WATER QUALITY ISSUES AND ACTIVITIES IN MINNESOTA[1]

Gyles W. Randall[2]

Within the last few years there has been considerable public concern over the occurrence of nitrates (NO_3^-) in both ground and surface waters. This is especially significant since 50% of drinking water for the U.S. comes from groundwater supplies and this increases to 85% in the rural areas (CAST, 1985). The issue has at times become emotional and fingers have been pointed regarding the cause of nitrates in our water supply. Consequently, steps are being taken to establish the relationship between N management (fertilizer and manure), fate of N in the soil, and the occurrence of nitrates in groundwater at a number of locations in the U.S.

Factors Affecting NO_3^- Leaching and Groundwater Quality

The amount of NO_3^- that leaches from a soil depends on the amount of water that moves through the soil and the amount of NO_3^- in the soil when the water drains through and out of the soil profile (Pratt, 1984). Other factors such as the soil, climate, irrigation, crop grown, and N management either directly or indirectly affect NO_3^- leaching from the rooting zone. Additionally, the soil landscape and geology of the area affect the degree of NO_3^- occurrence in the groundwater.

Drainage water that leaves the upper root zone percolates through an unsaturated zone to a saturated zone at some depth below. In some cases, tile lines are installed to transport the excess water from the perched water table of a soil profile. This tile transports mobile nutrients, i.e. NO_3^-, from the soil profile to surface water. The rate of percolation can vary tremendously from high values in areas of high drainage volumes and sandy soil materials to low values in areas of low drainage volumes and clayey soil materials. Consequently, the travel time for NO_3^- to reach an aquifer (water bearing rock formation) depends not only on the depth of the aquifer but also on the properties of the soil.

<u>Site Specific Nature of Contamination</u>

From the previous section it is quite obvious that the effects of agriculture on groundwater are very <u>site specific</u>. Consequently, those conducting research, its interpretation, and the extension of agricultural chemical management practices need to keep this in mind. It is imperative that individuals involved in general public education and regulatory activities be cognizant of site specificity rather than generalizing across a State or the Nation.

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[2] Soil Scientist and Professor, Southern Experiment Station, University of Minnesota, Waseca, MN 56093

In Minnesota, agriculturally sensitive areas to groundwater contamination have been identified. The areas receiving priority attention are primarily (1) the coarse-textured, irrigated soils and (2) the mediumtextured, shallow, loess soils located over fractured limestone (Karst) and sandstone in southeastern Minnesota. Intensive livestock production with subsequent manure availability is also a characteristic of this latter area. Even though the majority of Minnesota's crop production and fertilizer usage occurs on the finer-textured, glacial till soils, these areas are presently considered less sensitive due to slow percolation rates, greater denitrification potential, and greater depth to the groundwater.

Past Research Activity

Coarse-Textured Soils

Numerous studies have been conducted on sandy soils in Minnesota. One of them, using tagged N (15N) was conducted to determine if proper N rates and split applications would reduce NO_3^- loss below the rooting zone and decrease the potential for NO_3^- movement to the aquifer (Gerwing et al., 1979). They spring-applied two rates of N as either single or split applications to a Sverdrup sandy loam soil planted to corn. This soil is underlain by mixed layers of sand and gravel down to the aquifer at 15 feet. Rainfall and irrigation totaled 31.5 inches during the growing season. Their results indicated substantially higher NO_3-N concentrations in the soil solution at 5' and 8' depths with the single application (Table 1). In addition the percent of N derived from the labeled 15-N fertilizer was less with the split applications. By early September, NO_3-N concentrations in the aquifer (15' deep) were increased by 7 and 10 mg/L with the 160 and 240 lb N/A rates, respectively, when added as single applications. Split applications had minimal effect on the aquifer. No accumulation of NO_3-N was detectable in soil samples taken to a depth of 10 feet after harvest. In summary, this study indicated that substantial quantities of N from fertilizers can be leached as NO3 from the root zone of sandy soils into the subsoil or aquifer during one growing season. Split applications of N and/or the use of nitrification inhibitors are definitely best management practices (BMP's) for these irrigated, sandy soils.

