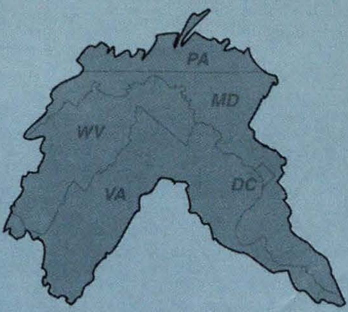
UNITED STATES GEOLOGICAL SURVEY

SELECTED TRACE-ELEMENT AND ORGANIC CONTAMINANTS IN STREAMBED SEDIMENTS OF THE POTOMAC RIVER BASIN, AUGUST 1992



Water-Resources Investigations Report 95-4267

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ABSTRACT

This report describes the occurrence and distribution of five selected contaminants in streambed sediments at 22 stream sites in the Potomac River Basin. Lead, mercury, and total DDT (dichlorodiphenyltrichloroethane) were detected at all sites, and chlordane and total PCB's (polychlorinated biphenyls) were detected at most sites. At six sites, streambed-sediment concentrations of contaminants were detected at levels with the potential to cause frequent adverse effects on aquatic organisms that live in the sediments. Chlordane was detected at these high levels at sampling sites on the Anacostia River, the North Branch Potomac River, Bull Run, and Accotink Creek; mercury was detected at these levels at sites on the South River and the South Fork Shenandoah River; and total PCB's were detected at these levels at the site on the South Fork Shenandoah River. The highest concentrations of all five contaminants generally occurred at sampling sites downstream from areas with industrial plants, urban centers, or orchard and agricultural activity. The occurrence of these contaminants in streambed sediments of the Potomac River Basin is of concern because the contaminants (1) are environmentally persistent, (2) are available for downstream transport during high streamflow periods, and (3) have the potential to cause adverse effects on the health of aquatic organisms and humans through bioaccumulation.

INTRODUCTION

Background

The U.S. Geological Survey (USGS) is implementing the National Water-Quality Assessment (NAWQA) program to describe and explain water-quality conditions and trends of the Nation's surface-water and ground-water resources (Gilliom and others, 1995). One of the first areas to be studied as part of the full-scale NAWQA program is the Potomac River Basin, where water-quality sampling activities for the study were begun in 1992. A major goal of the Potomac River Basin study is to describe the occurrence and distribution of a wide variety of physical, chemical, and biological water-quality characteristics of streams and ground water in the basin.

Some of the chemical compounds of interest in the NAWQA program, including many trace elements and synthetic organic compounds, do not easily dissolve in streamwater, but instead tend to accumulate in streambed sediments and aquatic biological tissues. When these compounds accumulate in sufficiently high concentrations in sediments or tissues, they can act as contaminants that can adversely affect the health of aquatic organisms. To address the occurrence and distribution of selected trace-element and organic contaminants in streams in the Potomac River Basin, a survey of contaminants in streambed sediments and aquatic biological tissues was conducted in 1992.

Purpose and Scope

This report presents the results of a survey of contaminants in streambed sediments in selected streams of the Potomac River Basin. The report focuses on five selected contaminants, including two trace elements—lead and mercury—and three organic compounds—chlordane, total DDT (dichlorodiphenyltrichloroethane),

Streambed-sediment samples were collected and composited from a variety of depositional settings within stream reaches that averaged 300 feet in length at each sampling site.

