TRENDS IN ACETOCHLOR CONCENTRATIONS IN SURFACE WATERS OF THE WHITE RIVER BASIN, INDIANA, 1994-96

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Corn herbicides are used extensively in the White River Basin and account for about 70 percent of the total agricultural pesticide use in the basin. Acetochlor, a corn herbicide registered for use in 1994, is expected to reduce the total amount of corn herbicides used because of its broad-spectrum weed control and low use rates. Acetochlor is considered to be a probable human carcinogen, and its continued registration is contingent on concentrations in surface and ground water not exceeding target levels. During 1994, acetochlor was detected in only trace concentrations near the mouth of the White River and not at all in a small stream (93-square-mile drainage) in the northern part of the basin. By 1996, peak concentrations were about 2 and 3 micrograms per liter near the mouth of the White River and in the small stream, respectively. The estimated annual average concentration of acetochlor near the mouth of the White River in 1996 was 0.15 micrograms per liter, well below the 2 micrograms per liter criterion for surface-water supplied community-water systems.

INTRODUCTION

The U.S. Geological Survey, as part of the White River Basin study of the National Water-Quality Assessment Program, has been monitoring the concentrations of selected pesticides in surface water at several locations in the White River Basin. Acetochlor, a corn herbicide, was added to the list of monitored pesticides in 1994.

Acetochlor is used to control grasses and some broadleaf weeds in corn and was conditionally registered by the U.S. Environmental Protection Agency (USEPA) in 1994 (Stephen Johnson, U.S. Environmental Protection Agency, written communication, 1994). Because of the broad-spectrum weed control provided by acetochlor and low labeled use rates, the USEPA expects that use of acetochlor will significantly reduce total amounts of herbicides used in the United States (Stephen Johnson, written communication, 1994). The continued registration of acetochlor is conditional on targeted reductions in the use of the herbicides alachlor, atrazine, butylate, EPTC, metolachlor, and 2,4-D. Acetochlor has chemical properties similar to alachlor and metolachlor and has been classified by the USEPA as a probable human carcinogen. The registration of acetochlor will be cancelled automatically if 1) the targeted reductions in the use of other herbicides are not met, 2) the measured concentration of acetochlor in ground water consistently exceeds 0.1 microgram per liter at a large number of wells or exceeds 1.0 microgram per liter in ground water at a small number of wells, or 3) if the annual average concentration of acetochlor exceeds 2.0 micrograms per liter in the surface-water supply of a specified number of community-water systems.

This paper briefly describes trends in acetochlor concentrations during 1994-96 near the mouth of the White River and in a small, predominantly agricultural stream in the northern part of the basin. For comparison, concentrations of alachlor, atrazine, butylate, cyanazine, and metolachlor—the five most commonly used corn herbicides in central and southern Indiana in 1993—also are presented.

DESCRIPTION OF THE WHITE RIVER BASIN

The White River Basin is part of the Mississippi River system and drains 11,350 square miles of central and southern Indiana (fig. 1). The long-term average streamflow of the White River near its confluence with the Wabash River in southwestern Indiana is 12,300 cubic feet per second. Streamflow is typically highest in April and May and lowest in late summer and fall. Average annual precipitation ranges from 40 inches in the northern part of the basin to 48 inches in the south-central part and usually is distributed evenly throughout the year. The northern third of

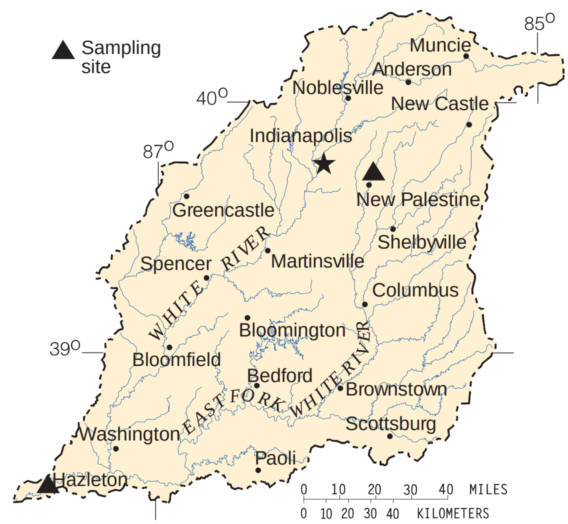

Figure 1. The White River Basin.

