May 2006
Volume 6, No. 5

Western Dairy News

for the West, about the West, from the West

From ammonia to $PM_{2.5}$

By Brent W. Auvermann
Texas A&M University System

Atmospheric ammonia (NH_3) is receiving a great deal more attention today than it has historically, but it is not alone. Respiratory health, water quality, climate change, nuisance odor, visibility, and energy conservation are all environmental or quality-of-life considerations that involve NH_3 in one way or another. And it's not just NH_3 that's under the gun; all nitrogen species in the atmosphere, with the possible exception of ordinary nitrogen gas (N_2), participate in the atmospheric systems that influence our quality of life, our environment and our natural resource base. But NH_3 is the nitrogen compound with the highest profile at present. Why?

Ammonia's public importance results from these characteristics:

• It is highly reactive in the environment. Ammonia is easily soluble in water; its polar charge causes it to react with nearly any conceivable surface; and it readily combines with anionic species to form soluble salts.

• It is ubiquitous. In many cases, most notably in agriculture, NH_3 is the most abundant N species released as a waste product by biological or chemical processes.

• It has a distinctive, easily recognized odor profile. Although NH_3 is among the weakest odorants associated with livestock production, people know when it's around.

• It is an important source of N for the biosphere. Nitrogen is an essential macronutrient for the synthesis of proteins, and both plants and animals can either use NH_3 directly or convert it to another N form that they can use.

In January 2006 at the John Airy Symposium, James Galloway showed that humans have increased the amount of reactive N in the global environment (see Figure 1). Other than the small amount of N_2 converted to NH_3 by legumes, the vast majority of that increase has resulted from industrial production of NH_3, which has helped to fuel the Green Revolution and feed a rapidly growing, global population.

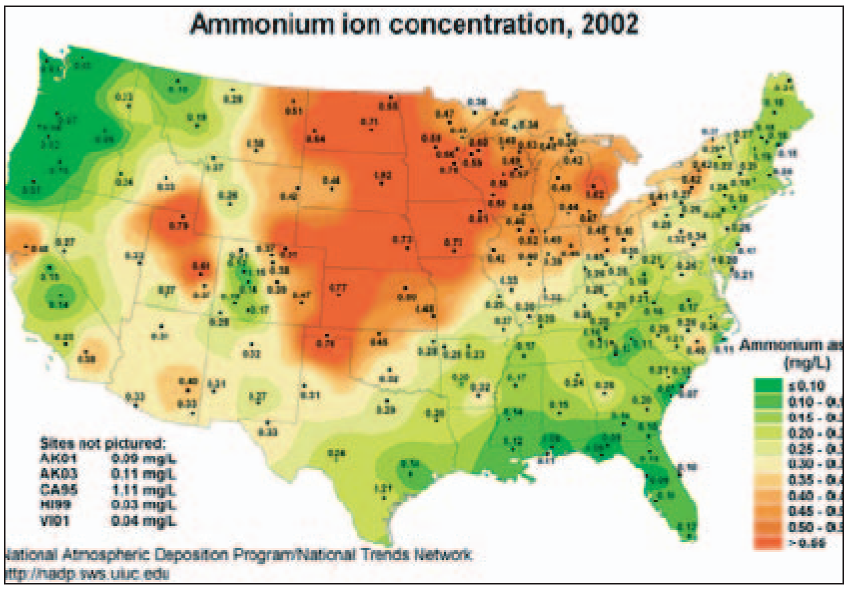

Figure 4: Concentrations of aqueous ammonia in precipitation across the U.S. in 2002. Not all of the "hot spots" (shown in orange and red) are solely the result of livestock production. Fertilizer use, prevailing winds, orographic and topographic influences, other NH_3 sources, atmospheric sinks and dry-deposition processes all play important roles in interpreting a chart like this one.

