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

John T. Walker, Wayne Fowler, U.S.EPA/NRMRL/APPCD; Wayne Robarge, North Carolina State University, Department of Soil Science

Introduction

Globally, domestic animals are the largest source (22 Tg N yr⁻¹, 1 Tg = 10¹² g) of atmospheric NH₃ comprising approximately 40% of natural and anthropogenic emissions combined, while synthetic fertilizers and agricultural crops together contribute an additional 12.6 Tg NH₄-N yr⁻¹ (23% of total emissions). Within and downwind of mixed (animal and crop production) agricultural regions, NH₃ therefore plays a significant role in atmospheric chemistry, particularly the formation of inorganic PM₂.₅ and deposition of nitrogen to terrestrial and aquatic systems. While animal production facilities have been identified as important sources of NH₃, there are few estimates of total NH₃ 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 NH₃ 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 86% of the land within 500 m of the housing/lagoon complex is planted with soybean, corn, or wheat. The remaining land is primarily 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 (Ordinario International) is a 35 mm long, 11 mm i.d. FEP Teflon tube containing a Teflon filter on one end and through which NH₃ 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 NH₃ concentrations. The samplers are calibrated (Fig. 2) in an exposure chamber using a range of known NH₃ concentrations (Scott Specialty Gases). The median analytical blank value corresponds to an atmospheric concentration of 1.75 ug NH₃ m⁻³ (N = 271). The median coefficient of variation for triplicate samples is 7.8% (N = 889).

Results

In this case, Xₛ is the stomatal compensation point, Xₐ is the NH₃ concentration in air, and Rₛ and Rₐ are the aerodynamic, quasi laminar sub-layer, cuticular, and stomatal resistances to deposition, respectively. The stomatal compensation point is calculated from assumed values of leaf apoplast NH₃ and H⁺ concentrations. The median analytical blank value corresponds to an atmospheric concentration of 1.75 ug NH₃ m⁻³ (N = 271). The median coefficient of variation for triplicate samples is 7.8% (N = 889).

Dry Deposition Model

The flux (F) of NH₃ is calculated using the single-layer canopy compensation point model:

\[ F_{\text{can}} = \frac{X_a - X_{\text{comp}}}{R_s + R_a} \]  

where Xₐ is the canopy compensation point, X is the NH₃ concentration in air, and Rₐ and Rₛ are the aerodynamic and quasi laminar sub-layer resistances to deposition, respectively. When the atmospheric concentration of NH₃ is above the canopy compensation point, the canopy becomes a sink for NH₃.

Conclusions

Using a steady-state emission factor of 7.0 kg NH₃ animal⁻¹ yr⁻¹, average dry NH₃ deposition within 500 m of the housing/lagoon complex accounts for approximately 13% of emissions. The majority of NH₃ emitted is therefore available for PM₂.₅ 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.