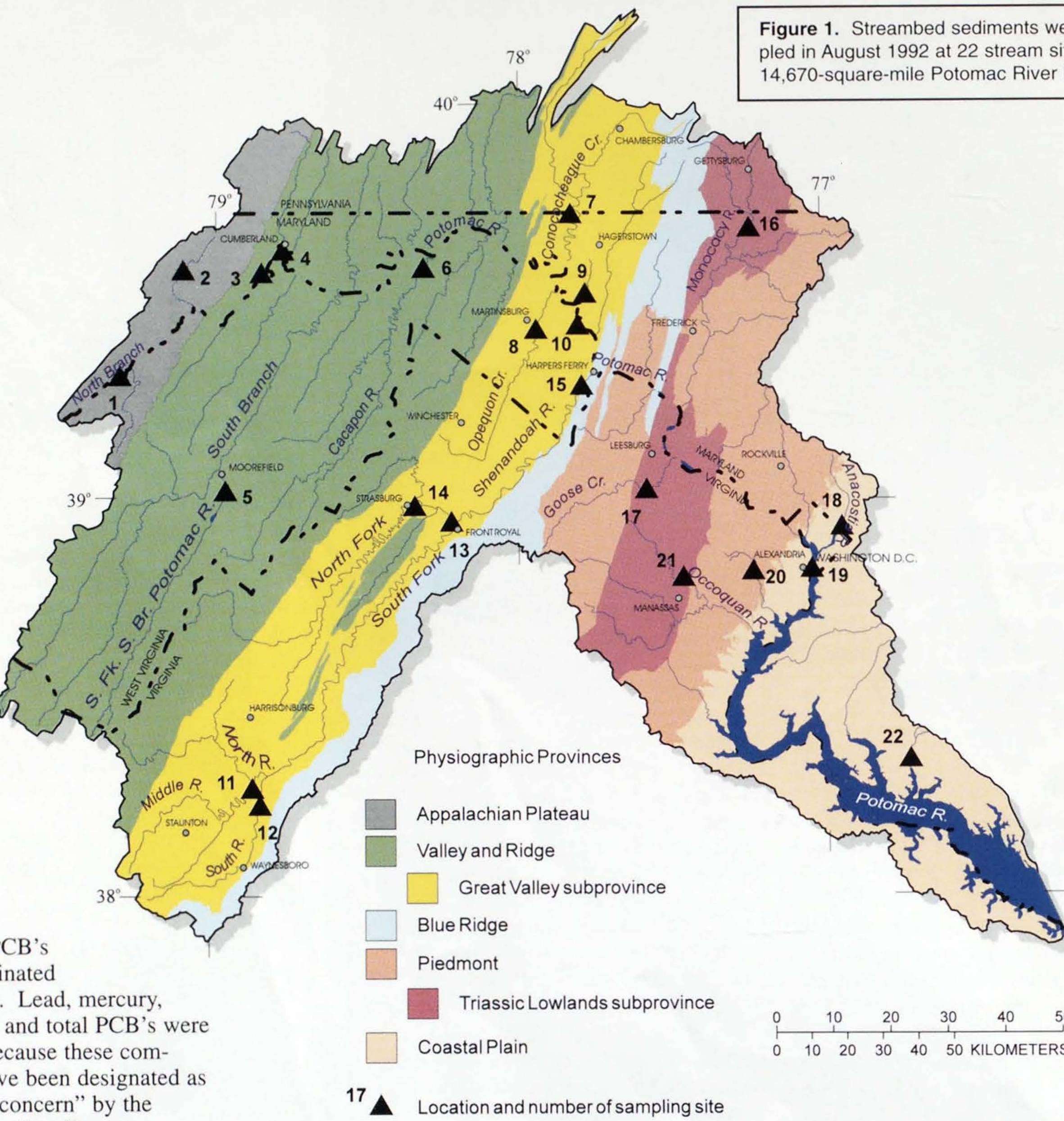


Figure 1. Streambed sediments were sampled in August 1992 at 22 stream sites in the 14,670-square-mile Potomac River Basin.

and total PCB's (polychlorinated biphenyls). Lead, mercury, chlordane, and total PCB's were selected because these compounds have been designated as "toxics of concern" by the Chesapeake Bay Program (Chesapeake Bay Program, 1991a); total DDT was selected because of national concern regarding its environmental effects during the last several decades. The report describes the results of streambed-sediment sampling at 22 stream sites throughout the Potomac River Basin in August 1992, and addresses the following questions about the occurrence and distribution of the five contaminants in streambed sediments of the basin:

(1) Which stream sites have streambed sediments with elevated concentrations of these contaminants?

(2) What is the relation between elevated concentrations of these contaminants in streambed sediments and potential upstream contaminant sources?

(3) What are some of the important environmental implications of the occurrence of these contaminants in streambed sediments?

Streambed-Sediment Sampling and Analysis

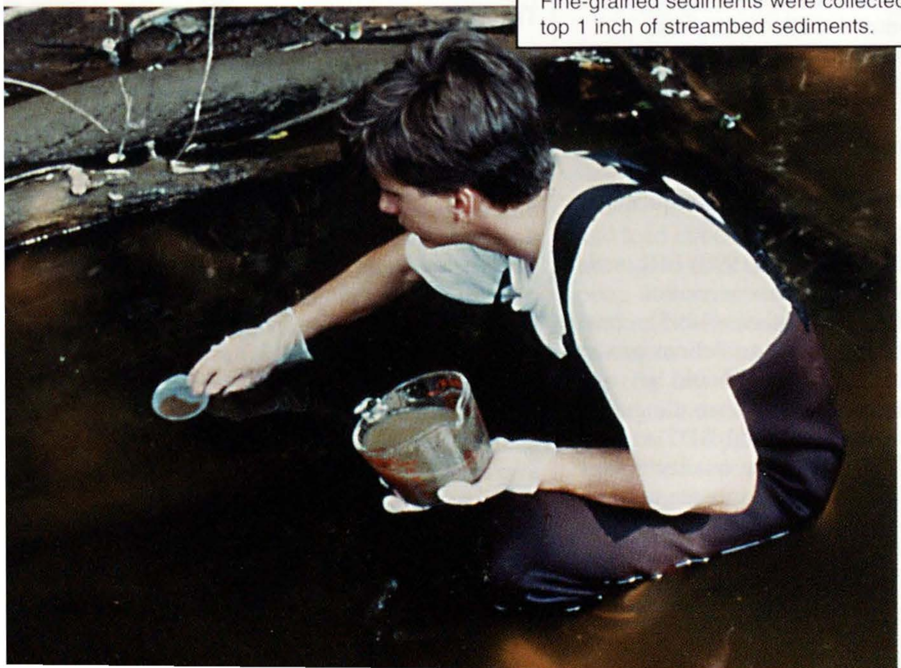
The sampling sites that were selected for assessing the occurrence and distribution of contaminants in streambed sediments in the Potomac River Basin cover a range of physiographic settings (fig. 1), stream sizes (table 1), and land uses. Drainage areas for the 22 sites generally range from about 20 to 12,000 square miles (table 1), and include parts of the 7 physiographic provinces and subprovinces and parts of the four States in the Potomac River Basin (fig. 1).

At each of the 22 sampling sites, fine-grained streambed sediments were collected and composited from a variety of depositional settings within stream reaches that averaged about 300 feet in length. Samples were collected from the top 1 inch of fine-grained sediments using a scoop in wadeable streams or a dredge in deeper streams; sampling equipment was constructed from inert materials. All sites were sampled during low streamflow conditions when no fine-grained sediments were in suspension in the water column. Each sample was sieved into subsamples in the field for laboratory analysis.

Table 1. Streambed-sediment sampling sites in the Potomac River Basin, August 1992

Sampling site number	Station number	Station name	Drainage area, in square miles
1	01595000	North Branch Potomac River at Steyer, Md.	73.0
2	01596500	Savage River near Barton, Md.	49.1
3	01600000	North Branch Potomac River at Pinto, Md.	596
4	01603000	North Branch Potomac River at Cumberland, Md.	875
5	01608000	South Fork South Branch Potomac River near Moorefield, W. Va.	283
6	01611500	Cacapon River near Great Cacapon, W. Va.	677
7	01614500	Conococheague Creek at Fairview, Md.	494
8	01616500	Opequon Creek near Martinsburg, W. Va.	272
9	01617800	Marsh Run at Grimes, Md.	18.9
10	01618000	Potomac River at Sheperdstown, W. Va.	5,936
11	01625000	Middle River near Grottoes, Va.	375
12	01627500	South River near Harriston, Va.	212
13	01631020	South Fork Shenandoah River below Cabin Run at Front Royal, Va.	1,647
14	01634000	North Fork Shenandoah River near Strasburg, Va.	768
15	01636500	Shenandoah River at Millville, W. Va.	3,040
16	01639000	Monocacy River at Bridgeport, Md.	173
17	01644000	Goose Creek near Leesburg, Va.	332
18	01651010	Anacostia River near Bladensburg, Md.	130
19	01652589	Potomac River below Oxon Creek at Alexandria, Va.	11,880
20	01654000	Accotink Creek near Annandale, Va.	23.5
21	01657000	Bull Run near Manassas, Va.	147
22	01661050	St. Clement Creek near Clements, Md.	18.5

