ANHYDROUS AMMONIA APPLICATION IN DRY SOIL

John Sawyer, Professor, Department of Agronomy, Iowa State University

It's getting closer to the time that anhydrous ammonia (NH_3) applications could begin (remember 50°F and continued cooling 4-inch soil temperature, and the colder the better). However, some areas of Iowa have dry soils this fall. Can anhydrous ammonia be applied to dry soil? Will it be held in dry soil?

Can anhydrous ammonia be applied to dry soils?

Yes. Dry soil can hold ammonia. Even air dried soil contains some moisture, although quite low. Ammonia dissolves readily in water, but it is held or retained in soil by clay and organic matter. The problem with dry soil and low moisture is that soil moisture is needed to temporarily hold ("go into solution") the ammonia so it can become attached to clay or organic matter as ammonium. If dry soils are cloddy and do not seal properly, the ammonia can be lost at injection, or seep through the large pores between clods after application. Therefore, proper depth of injection and good soil coverage are a must for application into dry soils. Wing sealers immediately above the outlet port on the knife can help close the knife track, limit the size of the retention zone, and reduce vertical movement of ammonia. Closing disks can reduce ammonia loss by covering up the injection track with soil that traps the ammonia as it moves to the soil surface. Reducing the application rate or narrowing the knife spacing reduces the concentration of ammonia in each injection band.

What happens when anhydrous ammonia is injected into soil?

Several physical and chemical reactions take place: dissolution in water, reaction with soil organic matter and clay, and attachment of resulting ammonium ions on the soil cation exchange complex. These reactions all tend to limit the movement of ammonia, with water having the greatest initial effect. The highest concentration of ammonia is at/near the point of injection, with a tapering of the concentration toward the outer edge of the retention zone. Usually the greatest ammonia concentration is within the first inch or two of the injection point, with the overall retention zone being up to 3-4 inches in radius in most soils. The size and shape of an ammonia retention zone vary depending upon the rate of application, knife spacing, the soil, and soil conditions at injection (soil texture, soil structure, organic matter, and moisture status).

Ammonia moves farther at injection in coarse-textured soils and soils low in moisture. Also, if the injection knife causes sidewall smearing (when soils are wet), then ammonia may preferentially move back up the knife slot. Movement toward the soil surface can also occur for some time after application if the soil dries and the knife track "opens up" as the soil dries (also less soil moisture to retain free ammonia in solution with drying soils). A similar movement within the soil can occur if the soil breaks into clods at application and there are large air voids left in the soil and poor knife track coverage. These conditions can result in greater ammonia concentration toward the soil surface, and greater potential for loss to the atmosphere at or after application.

When ammonia is injected into soil, the initial reaction at the point of release is violent. The ammonia reacts and binds with soil constituents such as organic matter and clays. It reacts with water to form ammonium (NH_4^+). These reactions help retain ammonia at the injection point. With the high affinity for water, soil moisture is important for limiting the movement of ammonia, but does not ultimately determine retention in soil. After conversion to ammonium, which is a positively charged ion, it is held on the soil exchange complex and does not move with water. Only after conversion to nitrate (NO_3^-), via the nitrification process, can it be lost from soil by leaching or denitrification.

Chemical and biological reaction of anhydrous ammonia in soil

1) $NH_3 + H_2O = NH_4^+ + OH^-$

This is chemical reaction of ammonia with water and causes an initial alkaline pH in the ammonia retention zone (pH can temporarily rise above 9 at the point of highest concentration). It is free ammonia and not ammonium that can be lost from soil at application and is damaging to microorganisms and plant seedlings. As pH goes above 7.3, the equilibrium between ammonium and ammonia results in increased free ammonia (the percentage as ammonia would be 1% at pH 7.3, 10% at pH 8.3, and 50% at pH 9.3).

2) $2NH_4^+ + 3O_2 \Rightarrow 2NO_2^- + 2H_2O + 4H^+$

3) $2NO_2^- + O_2 \Rightarrow 2\ NO_3^-$

These two reactions are the steps in the biological nitrification process that occurs with ammonium in soil, and ultimately results in a lowering of pH back to the original pH or lower. Nitrification occurs first at the outer edges of an ammonia band, and progresses inward as the initial effects of ammonia injection decrease and the soil conditions become more conducive to microbial growth.

What about damaging corn next spring?

The potential is usually low for fall-applied ammonia to damage corn seed or seedlings. However, if the soil remains dry (and limits nitrification), the ammonia is injected shallow or there is poor soil structure (ammonia placed near the seed location), or the rate of application is high, then it is possible for ammonia damage to occur. The best cure is to inject deep enough with friable soil coverage to get adequate soil separation between the point of ammonia injection and the depth where corn seed will be planted, or offset ammonia bands from future corn rows. For example, if the injection point is 6 to 8 inches in depth, the outer edge of the ammonia retention zone (which would be low in ammonia concentration) is 4 inches from the point of injection, and seed is planted at a 2-inch depth directly over the ammonia track, then the seed would be outside the applied ammonia band. Shallower injection, greater ammonia movement upward from the injection point, wider knife spacing, or higher rates can lead to ammonia being in the seeding area at rates high enough to cause damage.

Bottom line

Be mindful of what is happening at application, especially if soil conditions are not ideal. If you make an application round in the field, and you can still smell ammonia from that application, then you should make adjustments or wait for better conditions. If the soil is breaking into clods, there isn’t good coverage of the knife track with loose soil, and ammonia is escaping (remember your nose tells you if ammonia is escaping; a white vapor is condensed water vapor, not ammonia which is colorless), then stop and either change the way the equipment is working or is set up, or wait until the soil has better structure or moisture.