the basin is covered by 100 to 200 feet of silty-clay till interspersed with thin (5 to 10 feet) layers of sand and gravel and is characterized by low topographic relief. The relatively impervious till limits infiltration and promotes surface runoff. Tile drains are common in till-covered parts of the basin. The southwestern part of the basin typically is covered by 0 to 100 feet of loess (wind-blown silt), silty-clay till, dune sands, and lake clays overlying coal-bearing shales and sandstones. In general, soils in the southwestern part of the basin are more permeable and better drained than soils in the northern part. Drainage is poor, however, in southwestern parts of the basin where clay-rich deposits are prevalent and in low-lying areas where the water table is shallow. Where such conditions exist, drainage ditches and tile drains are common. The physiography of the rest of the basin is controlled by bedrock features, although the southeastern part of the basin is covered by a thin layer of glacial till. Soils in the southeastern part of the basin are generally highly erosive or poorly drained; subsurface drainage is difficult because tile drains tend to fill with silt. The south-central part of the basin is unglaciated and is characterized by a hill and valley landscape with higher relief than other parts of the basin. Bedrock outcrops are common in this region, and there is also an extensive area of karst characterized by numerous sinkholes and solution features. Soils are generally thin.

The primary land use is agriculture (fig. 2), which accounts for about 70 percent of the basin area. About 50 percent of the basin is cropland. Corn and soybean production is extensive in the northern, southwestern, and southeastern parts of the basin. In 1992, about 22 percent of the basin was planted in corn, and about 18 percent was planted in soybeans. These two crops accounted for 78 percent of all cropland. The south-central part of the basin is not farmed as extensively as other parts because of the hill and valley landscape; most of the forested land in the basin is located in this region.

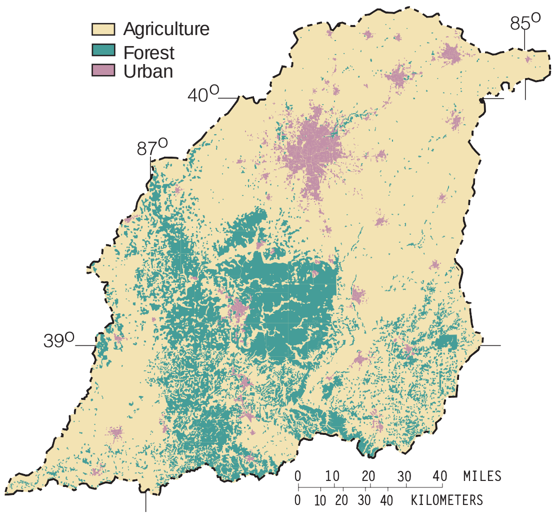

Figure 2. Land use in the White River Basin.

CORN HERBICIDE USE IN THE WHITE RIVER BASIN

Herbicides are used extensively in the White River Basin, and herbicides applied to corn account for about 70 percent of the total agricultural pesticide use (Anderson and Gianessi, 1995). Herbicides are applied during spring planting to virtually all of the corn crop. Annual pesticide-use information is not available for the White River Basin. Cropping patterns and practices in the basin are comparable to those elsewhere in the State; therefore, Statewide and regional information are indicative of pesticide use in the White River Basin. Triazine (primarily atrazine and cyanazine) and chloroacetanilide (alachlor and metolachlor) compounds and butylate were the most commonly used corn herbicides in central and southern Indiana during 1993 (Indiana Agricultural Statistics Service, 1994). Atrazine was applied to about 90 percent of the corn acreage. Alachlor, cyanazine, and metolachlor were applied to 20 to 40 percent of the corn acreage. Butylate was applied to about 10 percent of the corn acreage, but use of this compound was much more widespread in the southern part of the State than in the central part. Other herbicides, including 2,4-D and EPTC, were used to a lesser extent (2,4-D was used on about 10 percent of the corn acreage at an application rate significantly less than that for butylate; EPTC was used on less than 1 percent of the corn acreage). Alachlor and metolachlor also were used extensively on soybeans; 2,4-D also was used to a lesser extent on soybeans.

