

# NITROGEN LOSS FROM SPRINKLER APPLIED BEEF FEEDLOT EFFLUENT

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## Abstract

Loss of nitrogen from sprinkler applied beef feedlot effluent can be costly for both the producer and the environment. Sprinkler application of effluent is common throughout the Great Plains, though little work has focused specifically on N losses from beef feedlot effluent. We quantified ammonia (NH<sub>3</sub>) and nitrous oxide (N<sub>2</sub>O) losses from beef feedlot effluent applications under field conditions including variations in soil pH, soil water content, ammonium (NH<sub>4</sub><sup>+</sup>) concentration of the effluent, and weather conditions on NH<sub>3</sub> and N<sub>2</sub>O emission. Nitrogen losses during application were determined from the differences between NH<sub>4</sub><sup>+</sup>-N concentration of samples taken under the sprinklers and samples taken from the effluent. NH<sub>3</sub>-N and N<sub>2</sub>O emission following application were measured using a closed chamber technique with a recirculating configuration and acid traps. On a concentration basis, no NH<sub>4</sub><sup>+</sup>-N loss was detected during application. Following application, N losses from both volatilization and N<sub>2</sub>O emissions from soil were less than 1% of the original effluent NH<sub>4</sub><sup>+</sup>-N concentration. Soil pH and effluent NH<sub>4</sub><sup>+</sup>-N concentration did not significantly affect the percent of N lost. Weather factors including: soil temperature, air temperature, %WFPS, and relative humidity had varying effects on NH<sub>3</sub> and N<sub>2</sub>O emissions following application.

## Introduction

Beef effluent is a source of irrigation water and nutrients for plants, particularly N. When effluent is sprinkler applied some N can be lost to the environment. Effluent N may be dissolved NH<sub>4</sub><sup>+</sup> and suspended organic N. The NH<sub>4</sub><sup>+</sup>-N converts to NH<sub>3</sub> and is released into the atmosphere during and following application making it unavailable for plant uptake. Besides N loss for plant uptake, excess N gases can cause environmental and human health problems (Akiyama and Tsuruta, 2003; and Aroga et al., 2003). Both NH<sub>3</sub> and N<sub>2</sub>O are of interest.

Emission of NH<sub>3</sub> and N<sub>2</sub>O may vary with weather factors (wind speed, humidity, atmospheric temperature), soil characteristics (pH, temperature, soil texture, water content), and application method (Henry et al., 1999; Sogaard et al., 2002). According to the University of Nebraska-Lincoln, sprinkler application of effluent may result in the loss of the equivalent of 50% of the NH<sub>4</sub><sup>+</sup>-N in solution (Koelsch and Shapiro, 2006). As previous research shows, volatilization losses vary widely. Studies show that N<sub>2</sub>O losses are also variable. Although losses are generally small compared to those of NH<sub>3</sub> (Sharpe and Harper, 1997), N<sub>2</sub>O's global warming potential is of concern.

It is important to determine which factors affect NH<sub>3</sub> losses and N<sub>2</sub>O emissions. Quantifying these effects would allow producers to more accurately account for NH<sub>4</sub><sup>+</sup>/NH<sub>3</sub> loss, manage

applications to conserve N, and reduce N<sub>2</sub>O emissions. Such quantification would assist advisors and regulators in designing manure management systems, especially systems that use sprinkler application methods. To date, research on beef cattle effluent application through sprinkler systems has not largely been done, thus the objectives of this study were to:

- i. Determine the effect of soil pH, NH<sub>4</sub><sup>+</sup> concentration, water filled pore space, and weather conditions (wind speed, air and soil temperature, and relative humidity) on NH<sub>3</sub>-N and N<sub>2</sub>O loss.
- ii. Quantify NH<sub>3</sub>-N losses during and up to 48 h after sprinkler applied beef feedlot effluent.
- iii. Quantify short-term (120-192 h) N<sub>2</sub>O-N losses following sprinkler applied beef feedlot effluent.

