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Ammonia Volatilization from Manure Application

The purpose of this factsheet is to provide producers and farm managers with information that will help quantify the amount of ammonia loss that occurs when they apply manure on land. It also provides them with information regarding the factors that positively and negatively affect these losses.

The factsheet is also a good source of information on best management practices producers could use to mitigate and control ammonia losses from the land application of manure.

Sources of ammonia

Agricultural activities (livestock production and fertilizer application) have been identified as the major sources of atmospheric ammonia emissions in Alberta, followed by biomass burning. Within agricultural activities, ammonia emissions into the atmosphere occur primarily from livestock buildings, open feedlots, manure storage facilities, during manure handling and treatment and when manure is applied on land.

Producers can mitigate and control ammonia losses

Ammonia in livestock facilities results primarily from the breakdown of urea by the enzyme urease. In most livestock, urea is only present in the urine while urease is present in the feces. In poultry, urease is excreted with uric acid in the feces.

Most efforts to control ammonia losses from livestock operations have been focused on the land application of manure because the practice contributes largely to the overall ammonia losses from agriculture. Ammonia losses following land application of manure could reach up to 95 per cent of the total manure nitrogen-ammonium ($N\text{-}NH_4$) content. The amount of $N\text{-}NH_4$ lost depends on the manure characteristics and the environmental conditions.

Ammonia volatilization (gassing off) decreases the nutrient value of manure and results in a significant loss of its nitrogen. It also has a negative effect on the environment, such as soil acidification and eutrophication (deprivation of oxygen). Ammonia lost to the atmosphere combines with nitric acid to form airborne nitrate particles that have serious effects on human health and can cause visibility impairment.

Factors affecting volatilization

Significant volatilization of ammonia can occur within the first 24 hours after the land application of manure. More than 50 per cent of the total emission of ammonia can occur within the first six hours after application. Ammonia volatilization is highly dependent on manure management techniques and environmental factors.

1. Manure type and characteristics

Manure characteristics such as total nitrogen (TN), ammonium nitrogen ($NH_4\text{-}N$) and percentage of dry matter (% DM) play an important role in ammonia volatilization during manure application to soils. Generally, liquid manure and slurry have a high rate of ammonia loss compared to solid manure. The dry matter content has been shown to significantly affect ammonia volatilization. Reducing the dry matter content of dairy manure by dilution or separation has been shown to reduce ammonia emissions following land application.

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2. Environmental factors

- **Temperature**: Solar radiation increases the temperature of the manure. As manure temperature increases, ammonia volatilization increases, especially within the first few hours after manure is applied to the soil (50%). Researchers have found that 50 per cent of total nitrogen is volatilized as ammonia at a temperature of 30°C compared to 35 per cent when the temperature is 25°C. Manure applications should not be made when temperatures are high.
- **Wind**: An increase in wind speed will increase the rate of ammonia volatilization as the higher wind increases the mass transfer and air exchange between the manured surface and the atmosphere. Manure should be applied when the wind speed is low, and the weather is stable.
- **Rainfall**: Rainfall directly after manure application decreases the volatilization of ammonia because the rain improves infiltration of the ammonia into the soil and also reduces its evaporation. Generally, ammonia emissions decrease with an increase in relative humidity.

3. Manure application method and timing

The manure application method greatly affects ammonia losses, with the largest losses occurring from surface-applied manure that is not incorporated into the soil. Minimal losses occur if the nitrogen source is immediately incorporated into the soil. Research in Europe has found that incorporation of manure into soil is one of the most cost-effective measures for decreasing ammonia loss. Furthermore, applying liquid manure by band spreader or injection proved to be more cost-effective than measures designed to reduce ammonia emissions from buildings.

4. Soil characteristics and conditions

Soil conditions including the moisture content, texture, cation exchange capacity, pH and plant or residue cover all affect the rate and amount of ammonia loss. Some research studies have found more ammonia emissions from peat and heavy clay soils than from sand and clay soil when liquid manure was applied to grassland. Ammonia volatilization is favored by calcareous (chalky) soils. These losses may be reduced by soil acidification through the use of soil amendment.

Calculating ammonia losses: why?

Quantifying ammonia losses is important for productivity, environmental and economic reasons. Accurate ammonia loss estimates from manure are needed to improve nutrient management recommendations and to test the value of ammonia abatement techniques. More than $80 million worth of fertilizer value is lost annually in the United States because of ammonia volatilization from manure.

Calculating ammonia losses: how?

The following examples illustrate how to estimate the amount of ammonia lost when manure is applied under various management and environmental conditions.

Example 1

Assume 500 tonnes of semi-solid swine manure is to be applied on cultivated land in the spring immediately before planting and under warm, wet soil conditions. As per the *Agricultural Operation Practices Act* and Regulations (AOPA, 2004), the manure will be incorporated into the soil within 48 hours but not until 36 hours after application. Calculate the amount of nitrogen available for the crop.

First step: Calculate the manure ammonia content. See Table 1 for ammonia content of different types of livestock manure.

500 tonnes * 2.4 kg/tonne = 1,200 kg of ammonia

Second step: Calculate ammonia losses. See Table 2 for estimated losses under various external conditions.