Acetochlor was the fifth most commonly used corn herbicide in Indiana in 1994 and the third most used corn herbicide in 1995 (fig. 3). Anderson and Gianessi (1995) estimated that acetochlor was used on about 4 percent of the corn acreage in 1994; the percentage of the acetochlor-treated acres increased to about 21 percent in 1995 (Indiana Agricultural Statistics Service, written commun., 1996). Total use of alachlor and butylate decreased significantly after 1993. Use of corn herbicides in Indiana was about the same in 1993 and 1994 but decreased about 14 percent between 1994 and 1995. Much of this decrease can be attributed to an 11-percent decrease in the amount of cropland planted in corn.

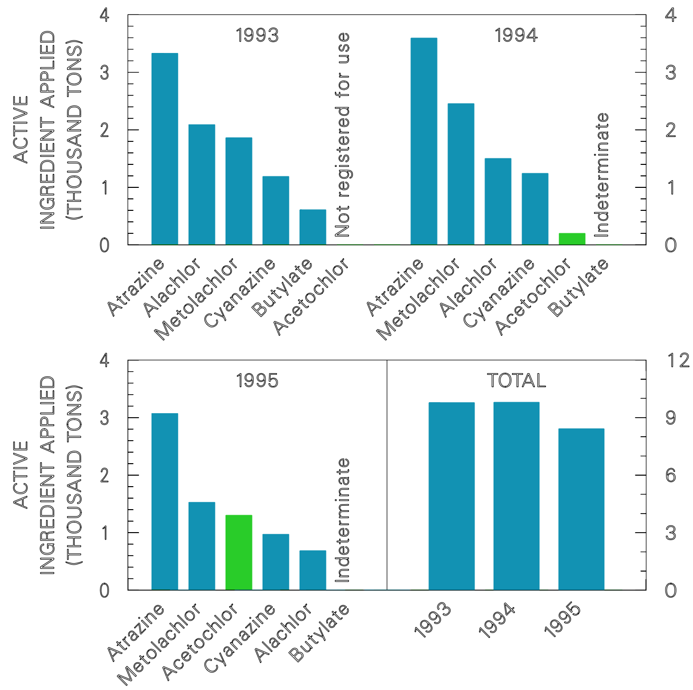

Figure 3. Corn herbicide use in Indiana, 1993-95. (Source of data: Indiana Agricultural Statistics Service, written commun., 1996, except 1994 acetochlor use which is estimated from information in Anderson and Gianessi, 1995; "Indeterminate" means the herbicide was used but in amounts too small to accurately quantify.)

STUDY APPROACH

Surface-water samples were collected from two sites in the White River Basin; one site on the White River at Hazleton, Ind., (near the mouth) and the other site on Sugar Creek near New Palestine, Ind., a small (93-square-mile) tributary (fig. 1). The area draining to the tributary site has geologic, physiographic, and land-use characteristics that are typical of most of central Indiana. The long-term average streamflow at this site is 103 cubic feet per second. Land use in the Sugar Creek Basin is predominantly agriculture (95 percent) with some rural residential areas (Crawford, 1996); most of the agricultural land is used for the production of corn and soybeans and, to a lesser extent, alfalfa and wheat. Both conventional and conservation tillage systems are common. Soils in the basin are poorly drained loams, and most of the cropland is underlain by tile-drainage systems.

Depth- and width-integrated samples were collected weekly to twice monthly from the two sites during May through August 1994-96 and approximately monthly during the other months, using sample collection procedures described by Shelton (1994). Samples were analyzed by the U.S. Geological Survey National Water Quality Laboratory for a selected group of pesticides. Dissolved pesticide concentrations in water samples were determined by gas chromatography/mass spectrometry methods (Zaugg and others, 1995; Lindley and others, 1996).