Table 1. N derived from fertilizer in the soil solution at 5 and 8-foot depths at the season maximum NO_3-N concentration (Gerwing et al., 1979).

Application[1] method	Sampling depth	NO_3-N	N derived from fertilizer
	feet	m/L	%
Single	5	116	69
Split	5	71	47
Single	8	77	25
Split	8	48	13

[1] N applied at 160 lb N/A as urea.

Medium-Textured Soils

Studies were conducted to evaluate the effect of N rate and time of application on the fate of N and corn production on a loess soil (Mount Carroll silt loam) in southeastern Minnesota (Jokela, 1985). A summary of his results indicated:

1) increasing N rate to 130 lb N/A was associated with higher yields and also higher residual NO_3^- left in the soil profile at the end of the season
2) yields and fertilizer N uptake were not affected by time of application (Preplant vs sidedress at the 8-leaf stage)
3) greater amounts of residual NO_3^- were found in the soil profile after the growing season with sidedress application compared to preplant application.

Jokela's studies also showed sizable losses of NO_3-N from the 0-5' profile after the growing season (Table 2). Approximately 65% of the NO_3-N in the profile in early November was not found in early May of the following spring and suggests that it may have leached below 5' between the growing seasons. Rainfall during April was above normal in both years.

Table 2. Nitrate-N in 0-5' profile in Goodhue Co. as influenced by time of sampling.

N rate	1982 F	1983 S	1983 F	1984 S	Two-Yr Avg.Change
lb/A	lb NO_3-N/A				%
0	150	60	126	35	64
67	221	89	152	37	68
134	225	77	178	57	67

The relationship between time of N application and the distribution of NO_3-N in the soil profile is shown in Figure 1. Substantially more NO_3-N remained in the fall in the 0-1' profile with the 8-leaf application compared to N application at planting. By the following spring much of this had shifted to greater than 3' deep.

Based on these results residual NO_3-N remaining in the fall is highly susceptible to leaching from the rooting profile. In addition, any fall-applied fertilizer N which nitrifies to NO_3^- by early May could also be lost. These conditions suggest spring application of N to be more efficient and environmentally sound than fall application in southeastern Minnesota. In addition, N rates may need to be reduced slightly when sidedress applied to limit residual NO_3^- in the soil profile at the end of the growing season.