### **Materials and Methods**

The experimentation was conducted in 2012 at the Agricultural Research and Development Center (ARDC) of the University of Nebraska-Lincoln (UNL) near Mead, Nebraska. The soils at the study area were well drained Yutan silty clay loam formed in loess. The area was a dryland corner of a center pivot irrigated field and had been in a corn-soybean rotation.

Nitrogen gas emissions were measured with flux chambers (Figures 1a and 1b) constructed of stainless steel steam pans according to the GRACEnet protocol (Parkin and Venterea, 2010). Chambers were modified to trap NH<sub>3</sub> with the addition of a pump and a fritted midget bubbler acid trap. The pump, along with a small fan inside of the chamber, allowed the chamber headspace to be recirculated. Air within the chamber was circulated and bubbled through the acid trap for 30 minutes. After passing through the acid the scrubbed air was returned to the chamber. Nitrous oxide samples (Figure 2) were taken via syringe at each 10 minute increment of the 30 minute sampling period and injected into an evacuated vial. Analysis was performed by gas chromatography with an electron capture detector to quantify N<sub>2</sub>O.

Studies included comparison of:

- i. effluent NH<sub>4</sub><sup>+</sup> concentrations of 200, 100, and 0 ppm conducted in June
- ii. with and without tarps attached to the sides of the simulators to reduce the effect of wind during application in the soil pH experiment
- iii. soil pH values (5.84 and 7.29) each with NH<sub>4</sub><sup>+</sup>-N concentrations of 0 and 200 ppm, conducted in June and November 2012
- iv. warmer and cooler temperature with trials conducted in June and November of 2012
- v. other variables were recorded including: soil water content, wind speed, air temperature, soil temperature, and relative humidity, the effects of which were determined through regression analysis.

Collection jars containing sulfuric acid were placed under sprinklers to catch applied effluent samples for determination of change in NH<sub>4</sub><sup>+</sup> concentration during application. Ammonia emission samples were largely taken at -1, 0, 1, 2, 4, 7, 24, and 48 h after effluent application. Similarly N<sub>2</sub>O sampling was done at -1, 0, 1, 2, 4, 7, 24, 48, 120, and up to 192 h (Meisinger and Jokela, 2000; Sharpe and Harper, 2002).

## Results and Discussion

Effluent  $\text{NH}_4^+$  concentration did not affect cumulative emissions for  $\text{NH}_3$  and  $\text{N}_2\text{O}$ . Al-Kaisi and Waskom (2002) also found that  $\text{NH}_4$  concentration of liquid swine manure did not affect  $\text{NH}_3$  volatilization loss and attributed this to the similar weather conditions during application, concluding that the percentage lost was source independent. This would also explain our findings, as the plots received the treatments at the same time and experienced the same weather conditions throughout the sampling period. The lack of effluent  $\text{NH}_4^+$  concentration effect on  $\text{N}_2\text{O}$  emissions was probably due to small contribution of nitrate from the effluent relative to  $\text{NO}_3^-$  already in the soil and the water used as the 0 ppm  $\text{NH}_4^+$  treatment had 15 ppm  $\text{NO}_3^-$ -N which applied 3.39 lbs  $\text{ac}^{-1}$  of  $\text{NO}_3^-$ -N, while the effluent contained 0 ppm  $\text{NO}_3^-$ -N. Nitrate is used by bacterial denitrifiers when low oxygen conditions exist (Wrage et al., 2001), such as after the application of effluent or irrigation, and  $\text{N}_2\text{O}$  is released during denitrification. Differences in  $\text{N}_2\text{O}$  emissions were not seen between the 100 and 200 mg  $\text{NH}_4^+$ -N  $\text{kg}^{-1}$  effluent treatments. This may be because the  $\text{NH}_4^+$ -N was not subjected to the denitrifiers until significant nitrification had occurred. Had measurements continued, we might have seen a difference caused by effluent  $\text{NH}_4^+$  concentration as more  $\text{NO}_3^-$  became available to denitrifiers (Robertson and Groffman, 2007).

