T.B. Moorman and D.B. Jaynes, USDA-ARS, National Soil Tilth Laboratory, 2150 Pammel Drive, Ames, IA 50011. Phone: (515) 294-2308. FAX: (515) 294-8125.

K. Jayachandran, Iowa State University, Department of Agronomy.

J.M. Novak, USDA-ARS, Coastal Plains Soil, Water, and Plant Resources Center, Florence, SC.

J. Miller, C.A. Cambardella, and J.L. Hatfield, USDA-ARS, National Soil Tilth Laboratory, 2150 Pammel Drive, Ames, IA 50011. Phone: (515) 294-2308. FAX: (515) 294-8125.

Summary

The landscape of central Iowa is characterized by low ridges surrounding closed depressions (potholes), which are often drained by subsurface tiles. Our objectives were to quantitate the amount of atrazine leaching through the soils in this landscape and to relate the leaching pattern to sorption and degradation processes. Atrazine concentrations in subsurface tile drain water were normally below 1 ppb with a maximum concentration of 12 ppb. Deeper groundwater samples were typically devoid of atrazine above the 0.2 ppb reporting limit. Atrazine sorption (binding to soil) was greatest in surface soils within the pothole and least in shoulder slopes and backslope soils. Atrazine sorption decreased with depth, but substantially more atrazine was sorbed to subsurface soils in the pothole than other subsoils. Atrazine was degraded in subsurface soils, but the rates were much lower than in surface soils. The greater capacity of the soils in the depressional areas to adsorb atrazine appears to retard atrazine leaching sufficiently that concentrations in tile drains remain small. Atrazine may leach through less sorptive soils on the shoulders and summits of the ridges surrounding the potholes and move laterally towards the tile drains. However, the longer flowpath to the tile drain in conjunction with subsurface biodegradation would reduce the impact of atrazine leaching at these landscape positions.

Project Description

Atrazine is widely used to control weeds and has been detected in surface and groundwater throughout the Midwest. Factors such as climate, soil, and tillage are known to affect herbicide movement in soil, but the interaction of these factors at the field or watershed scales were not clearly understood. This project examined the distribution of atrazine in soil and water at a field site within the Walnut Creek Watershed and investigated the factors which control movement into tile drain and shallow groundwater. Specific attention was focused on the processes of sorption (herbicide binding to soil), degradation, and transport of atrazine. This area is characterized by a shallow, rolling topography with many poorly drained areas and potholes. The soils are primarily mollisols formed over thick deposits of glacial till. The 12-acre study site is rotated with corn and soybeans with disking and cultivation. Herbicides are applied at relatively low rates by banding. An extensive tile-drainage network conducts both surface and subsurface water from fields into small streams. The site was instrumented for collection of tile drainage water and groundwater. Deep cores were also taken at selected locations to determine the relative degradation rates and microbial activity in these soils and sediments. In addition, 4-foot core samples were taken from fields at pre-application, post-application, during the growing season, and after harvest. Herbicides and degradation products were extracted from water and soil samples and analyzed by gas chromatography or high performance liquid chromatography (HPLC).

Results

Runoff moves atrazine and water into the two pothole areas in the study area, one of which is tile drained. Despite the input of atrazine in runoff, atrazine concentration in the tile drainage water was generally below 3 ppb and was related to rainfall events (Fig. 1). Most transport occurred in the spring and early summer. The atrazine transported from the field in tile drainage water accounted for 0.11% of applied herbicide in 1992 and 0.59% in 1993. Atrazine was not applied in this field in 1993 and the atrazine loss during this year was apparently caused by the extremely high rainfall flushing residual atrazine from the soil. At locations throughout the watershed, atrazine was detected in shallow well water, but the frequency of detection declined as well depth increased (Table 1).

Table 1. Atrazine in well water from 44 well nests in the Walnut Creek watershed sampled during 1992.

	Depth 0 - 5 ft	5 - 10 ft	10 -15 ft	> 15 ft
No. Samples	893	722	236	335
No. Detections	217	141	15	9
Detections (%)	24	20	6	3
No. > 3 ppb	10	5	0	0

Analysis of the spatial variability of soils and their properties revealed that atrazine sorption was greatest in soils with high organic matter. These soils are located in the pothole area of the field (Table 2). The greater binding (sorption) of atrazine by these soils slows herbicide movement into the tile drain, thereby allowing more time for degradation. Atrazine sorption could be estimated using a device which measures electromagnetic conductivity of the soil. Although this methodology needs further testing, it appears to have considerable potential for mapping herbicide sorption at the field scale.

Table 2. Adsorption of atrazine by soils in different parts of the landscape.

Landscape Position	Depth (in)	Organic C (%)	Sorption (Kd)	Sorbed to soil (%)
Shoulder	0-6	1.7	2.5	71
	16-43	0.26	0.5	33
	55-83	0.06	0.3	23
Pothole	0-6	4.5	7.7	89
	16-43	1.3	3.2	76

