INFLUENCE OF NATURAL AND HUMAN FACTORS ON PESTICIDE CONCENTRATIONS IN SURFACE WATERS OF THE WHITE RIVER BASIN, INDIANA

U.S. Department of the Interior—U.S. Geological Survey

Pesticide concentrations in surface waters of the White River Basin are affected by natural and human factors. For example, concentrations of atrazine, a herbicide widely used on corn in the White River Basin, tended to be higher in an agricultural basin with permeable, well-drained soils, than in an agricultural basin with less permeable, more poorly drained soils. Concentrations of butylate, another herbicide used on corn, were substantially higher in an agricultural basin in the southern part of the White River Basin than in an agricultural basin in the central part of the White River Basin, corresponding to the higher use of this compound in southern Indiana. Concentrations of diazinon were substantially higher in a predominantly urban basin than in two predominantly agricultural basins, corresponding to the common use of this insecticide on lawns and gardens in urban areas.

INTRODUCTION

In 1991, the U.S. Geological Survey began the National Water-Quality Assessment (NAWQA) Program. The long-term goals of the NAWQA Program are to describe the status and trends in the quality of a large, representative part of the Nation's surface- and ground-water resources, and to provide a sound, scientific understanding of the primary natural and human factors affecting the quality of these resources (Hirsch and others, 1988). The White River Basin in Indiana was among the first 20 river basins to be studied as part of this program. A major component of the White River Basin study is to determine the occurrence and distribution of pesticides and to relate these to natural and human factors in the basin. This paper briefly describes the White River Basin and presents examples of how pesticide concentrations in streams are influenced by natural and human factors. Findings are based on selected pesticide data collected from October 1992 through September 1995 at three sites in small (17 to 93 square mile) drainage basins in the White River Basin and at one site near the mouth of the White River.

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 flow of the White River near its confluence with the Wabash River in southwestern Indiana is 12,300 cubic feet per second. Streamflow in the basin 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.

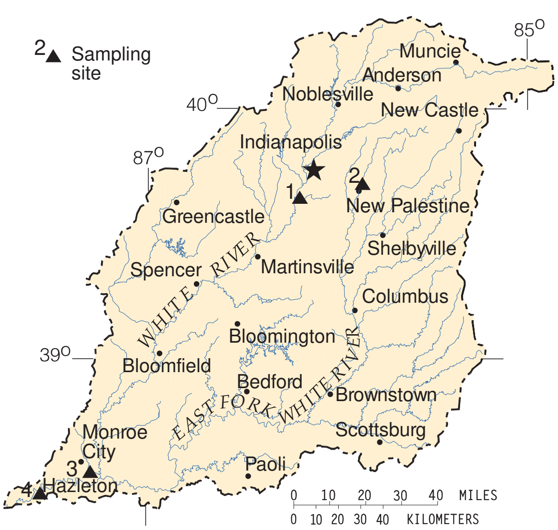

Figure 1. The White River Basin.

Geologic, geomorphologic, and hydrologic factors were used to divide the basin into six hydrogeomorphic regions that have similar natural characteristics (fig. 2). Three of the regions—the till plain, glacial lowland, and fluvial deposits—are defined primarily by glacial deposits. The remaining three—the bedrock upland, bedrock lowland and plain, and karst plain—are defined primarily by bedrock geology. The till plain, glacial lowland, and fluvial deposits are the most intensively farmed regions in the White River Basin. The till plain, an area of low topographic relief in the northern part of the basin, typically is covered by 100 to 200 feet of silty-clay till interspersed with thin (5 to 10 feet) layers of sand and gravel. The relatively impervious till limits infiltration and promotes surface runoff. Tile drains are common in the till plain. The glacial lowland, in 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

