OCCURRENCE OF PESTICIDES IN GROUND WATER IN THE WHITE RIVER BASIN, INDIANA, 1994-95

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Pesticides (herbicides and insecticides) are used extensively in the White River Basin. Application of herbicides to corn and soybeans accounts for most of the use. The U.S. Geological Survey collected samples from four networks of monitoring wells in the White River Basin during 1994-95. The most frequently detected compounds in ground water were desethyl atrazine (a breakdown product of atrazine) and the commonly used herbicides, atrazine and metolachlor. Insecticides commonly used in urban and agricultural areas were not found. The highest concentration of any pesticide detected was alachlor at 0.19 micrograms per liter. Most detections of atrazine and desethyl atrazine were in agricultural areas overlying fluvial deposits, which are vulnerable to pesticide contamination, but the concentrations were small (less than 0.1 microgram per liter).

INTRODUCTION

In 1991, the U.S. Geological Survey (USGS) began the National Water-Quality Assessment (NAWQA) Program. The long-term goals of the NAWQA Program are to describe the current water-quality conditions and trends in the Nation's rivers, streams, and ground water and to understand 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 of pesticides in the shallow aquifers of the basin. This paper presents the findings from pesticide data collected from 94 shallow monitoring wells from June 1994 through August 1995.

DESCRIPTION OF THE WHITE RIVER BASIN

The White River Basin is part of the Mississippi River system and encompasses 11,350 square miles of central and southern Indiana (fig. 1). The population of the White River Basin in 1990 was approximately 2.1 million; the Indianapolis Metropolitan Area accounted for about 60 percent of the total population. The primary land use in the basin is agriculture (fig. 2), which covers about 70 percent of the basin. In 1992, about 22 percent of the basin was planted in corn, and about 18 percent of the basin was planted in soybeans. Other cropland comprises a much smaller percentage of the basin and includes wheat and hay and, to a much lesser extent, apples, barley, cantaloupe, cucumbers, green beans, oats, potatoes, pumpkins, rye, sorghum, strawberries, tobacco, tomatoes, and watermelons. Most of the forested land in the basin is located in the south-central part of the basin. There is significant industrialization in the cities of Indianapolis, Muncie, and Anderson.

For the purposes of this study, the basin was divided into six hydrogeomorphic regions (fig. 3). These regions are based on factors affecting water quality, such as geology, physiography, and hydrology. Three of the regions—the bedrock uplands, bedrock lowland and plain, and karst plain—are defined primarily by bedrock characteristics. The remaining three regions—the till plain, glacial lowland, and fluvial deposits—are defined primarily by characteristics of glacial deposits and are the focus of this paper.

The till plain, which covers the northern part of the basin, typically is underlain by 100 to 200 feet of silty-clay till interspersed with thin (5- to 10-foot-thick) layers of sand and gravel. In most areas, shallow (less than 50 feet deep) water-bearing units in the upper part of the till sequence consist of sand and gravel lenses that may not provide adequate yields for domestic use. The glacial lowland, located in the southwestern

Figure 1. The White River Basin.

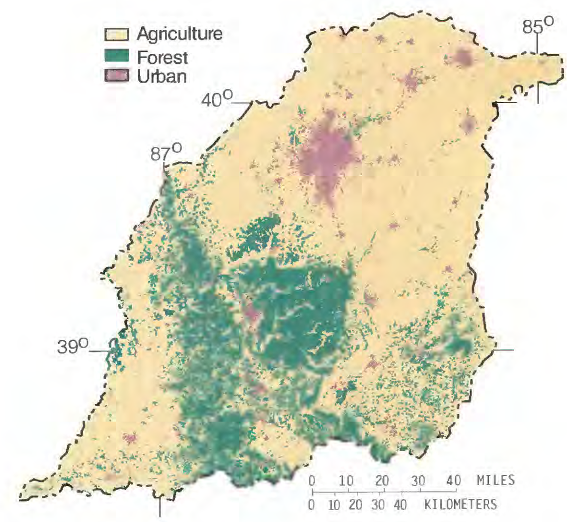

Figure 2. Land use in the White River Basin.

