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Ammonia emissions from anaerobic treatment lagoons at sow and finishing farms in Oklahoma

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ABSTRACT

Ammonia emissions were measured periodically for two years at manure treatment lagoons at sow and finishing facilities in Oklahoma. Path-integrated ammonia concentrations were measured around both lagoons using tunable diode lasers. Emissions were calculated from these concentrations and measured air turbulence statistics using a backward Lagrangian stochastic model. The maximum summer emissions were approximately 16 g m^{-2} s^{-1} (135 g d^{-1} hd^{-1}) (hd = head or 1 animal) at the sow lagoon and 5 g m^{-2} s^{-1} (39 g d^{-1} hd^{-1}) at the swine finishing lagoon. Winter emissions were non-zero and likely a result of barn effluent entering the lagoon on top of the frozen surfaces. Average daily emissions from the two lagoons were similar when normalized by animal mass, with annual average daily mean emissions of 130 g d^{-1} AU^{-1} ± 72 g d^{-1} AU^{-1} (1 animal unit, AU = 500 kg) and mean summer average daily mean emissions of 285 ± 71 g d^{-1} AU^{-1}. A semi-empirical model based on daily mean air temperature and daily mean wind speed accounted for 75% of the daily emission variability at the two lagoons.

1. Introduction

Measurements of ammonia emissions from swine waste lagoons are of interest because farms are required to report emissions in excess of 220 kg/day (100 lb/day) for the "Right-to-Know" regulations (Emergency Planning and Community Right-to-Know Act). Reported emissions from sow and finishing operations are usually difficult to compare due to different measurement methods and environmental conditions as well as limited information on the animal populations. There have been only a few studies of NH_3 emissions from lagoons at sow farms and of these studies very few have used micrometeorological approaches. Studies evaluating the emissions at sow operations vary by a factor of five. Harper and Sharpe (1998), using a micrometeorological method over an unspecified number of measurement days, determined a mean emission of 4.2 g hd^{-1} d^{-1}(hd, head = 1 animal). Harper et al. (2004) determined an annual emission at a sow facility of 6.0 g hd^{-1} d^{-1}. Similarly, there have been only a few studies of NH_3 emissions from finishing operations that used micrometeorological approaches. Although not a micrometeorological approach, Bicudo et al. (2004) measured emissions averaging 9.49 ± 0.110 and 12.2 ± 0.136 g hd^{-1} d^{-1} from two Minnesota finishing farms using a portable wind tunnel over twelve days from late spring through early summer. Szogi et al. (2005) measured emissions of 9.57 g NH_3 hd^{-1} d^{-1} using passive flux sampling during nine measurement days from winter through late fall and reported average pig-specific NH_3 emissions of 9.57 g hd^{-1} d^{-1}. Shores et al. (2005) measured average NH_3 emissions of 4.2 g hd^{-1} d^{-1} (10 mg NH_3-N m^{-2} s^{-1}) using open-path Fourier transform infrared spectroscopy (FTIR) on five days over a two-year period at a finishing operation in North Carolina. When considering the area of the lagoon, the average area-specific NH_3-N emissions was 10 mg m^{-2} s^{-1} (Shores et al., 2005). Zahn et al. (2001) used micrometeorology for making NH_3 a micrometeorological flux estimation technique to measure average emissions of 22.7 g NH_3 hd^{-1} d^{-1} during a 14-day measurement campaign in late summer and early fall at a Missouri finishing operation. They reported an average pig-specific emission rate of 22.7 g hd^{-1} d^{-1} finishing operation.

This study compares the annual and diurnal variability in ammonia emissions at sow and finishing operations located within 15 km of each other and over the same two years in Oklahoma. Due to the wide range of temperatures and wind speeds experienced during the study, the temperature and wind effects on the emissions were also assessed.

2. Methods

2.1. Farm description and operation

The sow facility consisted of three swine barns and a farm office and shop (Fig. 1). The facility had a capacity of 1225 breeding and

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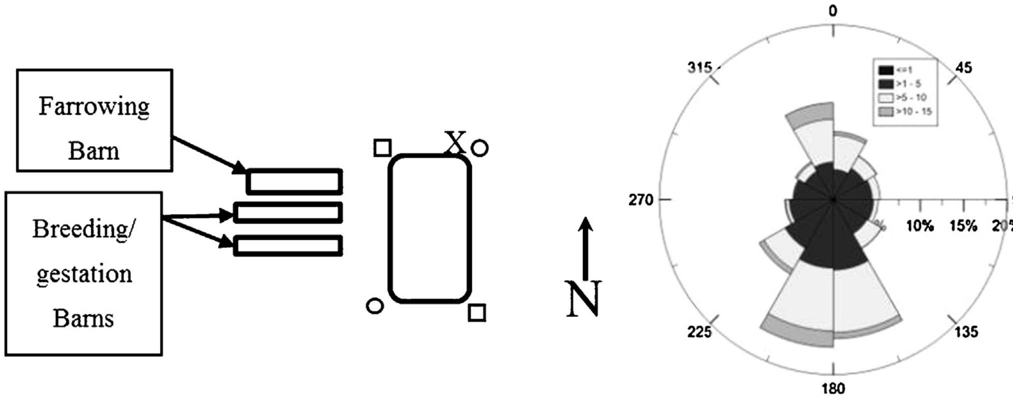