Al-Kaisi and Waskom (2002) reported  $\text{NH}_4^+$  losses with application of liquid swine manure of 8-27% during irrigation, and 24-56% following irrigation for a total average loss of 58% of total applied N. Other studies also show the majority of losses due to volatilization occur following land application, though this includes solid and liquid manures (Chastain and Montes, 2005). The results of our study show losses during application were negligible under low wind conditions and effluent concentration was not affected on very windy days. Losses due to volatilization following application were less than 1% of applied  $\text{NH}_4^+$ -N. Following application, our  $\text{N}_2\text{O}$  emissions also accounted for losses of less than 1% of the  $\text{NH}_4^+$ -N applied. Paul et al. (1993) found total  $\text{N}_2\text{O}$  emissions from liquid and solid beef, swine, and dairy manure over a 14 day period to be higher than our findings, at 0.09-2.22% of the added  $\text{NH}_4^+$ -N, though this was over a longer sampling period and at 10 times greater  $\text{NH}_4^+$ -N concentrations than our experiment.

Previous research shows both  $\text{NH}_3$  and  $\text{N}_2\text{O}$  fluxes largely occur immediately after application (Sharpe and Harper, 2002; Sharpe and Harper, 1997). These fluxes may return to initial levels within 48 hours, but have also been found to last several days before declining to background emissions (Meisinger and Jokela, 2000; Montes, 2002). Cumulative fluxes from this study agree with these findings. Although the timing of observed peak fluxes varied, these generally occurred for both  $\text{NH}_3$ -N and  $\text{N}_2\text{O}$  within 7 hours after application. Secondary peaks and increases in cumulative emission rates after 7 hours are likely due to precipitation events (Figure 3). Precipitation was found to cause pulses of  $\text{NH}_3$  emissions in Sharpe and Harper (2002). In this same study precipitation also resulted in elevated  $\text{N}_2\text{O}$  emissions. Decreased  $\text{O}_2$  concentration caused by increasing soil water limits  $\text{O}_2$ 's use as an electron acceptor in nitrification and inhibits the reduction of  $\text{N}_2\text{O}$  to  $\text{N}_2$  in the denitrification process.

Soil pH also did not affect  $\text{NH}_3$  and  $\text{N}_2\text{O}$  fluxes as expected. The equilibrium of  $\text{NH}_4^+$  with  $\text{NH}_3$  in solution is largely determined by pH and the potential for volatilization is expected to be greater with soil pH > 7.5 compared with lower pH (Barbarick, 2011; Henry et al, 1999). The

lack of a soil pH effect in our study likely was because our calcareous soil having a pH of 7.29. The soil pH may be important with higher soil pH calcareous soils. Increasing pH tends to favor increased nitrification and denitrification rates. Any soil pH effect on N<sub>2</sub>O emissions, which can occur both during nitrification and denitrification, may have been masked in our study by other factors including simultaneous nitrification and denitrification (Granli and Bockmen, 1994).

Weather factors did affect N losses on a rate basis during application. The effect of month on total cumulative N<sub>2</sub>O emissions in June and November, as well as the increases in N gas fluxes following sprinkler application and precipitation events, suggest that weather factors may also play a part in N gas emissions following application. In this study, both NH<sub>3</sub> and N<sub>2</sub>O emissions were found to correlate with some of the weather factors examined but only the positive relationship between N<sub>2</sub>O emissions and soil temperature was consistent. Increases in N<sub>2</sub>O production with increasing soil temperature would be expected, as microbial activity would likely increase (Robertson and Groffman, 2007). Though as indicated by the low R<sup>2</sup> values for this relationship and others, these relationships were not very strong. Many of the correlation coefficients also showed weak and varying relationships, making it hard to establish a clear effect of any of the weather factors on NH<sub>3</sub> and N<sub>2</sub>O emissions. The strongest relationships occurred between the cumulative N<sub>2</sub>O emissions at 24 hours after application with soil temperature, air temperature, and %WFPS. Again, increasing temperatures, as well as %WFPS increase soil microbial activity.

