

Comparison of Ammonia Emissions Determined with Different Sampling Methods

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ABSTRACT

Dynamic, flow-through flux chambers are sometimes used to estimate ammonia emissions from livestock operations; however, ammonia emissions from the surfaces are affected by many factors which can be affected by the chamber. Ammonia emissions estimated using environmental flow-through chambers may be affected by air exchange rate; however, chamber fluxes have not been directly compared to the flux from the same source when unaffected by a chamber. We compared measured ammonia fluxes and water evaporation from an EPA flux chamber and WTAMU wind tunnel using buffered ammonium sulfate solutions and distilled water. Emission rates were also measured in open pans in the laboratory and outside.

volatilization and evaporative flux are effected by temperature, pH, wind speed, and relative humidity, sampling methods that don't incorporate these factors can give inaccurate measures of flux (USEPA, 1982; Cole et al., 2007; Parker et al., 2008, 2009b; Hudson and Ayoko, 2008). Therefore, methods that replicate conditions similar to those at the sampling site would be more accurate. It is necessary to create and test methods that accurately replicate wind as well as humidity and temperature. If it is not possible to replicate weather conditions, it is then necessary to apply correction factors that will adjust measurements to actual field conditions. The objective of this research was to assess the accuracy of wind tunnels and flux chambers in measuring ammonia flux as compared to field conditions.

INTRODUCTION

Ammonia is a volatile inorganic compound (VIC) that has been studied for many years. Ammonia is prevalent in agricultural regions (Todd et al., 2008). Ammonia is a base that can form particles known to cause respiratory problems in humans (Todd et al., 2008; Koerkamp et al., 1998). Several methods have been used to quantify ammonia emissions from animal feeding operations. Some of this research has been conducted using flux chambers, wind tunnels, and other methods that do not mirror actual field conditions (Parker et al., 2009a, b). Varying field conditions can affect volatilization losses. Because

MATERIALS AND METHODS

Flux Chamber and Wind Tunnel Description

The 'USEPA' flux chamber used was dome-shaped with a 30 L volume and 0.13 m² footprint (Kienbusch, 1986). The WTAMU wind tunnel was rectangular with a 2.4 L volume. It had dimensions of 51 mm height, 305 mm length, and 152 mm width, with a surface area of 0.046 m² and cross-sectional area of 0.0062 m² (Parker et al., 2008, 2009a).

Experiment 1

In Experiment 1, tests were conducted simultaneously in the lab and field. Three different sized stainless steel pans were used with areas of 995 cm² (large), 735 cm² (medium), and 321 cm² (small). Each size pan was used both inside and outside. The large pan was used with the EPA (USEPA) chamber in the lab, and the small pan was used with the WTAMU wind tunnel in the lab (Rhoades et al., 2005; Parker et al., 2008; USEPA, 1982). The medium pan was left open in the laboratory (Figure 1). Large, medium, and small pans were placed outside and left open to ambient air conditions. The EPA chamber had a sweep air flow rate of 5 L/min (0.17 turnovers/min), while the WTAMU wind tunnel was set to 15 L/min (6.2 turnovers/min). An ammonium sulfate buffer solution was used in the pans in order to replicate the volatilization from a feedlot runoff storage pond (Cole et al., 2007). The solution was composed of the following: 15.22 g/L K₂HPO₄; 1.8 g/L KH₂PO₄;

1.88 g/L (NH₄)₂SO₄; 0.6 g/L NaOH and had an initial pH of 8.6 and initial N content of 400 mg/L (Parker et al., 2009b). Liquid samples were collected at 0800 and 1700 hr and analyzed for N at the USDA laboratory in Bushland, TX using the procedures of Cole et al. (2007). At the same times, the pans were weighed with an electronic balance to calculate the evaporation and nitrogen volatilization rates. Experiment 1 was conducted over a 48 hr period. Indoor and outdoor relative humidity and temperature readings were recorded every hour-on-the-hour using a portable humidity sensor (VWR, West Chester, PA) and 2 m weather station (Weather Hawk, Logan, UT). Because solution pH is also an important factor regulating the ammonia volatilization process, it was monitored along with the temperature of the solution. Average temperature inside was 21.5 °C while average outside temperatures was 30.0 °C. Relative humidity in the lab stayed relatively constant at 55 %; whereas relative humidity ranged from 17 to 80 % outside. Average wind speed outside was 0.1 m/s.