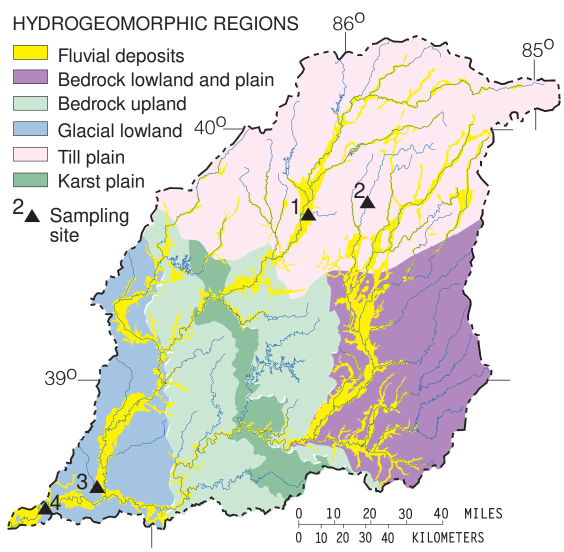

Figure 2. Hydrogeomorphic regions of the White River Basin.

lake clays overlying coal-bearing shales and sandstones. In general, soils in the glacial lowland are more permeable and better drained than soils in the till plain. However, drainage is poor in parts of the glacial lowland where clay-rich deposits are prevalent and in low-lying areas where the water table tends to be shallow. Where such conditions exists, drainage ditches and tile drains are common.

The population of the White River Basin in 1990 was approximately 2.1 million, about three-fourths of which are concentrated in the northern part of the basin. The primary land use is agriculture (fig. 3), which accounts for about 70 percent of the area of the basin. About 50 percent

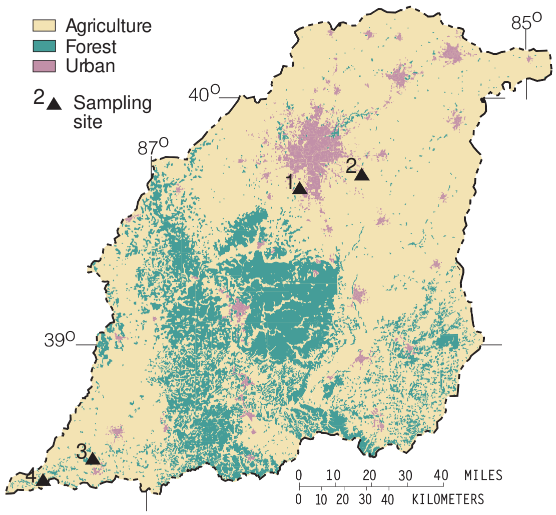

Figure 3. Land use in the White River Basin.

of the basin is cropland. Soybean and corn 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. Other crops account for a much smaller percentage of the basin and include hay (about 3 percent), wheat (about 2 percent), and, to a much lesser extent, apples, barley, cucumbers, green beans, melons, oats, potatoes, pumpkins, rye, sorghum, strawberries, tobacco, and tomatoes (each less than 0.1 percent). 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. Parts of the cities of Indianapolis, Muncie, and Anderson are intensively industrialized.

PESTICIDE USE IN THE WHITE RIVER BASIN

Herbicides applied to corn and soybeans dominate pesticide use in the White River Basin. Herbicides are applied during spring planting to virtually all of the corn and soybean crop. Triazine (primarily atrazine and cyanazine) and acetanilide (alachlor and metolachlor) compounds are the most commonly used herbicides. Insecticides are applied during the summer to about 25 percent of the corn crop but typically are not applied to soybeans. The estimated use of common agricultural pesticides in the White River Basin is shown in figure 4. About 96 percent of the total agricultural pesticide use in the basin is on corn and soybeans (Anderson and Gianessi, 1995). The application of fungicides and insecticides to apples, tomatoes, and watermelons (2.2 percent of use) and of herbicides to hay, pasture, and wheat (1.0 percent of use) accounts for most of the remaining agricultural pesticide use.

Nonagricultural use of pesticides in the White River Basin is not as well documented as agricultural use. Insecticides typically constitute a much larger percentage of the total amount of pesticides used in urban areas than in agricultural areas (Hodge, 1993). The insecticides allethrin, chlorpyrifos, diazinon, lindane, malathion, and propoxur, and the herbicides 2,4-D, MCPP, and glyphosate commonly are used in urban areas.

