention in recent years [14]. Concern about the role of ammonia as a precursor to environmental and health impacts led Environment Canada to declare ammonia as a toxic substance under the Canadian Environmental Protection Act (CEPA) in 2003. Ammonia is included in the international Gothenburg Protocol, which requires that all signatory nations quantify and reduce their emissions in relation to 1990 levels.

Ammonia emissions from farm operations have been identified by the National Agri-Environmental Health Analysis and Reporting Program (NAHARP) as one of the quantitative indicators of agricultural environmental performance in Canada. Based on current estimates, about 6% of all Canadian emissions can be attributed to land application of poultry manure. Poultry production in British Columbia constitutes some 15% of the total production in Canada, and the Fraser Valley of B.C. generates large quantities (approximately 280,000 tonnes) of poultry manure each year. While land application of poultry litter can provide essential plant nutrients for crop production, improper manure management can lead to ammonia volatilization from the litter, and it can be detrimental to the environment.

The principle objective of this project is to monitor the seasonal variations of ammonia emissions from land application of poultry manure, in order to derive effective emission factors for the BC ammonia indicator and inventory. These new emission factors can be compared to the emission factors currently being used by Environment Canada (EC).

This paper presents the findings from literature survey on ammonia emissions from land applied poultry manure, and results obtained from field experiments conducted during the spring, summer and fall periods of 2005.

BACKGROUND RESEARCH

Ammonia Emission Inventory from European Agriculture

Emission of ammonia originates primarily from agricultural activities. In Europe, livestock production is the dominant source (70 to 90 percent of total emissions) followed by application of mineral N-fertilizers (up to 20 percent of total). The most recent inventories rely on country or region specific data on N-excretion and management practices. They distinguish between different manure systems to assess losses of nitrogen at the various stages of manure handling. This method is often referred to as "N-flow" or "process-based model" (Misselbrook et al., 2000). It relies on the assessment of available nitrogen and ammoniacal nitrogen at each considered stage (i.e. housing, storage, application, etc.) and its potential loss as ammonia. Recently, this method ahs gained wider acceptance, and has been used for the national ammonia emission inventories of the UK, Denmark, Germany, Netherlands, Switzerland and Norway (Webb and Misselbrook, 2004).

After spreading of manure, the following factors play an important role in determining N-losses: meteorological conditions, e.g. temperature, humidity, turbulence, precipitation, etc., soil properties, e.g. pH, calcium content, water content, etc., manure properties, e.g. pH, viscosity, dry matter content, etc., application rate, and the way manure is applied. The minimum information necessary to arrive at region-specific emission factors for each animal type includes typical N excretion rates, the manure application method, N-volatilization rates for different application practices. If emission factors during the manure application stage are based on N-excretion during the housing stage, it is necessary to know the N-volatilization rates during the housing stage, the manure storage stage and the manure application stage.

National inventories and projections for ammonia emissions in Austria, Germany and Ireland are compiled by using methodologies agreed upon by the Convention on Long Range Transboundary Air Pollution (CLRTAP) as set out in the Joint EMEP/CORINAIR Atmospheric Emission Inventory Guidebook 2003. This guidebook outlines a detailed and simple methodology for calculating these emission factors. The detailed methodology requires input data of animal numbers, nitrogen excretion, and manure management systems. Ammonia emissions from dairy cows, other cattle, fattening pigs and sows are estimated with the detailed methodology. In contrast, the simple methodology uses an average emission factor per animal for each livestock category and multiplies this factor by the number of animals counted in the annual agricultural census. Emissions from laying hens, broilers, other poultry, sheep, horses, etc are estimated using the simple method. There are problems with the simple method since there is no actual measurement data for most ammonia emitting activities (housing and storage).

As well, uncertainties in emission values arise from oversimplified representations and related assumptions to quantify emissions in broad source categories. For instance, for manure spreading the ECETOC (the European Centre for Ecotoxicology and Toxicology of Chemicals) assigns emission factors as proportion of total N applied for each livestock type. For instance, 28.5% of total N was determined for cattle manure, 5.35% for pig manure, 37.6% for laying hens and 7.2% for broilers. However, EMEP/CORINAIR gives 20% of total N for manure from all livestock types. It is apparent that updated information on manure storage and manure management practices is necessary for major improvements in the method currently used in estimating the emission factors)

Lower emissions in Poland are a result of using dried manure from laying hens and employing a short time between application and incorporation of the manure.) According to the Finnish Environment Institute, ammonia emission factors, in units of [kg NH_3 per animal in one year], range from a high of 31.5 for dairy cattle to a low of 0.055-0.34 for poultry (laying hens and broilers), as compared to 14.9 for sows and 4.2 for sheep. These values are similar to the emission factors presented by the Ministry of Agriculture of the Czech Republic - being 0.21 for broilers, 0.27 for laying hens, 0.73 for turkey, and 24.5 and 11.9 are associated with dairy cows and sows, respectively.

Emission factors as derived from ammonia emission inventories in Norway were reported in units of [percent of total N]. For dry manure (which is relevant to poultry), emission factors range from 0.04 to 0.10 under spring and autumn conditions. By comparison, these factors range from 0.2 to 0.5 for surface spreading of liquid manure.

Current Canadian Emission Factors

Emission factors that are currently used by Environment Canada (EC) are compatible with the European methodology. For land application of poultry manure, they are classified as "uncontrolled emission" and "controlled emission", and according to the types of poultry manure: pullets (< 19 weeks), laying hens (> 19 weeks), laying hens in hatchery supply flocks, broilers (and roasters and Cornish), turkeys and other poultry. Controlled emission needs to have emission factors expressed in units of [kg NH_3/animal/year], whereas the uncontrolled emissions are reported as amount of N or NH_3 volatilized as [percent of N available in poultry manure].

Review of Field Trials for Land Application of Poultry Manure

Ammonia (NH3) emission inventories are required for modeling atmospheric NH3 transport and estimating downwind deposition. The derivation of the UK-based emission factors used in the calculation of that emission for a range of livestock classes, farm practices and fertilizer applications to agricultural land was described in [1]. An emission factor of 45% UAN (uric and ammoniacal N) content of the poultry manure was estimated from the results of field experiments. The average UAN content varies according to poultry type. A research study [2] used poultry excretal output, among other livestock classes, for estimating the quantity of manure for land application. The researchers concluded that the slow conversion of uric acid to urea could lengthen the ammonia emission period.

