Table 17. Standards, guidelines, and maximum concentrations of pesticides detected in water samples from streams in the Birmingham area, Alabama, 2000–01

[μg/L, micrograms per liter; E, estimated; —, no criteria; DNOC, 4,6-dinitro-2-methylphenol]

Organic chemical	Trade name	Maximum concentration (μg/L)	Drinking-water standard or guideline (μg/L)	Guideline for aquatic life (μg/L)
Herbicides				
Atrazine	Aatrex, Atred, Criazina, Gesaprim	8.88	3[a,b]	1.8[c]
Benfluralin	Balan	E .00619	—	—
Bentazon	Basagran	.196	—	—
Bromacil	Bromax, Hyvar, Urox B, Uragan	1.03	—	5.0[c]
Bromoxynil	Bison, Buctril, Moxy, Brominal	.07	—	5.0[c]
Deethylatrazine		E .522	—	—
Diuron	Direx, Karmex	2.264	—	—
DNOC	Sinox, Trifocide	E .30	—	—
Metolachlor	Dual, Pennant	.00543	—	7.8[c]
Pendimethalin	Prowl, Pre-M, Squaron, Stomp	.0654	—	—
Prometon	Pramitol, Princep	.926	—	—
Pronamide	Kerb	.0127	—	—
Simazine	Princep	8.6	4[a,b]	10[c]
Tebuthiuron	Perflan, Spike, Tebusan	.136	—	1.6[c]
Terbuthylazine		E .401	—	—
Triclopyr	Garlon, Grazon	.384	—	—
Trifluralin	Treflan, Tri-4, Trific, Gowan	E .0065	—	0.20[c]
Insecticides				
Aldicarb	Temik	E 0.064	7[a]	1[c]
Aldicarb sulfone		E .0833	7[a]	—
Carbaryl	Adios, Carbamine, Denapor, Drexel, Sevin	E .426	—	0.2[c]
Chlorpyrifos	Dursban, Brodan, Eradex, Genpest, Lorsban, Profos, Scout	.0208	—	0.0035[c], 0.083[d], 0.041[e]
Diazinon	D.Z.O., Basadin, Diazatol, Knox Out, Sarolex	.154	—	0.08[f]
Dieldrin	Panoram D-31	.00498	—	2.5[g] or 0.0019[h]
Malathion	Cython, Maltox	.156	—	0.1[e]

[a] Maximum contaminant level (U.S. Environmental Protection Agency, 2000b).

[b] Alabama Primary Drinking Water Standards (Alabama Department of Environmental Management, 2000b).

[c] Canadian Council of Ministers of the Environment, 2001.

[d] Criteria maximum concentration for aquatic life (U.S. Environmental Protection Agency, 1999).

[e] Criterion continuous concentration for aquatic life (U.S. Environmental Protection Agency, 1999).

[f] Great Lakes Water Quality Agreement (International Joint Commission United States and Canada, 1978).

[g] Acute aquatic life criteria (Alabama Department of Environmental Management, 2000d).

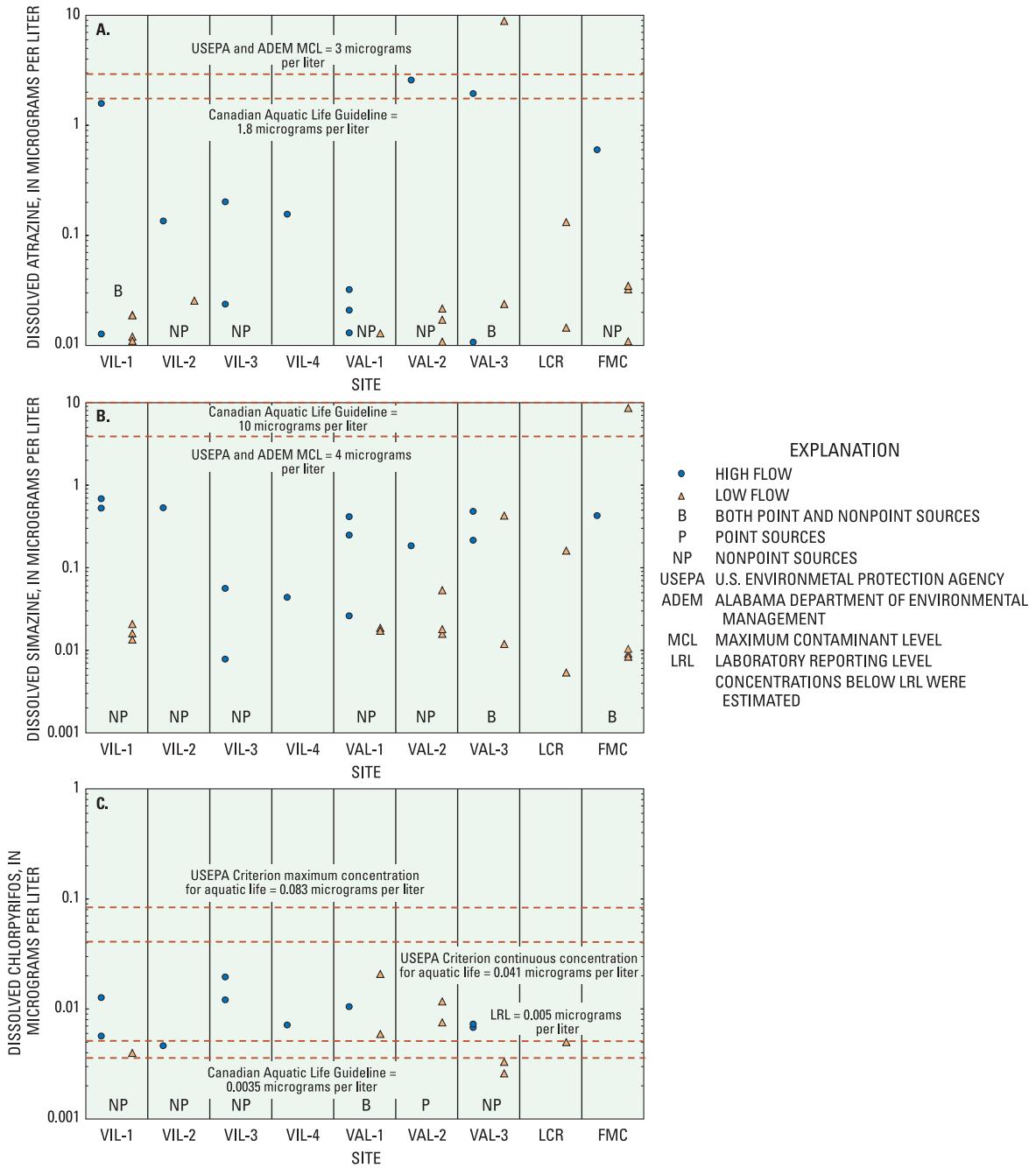[h] Chronic aquatic life criteria (Alabama Department of Environmental Management, 2000d).

Figure 24. (A) Dissolved atrazine, (B) dissolved simazine, and (C) dissolved chlorpyrifos concentrations detected in water samples during high and low flow at streams in the Birmingham area, Alabama, 2000−01.

the USEPA recommended water-quality criterion for aquatic life of 0.1 µg/L (table 17).

Ninety-four percent of the pesticide samples in this study contained more than one pesticide (appendix table 2-4). Atrazine, chlorpyrifos, diazinon, simazine, and tebuthiuron were detected at every urban site in the Birmingham study area (table 18). Carbaryl and prometon were detected at six of seven urban sites in the Birmingham study area (table 18). The site with the greatest number of pesticides (13) detected was VAL-3; the site with the fewest number of pesticides (8) detected was FMC (table 18). Prometon concentrations at VAL-2 were significantly greater than concentrations at FMC (table 6).

The number of pesticides present in the stream may be important from a toxicological standpoint. Generally, the effects of pesticide mixtures on biota or humans are not included in water-quality criteria, which are most commonly based on single-species, single-chemical toxicity tests conducted under laboratory conditions (Hampson and others, 2000). Some pesticides could be more toxic when combined with other toxic compounds than when present individually. The synergistic effects created from the low concentrations of multiple pesticides have yet to be quantified (Hoffman and others, 2000). The combined ecological effects of the pesticides in the streams are unknown.

Table 18. Pesticide detection frequencies in water samples from streams in the Birmingham area, Alabama, 2000–01

[Numbers shown are number of detections and the number of samples collected at each site. —, compound was not detected at this site; DNOC, 4,6-dinitro-2-methylphenol. Site locations are shown in figure 1]

	VIL-1	VIL-2	VIL-3	VIL-4	VAL-1	VAL-2	VAL-3	LCR	FMC
	HERBICIDES								
Atrazine	6 of 6	2 of 3	2 of 3	1 of 1	5 of 5	4 of 4	4 of 4	2 of 2	5 of 5
Benfluralin	1 of 6	—	—	—	—	—	—	—	—
Bentazon	—	—	—	—	1 of 5	—	—	—	—
Bromacil	—	1 of 3	1 of 3	1 of 1	—	—	1 of 4	—	—
Bromoxynil	—	1 of 3	—	—	—	—	—	—	—
Deethylatrazine	5 of 6	—	—	—	2 of 5	4 of 4	4 of 4	2 of 2	5 of 5
Diuron	—	1 of 3	2 of 4	1 of 1	—	—	—	—	—
DNOC	—	—	—		—	—	1 of 4	—	—
Metolachlor	—	—	—	1 of 1	—	—		1 of 2	—
Pendimethalin	—	—	1 of 3	1 of 1	1 of 5	2 of 4	1 of 4	—	—
Prometon	4 of 6	—	2 of 3	1 of 1	4 of 5	4 of 4	4 of 4	2 of 2	4 of 5
Pronamide	—	—	—	—	—	—	—	—	1 of 5
Simazine	6 of 6	1 of 3	2 of 3	1 of 1	5 of 5	4 of 4	4 of 4	2 of 2	5 of 5
Tebuthiuron	3 of 6	1 of 3	1 of 3	1 of 1	2 of 5	1 of 4	3 of 4	2 of 2	1 of 5
Trichlopyr	—	2 of 3	—	—	—	—	3 of 4	—	—
Trifluralin	1 of 6	—	2 of 3	—	—	1 of 4	—	—	—
	INSECTICIDES								
Aldicarb	—	—	—	—	—	—	—	1 of 2	—
Aldicarb sulfone	—	—	—	—	—	—	—	1 of 2	—
Carbaryl	1 of 6	2 of 3	2 of 3	1 of 1	1 of 5	—	2 of 4	2 of 2	—
Chlorpyrifos	3 of 6	2 of 3	2 of 3	1 of 1	3 of 5	2 of 4	4 of 4	1 of 2	—
Diazinon	4 of 6	2 of 3	2 of 3	1 of 1	5 of 5	4 of 4	4 of 4	2 of 2	2 of 5
Dieldrin	2 of 6	—	—	—	—	—	—	—	1 of 5
Malathion	—	—	—	—	1 of 5	1 of 4	1 of 4	1 of 2	—

Comparison of Pesticide Data from Urban Sites in Birmingham to Urban Sites Nationwide

Pesticide data from Village and Valley Creeks were compared to pesticide data collected from urban sites across the Nation in the NAWQA Program. More than 1,940 pesticide samples were collected from urban sites between 1991 and 2001 (U.S. Geological Survey, 2001). Pesticide concentrations from Village and Valley Creeks were plotted over a bar graph illustrating ranges, which included the lowest 25 percent, the middle 50 percent, and the highest 25 percent of the Birmingham data (fig. 25). To the right of each bar graph in figure 25 is another bar graph illustrating the same ranges for data collected at urban NAWQA sites nationwide. The statistical quartiles of both data sets were computed by using detected values in order to better illustrate the spread of the data. Concentrations of

pesticides were adjusted by censoring to a common detection threshold of 0.01 µg/L. The pesticide concentrations detected in this study fell within a narrower range than the concentrations reported nationally.