Regulatory Significance

Ammonia's amazing reactivity contributes to a couple of environmentally significant phenomena:

• **Water quality impairment.** Reactive N is a so-called "limiting nutrient" in many aquatic ecosystems, which means an incremental increase in reactive N (including NH_3) results in a corresponding increase in the aquatic species whose growth is limited by N availability. In N-limited watersheds, small increases in reactive N may cause explosive growth in algae or other populations, a phenomenon known as eutrophication. When those organisms die off, the residues extract a great deal of dissolved oxygen from the water, which may result in fish kills and other environmental damage.

• **Odor.** Ammonia has a distinct odor. Although it is a much weaker odorant than many trace species of N (e.g., amines, indoles), NH_3 releases from livestock or poultry facilities are often accompanied by emissions of those more potent odorants.

Because NH_3 is so easily identifiable by the human nose, annoyed neighbors often use it as their "whipping boy" in nuisance complaints related to odors, whether it is the primary odorant or not.

• **Air quality impairment.** In the presence of water vapor and a few, selected anionic species, NH_3 will dissolve and then react with those anions to form fine particles through a process known as nucleation

Western Dairy News is a collaborative effort of Dairy Specialists from:

Utah State University Extension
Cooperative Extension Washington State University
OSU Oregon State University Extension Service
NDSU Extension Service North Dakota State University
New Mexico State University
Colorado State University Knowledge to Go Places
K-State Research & Extension
The University of California Davis
University of Idaho Cooperative Extension System
Texas Cooperative Extension The Texas A&M University System
The University of Arizona Cooperative Extension College of Agriculture and Life Sciences

Production effort for Western Dairy News is generously sponsored by Monsanto Dairy Business

Western Dairy News

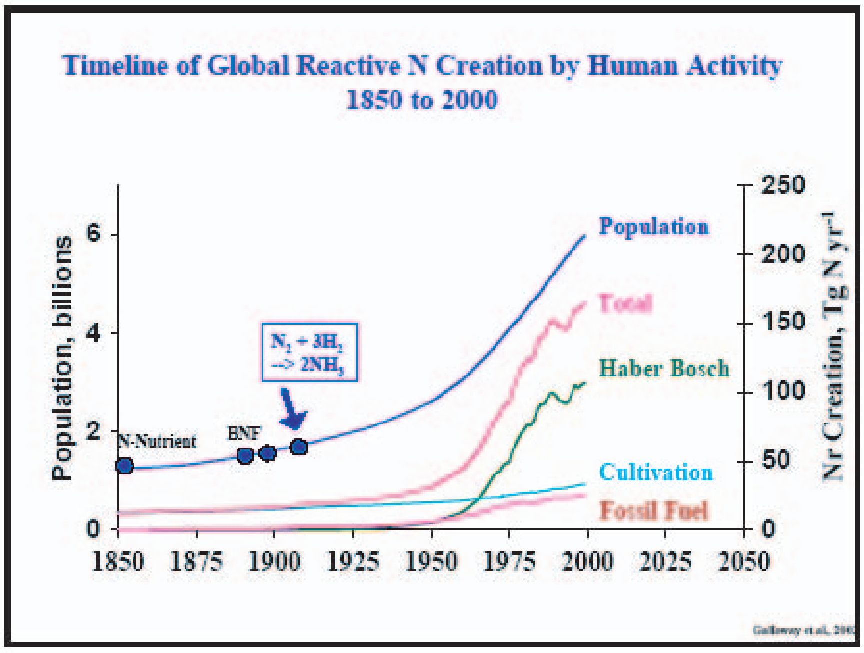

Figure 1 (above). During the industrial age, humans have dramatically increased the amount of reactive nitrogen in the global ecosphere, primarily by producing ammonia fertilizers via the Haber-Bosch process (Galloway, 2006).

