DISTRIBUTION, SOURCES AND FATE OF ATRAZINE IN A SANDY-TILL AQUIFER

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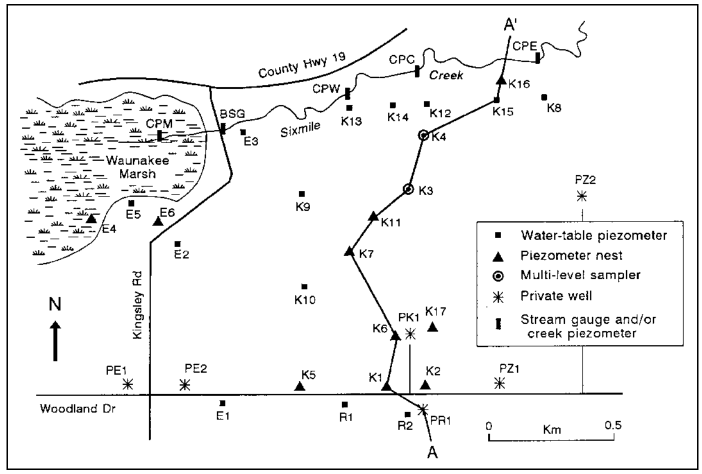
ABSTRACT

A field study around an atrazine-contaminated private dairy-farm well examined sources and extent of groundwater contamination from atrazine and its metabolites in a shallow glacial till aquifer. The shallow groundwater system is dominated by downward vertical hydraulic gradients and water from the till aquifer discharges to the bedrock aquifer. Where downward gradients exist it is possible to predict travel time (TT) and mean horizontal distance traveled (MHD) to various monitoring wells. The MHDs to many wells are small, and atrazine residue concentrations result from pesticide handling nearby. According to the TT estimates it takes decades to reach some deeper wells. Tritium ages suggest that part of the water at contaminated wells is > 7 yr old even in wells screened near the water table. Long TTs indicate that responses of groundwater quality to atrazine restrictions will be slow. Distribution of contamination signaled point and nonpoint sources. For atrazine and three metabolites, there were widespread detections, with highest concentrations near pesticide handling areas. If this site is typical, the inclusion of chlorinated metabolites in Wisconsin's groundwater standards for atrazine will increase standard violations and regulatory action. Concentrations of atrazine and desethylated atrazine in water from monitoring wells decreased with increased TTs to those wells. No increase occurred with TT of desethylated atrazine relative to parent compound, indicating that both undergo dissipation. Degradation of atrazine to desethylated atrazine (DEAT) is not a major pathway in groundwater. Evidence exists of increased desisopropylated atrazine (DIAT), and diamino-chloro-s-triazine (DIAM) relative to atrazine and DEAT concentrations with increased TT suggesting that microbial degradation may occur in groundwater. Other dissipation pathways include hydrolysis to the strongly sorbed hydroxyatrazine, irreversible sorption, mechanical dispersion, and chemical diffusion.

TECHNICAL SUMMARY

INTRODUCTION: Groundwater quality surveys by the Wisconsin Department of Agriculture, Trade and Consumer Protection (WDATCP) showed contamination of private drinking water wells by atrazine residues. In Wisconsin little atrazine research has been performed on fine-textured soils in the field. This 2.5-yr study was initiated in June 1989 to find the distribution of atrazine and metabolites (atrazine residues) in the shallow groundwater overlying a bedrock aquifer. Three metabolites were given regulatory significance in 1992 when included in Wisconsin's groundwater standards for atrazine. When total concentrations of the 4 compounds exceeds the enforcement standard (ES) of 3.0 ppb or the preventive action limit (PAL) of 0.3 ppb, regulatory actions are triggered. If data from this site are typical, inclusion of metabolites in groundwater standards has serious implications for regulating atrazine use.

METHODS: Fifty-five groundwater sampling points were installed at 25 locations (Figure, next page). Nested piezometers and multilevel samplers were used to measure water quality with depth. During well installation, drilling samples were peeled from the augers at 1.5-m intervals, characterized and analyzed for grain-size, organic matter content, and pH. Geology was investigated by interpretation of private well logs and previously existing geologic maps. Nested pairs of polypropylene piezometers were installed at four locations in Sixmile Creek and Waunakee Marsh -- CPM, CPW, CPC, and CPE -- to determine whether ground water is moving to or from the creek. Wells and multilevel ports were sampled monthly or bimonthly (in winter) from October 1989 to June 1992. Water was sampled at least twice from 5 private wells and analyzed for atrazine residues. Residues in groundwater were determined by chromatographic analysis. Methods through February 1992 allowed acceptable quantification of atrazine and DEAT. Methods used from April through June 1992 allowed quantification of DIAT and DIAM. At various times 3 extraction procedures were tried. Because atrazine residue concen-tration trends and averages are of interest, the extraction methods were compared so that all concentrations could be standardized.