A series of experiments was conducted using small wind tunnels to assess the influence of a range of environmental, manure and management variables on ammonia emissions following application of different manure types to grassland and arable land (both to stubble and growing cereal crops), in keeping with common practice in the UK [3]. Wind speeds through the tunnel canopies were controlled at 1 $m\,s^{-1}$. The concentration of NH_3–N in both the air entering and leaving each tunnel was determined by drawing a sub-sample of air (at 3–4 $l\,min^{-1}$) through absorption flasks containing phosphoric acid. Measurements of NH_3 emission continued for 12 d following solid manure applications. In addition to NH_3 emissions, measurements were also made of manure dry matter (DM) content, pH, total N content, total ammoniacal N (TAN) content and uric acid N content, plus soil moisture content and pH (top 10 cm), crop height (and growth stage for cereals), wind speed (at a height of 25 cm), air and soil temperatures (at 5 cm height and 5 cm depth, respectively) for each experiment. Differences in temperature were achieved by applying manure at different times of year. For solid manures, rainfall was identified as the parameter with most influence on ammonia emissions.

A multi-season study was conducted to quantify NH_3 volatilization rates from surface-applied poultry litter under no-till and plowed conservation tillage managements [4]. Litter was applied to supply 90 to 140 kg N ha^{-1}. Poultry litter was applied immediately after planting and before seed germination, with the standing stubble from the previous crop being 10 to 15 cm tall. Micrometeorological data and atmospheric NH_3 concentrations were determined 24 to 48 h before litter application and for 7 to 8 d following applications. Results showed that ammonia volatilization was rapid immediately after litter application and stopped in about a week. Total losses of NH_3 from surface-applied poultry litter ranged from 3.3 to 24% of the total N applied with the largest losses under summer (hot, dry, windy) conditions. Losses of 22 to 24% would be large enough to potentially decrease crop yields when poultry litter is used as the sole source of N fertilizer and applications are based on the N content of the litter. In addition losses of this magnitude have the potential to affect nearby natural ecosystems. Precipitation (rainfall) of 17 mm within 48 h of application greatly inhibited volatilization rates, probably by transporting litter N into the soil matrix, although 36 to 64% of the NH_4 in the poultry litter was volatilized before precipitation. Application of poultry to conservation-tilled cropland immediately before rainfall events would reduce N losses to the atmosphere but could also increase NO_3 leaching and runoff to streams and rivers.

A spreading experiment was conducted at Ultuna, 5 km south of Uppsala, Sweden. After storage, broiler manure and commercial fertilizer pellets (a mixture of broiler manure, harvest residues and stone meal) were spread to arable land at a rate of 110 kg [total-N] ha^{-1} [5], which corresponds to a rate of 4.4 t broiler manure per hectare and 2.7 t pellets per hectare. The broiler manure was applied with a spreader JF, type ST70-H, modified as a two-step spreader. The soil had a texture classified as clay (FAO, 1990) and 2-3% organic matter. The treatments were arranged as a randomized block design with three replicates. Ammonia emissions were measured from plots fertilized with broiler manure and pellets, respectively, with and without harrowing 4 h after spreading. For plots fertilized with broiler manure with no incorporation, the NH3 emissions were measured on five occasions over a period of 5 days and for plots fertilized by broiler manure and harrowed 4 h after spreading on three occasions during 2 days. The pellet applied plots, with and without incorporation. Totally, 13.5% of the nitrogen in the broiler manure was lost as ammonia after spreading without incorporation of the manure and 7.5% from plots with incorporation. After incorporation no ammonia emission occurred. No emissions occurred from plots fertilized with pellets. Incorporation after spreading of broiler manure was found to be an effective way to reduce ammonia emissions. The incorporation should be carried out as soon as possible after spreading, or at least not more than 4 h after spreading, to limit the ammonia losses to about half of the potential amount.

Based on a project specific to broiler litter and layer manure, research findings indicated there were no differences in emissions between any of the broiler litter treatments following land spreading, with total ammonia losses equivalent to 46-92% (average 63%) of the UAN applied over the 28 day measurement periods. Likewise, there were no differences in emissions following land spreading between the various layer manure removal methods or between layer manures from the different commercial unit houses. Total ammonia losses were equivalent to 67-118% of the UAN applied over the same period. That the percent ammonia emission exceeded 100% of UAN is indicative of the conversion of uric acid to ammonia-nitrogen during the period of observations.

MATERIALS AND METHODS

Spring Trial

Field tests were performed at the Agassiz Research Station of the Pacific Agricultural Research Center (PARC) in May-June 2005 using four different types of poultry manure (breeder, broiler, layer, and turkey) as the fertilizer materials. After manure application, wind tunnel canopies were positioned over each plot and air drawn through at a controlled rate. Sixteen framed wind tunnels were installed for the experiment, with the frames set 50 mm in the ground. Polycarbonate covers were secured on the frames after manure application. The general height of the tunnel is 450 mm and the width is 500 mm. A rotary anemometer was placed inside the blower unit of each tunnel, with orientation perpendicular to airflow. Airflow rates from the anemometers and temperatures inside the tunnels were transmitted to a multiplexer and thence a CR10X datalogger via a signal transmitter box. Four of the 16 anemometers had attached temperature probes which monitored ambient temperature within the tunnel. This data was also transmitted to the CR10X datalogger. Data were downloaded periodically from the datalogger onto a laptop computer.

Air sample inlet for the tunnel is located above the blower. Acid traps were set up using graduating cylinders that contained 100 ml of 0.01 M phosphoric acid to capture ammonia emissions. With suction from a pump, a sub-sample of tunnel air (at 2-3 L/min) was bubbled through the acid solution via a Tygon tube attached to the inlet of each tunnel and the inlet of the blower. The unit was connected to Erlenmeyer flasks to capture condensate. Flow restrictors were used to reduce the load on the pump. The volume of air was measured with flow meters. All equipments were placed inside weatherproof wooden boxes. The wind tunnel method and ammonia capture technique used in this study is similar to that used by Misselbrook et al. (2005).

On the first day when the rate of NH_3 volatilization was anticipated to be highest, the acid traps were changed at time intervals of 1 h, 2 h, and 5 h following manure application. Thereafter, 1-2 shift changes occurred in the morning and mid-afternoon for 8 days, and once a day after that until Day 21. A total of 32 liquid samples (2 bubblers per tunnel) obtained from each acid change shift were stored in a cooler at 5^oC. When the samples were ready for analysis, the liquid levels were filled to 120 ml if the bottles should contain fewer amounts due to field evaporation of the acid solution as a result of heat from the environment and the pumps inside the boxes. Once prepared, they were then analyzed using a flow injection analyzer (FIA). The amount of NH_3 volatilized during each interval was calculated from the amount of NH_3 trapped and the airflow data.

