

# Management to Minimize Nitrogen Fertilizer Volatilization

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**Clain Jones** Extension Soil Fertility Specialist  
Dept. of Land Resources and Environmental Sciences, Montana State University, Bozeman

**Brad D. Brown** Extension Soil and Crop Management Specialist, retired  
Parma Research and Extension Center, University of Idaho, Parma

**Rick Engel** Professor of Nutrient Management  
Dept. of Land Resources and Environmental Sciences, Montana State University, Bozeman

**Don Horneck** Former Professor of Soil Science  
Hermiston Agricultural Research and Extension Center, Oregon State University, Hermiston

**Kathrin Olson-Rutz** Research Associate  
Dept. of Land Resources and Environmental Sciences, Montana State University, Bozeman

Volatilization of ammonia from nitrogen fertilizers is controlled by a number of soil properties, environmental conditions, and management practices. This bulletin describes best management practices to minimize ammonia volatilization loss and increase nitrogen use efficiency, with a focus on urea fertilizer. The bulletin *Factors Affecting Nitrogen Fertilizer Volatilization* describes soil properties and environmental conditions affecting volatilization.



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All ammonium and ammonia-based fertilizers, including manure, have the potential for ammonia volatilization - the loss of nitrogen (N) to the air as ammonia gas. Our focus is on ammonia volatilization (hereafter referred to as simply volatilization) from urea and liquids containing urea, such as urea ammonium nitrate (UAN; Table 1) because urea fertilizers have the greatest potential for volatilization. They are also the most commonly used N fertilizers, and have been the focus of most volatilization studies. Most volatilization from urea typically occurs during a two- to three-week period after application. The conditions that affect volatilization (Table 2) are described in more detail in *Factors Affecting Nitrogen Fertilizer Volatilization* (see “Extension Materials” at end of document). Multiple and often interrelated factors make volatilization highly variable and difficult to predict under

**TABLE 1. Common N fertilizer sources and their grade.**

Fertilizer	Grade
Urea	46-0-0
Urea ammonium nitrate (UAN)	28-0-0 or 32-0-0
Ammonium sulfate	21-0-0-24
Ammonium nitrate	34-0-0
Calcium ammonium nitrate	27-0-0

field conditions. While urea’s volatilization losses under worst-case conditions can exceed 50 percent, losses can be minimized with proper management. This publication suggests practices that minimize volatilization losses and maximize N use efficiency in the inland Northwest and Montana.

**TABLE 2. Environmental and soil conditions with high and low risk for ammonia volatilization. The risk of volatilization increases as the number of high risk conditions increases, with soil moisture likely being the most important risk condition.**

High risk conditions	Lower risk conditions
Moist soil or heavy dew	Dry soil
High soil pH (>7.0)	Low soil pH (<6.0)
High soil temperature (>70°F) or frozen soil	Cool soil temperature
Crop residue, perennial thatch or sod	Bare soil
Low cation exchange capacity soil (sandy)	High cation exchange capacity soil (silt or clay-dominated)
Poorly buffered soils (low soil organic matter, low bicarbonate content, high sand content)	Highly buffered soils (high soil organic matter, high bicarbonate content, high clay content)

## Fertilizer Management

The key to reducing volatilization is to get ammonium- and ammonia-based fertilizers, including manure, into the soil to trap the ammonia produced. By evaluating your relative volatilization risk (Table 2), you can select the most appropriate practices presented in Table 3 and the following section to adopt.