Samples for trace-element analysis were sieved through a 63-micrometer nylon filter, digested to complete dissolution, and analyzed for 45 trace elements. Lead was determined by inductively coupled plasma-atomic emission spectrometry (Briggs, 1990), and mercury was determined by cold vapor-atomic absorption spectrophotometry (O'Leary and others, 1990). Samples for organic-compound analysis were sieved through a 2-millimeter stainless-steel sieve and analyzed for 40 organochlorine compounds, 80 semivolatile organic compounds, and all PCB congeners by the Methods Development Program of the USGS National Water-Quality Laboratory in Arvada, Colo. Chlordane, total DDT, and total PCB's were determined by dual capillary-column gas chromatography with electron-capture detection (Foreman and others, 1995).



Fine-grained sediments were collected from the top 1 inch of streambed sediments.

OCCURRENCE AND DISTRIBUTION OF SELECTED CONTAMINANTS

The occurrence of the five selected contaminants in streambed sediments of the Potomac River Basin generally correlates with their use in the basin by man for a variety of purposes (table 2). The uses of many of these contaminants have been regulated or banned in the last several decades because of an increased awareness of the adverse effects they can have on animal and human health. Some of their adverse effects on human health are listed in table 2.

The units of streambed-sediment concentration used in this report are parts per million (ppm) for trace elements and parts per billion (ppb) for organic compounds. Parts per million are equivalent to milligrams per kilogram of dry sediment, and parts per billion are equivalent to micrograms per kilogram of dry sediment. Streambed-sediment concentrations of the three organic compounds (chlordane, total DDT, and total PCB's) are the sum of the concentrations of several related compounds. Chlordane concentration is the sum of cis-chlordane, trans-chlordane, oxychlordane, cis-nonachlor, and trans-nonachlor concentrations. Total DDT concentration is the sum of o,p′-DDT, p,p′-DDT, o,p′-DDE, p,p′-DDE, o,p′-DDD, and p,p′-DDD concentrations. Total PCB concentration is the sum of the concentrations of all the PCB congeners that were detected. The laboratory considered the concentrations of individual chlordane and DDT compounds to be estimates if the concentrations detected were less than the laboratory's reporting limits. In this report, the sums of concentrations

Table 2. Summary of information on five selected contaminants sampled in streambed sediments, Potomac River Basin, August 1992
[ND, not detected]

Contaminant	Common sources and uses[1]	Regulation status[1]	Potential effects on human health[1]	Concentrations in this survey: Minimum	Concentrations in this survey: Median	Concentrations in this survey: Maximum	Laboratory reporting limits
Trace elements; concentration in parts per million[2]							
Lead	Batteries; pipes and plumbing; vehicle emissions; paint ingredients; solder; corrosion of brass; natural mineral deposits.	Use in paints, gasoline, and lead shot now limited.	Damage to nervous system, kidneys, brain; fatigue; anemia; paralysis; fetal brain damage; possible cancer.	15	31	110	4.0
Mercury	Manufacture of paint, paper, and vinyl chloride; batteries; ingredients in fungicides; natural mineral deposits.	Discharges to water and air now regulated.	Damage to kidneys and nervous system.	0.02	0.09	14.5	0.02
Organic compounds; concentration in parts per billion[3]							
Chlordane	Insecticide used to control termites and ants.	Most uses banned in 1978; total ban in 1988.	Possible cancer; dizziness; headache; fatigue; convulsions.	ND	2.17	66.6	1.0[4]
Total DDT	Insecticide used to control mosquitoes and spiders on a wide variety of crops and fruits.	Banned in 1972.	Possible cancer; damage to nervous system, liver, kidneys, skin.	0.09	1.13	23.9	1.0-2.0[4]
Total PCB's	Used in electrical transformers and plasticizers.	Banned in 1979.	Possible cancer.	ND	3.9	468	.1-.5

[1] U.S. Environmental Protection Agency, 1991; Chesapeake Bay Program, 1991b.
[2] Parts per million = milligrams of contaminant per kilogram of dry streambed sediment.
[3] Parts per billion = micrograms of contaminant per kilogram of dry streambed sediment.
[4] Reporting limits for individual compounds of chlordane and total DDT. Some individual compounds were detected at concentrations less than the reporting limit; these concentrations were considered to be estimated concentrations. Estimated concentrations of individual compounds were included in the sums of concentrations of related compounds for chlordane and total DDT.

of related compounds for chlordane and total DDT include these estimated concentrations.

On the basis of analysis of reference standards and duplicate samples, the laboratory analyses indicate a fair degree of reproducibility. Determinations of lead and mercury in reference samples show a 5.8-percent standard deviation for both elements. The standard deviation of the analyses of laboratory reference samples for chlordane and DDT compounds ranges from 11 to 23 percent. The standard deviation of the analyses of reference samples for total PCB's is about 7 percent.