A randomized complete block design was used for the experiment, with 4 treatments for the various types of poultry manure and 4 replicates for each treatment. Before application, manure samples were analyzed for moisture, ammonia-nitrogen, and total nitrogen contents. Based on these analyses, manure was surface-applied to the plots (0.5 × 2 m) by hand after weighing out specific amounts. In the spring and summer trials, rate was based on ammonia-nitrogen. In the fall trial, rate was based on total-N. The initial amounts of manure applied are reported in Table 1. Measurements of NH_3 emission continued for 21 days following manure applications.

Using the data associated with the sub-sample of tunnel airflow during each shift change, and assuming that ammonia capture rate is equal to the ammonia emission rate, the latter was computed from the trapped ammonia concentration values. The ammonia emission rate from the entire plot was then computed using the ratio of actual airflow rate (from the rotary anemometer readings) to the sub-sample airflow rate. Thus,

$$E = (Co - Ci)\, V\, R$$

where,

E = ammonia emission rate based on sub-sample tunnel air, [mg]
Co = concentration of ammonia at blower intake
Ci = concentration of ammonia at tunnel intake
V = volume of acid trap solution
R = $v\, A/Q$
V = anemometer wind speed
A = tunnel cross sectional area
Q = tunnel flow rate

These calculations were performed for all tunnels and all shifts.

Summer Trial

Field tests were performed at Agassiz Research Station of the Pacific Agricultural Research Center (PARC) in July 2005 using broiler manure as the fertilizer material. The experimental setup was essentially the same as that of the spring trial; however, the treatments included 4 heights of orchard grass (low 25 mm, medium-low 75 mm, medium-high 175 mm, and high 275 mm) and 4 replicates for each treatment. Manure was surface applied to the plots (0.5 × 2 m) by hand at a rate of 2.79 kg per tunnel or per m^2, which is the same as that used for the spring trial. This quantity of manure is equivalent to 100 kg NH4-N/ha or 470 kg N/ha, respectively.

Fall Trial

Field tests were performed at Agassiz Research Station of the Pacific Agricultural Research Center (PARC) in November-December 2005 using poultry manure as the fertilizer materials. A randomized complete block design was used for the experiment, with 4 treatments for the various types of poultry manure and 4 replicates for each treatment. Manure was surface applied to the plots (0.5 × 2 m) by hand after weighing out specific amounts. The initial amounts of manure applied are also reported in Table 1, and the application rate is based on 150 kg N/ha. By comparison, broiler manure was applied to arable land at a rate of 110 kg N/ha in a field test conducted by Rodhe and Karlsson (2002) in Sweden, whereas in the multi-season study conducted by Sharpe et al. (2004), litter was applied to supply 90 to 140 kg N/ha. Measurements of NH_3 emission continued for 21 d following manure applications.

As shown in Table 1, the initial ammonia content of the layer manure was significantly less for the fall 2005 trial (0.82%) than that for the spring 2005 trial (3.88%). The manure from the spring trial was observed to be very watery and thus trapped more ammonia, which could explain the higher percent of initial ammonia content. Since the layer manure samples from the fall trial were collected from stored manure piles, it is possible that the manure had gone through a passive composting process, with a loss of ammonia nitrogen. In contrast, the breeder and broiler manure samples were collected from fresh manure piles for both trials, and the initial ammonia contents were similar.

After the experiment, Tygon lines from the acid bubbler to the overflow cylinder, and the overflow cylinder itself were washed with acid. This sample was collected to measure any residual ammonia that may have been trapped in the lines or in the overflow as condensate. As well, manure scrapings were collected from each treatment plot to be analyzed again for ammonia-nitrogen content.

Table 1. Manure Analysis and Application Rates

Summer 2005 Grass Heights Trial				
Type of manure	**Application rate, kg/m^2**	**Moisture content, %**	**Total nitrogen, % d.b.**	**Ammonia-N, % d.b.**
Broiler manure	2.79	36.7	2.67	0.57
Fall 2005 Manure Types Trial				
Breeder manure	0.56	23.0	2.89	1.22
Broiler manure	0.68	32.1	3.06	0.52
Layer manure	0.30	13.4	5.90	0.82
Turkey manure	0.30	29.0	7.53	1.84
Spring 2005 Manure Types Trial				
Breeder manure	2.08	33.3	2.98	0.72
Broiler manure	2.79	36.7	2.67	0.57
Layer manure	1.26	79.5	6.26	3.88
Turkey manure	0.74	41.6	7.35	2.33

RESULTS AND DISCUSSION

Spring Trial

Using the data associated with the sub-sample of tunnel airflow during each shift change, and assuming that ammonia capture rate is equal to ammonia emission rate, the hourly and hence daily ammonia emission rates were computed from the trapped ammonia concentration values. Results are shown in Figure 1. The profiles of trapped ammonia concentration over the same period are shown in Figures A1-A4 for the four types of poultry manure in Appendix I.

Based on these results, the total amount of ammonia emitted over a period of 21 days was estimated, and eventually expressed in terms of the initial ammonia-nitrogen content of the manure, as depicted in Figure 2.