### N FERTILIZER SOURCE

Common N fertilizers and their grade are in Table 1. Volatilization from different fertilizers varies with the form of N they contain and how they dissolve and transform in the soil. Urea-based fertilizers, anhydrous ammonia and aqua ammonia have high volatilization potential because they can locally increase soil pH sufficiently to increase ammonium conversion to ammonia. Volatilization loss from ammonium nitrate is very low, often similar to unfertilized controls, but it can be difficult to obtain because of its potential use for making explosives. Calcium

**TABLE 3. Summary of urea management practices to minimize or prevent volatilization.**

- Delay application under high risk conditions
- Incorporate within one to two days after application with:
  - Tillage (> 2 inches deep)
  - Irrigation (> 0.5 inch)
  - Rainfall (when > 0.5 inch as a single event is expected)
- Subsurface band (> 2 inches deep)
- Add NBPT to surface applied urea
- Use a controlled-release N fertilizer
- Consider an alternate N source such as UAN, calcium ammonium nitrate or ammonium sulfate.

2 ammonium nitrate is still available in the US and has similarly low volatilization potential (1). Ammonium sulfate has intermediate volatilization potential, with higher losses in calcareous (containing free lime) soils than acidic soils.

Sprayed liquid urea can have lower volatilization potential than granular urea (2) in part because liquid urea leaves a thin, even distribution of urea, with less effect on soil pH. Urea ammonium nitrate has generally demonstrated lower volatilization loss than granular urea (Figure 1) probably because after spraying, it is less concentrated than prills. In addition, one-fourth of UAN is nitrate which has no chance of volatilizing. For more information on the mechanisms influencing differences among fertilizers see *Factors Affecting Nitrogen Fertilizer Volatilization*.

Enhanced efficiency urea fertilizers have been developed to reduce N losses and increase N use efficiency. How these products work and their effectiveness are explained in *Enhanced Efficiency Fertilizers* (see "Extension Materials" at end of document). Although there are numerous N fertilizer products that minimize volatilization, they may not produce a proportionate yield increase because N availability is not the only factor that affects crop yield. Also, N is often applied to meet high grain protein demands. At these higher N rates, yields won't necessarily benefit from moderately reduced volatilization losses. The impact of these specialized fertilizer products on crop yield varies with soil and environmental conditions. A few products have been broadly studied and ongoing testing will reveal more products' volatilization potential and influence on yields and protein.

Urea fertilizers can be 'stabilized' with the addition of chemical compounds that inhibit N transformations. The

most common inhibitor is N-(n-butyl) thiophosphoric triamide (NBPT) which is the active ingredient of Agrotain®. Volatilization loss from Agrotain®-urea ranged from four to 62 percent of the loss from conventional urea, and averaged about 30 percent, depending on climate, soil conditions, and the duration over which loss was measured (4, 5; Figure 1). Studies that track volatilization for only a few weeks may over-estimate NBPT's ability to protect urea from volatilization, as NBPT's effectiveness generally declines over time. NBPT breaks down more quickly in acidic than alkaline soils and as soil temperature and moisture content increase. Under cold weather application conditions, volatilization protection was found to last two to three weeks on acidic to neutral soils (pH 5.5 to 7.0), and more than seven weeks on an alkaline soil (pH 8.4; 5).

NBPT will be more effective at reducing volatilization losses under high risk conditions that favor fast losses from urea, such as in poorly buffered soils. NBPT does not prevent, but can inhibit urea volatilization for two to 10 weeks. This allows time for mechanical incorporation, irrigation, or sufficient rainfall to move surface applied urea below the soil surface and diffuse throughout the soil. Urea that converts to ammonium within the soil is less likely to be lost to the air as ammonia gas.

Over three years in central Montana, adding NBPT to fall, mid-winter or early-spring broadcast urea reduced volatilization but did not increase winter wheat yields. However, NBPT applied to fall broadcast urea increased grain protein by 0.6 to 0.8 protein units (%), making protein similar to that in winter wheat receiving urea broadcast in the spring without NBPT (6). NBPT combined with dicyandiamide (DCD, to slow nitrification and loss of N gas) limited volatilization loss from urea in a central Montana dryland study in the year when rainfall