Because of the many complex factors involved in bioaccumulation processes, contaminant concentrations in streambed sediments cannot be used as direct measures of the potential of the contaminants to cause adverse effects on human health. However, it is possible to relate sediment concentrations to the potential for adverse effects on the health of aquatic organisms that live in the sediments. Long and others (1995) and Long and Morgan (1990) established sediment-quality guidelines useful for this purpose by relating contaminant concentrations in streambed sediments to observed adverse effects on aquatic organisms for a large number of studies in estuaries and bays of North America. Two concentrations were defined—Effects Range-Low (ERL) and Effects Range-Median (ERM)—which divide the range of contaminant concentrations and their potential effects on aquatic organisms into three bands (table 3). Sediment concentrations in the first band (less than the ERL value for the indicated contaminant) rarely cause adverse effects on organisms that live in the sediments, concentrations in the middle band (between the ERL and ERM values) occasionally cause adverse effects, and concentrations in the third band (greater than the ERM value) frequently cause adverse effects.

Long and Morgan's (1990) ERL and ERM values for chlordane were not updated by Long and others (1995); consequently, the chlordane guidelines presented in table 3 probably should be applied with more caution than the guidelines for lead, mercury, total DDT, and total PCB's. The sediment-quality guidelines for all five contaminants are used in this report to estimate the potential for adverse effects on aquatic organisms posed by the measured contaminant concentrations in the streambed-sediment samples. It should be noted that these guidelines can only serve as informal preliminary screening tools for streambed sediments in freshwater streams, and do not replace the need for toxicity testing to determine specific adverse effects on aquatic organisms.

Trace Elements

The concentrations of lead and mercury discussed in this report represent the sum of the naturally occurring elements contained in the mineral grains of the sediments and the elements attached to the mineral grains as a result of contamination from human activities. To obtain an estimate of the proportion of the lead and mercury due to contamination, the proportion contained in the mineral grains was determined from comparisons to worldwide averages of elemental concentrations in the Earth's crust, or average crustal abundances. Fyfe (1974) computed the average crustal abundances of lead and mercury to be 13 ppm and 0.08 ppm,

Table 3. Streambed-sediment-quality guidelines and their relation to the potential occurrence of adverse effects on aquatic organisms

[ERL, Effects Range-Low; ERM, Effects Range-Median; ppm, parts per million; ppb, parts per billion]

Contaminant	Less than ERL	ERL	ERL - ERM	ERM	Greater than ERM
Lead	Rare adverse effects on aquatic organisms	46.7 ppm[1]	Occasional adverse effects on aquatic organisms	218 ppm[1]	Frequent adverse effects on aquatic organisms
Mercury		0.15 ppm[1]		0.71 ppm[1]	
Chlordane		0.5 ppb[2]		6.0 ppb[2]	
Total DDT		1.58 ppb[1]		46.1 ppb[1]	
Total PCB's		22.7 ppb[1]		180 ppb[1]	

[1] Long and others (1995)

[2] Long and Morgan (1990)

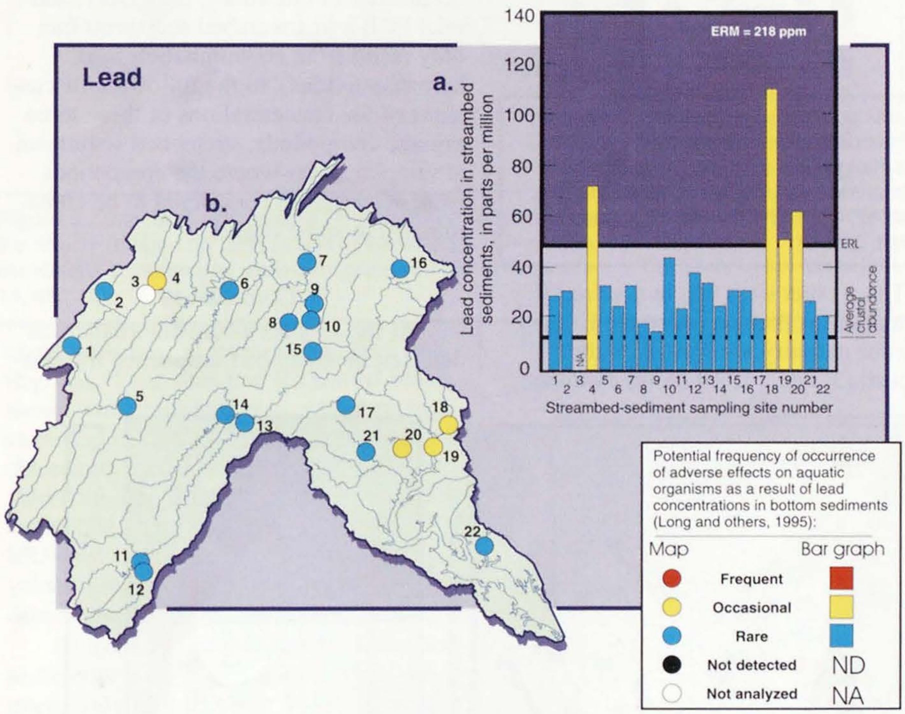


Figure 2. Lead concentrations in streambed sediments at all sites exceeded the average crustal abundance value for lead; concentrations at four sites exceeded the Effects Range-Low (ERL) value. The four sites where lead concentrations in streambed sediments exceeded the ERL value are near urban areas in Washington, D.C. (sites 18-20), and Cumberland, Md. (site 4).

respectively. In the discussions of lead and mercury concentrations in streambed sediments that follow, these average crustal abundances of lead and mercury are used to provide a frame of reference for the proportion of lead and mercury that might be related to contamination.

Lead

Streambed-sediment samples collected at all sites where lead was analyzed had lead concentrations that exceeded the average crustal abundance of lead of 13 ppm, indicating that the occurrence of lead in these streambed sediments may be related to contamination by human activities (fig. 2a). None of the sites had a lead concentration that exceeded the ERM value of 218 ppm for lead. However, streambed sediments at 4 of 21 sites had lead concentrations that exceeded the ERL value of 46.7 ppm, the level above which the potential exists for occasional adverse effects on aquatic organisms that live in the sediments.

