Urea Fertilizer

Urea ($CO(NH_2)_2$) is the most commonly used nitrogen (N) fertilizer. The high N content per unit material (46%), lower cost, ease of storage, along with solid and liquid formulation options make it a popular choice for farmers. However if urea is not incorporated quickly after surface application, a large percentage of its N can be lost in the form of ammonia (NH_3) gas. Besides reducing a farmer's bottom line, ammonia emissions negatively impact the environment. This fact sheet will outline the factors influencing volatilization of ammonia from urea and discuss management tactics that can help reduce fertilizer losses.

Conversion of Urea

Urea reacts with the water in the soil immediately after application through a biological process called hydrolysis. The urea is converted to ammonium carbonate which can quickly transform into ammonia gas. If the ammonia is not captured and converted to ammonium (NH_4^+) quickly after it is formed, ammonia will be lost into the air. Soil pH, soil temperature, soil moisture, placement of the urea, wind speed, soil chemical and biological properties, and timing and amount of rain or irrigation all influence the percentage of N lost through volatilization.

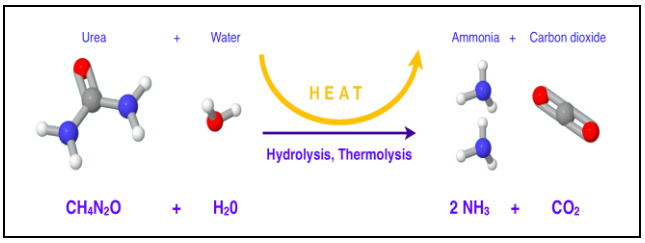

Figure 1: Urea is converted to ammonium carbonate and then ammonia gas. If the ammonia gas is not captures and converted to ammonium, it can be lost to the air through volatilization.

Soil pH

The conversion of ammonium to ammonia gas (NH_4^+ to NH_3) is controlled by pH. As hydrolysis occurs the initial pH around the granule will increase. Once the pH exceeds 7.5, volatilization losses increase drastically. Additionally soils with a high pH are more susceptible to ammonia volatilization than acidic soils.

Temperature

Ammonia gas loss increase greatly over 60˚F. At temperatures below 45 degrees Fahrenheit ammonia loss is limited. Early and late season applications of urea will have reduced risk of loss from temperature, but may be at increased risk for volatilization losses due to soil moisture.

Figure 2: Urea fertilizer is a popular nitrogen fertilizer choice for farmers due to its high nitrogen content per unit material (46%), low cost per unit nitrogen, ease of storage and suitability for use in solid or liquid formulations.

Soil Moisture

High moisture conditions common during early spring and late fall can increase volatilization risk of surface-applied urea. Hydrolysis approaches zero when the soil is dry as the conversion requires water. Urea applied to fine sandy loam and silt loam soils are at the most risk for losses compared to heavier clay soils. These losses can be reduced by changing the urea fertilizer placement.

Placement

Urea fertilizers are typically either surface-applied (broadcast application) with or without post application incorporation, or surface- or subsurface-banded. Surface application of urea fertilizer without incorporation can lead to substantial loss of N in the form of ammonia

gas. Subsurface- and surface=banding reduce the potential for ammonia gas volatilization; however, surface banding relies on rainfall or irrigation to move the nitrogen to the roots or rooting zone. Application in a localized band allows for more efficient use of N and as a result, lower application rates can be used than would be needed if the urea was broadcast on the surface and not incorporated. In row crop production, when urea is used as a band-applied starter, the planter should be carefully checked to ensure placement is not closer than 2 inches beside and below the seed, and be calibrated to apply no more than 65 lbs urea per acre (30 lbs of actual N from urea).

Wind Speed

Ammonia gas losses from surface-applied urea increase in windy conditions. Wind lowers the ammonia concentration above the field to levels lower than what is found at the surface of the urea, causing additional volatilization.

Soil Properties

Soils with a large cation exchange capacity (CEC) can retain more ammonium, reducing the chance of loss of N through volatilization. Ammonia volatilization risk is highest on sandy soils which have low CEC and a low pH buffer capacity. Muck soils with high organic matter levels and or large amounts of residue on any soil can also increase volatilization due to increase microbial activity. When urea sits on top of residue it is further exposed to volatilization.

Rain/Irrigation

If no rain occurs after application and the urea is not incorporated, N loss can be significant. As rainfall or irrigation increases more urea from the surface moves into the soil profile, (Table 1). Typically, half an inch of rain is sufficient to reduce N losses. Higher levels of rainfall can result in additional N loss.

Table 1: An example of the significance of rainfall for reducing N losses from surface-applied urea.

Rainfall (in)	Days after application	N losses (%)
0.4	2	0
0.4	3	<10
0.1-0.3	5	10-30
0.3-0.4	9	10-30
0	6	>30

Source: Fox, R.H. and L.D. Hoffman (1981). The effect of N fertilizer source on grain yield, N uptake, soil pH, and lime requirement in no-till corn. Agronomy Journal. 73:891–895.

Management to reduce losses

Many different tactics can be used to reduce the potential of volatilization:

- Time surface applications when soil temperatures are low and there is a chance of some rainfall. Do not apply urea to saturated soil.
- Apply urea before a light rainfall or irrigation. Avoid applications when more than ½ inch of rain is forecasted.
- Incorporate urea by irrigation or tillage.
- Apply urea in the starter band (no more than 30 lbs of actual N from urea, liquid or granular), or as a surface- or subsurface-band using a liquid formulation.
- Use urea treated with a urease inhibitor or a coated urea controlled release fertilizer. Urease inhibitors typically reduce volatilization for 10-14 days. Controlled release fertilizers can help extend N release over an entire growing season. For more information on coatings and inhibitors, see Agronomy Fact Sheet #45 (Enhanced-Efficiency Nitrogen Sources).

Concluding Remarks

With proper urea fertilizer management, volatilization losses can be reduced. Understanding the factors that can affect ammonia gas volatilization is important to making the proper application decision.

Additional Resources

- Cornell University Agronomy Fact Sheet #45 (Enhanced-Efficiency Nitrogen Sources) http://nmsp.cals.cornell.edu/guidelines/factsheets.html

Disclaimer

This fact sheet reflects the current (and past) authors' best effort to interpret a complex body of scientific research, and to translate this into practical management options. Following the guidance provided in this fact sheet does not assure compliance with any applicable law, rule, regulation or standard, or the achievement of particular discharge levels from agricultural land.

For more information

Cornell University Cooperative Extension

Nutrient Management Spear Program
http://nmsp.cals.cornell.edu

Andrew Gardinier, Quirine Ketterings,
Bill Verbeten, and Mike Hunter

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