Groundwater Impacts of Potato and Vegetable Production

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The leaching of agrichemicals to groundwater is a major source of nonpoint groundwater pollution (Hallberg, 1986) and an issue of "great public concern" (US Congress Office of Technology Assessment, 1990). And though Wisconsin has made great strides in eliminating or reducing groundwater impacts from sources like landfills, wastewater disposal, hazardous waste facilities, and leaky underground storage tanks, little progress has been made with agrichemicals.

The reasons for this are not obscure: we may be able to leakproof a petroleum storage tank, eliminate some hazardous chemical in manufacturing, or treat wastes which may pollute the environment if released indiscriminately. But how can we leakproof a farm field? eliminate nitrogen? treat water leaching through soil? More so than for any other groundwater problem, the issue of agrichemical impacts on groundwater quality is complex and challenging.

Extent of Agrichemical Groundwater Pollution

Information on the extent of agrichemical groundwater pollution is somewhat sketchy and difficult to interpret. However, some recently available information helps paint a general picture of its nature and frequency.

US situation

The USEPA (1990) conducted a national survey in the late 1980s for pesticides and nitrate in drinking water wells (Table 1). The study found a surprisingly high percentage of wells contained at least one pesticide (about 10 of community and 4% domestic wells). Equally

Table 1. Results of USEPA national survey for pesticides and nitrate.

Pesticides	Percent of wells
Community wells with at least one pesticide	10.4
Domestic wells with at least one pesticide	4.2
Domestic wells exceeding Health Advisory Level	0.2
Domestic well exceeding Maximum Contaminant Level	0.6
Nitrate-N	
Community wells exceeding 10 mg L^{-1}	1.2
Domestic wells exceeding 10 mg L^{-1}	2.4

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surprising was the low incidence of exceedences of the nitrate standard (10 mg L^{-1}), about 1-2%.

Wisconsin situation

Though a systematic study of agrichemicals in Wisconsin groundwater similar to that of EPA's national study has not been performed, data are available to depict a general picture of the situation in Wisconsin. The picture appears gloomy compared with the US as a whole.

Nitrate in Wisconsin wells. A substantial amount of nitrate testing data is available from the Central Wisconsin Groundwater Center database. The database contains about 22,000 NO_3-N analyses from domestic well samples mainly submitted through county Extension offices. These data (Table 2) indicate that the NO_3-N standard (10 mg L^{-1}) exceedence rate for Wisconsin as a whole is roughly 10%. However, a great disparity exists between what might be termed more agricultural counties and less agricultural counties. Less agricultural counties have NO_3-N exceedence rates of about 1-3% (close to the national average), compared to 10, 15, or even 19% in more agricultural counties. The 1-3% exceedence rate in less agricultural counties might represent the typical expected contribution of nonagricultural sources (e.g., septic systems and lawn fertilization). An interesting aside is that the exceedence rate in some agricultural counties with thick and heavy soils, such as Brown and Winnebago, is relatively low.

Table 2. NO_3-N exceedence rates for samples taken from domestic wells; selected counties (Source: Central Wisconsin Groundwater Center database.)

County	Number of records	% exceeding 10 mg L^{-1}
	More agricultural	
Brown		4.0
Juneau		13.5
Pierce		17.6
Portage		19.0
Sauk		14.0
Trempeleau		17.6
Waushara		10.9
Wood		6.4
	Less agricultural	
Lincoln		2.2
Oneida		4.7
Sawyer		1.5
Taylor		2.6
Vilas		1.2

Pesticides in Wisconsin wells. The only broad pesticide sampling program performed in Wisconsin is for atrazine residues. These data show that about 30% of sampled wells contain atrazine residues, with 17% of wells exceeding Wisconsin's Preventive Action Limit and 2.5% exceeding the

Enforcement Standard (J. Postle, Wisconsin Dept. of Agriculture, Trade, and Consumer Protection, pers. comm.; 1994). The detection rate for this pesticide alone is substantially greater than US detection rate for all pesticides.