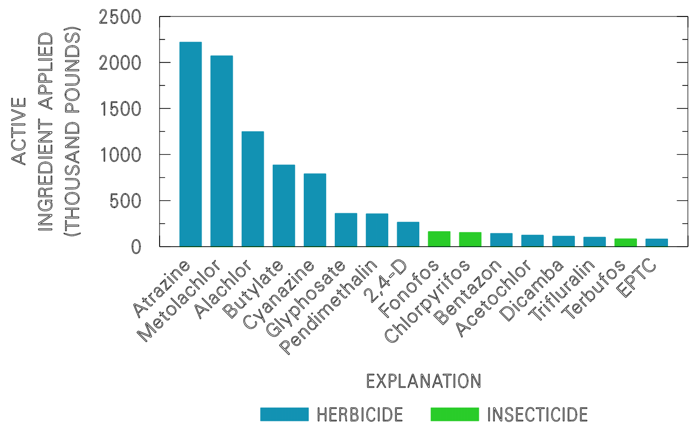

Figure 4. Estimated use of the 16 most common agricultural pesticides in the White River Basin. [1992-94 average annual usage, except acetochlor, which is 1994 usage. Source of data: Anderson and Gianessi (1995).]

STUDY APPROACH

Surface-water samples were collected from four sites in the White River Basin; three sites on small tributaries and one site near the mouth of the White River (fig. 1). The sites on the small tributaries were selected to represent different combinations of homogeneous natural features and land use (Gilliom and others, 1995). Site locations, drainage areas, land use, and soil-drainage characteristics are given in table 1. Little Buck Creek (site 1) and Sugar Creek (site 2) are in the till plain hydrogeomorphic region. Little Buck Creek is an urbanizing basin in suburban Indianapolis. Land use in the Sugar Creek Basin is predominantly row-crop agriculture (corn and soybeans) with some rural residential areas. Kessinger Ditch (site 3) is in the glacial lowland hydrogeomorphic region. Land use in the Kessinger Ditch Basin is similar to that in the Sugar Creek Basin.

Table 1. Sampling site, drainage area, land use, and soil-drainage characteristics, White River Basin

[Source of land-use information: Mitchell and others (1977) as revised by Hitt (1994). Source of hydrologic soil-group information: Soil Conservation Service (1991). < symbol indicates less than]

Sampling site number (fig. 1) and name	Drainage area (square miles)	Land use (percent)				Percent of soils in A or B hydrologic soil group[1]
		Agriculture	Forest	Urban	Other	
1 Little Buck Creek near Indianapolis, Ind.	17	42	< 1	57	< 1	52
2 Sugar Creek near New Palestine, Ind.	93	95	1	3	1	30
3 Kessinger Ditch near Monroe City, Ind.	56	94	4	< 2	< 1	68
4 White River at Hazleton, Ind.	11,305	69	22	7	2	32

[1] Soils in these groups have moderate to high infiltration rates when thoroughly wetted and are moderately well drained to well drained.

Depth- and width-integrated samples were collected from the streams weekly to twice monthly during May through August and approximately monthly during the rest of the year following procedures described by Shelton (1994). Samples were analyzed by the U.S. Geological Survey National Water Quality Laboratory for a selected group of pesticides. This group included 8 of the 10 most commonly used agricultural pesticides in the White River Basin (fig. 4) and several of the pesticides commonly used in urban areas. Dissolved pesticide concentrations in water samples were determined by gas chromatography/mass spectrometry methods (Zaugg and others, 1995).

FINDINGS

Pesticide concentrations in streams in the White River Basin are affected by basin characteristics such as geology, geomorphology, land use, and soils. They also are affected by agricultural practices such as

patterns of pesticide use, tile drainage, and cropping methods. Examples follow of how concentrations of three pesticides (atrazine, butylate, and diazinon) in surface waters are influenced by natural and human factors.

