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Dry Deposition of Ammonia in the Vicinity of a Swine Production Facility

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Introduction

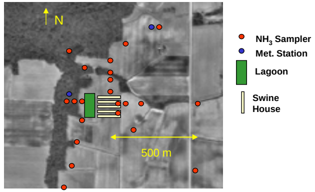
Globally, domestic animals are the largest source (22 Tg N yr^{-1}, 1 Tg = 10^{12} g) of atmospheric NH_3, comprising approximately 40% of natural and anthropogenic emissions combined, while synthetic fertilizers and agricultural crops together contribute an additional 12.6 Tg NH_3-N yr^{-1} (23% of total emissions). Within and downwind of mixed (animal and crop production) agricultural regions, NH_3 therefore plays a significant role in atmospheric chemistry, particularly the formation of inorganic $PM_{2.5}$, and deposition of nitrogen to terrestrial and aquatic systems. While animal production facilities have been identified as important sources of NH_3, there are few estimates of local NH_3 deposition for U.S. systems. Such estimates are required for evaluation of sub-grid scale processes in regional atmospheric models, estimation of potential uncertainty in emission measurement techniques such as inverse Gaussian modeling, and for assessing the risk of neighboring ecosystems to nitrogen deposition. This project examines the dry deposition of NH_3 within 500 m of a swine production facility in eastern North Carolina using a combination of measurements and modeling. Measurements began in April, 2003 and will continue through April, 2005.

Methods

Site Description

The measurement site is a 5000-head swine production facility located in the Coastal Plain region of North Carolina. The site consists of a 1.7 ha waste lagoon and five naturally-ventilated swine houses, each containing an average of 1000 finishing hogs. Approximately 85% of the land within 500 m of the housing/lagoon complex is planted with soybean, corn, or wheat. The remaining land is a patchwork of riparian zones covered by pine and hardwood with dense understory.

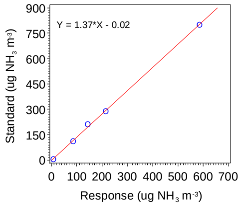
Figure 1. Site Layout



Passive Samplers

Ammonia concentrations are measured using a diffusion-type passive sampler. The sampler (Gradko International) is a 35 mm long, 11 mm I.D. FEP Teflon tube containing a Teflon filter on one end through which NH_3 gas diffuses and is adsorbed onto two acid-coated screens located at the other end. Passives are deployed in triplicate at 22 locations at a height of 1.5 m and are exposed for one week, yielding weekly average NH_3 concentrations. The samplers are calibrated (Fig. 2) in an exposure chamber using a range of known NH_3 concentrations (Scott Specialty Gases). The median analytical blank value corresponds to an atmospheric concentration of 1.75 ug NH_3 m^{-3} (N = 271). The median coefficient of variation for triplicate samples is 7.8% (N = 889).

Figure 2. Passive samplers and calibration curve



Dry Deposition Model

The flux (F) of NH_3 is calculated using the single-layer canopy compensation point model:

$$F_{NH_3} = \frac{X_c - X_a}{R_a + R_b} \qquad (1)$$

where X_c is the canopy compensation point, X_a is the NH_3 concentration in air, and R_a and R_b are the aerodynamic and quasi laminar sub-layer resistances to deposition, respectively. When the atmospheric concentration of NH_3 is above the canopy compensation point, the canopy becomes a sink for NH_3.

In this case, X_c is calculated according to

$$X_c = \frac{X_a (R_a + R_b)^{-1} + X_s R_s^{-1}}{(R_a + R_b)^{-1} + R_w^{-1} + R_s^{-1}} \qquad (2)$$

where X_s is the stomatal compensation point and R_w and R_s are the cuticular and stomatal resistances to deposition, respectively. The stomatal compensation point is calculated from assumed values of leaf apoplast NH_4^+ and H^+ concentrations. Aerodynamic, quasi laminar sub-layer, cuticular, and stomatal resistances are parameterized using standard meteorological variables. The atmospheric concentration of NH_3 is modeled as a function of distance from the source (Fig. 4) using non-linear least squares. Dry deposition is then estimated using modeled concentrations as inputs to equations 1 and 2 such that a circular deposition "surface" of radius = 500 m is produced.

Results

Figure 3. Weekly average NH_3 concentrations

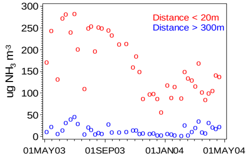


Figure 4. Example of concentration vs. distance model

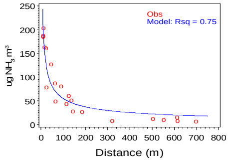


Figure 5. Deposition model output for the week of 09/29/03

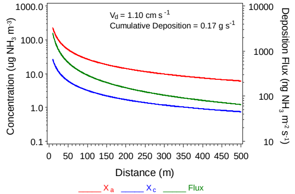
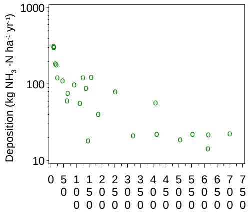


Figure 6. Average dry deposition gradient from the source to 700 m



Conclusions

Using a steady-state emission factor of 7.0 kg NH_3 $animal^{-1}$ yr^{-1}, average dry NH_3 deposition within 500 m of the housing/lagoon complex accounts for approximately 13% of emissions. The majority of NH_3 emitted is therefore available for $PM_{2.5}$ formation and deposition to downwind ecosystems. Though limited in spatial extent, high deposition rates near the source (Fig. 6) are likely to exceed the critical nitrogen loads for most ecosystems, suggesting that siting requirements for animal production facilities should consider local nitrogen deposition as a potential environmental burden.