Wisconsin potato/vegetable growing areas

Since no systematic nitrate and pesticide sampling has been done for vegetable growing areas of Wisconsin, an alternative way is needed. One way to discern the agrichemical impacts in potato/vegetable growing areas is to examine the nitrate standard exceedence rates for some potato and vegetable growing townships. Table 3 contains NO_3-N standard exceedence rate for some such townships in central Wisconsin. The exceedence rates in these townships, which sometimes exceeds 40%, is much higher than the national rate and the rates for Wisconsin agricultural counties taken as a whole (Table 3).

Table 3. NO_3-N standard exceedence rates for samples taken from domestic wells; selected vegetable growing townships (Source: Central Wisconsin Groundwater Center database.)

Township	Number of records	% exceeding 10 mg L^{-1}
Almond	98	44
Buena Vista	32	38
Plover	351	23
Port Edwards	140	10
Saratoga	72	16
Stockton	106	26

US domestic wells		2.4
Typical Wisconsin agricultural county		8-19

Agrichemical Leaching Under Irrigated Potato and Vegetables

Testing data from domestic wells indicates that the groundwater of potato/vegetable growing areas of Wisconsin is impacted by agrichemicals. But we know little about how agrichemicals are leached to groundwater below fields, and how we can improve practices or take other management steps to reduce groundwater impacts. We have been monitoring groundwater under four irrigated fields in central Wisconsin with a view toward filling these information gaps. This effort is still in progress, so the results represent information available to date. The work is a cooperative effort between two potato/vegetable growers, county conservation and Extension staff, UW-Extension Nutrient Pest Management Program, and UW-Extension Central Wisconsin Groundwater Center. The interest and cooperation of the growers has been commendable.

Study fields and instrumentation

Three study fields are 103-134 acres and the fourth is 30 acres (Fig. 1) Local geology consists of 59-89 ft of medium sand with a 3-ft thick silt and clay unit occurring 20-26 ft below grade. Soils are the

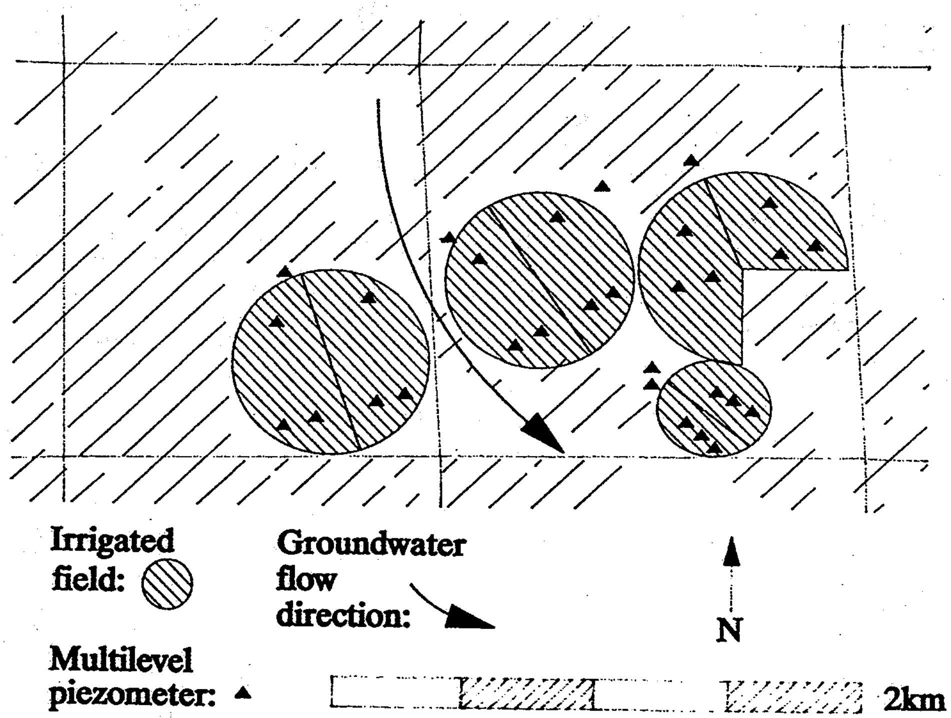

Fig. 1. Location and instrumentation of study fields.