The most frequently detected herbicide in urban areas in the NAWQA Program was prometon (fig. 26). In the Birmingham study area, prometon was the third most commonly detected herbicide, after atrazine and simazine. All three of these compounds belong to the same category of triazine herbicides. Metolachlor and diuron, also herbicides, were detected more frequently on a national basis than in the Birmingham study area. The most frequently detected insecticide, both locally and nationally, was diazinon (fig. 26). The second and third most frequently detected insecticides were carbaryl and chlorpyrifos, respectively (fig. 26).
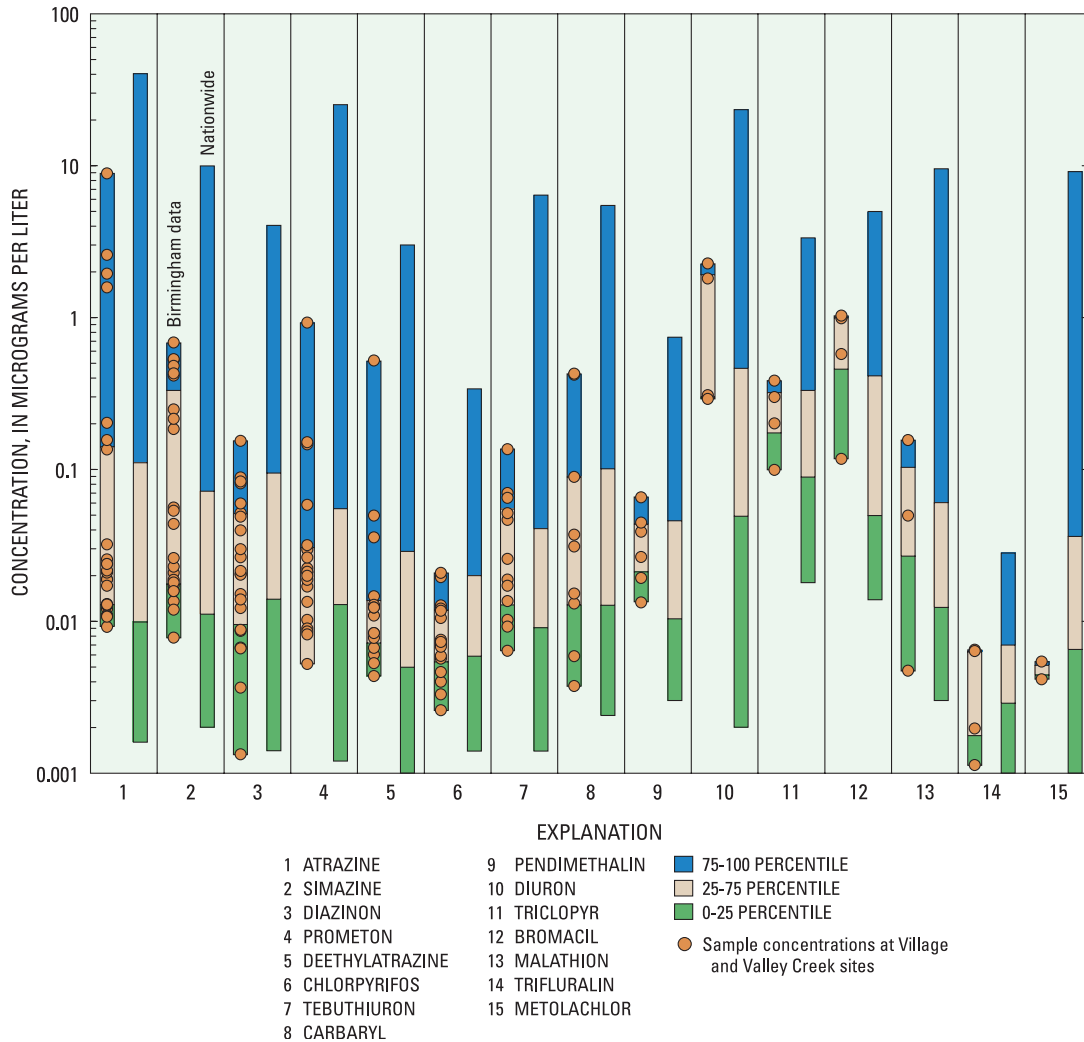

Figure 25. Comparison of pesticides in water samples from urban sites in the Birmingham area, Alabama, to urban sites nationwide.
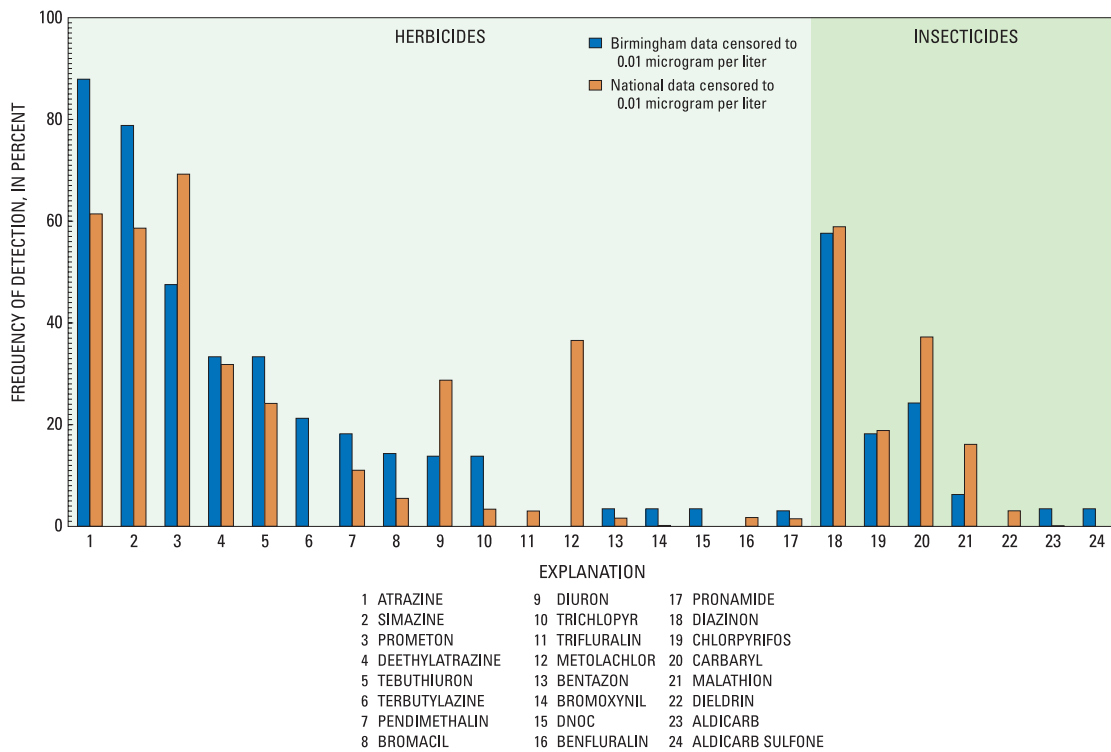
Figure 26. Comparison of frequencies of detection for pesticides in water samples from streams in the Birmingham area, Alabama, to urban sites nationwide.

Polycyclic Aromatic Hydrocarbons

Polycyclic aromatic hydrocarbons (PAHs) are formed during combustion processes and may enter surface-water systems in a variety of ways, including atmospheric deposition, surface runoff, and soil leaching (Smith and others, 1988). Several PAHs have been identified as carcinogens or mutagens. Sources of PAHs include domestic sewage, asphalt surfaces, car tires, vehicular exhaust, crude oil, and petroleum (Dojlido and Best, 1993).

Sixteen PAHs were detected in water samples from the Birmingham study sites (appendix table 2-5). PAHs were detected at all sites except LCR (table 19). Fluoranthene and pyrene were the most frequently detected PAHs (fig. 27). Ninety-nine percent of the detections were estimated values qualified with an "E" and were not compared to criteria because of uncertainty associated with the estimated value (appendix table 2-5). The maximum concentration of fluoranthene was 2.82 µg/L (VAL-2), which exceeded the Canadian guideline of 0.04 µg/L for the protection of aquatic life (Canadian Council of Ministers of the Environment, 2001). The maximum concentration of phenanthrene was 2.27 µg/L (VAL-3), which exceeded the Canadian guideline of 0.4 µg/L for the protection of aquatic life (Canadian Council of Ministers of the Environment, 2001).