Patterns in atrazine concentrations in streams illustrate the effect of differences in natural factors such as geology, geomorphology, and soils on pesticide runoff and transport. Atrazine is the most commonly used corn herbicide in Indiana, and its use is widespread. In 1993, atrazine was applied to about 90 percent of the corn crop in central and southern Indiana, and the rate of application was similar in these two regions (Indiana Agricultural Statistics Service, 1994). Because of this widespread use and similar cropping and pesticide application practices throughout the basin, differences in concentrations of atrazine are attributed to natural factors. ***Atrazine concentrations in Kessinger Ditch tended to be several times higher than in Sugar Creek (table 2 and fig. 5), possibly reflecting the movement of water to streams in the Kessinger Ditch Basin through the more permeable and better drained soils (table 1).*** Only low levels of atrazine (0.13 micrograms per liter maximum concentration) were found in shallow ground water in the White River Basin indicating that atrazine is not migrating to ground water (Fenelon and Moore, 1996). Maximum atrazine concentrations occur in late May or June and are associated with the first runoff following application (Crawford, 1995).

Table 2. Distribution of atrazine, butylate, and diazinon concentrations at four sites in the White River Basin, 1992-95

[< 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
Little Buck Creek near Indianapolis, Ind.							
Atrazine	59	59	0.11	0.42	1.3	2.0	10.
Butylate	59	8	< 0.008	< 0.008	0.008	0.011	0.017
Diazinon	59	51	0.038	0.083	0.32	0.45	1.10
Sugar Creek near New Palestine, Ind.							
Atrazine	66	66	0.19	0.81	3.8	7.5	30.
Butylate	66	13	< 0.008	< 0.008	0.015	0.019	0.051
Diazinon	66	24	< 0.008	0.008	0.023	0.043	0.10
Kessinger Ditch near Monroe City, Ind.							
Atrazine	55	55	1.0	3.5	8.1	20.	100.
Butylate	55	55	0.049	0.12	0.21	0.65	1.4
Diazinon	55	0	< 0.008	< 0.008	< 0.008	< 0.008	< 0.008
White River at Hazleton, Ind.							
Atrazine	72	72	0.82	2.8	6.4	8.7	10.
Butylate	72	33	< 0.008	0.008	0.016	0.024	0.042
Diazinon	72	48	0.008	0.010	0.014	0.032	0.10

Differences in butylate concentrations in streams in two different parts of the basin illustrate the effect of regional patterns of pesticide use on pesticide runoff and transport. Butylate, a herbicide used on corn, is the fourth most commonly used agricultural pesticide in the White River Basin. ***In contrast to atrazine, butylate is used more extensively in the southern part of the basin than in the northern part.*** The percentage of acres treated with butylate in 1993 was about eight times greater in southern Indiana (17 percent) than in central Indiana (2 percent), and the total amount of butylate applied was four times greater in southern Indiana than in central Indiana (Indiana Agricultural Statistics Service, 1994). ***Butylate concentrations were substantially higher in Kessinger Ditch (in southern Indiana) than in Sugar Creek (table 2 and fig. 6).*** Maximum concentrations of butylate tended to occur in late May and early June. Detectable levels of butylate were found year round in Kessinger Ditch, in contrast to the other three sites where it was found only during the growing season. Differences in pesticide concentrations resulting from regional-use patterns would be magnified in these two basins because of the influence of natural factors, as evidenced by