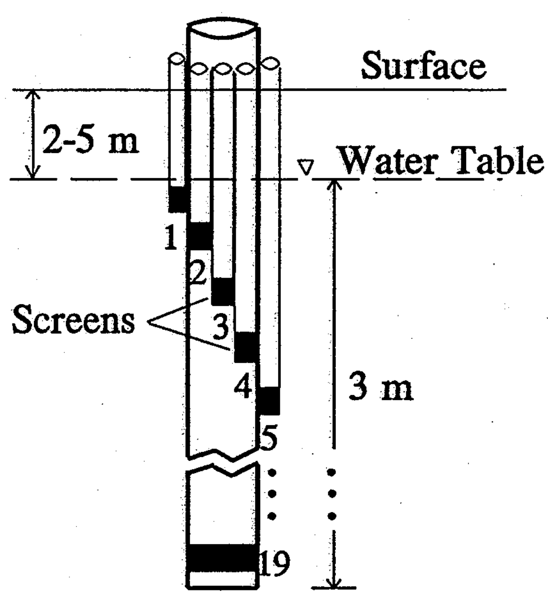

Fig. 2. Construction of multilevel piezometers.

Plainfield sand and Friendship loamy sand (Typic Udipsamments). Groundwater flows at about 1 ft d^{-1} generally from the northwest to southeast (Fig. 1). The water table occurs about 5 ft deep in the northwest and 16 ft deep in the southeast.

The fields were split in two along a groundwater flow-line. Conventional and Best Management Practices are being implemented on opposite sides of the split. Groundwater quality is being monitored by three multilevel piezometers (Fig. 2) installed in each half-field ("in-field" piezometers), and 1-2 multilevel piezometers installed upgradient of each field ("upgradient" piezometers). Multilevel piezometers are special types of groundwater monitoring wells. Ours consist of 18-0.25 in. i.d. polypropylene tubes attached to a 32 mm (1.25 in.) PVC pipe. Each tube terminates in a screen 6, 8, 10, or 16 in. long while the PVC pipe ends in a 10 in.-long screen. The screens cover a collective, continuous span of 10 ft (Fig. 3), from 9.8 ft below the water table (on the date of installation) to 15 in. above the water table. Screen above the water table was designed to help accommodate water table rises.

Groundwater monitoring

Groundwater is sampled from the multi-level piezometers at 2-week to 2-month intervals, depending on season. Sampling parameters include pH, specific conductance, temperature, NO_3-N, Cl, alkalinity, Ca, Mg, Na, K, Fe, Al, SO_4, and pesticides. Twenty-one sampling rounds (Jan. '92 - Jan. '94) have been completed to date. During most rounds, samples are obtained only from alternate ports. The pH, specific conductance, temperature, NO_3-N, Cl are analyzed on each sampling round. Pesticide and more complete inorganic analyses are conducted infrequently at a limited number of multi-level piezometers.

Samples are collected by suction from the surface using a multichannel peristaltic pump. Sample collection, filtration, preservation, and analysis proceeds by standard, state-approved methods in a certified laboratory.

Results

Profile of groundwater chemistry under irrigated fields. Fig. 3 shows a typical profile of NO_3-N, and Cl at one of the in-field multilevel piezometer locations. The piezometer at this location is measuring the quality of groundwater that recharged solely from precipitation falling on this field. Water that recharged from further upgradient is passing below the bottom screen on the multilevel piezometer.

