ASSESSING THE SOURCE OF GROUNDWATER NITRATES: AND YOU THOUGHT GOOD WINE TOOK TIME

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ABSTRACT

Controversy continues with elevated groundwater nitrate concentrations being attributed to N fertilizer use. Current research defining best management practices in farming system N management seldom addresses the influence these practices have on groundwater. Why? The results of this Missouri research show that the influence of management on groundwater nitrates may last for decades. The study provides support for time requirements when assessing farming system impact on groundwater quality.

INTRODUCTION AND OBJECTIVES

At the 1991 North Central Extension-Industry Soil Fertility Conference numerous research results were presented on N fertility management and techniques for monitoring crop N needs. Nitrogen fertilizer management continues to be of great interest as evidenced by the amount of research presently being conducted. This, in part, can be attributed to increased public awareness that N fertilizer use may have an impact on groundwater quality. The "smoking gun" association given to groundwater nitrates coming from N fertilizers stems primarily from the widespread use of N fertilizers in agriculture and the numerous groundwater surveys that have been conducted in agricultural regions over the past decade. The surveys mostly come from groundwater wells that have been constructed for purposes of domestic and livestock use. The results of water analyses from these wells can be misinterpreted because all possible contaminant sources are not considered, nor can they be evaluated. At the same time, the cost of constructing wells for monitoring field-scale farming activities on groundwater is generally prohibitive. Therefore, existing wells have been the only choice for groundwater quality assessment. The most accurate assessment of farming practices on water quality can only be accomplished when wells are constructed within fields. Even then, the assessment requires a knowledge of water flow underneath a field and a consideration of the influence of adjacent fields.

A primary objective of the Management Systems Evaluation Areas (MSEA) Program is to evaluate farming systems through assessment research. Wells constructed during 1990 and 1991 at each of the MSEA sites were constructed specifically for groundwater assessment of farming systems. In Missouri, our focus is on the assessment of farming system impacts on a shallow

aquifer underlying a claypan soil. What have we learned thus far regarding farming systems and nitrates? The purpose of this paper is to provide some points that help to illustrate the difficulty and challenge of making a quick assessment of farming systems and N fertilizer use on nitrate concentrations in groundwater.

METHODS

The research area is a 28-square mile watershed in North Central Missouri near the town of Centralia. Shallow wells were drilled to varying depths from 10-60 feet on each of three fields within the watershed in early 1991. Well construction was done carefully with appropriate cement and bentonite seals above the well screen. These three fields and the accompanying wells serve as the basis for doing groundwater quality assessment of three different farming systems. The three farming systems vary in N management. Farming systems 2 and 3 use 47% and 30% less N fertilizer, respectively, than farming system 1. Fields were selected based upon similar soils and topography, appropriate ground and surface water monitoring sites, and a comparable most recent 10-year cropping history. The research area is characterized as a dissected till plain from pre-Illinoian glaciers. Covering the glacial drift is a mantle of Illinoin and Wisconsin loess. Soils are predominately of a Putnam-Mexico soil association and are characterized by a Bt horizon that commonly impedes drainage during winter and early spring, but will also crack and allow for rapid water movement during dry summer and early fall months. Average annual precipitation is about 36 inches. Groundwater samples were taken prior to initiation of the MSEA farming systems and have been sampled quarterly since then.

RESULTS AND DISCUSSION

From the first sampling in the spring of 1991, groundwater nitrate-N concentrations were quite different between the three fields (Fig. 1). Groundwater from fields 1 and 2 have similar nitrate concentrations with depth, but field 3 has nitrate concentrations nearly twice that of the other two fields. Why is there such a difference between these fields? Are these differences in nitrate concentrations due to differences in hydrologic properties between fields, or could they be the result of different management practices prior to the 10-year period used to select

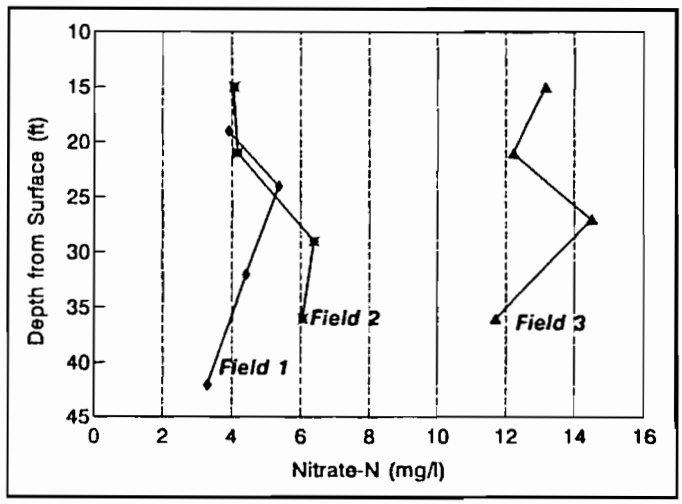

Figure 1 Average concentration of water nitrate-N with depth for three Missouri fields

fields? These questions deserved our attention since our hypothesis that water quality under the three fields would be similar was rejected when considering nitrate concentrations.