Estimated percentage of ammonia lost if manure is applied under warm, wet conditions and not incorporated for up to 48 hours ranges between 25 per cent and 31 per cent.

This situation implies a loss ranging between:

1,200 kg * 0.25 = 300 kg of ammonia

and

1,200 kg * 0.31 = 370 kg of ammonia

Third step: Calculate the amount of ammonia available for crop uptake.

This amount will range between:

1,200 – 300 kg = 900 kg of ammonia

and

1,200 – 370 kg =830 kg of ammonia

Example 2

Assume the 500 tonnes of manure from Example 1 above was not incorporated at all but left on the surface of the soil for over 5 days.

First step: Calculate the manure ammonia content. See Table 1 for ammonia content of different types of livestock manure.

500 tonnes * 2.4 kg/tonne = 1,200 kg of ammonia

Second step: Calculate ammonia losses. See Table 2 for estimated losses under various external conditions.

Estimated percentage of ammonia lost if manure is applied under warm, wet conditions and not incorporated at all is 75 per cent resulting in a loss of:

1,200 kg * 0.75 = 900 kg of ammonia

Third step: Calculate the amount of ammonia available for crop uptake.

1,200 – 900 kg = 300 kg of ammonia

Table 1. Ammonia content of various manure types

Manure type	Ammonia content (kg/ton of semi-solid manure)
Poultry manure	4.2
Swine manure	2.4
Dairy manure	1.9
Beef manure	0.8

Source: Nova Scotia Agricultural College

Table 2. Estimated loss (%) of the ammonium-nitrogen fraction due to weather and soil conditions

Day after application	Average	Cool (<10°C)		Warm (>25°C)	
		Wet	Dry	Wet	Dry
Spring					
Incorporated within 1 day	25	10	15	25	50
Incorporated within 2 days	30	13	19	31	57
Incorporated within 3 days	35	15	22	38	65
Incorporated within 4 days	40	17	26	44	73
Incorporated within 5 days	45	20	30	50	80
Not incorporated	66	40	50	75	100
Injected	0	0	0	0	0
Fall					
Early fall applied	66	40	50	75	100
Late fall applied	25	25	25	N/A	N/A
Cover crop	35	25	25	40	40

Source: Ontario Ministry of Agriculture, Food and Rural Affairs

Prevent ammonia volatilization

Land application measures to reduce ammonia emissions aim to minimize the amount of manure and time of exposure on the ground. A range of techniques (discussed below) are available for reducing ammonia emission during the land application of manure. Application method or incorporation method and external factors need to be taken into account when predicting ammonia volatilization following manure application.

Ammonia volatilization is increased by higher temperatures and by increased wind speeds. Soil factors such as residue cover, soil pH and soil texture (sands vs. silt loams) can affect ammonia loss but soil factors are usually secondary to the factors such as application method and manure type.

The following are the currently available best management practices for reducing ammonia volatilization during the land application of manure.

- Direct injection of manure into the soil reduces ammonia losses compared to surface application methods. The reduction in ammonia emissions by injection could reach up to 100 per cent (Table 2), but it will also result in the increase of nitrous oxide emissions from agricultural soils by up to 100 per cent. The costs to inject manure are estimated to be $0.003 per gallon above the cost to haul and spread liquid manure. By injecting the manure, a portion of the added cost can be recaptured agronomically in the form of reduced nitrogen losses compared to manure application by broadcasting.
- The incorporation of manure immediately after spreading could result in a substantial reduction in ammonia losses (see the section on "Calculating ammonia losses: how?") as well as a possible decrease in odour emissions and run-off or discharge of manure from the manure application area. Conventional tillage equipment is generally used to incorporate surface-applied manure into the soil. The *Agricultural Operations Practices Act* (2004) requires that a person must not spread manure if it cannot be incorporated within 48 hours, unless the manure is spread on forage or direct seeded crops or the land is frozen or snow covered.
- Band spreading liquid manure on the soil surface but beneath the crop canopy using drop hoses or "sleighfoot" applicators can reduce ammonia emissions relative to broadcasting by up to 80 per cent. Generally, banding conserves ammonia by reducing the exposure of manure to the air, but the method works best under a crop canopy. The crop canopy both reduces advection (transfer of heat by horizontal flow of air), thereby inhibiting ammonia volatilization, and directly absorbs up to 40 per cent of any released ammonia.
- The timing of application is an important consideration affecting the release of manure nitrogen into the atmosphere. Ammonia loss is generally greater during the spring and summer. Also, incorporation time and weather affect ammonia losses. Significant volatilization occurs within the first 24 hours after application on a warm, wet or dry day (Table 2). Losses of ammonia can be reduced by night-time application. Dispersion across the landscape may require application at different times of the day.
- Research has demonstrated that some products can effectively reduce ammonia losses through either a binding or a pH effect. Dropping the manure pH below 7 before it is applied can reduce ammonia emissions. Urease inhibitors may also prove effective. Costs are product specific and often determined as much by application rate and frequency as by the cost per unit weight of the product.

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