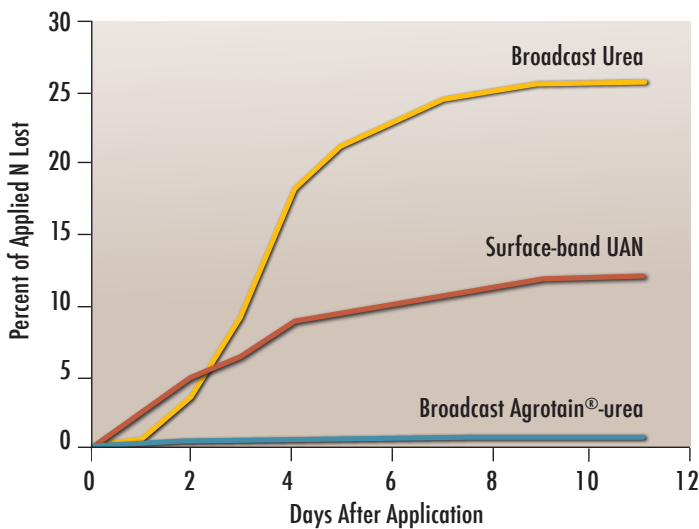


FIGURE 1. Percent of applied N lost from UAN and broadcast urea with and without Agrotain® from a newly seeded field irrigated only before fertilizer application (3). Average soil temperature was 50°F, pH 6.5.

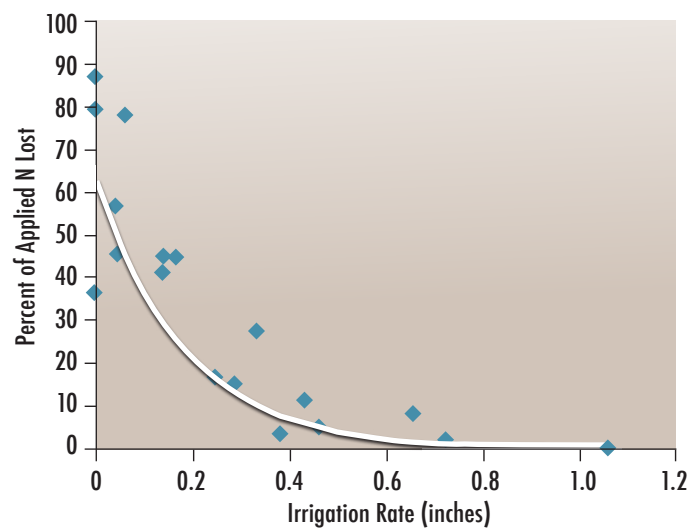


FIGURE 2. Percent of applied N lost to volatilization from urea broadcast in the spring on moist soil followed by different rates of irrigation on winter wheat (16). Average soil temperature was 44°F, pH 6.5.

incorporated the urea 5 days after broadcast. Camelina yields were greater with the NBPT-DCD treated (1407 lb/ac) than untreated (1020 lb/ac) urea. When incorporation by rainfall did not happen within 7 days of broadcast, NBPT-DCD treated and untreated urea had the same N loss and camelina yields, which were limited by water rather than N (7).

Controlled-release products, such as polymer-coated urea, have volatilization losses similar to well incorporated granular urea. The slow release of urea from polymer-coated and NBPT-urea results in low soil ammonium content and minimal localized pH increase, therefore low volatilization loss (8). Polymer-coated urea broadcast on sod in September and watered daily had 40 to 51 percent less volatilization loss than conventional urea in Utah and improved growth. This suggests polymer-coated urea could reduce volatilization losses and increase yields in perennial forage systems (9). Unlike NBPT-urea, the effectiveness of a polymer-coat to protect urea can last for several months. Under dry, cool conditions, N release from polymer-coated urea is very slow; therefore application of polymer-coated urea must be timed well in advance of crop N need to ensure the N is available.

#### PLACEMENT

Broadcasting urea without incorporation increases volatilization loss and should be avoided on well-buffered soils that are common in our region. If broadcasting is the only feasible option, consider using a management practice that minimizes volatilization (Table 3). Based on lab trials, timing urea application so it can be followed quickly by incorporation may be more important than applying urea on dry rather than moist soils (10).