Figure 1. Spring Trial: Ammonia emission rates for four types of poultry manure

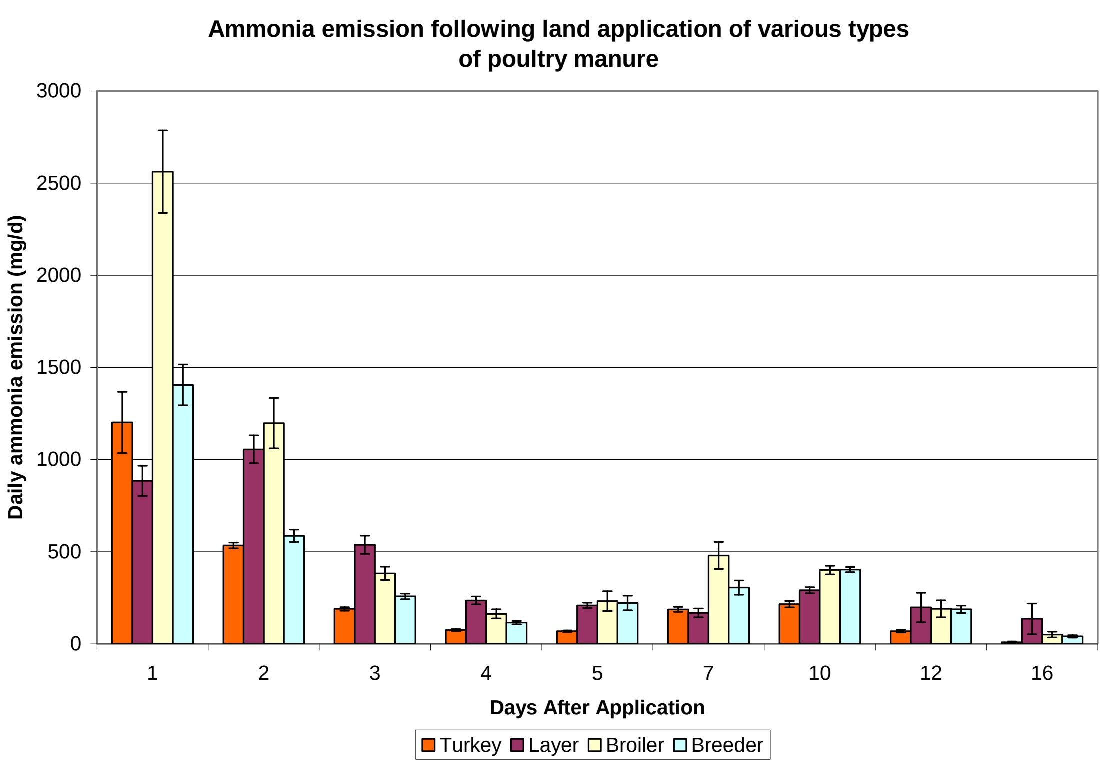
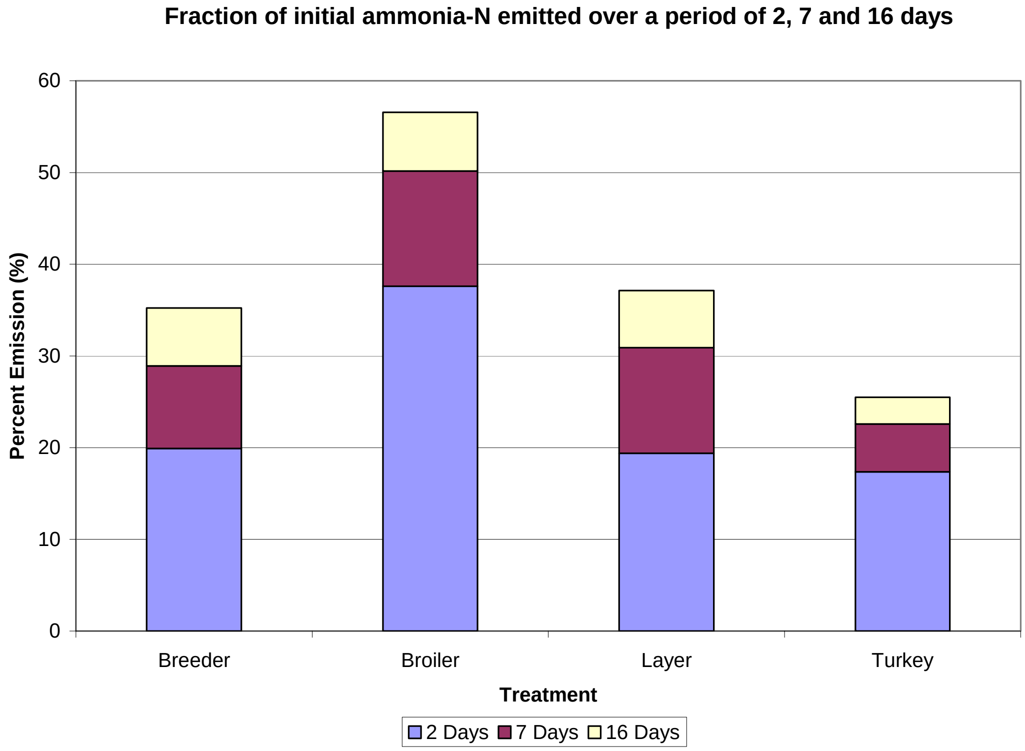


Figure 2. Percent ammonia emission – spring trial



Summer Trial

The profiles of ammonia emissions over a period of 14 are shown in Figure 3 for the four orchard grass heights, with error bars indicating the variation due to the replicates. Evidently, the overall pattern of ammonia emissions was similar for all treatments. The NH_3 volatilization rate from applied manure was rapid immediately (day 1) after manure application and decreased with time, as expected. Ammonia emissions were consistently higher for the low (25 mm) and medium low (75 mm) grass heights, whereas the lowest emission was associated with the high (275 mm) grass height. Aside from the fact that a taller grass canopy was able to take up more ammonia-nitrogen form the manure, wind speed might be another contributing factor.

Higher air velocities at the ground-air interface could have induced more air mixing within this zone, thus increasing the diffusion of ammonia, lowering the NH_3 concentration in the air above the manure, and eventually stimulating further NH_3 volatilization. This relationship between wind speed and ammonia volatilization explains why the most emissions were seen in the low grass (higher wind speeds). In this aspect, Huijsmans et al. (2003) had observed that wind speed exerted a substantial effect on the volatilization rate, only when manure was surface applied or surface incorporated.

Examination of the rotary anemometer readings indicated that the measured data were relatively constant for all tunnels during the field test period; however, they were different among the treatments, for instance, the average reading was 11.78±0.31 m/s for the medium low grass height, whereas it was 14.23±0.06 m/s for the low grass height.

The wind speed profiles derived from the hot wire anemometer measurements on two occasions are shown in Figures 9 and 10. Air velocity is seen to increase with height from the soil surface; moreover, as grass height increases, the difference in air velocity between treatments increases in the zone 20-40 cm above the soil surface, this relationship being most pronounced for the high grass. This relationship is a result of the wind speed being conserved within the tunnel; that is, relatively lower wind speeds within the grass are associated with relatively higher wind speeds within the upper region of the tunnel.