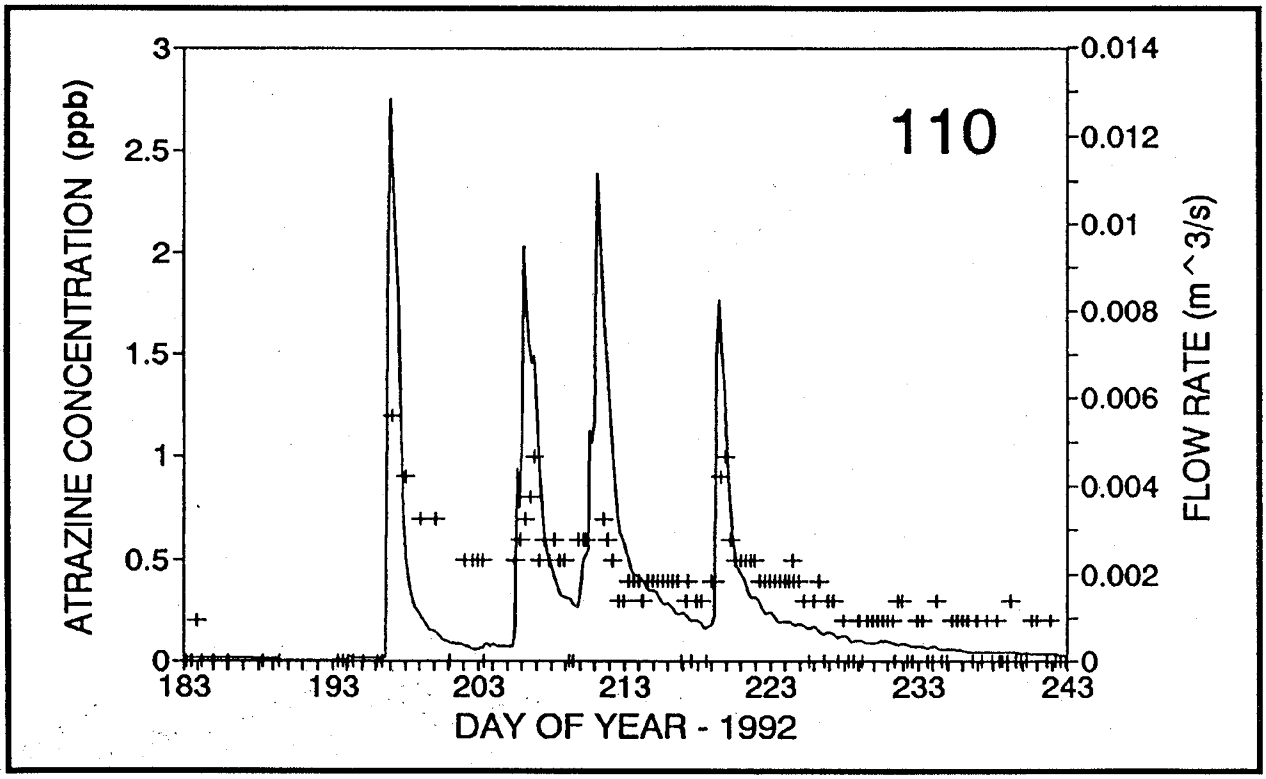

Figure 1. Atrazine concentration (ppb) and water flow (solid line) from a pothole tile drain in 1992. Individual storms appear as sharp peaks in water flow along with the associated increase in atrazine concentration.

Degradation rates also decreased in the subsurface sediments. In addition to dealkylation, forming desethylatrazine (DEA) and desisopropylatrazine (DIA), the atrazine ring is metabolized by soil microorganisms. Breakdown of the triazine ring accounts for 10 to 15% of the applied atrazine, compared to almost 50% which is irreversibly bound to soil in the form of atrazine or metabolites. As depth increases the population of atrazine-degrading microorganisms decreases, which reduces both ring breakdown and the formation of bound residues.

Although total bacterial populations were above 45 million cells/lb soil in the 16 to 43-inch depth, only 1% of this population was capable of atrazine degradation and atrazine-degrading populations declined in the deeper till sediments. Atrazine which is able to enter the deeper part of the profile (below 16 inches) persists for many months before degrading. The thick layer of glacial till, which separates the shallow groundwater from deeper aquifers which supply drinking water, is only slowly transmissive to water. Atrazine is apparently degraded or bound before it reaches deep drinking water aquifers.

Technology Transfer

The information gathered during the course of this project directly relates to the original objectives of the Management Systems Evaluation Area project. This and related studies show that conventional agricultural practices on glacial till soils, such as those at the Walnut Creek Watershed, are not a threat to groundwater aquifers which supply drinking water. We have identified the major routes of contaminant movement to be runoff and tile drainage. This knowledge is also prerequisite to the design of farm management practices which are economically viable with minimal environmental impact.

Public Affairs Activities

Information sources:

"Water Quality Colloquium and Field Tour, Research Updates from the Management Systems Evaluation Areas Project", July 19-20, 1994, Scheman Continuing Education Center, Ames Iowa. Sponsored by Iowa State University Extension.

"Word from Walnut Creek" (newsletter), Summer, 1994. Iowa State University Extension. Future editions are expected.

Walnut Creek Field Days. The dates for 1995 have not been announced.

Scientific reports:

Cambardella, C.A., T.B. Moorman, J.M. Novak, T.B. Parkin, D.L. Karlen, R.F. Turco, and A.E. Konopka. 1994. Field-scale variability of soil properties in central Iowa soils. Soil Sci. Soc. Am. J. 58:1501-1511.

Jayachandran, K., T.R. Steinheimer, L. Somasundaram, T.B. Moorman, R.S. Kanwar, and J.R. Coats. 1994. Occurrence of atrazine and degradates as contaminants of subsurface drainage and shallow groundwater. J. Environ. Qual. 23:311-319.

Jayachandran, K., T.B. Moorman, N. Stolpe, P.J. Shea, C.A. Cambardella, E.A. Douglass, and M.D. Jawson. 1994. Sorption and degradation of atrazine in soils and subsurface sediments from the American midwest. Abstracts of Eighth Intern. Cong. Pestic. Chem., p 865. Washington, D.C.

Jaynes, D.B., J.L. Hatfield, and P.J. Soenksen. 1994. Water and chemical transport in subsurface and tile discharge of Walnut Creek. Pages 430-445. A.R. Dutton (ed.) Toxic Substances and the Hydrologic Sciences. Am. Inst. Hydrol., Minneapolis, MN.