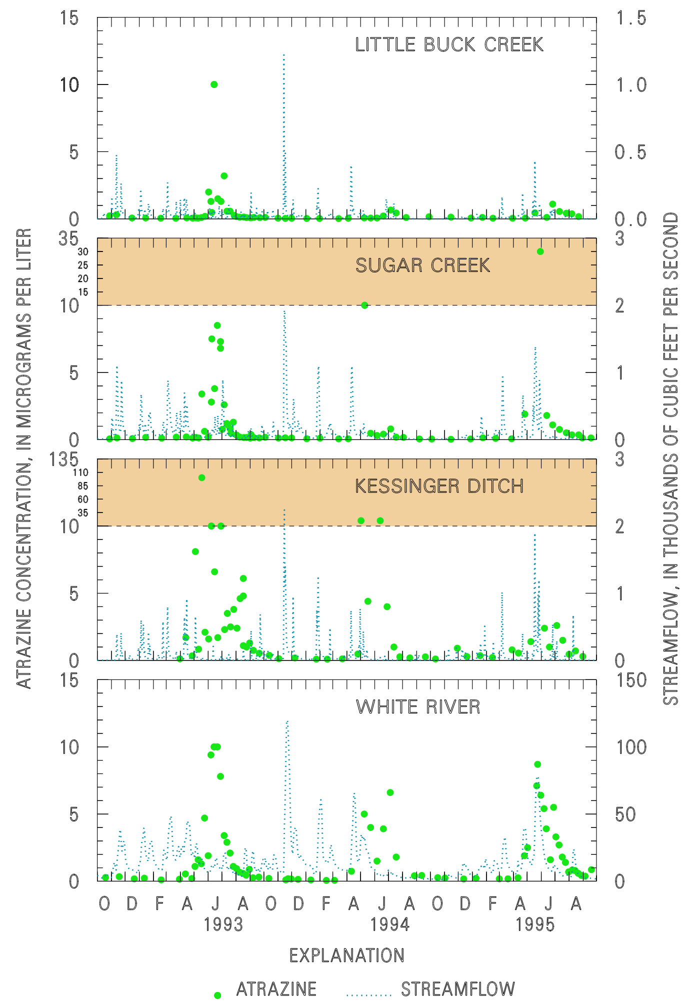

Figure 5. Relation of atrazine concentration and streamflow to time at four sites in the White River Basin. (The dashed line and shading indicate a change in the concentration scale.)

differences in atrazine concentrations. Only low concentrations of butylate were detected in the White River at Hazleton.

Trends in the concentration of the insecticide diazinon illustrate the effect of land use on pesticide concentrations in streams. Diazinon is commonly applied during midsummer in Indiana to combat insect infestations in lawns and gardens and is less commonly used for agricultural purposes in the basin. ***Diazinon concentrations were substantially higher in the predominantly urban Little Buck Creek than in the two predominantly agricultural streams (table 2 and fig. 7), corresponding to the common use of this insecticide in urban areas.*** Diazinon was not detected in Kessinger Ditch but was occasionally detected in low concentrations in Sugar Creek, which probably reflects its use in residential areas in this basin. As with butylate, only low concentrations of diazinon were found near the mouth of the White River. Peak concentrations of diazinon typically occurred in mid- to late summer.

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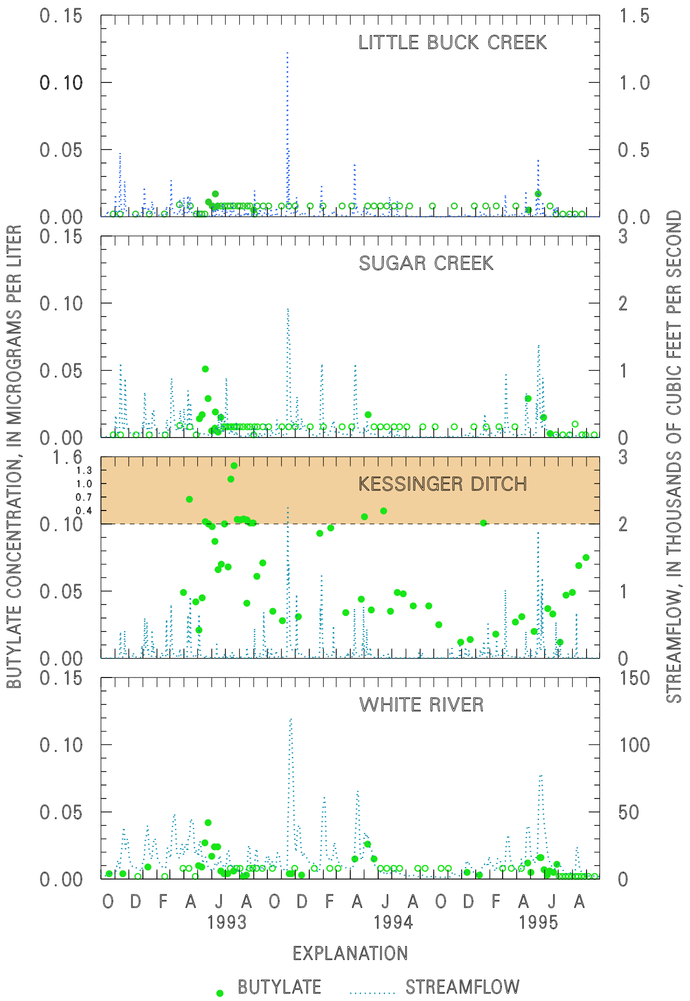