Figure 1. Photograph of the flux chamber and wind tunnel used in the laboratory for Experiment 1.

Experiment 2

In Experiment 2, both the WTAMU wind tunnel and EPA chamber were placed outside adjacent to the identical pans (Figure 2). The pans were filled with the ammonia solution as described in Experiment 1. The pans were weighed on an electronic balance at 0800, 1600, and again at 0800 hr, 24 hr later. Several 30 ml samples were taken from each pan at 0800, 1600, and again at 0800 hr to determine nitrogen content in the solution. Weather data was recorded by the weather station as well as being recorded with a VWR humidity/temperature reader. Temperatures averaged 26.4 °C and humidity averaged 34.9 %. Wind speed averaged 0.2 m/s.

Experiment 3

The EPA chamber and the WTAMU wind tunnel were placed with the matching pans included in the same conditions as Experiment 2 (Figure 2). Instead of the ammonia solution, distilled water was used to measure evaporative flux. Temperature and relative humidity readings were collected every hour for 24 hr. Pans were weighed on an electronic balance every 2 hr. Because the chambers and pans were located on the north side of the building, direct sunlight was only on the pans from approximately 1100 until 1900 hr. The average temperature was 24.5 °C, average relative humidity was 52.5 %, and average wind speed was 0.1 m/s during the 24 hr testing period.

Experiment 4

In the fourth experiment, which was conducted on the roof of our lab building, the pans were exposed to higher winds, greater heat, and more sunlight throughout

the day. Relative humidity was much lower. The experimental setup was identical to Experiment 2 except that only evaporative flux was measured. The experiment was carried out over a 24 hr period because the large pan was almost entirely evaporated by the end of that period. The pans were placed at 1 m height on a table, and the weather station was placed at 2 m height above the pans. Average temperature for the 24 hr period was 31.9 °C, average relative humidity was 18.0 %, and wind speed averaged 2.9 m/s with gusts of 5 m/s.

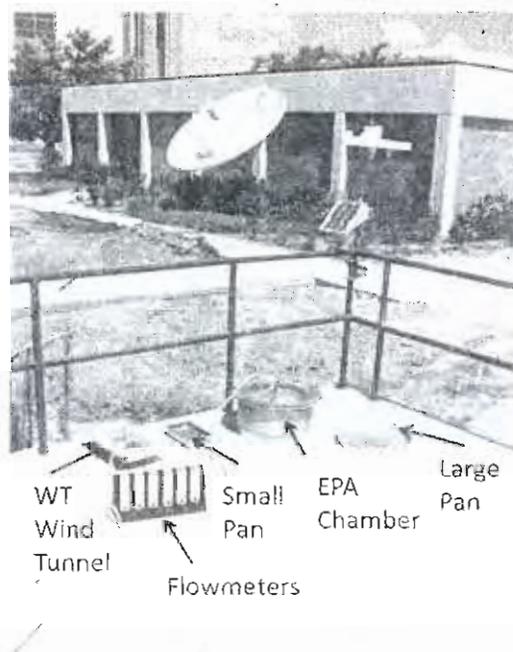


Figure 2. Photograph of the experimental setup for Experiments 2 and 3. The wind tunnel was placed over an identical small pan, and the EPA flux chamber was placed over an identical large pan.

RESULTS AND DISCUSSION

Experiment 1

Ammonia volatilization and evaporative flux data for Experiment 1 is presented in

Figure 3. Evaporation rates were much higher for the pans outside than inside the lab. Maximum evaporative flux was about $8,000 \text{ mg m}^{-2} \text{ min}^{-1}$ for the outside pans. The maximum for the inside pans was near $2,500 \text{ mg m}^{-2} \text{ min}^{-1}$. Maximum ammonia flux was near $3,500 \text{ } \mu\text{g m}^{-2} \text{ min}^{-1}$ outside and $2,800 \text{ } \mu\text{g m}^{-2} \text{ min}^{-1}$ inside. The relationship between flux and evaporation is shown in Figure 3.

Experiment 2

Ammonia volatilization and evaporative flux rates for Experiment 2 are presented in Figure 4. The open pans had much higher flux rates than the EPA chamber and were similar to the WTAMU wind tunnel. The wind tunnel was much closer to evaporation and volatilization rates in comparison to the EPA chamber; however the wind tunnel was not entirely accurate. Maximum evaporative flux was near $11,000 \text{ mg m}^{-2} \text{ min}^{-1}$ and maximum ammonia flux was over $11,000 \text{ } \mu\text{g m}^{-2} \text{ min}^{-1}$.