Three of the four sites where lead concentration in streambed sediments exceeded the ERL value are near Washington, D.C.—site 18 on the Anacostia River, site 19 on the Potomac River, and site 20 on Accotink Creek; the fourth site is site 4 on the North Branch Potomac River (fig. 2b). The highest lead concentration (110 ppm) was detected in sediments from site 18 on the Anacostia River, just northeast of Washington, D.C., which drains an intensively developed urban area. Streambed sediments at site 19 on the Potomac River downstream from Washington, D.C., had a lead concentration of 51 ppm; the streambed sediments at this site represent a composite of materials derived from 11,880 square miles of Potomac River Basin drainage area. The lowest lead concentration (15 ppm) was detected in streambed sediments from site 9 on Marsh Run, which drains a small, relatively unpopulated and highly agricultural watershed.

Mercury

The median mercury concentration in streambed-sediment samples collected at sampling sites where mercury was analyzed was 0.09 ppm (about the same as the average crustal abundance of mercury of 0.08 ppm), but the range of concentrations was large, with a maximum value of 14.5 ppm (fig. 3a), more than 150 times greater than the median. Streambed sediments at six of the sites had mercury concentrations greater than twice the average crustal abundance value, indicating probable mercury contamination. Of these six sites, two had mercury concentrations that exceeded the ERM value of 0.71 ppm for

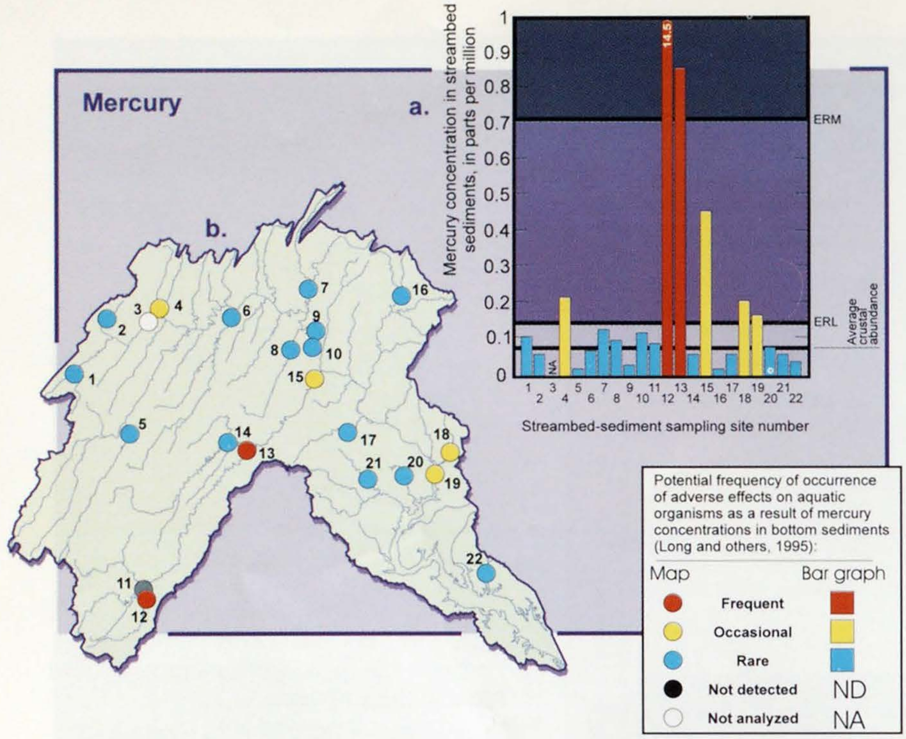


Figure 3. Mercury concentrations in streambed sediments at many sites generally were at or near the average crustal abundance value for mercury; concentrations exceeded the Effects Range-Median (ERM) value at two sites and the Effects Range-Low (ERL) value at four other sites. The six sites where mercury concentrations in streambed sediments exceeded the ERL or ERM values are in the Shenandoah River Basin (sites 12, 13, and 15) and urban areas in Washington, D.C. (sites 18 and 19), and Cumberland, Md. (site 4).

mercury, the level above which the potential exists for frequent adverse effects on aquatic organisms that live in the sediments.

The two sites where mercury concentrations in streambed sediments exceeded the ERM value for mercury—site 12 on the South River and site 13 on the South Fork Shenandoah River—are located in the Shenandoah River Basin (fig. 3b). The highest concentration of mercury was 14.5 ppm in streambed sediments at site 12 on the South River, followed by 0.86 ppm at site 13 on the South Fork Shenandoah River and 0.46 ppm at site 15 on the Shenandoah River. Since 1979, the Virginia Water Control Board (now the Virginia Department of Environmental Quality) has conducted several surveys for mercury in streambed sediments near sites 12 and 13 (C.T. Mizell, Virginia Department of Environmental Quality, written commun., 1995). Their surveys also have detected mercury in streambed sediments at concentrations that exceeded the ERM value for mercury, although the concentrations in their surveys are not as high as the concentrations in the 1992 survey. The Virginia Department of Environmental Quality is continuing to monitor mercury contamination at these sites through periodic collection and analysis of fish tissues.

Three other sites that had mercury concentrations that exceeded the ERL value for mercury are site 18 on the Anacostia River, site 19 on the Potomac River, and site 4 on the North Branch Potomac River; all three sites are downstream from major urban areas. Sediments from site 19 on the Potomac River downstream from Washington, D.C., had a mercury concentration of 0.17 ppm, about twice the median concentration for the 21 sampled sites. Sites 5, 9, 16, and 22, which had the lowest mercury concentrations—less than 0.05 ppm—drain relatively undeveloped areas that are mainly characterized by forests and farmland.

Organic Compounds

Unlike lead and mercury and other trace elements that occur in streambed sediments, and which can be derived from natural mineral sources as well as contamination from human activities, the occurrence of chlordane, total DDT, and total PCB's in streambed sediments can only result from contamination from human activities. In the following discussions of the concentrations of these three organic compounds, streambed sediments at sampling sites where the compounds were detected are considered to be contaminated to some degree.

