Dairy Manure and Air Quality: The Issues

J. Mark Powell, Larry Satter, Tom Misselbrook [1]

INTRODUCTION

Why the Concern?

The trend towards fewer and larger livestock farms has heightened public concern about pollution. Over the past several years, environmental policy related to animal agriculture has focused on land application of manure, especially methods to stop or reverse soil phosphorus build-up, runoff, and the subsequent pollution of lakes, streams and other surface water bodies. Policy is now focusing on the reduction of air emissions from animal agriculture. For dairy operations, ammonia is by far the most important potential air pollutant. The adverse effects of agricultural ammonia emissions extend to regional, national and global scales (NRC, 2003). Under the federal Consolidated Emissions Reporting Rule, all states are required to report agricultural ammonia-nitrogen (NH_3-N) gas emissions to the U.S. Environmental Protection Agency (EPA) by the end of 2004. The data EPA collects will be used in air quality regulations to control the air-borne particulates and haze that affect many regions of the country.

Environmental Impacts of Ammonia Losses

The environmental impact of ammonia emissions is dependant upon two issues:

(1) Response of different ecosytems to the amount of atmospheric N that is deposited, and
(2) Air quality consequences of ammonia-N emissions.

A proportion of manure ammonia-N emitted to air is deposited near its source (e.g., barn, lagoon, fields where manure has been applied) where it can be utilized by crops and other plants. However, a significant amount of manure ammonia-N is transported greater distances from the source. From a land perspective, when ammonia-N is deposited in natural ecosystems, the N contributes to ecosystem fertilization, acidification, and eutrophication (accelerated aging). While not a known concern in Wisconsin, this N input can cause dramatic shifts in the native vegetation, such as enhancing grass growth which can displace native species and create fire hazards in more arid (western) regions. From a water quality perspective, the ammonia gas produced by livestock farms in the upper Mississippi River basin is thought to be a major source of N contributions to the Mississippi river and, subsequently, to the hypoxia (oxygen depleted) zone in the Gulf of Mexico (Burkart and James, 1999).

Of more local concern is the potential for emitted ammonia to combine with acidic compounds in the upper atmosphere to form particulates. These particulates have been related to atmospheric haze, and also have been attributed to a variety of adverse human health effects, including premature mortality, chronic bronchitis, asthma, and other respiratory ailments.

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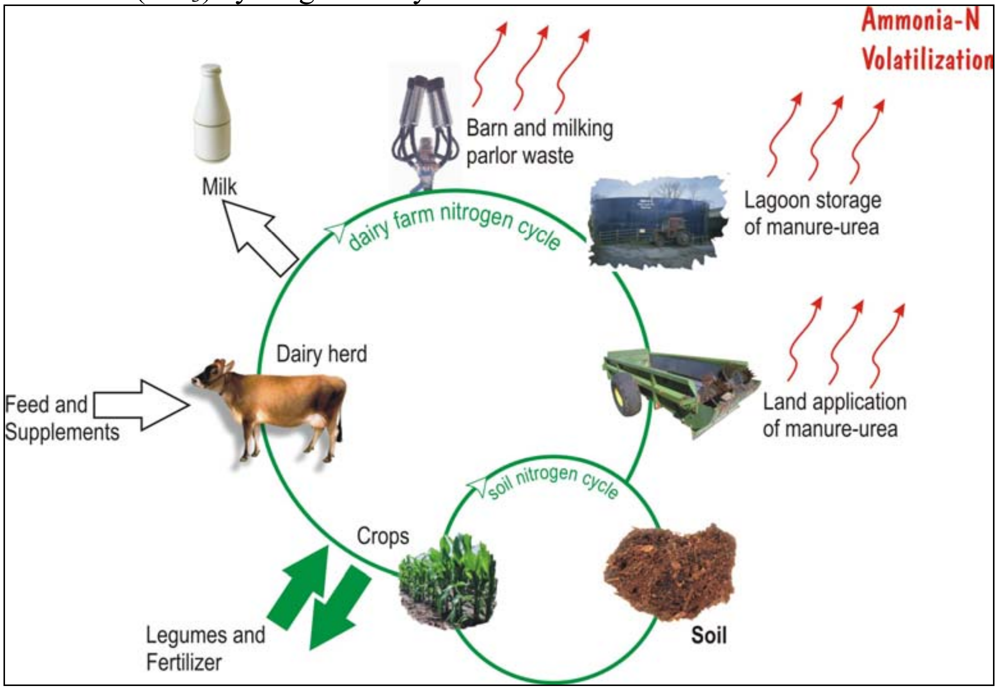
[1] Agroecologist and Dairy Nutritionist (emertitus). USDA-Agricultural Research Service Dairy Forage Research Center, Madison, WI, USA. Senior Research Scientist, Institute of Grassland and Environmental Research, Devon, U.K.