Historical Information

Historical information on the three fields was general since most of information obtainable was based upon memory of those who had either owned or operated on those fields. Table 1 gives an outline of information that was obtained through interview. All three fields have a history of being farmed by both owner and lessee. Of the three fields, field 3 has more years of owner operation than the other two fields. Cropping has varied tremendously over the last 30 years. During the 1980's, soybean and wheat were the most common crops grown on the three fields. Fields 1 and 2 had a few years of grain sorghum. During the 60's and 70's corn was grown less than 20% of the time on field 1 and 2 but about 50% of the time on field 3. Nitrogen fertilizer rate was reported to be similar between fields, thus the main difference was in intensity of corn-years. This 20-year period corresponds with a period of increasing N fertilizer use in corn production in the Mid-West. Based on number of corn-years, it is likely more N fertilizer was applied on field 3 during this period than on either of the other 2 fields.

The most significant contrast between the 3 fields comes from observing the historical record on use of animal manures or allowing animals to graze on crop residues following harvest. Again, little difference exists on the fields during the last 8 to 10 years. Prior to that time field 3 was used extensively for over-wintering of livestock and for manure application during most years between 1930-1981. The exception was an 8-year period during the late 60's and early 70's when no animals were confined nor manures applied on field 3.

What does this all mean? Although no direct cause-and-effect relationship can be established, this information would suggest that the differences that exist in nitrate-N concentrations in groundwater beneath these three fields now could have been the result of varied management practices that occurred prior to 1980. If this is true, nitrates found in groundwater in the 1990's may be the result of over supplementing crop N needs with a concurrent application of both manures and N fertilizer from a period between 10 and 60 years earlier.

Nitrate Source

Attributing groundwater nitrates to fertilizers or manures or some other source or combination of sources is difficult. One method that has been used with mixed results is analyzing for ^{15}N and calculating $^{15}N/^{14}N$ values. The theoretical basis of this technique is that $^{15}N/^{14}N$ values change depending on whether the N comes from soil organic matter, fertilizer, or

Table 1. Historical sketch of three Missouri fields selected for groundwater assessment. Years and fractions, in most cases, are estimates.

Management Parameters	Field 1	Field 2	Field 3
Land User	1930-60 owner 1961-77 lessee 1 1978-86 lessee 2 1987-90 lessee 3	1930-60 owner 1961-90 lessee	1930-66 owner 1966-74 lessee 1975-90 owner 2
Cropping	Cultivated through most of the 1900's. 1930-60 ? 1961-77 soybean (.9), corn(.1) 1978-86 soybean (.5) sorghum (.4) wheat (.1) 1987-90 soybean (.4) sorghum (.3) wheat (.3)	Cultivated and pastured through 1900's 1930-60 ? 1961-80 soybean (.4) wheat (.4) corn (.2) 1981-90 soybean (.5) wheat (.4) sorghum (.1)	Cultivated through most of the 1900's 1930-60 corn (.7) oats (.2) wheat (.1) 1961-80 corn (.5) soybean (.3) wheat (.2) 1981-90 soybean (.5) wheat (.5)
Animals/Manures	1930-60 ? 1961-80 animal operation near, < 50 animals, little or no manures on field 1981-90 no animals, no manures	1930-76 north end of field pastured little or no manures on field 1977-90 no animals, no manures	1930-66 over-wintered cattle, sheep, hogs (100s), a few years feeders were drug into field, manures from two feedlots 1967-73 no animals, no manures 1974-81 over-wintered cattle (100s), manures from feedlot 1982-90 no animals, no manures

manures. Water samples from these fields are being analyzed for ^{15}N but are not available at this time.

Hydrologic measurements have also been conducted on the wells from the three fields. To date, no clear difference has been found to help explain the contrast in nitrate-N concentrations.

Will It Change?

Since the first sampling during the spring of 1991, most wells on the 3 fields have remained fairly stable in their nitrate-N concentration. However, based upon the year and a half worth of quarterly sampling, some wells on field 3 seem to be decreasing in nitrate-N concentration at a very slow rate. Crude estimates from this short period would suggest that a minimum of 5-20 years of similar nitrate-N concentration decline would be needed in order for field 3 to compare to the other 2 fields as they are today. This is further reinforced when comparing the concentrations of nitrate in the solid material of the aquifer. Averaged over a depth of 10 to 50 feet, nitrate-N are about 4 mg/kg of material for fields 1 and 2, and about 8 mg/kg of material for field 3. We hypothesize the loess and glacial till on field 3 have stored a great deal of nitrate and now are acting as a buffer to rapid change in groundwater nitrates.

The time requirement for a newly imposed farming system to express effects on groundwater is obviously very site specific since it will be strongly related to the soil and aquifer matrix. A sandy alluvial aquifer will not behave as the glacial till aquifer described here. If farming system assessment on groundwater quality is to include insitu groundwater wells, time (even on the order of decades) has to be recognized as essential.

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