RESEARCHREPORT
ENVIRONMENT

Title: Evaluation of the ammonia emissions from swine production units in Iowa - NPB # 02-040

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Abstract: Emission of ammonia from swine production facilities is of a major concern from an ecological viewpoint due to deposition and a potential health effect due to formation of 2.5 micron (μm) particles. One of the critical factors in ammonia emission is the variation in the emission rate from swine production facilities throughout a production cycle and the variation in the ammonia concentrations at various distances from a building. This study was conducted to measure ammonia concentrations in the air surrounding a 3,600 head grow-finish unit throughout a production cycle. Measurements were made at 16 m (50 ft) and 33 m (100 ft) downwind of the buildings at a height of 1 m (3 ft), 6 m (18 ft), and 12 m (36 ft) at 33 m (100 ft) from the buildings with a ion mobility spectrometer with an accuracy of 5 ppb_v. An additional study was conducted to measure ammonia concentrations during application of manure and anhydrous ammonia.

Ammonia concentrations varied during the production cycle with the concentrations near 1000 ppb_v at 50 feet and rapidly decreasing to less than 200 ppb_v at 100 feet from the buildings. This decrease in concentration was typical throughout the complete production cycle. There was a decrease in ammonia concentrations with height above the surface. The variation among days during a week was large and it was not uncommon to observe variations within a day from 50 to 1000 ppb_v. This magnitude of variation decreased with distance because of the lower maximum values. The large variation with time was due to the extreme turbulent regime observed within close proximity of production buildings. This degree of variation has prohibited the use of traditional micrometeorological methods to estimate emission rates from buildings. Ammonia concentrations at 1 m above the surface during manure application reached a maximum of 400 ppb_v within six hours following application and remained at 100 ppb_v for the next 24 hours. In contrast, ammonia concentrations at 1 m above the surface reached 250 ppb_v within 2 hours and then rapidly decreased to less than 10 ppb_v within 4 hours after application. The patterns of ammonia emission following application of manure were caused by manure being deposited on the surface compared to the ammonia being injected into the soil. Understanding variations in ammonia concentrations around swine production units provides increased confidence in evaluating management practices that reduce ammonia emissions.

Introduction: Ammonia emissions from swine production are from the rapid conversion of urea in urine to ammonia by urease and from nitrogen transformations in manure. Ammonia emission from livestock production units is considered as one of the primary sources of ammonia to enter the atmosphere. There are recommendations that ammonia emissions be reduced and the ammonia emission factors that are currently being used for swine exhibit a large amount of variation amount systems. These emission factors have been developed with limited data sets that don't completely represent a complete production cycle. The measurements that have been conducted are from positions within the building or within fans; however, there are few measurements that represent a complete facility.

There is little information about the variation in ammonia concentrations surrounding swine production facilities throughout a production cycle. Improvement in our understanding of ammonia emissions will help develop improved models of alternative management of production units to reduce ammonia. This study was designed to evaluate ammonia emissions from a grow-finish unit throughout a production cycle.

Objectives:

The objectives of this study were to:

1. Quantify the release of ammonia into the atmosphere from swine confinement buildings, manure storage, and manure application systems; and
2. Characterize the transport of ammonia both vertically and horizontally from the site of origin into the atmosphere.

Materials and Methods: Description of the site: Measurements were made adjacent to a grow-finish facility that consisted of three 1,200-head buildings with natural ventilation. This facility was located in central Iowa about 10 miles northwest of Ames on fairly level terrain and no windbreaks adjacent to the facility. The stages of pork production during these observation periods are shown in Table 1.

Measurement date	Number of Animals	Size of animals
DOY 134-139 (May 14-19)	3000 (134) 0(136)	290(134) none
DOY 155-161 (June 4-10)	122-3600	50 lbs
DOY 182-189 (July 1-8)	3600	90 lbs
DOY 210-217 (July 29- Aug 5)	3500	175 lbs
DOY 246-253 (Sept 3-11)	3500	250 lbs

Table 1. Number and size of animals during each of the measurement sequences

Detection methods:

Ammonia measurements were made using an IonPro ion mobility spectrometer from Molecular Analytics, Sparks, MD. The working range was 0-300 ppb_v with linearity observed up to 1000 ppb_v. Calibration was performed using an inboard permeation tube set to generate 150 ppb_v ammonia. Zero and 150 ppb_v were checked daily and adjusted as necessary. There are four ports on this unit and each port was positioned at a different height and distance from the building in an attempt to quantify the ammonia concentration in a plume leaving the building site. The four positions were 1 m above the ground surface and 16 m away from the building (1,16), 1 m above the surface at 33 m away from the building (1,33), 6 m above the

surface at 33 m away from the building (6,33), and 12 m above the surface at 33 m away from the building (12,33). Teflon tubing was placed at these positions and connected to the spectrometer to provide continuous air flow from the position to the spectrometer. A preliminary study was conducted to evaluate the variation adjacent to the buildings and it was decided that 16 m from the building eliminated some of the variation induced by individual fans and opening and closing of the sidewall curtains.

A meteorological station was placed at the tower to record air temperature, water vapor pressure, windspeed, and wind direction. These instruments were placed at 2 m above the surface and recorded as 30 minute averages throughout the day. During each of the measurement periods a R.M. Young 3-d sonic anemometer was placed at the tower at 5 m to collect data to be used in the calculation of the turbulent transfer coefficient. These data were collected 10 hz and summarized into 30 minute diffusivity values.

Ammonia data collected over the field site during manure and anhydrous ammonia application was sampled at a height of 1 m above the ground surface. The sampling mast was placed in the field prior to application and then the manure or anhydrous ammonia applied around the sampling mast. This provided a tie sequence of the change in ambient ammonia concentrations during and after application. Wind speed and diffusivity values were collected at the 1 m height. All data were collected at 1 minute intervals for a 36 hour period.

Results:

Objective 1.

Quantify the release of ammonia into the atmosphere from swine confinement buildings, manure storage, and manure application systems.

Ammonia concentrations varied with distance from the production building. These concentrations decreased rapidly for all of the measurement sequences throughout the production cycle. For the first sequence which occurred when pigs were being removed from the building for market there was large values at the beginning of the period and then decreased to no emission at the end of the measurement period (Fig. 1). At an 8 m position from the building the concentrations were near 1000 ppb_v at times during the first day and then showed peaks in excess of 500 ppb_v on subsequent days. However, concentrations at the 33 m profile were always less than 100 ppb_v at any time during the measurement period. On Day-of-Year (DOY) 136 the building was closed and all levels were at ambient concentrations (Fig. 2). The rapid decrease in ammonia concentrations with distance shows the rapid dispersion present in the atmosphere surrounding production buildings.

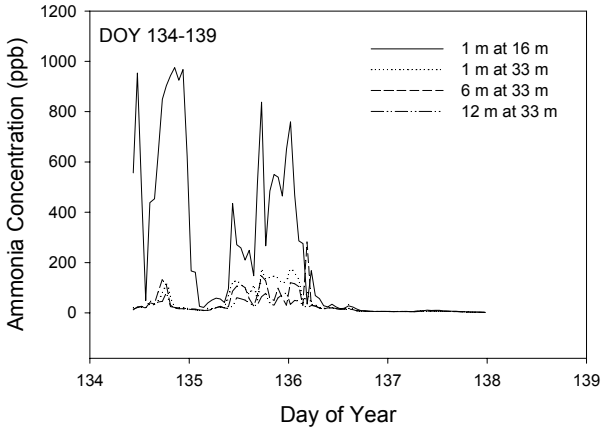


Figure 1. Ammonia concentrations at four positions relative to the swine production building in the DOY 134-139 period.

For the next measurement cycle the building had been repopulated and pig size was small because this was the beginning of the finishing cycle. Concentration measurements were repositioned at the point nearest the building from 8 to 16 m. Concentrations at this position exceeded 1000 ppb_v at several times during the measurement sequence. However, we observed in the first series the concentrations decreasing rapidly at 33 m and exceeded 400 ppb_v for only 1 hour during this time (Fig. 2). The concentration profiles with height showed little difference among the three positions.