Figure 1. Ammonia (NH_3) cycling on dairy farms.



Ammonia (NH_3) Cycling: How NH_3 is Formed and Lost on Dairy Farms

Ammonia-N losses from dairy operations begin to occur immediately after feces and urine are excreted from the animal, and continue through manure handling, storage and land application (Fig. 1). Only 20 to 30% of the N (protein) fed to dairy cows is converted into milk. The remaining N is excreted about equally in urine and feces. About three-fourths of the N in urine is in the form of urea. Urease enzymes, which are present in feces and soil, rapidly convert urea to ammonium (NH_4^+). Ammonium is then transformed quickly into ammonia gas (Fig. 2). Ammonia gas can be lost to the atmosphere through a process called volatilization. Feces contain little or no urea. For this reason urinary N is much more vulnerable to ammonia volatilization than is fecal N.

Figure 2. Ammonia-N emission process.

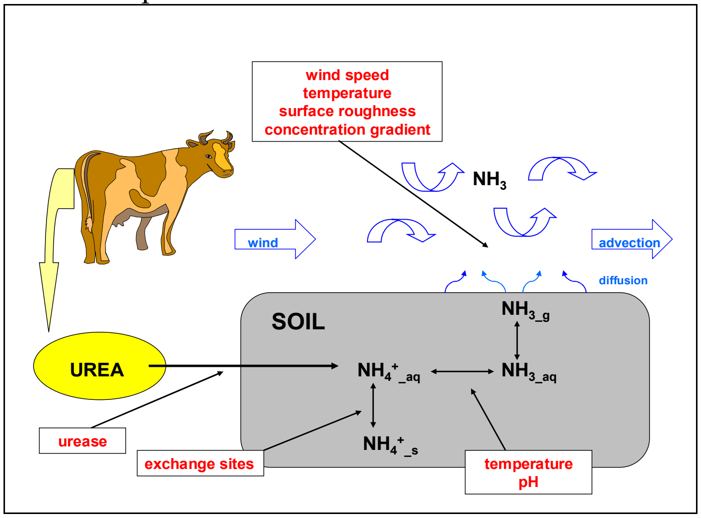
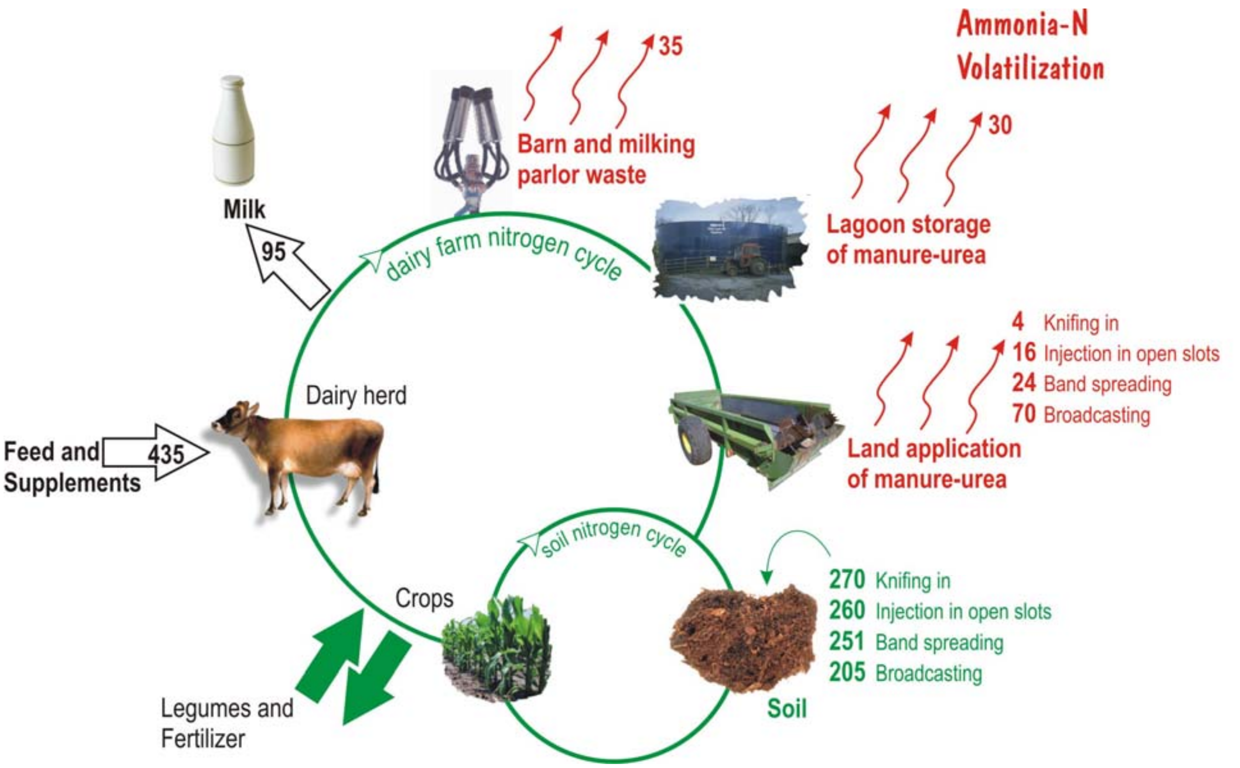


