Ammonia Emissions from Broiler Houses in Pennsylvania During Cold Weather

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ABSTRACT

The influence of common broiler house management strategies and practical means of reducing ammonia (NH_3) emissions are under study. Ammonia emissions during cold weather conditions from four broiler houses in Pennsylvania are described in this paper. Manure management differed among the houses as two houses had chicks placed on built-up litter while the other two houses had new litter for each flock. Ammonia level was determined using electrochemical sensors; ventilation rate was accurately estimated by monitoring runtime of the ventilation fans whose airflow rates were calibrated with a portable anemometer array, also known as the Fan Assessment Numeration System (FANS). Mean daily ammonia emission rates over 32 study periods, of 24 hours each, ranged from 0 to 1.28 g NH_3 bird^{-1} d^{-1}, with a mean of 0.49 g NH_3 bird^{-1} d^{-1}; coefficient of variation (CV) of 13.3%. For built-up and new litter houses, respectively, the mean of daily emissions was 0.61 g NH_3 bird^{-1} d^{-1} [CV 13.8%] and 0.36 g NH_3 bird^{-1} d^{-1} [CV 10.7%]. Expressed in terms of 500 kg animal units (AU), emissions ranged from 2 to 1149 g NH_3 AU^{-1} d^{-1}. Bird age was from 1 to 44 days old. A regression equation is provided for emission rate versus bird age. Use of new litter, versus built-up litter, provided reduced ammonia emissions over a flock cycle.

Keywords: poultry, winter, chicken, ventilation, air quality, litter

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INTRODUCTION

A multi-state, multi-disciplinary project is developing a comprehensive database of ammonia emissions from poultry facilities located in the United States. Reasonable estimates of ammonia emissions are needed by the poultry industry so that they can participate in discussions about their industry's impact on local and regional air quality. There is a limited amount of scientific estimates of ammonia emissions from U.S. poultry facilities despite the interest of agencies and concerned citizen groups in mitigating ammonia emission from livestock facilities (National Academy of Science, 2002). Baseline data on aerial emissions from an assortment of poultry facilities that are operated under the variety of management styles used in the U.S. will help establish the inventory of ammonia sources. Although in many ways broiler houses appear to be similar throughout the U.S., there are differences in management and equipment selection and maintenance that provide large differences in effectiveness of the environmental control system performance in the houses. Emission rate from livestock housing is often expressed in terms of mass of ammonia release per mass of animal housed over a given time period. Broiler chicks, weighing about 40 g each, grow rapidly into 2-3 kg market weight birds. Thus, both number and weight of birds need to be known in determination of the emission rate.

Emission rate is simply determined as the product of ammonia level and ventilation exhaust airflow rate. Simple in concept; but in practice, both values are difficult to determine accurately within commercial poultry house conditions. Mechanically (fan) ventilated facilities can be more easily monitored than naturally ventilated facilities for ventilation rate by determining fan capacity and runtime. Ammonia instrumentation suffers from the challenges of high cost for highly accurate models or inconsistent accuracy and reliability for more affordable sensor technologies. Deciding on representative ammonia sampling locations in a house is not always straightforward since ammonia is lighter than air yet accumulates near the litter for floor–raised birds. Monitoring near the air exhaust is necessary for emission determination. The objective of this paper is to present cold-weather ammonia (NH_3) emission rates for modern U.S. broiler chicken housing located in a cold climate region.

METHODS

Overview

Data from cold weather conditions at four mechanically ventilated broiler houses are included in this paper. The data represent 32 study days of data collection. When housing birds under two-weeks of age, minimum ventilation rate was used in an attempt to maintain indoor moisture level and air quality. The broiler industry typically provides minimum ventilation through timer-controlled fan operation. Timer "on" time is increased as the birds grow in size to coincide with increased respiratory and excreted moisture levels. The houses were located in a portion of the United States that is considered a cold winter climate with about 3250 heating degree days (18.3^{o}C base; 5200 heating degree days at 65^{o}F base).

The four houses in Pennsylvania (PA) were each 14.6 m wide x 152.4 m long (48 ft x 500 ft) and housed a nominal 32,500 or 32,700 birds during cold weather, Farm B and Farm H, respectively. Placement density was 14.6 or 14. 7 birds per m^2 (1.35 or 1.36 birds per ft^2), Farm B and Farm H, respectively. All houses had Cobb-Cobb bird strain with the exception of House 1 at Farm H, which had Ross-Arbor Acres birds. The four houses were paired, for repetition of conditions, on two farm sites, with different managers, under contract to different companies. All four were recently built (2000-2001) by the same construction company and were identical for purposes of this study. Houses had fully-insulated suspended ceiling and walls. They had the same ventilation system design including fan model specifications (ten 132 cm (52 in) and four or five 91 cm (36 in) diameter fans), eave box-inlet design and placement (automatically static pressure controlled), and control instrumentation (electronic controller). Table 1A and 1B provide more detail.