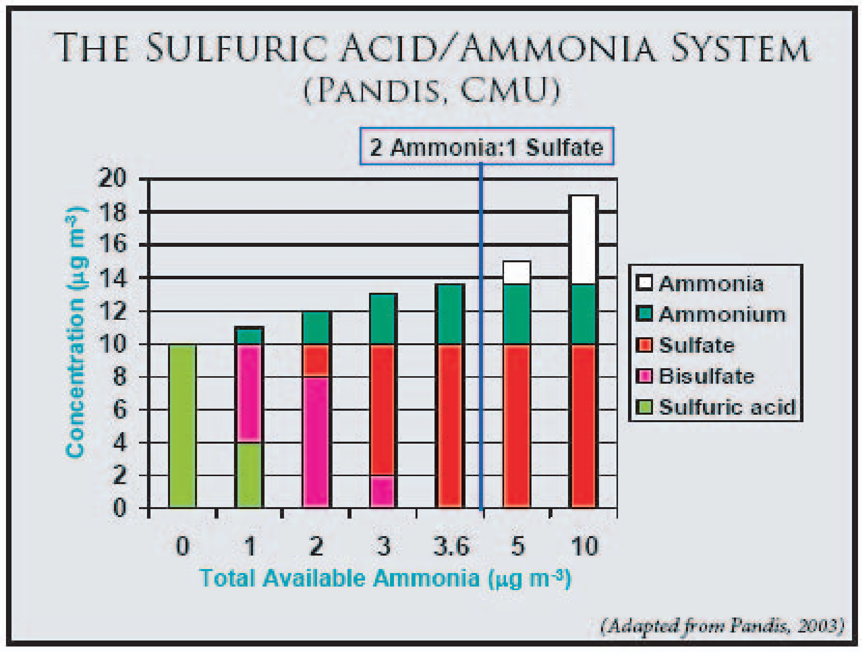

Figure 2 (above). As atmospheric NH_3 concentrations increase in the presence of atmospheric sulfate, the two species react to form fine particles until all of the SO_4 ions have been soaked up by NH_3. Two molecules of NH_3 are required for each SO_4 molecule to form ammonium sulfate aerosol. If NH_3 concentrations increase beyond that 2:1 ratio with SO_4, the excess NH_3 is available to react with other anionic species, especially NO_3.

(Figure 2). The major anions in this context are atmospheric sulfate (SO_4) and nitrate (NO_3), which are both products of combustion. Where significant amounts of SO_4 and/or NH_3 are present in the air, ammonium sulfate or ammonium nitrate aerosols may contribute to impaired visibility, increased respiratory health risk, or both.

EPCRA

Perhaps the highest-profile current regulatory context in which NH_3 emissions are important to the livestock industry is an indirect one.

The Emergency Preparedness and Community Right-to-Know Act (EPCRA) is a federal statute intended to protect public health and safety from the release of "hazardous substances" to the environment. The Environmental Protection Agency, which is responsible for implementing the Act, has established a list of "hazardous substances" to which the monitoring and reporting provisions of EPCRA apply. If one of those substances is released to the environment in an amount exceeding the EPCRA "reportable quantity," or RQ, that release must be reported to the designated state agency and the release must be monitored.

Ammonia is on the list of "hazardous substances," and its RQ is 100 lbs. For releases that occur over an extended period of time rather than in a single, discrete event (e.g., a train derailment), the RQ is interpreted as 100 lbs/day. Consequently, if EPCRA is applied to dairy facilities, the barns, open lots and manure-storage structures would be subject to a combined RQ analysis to determine which dairies must monitor and report their NH_3 emissions.

How large must a dairy or feedyard be to release 100 lbs/day of NH_3 and trigger the EPCRA monitoring and reporting provisions? Of course, such a calculation ought to be site-specific, because no two dairies or feedyards are exactly alike. But we can make some back-of-the-envelope estimates to give us a sense of the range of answers we are likely to expect (Figure 3).