Figure 3 illustrates potential ammonia-N losses from a free stall barn, slurry manure system using an uncovered earthen pit for manure storage. Nitrogen flow through the system from feed through the cow, manure, field application of manure, and eventually back to feed is shown. Modeled losses from four different systems for field spreading manure are also shown. Of the field spreading techniques, atmospheric ammonia losses are highest with broadcast and lowest with knifing manure applications.

Figure 3. Model of annual N (lbs) inputs, outputs, and cycling for a typical lactating dairy cow.



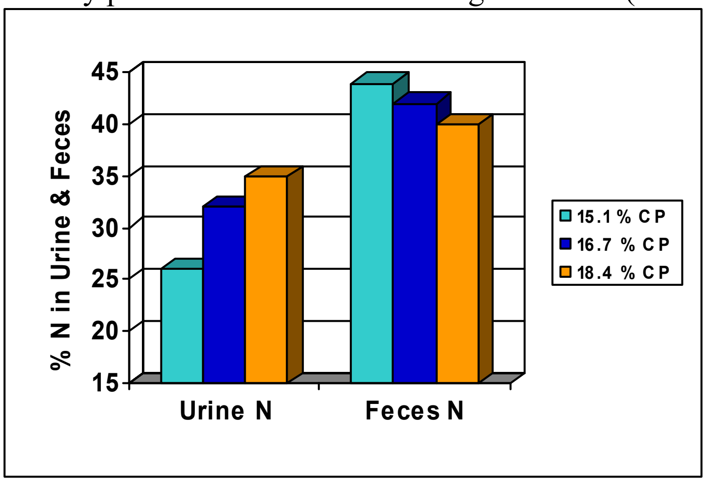
<u>Assumptions</u>: The numbers represent one cow, producing 18,400 lbs milk per year containing 3.2% crude protein. The cow is lactating during 10 months of the year, and dry for two months. She consumes 15,920 lbs feed dry matter per year containing 17.5% crude protein while lactating and 13% protein while dry. To calculate N flows for the entire mature herd, multiply the numerical values in Figure 3 by the number of lactating cows plus dry mature cows in the herd.

While this model of N flow through a dairy operation is indicative of what may be expected under average conditions in a confinement-based feeding operation in Wisconsin, many factors affect actual loss. Factors such as: 1) Farm size and animal density (cow number per unit land area); 2) Animal diet impacts on milk production and relative excretion of N in urine and feces; 3) Housing type; 4) Manure collection and storage; 5) Soil type and land application practices; and 6) Weather (short-term) and climate (long-term).

