AIR QUALITY

Atmospheric Ammonia: Understanding Its Effects

AIR QUALITY EDUCATION IN ANIMAL AGRICULTURE

Issues: Atmospheric Ammonia
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Ron Sheffield, Associate Professor
Biological and Agricultural Engineering, Louisiana State University

This publication discusses negative effects of increasing atmospheric ammonia emissions and how agriculture is a major contributor to these emmisions.

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The Agricultural Connection to Atmospheric Ammonia

Dramatic increases in atmospheric ammonia emissions have been reported in recent years in areas of intensive animal agriculture. The U.S. Environmental Protection Agency (EPA) estimates that animal agriculture accounts for 50 percent to 85 percent of total man-made ammonia volatilization in the United States (*Figure 1*).

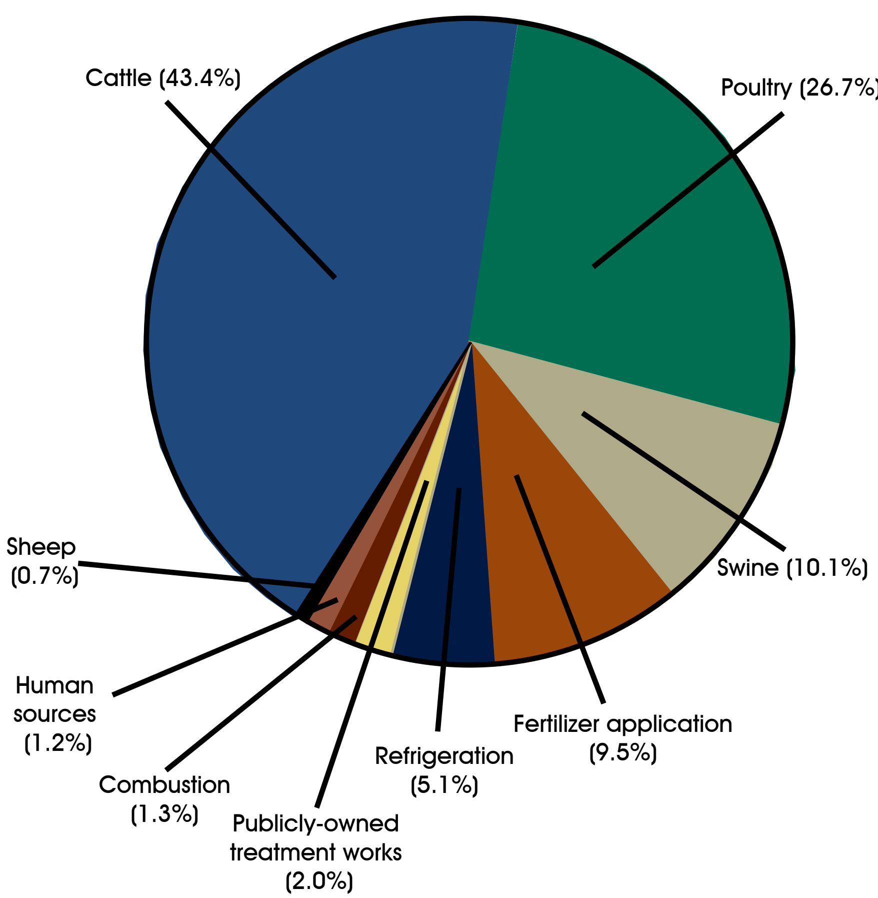

Figure 1. Estimates of ammonia emissions from man-made sources in the U.S. in 1994 (Battye et al., 1994).

Why Are We Concerned with Ammonia Deposition?

A recent study by the National Research Council (NRC, 2002) identified ammonia emissions as a major air quality concern at regional, national, and global levels. Ammonia has many potential negative impacts. Deposition of atmospheric ammonia

Ammonia deposition contributes to nutrient enrichment (eutrophication) of surface waters.

can cause eutrophication (nutrient enrichment) of surface waters, where phosphorus concentrations are sufficient to support harmful algal growth. Nutrient enrichment and eutrophication lead to the decline of aquatic species, including those with commercial value. Sensitive crops such as tomatoes, cucumbers, conifers, and fruit cultures can be damaged by over-fertilization caused by ammonia deposition if they are cultivated near major ammonia sources (van der Eerden et al., 1998). The deposition of ammonia on soils with a low buffering capacity can result in soil acidification or basic cation (positively charged ion) depletion.

Volatilized ammonia can travel hundreds of miles from the site of origin. In Europe, scientists have concluded that nitrogen pollution in the Mediterranean Sea is caused in large part by ammonia emissions in northern Europe. Ammonia emissions from the Midwestern United States may contribute to eutrophication of the Gulf of Mexico. The Chesapeake Bay is likely receiving ammonia deposition from upwind areas with intensive agricultural operations such as Ohio and North Carolina.