A major difference in management between the two PA farm sites was that Farm H provided new litter (wood shavings) to each flock of birds while Farm B cleaned out litter once per year. All data presented here for Farm B are on built-up litter. Farm B practiced partial house brooding while Farm H brooded in the entire house. The 91 cm (36 in) timer fan for minimum ventilation was located in the unheated non-brood end of Farm B houses and was located in the middle of houses at Farm H.

Instrumentation

A Portable Monitoring Unit (PMU) for ammonia measurement was installed in each broiler house and monitored the primary minimum ventilation timer fan used for cold weather ventilation. Detailed information about the design and specifications of the PMU are found elsewhere (Xin *et al*. 2002). PMUs collected data at each house for about 48-hours. The interval between collection periods was typically two or three weeks. A “Day” of data collection was from noon of one day to noon of the following day.

As an overview, each PMU had two electrochemical ammonia sensors (0-200 ppm; PAC III, Draeger Safety, Inc, Pittsburgh, PA) with plumbing and controls for cycling fresh, outside air (14 minute duration) and poultry house air (6 minute duration) past the sensors. Sensors were purged with fresh air to reduce sensor saturation from continuous ammonia exposure. Air was collected via two lengths of polyvinyl-chloride 3/8-inch o.d. transparent flexible tubing that were positioned either in front of the exhaust fan (1/3 fan diameter down from top, 6-inch horizontal offset from fan center, 18-inches in front of fan intake) or outside the poultry house, at the eaves in between inlet boxes on the house sidewall that did not have exhaust fans. The PMU ammonia sensors were located in series for exposure to the air stream under positive pressure. Data presented here represents the average of both sensor readings.

Table 1A. Description Farm B broiler houses, litter conditions, and flock characteristics during the study periods. Flock placements were on October 31, 2002 and January 2, 2003. Farm B was managed with built-up litter, which for the October-placed flock was 8 cm deep and had been previously used on 5 flocks. Originally the litter was 1 cm deep kiln-dried wood shavings. Farm B applied a commercial litter amendment the day before flock placement in the brood section at the rate of one 22.7 kg bag/ 93 m^2 (50-lb bag/1000 ft^2).

Date Farm B	Ventilation Description	Outside T average (range) (°C)	Bird Age (days)	Heat Type (House Sections Used)	House T (°C)
Nov. 12-14, 2002	minimum ventilation single 91-cm timer fan on-off cycle of 120s- 180s	6.3 (-0.6, 14.4)	13-15	radiant brooders & space heaters (whole house)	Setpoint 28
Nov. 19-21, 2002	Same as above except two 91 cm timer fans	2.8 (-1.7, 11.1)	20-22		Setpoint 27
Jan. 7-9, 2003	Two 91 cm timer fans on-off cycle of 130s – 170s (220s – 240s on Jan. 8) with temperature override 30.6°C (87°F)	1.1 (-5.0, 7.8)	6-8	radiant brooders & space heaters (3/4 & whole)	House 2: 30.3 House 3: 29.8
Jan. 21-23, 2003		-9.7 (-14.5, -1.5)	20-22	space heaters (whole house)	House 2: 26.4 House 3: 26.0
Feb. 8-10, 2003	Two 91 cm timer fans on-off cycle of 240s – 60s with temperature override 24.3°C (75.5°F); third 90 cm fan setpoint 24.6°C (76.5°F)	-4.6 (13.9, 2.1)	38-40	space heaters (whole house)	House 2: 23.2 House 3: 23.2

Sensors recorded data every 1-minute. Ammonia sensors were calibrated within 24-hours prior to field placement with nitrogen (N_2) gas (0 ppm ammonia) and ammonia (+ N_2 balance) calibration gas for span check (either nominal 20, 50 or 100 ppm, depending on the anticipated ammonia level at the farm site). Sensors were checked for calibration with the same procedure upon returning from data collection. Measurement of building-outdoors static pressure difference was also included in the PMU.

The electrochemical sensors worked well with their purged-air monitoring scheme. The two sensors generally indicated ammonia level within 1 ppm of each other once the reading stabilized within the 6-minute house air exposure. Initial concern with the accuracy (± 3% of span calibration or 3 ppm) of the sensors has been reduced through frequent calibration checks and recalibration for anticipated ammonia level in a particular house.

Table 1B. Description of Farm H broiler houses, litter conditions, and flock characteristics during the study periods. Flock placement was on December 4, 2002. Farm H provided new litter (1 cm deep wood shavings) to each flock and used no litter amendment. Pancake brooders supplied heat with birds in whole house during each study period.