As the size of the animal increased there began to emerge some larger impact on the positions away from the building. This period was during the middle of

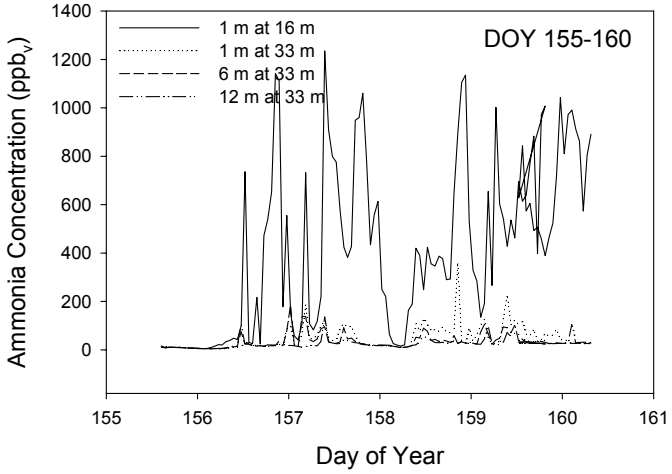


Figure 2. Ammonia concentrations at four positions relative to the swine production building for observations in the DOY 155-160 period.

the summer with higher temperature and humidity conditions. Concentration values at 16 m didn't exceed 1000 ppb_v at any time during this measurement cycle; however, there was more effect at the positions away from the building than previous times (Fig. 3). These concentrations followed the same trend at the position closest to the building but did not exceed 200 ppb_v for this measurement cycle (Fig.3). The

data collected on DOY 185 shows the extreme turbulence surrounding the building because all of the positions show a similar range in ammonia concentrations.

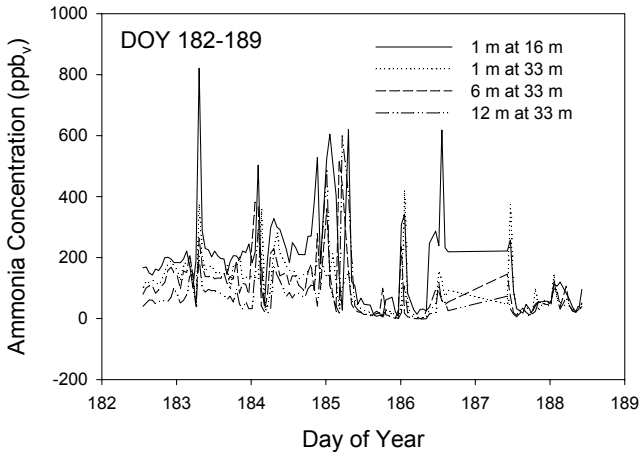


Figure 3. Ammonia concentrations at four positions relative to the swine production building for observations in the DOY 182-189 period.

During the next measurement cycle the pigs had increased in size and the ambient conditions were typical of summer in central Iowa. Ammonia concentrations did not exceed 400 ppb_v at any time during this period and there was less evidence of a spatial gradient (Fig. 4). There was less difference among the positions during this measurement sequence compared to the earlier measurement periods.

The last sequence of measurements was collected when the pigs were near the end of the production cycle. Ammonia concentrations for this period exceeded 500 ppb_v for one hour at the 6 m height on the tower 33 m from the building (Fig. 5). The reason for this large concentration value in the measurement sequence is not clear

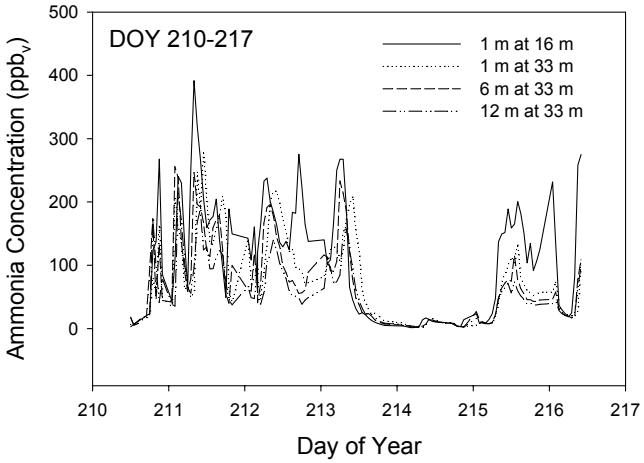


Figure 4. Ammonia concentrations at four positions relative to the swine production building for observations in the DOY 210-217 period.

or evident since none of the other positions showed this large of concentration. A possible explanation is that this observation occurred in the evening and the development of inversion conditions would create this range of differences due to

inadequate missing of the atmosphere. Typical concentration values for this interval showed the concentrations at 16 m were less than 300 ppb_v and decreased with values at the rest of the positions showing a decrease with distance from the building (Fig. 5).