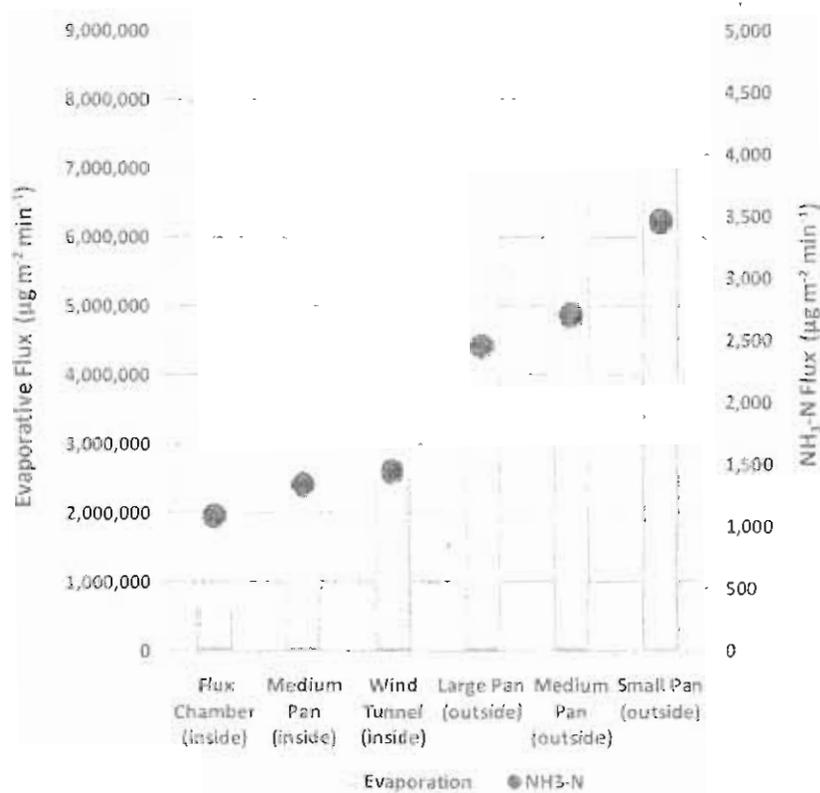


Figure 3. A comparison of evaporative and $\text{NH}_3\text{-N}$ flux for Experiment 1.