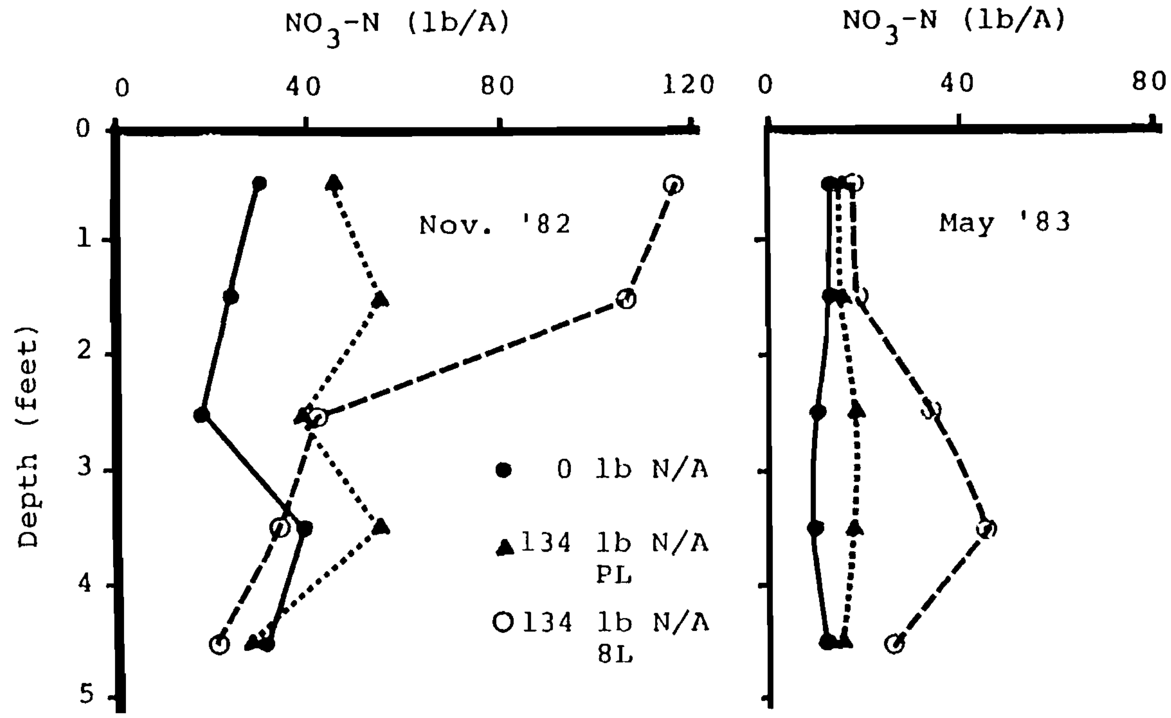

Fig. 1. Effect of N rate and time of application on the NO_3-N in the soil profile in 1982-83.

Fine Textured Soils

A number of studies have been conducted on the fine-textured, glacial till soils of southern Minnesota to relate N management practices to NO_3^- movement in the soil, into the tile water, and uptake into the plant. These practices have included rate of application, time of application, crop sequence, and tillage system.

Rate of application

Using the proper application rate of N can have a greater effect on crop yield, N efficiency, economical return, and the environment than any other management tool. Application rates that are either too high or too low result in less profit to the farmer. To arrive at the optimum rate of N application the grower must consider the crop being fertilized and the productive capacity of the soil when setting a realistic yield goal. In addition, credits for N, which may be present due to previous legume crop, manure, residual NO_3^- carried over from past fertilization, or N in the irrigation water, must be considered.

Tile drainage plots were established in 1974 on a Webster clay loam at Waseca. Nitrogen was applied annually at rates of 0, 100 and 200 lb N/A from 1975 through 1979 to continuous corn. This site has an annual precipitation of 30". The first two years were extremely dry, however, and yields did not exceed 75 bu/A. Consequently, residual NO_3-N remaining in the 0-3' profile at the end of the second year (1976) ranged from 43 lb/A with no N applied to 241 lb/A with the 200-lb rate (Table 3). Above normal rainfall in the third year (1977) resulted in tile line drainage that averaged 58 mg NO_3-N/L with the 200-lb rate with no increase in corn yield over the 100-lb rate. It should be emphasized that NO_3-N concentrations averaged greater than 10 mg/L in the tile drainage water from these high organic matter soils (5 to 6%) even when no N was applied. These results indicate that substantial amounts of NO_3^- can accumulate in these soils under dry conditions and then are highly susceptible to leaching.

Table 3. Residual nitrate-N, corn yield and average NO_3-N concentration in tile water as affected by N rate.

Annual N rate	Residual[1/] NO_3-N in top 3'	1977 Yield	Avg. NO_3-N[2/] concentration in tile water
lb/A	lb/A	bu/A	mg/L
0	43	94	13
100	125	146	41
200	241	146	58

1/ October, 1976
2/ Flow-weighted average during 1977

Time of Application and Crop Sequence

Time of N application is important in increasing N efficiency and reducing potential N loss because a shorter time interval between fertilizer application and maximum crop uptake reduces the probability of loss due to either leaching or denitrification. For this reason and others, many corn growers throughout the Corn Belt are returning to spring and early summer applications.