Chlordane

At the 13 sites where chlordane was detected in streambed sediments, the con-

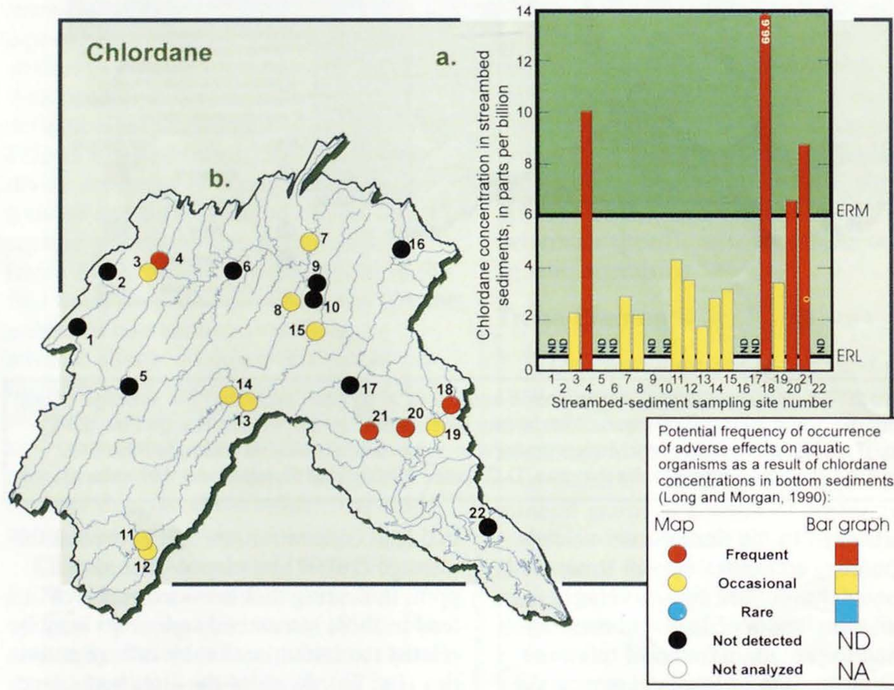


Figure 4. Chlordane concentrations in streambed sediments were detected at 13 sites; concentrations at 4 sites exceeded the Effects Range-Median (ERM) value. Seven of the 13 sites where chlordane was detected in streambed sediments are located in the Great Valley (sites 7, 8, 11-15); 4 are in the Washington, D.C., area (sites 18-21), and 2 are in the Cumberland, Md., area (sites 3-4).

centrations ranged from 1.67 to 66.6 ppb (fig. 4a). Four sites had streambed sediments with chlordane concentrations that exceeded the ERM value of 6 ppb for chlordane. The other nine sites where chlordane was detected in streambed sediments had concentrations less than the ERM value, but greater than the ERL value of 0.5 ppb. Chlordane was not detected at 9 of the 22 sampled sites.

Chlordane was detected in streambed sediments at sites 7, 8, and 11-15 in the intensively farmed Great Valley; five of these sites are in the Shenandoah River Basin (fig. 4b). Sites 18, 20, and 21 on streams in the heavily urban Washington, D.C., area had streambed sediments with chlordane concentrations that exceeded the ERM value. The chlordane concentration (66.6 ppb) in streambed sediments at site 18 on the Anacostia River was more than 10 times greater than the ERM value. This high chlordane concentration in streambed sediments at site 18 is corroborated by streambed-sediment samples collected by Wade and others (1994) at six sites several miles downstream from site 18, where chlordane concentrations in sediments ranged from 28 to 140 ppb. The sediments at site 19 on the Potomac River, which drains most of the Potomac River Basin, had a chlordane concentration (3.39 ppb) that was between the ERL and ERM values. Site 4 on the North Branch Potomac River had streambed sediments with a chlordane concentration that exceeded the ERM value.

Total DDT

Total DDT concentrations in streambed sediments at seven sites exceeded the ERL value of 1.58 ppb for total DDT (fig. 5a). The highest total DDT concentration in sediments (23.9 ppb), although 15 times greater than the ERL value, was only about one-half the ERM value of 46.1 ppb for total DDT. Total DDT concentrations in streambed sediments at 10 of the 22 sites were less than 1 ppb.

Of the seven sites that had total DDT concentrations exceeding the ERL value, five sites are in the Great Valley—site 7 on Conococheague Creek, site 8 on Opequon Creek, site 11 on the Middle River, site 14 on the North Fork Shenandoah River, and site 15 on the Shenandoah River (fig. 5b). The second highest total DDT concentration detected in streambed sediments was 15 ppb at site 15 on the Shenandoah River, which drains