Table 19. Polycyclic aromatic hydrocarbon detection frequencies in water samples from streams in the Birmingham area, Alabama, 2000–01

[PAH, polycyclic aromatic hydrocarbon. Numbers shown are number of detections and the number of samples collected at each site. —, compound was not detected at this site. Site locations are shown in figure 1]

| PAH	VIL-1	VIL-2	VIL-3	VIL-4	VAL-1	VAL-2	VAL-3	LCR	FMC
Acenaphthene	4 of 4	2 of 3	1 of 3	1 of 1	2 of 6	4 of 5	2 of 4	—	1 of 2
Acenapthylene	2 of 4	3 of 3	1 of 3	—	2 of 6	2 of 5	1 of 4	—	1 of 2
Anthracene	3 of 4	1 of 3	1 of 3	—	4 of 6	3 of 5	2 of 4	—	1 of 2
Benz-a-anthracene	3 of 4	1 of 3	—	—	2 of 6	1 of 5	2 of 4	—	1 of 2
Benzo(a)pyrene	3 of 4	1 of 3	—	—	3 of 6	1 of 5	2 of 4	—	1 of 2
Benzo[b]fluoranthene	3 of 4	1 of 3	—	1 of 1	3 of 6	1 of 5	2 of 4	—	1 of 2
Benzo[ghi]perylene	3 of 4	1 of 3	—	—	3 of 6	1 of 5	2 of 4	—	—
Benzo[k]fluoranthene	3 of 4	1 of 3	—	—	3 of 6	1 of 5	2 of 4	—	1 of 2
Chrysene	3 of 4	1 of 3	—	1 of 1	4 of 6	2 of 5	3 of 4	—	1 of 2
1,2-5,6-dibenzanthracene	3 of 4	1 of 3	—	—	1 of 6	1 of 5	1 of 4	—	—
Fluoranthene	4 of 4	3 of 3	2 of 3	1 of 1	5 of 6	5 of 5	3 of 4	—	2 of 2
Fluorene	4 of 4	2 of 3	2 of 3	1 of 1	3 of 6	4 of 5	2 of 4	—	—
Indeno[1,2,3-cd]pyrene	3 of 4	2 of 3	1 of 3	—	3 of 6	1 of 5	2 of 4	—	—
Naphthalene	3 of 4	3 of 3	2 of 3	—	3 of 6	3 of 5	2 of 4	—	—
Phenanthrene	3 of 4	2 of 3	1 of 3	—	4 of 6	3 of 5	3 of 4	—	1 of 2
Pyrene	4 of 4	3 of 3	2 of 3	1 of 1	5 of 6	5 of 5	3 of 4	—	2 of 2
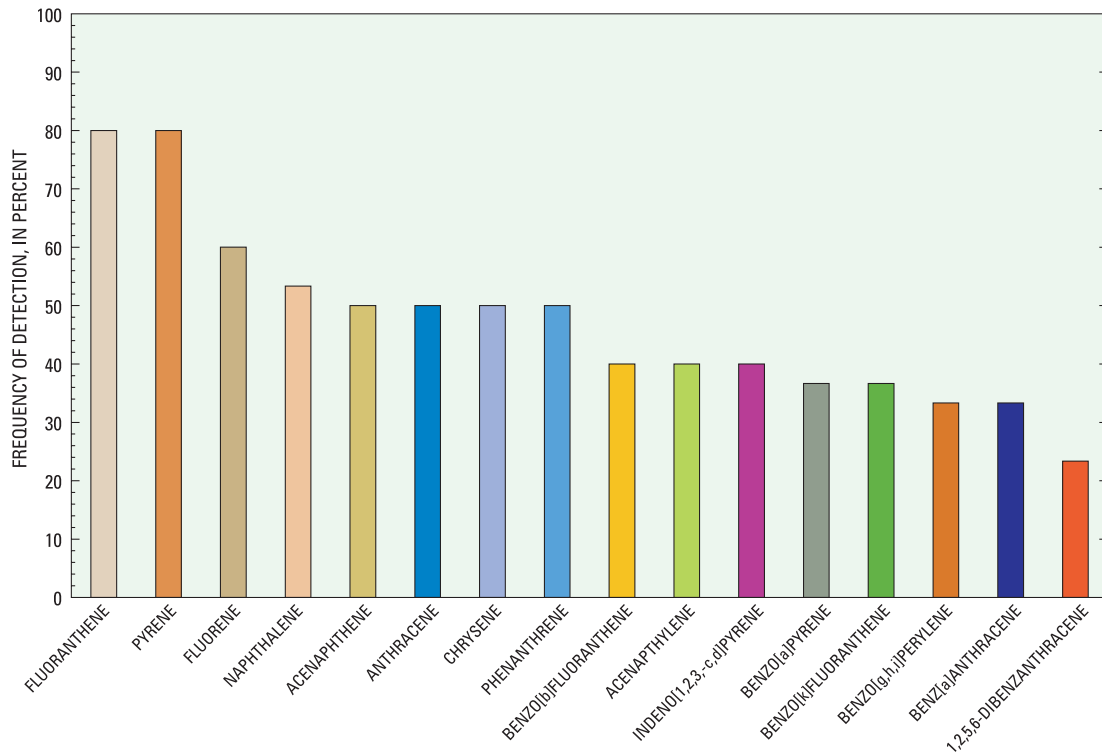
Figure 27. Frequencies of detection for polycyclic aromatic hydrocarbons in water samples from streams in the Birmingham area, Alabama, 2000–01.

Bed Sediment and Fish Tissue

Bed-sediment and fish-tissue samples were collected at VIL-1, VIL-2, VIL-3, VAL-1, VAL-2, and FMC and analyzed for trace and major elements and organic compounds.

Trace and Major Elements in Bed Sediment

Bed-sediment samples from Village and Valley Creeks and FMC were analyzed for 46 trace and major elements, 10 of which are classified by the USEPA (Code of Federal Regulations, 1996) as trace-element priority pollutants (TEPPs) (table 20; appendix table 3-1). Probable-effect levels (PELs) have been established for 8 of the 10 TEPPs, excluding nickel and silver (table 20). A general pattern of increasing concentrations of TEPPs in a downstream direction in Village Creek, especially between VIL-1 and VIL-2, and decreasing concentrations in a downstream direction in Valley Creek was identified. These patterns indicated potential points of origin for the introduction of these contaminants to Village and Valley Creek—upstream from VIL-2 and VAL-1, respectively.

Samples from VAL-1 contained the highest concentrations of chromium, copper, lead (fig. 28A), mercury, and silver among all sites (table 20). Samples from VIL-2 contained the highest concentrations of cadmium (fig. 29), nickel, selenium, and zinc among all sites (table 20). At both sites, the concentrations of arsenic, cadmium, chromium, copper, lead, and zinc (also
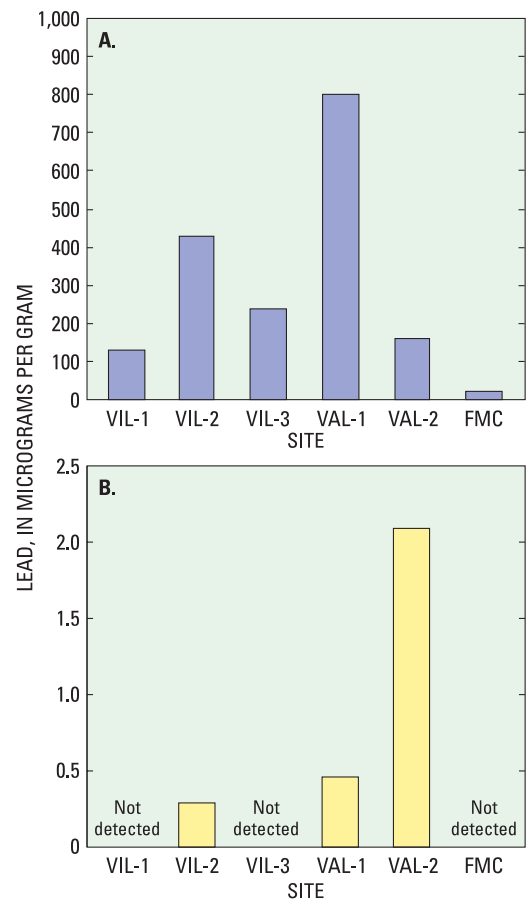

Figure 28. Concentrations of lead detected in (A) bed sediment and (B) fish-liver tissue (*Lepomis* species) from streams in the Birmingham area, Alabama, 2000.

Table 20. Concentrations of trace-element priority pollutants detected in bed-sediment samples from streams in the Birmingham area, Alabama, 2000

[Values are in micrograms per gram; PEL, probable effect level; LRL, laboratory reporting level; <, less than; na, not available. Shaded values are concentrations that exceeded the PEL. Site locations are shown in figure 1]

| Analyte	VIL-1	VIL-2	VIL-3	VAL-1	VAL-2	FMC	PEL	National median value[a]	LRL
Arsenic	**22**	**20**	**21**	**21**	14	11	17	6.3	0.01
Cadmium	.60	**19**	**10**	**4**	.82	< .1	3.53	.4	.1
Chromium	83	**170**	**110**	**180**	88	47	90	64	1
Copper	45	**210**	120	**320**	54	16	197	27	1
Lead	**130**	**430**	**240**	**800**	**160**	23	91.3	27	4
Mercury	.27	.45	.23	**1.60**	.19	< .02	.49	.06	.02
Nickel	38	57	41	47	21	18	na	27	2
Selenium	.80	1.90	1.20	1.50	.70	.51	4.00	.70	.10
Silver	.20	4.00	1.40	20.00	.90	.44	na	na	.10
Zinc	270	**4,000**	**2,400**	**1,200**	**330**	120	315	110	4

[a] Rice, 1999.
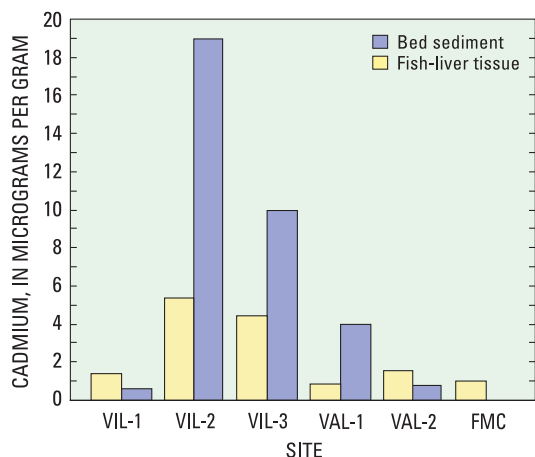
Figure 29. Concentrations of cadmium detected in bed sediment and fish-liver tissue (*Lepomis* species) from streams in the Birmingham area, Alabama, 2000.

mercury at VAL-1) exceeded PELs that have been found to result in deleterious effects on aquatic biota (Canadian Council of Ministers of the Environment, 1995).

Lead concentrations in bed sediment were elevated above the PEL at all sites in Village and Valley Creeks (table 20). Zinc concentrations were elevated above the PEL at both sites on Valley Creek and at VIL-2 and VIL-3; cadmium and chromium concentrations were elevated above the PELs at VAL-1 and at VIL-2 and VIL-3—the two downstream sites on Village Creek (table 20).