SOURCES OF AMMONIA-N LOSS

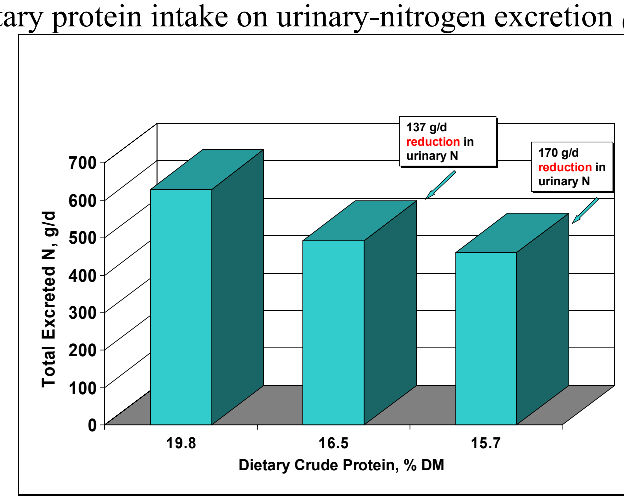
Amount of Protein Fed To Dairy Cattle
Nitrogen excretion by dairy cows via urine and therefore the amount of manure-N susceptible to loss as ammonia-N is highly influenced by the amount and type of protein fed. As the amount of protein in feed exceeds that which is required by the cow, relatively less of the N goes into milk and more goes directly into urine production (Fig. 4). Knowing the amount of N that dairy cows excrete in urine and feces is the first approximation of how much N is vulnerable to loss as ammonia.

Figure 4. Effect of dietary protein intake on urine-nitrogen content (*Broderick, 2003).*



Significant reductions in urine-N production can be obtained by reducing dietary protein levels (Fig. 5). For example, if 17.5% dietary protein currently represents an industry average for lactating cows, careful reformulation of diets to contain 16.5 to 16.7% crude protein (which meets requirements for the lactating cow and still provides a reasonable margin of safety) would reduce N excretion in urine by about 20%. Diet formulation to eliminate excess protein usually reduces feed cost <u>and</u> is one of the most effective tools for reducing atmospheric emissions of N-containing compounds from dairy farms.

Figure 5. Impact of dietary protein intake on urinary-nitrogen excretion *(Broderick et al., unpublished).*



Ammonia-N Loss From Housing

Ammonia-N emissions from livestock housing and storage systems can range from 10 to 85% of the N excreted by a dairy cow (Table 1). The main factors that affect this value are manure handling and storage system, bedding type, frequency of manure removal, ventilation and temperature. Lowest ammonia loss occurs on farms that scrape and remove manure daily. Highest losses occur in outside areas where no manure is collected.

Table 1. Nitrogen lost in various types of manure handling and storage systems (*Adapted from MWPS, 2001*).

System	Nitrogen Lost (%)
- - - - - - - - - - Solid manure - - - - - - - - - -	
Daily scrape and haul	20 to 35
Manure pack	20 to 40
Open lot	40 to 55
- - - - - - - - - - Liquid manure - - - - - - - - - -	
Underfloor pit*	15 to 30
Above-ground tank*	10 to 30
Holding pond	20 to 40
Anaerobic lagoon	70 to 85

Dairy farms in Wisconsin typically have one or more of the following animal housing and manure collection systems:

1) <u>Confinement free stall</u>. Free stall systems are common on large dairy farms. Cows are under roof and are free to move between stalls. Sand or mattresses covered with a minimum of bedding are used in free stalls. Slurry manure is scraped two or three times per day from the concrete alleys, and is typically hauled daily for field application or stored in an earthen pit that is emptied two or more times per year. A few larger dairies separate manure solids from the slurry. The solids may be composted. The liquid is either irrigated onto fields or used to flush alley manure. Ammonia-N loss from free stall barn floors is greatest during the summer and lowest in winter.

