

# Managing Urea-Containing Fertilizers<sup>1</sup>

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## Importance of Urea as a Fertilizer Source

Nitrogen fertilizer use in Wisconsin as anhydrous ammonia, urea-ammonium nitrate solutions, and urea ranged from about 148,000 to 213,000 tons of N during the 1995-2000 period (Terry and Kirby, 2001). This amount is similar to that used about 10 years earlier when 170,000 tons of N was used in 1984. However, a substantial materials shift has occurred since 1984 when about 56% of the N used as the major three sources was urea or N solutions. The percentage of urea-containing materials has increased to 80% in 1999 and 76% in 2000. This increased utilization of urea-containing fertilizers parallels the national trend and emphasizes the need to manage urea effectively.

The increased utilization of urea-containing fertilizers in Wisconsin has occurred largely at the expense of anhydrous ammonia which has experienced a reduced market share from about 44% of the N in 1984 to 20 to 25% of the three major N sources at present. Nitrogen utilization from other N sources ranges from about 16,000 to 25,000 tons of N annually and includes materials such as ammonium nitrate, ammonium sulfate, ammonium thiosulfate, aqua ammonia, calcium nitrate and others. Utilization as ammonium nitrate plus ammonium sulfate ranged from about 24,000 tons of N in 1999 to 13,000 in 2000.

## Reactions of Urea in Soils

Management of urea-containing fertilizers requires an understanding of the reactions urea undergoes when added to soils. Urea is hydrolyzed or broken down to ammonia and carbon dioxide through the action of a soil enzyme, urease. Urease occurs naturally in essentially all soils and plant materials. Components of the urea reactions in soil are illustrated in Figure 1. In most soils, urea hydrolysis occurs rapidly (Figure 2) after urea-containing fertilizers are applied. Where granular urea was broadcast on the surface of a silt loam soil at a rate of 100 lb N/acre, about half of the urea was hydrolyzed within 2 days after application at 50° F and over 80% was broken down within 4 days. Urea hydrolysis is much more rapid at higher temperatures. More than 90% of the added urea was hydrolyzed within 2 days at a temperature of 79° F. Alternatively, cold temperatures slow down urea decomposition in soil. Kissel (1988) reported that at 35° F, about half of the applied urea was hydrolyzed after 4 days and about 10 days was needed for complete decomposition.

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One of the results of urea breakdown in soil is an increase in soil pH in the zone where urea hydrolysis has occurred. This pH increase is important for determining the relative amounts of ammonia present in a gaseous form that potentially could be lost to the atmosphere. This process is called ammonia volatilization, and it is one of the major concerns for effective management of urea fertilizers. The percentages of the ammoniacal N in ammonium and ammonia forms at various soil pH levels are shown in Table 1. At pH values below 7, less than 0.6 % of the N is present in the gaseous ammonia form, thus limiting the potential for ammonia loss to the atmosphere. Where pH values are 8 or higher, a substantial percentage of the N is in the ammonia form, leading to greater potential for gaseous loss of ammonia from the soil. Figure 3 illustrates the effect of urea hydrolysis on soil pH over time in a silt loam soil at two temperatures. At both 50° F and 79° F, soil pH reaches values above 8 where a substantial percentage of the N applied would exist as ammonia gas. High soil pH values are reached earlier at the higher temperature because urea hydrolysis is more rapid than at lower temperature. The soil pH values found during and after urea hydrolysis show that a substantial portion of the ammoniacal N would be present as ammonia and could potentially be volatilized.

#### Extent of Ammonia Volatilization Losses

Ammonia loss from urea-fertilized soils usually occurs only when urea-containing fertilizer is surface-applied and not incorporated. The amount of nitrogen lost through ammonia volatilization from surface applied urea-containing fertilizers is greatly affected by soil and climatic conditions. Factors favoring ammonia loss from surface-applied urea include:

- No rainfall or irrigation after application
- Crop residue on the soil surface
- High temperatures
- High soil pH
- Low soil clay and organic matter content (low cation exchange capacity)
- Application to initially moist soil followed by drying conditions.

If rainfall or irrigation occurs soon after surface application of urea, the urea moves into the soil with the water and is protected from ammonia loss in the same way as soil incorporated urea. About 0.2 to 0.5 inch of rainfall within 24 hours after urea application usually prevents ammonia volatilization. As little as 0.1 inch of rain can minimize ammonia loss. At 50° to 70° F, ammonia loss will be low if rainfall occurs within 2 to 4 days after urea application. Significant losses of ammonia are likely if no rainfall occurs within 5 days after urea is surface applied. Based on long term Wisconsin weather data there is a 60% chance of receiving at least 0.1 inch of rainfall in a 4-day period in May.

Although ammonia loss from urea-containing fertilizers can cause crop yield reductions due to nitrogen deficiencies, the frequency and extent of nitrogen losses from urea fertilizers are less than commonly believed. Data presented below and management recommendations from other states (Kissel et al., 1988) show that even when conditions

are considered ideal for ammonia loss (lots of residue and urease, warm temperatures, and moist soil), losses are unlikely to exceed 20% of the surface-applied urea. Higher losses are possible from surface applications on sandy soils.