Arsenic concentrations were elevated above the PELs at all sites on Village Creek and the most upstream site on Valley Creek (table 20); however, these values have not been adjusted for natural background levels. A recent survey of stream sediment in northern Alabama, including streams in Jefferson County, reported naturally elevated arsenic concentrations (Goldhaber and others, 2001). In that survey, the sources of arsenic-enriched bed sediments in the carbonate valleys were related to the arsenic-enriched coals from nearby coal fields in Jefferson County. These naturally enriched levels ranged from 7 to 14 µg/g in Jefferson County. Concentrations of arsenic in bed sediment at FMC and VAL-2 were within this naturally enriched range—all other concentrations at sites on Village and Valley Creeks exceeded the naturally enriched range (table 20). Goldhaber and others (2001) did consider the urban area of Birmingham to be a possible source of arsenic from industrial pollution.

With the exception of silver, the concentrations of the TEPPs in the bed-sediment sample from FMC were the lowest in the study, and none exceeded the PELs (table 20). The concentration of silver at VAL-1 (20 µg/g)

was five times greater than that detected at VIL-3 (4 µg/g), and 45 times greater than that detected at FMC (0.44 µg/g). Zinc concentrations in the bed-sediment samples from VIL-2, VIL-3, and VAL-1 were 4 to 12 times greater than those in the samples from VIL-1 and VAL-2. Concen-trations of TEPPs in bed sediment, except for silver, were consistently highest in Village and Valley Creeks and lowest in FMC, indicating possible anthropogenic sources of these TEPPs from the urban land-use activities in the watersheds of Village and Valley Creeks. Potential sources include point sources, such as municipal wastewater, industrial, and commercial discharges, and nonpoint sources, such as runoff from residential, commercial, and industrial areas.

The concentrations of nine TEPPs (arsenic, cadmium, chromium, copper, lead, mercury, nickel, selenium, and zinc) in the bed-sediment samples from VIL-1, VIL-2, VIL-3, and VAL-1 exceeded the national median values reported by Rice (1999; table 20). At VAL-2, the concentrations of seven TEPPs (arsenic, cadmium, chromium, copper, lead, mercury, and zinc) exceeded the national median values (table 20). In contrast, only arsenic and zinc concentrations in the bed-sediment sample from FMC exceeded the national median values (table 20).

On a regional level, bed-sediment concentrations of antimony, beryllium, cadmium, chromium, copper, lead, magnesium, mercury, molybdenum, nickel, selenium, silver, and tin at the Village and Valley Creek sites exceeded concentrations at 21 sites in Alabama, Mississippi, and Georgia sampled in 1998 by the USGS as part of the NAWQA Program (Zappia, in press). Concentrations of silver at VAL-1 exceeded concentra-tions from 770 sites sampled nationwide from the 1991 and 1994 USGS NAWQA studies (Zappia, in press).

Concentrations of the TEPPs in each sample were summed to compare bed sediment among the six sites (fig. 30A). The highest summed concentration of the TEPPs (4,912 µg/g) occurred in the bed-sediment sample from VIL-2; the lowest summed concentration of the TEPPs (236 µg/g) occurred at FMC. In Village Creek, concentrations of 8 of the TEPPs (cadmium, chromium, copper, lead, nickel, selenium, silver, and zinc) in bed sediment were highest at VIL-2, followed by VIL-3 and VIL-1—whereas in Valley Creek, however, concentrations of all 10 priority pollutants were highest at VAL-1 and decreased in a downstream direction. Zinc, lead, and copper were the three most abundant TEPPs detected in the bed-sediment samples from Village and Valley Creeks (fig. 30). Zinc accounted for 81 percent of the summed concentrations of the 10 TEPPs detected in the bed-sediment samples from VIL-2 and VIL-3 and
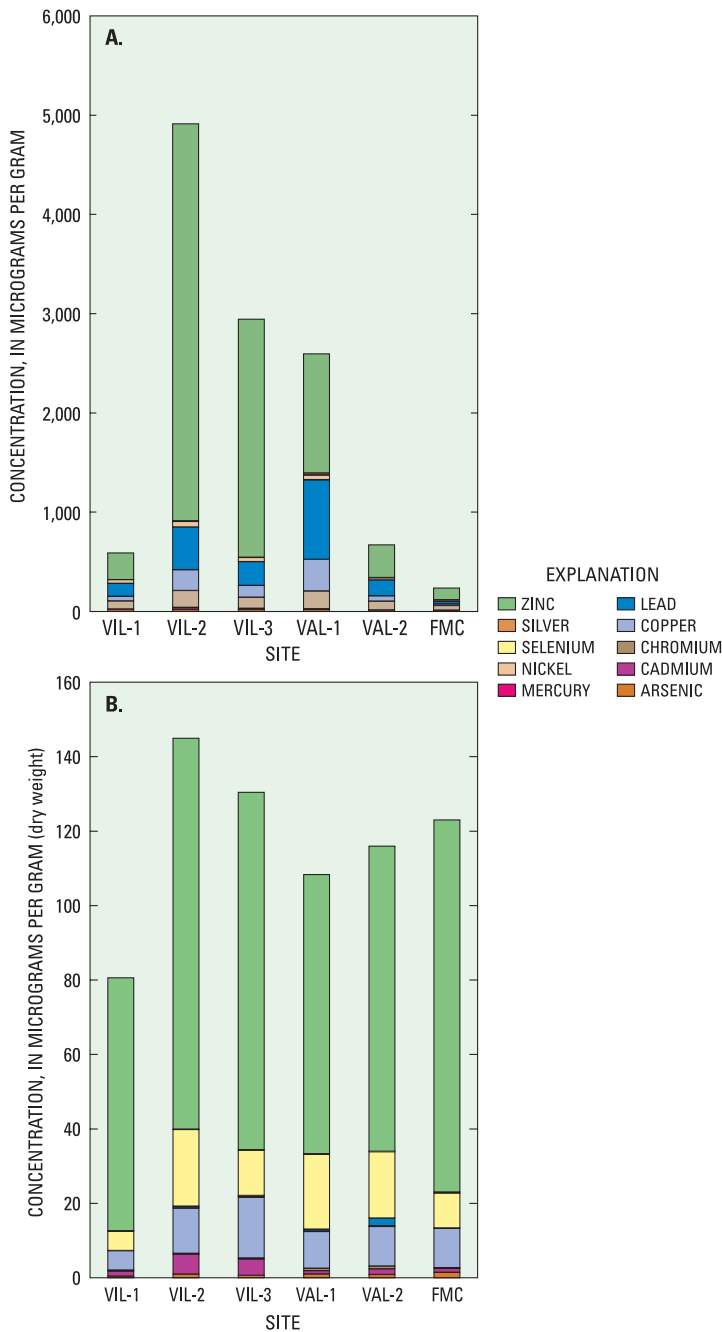
Figure 30. The sum of the concentrations of trace-element priority pollutants detected in (A) bed sediment and (B) fish-liver tissue (*Lepomis* species) from streams in the Birmingham area, Alabama, 2000.

Valley Creek, there was a general decrease in concentration of the non-TEPPs in a downstream direction (appendix table 3-1). In Village Creek, the summed concentrations of the non-TEPPs were similar among the three sites. With the exception of organic carbon, there was no general pattern of increasing concentration in a downstream direction. Organic carbon concentrations in samples from VIL-2 and VIL-3 were higher than those detected in the sample from VIL-1. The organic carbon in the VIL-2 sample also was higher than that in VIL-3, indicating a source upstream from VIL-2. The bed-sediment sample from FMC generally had the lowest detected concentrations of the 36 non-TEPP elements (appendix table 3-1). Only gold and thallium were not detected at any site.

Trace and Major Elements in Fish-Liver Tissue

Fish-liver tissue samples were analyzed for 22 elements (table 21). Concentrations could not be compared to standards because NAS/NAE and Canadian standards for trace-element concentrations in fish-liver tissue do not exist. No discernible pattern of concentration increase or decrease in a downstream direction among the sites was identified for most of the analytes. The lack of such a pattern may be due to the complexity of fish tissues, the behavior of the fishes, the differences in bioavailability of the elements, and other environmental factors. Four trace elements (antimony, beryllium, silver, and uranium) were not detected in quantifiable amounts in samples from any of the sites.

Cadmium and lead were the most variable of the TEPPs detected in fish-liver samples. The samples from VIL-2 and VIL-3 contained more than twice the concentration of cadmium than samples from any other site (fig. 29) and the sample from VAL-2 contained more than four times the concentration of lead than any other site (fig. 28B). Concentrations of cadmium, selenium, and zinc were highest in fish-liver samples from VIL-2; concentrations of lead and chromium were highest in fish-liver samples from VAL-2; concentrations of copper and mercury were highest at VIL-3; concentrations of arsenic were highest at FMC (table 21). Arsenic is typically not used in metabolic processes of aquatic organisms. The bioavailability of arsenic depends on several factors—including concentration in the bed sediment or water column, the speciation of arsenic present, and other environmental factors such as pH, sulfide, and iron concentrations (Agency for Toxic Substances and Disease

about 50 percent of the summed TEPP concentrations in bed-sediment samples from each of the other four sites. Lead accounted for the second largest component of the TEPPs from all sites except FMC, where chromium was the second largest component.

Samples from VIL-2 and VAL-1 contained the highest concentrations of the non-TEPP elements. In

Table 21. Concentrations of trace and major elements detected in fish-liver tissue (*Lepomis* species) from streams in the Birmingham area, Alabama, 2000

[Values are in micrograms per gram, dry weight recoverable; LRL, laboratory reporting level; <, less than; na, not available; E, estimated value. Site locations are shown in figure 1]

Analyte	VIL-1	VIL-2	VIL-3	VAL-1	VAL-2	FMC	LRL
Aluminum	5.0	7.5	4.0	14.6	66.4	10.6	1.000
Antimony	< .2	< .24	< .22	< .36	< .25	< .52	.100
Arsenic	.41	.99	.66	1.03	.87	1.46	.100
Barium	< .1	.22	.12	.24	.79	.21	.100
Beryllium	< .2	< .24	< .22	< .36	< .25	< .52	.100
Boron	1.2	1.50	1.13	1.49	1.29	2.58	.200
Cadmium	1.4	5.34	4.40	.88	1.54	1.02	.100
Chromium	< .5	< .5	< .5	.61	.75	< .5	.500
Cobalt	1.1	.34	.28	.75	.94	1.68	.100
Copper	5.2	12.1	16.3	9.9	10.6	10.5	.500
Iron	410	283	323	498	568	738	1.000
Lead	< .2	.29	< .22	.46	2.09	< .52	.100
Manganese	3.2	5.6	4.5	6.4	10.4	6.9	.100
Mercury	E .04	.25	.26	.17	.19	.13	na
Molybdenum	.7	1.80	1.55	1.94	1.11	1.01	.100
Nickel	< .2	< .24	.23	< .36	.32	< .52	.100
Selenium	5.2	20.6	12.2	20.1	17.8	9.3	.100
Silver	< .2	< .24	< .22	< .36	< .25	< .52	.100
Strontium	.2	.30	.41	.86	1.46	.42	.100
Uranium	< 2	< .24	< .22	< .36	< .25	< .52	.100
Vanadium	.4	.72	.86	.91	1.35	1.17	.100
Water in tissue (percent)	70	76.7	77.4	77.7	80.1	79.7	na
Zinc	68	105	96	75	82	100	.500

Registry, 2000a). Fish-liver samples from VIL-1 had the lowest concentrations of 12 of the 22 elements (table 21).