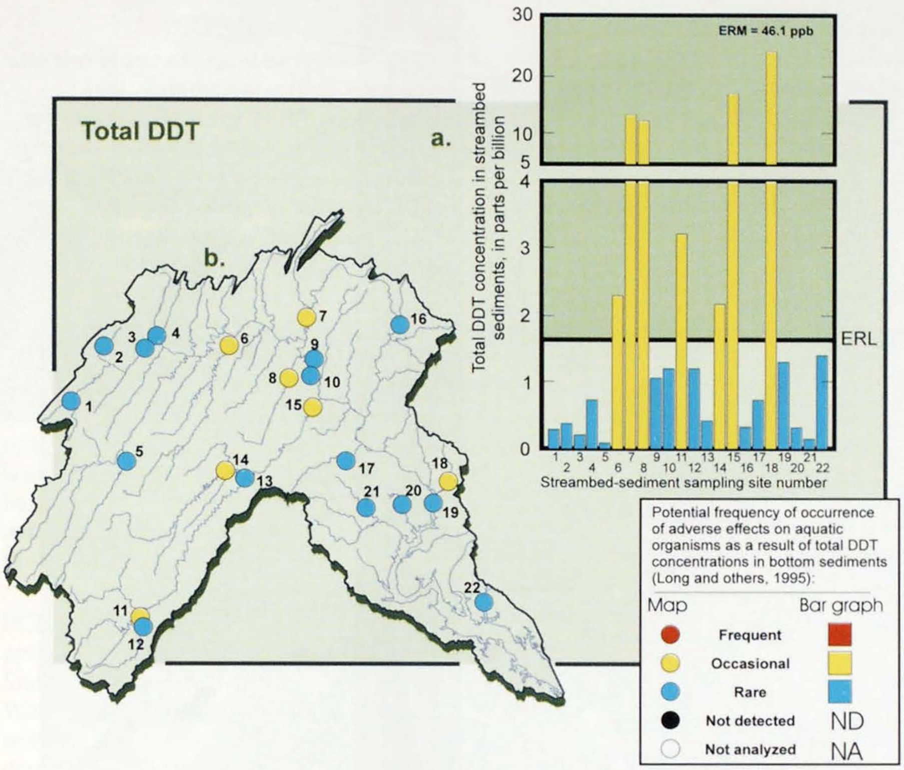


Figure 5. Total DDT was detected in streambed sediments at all sites; concentrations exceeded the Effects Range-Low (ERL) value at seven sites. Five of the seven sites where total DDT concentrations in streambed sediments exceeded the ERL value are in the Great Valley (sites 7, 8, 11, 14, and 15).

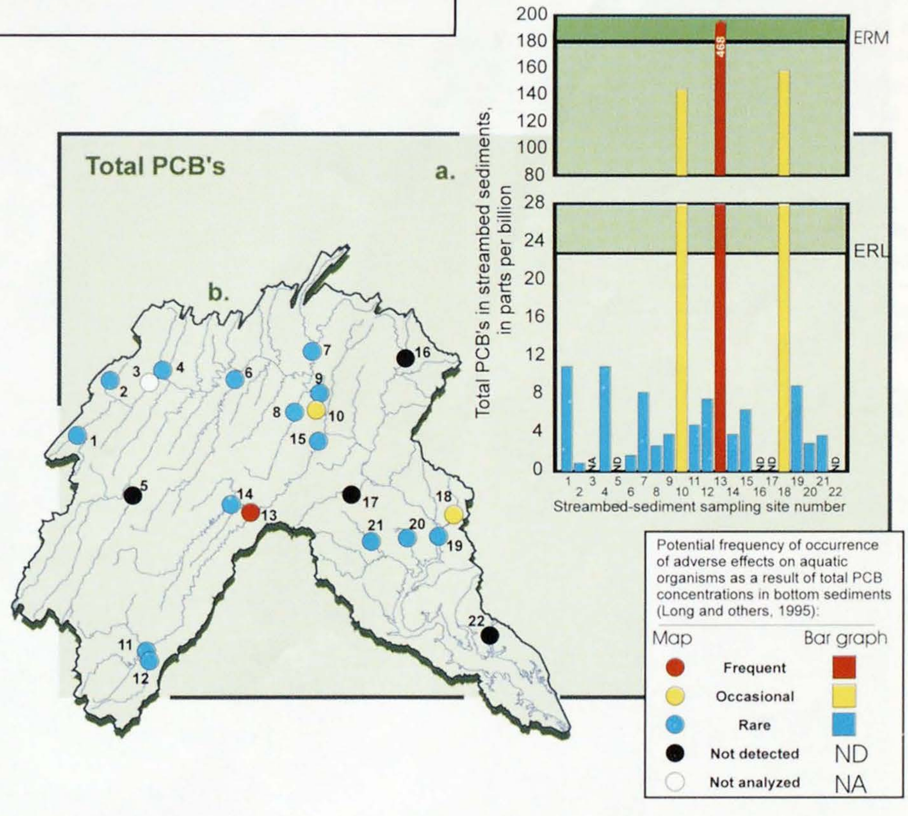


Figure 6. Total PCB's were detected in streambed sediments at 17 sites; concentrations exceeded the Effects Range-Median (ERM) value at 1 site and the Effects Range-Low (ERL) value at 2 other sites. Concentrations of total PCB's in streambed sediments were highest at site 13 on the South Fork Shenandoah River, site 18 on the Anacostia River, and site 10 on the Potomac River at Shepherdstown, W.Va.

nearly all of the Shenandoah River Basin. The other site in the central part of the Potomac River Basin where the total DDT concentration in streambed sediments exceeded the ERL value is site 6 on the Cacapon River, which drains an area that is mostly forested and undeveloped, but which has some agricultural activity. The streambed sediments at site 18 on the Anacostia River had the highest total DDT concentration in the Potomac River Basin; the concentration at this site, which drains a highly urban area, was 23.9 ppb. Streambed sediments at five sites in the westernmost part of the Potomac River Basin had total DDT concentrations that were less than 1 ppb.

Total PCB's

Streambed sediments at only one site had a total PCB concentration that exceeded the ERM value of 180 ppb for total PCB's (fig. 6a). Two other sites had streambed sediments with total PCB concentrations that exceeded the ERL value of 22.7 ppb but were less than the ERM value. Total PCB concentrations at the