### **Conclusion**

In summary, the University of Nebraska-Lincoln recommendation is that 50% loss of effluent NH<sub>4</sub><sup>+</sup> occurs from sprinkler application. Our results show losses during, and following sprinkler application of beef feedlot effluent are well below 50%, and are typically likely to be less than 10%. Under very windy conditions, much of the effluent was not collected in our jars but this cannot be equated to losses from the field since high wind speed did not change NH<sub>4</sub><sup>+</sup> concentration of the effluent during application. Following application, less than 1% of the applied N is lost through both volatilization and N<sub>2</sub>O emissions. The losses following effluent application were lower than those reported by other studies; however, beef feedlot effluent generally has lower N concentrations compared to other species and manure forms. Soil pH and weather factors including: wind speed, soil temperature, air temperature, %WFPS, and relative humidity; inconsistently affected the rate of NH<sub>3</sub> and/or N<sub>2</sub>O emissions, but effects have been observed in other studies. Cumulative N<sub>2</sub>O emissions within 24 h after application were several times greater with soil and air temperature >25°C compared with <15°C, especially when higher temperature is combined with greater %WFPS. Application of beef feedlot effluent through sprinkler irrigation is an efficient means of N application, with less than 10% of applied N emitted as NH<sub>3</sub> and N<sub>2</sub>O. Losses due to drift on a field scale, as well as losses from other sprinkler systems, need to be examined.

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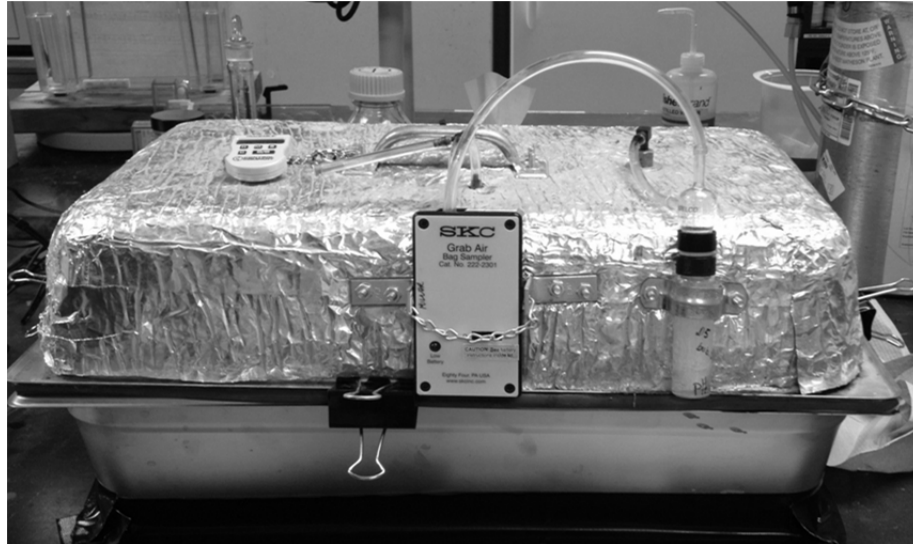
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## Figures

Figure 1. The flux chamber system a) with a SKC Grab Air Bag Sampler Cat. No. 222-2301 and fritted midget bubbler b) the inside of the flux chamber lid.

a)



b)