The concentrations of the 10 TEPPs detected in fish-liver samples from six sites were summed for comparison among sites (fig. 30B). Those sites with the greatest summed concentrations of TEPPs in fish-liver tissue were VIL-2 and VIL-3. The site with the lowest summed concentrations was VIL-1. Zinc, selenium, and copper were the most abundant TEPPs detected in fish-liver tissue (fig. 30B). On a regional level, concentrations of lead and molybdenum in fish-liver tissue samples at sites in the Birmingham area exceeded concentrations detected at 21 other sites in Alabama, Mississippi, and Georgia sampled in 1998 (Zappia, in press).

Comparison of Trace-Element Priority Pollutants in Bed-Sediment and Fish-Liver Samples

The concentrations of TEPPs in samples of bed sediment and fishes were compared to determine the likelihood of uptake and sequestration of trace elements from the bed sediment to tissue. The mechanism for uptake may be highly variable among aquatic organisms and the sample size was small; therefore, this result should be viewed with caution. Cadmium (rho = 0.976) in fish tissue was the only trace element that showed significant positive correlation to the concentration of TEPP in bed sediment.

Organic Compounds in Bed Sediment

Bed-sediment samples from the Birmingham study sites were analyzed for 89 organic compounds, including organophosphate and organochlorine pesticides, PAHs, and PCBs. Forty-six of those compounds were detected in quantifiable concentrations (table 22).

Chlorpyrifos was the only organophosphate pesticide detected in bed-sediment samples from the Birmingham study sites, and the concentrations were

Table 22. Concentrations of pesticides and other organic compounds detected in bed-sediment samples from streams in the Birmingham area, Alabama, 2000

[Values are in micrograms per kilogram unless otherwise noted; PEL, probable effect level; E, estimated value; <, less than; na, not available; g/kg, grams per kilogram. Shaded values are concentrations that exceeded the PEL. Site locations are shown in figure 1]

Analyte	VIL-1	VIL-2	VIL-3	VAL-1	VAL-2	FMC	PEL[a] (dry weight)
1,6-dimethylnaphthalene	E 2.7	57.7	81.8	E 27.1	E 27.7	< 50	na
1,2-dimethylnaphthalene	< 50	< 50	E 20.7	< 50	E 2.9	< 50	na
1-methylpyrene	E 14	77.6	109	92.2	68.1	E 4.8	na
1-methylphenanthrene	E 20.6	120	158	96.3	93.1	E 12.5	na
2,3,6-trimethylnaphthalene	< 50	E 47.2	E 41.2	E 22.8	E 19.9	< 50	na
2,6-dimethylnaphthalene	E 3.5	76.2	147	E 30.4	E 33.4	E 3.6	na
2-ethylnaphthalene	< 50	E 11.9	E 12.4	E 17.3	E 3.4	< 50	na
2-methylanthracene	E 9.5	58	83.2	E 47.4	52.6	E 2.7	na
4*H*-cyclopenta-phenanthrene	E 36.7	134	209	203	148	E 7.7	na
9,10-anthraquinone	110	278	286	416	253	E 47.5	na
9h-fluorene	E 12.8	106	170	85.9	67.6	E 9.6	na
Acenaphthene	E 8.6	83.5	168	62.5	50.5	E 2.1	88.9
Acenaphthylene	E 7.4	82.2	112	56.7	52.6	E 2.2	128
Acridine	E 29.6	E 42.5	< 50	128	50.4	< 50	na
Anthracene	E 49.7	305	441	302	247	E 19.8	na
Benz(*a*)anthracene	268	1,020	1,150	1,110	1,170	69	385
Benzo[*a*]pyrene	274	929	1,120	1,180	1,050	80.1	782
Benzo[*b*]fluoranthene	354	1,140	1,550	1,220	1,120	113	na
Benzo[*ghi*]perylene	214	E 305	859	848	E 292	59.3	na
Benzo[*k*]fluoranthene	302	1,000	1,230	732	909	109	na
bis(2-Ethylhexyl) phthalate	114	985	1,150	940	1,070	E 38.5	na
Butylbenzylphthalate	E 10.4	295	134	92	68	< 50	na
Carbazole	51	174	258	273	154	E 14.2	na
Carbon, total (g/kg as carbon)	12	55.45	69.32	33.96	30.03	17.76	na
Chlordane	34	54	53	46	66	< 3	8.87
Chlorpyrifos	4.15	23.1	9.28	15.7	10.3	.25	na
Chrysene	380	1,220	1,410	986	1,400	104	862
DDE, *p,p'*	.4	3.72	7.1	.78	.87	< .2	6.75
DDT, *p,p'*	.6	2.7	< 5.2	1.5	1.2	< .5	4.77
Dibenz[*a,h*]anthracene	60	E 103	273	208	E 112	E 19.5	135
Dibenzothiophene	E 10.1	72.9	86.6	75.2	60.8	E 1.4	na
Diethyl phthalate	< 50	< 50	< 50	E 14.5	< 50	< 50	na
Di-*n*-butyl phthalate	E 11	E 41.7	E 44.8	E 21.7	E 31.1	E 21.7	na
Di-*n*-octylphthalate	< 50	94.2	< 50	1,390	57.3	< 50	na
Fluoranthene	655	1,970	1,710	2,830	1,990	202	2,355
Indeno[1,2,3-*cd*]pyrene	258	E 425	1,000	1,040	E 445	88.7	na
Isoquinoline	< 50	< 50	< 50	E 21	< 50	< 50	na
Naphthalene	E 3.1	< 50	258	< 50	< 50	< 50	391
PCB, total	5.7	95	85	28	39	< 5	277
p-CRESOL	E 7.9	262	182	E 47.1	79.9	< 50	na
p-dichlorobenzene	< 50	E 12	< 50	< 50	E 13.6	< 50	na
Phenanthrene	286	1,210	1,490	1,320	1,000	104	515
Phenanthridine	E 9.8	E 29.8	< 50	E 39	E 27.6	< 50	na
Phenol	E 6.5	56	63.9	E 38.6	E 14.2	E 7.4	na
Pyrene	504	1,400	1,390	2,160	1,420	161	875
Quinoline	< 50	E 1.6	E 12.7	< 50	< 50	< 50	na

Table 22. Concentrations of pesticides and other organic compounds detected in bed-sediment samples from streams in the Birmingham area, Alabama, 2000—Continued

[Values are in micrograms per kilogram unless otherwise noted; PEL, probable effect level; E, estimated value; <, less than; na, not available; g/kg, grams per kilogram. Shaded values are concentrations that exceeded the PEL. Site locations are shown in figure 1]

Analyte	VIL-1	VIL-2	VIL-3	VAL-1	VAL-2	FMC	PEL[a] (dry weight)
			Nondetections				
1,2,4-trichlorobenzene	< 50	< 50	< 50	< 50	< 50	< 50	na
1-methyl-9h-fluorene	< 50	< 50	< 50	< 50	< 50	< 50	na
2,2'-biquinoline	< 50	< 50	< 50	< 50	< 50	< 50	na
2,4-dinitrotoluene	< 50	< 50	< 50	< 50	< 50	< 50	na
2,6-dinitrotoluene	< 50	< 50	< 50	< 50	< 50	< 50	na
2-chloronaphthalene	< 50	< 50	< 50	< 50	< 50	< 50	na
2-chlorophenol	< 50	< 50	< 50	< 50	< 50	< 50	na
3,5-xylenol (dimethylphenol)	< 50	< 50	< 50	< 50	< 50	< 50	na
4-bromophenyl phenyl ether	< 50	< 50	< 50	< 50	< 50	< 50	na
4-Chloro-*m*-cresol (4-chloro-3-methylphenol)	< 50	< 50	< 50	< 50	< 50	< 50	na
4-Chlorophenyl phenyl ether	< 50	< 50	< 50	< 50	< 50	< 50	na
Aldrin	< .2	< .2	< .2	< .2	< .4	< .2	na
Azobenzene	< 50	< 50	< 50	< 50	< 50	< 50	na
Benzo[c]cinnoline	< 50	< 50	< 50	< 50	< 50	< 50	na
bis-2-Chloroethyl ether	< 50	< 50	< 50	< 50	< 50	< 50	na
bis(2-Chloroethoxy)methane	< 50	< 50	< 50	< 50	< 50	< 50	na
C8-alkylphenol	< 50	< 50	< 50	< 50	< 50	< 50	na
Diazinon	< .2	< .2	< .2	< .2	< .2	< .2	na
m-Dichlorobenzene	< 50	< 50	< 50	< 50	< 50	< 50	na
o-Dichlorobenzene	< 50	< 50	< 50	< 50	< 50	< 50	na
Dieldrin	< .2	< .2	< .2	< .2	< .2	< .2	na
Dimethyl phthalate	< 50	< 50	< 50	< 50	< 50	< 50	na
Endosulfan	< .2	< .2	< .2	< .2	< .2	< .2	na
Endrin	< .2	< .2	< .2	< .2	< .2	< .2	na
Ethion	< .2	< .2	< .2	< .2	< .2	< .2	na
Heptachlor epoxide	< .2	< .2	< .2	< .2	< .2	< .2	na
Heptachlor	< .2	< .2	< .2	< .2	< .2	< .2	na
Hexachlorobenzene	< 50	< 50	< 50	< 50	< 50	< 50	na
Isophorone	< 50	< 50	< 50	< 50	< 50	< 50	na
Lindane	< .2	< .2	< .2	< .2	< .2	< .2	na
Malathion	< .2	< .2	< .2	< .2	< .2	< .2	na
Methoxychlor	< 2	< 2.5	< 2.5	< 2.5	< 2.5	< 2.5	na
Methylparathion	< .2	< .2	< .2	< .2	< .2	< .2	na
Mirex	< .2	< .2	< .2	< .2	< .2	< .2	na
Nitrobenzene	< 50	< 50	< 50	< 50	< 50	< 50	na
N-nitrosodi-N-propylamine	< 50	< 50	< 50	< 50	< 50	< 50	na
n-Nitrosodiphenylamine	< 50	< 50	< 50	< 50	< 50	< 50	na
p,p'-DDD	< 1.9	< 1.1	< 3	< 2.1	< 2.4	< .5	na
Parathion	< .2	< .2	< .2	< .2	< .2	< .2	na
Pentachloroanisole	< 50	< 50	< 50	< 50	< 50	< 50	na
Pentachloronitrobenzene	< 50	< 50	< 50	< 50	< 50	< 50	na
Toxaphene	< 50	< 50	< 50	< 50	< 50	< 50	na
Trithion	< .2	< .2	< .2	< .2	< .2	< .2	na

