

Characterizing Ammonia Emissions from Swine Farms in Eastern North Carolina – Part I. Conventional Lagoon and Spray Technology for Waste Treatment

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Species: Swine

Use Area: Manure Storage

Technology Category: Anaerobic Digestion and Manure Injection

Air Mitigated Pollutants: Ammonia

Description:

The conventional lagoon and spray technology (LST) is the current system predominantly used in North Carolina to manage pig waste (Aneja et al., 2008). It consists of anaerobic lagoons to store and biologically treat pig waste (~99.5% liquid). Effluent from the lagoons are sprayed on surrounding crop fields as a nutrient source. Four distinct components and associated processes of LSTs release NH₃ to the atmosphere: (1) production houses, (2) waste storage and treatment systems such as lagoons, (3) land application through injection or spraying, and (4) biogenic emissions from soils and crops (Aneja et al., 2001).

Mitigation Mechanism:

The manure is treated under aerobic conditions and the treated manure is sprayed on the crops as a source of fertilizer. Crops use the nitrogen in the manure as a source of nutrients. Additionally some of the NH₃ emissions are reduced by the storage of waste in a sludge composition at the bottom of the lagoon. The primary mitigation mechanism would be biological catabolism of compounds contributing to the relatively high carbon loading manure effluent flushed into the lagoons.

Applicability:

Where permissible, lagoon spray technology, as described in this study, is applicable for swine production systems that would have flush systems and environmental (climatic) conditions similar to North Carolina. Ammonia flux measurements were made during two different seasons at two conventional (*i.e.* LST) swine farms in eastern North Carolina. The two finishing conventional farms were Stokes and Moore Brothers farms, respectively. Our measurements of NH₃ flux were limited to two two-week long periods, representing warm and cold seasons. The fall and winter intensive measurements were conducted during September 9-October 11, 2002 and January 6-February 2, 2003, respectively.

Ammonia fluxes from the waste storage lagoons were measured by a dynamic flow-through flux chamber system interfaced to an environmentally controlled mobile laboratory. The on-site measurement period for each season was limited to two weeks at the experimental farm sites. Ammonia fluxes from the animal storage waste lagoons, other water holding structures, and spray fields at the two conventional and several potential Environmentally Superior Technology (EST) sites were measured by the dynamic flow-through flux chamber system. The times of spray did not occur close to our measurement periods.

For ammonia flux measurements using the dynamic chamber system, sampling consists of measuring the gaseous ammonia concentration of the sample stream exiting the dynamic chamber system on a continuous basis. Simultaneous continuous measurements of ambient ammonia concentration, lagoon temperature, lagoon pH, air temperature, relative humidity, wind speed, wind direction, and solar radiation were also made and recorded. One to three samples of lagoon waste adjacent to the floating platform were collected each day and stored near 0°C during ammonia flux measurement periods in order to determine the concentration of total Kjeldahl nitrogen (TKN), and total ammoniacal nitrogen (TAN) in the liquid lagoon effluent.

Barn emissions were measured using an Open-Path Fourier Transfer Infrared (OP-FTIR) spectroscopy system. NH₃ emissions from barn houses were estimated from average ammonia concentration measured by OP-FTIR and the rated flow rate for the fan size and setting. Operation of fans were monitored to determine when they were on or off

during the entire sampling period. Estimated flow rates from naturally ventilated barns were calculated using wind velocity readings.

The average lagoon NH_3 fluxes for the two conventional farms during the fall and winter months were 2017 ± 751 and 262 ± 100 $\text{g-N m}^{-2} \text{min}^{-1}$, respectively. These averages were comparable to those found in the previous study from a typical swine farm (Farm #10) in North Carolina (Aneja et al., 2000).

Typical diurnal variation of lagoon NH_3 flux was observed during the measurement periods. The NH_3 flux increased exponentially with increasing lagoon temperature, and the best-fitted regression relationship between the two is:

$$\log_{10}(N) = 0.051T_l + 1.943 \quad (1)$$

($R^2 = 0.82$ and $p < 0.0001$), Here, F denotes the average $\text{NH}_3\text{-N}$ emission from the conventional lagoon in $\mu\text{g min}^{-1}/1000 \text{ kg-lw}$, where T_l is the lagoon temperature in $^\circ\text{C}$, and D is a hot-air variable that is equal to zero if lagoon is warmer than air, but is equal to $\Delta T = T_a - T_l$ when $T_a > T_l$ and T_a is air temperature in $^\circ\text{C}$ at 2m height.

This regression relationship showed very good agreement with that of Aneja et al.(2000) based on Farm #10 flux measurements.

Relationships between lagoon NH_3 flux and chemical parameters, such as pH, TKN and TAN of lagoon waste were also examined. The lagoon pH stayed in a relatively narrow range from 7.7 to 8.5 during fall and winter seasons. No significant correlation between pH and lagoon NH_3 flux was observed during the experimental periods at either farm. Additionally, TKN and TAN concentrations were not found to be significantly correlated with lagoon NH_3 flux over the entire data set. Although positive correlations of TKN and TAN with NH_3 flux were found in individual seasons.

The influence of atmospheric environmental parameters on lagoon ammonia flux was investigated. Ammonia flux was found to be significantly correlated with lagoon temperature and the difference between air and lagoon temperature ($\Delta T = T_a - T_l$). ΔT is considered a measure of near-surface atmospheric stability, and is known as the 'hot air' effect. The multiple regression equation for the average lagoon emissions at the two conventional farms is:

$$\text{Log}_{10} F = 3.8655 + 0.0449T_l - 0.05946D \quad (2)$$

in which T_l is the lagoon temperature and D is the 'hot air' variable. F is the the normalized ammonia emission rate. T_l and D are expressed in units of $^\circ\text{C}$, and F in units of $\text{kg-N min}^{-1} (1000\text{kg lm})^{-1}$

Barn emissions were measured for one season at Stokes farm (naturally ventilated) and two seasons at Moore farm (mechanically ventilated). Emissions normalized by live animal mass were found to be comparable to other studies. The statistical-observational model developed and described herein and the barn emissions protocol is proposed as a valid and objective approach to be used to compare the emissions from potential environmental superior technologies in order to evaluate the effectiveness of such technologies.

Limitations:

LSTs has been shown to be an effective and affordable biological treatment technology for processing high organic concentration waste streams typical of flushed animal manure. Environmental issues, including ammonia emissions, however have been identified with this system relative to long term sustainability. In addition, some states and regions, including North Carolina, have regulatory restrictions permitting new or expanding farm facilities that utilize LST

Cost:

Ten year annualized costs for a "Baseline" LST for a 4,320-head finishing farm using a pit recharge system of manure removal is predicted to be approximately \$90 per 1,000 lbs. steady state live weight per year (Williams, 2006. see Table 8a, page 58).

Implementation:

Implementation of LST should be consistent with regulatory limitations noted above.

Technology Summary:

The cost of an LST is low, and has the benefit of being a source of nutrients for crops. It is though perceived that it has a large negative effect on the environment as a result of emissions of ammonia, odor, and pathogens. There are environmental concerns in North Carolina, particularly in eastern North Carolina where approximately 6 million hogs

reside in a six county region. As a result the State of North Carolina is examining the possible use of alternative technologies known as potential Environmentally Superior Technologies (ESTs) to reduce the environmental impact. The effectiveness of the ESTs are evaluated by a comparison to the current LST emissions. The comparison will be achieved by the use of a statistical-observational model based on measurements.

Additional Resources:

Additional and detail information re materials and methods and cost information is available at http://www.cals.ncsu.edu/waste_mgt/

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