Ammonia Emissions from Animal Housing Facilities

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Ammonia (NH_3) is volatilized from animal manure in buildings, during manure storage, and following land application of manure. Of these sources, land application of manure is probably the largest contributor of ammonia emissions from livestock and poultry operations; in the UK, land application of manure is the single largest source of such emissions (IGER Innovations, 2004). However, land application typically occurs during short time periods and management practices, such and injection or rapid incorporation of manure into the soil, can minimize ammonia losses through volatilization. In contrast, ammonia emissions from both animal housing facilities and manure storage units are continuous year-round. Numerous researchers are beginning to study ammonia emissions from animal housing facilities and manure storage units. This paper will provide some background information on ammonia emissions from animal housing facilities and will summarize recent research findings regarding the quantification of ammonia emissions from this source.

Background

Ammonia release from animal sources is prevalent due to the inefficient conversion of feed nitrogen to animal product (Bicudo et al., 2002). Livestock and poultry are often fed high protein feed, which contains surplus nitrogen, to ensure that the animals' nutritional requirements are met. Nitrogen that is not metabolized into animal protein is excreted in the urine of swine and cattle and in the uric acid of poultry where further microbial action releases ammonia into the air during manure decomposition.

Because ammonia is generated during the microbial degradation of manure, ammonia emissions tend to be higher from animal housing facilities in which manure is stored. In general, these facilities use litter or deep pit manure handling systems that store manure for some period of time before it is removed to a manure storage unit or land applied. A litter manure handling system consists of dry, absorbent material (litter) such as wood shavings or peanut hulls that is spread on the floors of animal housing facilities to absorb manure (NRAES, 1992). Broilers and turkeys are typically raised on litter. Large amounts of manure are allowed to accumulate in the litter because the litter is generally removed from broiler and turkey grower houses once a year. As a result, more ammonia is generated and emitted as the litter ages.

A deep pit manure handling system consists of slatted, concrete floors on which the animals are raised and an underground concrete pit beneath the floor for manure storage. Layer hen housing typically uses a deep pit system. This system is also popular for swine and some dairy facilities. For layer hens, the manure is allowed to accumulate for some time until it can be mechanically scraped and removed. The manure in swine and dairy housing deep pits may be removed with gravity-flow channels, flushing systems, or mechanical scrapers (MWPS, 2000). The amount of time that manure is stored in a deep pit varies between operations. Ammonia emissions will tend to increase with manure storage time.

Measuring Ammonia Emissions

Ammonia concentrations in livestock and poultry housing have been well documented since high ammonia levels are associated with decreased animal production. However, researchers are just beginning to quantify ammonia emissions from animal housing facilities as government agencies and concerned citizens have become more concerned about agricultural ammonia emissions in recent years (NAS, 2002).

Emissions refer to the rate at which a gas is released into the air (Bicudo et al., 2002). Ammonia emission rates from animal housing facilities are determined by multiplying the ammonia concentration in the building by the ventilation rate through the building. The technology to accurately measure in-house ammonia concentrations has been available for some time; however, determining ventilation rates through animal housing has been much more difficult until recently.

Ventilation rates cannot simply be determined by counting the number of fans and multiplying by some average fan ventilation rate. This method would merely provide a rough estimate of emission rates. Instead, researchers use one of three methods to measure building ventilation rates: 1) building static pressure; 2) building carbon dioxide (CO_2)

balance; and, 3) automated airflow measurement system. The first method uses building static pressure measurements and fan performance data from the fan's manufacturer to determine ventilation rates. However, this method tends to be inaccurate if the fans are not in a condition similar to the standard fans used in performance tests due to dust accumulation on shutters and fan blades and worn fan belts. The second method uses the relationship between the metabolic heat production and CO_2 production of the animals inside the building. This method requires valid heat production values for the animals and assumes that CO_2 production is solely from animal respiration. However, much of the heat production data was collected from 20 to 50 years ago and may no longer be valid due to advances in animal genetics and nutrition (Bicudo et al., 2002). Furthermore, measured CO_2 concentrations may include CO_2 from both animals and microbial activities related to manure decomposition. Therefore, building ventilation rates based on the building carbon dioxide (CO_2) balance method may lack the accuracy that is necessary to determine accurate ammonia emission rates. The third method uses an automated airflow measurement system, referred to as the Fan Assessment Numeration System (FANS), to determine ventilation rates. The FANS consists of five anemometer-driven generators mounted on a horizontal bar that are controlled and monitored with a computer (Figure 1). The system is placed in front of the backside of a working fan and the bar travels vertically over the area of the fan face. A computer program determines the total airflow through the fan. The FANS has been demonstrated to be highly accurate and is the best method to determine ventilation rates through a building. The main disadvantage of FANS is that it can be used only for buildings that are mechanically ventilated.