[a] Canadian Council of Ministers of the Environment, 1995.

quantifiable in samples from all sites (fig. 31). Concentrations of chlorpyrifos were highest in bed-sediment samples from VIL-2 and lowest in samples from FMC (table 22). The concentrations in bed-sediment samples from VAL-1 and VAL-2 were higher than concentrations from VIL-1 or VIL-3 (table 22). The presence of chlorpyrifos in bed sediment was of particular interest to the city of Birmingham because of the fish kill that resulted from the 1997 spill of Dursban into Village Creek. In addition to a lethal effect on fishes, chlorpyrifos is acutely toxic to some species of aquatic invertebrates at water-column concentrations as low as 0.0035 µg/L, and has been shown to decrease densities of aquatic invertebrates (Odenkirchen and Eisler, 1988). However, since chlorpyrifos has a half-life of about 24 days in a water-column-sediment mixture and about 9 hours in fishes (Odenkirchen and Eisler, 1988), it is unlikely that there was any residual chlorpyrifos in the bed sediment of Village Creek that can be directly attributed to the Dursban spill in 1997. The presence of persistent
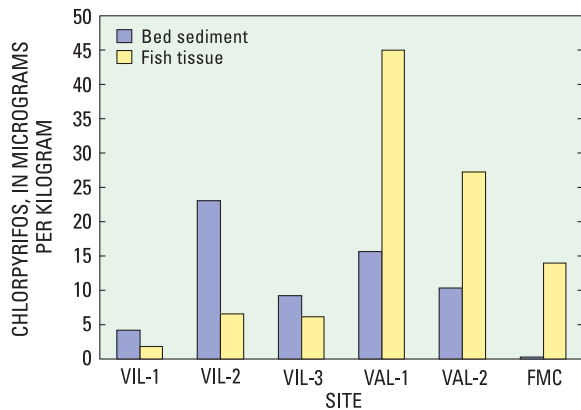
Known degradation products, or metabolites, include DDE and DDD, which are also highly persistent. DDE is commonly produced in oxygen-rich environments, such as streams and some soils; DDD is produced only in oxygen-depleted environments, such as ground water (Chapelle, 1993).

The bed-sediment concentrations of DDD, DDE, DDT, and the ratio of DDT/total DDT at the six sites in the Birmingham area are provided in table 23. The *p,p*'-DDT isomer was detected in the bed-sediment samples at VIL-1, VIL-2, VAL-1, and VAL-2; the *p,p*'-DDE isomer was detected at every site on Village and Valley Creeks; the *p,p*'-DDD isomer was not detected at any site (table 23; fig. 32A). The highest concentration of *p,p*'-DDT (2.7 µg/kg) occurred at VIL-2; the highest concentration of *p,p*'-DDE (7.10 µg/kg) occurred at VIL-3 and exceeded the PEL of 6.75 µg/kg at that site (fig. 32A; table 22). The highest total DDT concentration, based on only the *p,p*'-DDE and the *p,p*'-DDT isomers, occurred at VIL-3 (fig. 32A).

Figure 31. Concentrations of chlorpyrifos detected in bed sediment and fish tissue (*Lepomis* species) from streams in the Birmingham area, Alabama, 2000.

organochlorine compounds, such as DDT, in the aquatic environment may be related to both past and present land use in the watershed. DDT is relatively immobile and highly persistent in the soil environment, with a reported half-life of between 2 and 15 years (Agency for Toxic Substances and Disease Registry, 2000b). The reported half-life for DDT in the water environment is approximately 56 days in lakes and 28 days in river water (Agency for Toxic Substances and Disease Registry, 2000b). DDT can be degraded in both the soil and aquatic environments; however, degradation occurs much more slowly in soils.
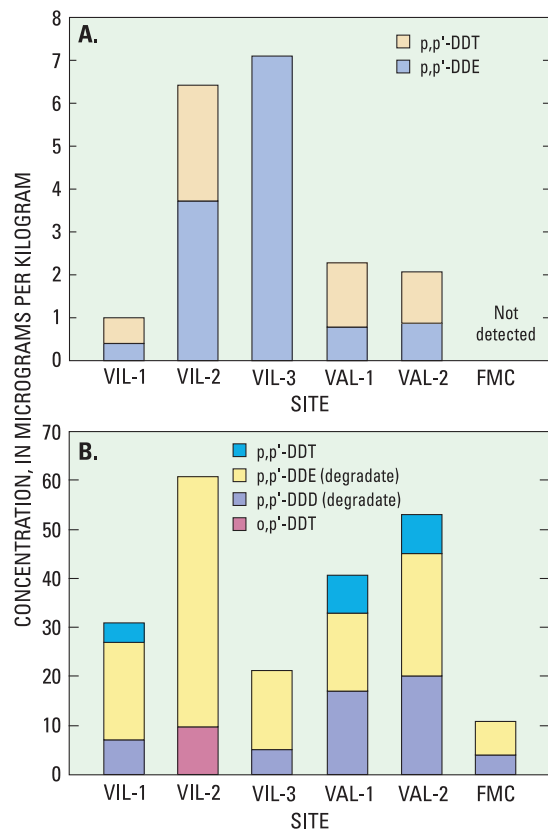

Figure 32. Concentrations of DDT and its degradation products detected in (A) bed sediment and (B) fish tissue (*Lepomis* species) from streams in the Birmingham area, Alabama, 2000.

Table 23. Concentrations of DDT and its degradation products detected in bed-sediment and fish-tissue samples at selected stream sites in the Birmingham area, Alabama, 2000

[Values are in micrograms per kilogram; NA, no analysis for this isomer; <, less than; ND, not able to be determined because of censored or missing values. Ratios in **bold** indicate recent mobilization and introduction of residual DDT into the hydrologic system at the site]

Site label (fig. 1)	o,p'-DDD	p,p'-DDD	o,p'-DDE	p,p'-DDE	o,p'-DDT	p,p'-DDT	Total DDT[a]	DDT[b]/ total DDT	DDE, percent of total DDT	DDD, percent of total DDT
				Bed sediment						
VIL-1	NA	< 1.9	NA	0.40	NA	0.6	1.0	ND	40	ND
VIL-2	NA	< 1.1	NA	3.72	NA	2.7	6.4	ND	58	ND
VIL-3	NA	< 3.0	NA	7.10	NA	< 5.2	7.1	ND	100	ND
VAL-1	NA	< 2.1	NA	.78	NA	1.5	2.3	ND	34	ND
VAL-2	NA	< 2.4	NA	.87	NA	1.2	2.1	ND	42	ND
FMC	NA	< .5	NA	< .2	NA	< .5	ND	ND	ND	ND
				Fish tissue						
VIL-1	< 5	7	< 5	20	< 5	4	31	**0.13**	65	23
VIL-2	< 5	< 5	< 5	51	9.7	< 5	61	**.16**	84	ND
VIL-3	< 5	5.1	< 5	16	< 5	< 5	21	ND	76	24
VAL-1	< 5	17	< 5	16	< 5	7.6	41	**.19**	39	42
VAL-2	< 5	20	< 5	25	< 5	7.9	53	**.15**	47	38
FMC	< 5	3.9	< 5	7	< 5	< 5	11	ND	64	36

[a] Total DDT values for bed sediment are estimated from p,p'-isomer data only. Total DDT values for fish tissue are estimated from the p,p'- and o,p'-isomer data.
[b] DDT values for fish tissue are estimated from the p,p'-DDT and o,p'-DDT isomers only.

Studies have indicated that the ratio of DDT[2] / total DDT[3] can be used to determine how long DDT has been in the environment (Nowell and others, 1999). Nowell and others (1999) reported that a ratio exceeding 10 percent (in bed sediment or fish samples) was considered to be indicative of recent movement of DDT (as compared to historical use) into the hydrologic system, for example, by erosion of DDT-contaminated soil. In this study, an accurate estimate of DDT and total DDT for bed-sediment samples could not be made for two reasons: (1) bed-sediment samples were analyzed for the p,p'-isomer of DDT and its metabolites only—o,p'-isomers were not quantified and, (2) p,p'-DDD and p,p'-DDT values were censored at relatively high concentrations.

Chlordane is another persistent organo-chlorine pesticide. Chlordane actually is a mixture of many compounds, the most abundant being *cis*- and *trans*-chlordane (24 and 19 percent, respectively), heptachlor (10 percent), and nonachlor isomers (7 percent). Chlordane was detected in bed-sediment samples from all sites except FMC (fig. 33A). Detections ranged from 34 µg/kg at VIL-1 to 66 µg/kg at VAL-2 (table 22). Chlordane concentra-tions at all sites, except FMC, were

[2]DDT refers to the sum of o,p'-DDT and p,p'-DDT.
[3]Total DDT refers to the sum of o,p'-DDD, p,p'-DDD, o,p'-DDE, p,p'-DDE, o,p'-DDT, and p,p'-DDT.

over 3 times the PEL of 8.87 µg/kg; such levels have been linked to physiological changes in aquatic biota (Nowell and others, 1999).