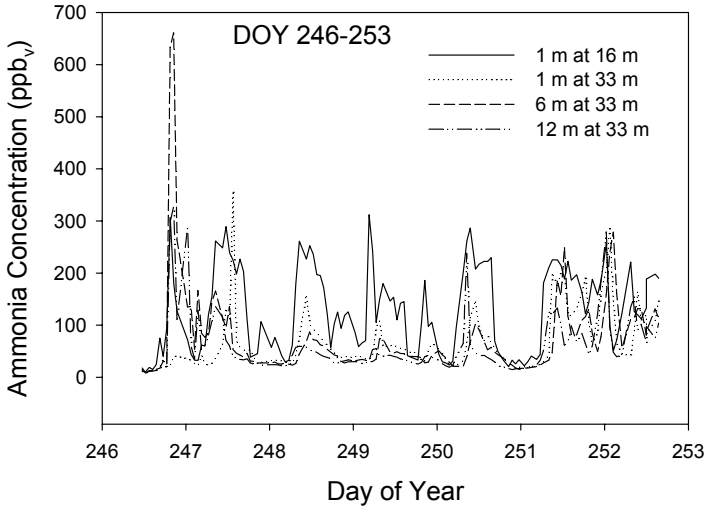


Figure 5. Ammonia concentrations at four positions relative to the swine production building for observations in the DOY 246-253 period.

Objective 2:
Characterize the transport of ammonia of ammonia both vertically and horizontally from the site of origin into the atmosphere.

Concentration gradients from the swine production unit showed large variation during the production cycle and among days within each of the phases of growth. There is a rapid decline in the concentration away from the building. We computed the ammonia gradients for three different pathways of ammonia movement. These gradient paths were at the 1 m height between the 8 or 16 m position and the 33 m position, between the 1 and 12 m positions at the 33 m distance, and between the 8 or 16 m position and the top of the tower at 12 m. This perpendicular distance provides a measure of how rapidly the plume of ammonia disperses into the atmosphere. The critical part of the data set began to emerge when we evaluated the wind speed and turbulence data for the site. It was apparent there was no consistency in the measurements which led to an additional study conducted in 2003 around the same facility. In this study, we placed five 3-dimensional sonic anemometers at different locations on the north side of the facility with the positions located to provide a different position in the wake of the building. The estimation of the diffusivity as shown in Figure 6 demonstrates the differences due to position. There are periods throughout the day in which the two systems which should produce similar results on this day because of their position did not agree. The variation we observed with the point measurements created an opportunity for us to employ a Lidar system from the University of Iowa and Los Alamos National Laboratories to measure the 2-d structure of particulate and water vapor plumes over this facility. These data show that the plume structure is not well-behaved and the short-term variation (1minute time scale) in plume location and shape causes

concern about the appropriate micrometeorological methods to use in calculating the emission rates and dispersion characteristics. We observed that the vertical velocities of momentum transfer, i.e., the upper movement of wind in the region adjacent to the building were between 1 and 5 m s^{-1} which is 10 times higher than we expected. This is unusual because the mean wind speed during these studies was between 2-5 m s^{-1}.

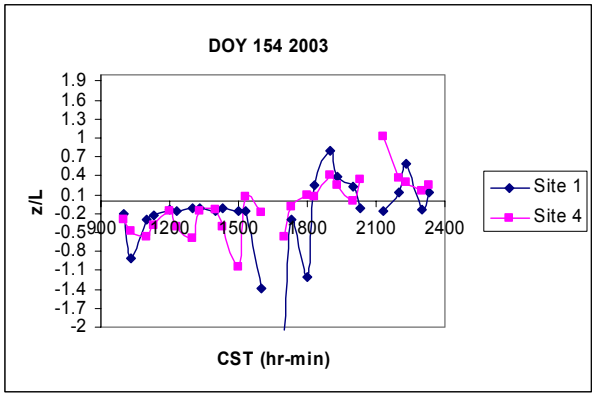
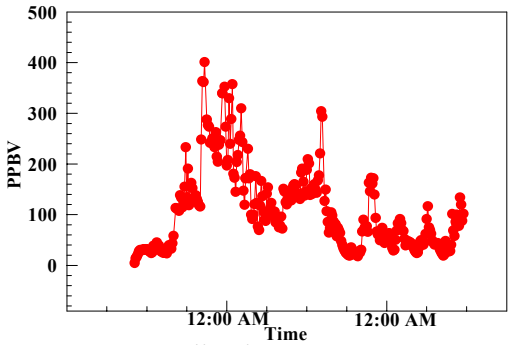