In field studies at Lancaster and Arlington, corn yields were influenced by ammonia losses from surface-applied urea-containing fertilizers in only one of four experiments (Oberle and Bundy, 1987). Field measurements of the amount of ammonia volatilized in the one yield-affected experiment (Table 2) showed that 16% of the urea-N and 12% of the UAN-N were lost. Where urea was applied to grass pasture during warm weather (June), 19% of the urea-N was lost within 1-2 days after application (Table 2), and dry matter yields were reduced by this loss. Rainfall within 24 hours of application is needed to control ammonia losses from summer urea applications to grass pastures.

### Nitrogen Source and Management Comparisons

Nitrogen source comparisons of urea-containing materials with other fertilizers not susceptible to ammonia volatilization sometimes show lower yields where N is applied as urea. These differences are often attributed to ammonia loss from the urea-containing materials, but other factors also may contribute to these differences.

#### *Nitrogen source comparisons in no-till corn*

Many N source comparisons involving surface-applied urea-containing fertilizers and N sources such as ammonium nitrate or ammonium sulfate that are not subject to ammonia volatilization have been reported. Some of these experiments show better performance of the non-urea fertilizers, and these source differences are often attributed to ammonia loss from the urea-containing materials. Examples of these comparisons showing differences among N sources are shown in Table 3 (Mengel et al., 1982). Other studies such as Bundy et al., 1992 showed no differences between N sources (Table 4).

In a 3-year comparison of N fertilizer sources applied to no-till corn, Bundy and Andraski (1997) found that surface-applied ammonium nitrate tended to be more effective in increasing corn yields than urea or UAN solution applied using several methods (Table 5). This study included a treatment in which 0.5 inch of simulated rain was applied immediately after a surface application of UAN solution to theoretically eliminate the possibility of ammonia volatilization. As shown in Table 5, yields with ammonium nitrate were higher than surface applications of UAN and urea in two of the three years. Where rainfall was added to the UAN treatment immediately after application, yields still tended to be lower than with ammonium nitrate, suggesting that source differences other than N loss through ammonia volatilization contributed to the yield differences.

#### *Urease inhibitors to control ammonia loss*

Chemical inhibitors of soil urease activity have been evaluated as a method of controlling ammonia loss from surface-applied urea-containing fertilizers. A class of compounds

known as phosphorodiamides are effective urease inhibitors, and one of these compounds, N-(n-butyl) thiophosphoric triamide (NBPT), is the active ingredient in a commercially available urease inhibitor (Agrotain). Hendrickson (1992) summarized a comprehensive regional study of the use of NBPT with surface-applied urea-containing fertilizers. Results from 78 field experiments conducted in 17 states over a 6-year period showed small yield increases from NBPT use when data from all experiments were considered (Table 6). The yield advantage from the urease inhibitor increased when only N responsive sites or sites where significant ammonia loss occurred were considered.

Results from Hendrickson (1992) and other studies with NBPT (Bundy, 1992) indicate that consistent yield increases from using a urease inhibitor should not be expected. For example, beneficial yield increases occurred in only 35 to 40% of the trials, and NBPT significantly reduced yields in 5 to 10% of the trials. The potential for economic gains from using a urease inhibitor are greatest where the risk of ammonia loss from urea is high and the crop will respond to the N conserved by the inhibitor.

Urease inhibitors have little or no effect on the nitrification process in soil. Therefore, urease inhibitors should not be expected to influence nitrate leaching losses.

#### *Winter applications of urea*

Research in Illinois (Illinois Agron. Handbook, 2000-2001) has shown poor performance of surface applied urea when these applications were made to frozen soils in February (Table 7). Although the mechanisms responsible for the lower yields with winter urea applications relative to other times and methods of application are not known, the substantial yield reductions observed with this treatment indicate that winter surface applications should be avoided.

#### *Performance of preplant urea applications on sandy soils*

Kelling et al. (1984) observed marked differences in the effectiveness of urea as a nitrogen source for corn on sandy irrigated soils. In this study, preplant urea was broadcast applied and immediately incorporated into the soil, while sidedress urea was banded about 4 inches deep 4 to 6 weeks after planting. Anhydrous ammonia was injected at the same N rates at both preplant and sidedress times. As shown in Table 8, preplant urea was significantly less effective than anhydrous ammonia at all N rates, but there was no difference between the N sources at the sidedress application time. Use of the nitrification inhibitor N-Serve (nitrapyrin) improved the effectiveness of preplant urea, but anhydrous ammonia was still more effective at the preplant application time.

### Summary

- Urea-containing fertilizers have become increasingly important nitrogen sources in Wisconsin. In 1999-2000, 75-80 % of the fertilizer N applied contained urea.

- Ammonia loss from urea-containing fertilizers usually occurs only with unincorporated surface applications.
- Several factors favor ammonia loss from urea-containing fertilizers including no rainfall after application, high crop residue cover, warm temperatures, and initially moist soils.
- Even when conditions are considered ideal for ammonia loss the actual losses seldom exceed 20% of the applied nitrogen.
- Nitrogen source comparisons with surface-applied materials often show better performance with non-urea fertilizers. Factors other than ammonia volatilization may contribute to these results.
- Chemical urease inhibitors can reduce ammonia loss, but economic benefits of these inhibitors are not consistent.
- Winter applications of urea on frozen soils may be subject to losses.
- Preplant applications of urea on sandy soils should be avoided.

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