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 that overlie coal-bearing shales and sandstones. Shallow unconsolidated water-bearing units are rarely sufficient for domestic use; most households use bedrock aquifers for water supply. The fluvial (river) deposits fill river valleys that cut across the other five hydrogeomorphic regions. The fluvial deposits are composed of approximately 10 to 100 feet of glacial and modern river deposits of sand, gravel, and silt under and adjacent to most of the major rivers and streams in the basin. Fluvial deposits are most extensive along the White River near Indianapolis and south of Bloomfield and along the East Fork White River near Columbus and Seymour. The fluvial aquifers are highly permeable and rapidly recharged, which make them capable of producing large quantities of water for supply. These characteristics also make them vulnerable to contamination.

PESTICIDE USE IN THE WHITE RIVER BASIN

The estimated annual agricultural use of the 36 most commonly used pesticides in the White River Basin is nearly 10 million pounds (table 1). Pesticides applied to corn and soybeans account for about 96 percent of the total agricultural pesticide use in the basin (Anderson and Gianessi, 1995). Herbicides are applied in the spring during planting to virtually all of the corn and soybean crop. Insecticides are applied during the summer to about 25 percent of the corn crop but are typically not applied to soybeans (Anderson and Gianessi, 1995). Triazine compounds (primarily atrazine and cyanazine) and acetanilide compounds (primarily alachlor and metolachlor) are the most commonly used herbicides. Total herbicide use on corn and soybeans decreased about 3 percent in Indiana during the period 1990-94, despite a 10 percent increase in corn and soybean acreage (National Agricultural Statistics Service, 1994; 1991).

Table 1. Agricultural pesticide use in the White River Basin

[1992-94 average annual usage, except acetochlor which is 1994 total. Source of data: Anderson and Gianessi, 1995. Pesticides highlighted in light blue were analyzed for in ground water]

Pesticide	Active ingredient applied (thousand pounds)	Rank by use	Pesticide	Active ingredient applied (thousand pounds)	Rank by use
Herbicides					
2,4-D	265	8	Ethalfluralin	38	17
Acetochlor	125	10	Glyphosate	361	6
Alachlor	1,250	3	Imazaquin	44	16
Atrazine	2,220	1	Linuron	79	14
Bentazon	143	9	Metolachlor	2,070	2
Butylate	887	4	Metribuzin	74	15
Clomazone	32	20	Paraquat	36	18
Cyanazine	791	5	Pendimethalin	357	7
Dicamba	113	11	Simazine	35	19
EPTC	83	13	Trifluralin	102	12
Insecticides					
Acephate	2.1	13	Methyl parathion	1.7	15
Carbaryl	14	8	Oil	45	4
Carbofuran	44	5	Permethrin	11	9
Chlorpyrifos	154	2	Phorate	39	6
Dimethoate	5.1	11	Propargite	2.0	14
Endosulfan	1.4	16	Tefluthrin	6.8	10
Fonofos	163	1	Terbufos	85	3
Malathion	4.1	12	Trimethacarb	19	7