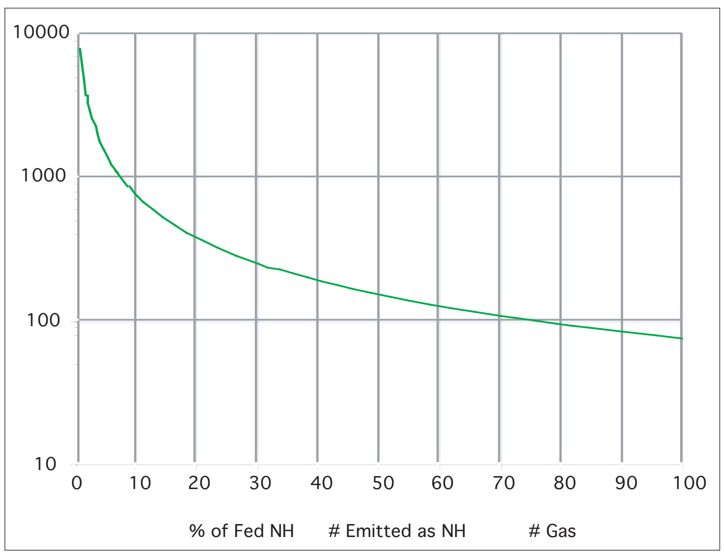

Figure 3. The size of a dairy likely to release more than the Reportable Quantity of ammonia (100 lbs/day) and trigger EPCRA monitoring and reporting provisions depends on the dairy's overall nitrogen-use efficiency. The more efficiently the dairy converts feed nitrogen into controlled exports (e.g., milk, calves) and preserves the nitrogen in its manure, the larger the dairy can be before it would trigger EPCRA. No dairy will ever achieve 100% efficiency. In fact, recent studies of cattle feedyards suggest that typical NH_3 emissions from open lot systems will be on the order of 50% of the NH_3 equivalents fed to animals. If that is even close to correct, then dairies as small as 200 head might be subject to EPCRA.

Conclusion

Given the outcomes of EPCRA lawsuits in *U.S. v. Buckeye Egg Company*, *Sierra Club v. Seaboard Farms* and *Sierra Club v. Tyson Foods et al.*, it seems likely that EPCRA will eventually be applied to all livestock and poultry facilities despite recent attempts to exempt animal-feeding operations from EPCRA enforcement:

- In October 2005, U.S. Senators Sam Brownback (R-KS) and Larry Craig (R-ID) tried to insert an exemption rider into the conference report of the agricultural appropriations bill. The exemption language, adopted by Senate conferees on October 25th, was rejected by the conference committee in their October 27th report.
- On March 27, 2006, a group of 29 signatories from environmental advocacy groups, medical schools and public health organizations submitted to the EPA an extensively documented letter opposing a proposed EPCRA exemption for the poultry industry.

Ammonia emissions from AFOs will be the focus of public scrutiny for a long time to come, not only because of EPCRA but also because of ammonia's contribution to local and regional air pollution. To underscore the point, monitoring data from the National Atmospheric Deposition Program (Figure 4) suggests that atmospheric NH_3 enrichment is associated, to some extent, with intensive livestock production.

Dairymen and other livestock producers are well advised to pay close attention to the regulatory developments surrounding this complicated, ubiquitous compound.

Acknowledgments

I gratefully acknowledge Drs. Spyros Pandis, Rich Scheffe, James Galloway, Andy Cole, Rick Todd, David Parker and Saqib Mukhtar, who have made some of their data, images and graphs available for public use.

Western Dairy News is published as a service to people interested in the health and welfare of the Western dairy industry. Archives of this publication may be found at:
http://animalscience-extension.tamu.edu/dairy/wdn.html

For further information contact:
Dr. Ragan Adams, Editor
ILM, CSU-VTH
300 W. Drake Road
Fort Collins, CO 80523
970-297-0371
radams@lamar.colostate.edu

Material published in **Western Dairy News** is not subject to copyright. Permission is therefore granted to reproduce articles, although acknowledgement of the source is requested.

Cooperative Extension programs are available to all without discrimination.