2) <u>Stanchion or tie stall</u>. Stanchion or tie stall barns are most common on dairy farms having 100-125 cows or less. Cows are confined to a stall and manure is collected in a gutter behind the cows. Moderate to large amounts of straw, wood shavings, or crop residue are used for bedding. The manure mixed with bedding is typically removed with a gutter cleaner twice daily, and field applied daily or stored for later field application. Cows may have access to a small exercise lot, or may be allowed access to a pasture to graze for part of the day.

3) <u>Loose housing and manure pack</u>. This system is found on smaller dairies. Cows are housed in an open shed where large amounts of bedding material absorb moisture. The bedded manure pack may build up considerably in depth before being emptied once or twice per year. This system requires less capital, and often is used in conjunction with grazing.

4) Grazing with no housing. A system more common on smaller rather than larger dairy farms. When weather permits, some dairy operators only bring cows into a building to be milked and, possibly, offered some supplemental feed. The remainder of the day, cows are on pasture, and most of the urine and feces is deposited in the paddock. Ammonia-N loss from pasture is generally proportional to livestock stocking rates and the amount of time spent on pasture, which, in turn, is proportional to the amount of urine and feces deposited in these locations. The spatial location of manure deposition and soil, weather, and climatic conditions all affect the actual rate and extent of ammonia-N loss from these areas.

Ammonia-N Loss from Manure Storage

Solid and semi-solid dairy manure is stored in piles on concrete or earthen pads. Liquid manure is stored in concrete, earthen, or lined lagoons or above-ground storage tanks. Liquid manure systems in Wisconsin are typically not covered. However, in some European countries (e.g., The Netherlands and Denmark) manure storage structures must be covered. These lagoons may be covered with biological material (e.g., straw) or impermeable material (e.g., synthetic polymers) in an attempt to reduce losses of ammonia-N as well as odor. Ammonia loss from manure storage depends on the structure used (Table 1). Lowest N losses occur on farms that conserve urine-N in underground pits and in bedded packs. Very large amounts of ammonia are emitted from anaerobic lagoons, especially during agitation before manure tankers are filled for field application.

Ammonia-N Emissions from Land Application of Manure

Ammonia loss from land-applied dairy manure can vary tremendously depending numerous factors, including: 1) Weather conditions such as temperature, wind speed, rainfall; 2) Manure application methods such as degree of incorporation, rate of application, zone of application, and timing of application; 3) Manure characteristics including pH, dry matter and ammonium-N contents; and 4) Soil conditions such as moisture, texture, organic matter content, and surface residue cover.

Ammonia losses during field application of manure are usually expressed as a percentage of the total ammoniacal N (TAN) of the manure. TAN is the sum of the ammonium-N (NH^4+) content of the manure plus the ammonia-N content. Of manure-N, TAN is the portion that is susceptible to atmospheric loss. It is also the portion of N that is potentially available to plants. Ammonia losses can range from close to 100% of TAN for surface manure application during periods of optimal volatilization conditions, to only a few percent when manure is injected or incorporated immediately into the soil (Table 2).

Recommendations on how to apply manure to fields must consider the complete chain of events that affect manure-N, as well as other nutrients, cycling in soils. For example, if manure is injected or incorporated into soil to minimize ammonia-N loss, an increased risk for nitrate loss to groundwater may result. In addition, incorporation of manure has the potential to increase runoff and the associated losses of sediment and phosphorus (P) which could degrade surface water quality. The selection of appropriate manure management practices for individual farms needs to be tailored to the specific conditions existing at a site.

Table 2. Qualitative comparisons of major N loss pathways for manure application under various management regimes and environmental conditions (*Adapted from Meisinger & Thompson, 1996).*

Manure Management			Soil Drainage	Nitrogen Loss Processes	
Rate	Time	Placement		Ammonia	Leaching
		- - - - - - - - - - Placement Comparisons - - - - - - - - - -			
Medium	Spring	Surface	Well	High	Med.
Medium	Spring	Incorporated	Well	Low	Med.
Medium	Spring	Injected	Well	Low	Med.
		- - - - - - - - - - Soil Drainage Comparisons - - - - - - - - - -			
Medium	Spring	Incorporated	Excess	Low	High
Medium	Spring	Incorporated	Poor	Low	Med.
		- - - - - - - - - - Application Rate Comparisons - - - - - - - - - -			
Low	Spring	Incorporated	Poor	Low	Low
Medium	Spring	Incorporated	Poor	Low	Med.
High	Spring	Incorporated	Poor	Low	High
		- - - - - - - - - - Time of Year Comparison - - - - - - - - - -			
Medium	Fall	Surface	Well	High	High
Medium	Winter	Surface	Well	Med.	High
Medium	Spring	Surface	Well	High	Med.
Medium	Summer	Surface	Well	High	Med.