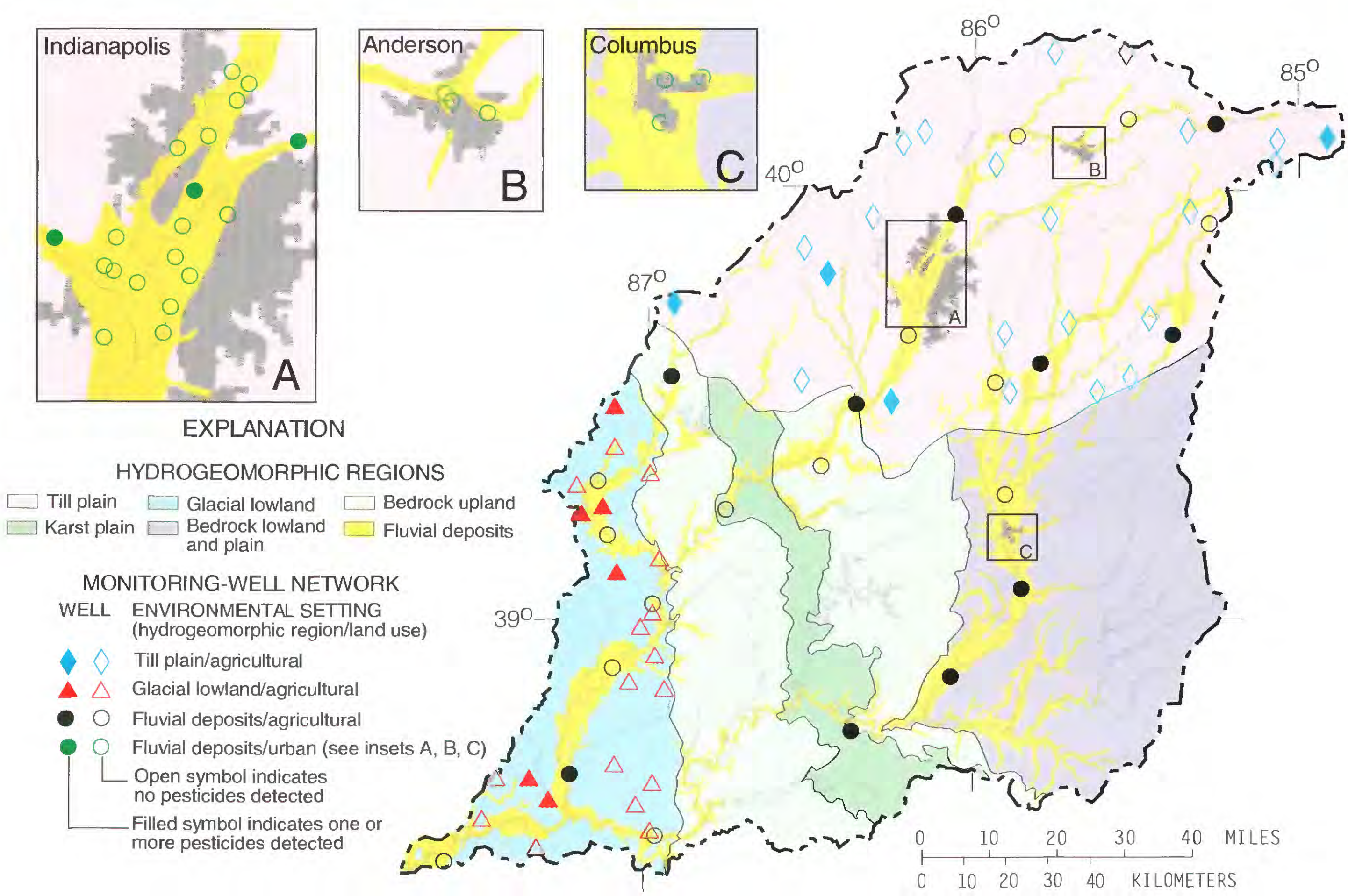

Figure 3. Hydrogeomorphic regions, monitoring-well networks, and wells with pesticide detections in the White River Basin.

Urban use of pesticides in the White River Basin is not as well documented as agricultural use. Most pesticide applications in urban areas are applied to lawns, gardens, and golf courses, along roadways, and as insect control in and around buildings. Insecticide use, as a percentage of total pesticide use, is typically higher 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.

STUDY APPROACH

The USGS installed four monitoring-well networks in the White River Basin (fig. 3). The networks are designed to assess the concentrations and distributions of pesticides in shallow ground water associated with four different environmental settings. The settings are defined by a combination of hydrogeomorphic and land-use conditions. Networks in the till plain (23 wells), glacial lowland (22 wells), and fluvial deposits (24 wells) are in agricultural settings. An additional network in the fluvial deposits (25 wells) is in the urban settings of Indianapolis, Anderson, and Columbus (insets of fig. 3).

Well locations within each network were randomly selected. Two-inch polyvinyl chloride (PVC) wells with short screens (2.5 to 7.5 feet) were finished in the uppermost water-bearing unit. A hollow-stem, rotary auger was used to install the 10- to 67-foot wells following NAWQA protocols (Lapham and others, 1995). Although all the wells were developed, median well yields from the till plain and glacial lowland networks were small—0.3 and less than 0.1 gallons per minute, respectively. Wells from the fluvial networks had median well yields of greater than 5 gallons per minute.

Filtered samples were collected in the summers of 1994 and 1995 from 94 wells by use of a submersible pump following NAWQA protocols (Koterba and others, in press). Samples were analyzed for 20 herbicides and 11 insecticides, including more than half of the commonly used pesticides in the White River Basin (table 1). The USGS National Water Quality Laboratory determined pesticide concentrations by gas chromatography/mass spectrometry methods (Zaugg and others, 1995). A quality-assurance program was used in the field and the laboratory to evaluate and ensure the reliability of the analytical data.