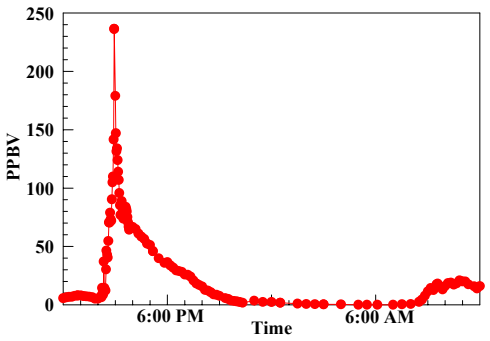
Figure 6. Variation in diffusivity at two locations adjacent to a grow-finish unit throughout one day in 2003.

Ammonia concentrations before and after an infected liquid swine manure application showed a rapid increase in concentration and then a decay in the ammonia concentrations (Fig. 7a).

The ammonia concentrations following the manure application increased to nearly 400 ppb_v and then decreased to less than 100 ppb_v within 12 hours. In contrast, ammonia concentrations following anhydrous ammonia application increased to a peak concentration of 250 ppb_v and then rapidly decreased to less than 10 ppb_v within 6 hours after application (Fig. 7b.) The difference in the time sequence of these ammonia concentrations can be attributed to the presence of manure on the surface following the manure application compared to anhydrous that is injected into the soil and quickly covered. The field size for the manure application was an 80 ha field typical of most application sites so we expect these concentration changes to be realistic for fall applications.



7a. Manure application



7b. Anhydrous ammonia application

Figures 7a and 7b. Ammonia concentrations following a manure application (a) and anhydrous ammonia application (b) during the fall of 2002.

Discussion: The observations we have collected in these studies show the variation in ammonia concentrations adjacent to a grow-finish unit. The concentrations observed at the four locations downwind of the unit showed a rapid decrease with distance for the majority of the observations; however, there were a couple of days in which the concentrations at all of the sampling positions were similar. These days were characterized by extreme variation in windspeed and higher windspeeds indicating that mixing around the building was very efficient. The gradients of ammonia from the building were not strongly correlated with any meteorological parameter in this study. Application of standard micrometeorological methods for estimating ammonia concentrations adjacent to buildings have to be viewed with caution because of the turbulence conditions.

The plume studies showed a rapid vertical mixing that was higher than expected given the windspeed conditions. These results have led to other studies in attempting to define the turbulence regime in the wake of buildings and to improve our understanding of the mixing and transport properties of air around production buildings. These data show we can measure the ammonia with a large degree of confidence; however, estimating the emission rate on grow-finish units with curtain wall construction will require better parameterization of the turbulence regime.

Lay Interpretation: Ammonia concentrations in the air adjacent to and downwind of swine production units are of concern to producers. Most of the existing measurements have been conducted with single point monitors or at locations adjacent to or within the building and are often conducted for a short period of time. We conducted a study on the ammonia concentrations at various positions downwind of a grow-finish unit throughout a production cycle in 2002. Ammonia concentrations were measured with a sensitive ammonia analyzer at four positions. There was a rapid decrease in concentration with distance and with height above the surface for a majority of the observations. The ammonia concentrations decreased during the production cycle because of the more rapid mixing of air between the building and the first sampling location. There were a few periods that covered an entire day in which there was little difference in the ammonia concentrations at the four positions and these were caused by very rapid mixing of the air. On these days

the concentrations were not lower than other days, just more uniform. In these studies we found that the variation in mixing of the air surrounding a building will have to be quantified with different techniques than what are currently used. When we measured the rate of mixing with a Lidar system we found the vertical rate of mixing was about 10 times larger than expected which indicates that air flow around buildings is not well understood.

We found ammonia concentrations during and following manure and anhydrous ammonia application to increase rapidly during application and then decrease following application. The patterns were different between the two nutrient sources because of the presence of the manure on the soil surface acting as a continual source of ammonia; however, these concentrations were quite low (less than 100 ppb_v) and within 48 hours were near ambient levels of less than 10 ppb_v.

These results characterizing a complete growing cycle demonstrate the large changes that occur around a production unit but also the extreme caution that has to be exercised in conducting measurement programs around swine production units. The rapid decrease in ammonia concentrations with distance from a facility shows the ability of the atmosphere to disperse material and act as a transport mechanism.

Publications:
These data are being incorporated into a scientific journal paper that will be submitted in the summer of 2004.