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 odors associated with livestock production, people know when it’s around.
  • It is an important source of N for the biosphere. Nitrogen is an essential macro-nutrient 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.
and/or NH equivalents fed to animals. If that is even close to 2:1, ammonium nitrate aerosols may contribute to impaired visibility, increased respiratory health risk, or both.

**EPCRA**

Perhaps the highest-profile current regulatory context in which NH₃ 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 NH₃ emissions.

How large must a dairy or feedyard be to release 100 lbs/day of NH₃ 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).

**Conclusion**

Given the outcomes of EPCRA lawsuits in U.S. v. Bucheye Egg Company, Sierra Club v. Seaboard Farms and 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 conference 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 NH₃ 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**

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**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). The major anions in this context are atmospheric sulfate (SO₄) and nitrate (NO₃), which are both products of combustion. Where significant amounts of SO₄ and/or NH₃ are present in the air, ammonium sulfate or ammonium nitrate aerosols may contribute to impaired visibility, increased respiratory health risk, or both.

**Figure 2** (above). As atmospheric NH₃ concentrations increase in the presence of atmospheric sulfate, the two species react to form fine particles until all of the SO₄ ions have been soaked up by NH₃. Two molecules of NH₃ are required for each SO₄ molecule to form ammonium sulfate aerosol. If NH₃ concentrations increase beyond that 2:1 ratio with SO₄, the excess NH₃ is available to react with other anionic species, especially NO₃.

**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 outputs (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 NH₃ emissions from open lot systems will be on the order of 50% of the NH₃ equivalents fed to animals. If that is even close to correct, then dairies as small as 200 head might be subject to EPCRA.

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**Table 1:**

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**Figure 3:**

- **Timeline of Global Reactive N Creation by Human Activity 1850 to 2000**
- **The Sulfuric Acid/Ammonia System (Pandis, CMU)**