FINDINGS

A summary of the results of pesticide sampling of 94 shallow wells is presented in tables 2 and 3. ***Most of the pesticides that were analyzed for, including all 11 insecticides, were not detected above the reporting limit in any well*** (table 2). (A reporting limit is the smallest measured concentration of a constituent that may be reported reliably.) ***Seven herbicides and one atrazine metabolite (desethyl atrazine, a breakdown product of atrazine) were detected at least once (table 3). Of these eight compounds, only four—atrazine, desethyl atrazine, metolachlor, and metribuzin—were detected more than twice. The highest measured concentration of any compound detected was 0.19 μg/L (micrograms per liter) of alachlor, whereas the most frequently detected compound was desethyl atrazine (14 of 94 samples).*** All seven herbicides that were detected have a high potential for leaching into ground water because of their chemical and physical characteristics (U.S. Environmental Protection Agency, 1988).

No pesticide listed in tables 2 or 3 was present in a concentration that exceeded a U.S. Environmental Protection Agency (USEPA) national drinking-water standard or guideline (Nowell and Resek, 1994). These standards and guidelines are set by the USEPA as maximum concentrations of pesticides in drinking water that will not cause adverse health effects in humans. Although the monitoring wells installed for this study are not used for drinking water, some households use shallow ground water as a drinking-water supply, especially in the fluvial deposits. Of the pesticides that were not detected (table 2), about half have an established USEPA standard or guideline. With the exception of dieldrin, reporting limits for these pesticides were a minimum of 50 times less than their respective standard or guideline (the reporting limit for dieldrin is four times greater than its guideline). Of the pesticides that were detected in at least one sample (table 3), all but desethyl atrazine have an established standard or guideline. The maximum concentration of each of the detected pesticides was at least 10 times less than the pesticide's respective standard or guideline.

The occurrence of pesticides in shallow ground water in the White River Basin contrasts with conditions observed in the White River at a site near the mouth of the river at Hazleton, Ind. (Crawford, 1995). A significantly greater frequency of detections and much higher concentrations of atrazine and metolachlor were observed in the river than in the ground water. Atrazine and metolachlor were detected in nearly all 155 samples collected from the river during 1991-95. In addition, the atrazine and metolachlor concentrations were as great as 11 and 4.9 μg/L, respectively—more than 40 times the maximum concentrations measured

Table 2. Selected pesticides *not* detected above the reporting limit in ground water from four environmental settings in the White River Basin, 1994-95

Herbicide	Reporting limit (micrograms per liter)	Insecticide	Reporting limit (micrograms per liter)
Acetochlor	0.009	Chlorpyrifos	0.008
Benfluralin	.013	Diazinon	.008
Butylate	.008	Dieldrin	.008
Cyanazine	.013	Ethoprop	.012
DCPA	.004	Fonofos	.008
EPTC	.005	Lindane	.011
Ethalfluralin	.013	Malathion	.014
Linuron	.039	Methyl parathion	.035
Napropamide	.010	Phorate	.011
Pebulate	.009	Propargite	.013
Pendimethalin	.018	Terbufos	.013
Propachlor	.015		
Trifluralin	.012		

Table 3. Occurrence of selected herbicides and an atrazine metabolite in ground water from four environmental settings in the White River Basin, 1994-95
[< symbol indicates less than]

Herbicide or metabolite	Reporting limit (micrograms per liter)	Environmental setting (hydrogeomorphic region/land use)							
		Till plain/agricultural (23 samples)		Glacial lowland/agricultural (22 samples)		Fluvial/agricultural (24 samples)		Fluvial/urban (25 samples)	
		Number of samples above reporting limit	Maximum concentration (micrograms per liter)	Number of samples above reporting limit	Maximum concentration (micrograms per liter)	Number of samples above reporting limit	Maximum concentration (micrograms per liter)	Number of samples above reporting limit	Maximum concentration (micrograms per liter)
Alachlor	0.009	0	<0.009	1	0.19	0	<0.009	0	<0.009
Atrazine	.017	1	.05	2	.13	4	.09	1	.04
Desethyl atrazine[1]	.007	1	.03	3	.02	9	.09	1	.01
Metolachlor	.009	1	.01	4	.04	1	.11	1	.02
Metribuzin	.012	2	.10	2	.08	0	<.012	0	<.012
Prometon	.018	0	<.018	0	<.018	0	<.018	2	.07
Simazine	.008	0	<.008	0	<.008	0	<.008	1	.04
Tebuthiuron	.015	0	<.015	0	<.015	0	<.015	1	.02