Date Farm H	Ventilation Description	Outside T average (range) (°C)	Bird Age (days)	House T (°C)
Dec. 4-6, 2002	minimum ventilation single 0.91 cm timer fan on-off 90s - 300s	-6.1 (-16.1, 0.0)	1-3	Room T: 27-29
Dec. 17-19, 2002	Same as above except 100s-300s Dec. 17 or 120s-280s Dec. 19 in House 1. In House 2: 90s-310s on Dec. 17 and 130s-280s Dec. 19.	-2.8 (-10.6, -6.1)	13-15	Setpoint T both Houses:29
Jan. 2-4, 2003	One 0.91 cm fan on continuously with four more 0.91 cm fans used, as needed, for temperature control.	0.2 (-1.7, 8.0)	30-32	House 1: 24.9 House 2: 24.3
Jan 14-16, 2003		-5.4 (-2.0, -10.0)	42-44	House 1: 20.9 House 2: 20.8

The exhaust fan ventilation capacity was determined with a Fan Assessment Numeration System (FANS) unit. Details of this unit's design and performance specifications are provided elsewhere (Gates *et al.* 2002; Casey *et al.* 2002). The FANS was used to evaluate each fan over a range of typical operating static pressure differences. Under minimum ventilation during cold weather the fan on-off times were known so that ventilation rate is a constant over the evaluation time period. Fan on-off time was provided by the farm manager, verified with electronic controller settings, and with fan motor loggers. Average static pressure difference over the fan on-time interval was used to determine fan ventilation rate, using fan curves for each fan as determined from the FANS testing.

RESULTS and DISCUSSION

Table 2 provides mean daily emission rates for the four broiler houses during a cold weather period from November 2002 into February 2003. The daily variability (for consecutive days) of ammonia emission rate from a house was relatively small over this cold weather study period. During periods of minimum ventilation, daily variability in emission from an individual house was primarily related to variation in ammonia level rather than fluctuations in ventilation rate. Overall, the mean daily ammonia emission varied from 0 to 1.28 g NH_3 bird^{-1} d^{-1} for 1 to 44 day old birds (coefficient of variation [CV] 13.8%; mean value of 0.49 g NH_3 bird^{-1} d^{-1}. On built-up litter, it varied from 0.21 to 1.28 g NH_3 bird^{-1} d^{-1} for 6 day old and 38 day old birds, respectively, with CV of 13.8%; mean 0.61 g NH_3 bird^{-1} d^{-1}. On new litter emissions ranged from 0 to 0.91 g NH_3 bird^{-1} d^{-1} for 1 day old and 42 day old birds, respectively, with CV of 10.7%; mean 0.36 g NH_3 $bird^{-1}$ d^{-1}. There is a need for careful characterization of broiler house management and litter conditions so that variability among emission rates can be partially explained. Figure 1 provides a regression equation with statistical parameters for all the daily mean emission rate data.

Emissions data are also presented in relation to the number of 500-kg animal units (AU) in the house during the study period. Bird weights were estimated based on days of age using growth data of the same or similar bird strain (Wheeler, 1998). The actual bird numbers in the house during the study days (placement minus culls and mortality) was used. Ammonia emission ranged from 2 to 1149 g NH_3 AU^{-1} d^{-1}. Houses with built-up litter had emission rates ranging from 335 to 1149 g NH_3 AU^{-1} d^{-1} for 40 day old and 8 day old birds, respectively. On new litter emissions ranged from 2 to 316 g NH_3 AU^{-1} d^{-1} for 2 to 32 day old birds, respectively. For the data presented here, representing cold weather conditions, Farm B averaged 579 g NH_3 AU^{-1} d^{-1} over 18 study days while Farm H averaged 136 g NH_3 AU^{-1} d^{-1} over 12 study days.

Comparing these results to other published ammonia emissions, Groot Koerkamp *et al.* (1998) reported 53, 100, 180 or 199 g NH_3 AU^{-1} d^{-1} for broilers raised on litter from four European countries (Denmark, The Netherlands, Germany and England, respectively). Four replicates of typical broiler house practices were monitored in each country for a 24-hour summer and winter period. The emission values represent mean values of bird age, season, and manure removal.