Recent U.S. Research Findings

Ammonia emission rates from poultry buildings are currently being studied under a multi-state (Iowa, Kentucky, and Pennsylvania) research project funded by USDA. Researchers from Iowa State University have quantified ammonia emission rates from two types of layer housing: 1) housing with manure belt manure handling systems (belt houses; and, 2) housing with deep pit manure handling systems (high rise houses). The manure belt systems use conveyor belts, located under each level of layer cages, to collect manure. The belts are moved every few days and the manure coming off the belts is hauled to an open

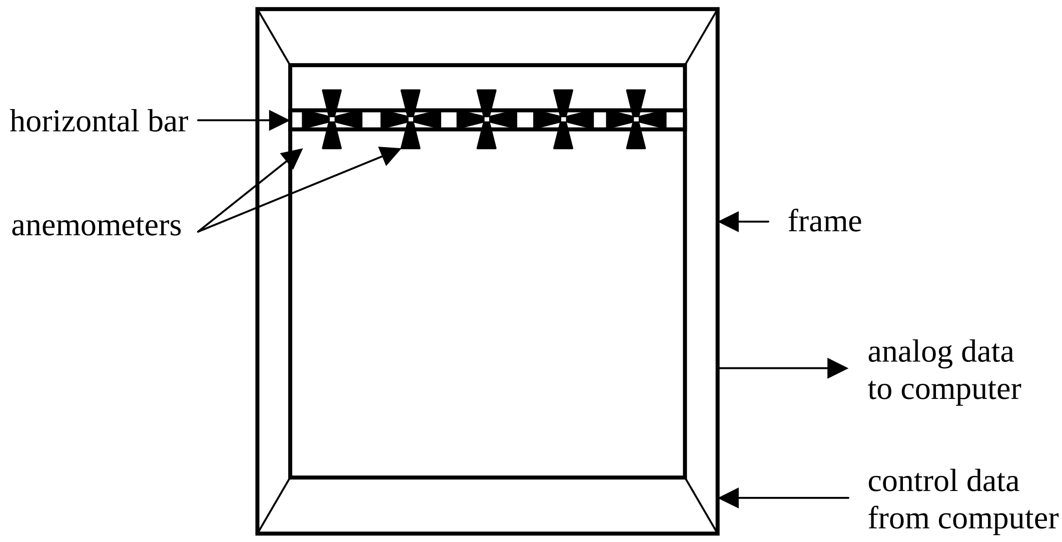

Figure 1. Schematic drawing of the Fan Assessment Numeration System (FANS) used to determine airflow rates through fans.

storage structure or applied immediately to cropland (Donald, 2001). Results indicated that the average ammonia emission rates from the belt houses and high rise houses were 0.14 and 1.1 g NH_3/d-hen (0.00032 and 0.0023 lb/d-hen), respectively (Liang et al., 2003). Another important finding was that ammonia emission rates varied seasonally and diurnally. Ammonia emission rates tended to be higher during the late spring and summer than during the rest of the year. Further analysis of data indicated that emission rates were higher during the warm weather due to higher ventilation rates (Liang et al., 2003). Ammonia emission rates varied diurnally, even when ventilation rates remained constant. This is likely due to variations in animal activity throughout the day. Although ammonia emission rates from the belt houses were much lower than those from high rise houses, it is important to note that the ammonia emissions from the belt house were merely "transferred" to either an open storage shed or to cropland to which the manure was applied.

Researchers from Iowa State also studied ammonia emission rates from high rise layer houses in which flocks were fed two different diets: 1) a standard diet; and, 2) a low protein diet. Results indicated that average ammonia emission rates from the houses in which flocks were fed the low protein diet were slightly lower (0.99 g/d-hen or 0.0022 lb/d-hen) than the rates from the houses in which the standard diet was fed (1.1 g/d-hen or 0.0023 lb/d-hen) (Liang et al., 2003). Further research into the effects of low protein diets on ammonia emission rates should reveal whether such dietary strategies are an effective means of reducing ammonia emissions.

Researchers from the University of Kentucky and Penn State quantified ammonia emission rates from broiler housing that used new litter for each flock or reused litter for several flocks throughout the year. Results indicated that average ammonia emission rates were much lower from housing that used new litter for flock (0.043 g/d-bird or 0.000094 lb/d-bird) than from housing that reused litter for several flocks (0.61 g/d-bird or 0.00013 lb/d-bird) (Wheeler et al., 2003). Although using new litter for each new flock increases an operation's expenses, this practice may provide an effective method of ammonia emissions reduction. Furthermore, such a practice may also result in increased health and animal gains through the reduction of in-house ammonia concentrations.