[1]This atrazine metabolite had a below normal analytical method recovery rate and, as a result, actual concentrations may be higher than the concentrations reported in this table.

in the ground water during 1994-95. Acetochlor, alachlor, cyanazine, metribuzin, prometon, and simazine were detected in more than one third of the river samples and in appreciable concentrations (maximum concentration greater than or equal to 0.2 µg/L). Of these six pesticides, only alachlor, prometon, and simazine were detected in the ground water, and in only 1 or 2 percent of the samples; the pesticides detected were at much lower maximum concentrations than were present in the river.

The greatest percentage of wells (42 percent) where at least one pesticide was detected are on agricultural land overlying fluvial deposits (fig. 3). This result is not surprising. The agricultural land overlying fluvial deposits is intensively farmed because of its fertile soils. In addition, the fluvial deposits are vulnerable to contamination because of shallow water tables and rapid horizontal and vertical water flow through the deposits (Soller and Berg, 1992). The percentage of wells where a pesticide was detected on agricultural land overlying fluvial deposits is much greater than statewide percentages (8 percent and between 8 and 14 percent) reported in two pesticide studies (Risch, 1994; Barnett and others, 1994). The greater frequency of detections in this study is due primarily to two factors. First, monitoring wells were used in this study to target the upper part of a highly vulnerable aquifer. Second, most of the pesticide compounds in this study were detected at concentrations less than the lowest reporting limit (0.05 µg/L) used in the two statewide studies. For example, 79 percent of the detections of the three most commonly detected pesticide compounds in this study were less than 0.05 µg/L (fig. 4). ***Pesticides in ground water underlying agricultural areas of the till plain and glacial lowland were uncommon***; most aquifers in these environmental settings are not vulnerable to contamination because they are protected by overlying clay-rich tills. ***The lowest percentage (12 percent) of wells where at least one pesticide was detected are on urban land overlying fluvial deposits (fig. 3).*** Most (five of seven) of the pesticide detections in the urban environmental setting are from one well. Few pesticide detections in the urban setting is probably the result of lower overall pesticide application rates than in the agricultural settings.

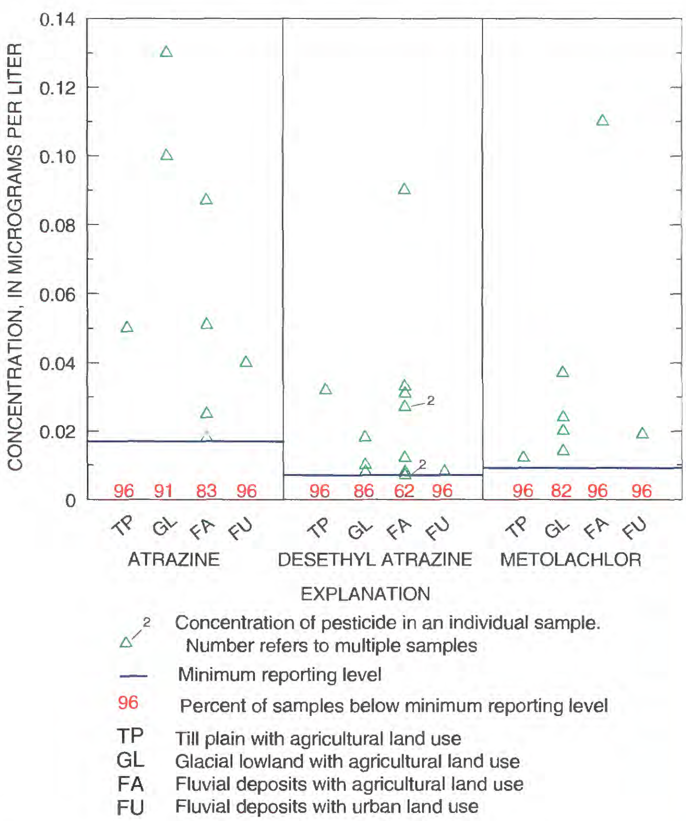

Figure 4. Distribution of concentrations of atrazine, desethyl atrazine, and metolachlor in ground-water samples from four environmental settings in the White River Basin, 1994-95.

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