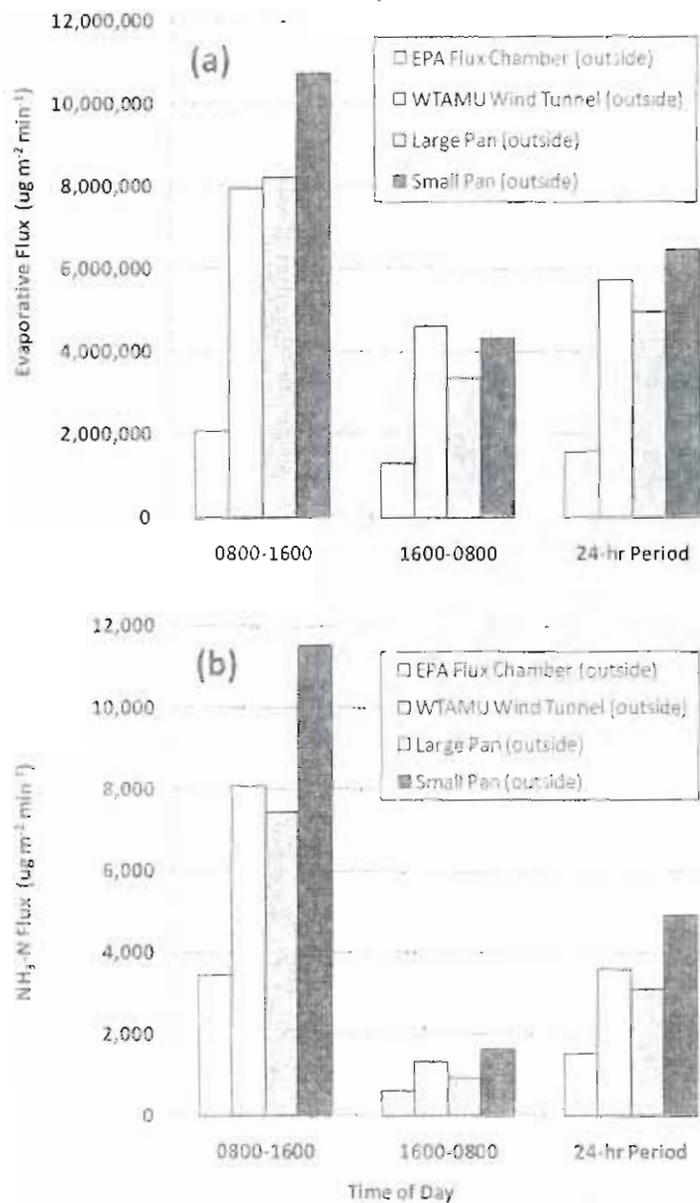


Figure 4. Evaporative flux (a) and ammonia flux (b) for Experiment 2

Experiment 3

Data for Experiment 3 is represented in Figures 5 and 6. Maximum evaporative flux for the large pan was near $14,000 \text{ mg m}^{-2} \text{min}^{-1}$; whereas, the EPA chamber was much lower, with a maximum near $4,000 \text{ mg m}^{-2} \text{min}^{-1}$. The maximum for the small pan

approached $16,000 \text{ mg m}^{-2} \text{min}^{-1}$ and the maximum for the wind tunnel was near $14,000 \text{ mg m}^{-2} \text{min}^{-1}$. The WTAMU wind tunnel mirrored the replicate open pan extremely well, except for the peak evaporative flux region near 1200 hr.

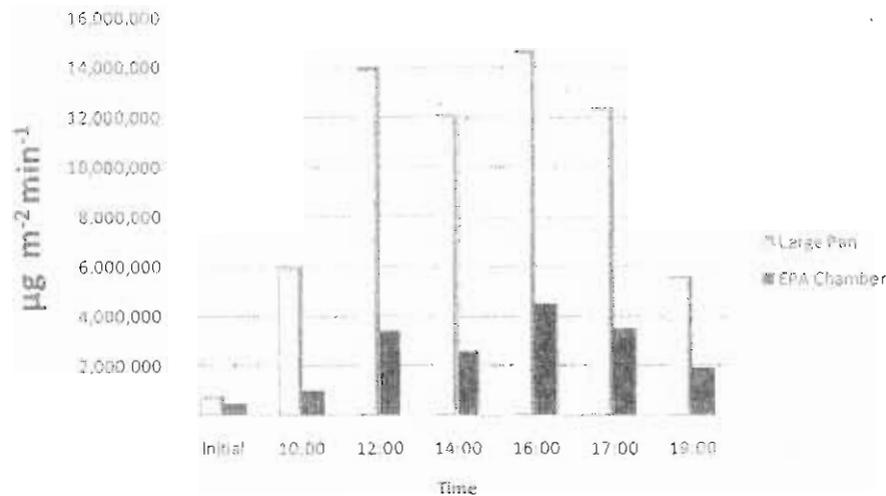


Figure 5. A comparison of evaporative fluxes for the EPA flux chamber and an identical open pan located adjacent to the flux chamber (Experiment 3).