Figure 9. Wind speed profiles as a function of height from soil surface (July 13-14, 2005)

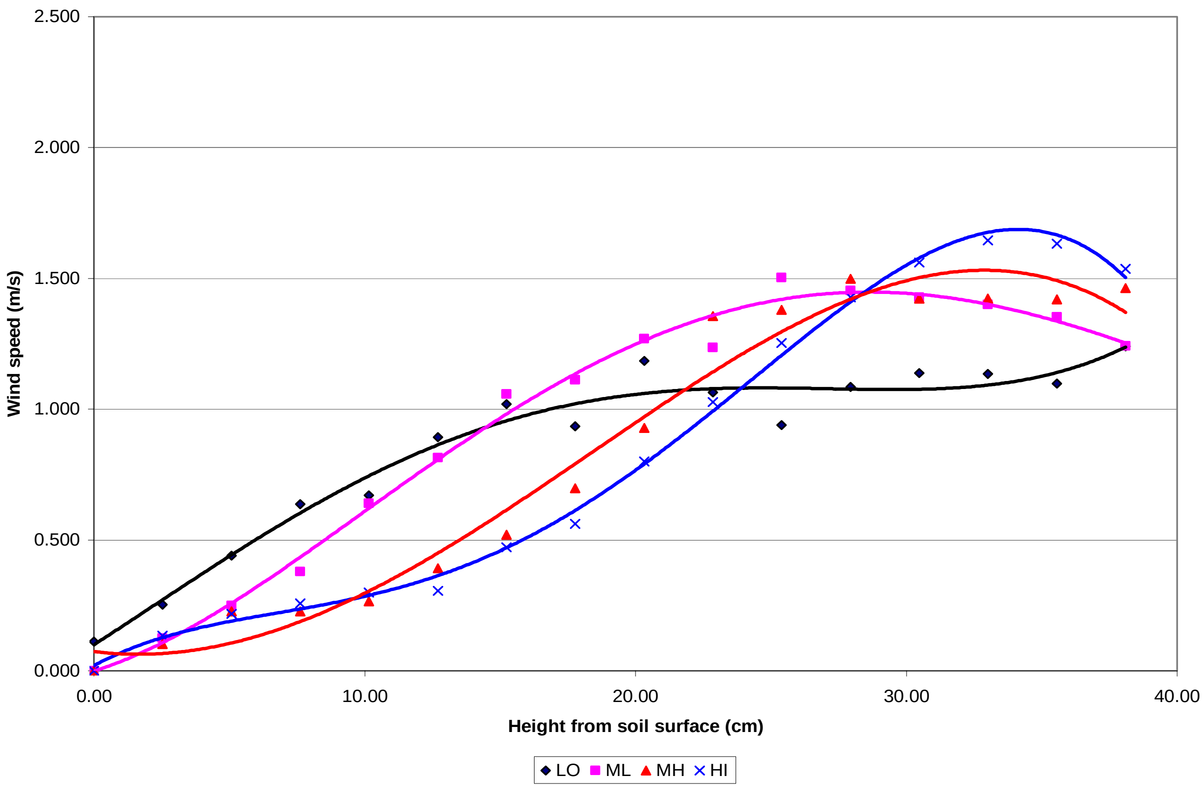
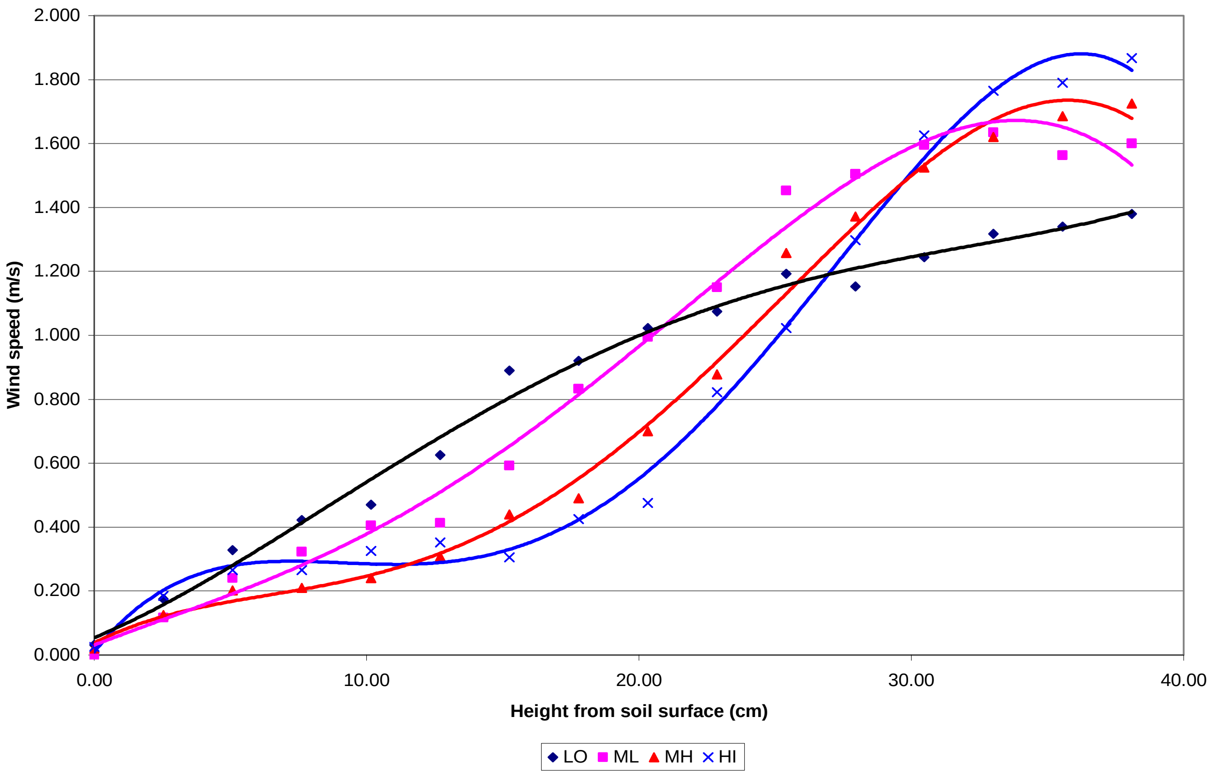


Figure 10. Wind speed profiles as a function of height from soil surface (July 20, 2005)



Further processing of the data led to an estimate of the total amount of ammonia emitted over the first 7 days, and expressed as a fraction of the initial amount of ammonia-nitrogen in the broiler manure. As shown in Figure 4, losses of ammonia during this period amounted to 65.3%, 59.6%, 56.0% and 42.8% of the initial ammonia-N for the orchard grass heights of 25 mm, 100 mm, 175 mm and 275 mm, respectively. When compared to the initial amount of total N in the broiler manure, such losses ranged from 9.1 to 13.9%. This is in good agreement with results (13.5% of the nitrogen in the broiler manure was lost as ammonia over the first 5-day period) obtained by Rodhe and Karlsson (2002) for plots fertilized with broiler manure with no incorporation. It is also in the same order of magnitude (3.3 to 24%) as reported by Sharpe et al. (2004), who considered losses of 22 to 24% to be large enough to potentially decrease crop yields when poultry litter is used as the sole source of N fertilizer and applications are based on the N content of the litter. According to Fulhage and Pfost (1994), until poultry manure is incorporated into the soil, its ammonia-N losses generally ranged from 20% within two days of application, to 80% after 7 days of application; in other words, only 20% of initially applied ammonia-N is available for crops if it took more than 7 days till incorporation.