Note that the concentrations of chemical constituents are not constant. For instance, NO_3-N values have a range from about 18 to over 30 mg L^{-1}, with an average of about 25 mg L^{-1}. The sinuous concentration/depth curve is not an accident, but rather reflects the transport processes that moved precipitation and dissolved chemical constituents from the soil surface, to and below the water table. We interpret the pattern in Fig. 3 to contain two distinct arrivals of Cl, one originating as KCl fertilizer applied in the spring of 1991, and the other originating as KCl applied in 1992. Hence, the Cl minimum at about 100 cm below the water table demarcates the boundary between the two Cl arrivals. We postulate that most of the NO_3-N in Fig. 3 between 50 and 250 cm below the water table is from N applications made in 1991. The NO_3-N mass under the curve is equal to about 120 lb/acre, or roughly half the N applied in that field in 1991.

Profile changes over time. The groundwater chemistry profile changes with time, rather than remaining stationary. Fig. 4 (which displays only some of the available data) clearly shows the arrival of 1992 recharge water, beginning with an increase in Cl concentrations in

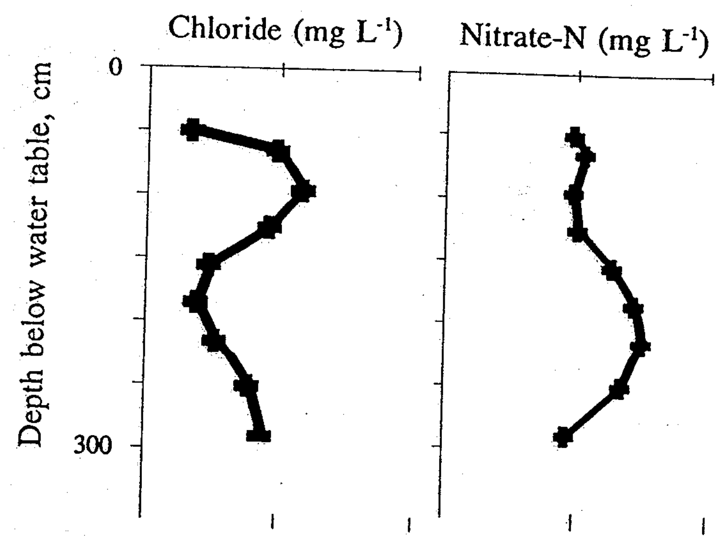

Fig. 3. Profiles of NO_3-N and Cl at one multilevel piezometer location.