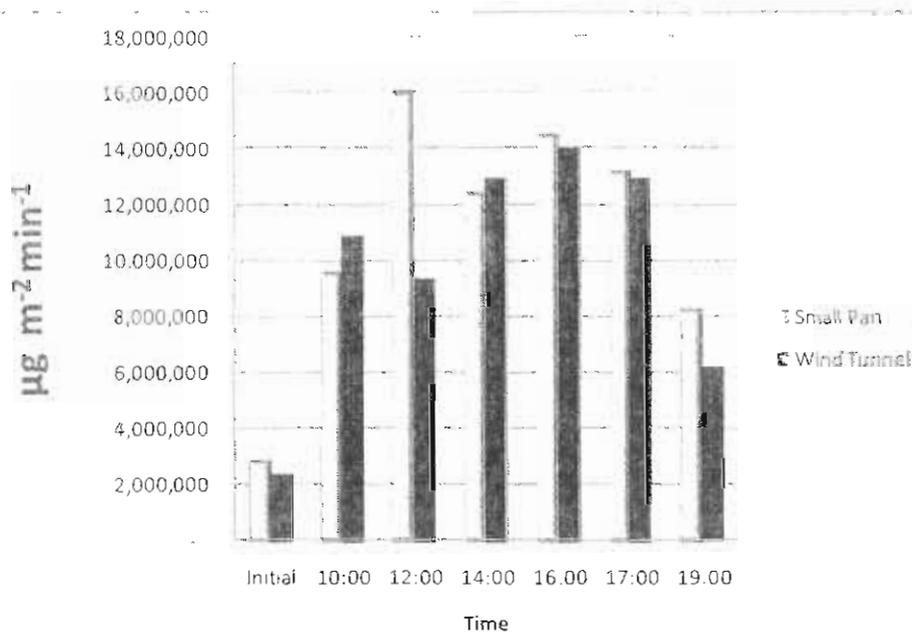


Figure 6. A comparison of evaporative fluxes for the WTAMU wind tunnel and an identical open pan located adjacent to the wind tunnel (Experiment 3).

Experiment 4

Evaporative flux on the roof in Experiment 4 was much higher than for the other studies. A maximum evaporation near $35,000 \text{ mg m}^{-2} \text{min}^{-1}$ was reached in the

small pan and $23,000 \text{ mg m}^{-2} \text{min}^{-1}$ in the large pan (Figures 7 and 8). Evaporation from pans in the EPA chamber and WTAMU wind tunnel were noticeably lower than the pans without chambers.

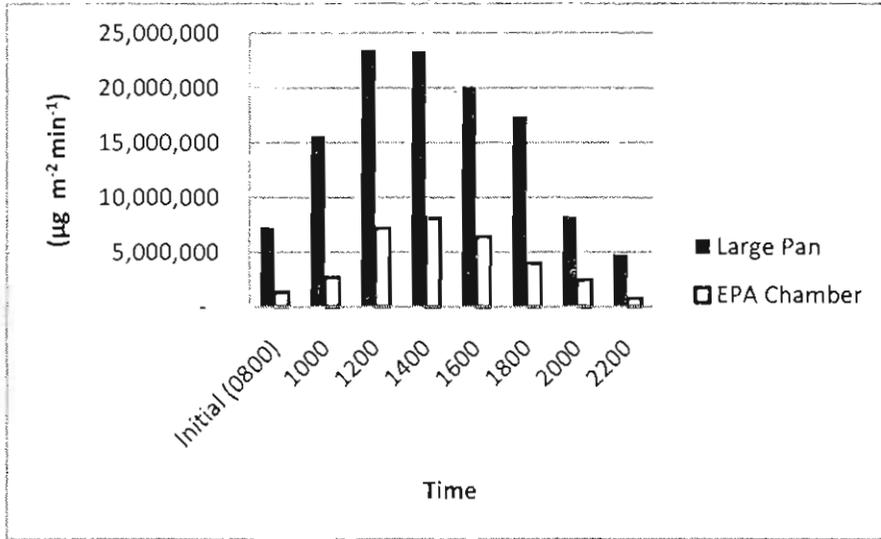


Figure 7. A comparison of evaporative fluxes for the EPA flux chamber and an identical open pan located adjacent to the EPA chamber (Experiment 4).

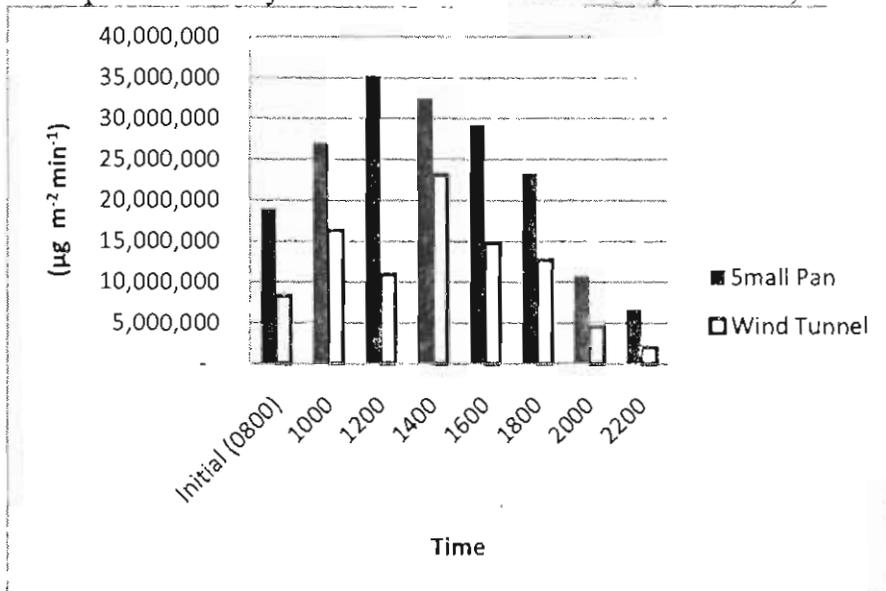


Figure 8. A comparison of evaporative fluxes for the WTAMU wind tunnel and an identical open pan located adjacent to the wind tunnel (Experiment 4).