Studies conducted at the Southern Experiment Station, Waseca using ammonium sulfate clearly show both a yield and environmental advantage for the spring preplant application compared to the late-fall, plowed down application (Table 4). Corn yields over the five-year period were increased by 15 and 5% with spring application at the 120-lb and 180-lb rates, respectively. Spring application of N also reduced NO_3^- losses to the tile lines by about 30%. The 180-lb N rate maximized corn yield but also resulted in higher NO_3^- losses thru the tile lines. Continuous soybeans lost as much NO_3-N in the tile water as the average of the two 180-lb N treatments applied to corn. These data clearly indicate (1) an advantage for spring application of N and (2) substantial N can be lost thru the tile lines when soybeans are grown continuously.

Table 4. Corn and soybean yields and NO_3-N lost thru the tile lines as influenced by N rate and time of application at Waseca.

Crop	N Treatment Rate	N Treatment Time	Five-year Avg. Yield	Four-year NO_3-N lost thru tile lines
	lb/A		bu/A	lb/A
Corn	0	----	66	28
"	120	Fall	130	107
"	120	Spr.	150	75
"	180	Fall	159	136
"	180	Spr.	167	106
Soybeans	0	----	44	119

Conservation tillage

Conservation tillage practices are becoming commonplace for a number of reasons, one of which is to reduce water runoff and subsequent erosion. It then follows that a greater proportion of the precipitation will infiltrate into the soil and perhaps percolate thru the soil. It seems reasonable that as the volume of percolating water increases, the likihood of NO_3^- leaching increases. For this reason some speculate that conservation tillage may in fact increase NO_3^- losses to the groundwater. Data to address this hypothesis are limited.

Tile drainage plots at the Southern Experiment Station have been monitored to determine the effect of primary tillage on the NO_3-N concentrations and losses in the tile water, NO_3^- accumulation :n the soil profile, and crop yield. Nitrogen applied at 180 lb N/A as ammonium nitrate was spring-applied annually to continuous corn on this clay loam site. Data from the 5-year period (1982-86) indicate little difference between the moldboard plow and no tillage systems for either total tile drainage or NO_3-N losses (Table 5). Additional years will be needed to determine if thrs effect changes over time. Moreover, numerous studies will need to be conducted over a wide range of soil permeability levels with various tillage systems before this question is answered satisfactorily.

Table 5. Effect of primary tillage on corn yield, tile line drainage and NO_3-N lost through the tiles from 1982-1986.

Parameter	Tillage: Moldboard Plow	Tillage: No Tillage
Avg. grain yield (bu/A)	134	127
Total tile discharge (acre inches)	57	61
Total NO_3-N lost in tile (lb/A)	137	149
N lost via tile lines as a percent of applied N (%)	15	17

Randall & Kelly, 1987

These studies on fine-textured soils indicate that NO_3^- can move out of the plant root system by leaching below the maximum rooting depth and/or through tile water discharge. In addition, significant losses of N can occur via denitrification on these soils. The proportion of NO_3^- lost by leaching to that lost by denitrification will depend on water flow characteristics of the soil, soil organic matter level, depth of NO_3^- in the soil profile, and soil temperature.

Future Research Activity

Soil fertility research in the next 10 years must address the environmental aspects of N management as well as economic issues. This research will need to examine more closely the effects of N rate, time of N application, nitrification inhibitors, animal manure, crop rotations, and legume-fixed N. It is important that information on soil water, N accumulation/movement through the profile, total plant uptake of N, other soil physical parameters, and weather be gathered in addition to crop yields. Only through this detailed data base will we be able to assess both the economical and environmental effects of agricultural practices at the experimental sites. These data will allow the development of models to predict the effects over a wider range of soils and growing conditions.