Several PAHs also were detected in measurable quantities at all sites. Among the nonpesticide organic compounds for which bed-sediment samples were analyzed, those accounting for the largest percentage of the summed concentrations (from 10 to 16 percent) at each site were fluoranthene and pyrene (table 22). Concentrations of organic compounds that exceeded PELs are highlighted in table 22—concentrations of eight PAHs (in decreasing order of concentration, fluoroanthene, pyrene, phenanthrene, chrysene, benzo[a]pyrene, benz[a]anthracene, dibenz[ah]anthracene, and acenaphthene) exceeded PELs at sites on Village and Valley Creek (table 22). Concentrations of pyrene, phenanthrene, chrysene, benzo[a]pyrene, and benz(a)anthracene exceeded PELs at all sites except VIL-1 and FMC. PAH concentrations in bed-sediment samples from FMC and VIL-1 did not exceed PELs.

Bed-sediment samples from VAL-1 had the highest summed concentrations and FMC had the lowest summed concentrations of all organic compounds analyzed (table 22). In Village Creek, concentrations of 75 percent of the detected organic compounds were lowest at VIL-1 and increased in a downstream direction from VIL-2 to VIL-3. Concentrations of 25 percent of the detected
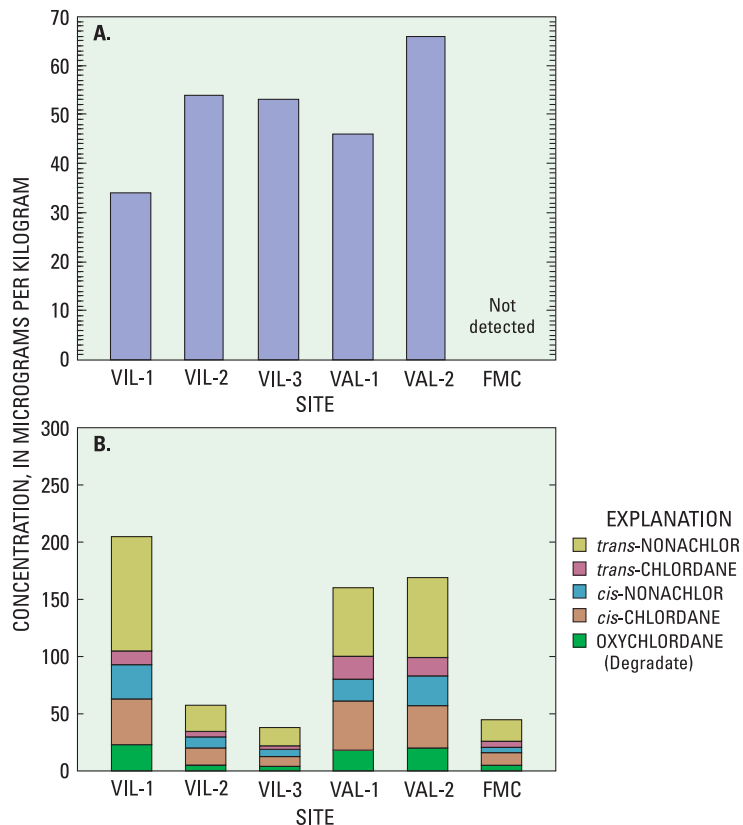
Figure 33. Concentrations of (A) total chlordane detected in bed sediment and (B) components of total chlordane detected in fish tissue (*Lepomis* species) from streams in the Birmingham area, Alabama, 2000.

organic compounds, including chlorpyrifos, were highest at VIL-2, followed by VIL-3 and VIL-1 (table 22). In contrast, concentrations of about 70 percent of the detected organic compounds in Valley Creek were highest at VAL-1 and decreased in a downstream direction from VAL-1 to VAL-2 (table 22).

Organic Compounds in Fish Tissue

Fish-tissue samples were analyzed for PCBs, 26 organochlorine pesticides, and 19 organophosphate pesticides. Tissue analysis data are presented as reported by the NWQL in table 24. Fourteen organic compounds were quantifiable in the fish-tissue samples. Eight were detected in the samples from all six sites (chlorpyrifos, total DDT, *cis-* and *trans-*nonachlor, *cis-* and *trans-*chlordane, oxychlordane, and total PCBs). Total chlordane refers to the total of the *cis-* and *trans-*chlordane, *cis-*and *trans-*nonachlor, and oxychlordane concen-trations (Nowell and other, 1999). Although the chlordane isomers (*cis-* and *trans-*) are the most abundant components of chlordane, *trans-*nonachlor is the most persistent component. The predominance of *trans-*nonachlor as compared to the other components in fish tissue can be used to indicate a reduction in chlordane

input to the hydrologic system (Nowell and others, 1999).

Total chlordane was detected in the highest concentrations in fish tissue collected at VIL-1, VAL-2, and VAL-1 (table 24). Among the components of total chlordane, *trans-n*onachlor accounted for the largest percentage (38 to 49 percent of the total) among the three streams (fig. 3B). The greatest percentage of the more persistent component of chlordane, *trans-*nonachlor, at all sites indicated long-term residual chlordane in the hydrologic system, not recent input. Total chlordane concentrations in fish-tissue samples from VIL-1, VAL-1, and VAL-2 exceeded guidelines for the protection of fish-eating wildlife (table 24; National Academy of Science/National Academy of Engineering, 1973) and the USEPA screening criterion for edible fish (U.S. Environmental Protection Agency, 1995). A comparison of pesticide concentrations in whole fish samples, as were collected in this study, with standards or guidelines for edible fish is appropriate only as a screening procedure to determine whether additional sampling is warranted (Nowell and Resek, 1994).

Chlorpyrifos was detected in fish-tissue samples from every site. The highest concentrations were found in samples from VAL-1 and VAL-2, respectively, and the lowest concentration from VIL-1 (fig. 31; table 24). Chlorpyrifos also was detected in bed-sediment samples from every site (fig. 31; table 22). The highest concentrations in bed sediment, however, were found in samples from VIL-2 and VAL-1, and the lowest concentration from FMC. In contrast, all fish-tissue samples from Village Creek had lower concentrations of chlorpyrifos than were detected in bed-sediment samples from the same sites—and all fish-tissue samples from Valley Creek had higher concentrations of chlorpyrifos than were detected in bed-sediment samples.

Dieldrin was detected in all of the fish-tissue samples in the Birmingham study (table 24). Dieldrin is both a degradation product of aldrin and a directly applied insecticide. The use of dieldrin began in the 1950's to control pests on cotton and corn, and to kill termites around buildings; however, its use was discontinued by the USEPA in 1987. Dieldrin binds tightly to soil, breaks down very slowly, and is readily washed into streams and waterways by rainfall. Because dieldrin is soluble in lipids, it has a tendency to be stored in fat tissue and leaves the body very slowly. Concentrations of dieldrin were highest in fish-tissue samples from VIL-1, VAL-1, and VAL-2 (table 24). Dieldrin concentrations at these sites

Table 24. Concentrations of pesticides and polychlorinated biphenyls (PCBs) detected in fish tissue (*Lepomis* species) from streams in the Birmingham area, Alabama, 2000

[Values are in micrograms per kilogram; NAS/NAE, National Academy of Sciences/National Academy of Engineering; FDA, Food and Drug Administration; USEPA, U.S. Environmental Protection Agency; <, less than; —, no value; E, estimated; PCB, polychlorinated biphenyl. Shaded values are concentrations that exceeded environmental or human health criteria]

| Analyte | Site label (fig. 1) | | | | | | Environmental criteria | Human health criteria | | |
	VIL-1	VIL-2	VIL-3	VAL-1	VAL-2	FMC	NAS/NAE recommended guideline for freshwater whole fish[a]	FDA action level for edible fish[b]	USEPA screening criteria for edible fish[c]	International legal limit for edible fish[d]
Organochlorine pesticides and PCBs										
Dieldrin	**140**	34	23	**170**	**120**	35	100	300	—	300
Aldrin	< 5	< 5	< 5	< 5	< 5	< 5	100	300	—	—
alpha-BHC	< 5	< 5	< 5	< 5	< 5	< 5	—	—	—	—
beta-BHC	< 5	< 5	< 5	< 5	< 5	< 5	—	—	—	—
Chlordane, *trans*	12	E 4.7	E 3.1	20	16	5.3	—	—	—	—
Chlordane, *cis*	40	15	8.6	43	37	11	—	—	—	—
Nonachlor, *cis*	30	9.7	6.3	19	26	4.6	—	—	—	—
Nonachlor, *trans*	100	23	16	60	70	19	—	—	—	—
Oxychlordane	23	E 4.9	E 3.9	18	20	5.1	—	—	—	66,100
Total chlordane[e]	**205**	57.3	37.9	**160**	**169**	45	100	300	80	300
Heptachlor epoxide	**39**	E 3.2	< 5	**17**	**20**	E 3.9	100	300	10	300
Heptachlor	< 5	< 5	< 5	< 5	< 5	< 5	100	300	—	—
DCPA	< 5	< 5	< 5	< 5	< 5	< 5	—	—	—	—
DDD, *o,p'*	< 5	< 5	< 5	< 5	< 5	< 5	—	—	—	—
DDD, *p,p'*	7	< 5	5.1	17	20	3.9	—	—	—	5,000
DDE, *o,p'*	< 5	< 5	< 5	< 5	< 5	< 5	—	—	—	—
DDE, *p,p'*	20	51	16	16	25	7	—	—	—	5,000
DDT, *o,p'*	< 5	9.7	< 5	< 5	< 5	< 5	—	—	—	—
DDT, *p,p'*	4	< 5	< 5	7.6	7.9	< 5	—	—	—	5,000
Total DDT[f]	31	61	21	41	53	11	1,000	5,000	300	5,000
delta-BHC	< 5	< 5	< 5	< 5	< 5	< 5	100	—	60,000	—
Endrin	< 5	< 5	< 5	< 5	< 5	< 5	100	300	3,000	300
Hexachlorobenzene	< 5	< 5	< 5	< 5	< 5	< 5	—	—	70	—
Lindane	< 5	< 5	< 5	< 5	< 5	< 5	—	—	80	—
Methoxychlor, *o,p'*	< 5	< 5	< 5	< 5	< 5	< 5	—	—	—	—
Methoxychlor, *p,p'*	< 5	< 5	< 5	< 5	< 5	< 5	—	—	—	—
Mirex	< 5	< 5	< 5	< 5	< 5	< 5	—	—	2,000	100
PCB total	**170**	**660**	**700**	**320**	**470**	**120**	500	2,000	10	2,000
Pentachloroanisol	< 5	< 5	< 5	< 5	< 5	< 5	—	—	—	—
Toxaphene	< 200	< 5	< 5	< 5	< 5	< 5	100	5,000	100	100
Organophosphate pesticides										
Diazinon	< 5	< 5	<5	E1.52	< 5	< 5	—	—	—	—
Disulfoton	< 5	< 5	< 5	< 5	< 5	< 5	—	—	—	—
Ethion	< 5	< 5	< 5	< 5	< 5	< 5	—	—	—	—
Ethoprop metabolite	< 5	< 5	<5	< 5	< 5	< 5	—	—	—	—
Fenthion	< 5	< 5	< 5	< 5	< 5	< 5	—	—	—	—
DEF	< 5	< 5	<5	< 5	< 5	< 5	—	—	—	—
Chlorpyrifos	E1.76	6.52	6.12	44.97	27.19	14	—	—	—	—
Fonofos	< 5	< 5	< 5	< 5	< 5	< 5	—	—	—	—
Malathion	< 5	< 5	< 5	< 5	< 5	< 5	—	—	—	—
Methidathion	< 5	< 5	< 5	< 5	< 5	< 5	—	—	—	—
Methyl parathion	< 5	< 5	< 5	< 5	< 5	< 5	—	—	—	—
Parathion	< 5	< 5	< 5	< 5	< 5	< 5	—	—	—	—