Although volatilization and evaporative flux was closely mirrored by the WTAMU wind tunnel in Experiment 2 and 3, when the pans were exposed to more volatile wind and temperature conditions in Experiment 4, the wind tunnel relationship was not as apparent. In all experiments, evaporation from pans in the wind tunnel more closely correlated to evaporation from open pans than did evaporation from pans in the EPA flux chamber. Both methods were most

accurate during night time conditions. In both Experiment 3 and 4, peak evaporation and volatilization times occurred between 1200 and 1400 hr.

CONCLUSIONS

The goal of this research was to assess the accuracy of wind tunnels and flux chambers in measuring ammonia flux when compared to field conditions. Although, at

times, flux measurements made using flux chambers and wind tunnels may correspond with field conditions, when more volatile conditions are present, these methods may greatly underestimate actual field results. A methodology to either correct, or better interpret, the data for volatilization and evaporative flux must then be established for these methods.

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LITERATURE CITED

- Cole, N. A., R. W. Todd, D. B. Parker, and M. B. Rhoades. 2007. Challenges in using flux chambers to measure ammonia emissions from simulated feedlot pen surfaces and retention ponds. Proc. Int. Symp. Air Qual. Waste Mgmt. Agric., ASABE, 26-29 Sept. 2007, Broomfield, CO.
- Hudson, N., and G. A. Ayoko. 2008. Odour sampling I: Physical chemistry considerations. Biores. Tech. 99:3988-3992.
- Kienbusch, M. R. 1986. Measurement of gaseous emission rates from land surfaces using an emission isolation flux chamber. User's Guide. EPA Contract No. 68-02-3889.
- Koerkamp, P. W. G., J.H.M. Groot, H.M. Metz, G. H. Uenk, V. R. Phillips, M. R. Holden, R.W. Sneath, J. L. Short, R. P. White, J. Hartung, J. Seedorf, M. Schroder, K. H. Linkert, S. Pedersen, H. Takai, J. O. Johnsen, and C. M. Wathes, 1998. Concentrations and emissions of ammonia in livestock buildings in Northern Europe. J. Agric. Engr. Res. 70:79-95.
- Parker, D. B., E. A. Caraway, M. B. Rhoades, N. A. Cole, R. W. Todd, K. D. Casey, C. D. Donnell, and J. P. Spears. 2008. Effect of wind tunnel air velocity on VOC flux rates from CAFO manure and wastewater. ASABE Paper No. 08-3897.
- Parker, D. B., E. A. Caraway, M. B. Rhoades, N. A. Cole, R. W. Todd, K. D. Casey, C. D. Donnell, and J. P. Spears. 2009a. Effect of wind tunnel air velocity on VOC flux from CAFO manure and wastewater. Submitted to Trans. ASABE.
- Parker, D. B., E. A. Caraway, M. B. Rhoades, N. A. Cole, K. D. Casey, C. S. Paris, G. Galvin, and R. Ormerod. 2009b. Wind tunnels vs. flux chambers: area source emission measurements and the necessity for VOC and odour correction factors. Proc. 19th Intl. Clean Air and Env. Conference (CASANZ), 6-9 Sept. 2009, Perth, Australia.
- Rhoades, M. B., D. B. Parker, N. A. Cole, R. DeOtte, B. W. Auvermann, and Z.L. Buser. 2005. Factors affecting ammonia emission measurements with surface isolation flux chambers. ASABE Paper No. 05-4026.
- Todd, R.W., N. A. Cole, R. N. Clark, T. K. Flesch, L. A. Harper, and B. H. Baek. 2008. Ammonia emissions from a beef cattle feed yard on the southern High Plains. Atmos. Envir. 42:6797-6805.
- US EPA. 1982. Volatilization of organic pollutants from water. Contract No. R805150010. University of Toronto. EPA 600/3-82-019. USEPA. Athens, Georgia. 213 pp.

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