Unfortunately, in Montana studies, seeding with air drills after broadcasting did not incorporate fertilizer enough to reduce volatilization loss (11). Sub-surface banding can also help reduce volatilization loss from urea in calcareous or well-buffered soils. However, in acidic ( $\text{pH} < 7$ ), poorly-buffered soils, surface or subsurface bands can have higher volatilization loss than surface or incorporated broadcast urea (8, 12). For best results, bands should be at least two inches beneath the surface and the slit produced by banding or knifing should be well-closed to trap the ammonia produced by the urea band.

Fields with high plant residue or thatch have higher potential volatilization than bare soil (*Factors Affecting Nitrogen Fertilizer Volatilization*). In perennial grass systems, subsurface placement of urea by drilling or knifing increases plant N recovery, most likely from reduced volatilization loss (13). However, subsurface placement may not be feasible or may cause excessive stand disturbance. Alternatively, surface banding UAN in perennial grass systems led to higher N uptake than UAN sprayed uniformly on the surface (14).

#### TIMING

When possible, time broadcast applications of urea when the likelihood of a significant rainfall is high, or when irrigation or tillage can be used to incorporate the N. Urea broadcast on moist soil should have 0.5 inch of rain (15) or irrigation (Figure 2) in one event within a couple of days to dissolve prills and move urea deep enough into the soil to minimize volatilization. Furrow irrigation may exacerbate urea's volatilization by dissolving urea without pushing it down into the soil.



FIGURE 3. Moist soil (A) and snow covered soil (B) should be avoided for spreading urea fertilizer regardless of soil temperature. Urea applied to dry soil (C) can remain undissolved for at least a week with no volatilization loss. Images by R. Engel.

Surface soil moisture is a major contributor to broadcast urea's volatilization. This has been shown in cool season broadcast urea applications in semi-arid regions of Montana (5). Largest losses (30 to 44 percent of applied N) occurred after urea was applied to wet or snowy soil surfaces (Figure 3), followed by a period of slow drying with little or no precipitation. Losses were less (10 to 20 percent of applied N) when urea was broadcast on dry soil followed by only light scattered rainfall (<0.33 inch) and losses were least (<10 percent of applied N) when applied to a dry surface followed within two weeks by at least 0.75 inch of rainfall. Surfaces can be considered dry if there is insufficient moisture to dissolve the urea granule (Figure 3).

Avoid applications onto moist soil surfaces unless a large precipitation/irrigation event or mechanical incorporation is imminent or a N source with low volatilization is used. This is particularly important on fields with high amounts of surface residue or thatch due to the potential for rapid conversion of urea to ammonium and ammonia in perennial systems (see *Factors Affecting Nitrogen Fertilizer Volatilization*). At least 1.5 inches of water are needed within two days on fields with surface residue or thatch, compared to 0.5 inch of water on bare or tilled soil to move the urea off the residue and deep enough into the soil to prevent volatilization. However, timing urea application within two days before sufficient irrigation or precipitation may not be feasible. Other management practices are available to reduce potential volatilization (Table 3).

## Summary

A number of soil and climate factors interact to affect ammonia volatilization from N fertilizers, including urea. As a result, it is difficult to predict precisely how much N will be lost in a given situation. Recent research in Montana and Oregon suggests that surface soil moisture at the time of urea application and rainfall or irrigation after application play the biggest roles in affecting volatilization loss. Applying during cool periods is no longer thought to ensure minimal volatilization loss. Urea should not be applied in situations that promote significant volatilization, and best management practices should be adopted to minimize loss. Recommended best management practices include incorporating urea with equipment, irrigation, or rainfall; adding NBPT to surface applied urea or selecting a N fertilizer with lower volatilization potential; and avoiding broadcast applications under high risk conditions unless there is an opportunity to incorporate the urea within one to two days of application.

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