What Happens to Anhydrous Ammonia in Soil†

M. L Vitosh, MSU Crop and Soil Sciences Department

Anhydrous ammonia (AA) is the predominant fertilizer N source in Michigan in terms of the amount of actual N applied each year. There are several reasons why AA is used so widely. First, because AA is the initial step in the manufacture of almost all commercial N, and second it is the least costly source of fertilizer N. Anhydrous ammonia also contains 82% N, the highest nutrient concentration of any fertilizer.

Anhydrous ammonia also has some drawbacks that limit its total domination of the fertilizer market. Because AA is a gas that is stored as a pressurized liquid, special application equipment is always required. This application is sometimes relatively slow compared to other products. As AA is released from tanks, it is a gas that can be a risk to human health if proper safety precautions are not followed.

As AA is discussed in respect to other fertilizer N products, oftentimes information is stated that may or may not have a solid foundation. This article is a compilation of scientific data that has been evaluated from several perspectives of AA after it is applied to soil.

Retention in soil after application

Anhydrous ammonia applications result in bands of inorganic N beneath the soil surface. The bands are generally oval or tear-dropped shaped with the elongation being vertical. Generally more AA diffuses upward rather than downward and the width of the band increases as AA rate — all other things being equal. The zone of AA spreads to a diameter of approximately 2 to 5 inches depending on soil texture, AA rate, cation exchange capacity, and soil moisture content. Soil moisture content plays the most significant role in AA retention zones.

Anhydrous ammonia would stay in the gas form and be lost to the atmosphere if it did not react quickly with moisture in the soil. When AA is released in the soil, it is retained in the soil by various chemical and physical mechanisms. The most common are reactions with free hydrogen ions in the soil (function of pH) and with water. The result of these reactions is ammonium being formed, held to exchange sites, and not subject to loss in the soil.

Loss of AA as ammonia gas at the time of application is dependent on the depth of injection and the soil moisture status. Too little moisture will allow ammonia to escape up to the atmosphere. Too much moisture will prevent the sealing of the injection knife opening to the soil surface. The depth of injection relates to the distance the ammonia would have to move to be lost to the atmosphere.

†Schmitt, M. A. and G. W. Rehm. 1993. Soils, Fertilizer and Agricultural Pesticides Short Course. University of Minnesota, Minneapolis, MN. pp 51-58.

Figure 1 graphically shows the effects of application depth and soil moisture status on ammonia loss. While soil moisture level around 16% results in minimal ammonia loss at any application depth, either wetter or drier soil conditions favor deeper applications. In Figure 1, dry soil (2%) results in immediate (<2 hr) gas loss whereas wet soil (23%) had gradual soil N losses for the first day and a half. Note that maximum ammonia loss in either case was around 12% for this data set in which the AA was applied at a depth of only 3 inches. In Michigan, our fine-textured soils rarely get so dry that we see AA losses. On the other hand, soils have been very wet the past couple of years in instances and some losses due to poor sealing may have occurred.

For very wet soils, application management strategies that minimize N loss include applying the AA at least 6 inches deep and using some type of covering knife apparatus that closes the slot made by the knife. With very dry conditions, deeper applications are generally better.

Effect on soil microbial population

The chemical properties of AA cause it to be toxic to microorganisms in the zone of application. The extent of the microbe eradication is highly dependent on the micro-environment in the application zone. Soil sampled on the day of application showed a drastic reduction in soil bacteria, but the populations did not go to zero (Table 1). As the length of time increased after application, there was an increase in the bacterial population compared to the injection zone that had no AA applied in it. Approximately five weeks after application there were no major differences in the number of bacteria between the sets of plots, which had either 0 or 100 Ib N/A applied.

The effect AA had on soil fungi was a bit more long lasting than with the bacteria. This effect is characterized with the data in Table 2, with there still being a net negative effect in the row at 31 days after application. In a matter of inches from the center of the application zone, the effectof the AA drastically decreased. C. F. Eno and W. G. Blue summarize their research on soil bacteria and fungi stating: "Although applications of AA had an effect on the microbiological population of the soil, it does not seem that this is likely to cause more than a temporarily unbalanced conditions in the zone of retention."

Effect on soil physical and chemical properties

Anhydrous ammonia is often perceived as being detrimental to several physical and chemical soil properties, results from a long-term (10 yr) study comparing the effects of several N sources and a control provide data that is noteworthy (Table 3). Soil bulk density data, one measurement often used to determine soil compaction, was collected and showed that none of the N sources were significantly different from each other or the control (no N). This was true when measured in the plow layer (shallow) or just beneath the plow layer (deep).

Applications of all of the N fertilizer sources did, however, significantly reduce soil pH as compared to the control treatment. The equal lowering of pH among all the N sources was evident both in the shallow and deep soil samples. Because nitrification of ammonium is an acid forming reaction, the net effect will be a lowered pH; the exception being with ammonium sulfate. Soil organic matter was not affected by any of the fertilizer N sources at any time.