Fig. 1. Measurement configuration at the sow farm. TDL/scanner locations are indicated by the white circles. Towers with retro-reflectors mounted vertically are indicated by the white squares. The anemometers were located on the SE tower and the meteorological station (X). A wind rose chart for the measurement period is indicated to the right. Waste discharge into the lagoon was to the east of the barns.

gestation sows in each of two sow gestation units and 384 sows in a 16-room farrowing building for a total farm capacity of 2834 sows. The farm actual inventory varied from 2712 to 2777 sows over the course of the study (Table 1), with a mean of 2784 sows, corresponding. Including both sows and piglets, the mean inventory was equivalent to a total live mass (LM) of 1279 animal units (AU = 500 kg) including piglet LM. Manure was transferred to the lagoon weekly from the two gestation barns and every 2.5 weeks from the farrowing barn. Waste water from the two gestation units combined into one inlet, while wastewater from the farrowing unit entered the lagoon from a second inlet. Pits under the farrowing barn were back-filled with recycled water from the lagoon. The rectangular, clay-lined waste lagoon was located to the east of and was separated by a drainage swale from the barns and had a surface area of approximately 22,970 m^2, a liquid depth of approximately 5.5 m, an inner berm-to-water distance of 1.2–3 m and a maximum capacity of 72,800 m^3. The volatile solids loading rate at farm capacity was approximately 1294 kg ha^{-1} d^{-1}. Sludge from the lagoon had not been removed since construction. Lagoon liquid analysis was contracted by the producer every year for all nitrogen components.

The finishing facility, constructed in 1997, had a maximum capacity of 3024 finishing pigs, which ranged in mass from 86 kg to 138 kg. The inventory at the finishing farm varied from 2267 to 2909 hogs (Table 1). Since the gaseous lagoon emissions emanate from manure and effluent residing in the lagoon for many months, it was assumed that size of the herd contributing to the lagoon contents was the mean of 2742 hogs, corresponding to a total live mass of 464 AU. Manure was transferred three times a week from the barns to the lagoon by a pull plug system with fresh water recharge. Waste water from all three units combined into one lagoon inlet. The rectangular, clay-lined waste lagoon was located west of the barns (Fig. 2) and had a surface area of 22,500 m^2 and maximum capacity of 28,700 m^3. A 20% pump-out of the lagoon occurred on 1 June 2009. The volatile solids loading rate at farm capacity was approximately 1770 kg d^{-1} ha^{-1}.

Over the course of the study, the producer at the sow farm changed the feed ration from milo to corn on 10 June 2007 and then back to milo on 17 December 2007. Thirty-two groups of pigs were weaned at the sow farm between 30 July 2007 and 19 July 2009. The average group took 21.5 days from farrow to wean. At the finishing farm, 150 kg per metric ton distiller dried grains with solubles (DDGS) were added to the primarily corn ration and a phenethanolamine (Paylean®) was added to the feed for approximately 30 d prior to sending the finishing pigs to market. One cycle of production took approximately 120 days.

2.2. Measurements

Lagoon NH_3 emissions were measured at both farms for up to 21 days (d) each season over two years. These emissions were used to determine its characteristics including variation with time of year, stability of the atmosphere, and operation of the facility. The emissions were measured using models that rely on concentration and wind flow measurements. Atmospheric concentrations of NH_3 around the lagoons were measured using narrow-bandwidth open path tunable-diode laser absorption spectroscopy (TDLAS, Table 2), while the turbulence was measured using 3D sonic anemometers (Table 2).

The path-integrated concentrations (PICs) of NH_3 were measured by TDLAS (Model GasFinder2^{TM} NH3-OP, Boreal Laser Inc., Spruce Grove, Alberta, Canada) along optical paths (OP) defined by TDLAS/scanner systems and retro-reflectors. Lagoon pH and temperature at 0.3 m depth were measured from a float (Table 3). Measurements of atmospheric temperature, relative humidity, barometric pressure, solar radiation and surface wetness were measured and recorded at an automated weather station on the lagoon berm (Table 3). Information concerning farm operations

Table 1
Measurement periods.

Sow farm				Finishing farm			
Start date	End date	# days	Average inventory	Start date	End date	# days	Average inventory
6/27/2007	8/29/2007	63	2748	8/30/2007	9/18/2007	19	2267
11/7/2007	11/27/2007	20	2712	1/24/2008	2/19/2008	26	2660
11/28/2007	12/18/2007	20	2712	5/7/2008	5/29/2008	22	2747
4/23/2008	5/6/2008	13	2777	5/29/2008	6/10/2008	12	2747
10/1/2008	10/15/2008	14	2720	11/5/2008	12/2/2008	27	2909
1/8/2009	1/27/2009	19	2731	12/2/2008	12/16/2008	14	2880
4/1/2009	4/21/2009	20	2762	4/23/2009	5/14/2009	21	2882
6/25/2009	7/14/2009	19	2777	7/15/2009	8/4/2009	20	2845