ODOR CONSIDERATIONS

Odor control during manure spreading is a concern in areas where dairy farms are in proximity to non-farming developments or communities. Many of the recommended measures for odor control also reduce ammonia-N loss. These include:

- Incorporate manure soon after land application or, in a liquid system, apply slurries using band spreading/injection techniques;
- Minimize the time that odor is released into the air by having machinery in good repair and labor ready before starting to unload manure from storage; and
- Minimize agitation and exposure of manure to air.

AMMONIA-N LOSS EFFECTS ON AVAILABILITY OF MANURE-N

Ammonia loss is important because it is a direct loss of N available for crop production on farms. The loss of ammonia also reduces the ratio of nitrogen to phosphorus (N:P) in manure. This increases the likelihood of manure-P applications exceeding crop needs resulting in the build-up of soil test P levels beyond agronomic optimum levels. This situation is common on many of

Wisconsin's dairy farms. Runoff of P from these fields and the subsequent potential for pollution of lakes and streams is a major environmental concern.

Reducing ammonia losses from dairy farms and making greater use of the conserved manure-N often makes economic sense as well. Natural gas accounts for 75-90% of the cost of making anhydrous ammonia. As the price of natural gas continues to skyrocket, the fertilizer-N value of manure, and therefore the conservation of ammonia-N will become more important.

MANAGEMENT PRACTICES TO REDUCE AMMONIA-N EMISSIONS FROM DAIRY FARMS

Substantial reductions in ammonia-N loss from dairy operations can be achieved by feeding less protein to dairy cattle, reducing in-barn losses, covering manure storage, and incorporating manure in the field (Table 3).

Table 3. Impact of improved management practices on reductions in ammonia-N emissions.

Management Practice	Mechanism for Decrease in Ammonia-N Loss	Decrease in Ammonia-N Loss (%)
Remove excess and/or feed balanced dietary protein	Decrease N output in urine	10 - 15
Cover manure storage	Decrease ammonia escape	20 - 30
Incorporate or inject manure	Reduce ammonia production and loss	30 - 50

The following steps, in descending order of potential benefit, can be a guide for action to reduce ammonia-N emissions from dairy farms:

1. Remove excess protein from the cow's diet. This also can save on the cost of feed.
2. Incorporate manure in the field. However, beware of concerns with nitrate leaching and/or the potential for increased erosion and P losses.
3. Cover manure storage structures. Organic bedding such as straw used in free stall barns will form a crust on the surface of the slurry pit. This reduces ammonia-N losses and odors. Excessive agitation during unloading of the slurry from storage should be avoided.
4. For new construction, floors that divert urine away from feces can reduce ammonia-N emissions. Slatted floors facilitate this, but there is still considerable loss of ammonia-N from the surface of the slatted floor.

Implementation of steps 1-3 above could potentially reduce ammonia-N loss to the atmosphere from about 115 lbs/cow/year to 30-40 lbs/cow/yr, a 65-70% reduction. This would result in an additional 70-80 lbs N per cow available annually for application to field crops.

KEY POINTS

Ammonia-nitrogen (NH_3-N) emissions from dairy farms are becoming an environmental concern. These losses greatly reduce the fertilizer N value of manure for crop production.

Key management practices that can reduce ammonia-N loss include:

1. Remove excess protein from the cow's diet;
2. Improve manure handling and storage; and
3. Incorporate manure in the field - - being mindful of possible tradeoffs with regards to nitrate leaching, soil erosion and phosphorus losses.

Implementation of these practices could reduce ammonia-N loss by 65 to 70%. The result would be an additional 70-80 lbs N per cow available annually for application to field crops.

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