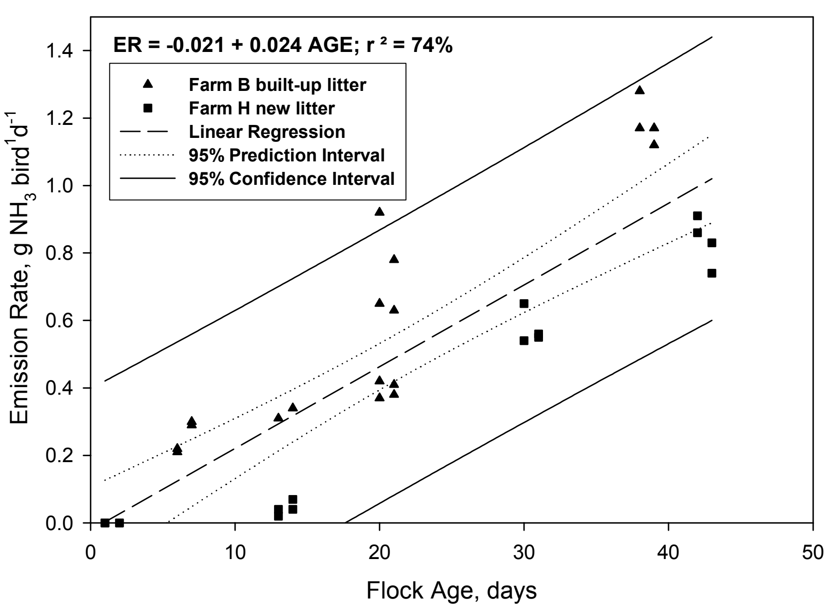

Figure 1. Emission rate during cold weather conditions from four PA broiler houses.

Table 2. Ammonia concentrations [NH_3], ventilation rates (VR), and ammonia emission rates (ER) from broiler houses during cold weather. Information on bird age, building ventilation schemes, and litter management are described in Tables 1A and 1B.

	Day 1			Day 2		
	[NH_3] Avg (Range) ppm	VR $m^3 h^{-1}$ per 10^3 birds	ER g NH_3 $bird^{-1} d^{-1}$ (g NH_3 $AU^{-1} d^{-1}$)	[NH_3] Avg (Range) ppm	VR $m^3 h^{-1}$ per 10^3 birds	ER g NH_3 $bird^{-1} d^{-1}$ (g NH_3 $AU^{-1} d^{-1}$)
Farm B November 12-14, 2002						
House 3	80 (65-102)	208	0.31 (394)	89 (70-105)	208	0.34 (435)
Farm B November 19-21, 2002						
House 2	129 (96-143)	390	0.92 (705)	110 (90-134)	390	0.78 (600)
House 3	89 (68-117)	404	0.65 (502)	85 (76-101)	404	0.63 (483)
Farm B January 7-9, 2003						
House 2	31 (28-34)	378	0.21 (1001)	36 (32-43)	443	0.29 (1115)
House 3	29 (25-32)	423	0.22 (1064)	37 (25-42)	447	0.30 (1149)
Farm B January 21-23						
House 2	48 (38-61)	426	0.37 (369)	50 (39-68)	419	0.38 (355)
House 3	52 (40-65)	443	0.42 (420)	53 (40-65)	432	0.41 (383)
Farm B February 8-10, 2003						
House 2	78 (80-99)	818	1.17 (365)	68 (56-79)	947	1.17 (347)
House 3	82 (39-98)	862	1.28 (401)	66 (59-80)	941	1.12 (335)
Farm H December 4-6, 2002						
House 1	0 (0 – 1)	88	0.00 (8)	0 (0 - 1)	88	0.00 (2)
House 2	2 (0 – 4)	89	0.00 (41)	0 (-1 - 3)	89	0.00 (5)
Farm H December 17-19, 2002						
House 1	7 (6-9)	175	0.02 (29)	10 (8-13)	204	0.04 (45)
House 2	13 (11-17)	164	0.04 (49)	17 (13-22)	231	0.07 (89)
Farm H January 2-4, 2003						
House 1	36 (29-44)	826	0.54 (261)	31 (25-38)	981	0.55 (256)
House 2	38 (26-53)	952	0.65 (316)	31 (26-37)	993	0.56 (257)
Farm H January 14-16, 2003						
House 1	47 (38-65)	1066	0.91 (227)	42 (36-53)	1073	0.83 (197)
House 2	40 (32-54)	1193	0.86 (215)	37 (29-43)	1112	0.74 (176)

* ER = Emission rate of NH_3 for time period = [NH_3] (ppm x 10^{-6}) x VV (m^3) x 17 (g/mol) / 0.0224 (m^3/mol) where VV = Ventilation volume of air in specified time period.

CONCLUSIONS

Ammonia emission rates from the four broiler houses that were evaluated under cold weather conditions ranged from 0 to 1.28 g NH_3 bird^{-1} d^{-1} for birds aged 1 to 44 days. Average emission from new litter houses was 0.36 g NH_3 bird^{-1} d^{-1} and built-up litter houses 0.61 g NH_3 bird^{-1} d^{-1}. A regression equation for emission rate versus bird age was presented. The overall coefficient of variation in emission rates among the houses was 13.3%. There was little variability in emission rate for consecutive days under study. Once characteristics of the litter, such as the use of new litter are known, then there can be more understanding of the reasons behind the variation in ammonia emission rates.

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