Figure 6. Relation of butylate concentration and streamflow to time at four sites in the White River Basin. (The dashed line and shading indicate a change in the concentration scale. An open circle indicates a concentration that is less than the analytical reporting limit and, therefore, is less than the indicated value.)

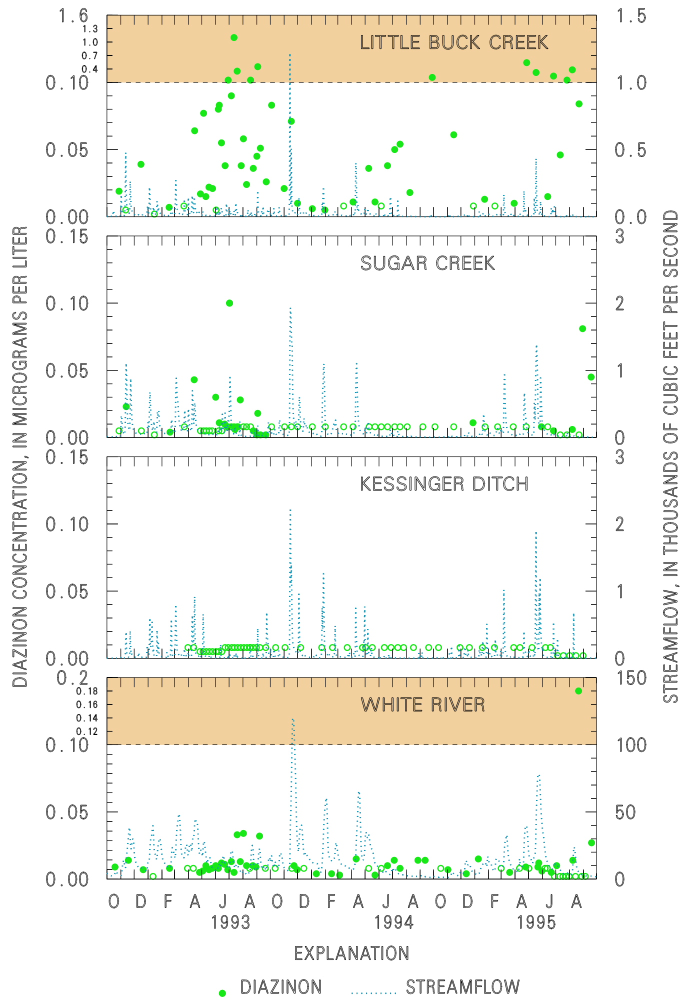

Figure 7. Relation of diazinon concentration and streamflow to time at four sites in the White River Basin. (The dashed line and shading indicate a change in the concentration scale. An open circle indicates a concentration that is less than the analytical reporting limit and, therefore, is less than the indicated value.)

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Prepared by

Charles G. Crawford

For more information, contact:
Project Chief
White River Basin Study
U.S. Geological Survey
5957 Lakeside Boulevard
Indianapolis, IN 46278-1996
317-290-3333