SITE HYDROLOGY: The shallow aquifer is in sandy glacial till. The deposits are yellow-brown calcareous gravelly sandy loam or loamy sand. Typical till grain-size distribution is 65 to 75 % sand, 15 to 30 % silt, and 1 to 15 % clay. Lenses of sandier material (as high as 97 % at 2.5 m depth) were observed. Sand lenses are glacial outwash deposits found only above the water table. Hydraulic conductivity data, however, indicate that sand lenses exist below the water table. Some samples contained higher silt and clay contents than are typical for Horicon till which may indicate clay lenses or a deeper soil column at these locations. Till thickness ranges from 4.6 to 30 m. Underlying the till is Cambrian sandstone above Precambrian rhyolite, granite and basalt. Average thickness of the sandstone is 210 m. There are two drumlins aligned SW-NE; the larger one rises 308 m above mean sea level and is topped with 7 m of soil and till over Prairie du Chien dolomite. It is the only place in the monitoring area where Ordovician Prairie du Chien bedrock remains. The potentiometric surface maps indicate a regional groundwater divide located 5 to 7 km northwest of the site which separates groundwater flowing east and south into the Yahara River basin and north and west to the Wisconsin River. Regional flow through the bedrock aquifer is southeasterly with a gradient of 0.0033.

RESULTS: Atrazine contamination was originally discovered in water from private well PK1. The Waunakee field study was initiated around that well to investigate extent of atrazine residue contamination in the shallow glacial till aquifer. Most of the field area is dominated by downward vertical hydraulic gradients, so that much of the water in the till aquifer discharges to the bedrock aquifer below. Although atrazine residues are widespread, concentrations are highest at K6, near PK1. The high concentrations and low concentration ratio of DEAT:atrazine (DAR) relative to most wells may indicate point-source contamination, especially since K6 is closest to the pesticide handling area. Whatever is responsible for the high concentrations at K6 is responsible for contamination at K17 and PK1. Though high, residues at K6 could result from normal field practice. Although evidence of point-source pollution exists, most groundwater residues arise from normal field applications; atrazine plus DEAT concentrations are generally < 1.0 ppb, with DAR > 1, although 1992 detections of DIAT and DIAM indicate contamination is more severe. The current ES and PAL of 3.0 and 0.3 ppb, including atrazine and 3 metabolites, have increased groundwater standards violations.

DISCUSSION: The relationships between groundwater TTs and residue concentrations give insight into atrazine fate in the aquifer. Atrazine and DEAT concentrations decrease with time spent in the aquifer indicating microbial degradation, but no evidence exists of atrazine degrading to DEAT. Other dissipation pathways must account for decreases of both compounds. Preliminary analyses from 1992 indicate that concentrations of DIAT and DIAM increase with aquifer TT and some microbial degradation is occurring. Age of the water and residues at some wells (as much as 24 yr), and the slow dissipation rates of atrazine residues, imply that the benefits of atrazine prohibition may not be observed for many years. Even if atrazine input to groundwater were to cease, it would be decades before groundwater concentrations dissipate to levels below those of regulatory concern. Also, DIAT and DIAM might cause greater contamination problems since their concentrations do not decrease with increased TTs.

PROJECT INFORMATION: This summary (Number 042), along with 4 others in this Site's Listing (Numbers 054, 051, 038, and 019) are all based on sequential research conducted between 1988 and 1993. The continuation project was supported in part and at different times by General Purpose Revenue Funds of the State of Wisconsin through the Wisconsin Departments of Agriculture, Trade, and Consumer Protection, the Wisconsin Department of Natural Resources, and the University of Wisconsin System to the UW-Madison Water Resources Center (WRC). The project also received partial support from the U.S. Department of the Interior through the Geological Survey (USGS) to the WRC. The final technical reports for this project

have been published and are available on loan from the WRC Library as document call numbers 051063 and 140719. To request a document call (608) 262-3069, email the library at askwater@macc.wisc.edu, or visit us on campus at 1975 Willow Drive, Madison, WI 53706.