In addition to its effects on water, plant, and soil systems, ammonia reacts with other compounds to form particulate matter (PM) with a diameter of 2.5 microns or less, which is referred to as $PM_{2.5}$ (*Figure 2*).

Once in the atmosphere, thermal nitrogen oxide may be transformed into secondary pollutants, such as nitric acid (HNO_3), nitrate, and organic compounds such as peroxyacetyle nitrate. In the presence of atmospheric water, nitric acid gas can dissolve as the ammonium ion (NH_4^+), where it may react with a number of dissolved anions to form very small aerosol particles, known as $PM_{2.5}$. Those ammonium salts are major components of both atmospheric nitrogen aerosols and wet-deposited nitrogen.

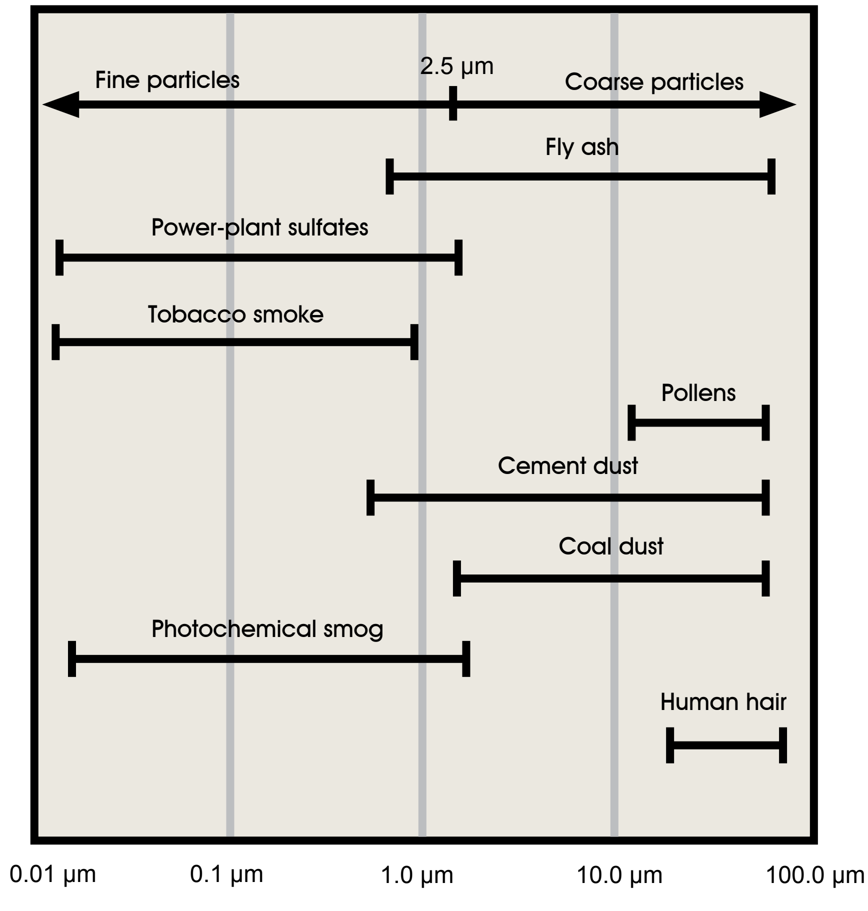

Figure 2. Size ranges of selected airborne particulates in micrometers (Adopted from Heinsohn and Kabel, 1999).

Health Effects

This classification of PM is of particular concern because the small size of the particles allows them to penetrate deep into the lungs. Several recent community health studies indicate that significant respiratory and cardiovascular problems are associated with exposure to $PM_{2.5}$. Other problems associated with long-term exposure to fine particles include premature death and increased hospital admissions from respiratory causes. Children, the elderly, and individuals with cardiovascular health or lung diseases, such as emphysema and asthma, are especially vulnerable to such health problems caused by $PM_{2.5}$.

These fine particles also contribute to the formation of haze. In the United States, haze has reduced natural visibility from 90 miles to between 15 and 25 miles in the East and from 140 miles to between 35 and 90 miles in the West (EPA, 2004). Visibility in the eastern United States is generally worse due to higher average humidity levels and higher levels of particulate matter.

In the United States, livestock and poultry production is the largest contributor of ammonia gas emissions, followed by agricultural fertilization. In animal production, ammonia gas emissions are caused by a series of reactions that begin with the hydrolysis of urea in the waste stream. Intensive agriculture accounts for nearly 65 percent of ammonia gas emissions. The primary nitrogen oxide sources in the United States are electric utilities, industrial boilers, and gasoline- and diesel-fueled vehicles. In 2002, the transportation sector contributed 56 percent of the nation's total nitrogen oxide emissions. The electric utility sector contributed 37 percent of those emissions, with the balance coming from industrial and miscellaneous sources. Human activities account for more than 90 percent of the total nitrogen oxide emissions.