TRENDS IN ACETOCHLOR CONCENTRATIONS

During 1994, acetochlor was detected in trace concentrations in the White River at Hazleton but was not detected in Sugar Creek near New Palestine. By 1996, peak concentrations of acetochlor were about 2 micrograms per liter in the White River and 3 micrograms per liter in Sugar Creek (figs. 4 and 5). The peak concentrations of acetochlor were considerably less than those for atrazine and roughly comparable to those for cyanazine—two other herbicides used in Indiana mainly on corn. The peak concentrations of all six herbicides typically were greater in Sugar Creek than in the White River. The 50th-, 75th-, and 90th-percentile concentrations, however, were higher in White River than in Sugar Creek

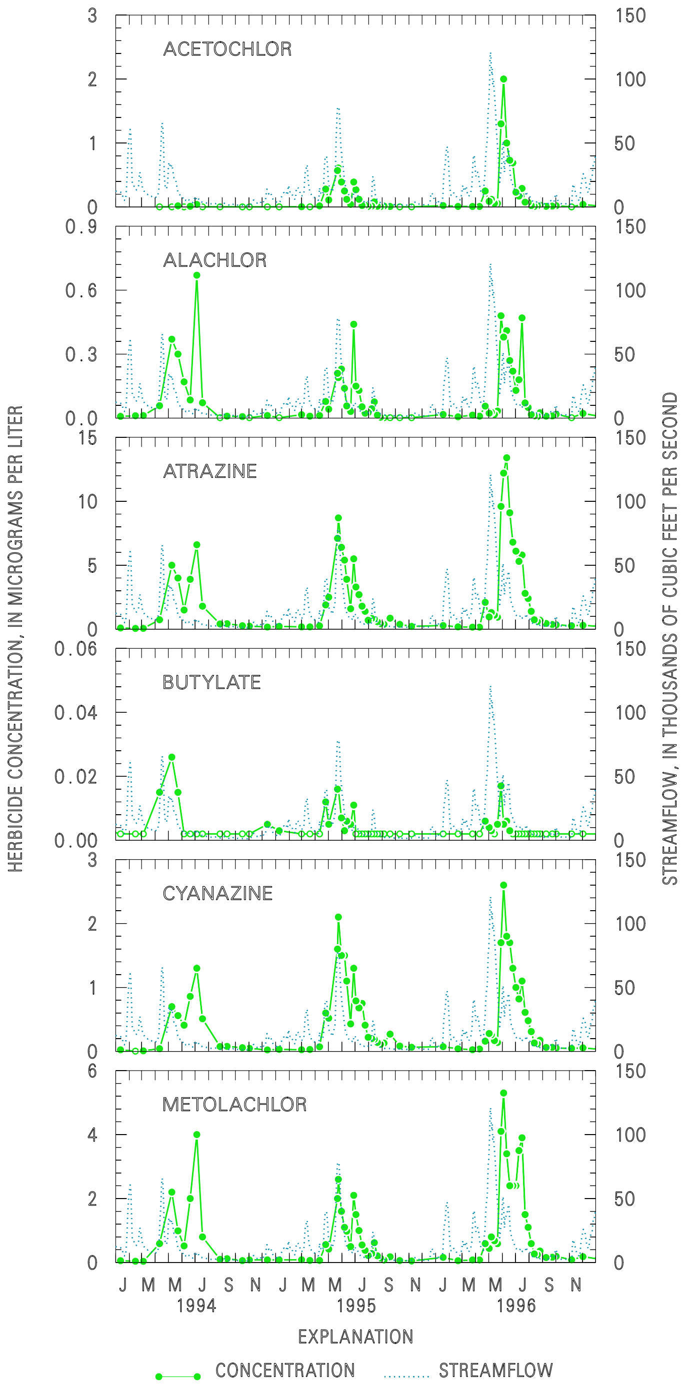

Figure 4. Relation of selected herbicide concentrations and streamflow to time in the White River at Hazleton, Ind. (An open circle indicates a concentration that is less than the analytical detection limit and, therefore, is less than the value shown.)