Figure 3. Summer Trial: Ammonia emission rates for four grass heights

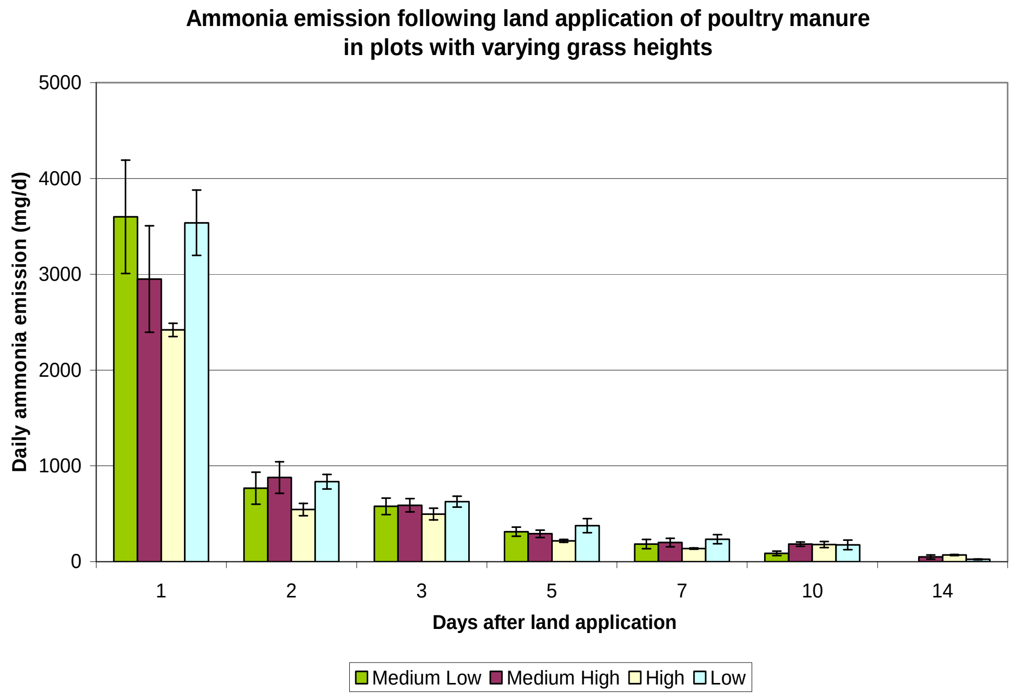
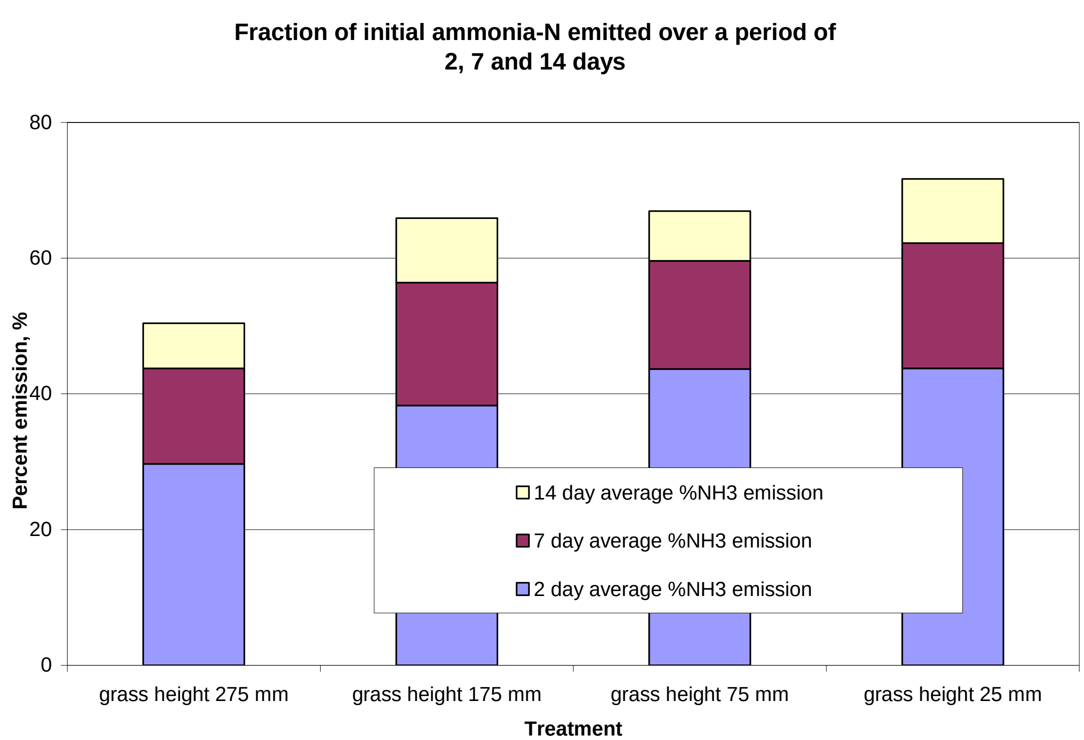


Figure 4. Percent ammonia emission – summer trial



Fall Trial

Using the data associated with the sub-sample of tunnel airflow during each shift change, and assuming that ammonia capture rate is equal to ammonia emission rate, the hourly and hence daily ammonia emission rates were computed from the trapped ammonia concentration values. Results obtained from averaging of the 4 replicates in each treatment are shown in Table 2; whereas Figure 5 shows the profiles of the daily ammonia emission rates along with the standard error (SE) bars that represent a 95% confidence interval (CI) for the data. Although they varied in the bulk amount of emissions over the 21 day period, all four types of poultry manure exhibited similar patterns of emissions with the most ammonia being emitted over the first few days and tapering off thereafter, as expected.

After 21 days, there were no observed differences in grass heights between the treatments, or between the plot areas versus outside grass area. Analysis of grass samples also confirmed that the differential uptake of ammonia nitrogen by the grass is negligible.