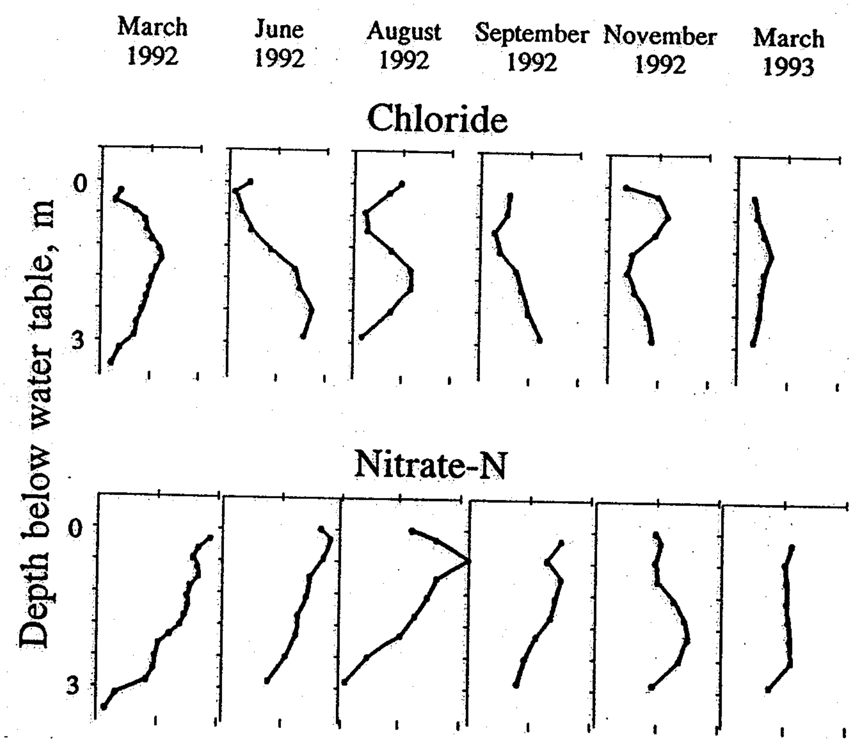

Fig. 4. Time series of NO_3-N and Cl profiles at one multilevel piezometer location.

June, 1992. Breakthrough of the Cl plume is complete by November. Apparently, 1993 recharge and dispersion processes in the aquifer have smeared the concentration profile by March, 1993.

Comparisons of upgradient and in-field groundwater quality. Results indicate marked differences between gross chemistry and agrichemical content in upgradient piezometers (which reflect background conditions) and in-field piezometers, both in terms of gross chemistry and agrichemical content. For instance, the pH is typically about 5.5 upgradient compared to about 5.0 in-field. More significantly, alkalinity decreases from about 15 mg L^{-1} ($CaCO_3$ equivalent) upgradient to less than 5.0 in-field. Solute content is markedly greater in-field, as indicated by specific conductances of 375 μS/m vs. 100 at upgradient piezometers. Average Ca concentrations were 23.4 mg L^{-1} at in-field locations compared to 7.2 mg L^{-1} upgradient. Other comparisons are Mg, 11.2 and 1.4; K, 20.0 and 0.62; and Cl, 13.2 and 2.5 mg L^{-1}.

Pesticides. Atrazine, de-ethyl atrazine, alachlor, metolachlor, metribuzin, and carbofuran were detected in groundwater below fields. Atrazine was detected at 3 of 4 fields, de-ethyl atrazine at 4 of 4 fields, metribuzin at 3 of 4 fields, metolachlor at 2 of 4 fields, and carbofuran at 2 of 4 fields. Pesticide concentrations were always below the Wisconsin Groundwater Enforcement Standard and generally less than 1 μg L^{-1}. Those detected substantially higher than 1 μg L^{-1} include metolachlor, detected as high as at 11 μg L^{-1}, and carbofuran, detected at 12 μg L^{-1}. Many of the pesticide detects were deeper in the groundwater, indicating they largely entered groundwater sometime prior to 1992.

Conclusion

Both agriculture and groundwater are vital to Wisconsin. The limited available data indicate that Wisconsin's groundwater is more severely impacted with agrichemicals than the nation's as a whole, and that groundwater in potato and vegetable growing areas of central Wisconsin is more agrichemically impacted than agricultural parts of Wisconsin in general. Ultimately, better information is needed to better manage Wisconsin's groundwater quality as well as to improve agricultural practices to minimize groundwater impacts.

Acknowledgement

We thank the cooperating growers for their help in improving groundwater quality and the science and art of agriculture in Wisconsin. The growers have provided more than access to their fields and records; they've taken risks by adopting new Best Management Practices, been patient with researchers and graduate students, and contributed to the education of neighbors. This project would not be possible without their time and assistance.

Literature Cited

Hallberg, G.R. 1986. Overview of agricultural chemicals in ground water. In Proceedings of the agricultural impacts on groundwater conference. Aug. 11-13, Omaha Nebraska. Water Well Journal Publishing Co., Dublin, OH.

USEPA, 1990. National pesticide survey phase 1 report. Washington D.C. EPA570/9-90-015.

USOTA (United States Office of Science and Technology Policy), 1990. Beneath the bottom line: agricultural approaches to reduce agrichemical contamination of groundwater. OTA-F-418. US Government Printing Office, Washington, D.C.