Nitrogen Deposition

When a gas or an aerosol moves from the atmosphere to the earth's surface, the process is called deposition. Dry deposition is the passive migration of aerosol particles or gas molecules to a surface, such as a grass blade, a tree leaf, a soil particle, or a body of water. Dry deposition flux — or the amount of matter deposited per unit area in a given period — is related to the probability that the surface will intercept particles or molecules carried along by air currents. In general, that probability increases as the concentration of particles or molecules in the air increases. Gases that are heavier than air also are more likely to undergo dry deposition than are gases lighter than air. In contrast, wet deposition occurs when a particle or gas molecule is collected from the air and carried to the earth's surface by precipitation.

Like dry deposition, wet deposition increases with the concentration of gases or particles in the air. In addition, water-soluble gases have a greater wet-deposition potential than do gases with low water solubility. Wet deposition can collect particles and gases from high altitudes. Nitrate and ammonia, the major components within the reactive nitrogen species pool, are relatively soluble in water and may be subject to both wet and dry deposition.

In the United States, livestock and poultry production is the largest source of ammonia emissions.

Ecological Effects

Increases in total nitrogen flux into the ecosystem can shift the plant, animal and microbial populations toward species that can use more nitrogen than the original, native species. Native ecosystems tend to develop in response to the nutrition provided by soil, water, and air. In nitrogen deposition, the microbial, animal, and plant life native to an ecosystem self-selects to use maximum benefit from the nitrogen available from all sources, including the atmosphere.

In self-selection, those species best adapted to use the available resources have a competitive advantage over species that are not as well adapted. For example, in the Southern High Plains, native turfgrasses such as buffalograss (*Buchloe dactyloides*) tend to be drought-tolerant, while imported grasses such as Kentucky bluegrass (*Poa pratensis*) wither and fade without supplemental irrigation.

Reviewers

Kevin A. Janni, Professor, Department of Bioproducts and Biosystems Engineering, University of Minnesota

Heidi Waldrip, USDA-Agricultural Research Service

Population shifts have been documented in a wide range of species in high alpine watersheds in the Rocky Mountains. Baseline nitrogen deposition in Rocky Mountain National Park has been estimated at less than 1.5 kilograms per hectare per year; over the past several years nitrogen deposition in the national park's Loch Vale watershed has reached as high as 7 kilograms per hectare per year. Some scientists associate the increased nitrogen deposition in these ecosystems with dramatic changes in vegetation, water chemistry, soil alkalinity, and populations of aquatic species.

Summary

Atmospheric ammonia is a leading culprit in haze and visibility issues in several areas of the country. Ammonia, through its role in the formation of PM 2.5, is also a concern for human health. Nitrogen is an important limiting nutrient in sensitive ecosystems, and atmospheric nitrogen deposition is a significant component of the ecosystems' balance. When excessive nitrogen deposition distorts that balance by enriching soils and surface water beyond the native species' capacity to adapt, long-term changes in species distribution and water and soil quality are likely. Either native plants adapt to use the excess nitrogen or nonnative species that use more nitrogen take over the ecosystem. Long-term monitoring of both dry and wet deposition of reactive nitrogen species may help predict or diagnose these ecosystem shifts.

References

Battye, R., W. Battye, C. Overcash, and S. Fudge. 1994. Development and Selection of Ammonia Emission Factors. EPA/600/R-94/190. Final report prepared for U.S. Environmental Protection Agency, Office of Research and Development. USEPA Contract No. 68-D3-0034, Work Assignment 0-3.

EPA. 2005. Timeline for Implementing the PM2.5 Standards. Washington, D.C.: United States Environmental Protection Agency. Available at: www.epa.gov/pmdesignations/documents/120/timeline.html.

EPA. 2004. What is Visibility Impairment? Washington, D.C.: United States Environmental Protection Agency. Available at: www.epa.gov/oar/visibility/what.html.

EPA. 1997. National Ambient Air Quality Standards for Particulate Matter; Final Rule, Federal Register. 62(138):38651.

Heinsohn, R. J., and R. L. Kabel. 1999. Sources and Control of Air Pollution. Upper Saddle River, N.J.: Prentice-Hall, Inc.

Van der Eerden, L. J. M., P. H. B. de Visser, and C. J. Van Dijk. 1998. Risk of damage to crops in the direct neighborhood of ammonia sources. *Environ. Pollution* 102(S1): 49-53.

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