Table 2. Daily ammonia emission rates associated with the land application of the various types of poultry manure – fall trial

Days ater land spreading	Ammonia Emission Rate, mg/d			
	Breeder manure	Broiler manure	Layer manure	Turkey Manure
1	1005	654	449	234
2	175	195	77	62
7	23	28	9	21
14	19	22	15	12
21	9	3	8	5

The ammonia emission rates were then expressed as a fraction of the initial amount of ammonia-nitrogen present in the manure, as demonstrated in Figure 6. These profiles suggested that the percent ammonia emissions are significantly different between the various types of poultry manure, 2 days ($p<0.001$), 7 days ($p<0.001$), and 21 days ($p<0.001$) after land application. After the first two days, breeder manure emitted the most emissions (54%), followed by broiler (41%), layer (26%), and then turkey (20%). This trend is consistent until the end of the trial on day 21; breeder manure had emitted the most emissions (80%), followed by broiler (66%), layer (40%) and turkey (20%).

Figure 5. Ammonia emission rates for the various types of poultry manure – fall trial

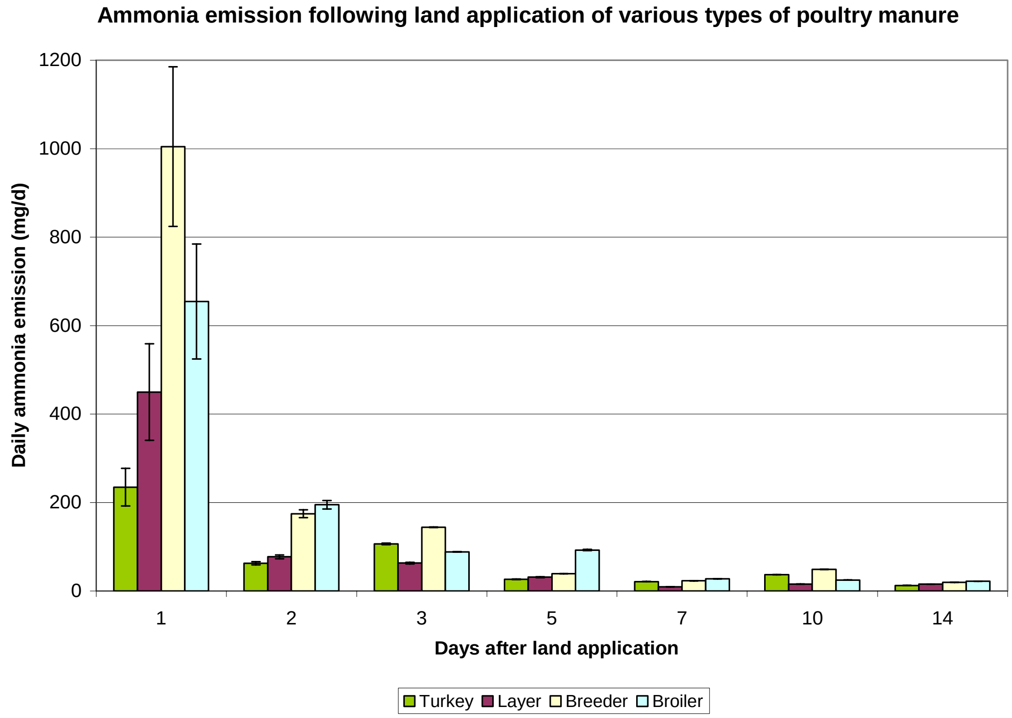
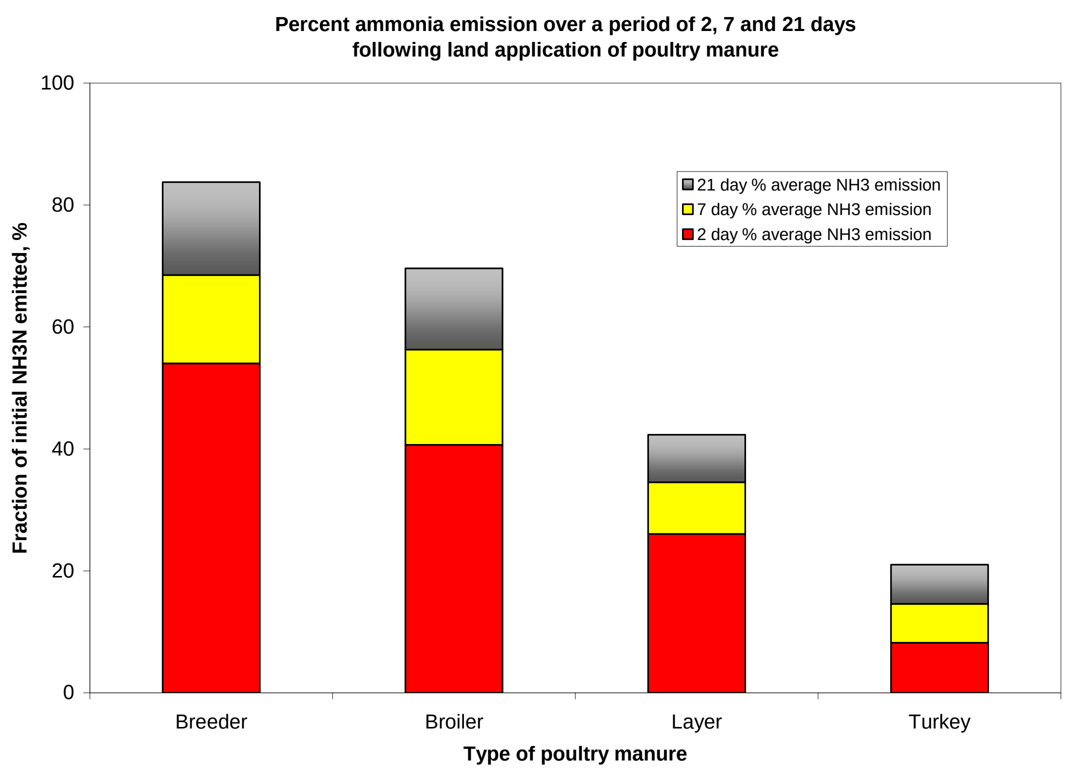