Educational Opportunities

The current public concern and confusion over agricultural impacts on groundwater quality will demand strong, broad-based educational programs. These programs must be delivered by both extension and industry. Those involved in these educational endeavors will need: a) a clear and objective understanding of the situation, b) patience because of the wide background of the audience, and c) an understanding of the ethical considerations raised by those with preformed attitudes.

This educational challenge will need to cover a much broader range than the customary farmer and dealer. We will need to direct more attention to the consultants, leaders, and urban public including the clergy and teachers.

Regulations on the usage of N fertilizers are not just idle talk but are a reality. We will need to develop precise research projects, with clear interpretations of data coupled with effective educational programs to aid in regulation development. That will be the challenge of the next decade.

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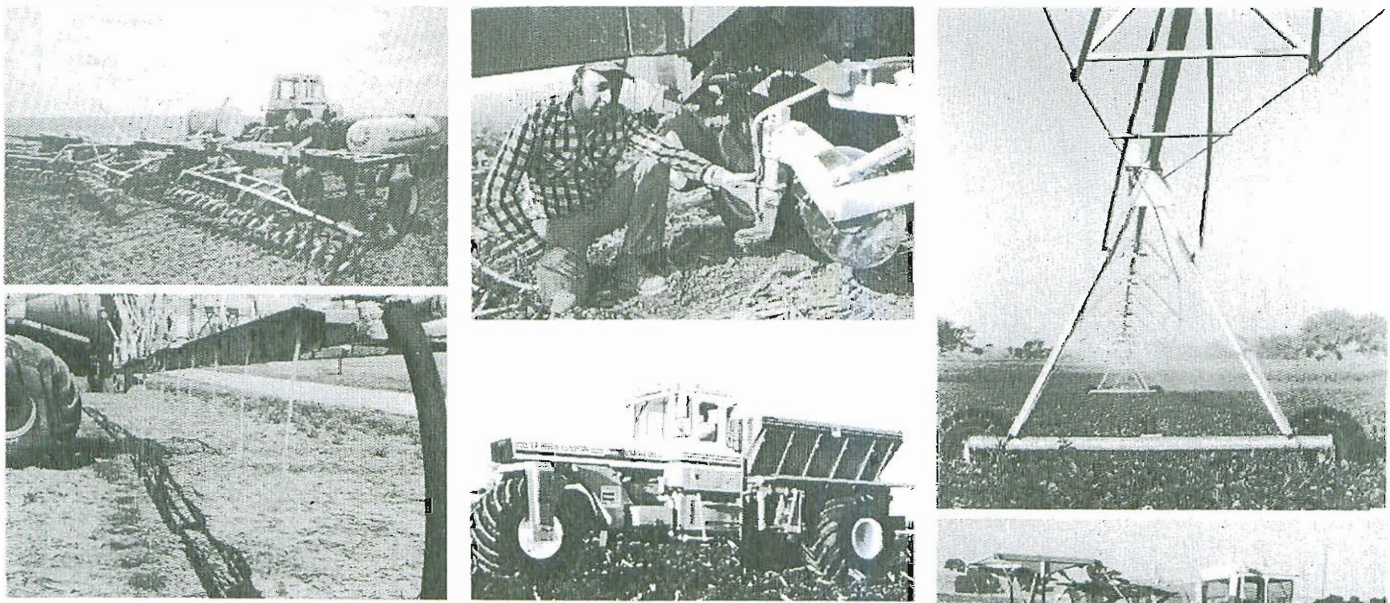

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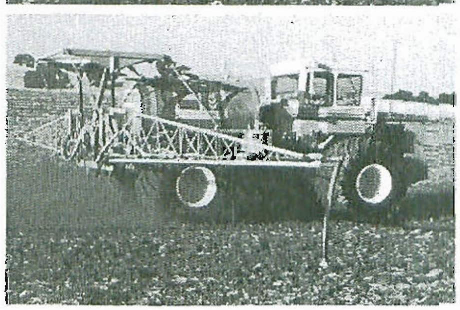

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