Knife spacing and AA concentrations

A management practice that lias been receiving widespread attention in the past several years is the switching of AA application knife spacing from 30 inches to 60 inches. This practice would allow less energy to be used in pulling the application equipment through the field and fewer knives to be maintained.

From an agronomic perspective, there may be a real advantage of this type of practice based on the concentration of AA that would be in each application zone. When AA is applied to soil, it creates a high pH and this results in an inhibition of nitrification (conversion of ammonium to nitrate). The higher the N concentration, the longer the inhibitory effect. Thus, as one would switch from 30 to 60 inch knife spacings, the concentration of AA would double in each zone.

Research work from Nebraska by Marake et al. (1993) summarized that on some of their fine-textured soils ammonium persistence greatly increased as application spacing increased. They measured a half-life of 66 days for AA with 60 inch row spacings, thus 25% of the applied AA would be present in the ammonium form 132 days after application.

The logistical configuration concern between the N application zone and crop rows has led to the primary recommendation that these wider row spacings only be used with sidedress AA applications. By using 60-inch spacings at sidedressing time, each plant will have a N application zone 15 inches away. Research work in Illinois comparing 30- and 60-inch rows concluded that knife spacings had no significant effect on yield (Table 4).

Planting corn after anhydrous application

A common question regarding spring AA application is how soon after application can corn be planted. The primary goal is that the seed cannot be planted in the AA retention zone, thus AA rate, application depth, and soil moisture and texture are important.

Figure 3 depicts the effect of application N rate and depth on corn stands. When 100 Ib N/A was applied corn stands were slightly reduced with the shallow application whereas the rate of 400 Ib N/A severely reduced stand at the 4 and 7 inch application depth. The 200 and 300 Ib N/A application rate effects were intermediate. Normal application rates of AA are generally between 100 and 200 Ib N/A with the typical application depth being around 7 inches. From this study, these stands would then be at 90% or greater.

In this study, the corn was planted directly over the marked zoned of AA application and the corn was planted on the same day as AA application. Assuming typical AA retention zones and an application spacing of 30 inches, the chance of planting directly over an AA zone would be approximately one-sixth. Hence, a 90% stand reported in this study would translate to 98% stand if planter rows were random with respect to AA rows.

Delaying time of planting with respect to AA application would increase stands in Figure 3, especially with the 300 and 400 Ib N/A rates. Assuming normal or wet soil moisture conditions, which would speed the conversion of ammonia to ammonium in the zone, a delay of several hours to a day between application and tillage or between application and planting should be adequate for typical Michigan conditions and practices.

Summary

Anhydrous ammonia is a widely used N fertilizer because of the many positive agronomic and logistical characteristics of the product. The effects AA has on the soil are generally minimal with regard to soil physical and chemical properties when compared to other N fertilizer sources.

While AA can have an immediate effect on soil microbe populations, these effects are localized and not long lasting. Altering the concentration of AA in the retention zone by varying knife spacing can have an effect on ammonium persistence in the band. This effect can lead to less N losses in the soil when conditions for loss are favorable. Yield data has concluded no significant difference in grain yields at different AA band application widths.

Table 1. Numbers of bacterial in soil in the anhydrous ammonia injector row compared with untreated areas (Eno and Blue, Soil Sci. Soc. Am. J. 18:178)

Time after Application	AA Treatment	Check	Neg
days	millions/gram soil		
0	0.26	2.25	-1.99
3	6.28	1.29	4.99
10	9.20	3.09	6.11
24	4.18	1.33	2.85
31	3.35	4.25	-1.17
38	0.95	0.93	0.02

Table 2. Soil fungi populations (net effect, treated area less untreated area) as affected by distance from the point of anhydrous ammonia injection and time after application (Eno and Blue, Soil Sci. Soc. Am. J., 18:178).

Days after application	Distance from injection point (inches)			
	1	2	3	
days	millions/grams soil			
0	-15.00	+2.00	+0.88	-1.13
3	-9.87	-5.62	-1.87	1.00
10	-5.75	-6.68	-4.12	-1.75
24	-13.00	-7.50	0.00	-2.50
31	-6.67	-4.17	4.50	-2.17

Table 3. Physical and chemical properties of soil taken from two layers in field plots (Stone et al., 1982, Coop. Ext. Serv., C-625, Kansas State Univ., Manhattan, KS).

N Source	Depth	Density	pH	OM
		lb/ft		
Control	shallow	81.7	6.4	2.3
Anhydrous		83.6	5.7	2.3
Urea		81.7	5.7	2.4
UAN-28		81.7	5.7	2.4
Control	deep	84.2	6.4	2.0
Anhydrous		83.6	5.9	2.1
Urea		84.2	5.8	2.1
UAN-28		84.7	5.9	2.1

Table 4. Corn grain yields as influenced by sidedress N knife injection spacing and N rate on an Illinois Fine-textured soil (Sawyer et al.. Agron. Abstracts, 1991. pg 300).