Another interesting research finding was that the variation of ammonia emission rates from a broiler house was relatively small in comparison to emission rates between houses at the same site (Wheeler et al., 2003). This indicates that numerous in-house factors may affect ammonia emissions and that houses must be carefully characterized during emission rate studies to determine sources of variation.

U.S. versus European Data

An emission factor refers to the total amount of gas that is released in to the air annually. Emission factors are usually expressed on a per animal basis. European researchers have quantified emission factors for several types of animal housing facilities (Groot Koerkamp et al., 1998). However, this data cannot necessarily be applied to animal production systems in the U.S. because animal categories and housing types often differ markedly between the U.S. and most European countries. However, results from the multi-state research project that was previously mentioned indicate that emission factors for layer hens in both belt and high rise houses and broilers on litter were similar to European values (Table 1).

Table 1. U.S. and European emission factors for layer hens and broilers.

Animal and Housing Type	U.S. Emission Factor (g/hen)	European Emission Factor (g/hen)
Layers, belt houses	53 (0.12 lb/hen)[a]	34 (0.075 lb/hen)[c]
Layers, high rise houses	385 (0.85 lb/hen)[a]	386 (0.86 lb/hen)[c]
	(g/bird)	**(g/bird)**
Broilers, litter	0 - 336 (0 - 0.74 lb/bird)[b]	78 - 174 (0.17 - 0.38 lb/bird)[c]

[a] Liang et al, 2003
[b] Wheeler et al., 2003
[c] Groot Koerkamp et al., 1998

Future Research Needs

Information on ammonia emissions from U.S. swine and dairy housing is extremely limited. This is due to the fact that most swine and dairy housing in the U.S. is naturally ventilated for which accurate ventilation data is difficult to obtain. However, researchers are studying the use of tracer gases to accurately determine ventilation rates through naturally ventilated buildings.

European researchers have found that ammonia emission rates for swine vary widely among both animal types and housing types (Tables 2 and 3). Ammonia emission rates also varied widely from dairy freestall barns (6 - 43 g/d-AU or 0.013 – 0.095 lb/d-AU). However, future research is needed to determine ammonia emission rates from U.S. swine and dairy housing.

Table 2. Ammonia emission rates from finish and gestation swine in Europe (Groot Koerkamp et al, 1998).

Animal Type	Ammonia Emission Rate (g/d-AU)	Ammonia Emission Rate (lb/d-AU)
Finish swine	10 - 310	0.022 - 0.68
Gestation swine	2.2 - 78	0.0048 - 0.17

Table 3. Ammonia emission rates from various types swine gestation facilities in Europe (Groot Koerkamp et al, 1998).

Housing Type	Ammonia Emission Rate (g/d-AU)	Ammonia Emission Rate (lb/d-AU)
Litter	18 - 78	0.040 - 0.17
Partly slatted	25 - 40	0.055 - 0.088
Fully slatted	2	0.0044

Summary

In summary, animal housing facilities are a continuous source of ammonia emissions throughout the year. These emissions tend to be most prevalent from facilities in which manure is stored such as houses that use litter or deep pit manure handling systems. Ammonia emission rates are determined by multiplying the ammonia concentration inside a building by the building ventilation rate. Researchers are just beginning to develop techniques to accurately determine ventilation rates for mechanically ventilated buildings. As a result, accurate ammonia emission rates can be estimated from housing that depends solely on mechanical ventilation such as broiler and layer facilities.

A recent multi-state research project funded by USDA focused on quantifying ammonia emission rates from poultry housing. Results indicated that ammonia emission rates for laying hens were lower from housing using manure belt manure handling systems than from high rise houses, which use deep pits. Furthermore, emission rates from high rise houses were slightly lower from flocks fed a reduced protein diet than from houses where flocks were fed a standard diet. Ammonia emissions rates from both belt and high rise houses varied widely both seasonally and diurnally. For broiler housing, ammonia emission rates were higher from houses that reused litter for several flocks than from houses that used new litter for each new flock. Another interesting finding was that emission rates varied greatly between broiler houses at the same site. Therefore, further evaluation of in-house characteristics may improve the understanding of the wide range of ammonia emission rates reported by researchers.

Ammonia emission rates from U.S. swine and dairy housing are very limited. This is due to the fact that most swine and dairy housing are naturally ventilated for which accurate ventilation rate data is difficult to obtain. Currently, researchers are studying the use of tracer gases to determine natural ventilation rates. Once a method is perfected, ammonia emission rates for both swine and dairy housing should be readily obtained.

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