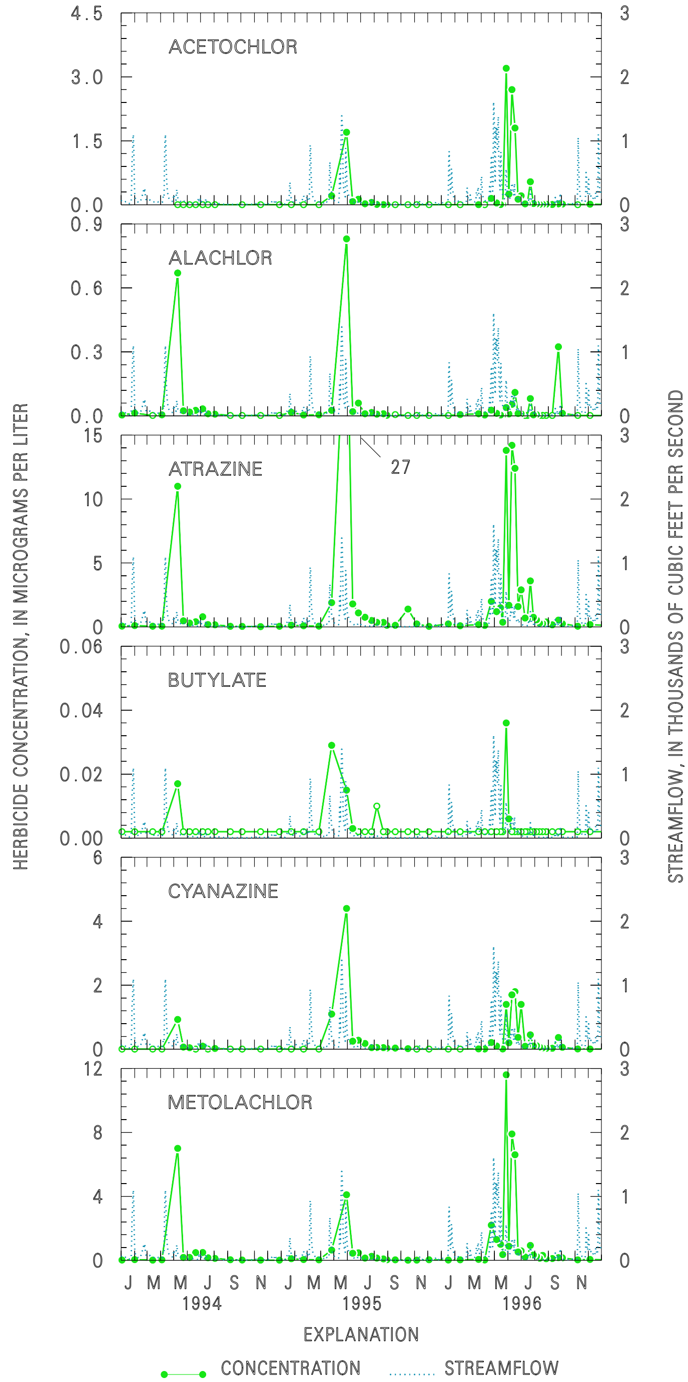

Figure 5. Relation of selected herbicide concentrations and streamflow to time in Sugar Creek near New Palestine, Ind. (An open circle indicates a concentration that is less than the analytical detection limit and, therefore, is less than the value shown.)

(table 1), indicating that elevated concentrations of the herbicides were sustained longer in the White River than in Sugar Creek. Concentrations of acetochlor show the same strong seasonal pattern as the other herbicides. The highest concentrations of herbicides in surface waters of the White River Basin typically occur during the first one or two periods of runoff following application and are a function of weather conditions prior to application and rainfall-runoff patterns after application (Crawford, 1995, 1996).

Planting of corn in Indiana in 1996 was anomalous with historical patterns. Because of unusually wet spring weather, planting progress was the slowest on record and was slower in southern Indiana than in central Indiana. Near the end of June, corn planting was 22 days behind average (Indiana Agricultural Statistics Service, 1996). The weather-related delays forced many farmers to switch to quick-maturing corn hybrids, to plant soybeans instead of corn, and/or to use postemergent application of herbicides rather than the more typical preemergent application. Postemergent application of herbicides could have resulted in increased use of atrazine and decreased use of acetochlor and metolachlor in 1996. Atrazine is effective against emerged grasses; acetochlor and metolachlor generally are less effective against emerged grasses. (Herbicide-use data for 1996 were not available for Indiana as of this writing.)

