

## AMMONIA EMISSIONS FROM ANIMAL FEEDING OPERATIONS

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The purpose of this paper is to summarize the state of knowledge regarding ammonia ( $\text{NH}_3$ ) emissions from animal feeding operations. Based on the information in published literature, the paper summarizes:

- The effects of  $\text{NH}_3$  emitted from animal production to the environment;
- Emission rates and quantities from animal buildings, storage and treatment facilities, and land application sites;
- Ammonia emission measurement methods;
- Models for  $\text{NH}_3$  emissions, transport and deposition; and
- Possible control strategies and technologies.

Atmospheric  $\text{NH}_3$  is produced by the decomposition of organic materials, biomass burning and fertilizer production and utilization. Ammonia is involved in plant metabolism and can be exchanged between vegetation and the atmosphere. Ammonia emissions abatement has had high environmental priority in parts of Europe in recent years, and it is receiving more attention in the United States as a potential air and water quality concern. The primary concerns about ammonia emissions into the atmosphere are: (1) nutrient deposition in nutrient sensitive ecosystems and (2) formation of aerosol particles that may cause haze and impair visibility and are also a concern for potential health effects from respirable particulate matter.

Agricultural activities, livestock production in particular, have been reported to be the largest contributor of  $\text{NH}_3$  emissions into the atmosphere. Farm animals consume a considerable amount of protein and other nitrogen (N) containing substances with their feed. The conversion of dietary

N to animal product is relatively inefficient, and 50 to 80% of the N consumed is excreted. Ammonia is produced as a consequence of bacterial activity involving the excreted organic N substrates.

Ammonia can be emitted from animal housing, manure storage and treatment facilities, and manure land application in animal production operations. Factors that affect  $\text{NH}_3$  volatilization include source characteristics (manure, building type, storage and treatment methods, and land application method), pH, temperature, wind speed, and surface characteristics. At this time, the majority of data for emissions from animal feeding operations are from Europe, where buildings, manure management and climate are often different than in the U.S. Previously, little research on ammonia emissions has occurred in the U.S., but research is increasing. Progress is being made in development of measurement equipment and methods, but the expense of measurement and lack of continuous measurement capability has hindered the development of reliable annual emission factors. Typically, data are collected over short durations, and extrapolations beyond the sampling periods and conditions are prone to error.

Emission rates are usually expressed in terms of mass of  $\text{NH}_3$  or ammonia nitrogen ( $\text{NH}_3\text{-N}$ ) per unit time and per animal (or live weight units) or per unit area (surface sources). Although air quality literature uses units of  $\text{NH}_3$  mass in reporting emission data, this paper uses  $\text{NH}_3\text{-N}$  mass because it simplifies its use in N accounting for confined animal production. To convert  $\text{NH}_3\text{-N}$  mass to  $\text{NH}_3$  mass, multiply by 1.214.

The ranges of measured emission rates can be large among the European and U.S. data. Building emissions range from 0.2 to 5, 0.12 to 1.48,

0.28 to 0.74, and 0.5 to 10 g NH<sub>3</sub>-N/h-AU (1 AU=500 kg live weight) for pigs, dairy cattle, beef cattle and poultry, respectively. Storage/treatment losses reported are 0.25 to 156 and 3 to 90 kg NH<sub>3</sub>-N/ha-day for lagoons and storage tanks, respectively. Land application losses range from 14 to 83%, 6 to 47%, and 0 to 7% of total NH<sub>3</sub>-N applied for surface spread, band spread and injected manure, respectively. Data on NH<sub>3</sub> emission measurements from beef cattle feedlots and large dairies with open housing in the U.S. are limited. The NH<sub>3</sub> losses from the various sources at animal production operations are often expressed in different units or on different basis, making it more difficult to calculate NH<sub>3</sub> loss per animal. Some of the reported emissions are derived from direct assumptions that a certain percentage of N excreted by the animal is lost due to NH<sub>3</sub> volatilization. Without measurements, these assumed emissions should be used with extreme caution. Additionally, N excretion data for all animal species need better documentation. Published information indicates  $\pm 30\%$  variation, and it is even complicated further with the current efforts in dietary manipulation to reduce N excretion.

Ammonia emission rates from different sources in animal feeding operations have been used to develop emission factors. The ammonia emission factor for animals in an animal production operation represents the sum of the annual mean emission rates from housing, manure storage/treatment and land application. Emissions factors are based on average annual conditions and typically a composite of various animal sizes and types for a particular animal species. Emission factors currently used in the U.S. are based on those developed for Europe. Composite emission factors in Europe are 14.8 to 23.5, 2.3 to 5.2 and 0.20 to 0.23 kg NH<sub>3</sub>-N/yr-animal for dairy, swine and poultry, respectively. The corresponding emission factors estimated for the U.S. based mainly on European data are 18.7 to 18.9, 4.7 to 6.0 and 0.18 to 0.24 kg NH<sub>3</sub>-N/yr-animal for dairy, swine and poultry, respectively. Emission factors need further determination, especially for livestock and poultry production in the U.S. Also, use of a composite emission factor should be discour-