Knife spacing (inches)		
N rate	30	60
lb/A	bu/A	
120	160	150
180	165	160
240	170	170
Ave.	165	163

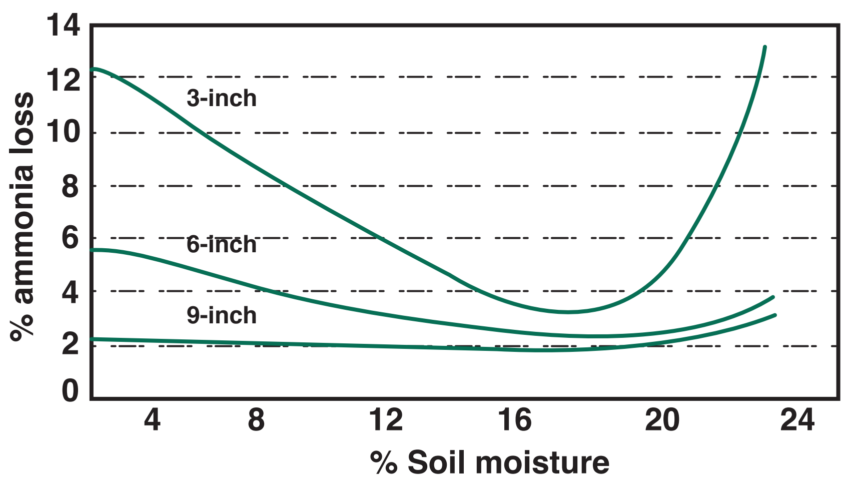

Figure 1. Losses of ammonia from soil us influenced by depth of application and soil moisture (Stanley and Smith, Soil Sci. Soc. Am. J., 20:557).

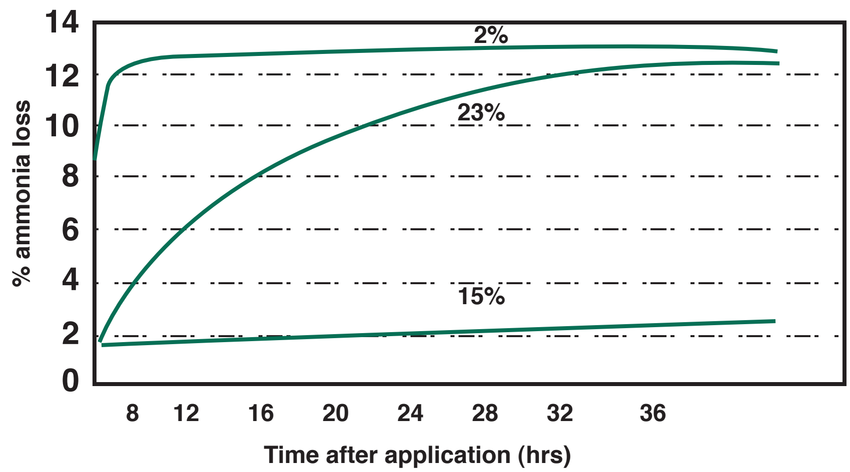

Figure 2. Rates of ammonia loss from soil at different soil moistures (Stanley and Smith. Soil Sci. Soc. Am. J., 20:557).

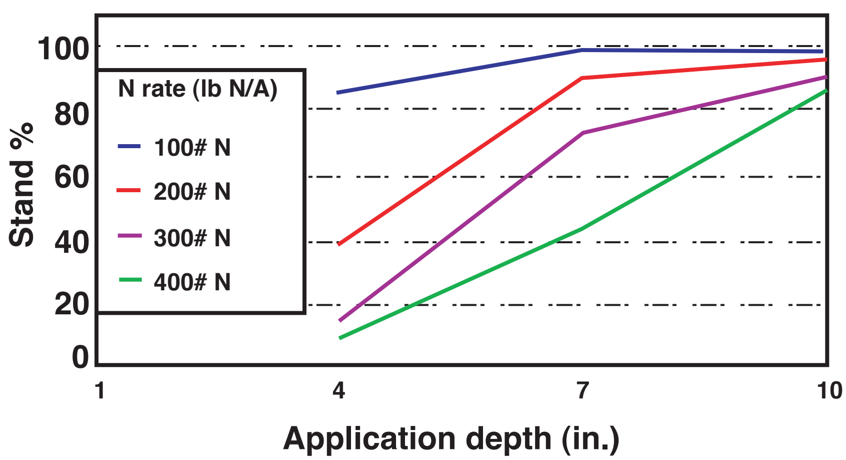

Figure 3. Corn stands 12 days after planting as influenced by rate and depth of anhydrous ammonia applied (lie same day as planting (Colliver and W elch, Agron. J., 62:341).

MICHIGAN STATE
UNIVERSITY