Sufficient data are available for the White River at Hazleton to estimate average herbicide concentrations and total loads (herbicide transport). Cubic-spline interpolation was used to estimate daily concentrations and loads (Carter and others, 1995). Average concentrations and loads were computed from the daily estimates for the calendar year and for the period when the highest concentrations occurred (May to July). The average concentration of acetochlor increased each year between 1994 and 1996 and averaged 0.15 micrograms per liter during 1996 (table 2). This concentration was considerably less than the 2.0 micrograms per liter criterion for surface-water-supplied community-water systems, the 1.8 micrograms per liter estimated annual average concentration for atrazine, and the 0.31 micrograms per liter estimated annual average concentration for cyanazine. The average concentration of acetochlor during May to July was about three times the annual average.

Table 1. Concentrations of selected herbicides at two sites in the White River Basin, 1994-96

[< symbol indicates less than]

Pesticide	Number of samples	Number of detections	Concentration, in micrograms per liter: 50th percentile	75th percentile	90th percentile	95th percentile	Maximum concentration
Sugar Creek near New Palestine, Ind.							
Acetochlor	53	32	0.006	0.043	0.25	1.8	3.2
Alachlor	58	40	.007	.018	.060	.32	.83
Atrazine	58	58	.36	1.2	3.6	14.	27.
Butylate	58	6	< .002	< .002	.006	.017	.036
Cyanazine	58	40	.039	.18	1.1	1.7	4.4
Metolachlor	58	58	.15	.48	2.2	7.0	12.
White River at Hazleton, Ind.							
Acetochlor	65	52	0.023	0.12	0.57	0.73	2.0
Alachlor	69	61	.026	.13	.37	.44	.67
Atrazine	69	69	.94	3.9	6.8	9.1	13.
Butylate	69	22	< .002	.004	.012	.016	.026
Cyanazine	69	68	.20	.75	1.5	1.7	2.6
Metolachlor	69	69	.44	1.1	2.6	3.9	5.3

Table 2. Estimated average concentration and load of selected herbicides in the White River at Hazleton, Ind., 1994-96

Herbicide	1994		1995		1996	
	January-December	May-July	January-December	May-July	January-December	May-July
Average concentration, in micrograms per liter						
Acetochlor	< 0.01	0.01	.07	0.23	0.15	0.51
Alachlor	.08	.26	.04	.13	.06	.21
Atrazine	1.2	3.6	1.3	3.9	1.8	5.8
Butylate	< .01	< .01	< .01	< .01	< .01	< .01
Cyanazine	.23	.69	.33	.98	.31	1.0
Metolachlor	.57	1.7	.38	1.1	.74	2.4
Load, in pounds						
Acetochlor	51	44	4,230	3,660	9,300	8,280
Alachlor	2,280	1,590	1,900	1,630	3,080	2,740
Atrazine	30,400	21,200	62,300	55,500	92,400	83,300
Butylate	175	79	126	93	104	73
Cyanazine	4,550	3,430	15,100	13,300	16,400	14,900
Metolachlor	14,100	9,090	17,600	15,300	36,800	33,200

The load of acetochlor in the White River at Hazleton during 1996 was about 10 percent of the atrazine load (table 2). Most of the annual herbicide load is transported during May to July and varies from about 60 percent in dry years to about 90 percent in wet years. The annual load of a specific herbicide transported by the White River is affected not only by the amount of herbicide used in the basin but also is highly correlated with the amount of runoff during May to July. This correlation is best illustrated by atrazine because use of this herbicide in Indiana has been relatively constant in the 1990's (fig. 6).

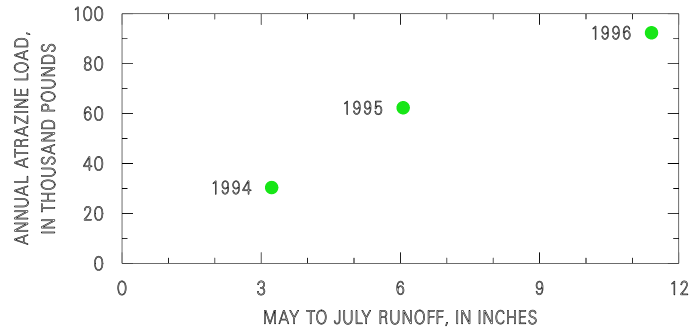

Figure 6. Relation of annual atrazine load and May to July runoff in the White River at Hazleton, Ind.

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