Figure 6. Percent ammonia emission – fall trial

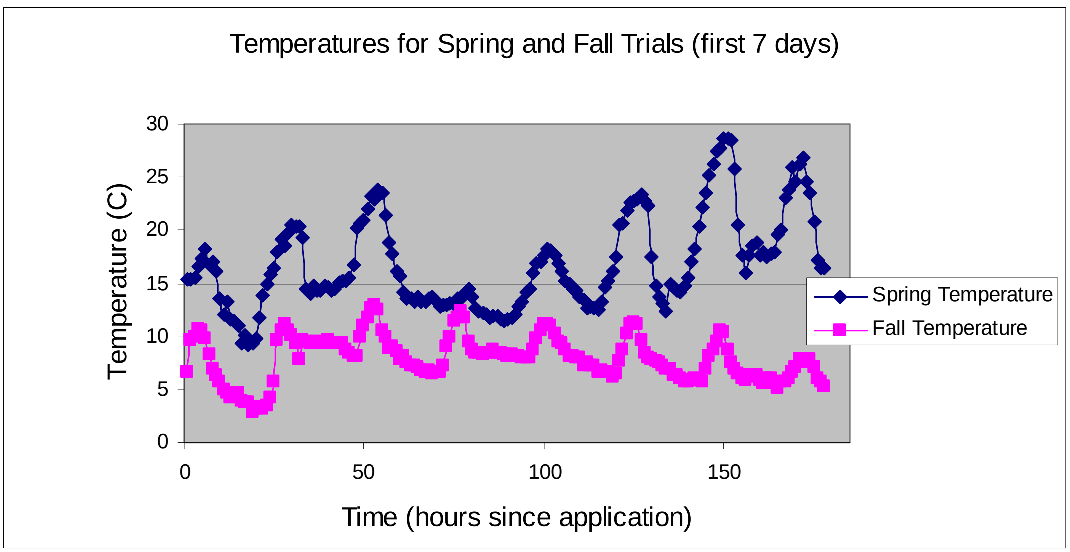


The lower percent ammonia emission of layer manure and turkey manure may be attributed to the characteristics of the manure at collection. Breeder and broiler manure had a pH of 8.8 and 8.9 respectively, which are more conducive to ammonia volatilization, whereas the pH of layer and turkey manure was 7.9 and 5.9 respectively. After the trial was completed, turkey manure was seen to be unevenly distributed in patches on the plots, and it was wet throughout, which might have trapped some ammonia-nitrogen and hence affected ammonia volatilization.

Effects of Temperature and Humidity

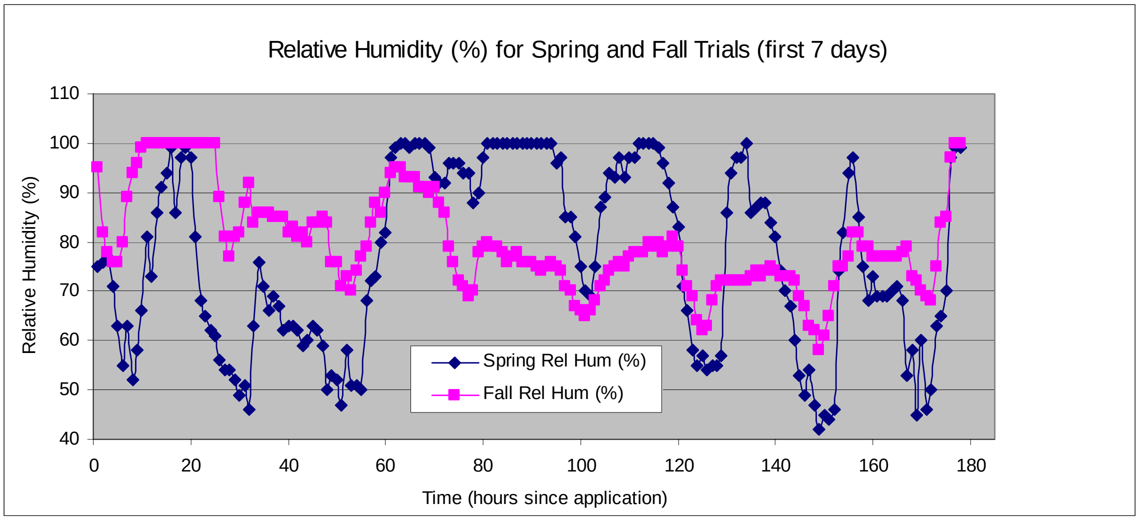
Temperature was consistently higher during the spring trial versus the fall trial. The difference in temperatures ranged from 4.7°C to 12.5°C in the first 48 hours since manure application, when emissions were the highest (Figure 7). However, higher spring temperatures did not result in higher emissions.

Figure 7. Temperature measurements for the spring and fall trials



In addition to temperature, higher humidity was observed to be relatively lower for the spring versus the fall trials in the first 48 hours (Figure 8), but again, it did not result in higher emissions.

Figure 8. Relative humidity measurements for the spring and fall trials



It appears that ammonia emissions in the spring and fall trials can be best correlated to manure characteristics. For instance, pH of treatment manure differs between spring and fall trials and appears to play a key role in the emissions. Upon comparison of spring and fall applications, the higher the manure pH, the more emissions were given off for all treatments.

Emission Factors

The ammonia emission values from all three trials will eventually be converted to uncontrolled emissions and reported as amount of N or NH_3 volatilized as [percent of N available in poultry manure].

CONCLUSIONS AND RECOMMENDATIONS

The seasonal variation of ammonia emissions from land application of poultry manure was monitored. The general trend of emissions was as expected, with the highest emissions occurring within the first two days, and gradually declining thereafter.

The wind tunnels have been useful in the measurements of ammonia emissions from the land application of poultry manure. For the trials involving different types of poultry manure, ammonia emission as a fraction of the initial amount of ammonia nitrogen present in the manure followed a similar trend with the broiler, layer and turkey manure in both the spring trial and fall trial. The percent of ammonia emitted ranged from 56-70% for broiler, 37-42% for layer and 20-25% for turkey. However, breeder manure had very different values, being 35% for the spring trial and 82% for the fall trial.

The summer experiment examining the effects of grass height on emissions illustrated wind speed as a key factor in emissions. Lower grass heights allowed more exposure to manure surface, where higher wind speeds occurred. This effect lowers the concentration gradient at the soil-air interface, allowing volatilization to occur. Aside from wind speed, a taller grass canopy was able to take up more ammonia-nitrogen form the manure. The percent ammonia emitted was 50% for the high grass height, as compared to 65-70% for the other grass canopies. These values were closer to the values pertinent to the fall trial, with medium grass height and various types of manure.

Ammonia emissions are expected to be higher with increasing ambient and soil temperature, and with lower humidity. However, this pattern was not observed in these trials. In theory, ammonia emissions from poultry manure spread onto land can persist for many weeks because of the slow conversion of uric acid to urea, and hence ammonia. However, such phenomenon was not observed in this study. It is probable that most of the uric acid had been converted to ammonium within a few days of the in-barn storage of the manure (Nahm 2005). The uric acid content of manure is being determined. It would provide a more complete account of the ammonia emission process.

Overall, this project illustrates that variation in ammonia emissions cannot be explained by seasonal data alone; rather, emissions are a result of many factors including and not limited to wind speed, manure pH and perhaps uric acid.

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