aged and emission factors for different production management systems and subsets of animal species (e.g., for pigs: sows/piglets, growing pigs, gestating sows, boars, etc.) should be developed and used instead. This would allow more accurate determination of ammonia emission for specific animal feeding operations. Another deficiency with the emission factors is that they are usually developed from measurements taken over short periods of time, during which the weather, operating conditions and animal sizes and numbers may not represent the annual average conditions. This leads to under or over estimation of ammonia emission factors when the value obtained during the short period of measurement is extrapolated annually. Thus, it is important to develop reliable and accurate measurement methods and to develop the capability to monitor continuously for long periods if accurate annual emission factors are to be determined. Also, increased emphasis on changing diets to reduce N excretion and other management changes to reduce ammonia emission have the potential to significantly change NH<sub>3</sub> emissions. This makes it necessary to reevaluate the emission factors developed earlier to incorporate changing trends in animal production operations.

Measurements of NH<sub>3</sub> concentration and flux provide a basis for formulating emission factors for the different sources at an animal production facility. They are necessary for estimating inputs for models and determining the effects of management changes for controlling emissions. Measurement methods currently used include chemiluminescence analyzers, denuders, detector tubes, optical absorption techniques, wet chemistry and gas chromatography. Ammonia fluxes are estimated using N mass balance, micrometeorological, chamber and wind tunnel, and tracer gas methods. Comparisons of various methods for measuring NH<sub>3</sub> fluxes can yield differences of greater than 200%. Agreement within 20-30% for different methods is generally considered good. Lack of a proven "ground-truth" method makes it difficult to calculate absolute errors. Mass balance on N should be considered with every measurement as a check on reasonability of NH<sub>3</sub> emission measurements, even though it may be difficult to deter-

mine the fate of all the N that is consumed by an animal.

Models are important for predicting emissions for different situations and the effects of changes of the factors that affect NH<sub>3</sub> emissions. Some empirical and mechanistic models have been published for NH<sub>3</sub> emission in buildings and from storage/treatment facilities and land application. Most of the empirical models use statistics to obtain correlations and relationships between factors that affect NH<sub>3</sub> emission. Mechanistic models are built based on the emission processes for the NH<sub>3</sub> source and NH<sub>3</sub> transfer to the atmosphere. Transport and deposition models usually

are based on Gaussian dispersion. However, the errors of the models are usually difficult to determine.

Reducing NH<sub>3</sub> loss from an animal feeding operation requires a whole farm systems approach, which shows how intervening in one aspect of the farm may affect NH<sub>3</sub> losses in other parts of the operation. Strategies for reducing NH<sub>3</sub> losses should be directed towards reducing: (1) NH<sub>3</sub> formation, (2) NH<sub>3</sub> loss immediately after it has been formed, or (3) the NH<sub>3</sub> loss potential. Some of the control practices that are potentially useful for reducing NH<sub>3</sub> loss from animal production facilities are summarized in Table 1.

TABLE 1. Potentially useful ammonia control practices for animal production.

Source or Location				
	Excreted Manure and Urine	Confinement Facilities	Treatment & Storage	Land Application
<b>Control Practice</b>	Reduce N excreted by reduced protein diets or improved balance of amino acids	Minimize emitting surface area	Cover to reduce emissions or collect gas	Injection or incorporation into soil soon after application
	Dietary electrolyte balance affecting urinary PH	Remove manure frequently (belt transport, scrape and/or flush)	NH <sub>3</sub> stripping, absorption and recovery	Application method to reduce exposure to air (e.g., low-pressure irrigation near surface, drag or trail hoses)
		Filter exhaust air (bioscrubbers, biofilters or chemical scrubbers)	Chemical precipitation (e.g., struvite)	Acidifying manure
		Manure amendments (acidifying compounds, organic materials-enzymes and biological additives)	Biological nitrification (aerobic treatment) Acidifying manure	

### **Research Needs and Issues**

Until recent years, most concern for ammonia lost from manure was because of the influence on reducing fertilizer value. Some of the previous research on N losses during storage, treatment and land application was also useful for determining overall ammonia losses to the atmosphere. However, much additional research is needed to specifically address ammonia losses from animal feeding operations and the nature and extent of environmental and health effects resulting from ammonia emissions. Specific research needs are:

Determination of environmental impacts of NH<sub>3</sub> deposition on land, crops and water;

- Determination of on-farm and off-farm health effects of NH<sub>3</sub>;
- Evaluation and standardization of NH<sub>3</sub> concentration measurement methods and NH<sub>3</sub> emission or flux methods;
- Improved determination of emission factors for various animal types and sizes and for various animal and manure management facilities and practices;
- Improvement and validation of models for NH<sub>3</sub> emission, transport and deposition;
- Evaluation of the effectiveness of technologies and control strategies; and
- Economic evaluation of control strategies.

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