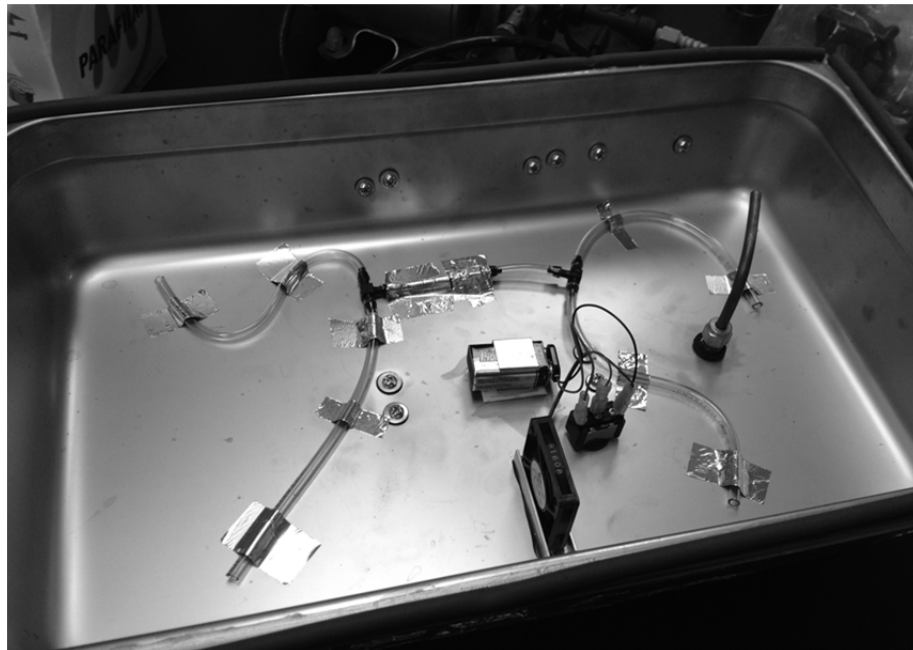
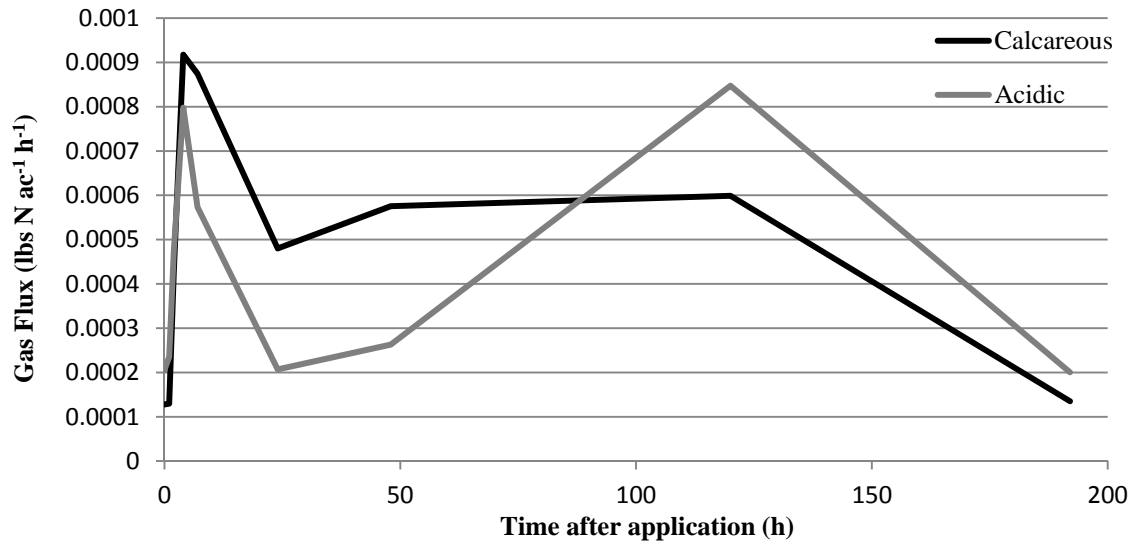


Figure 2. Chamber layout and framework for the sprinkler simulators in the study to determine the effect of  $\text{NH}_4^+$  concentration of effluent on  $\text{NH}_3$  and  $\text{N}_2\text{O}$  emission following effluent application.



Figure 3  $\text{N}_2\text{O}$  flux rates as affected by the interaction of soil pH x time in June, note the primary and secondary timing of peak emissions. Similar trends in peak emissions were seen for  $\text{NH}_3$  and  $\text{N}_2\text{O}$  in both June and November.



LSD = 1.85

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**PUBLISHED BY:**

**International Plant Nutrition Institute**  
**2301 Research Park Way, Suite 126**  
**Brookings, SD 57006**  
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