Table 24. Concentrations of pesticides and polychlorinated biphenyls (PCBs) detected in fish tissue (*Lepomis* species) from streams in the Birmingham area, Alabama, 2000—Continued

[Values are in micrograms per kilogram; NAS/NAE, National Academy of Sciences/National Academy of Engineering; FDA, Food and Drug Administration; USEPA, U.S. Environmental Protection Agency; <, less than; —, no value; E, estimated; PCB, polychlorinated biphenyl. Shaded values are concentrations that exceeded environmental or human health criteria]

Analyte	Site label (fig. 1)						Environmental criteria	Human health criteria		
	VIL-1	VIL-2	VIL-3	VAL-1	VAL-2	FMC	NAS/NAE recommended guideline for freshwater whole fish[a]	FDA action level for edible fish[b]	USEPA screening criteria for edible fish[c]	International legal limit for edible fish[d]
Organophosphate pesticides (Continued)										
Phorate	< 5	< 5	< 5	< 5	< 5	< 5	—	—	—	—
Profenofos	< 5	< 5	< 5	< 5	< 5	< 5	—	—	—	—
Propetamphos	< 5	< 5	< 5	< 5	< 5	< 5	—	—	—	—
Sulfotepp	< 5	< 5	< 5	< 5	< 5	< 5	—	—	—	—
Sulprofos	< 5	< 5	< 5	< 5	< 5	< 5	—	—	—	—
Terbufos	< 5	< 5	< 5	< 5	< 5	< 5	—	—	—	—
Trithion	< 5	< 5	< 5	< 5	< 5	< 5	—	—	—	—

[a] National Academy of Sciences/National Academy of Engineering, 1973.

[b] Nowell and Resek, 1994.

[c] U.S. Environmental Protection Agency, 1995.

[d] Nauen, 1983.

[e] Sum of *cis*-chlordane, *trans*-chlordane, *cis*-nonachlor, *trans*-nonachlor, and oxychlordane, excluding "<" values.

[f] Sum of *o,p*'-DDD, *p,p*'-DDD, *o,p*'-DDE, *p,p*'-DDE, *o,p*'-DDT, *p,p*'-DDT, excluding "<" values.

exceeded or equaled the criterion for the protection of aquatic life (100 µg/kg; table 24).

The concentrations of total PCBs in fish whole-body tissue were highest at VIL-2 and VIL-3, and exceeded guidelines for the protection of fish and wildlife (500 µg/kg; table 24). The lowest PCB concentration was detected in fish-tissue samples collected at FMC (fig. 34B). The concentrations of PCBs in fishes from all sites greatly exceeded the USEPA screening criterion for the protection of human health (table 24). A similar pattern was seen in the concentrations of total PCBs in bed sediment and fish tissue (fig. 34); however, concentrations in fish tissue were an order of magnitude greater than seen in the bed sediment (table 22).

The relative concentrations of DDT and its degradation products detected in fish tissue are shown in figure 32B. The maximum concentration of total DDT in fish tissue collected from Birmingham area streams was 61 µg/kg at VIL-2 (table 23). Concentrations of total DDT in fish-tissue samples from all sites were lower than any criterion for the protection of aquatic life or human health. Although *p,p*'-DDE was the only degradation product of DDT found in bed sediment (fig. 32A), fish tissue contained *p,p*'-DDD and *p,p*'-DDE (fig. 32B). In Village Creek, *p,p*'-DDE was detected in all fish-tissue samples (fig. 32B) accounting for 65, 84, and 76 percent of the total DDT in fish tissue at VIL-1, VIL-2, and VIL-3, respectively (table 23). In Valley Creek, *p,p*'-DDE and
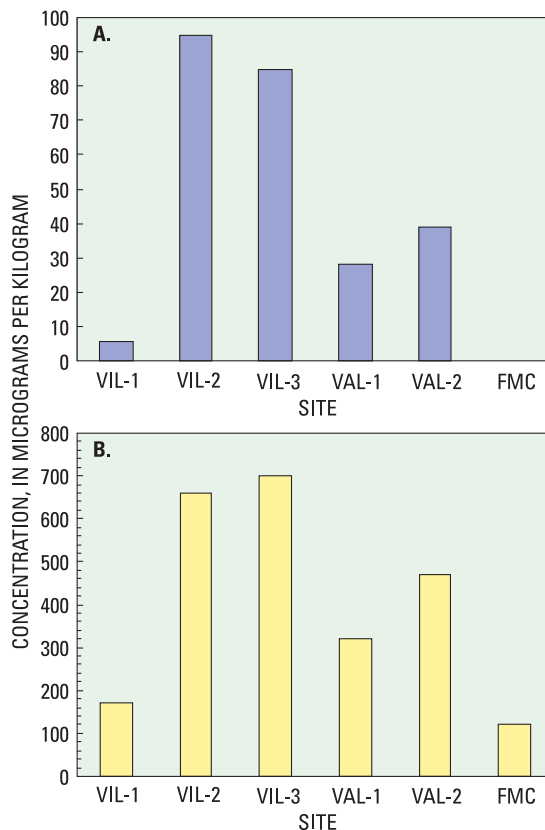

Figure 34. Concentrations of total polychlorinated biphenyls (PCBs) detected in (A) bed sediment and (B) fish tissue (*Lepomis* species) from streams in the Birmingham area, Alabama, 2000.

p,p'-DDD concentrations were relatively equivalent (fig. 32B), accounting for 39 and 42 percent of total DDT, respectively, at VAL-1, and 47 and 38 percent, respectively, at VAL-2 . No *o,p'*-isomers of DDD or DDE were detected at any of the Birmingham sampling sites. The ratios of DDT to total DDT at VIL-1, VIL-2, VAL-1, and VAL-2 were greater than 0.10, indicating recent mobilization of DDT. Although the ratio of DDT to total DDT could not be computed at VIL-3 or FMC because of censored values, the presence of detectable concentrations of the degradation products, DDE and DDD, and the absence of DDT indicated longer-term degradation of residual DDT (table 23).

Habitat

Habitat was evaluated by collecting data on specific physical and geomorphological characteristics of the stream reaches at six of the Birmingham sites, including VIL-1, VIL-3, VAL-1, VAL-2, LCR, and FMC (table 25). No significant correlations were detected between any habitat characteristic and the aquatic communities in the study sites. The stream reaches, however, differed in several ways (table 25). For example, the length of VIL-3 (349 m) exceeded that of the other stream reaches in order to include two riffle areas for the collection of benthic-invertebrates, whereas two or more riffles were present within a 200-m stream reach at all other sites. The riffles in VIL-3 were located at each end of the reach and were separated by a series of runs and shallow pools. VIL-1 and LCR had no discernable pools, however, pools in the other sites ranged from 6.7 to 18.3 percent of the reach (VAL-1 and VIL-3, respectively). FMC and VIL-1 were totally enclosed by riparian vegetation (zero canopy angle; table 25), whereas the other sites ranged from 37.1 to 99.7 degrees of open canopy angle (VAL-1 and LCR, respectively). Stream gradient differed little from reach to reach. Stream widths in VIL-1, VAL-1, and FMC were similar—with an average wetted channel width of 6.7 m; stream widths at VIL-3, VAL-2, and LCR were twice as large, with an average wetted channel width of 14.7 m.

Table 25. Habitat characteristics in selected streams in the Birmingham area, Alabama, 2000

[m, meter; m^2, square meter; m^3, cubic meter; rth, richest targeted habitat; m/s, meters per second; RW, right-of-way; OT, other—exposed rock; UI, urban industrial; UR, urban residential; SW, shrubs or woodland]

Characteristics	VIL-1	VIL-3	VAL-1	VAL-2	LCR	FMC
Reach length (m)	150	349	150	200	200	180
Reach stream surface area (m^2)	805.2	6,361	1,196	3,022	2,215	1,087
Reach volume (m^3)	147	1,802	844	899	538	119
Reach surface-water gradient	.00220	.00203	.00240	.00253	.00238	.00240
Mean bank height (m)	1.46	3.20	3.27	2.40	1.41	3.55
Mean channel bankfull width (m)	7.45	30.3	22.9	25.8	14.1	10.7
Mean wetted channel width (m)	5.75	18.2	7.97	15.1	11.4	6.04
Mean direction of flow (degrees magnetic)	145	237	235	181	196	38.6
Mean water depth (m) in reach	.182	.3	.1	.3	.246	.08
Mean water depth (m) at rth invertebrate sampling locations	.14	.10	.09	.22	.15	.10
Mean current velocity (m/s) at rth invertebrate sampling locations	.36	.43	.35	.32	.41	.27
Mean percent embeddedness in rth sampling sites	84	83	86	99	65	100
Riffle area in reach (percent)	42.9	13.2	35.3	22.3	16.0	29.0
Frequency of silt in riffle habitats (percent)	73	97	18	100	100	100
Pool area in reach (percent)	0	18.3	6.7	10.6	0	8.06
Run area in reach (percent)	57	68	58	67	84	63
Mean open canopy angle in the reach (degrees)	0	85	37.1	77.4	99.7	0
Mean open canopy angle in riffle habitat (degrees)	90	120	118	139	110	0
Mean bank vegetation cover (percent)	82	40	49	93	94	90
Mean riparian canopy closure in the reach (percent)	100	79.9	48.9	94.9	95.4	95.2
Mean riparian canopy closure in riffle habitat (percent)	100	75	51	97	88	99
Dominant riparian land use	RW/OT	UI	UR	SW	SW	SW