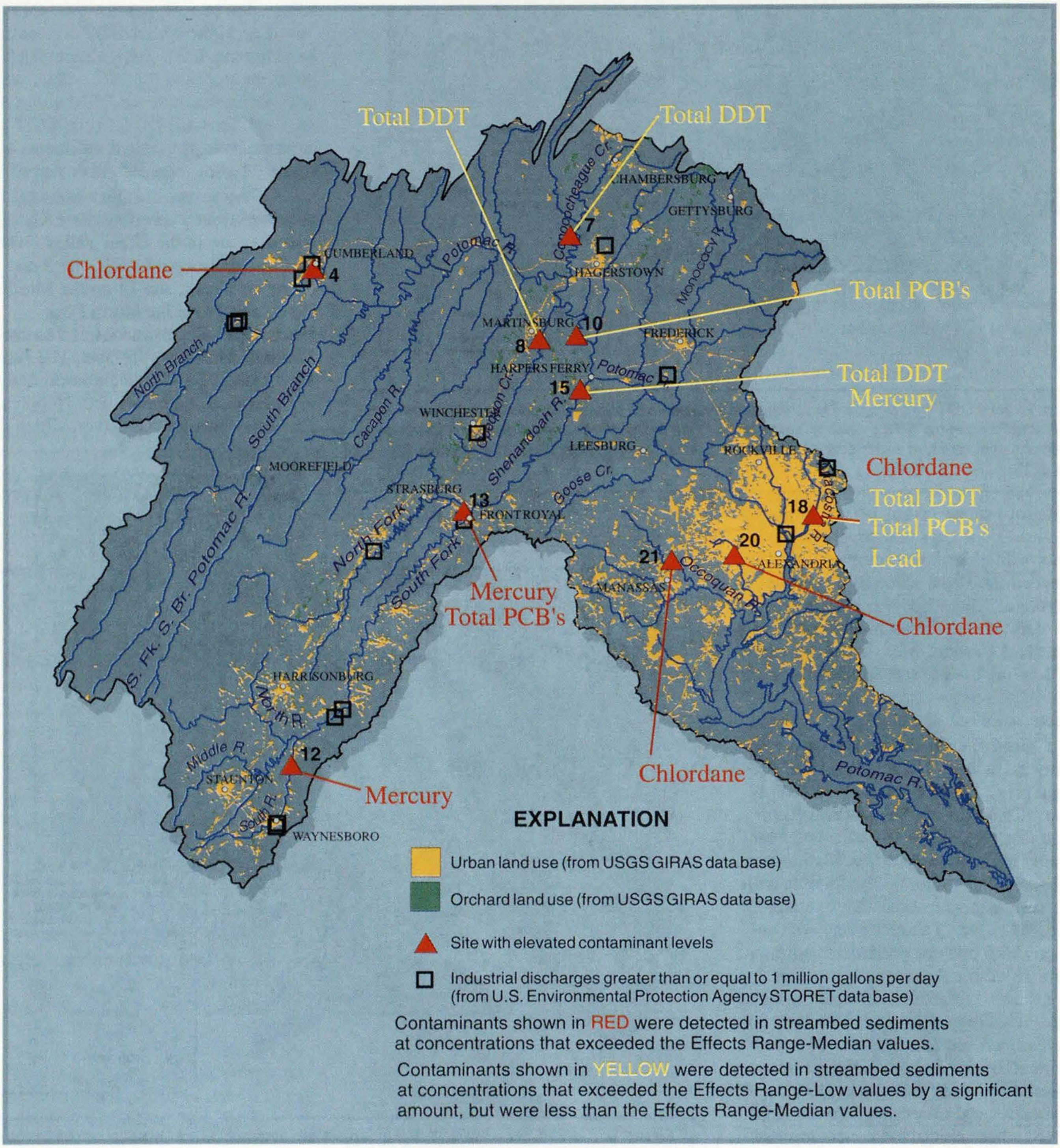
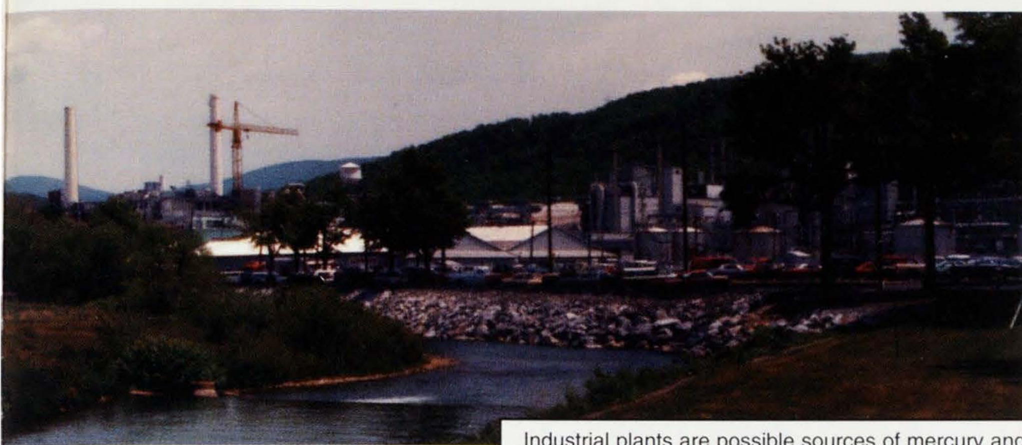


Figure 7. Mercury and total PCB contamination at sampled sites probably is related to industrial point sources in upstream areas; chlordane and lead contamination probably is related to urban nonpoint sources, and most total DDT contamination probably is related to orchard and cropland applications.



Industrial plants are possible sources of mercury and PCB contamination in streambed sediments.

other 14 sites where total PCB's were detected, were less than one-half the ERL value. PCB's were not detected in streambed sediments at 4 of the sampled sites.

The highest concentration of total PCB's in streambed sediments was 468 ppb at site 13 on the South Fork Shenandoah River (fig. 6b). The Virginia Water Control Board sampled streambed sediments near this site in 1988 and also detected high concentrations of total PCB's in the contaminated sediments (Virginia Water Control Board, 1992). The second highest concentration of total PCB's in streambed sediments was 131 ppb at site 18 on the Anacostia River, which drains a highly urban and developed area. The only other site that had a total PCB concentration in streambed sediments that exceeded the ERL value was site 10 on the Potomac River at Shepherdstown, W. Va., where the total PCB concentration was 108 ppb. No PCB's were detected in streambed sediments at sites 5, 16, 17, and 22, which drain mostly farmland and forest areas of the Potomac River Basin.

SOURCES CONTRIBUTING TO CONTAMINATION AT SELECTED SITES

There are many possible point and nonpoint sources of the five contaminants that were detected in streambed sediments at the 22 sampling sites in the Potomac River Basin. Possible point sources include poorly constructed landfills, chemical spills, and discharges from industrial, municipal, and commercial water-treatment plants. Possible nonpoint sources include atmospheric deposition and runoff from agricultural, urban, and mining areas. It is possible that the occurrence of a contaminant in streambed sediments at a sampling site is the result of a combination of several of these sources.

On a broad scale, it is possible to relate most of the high concentrations of contaminants in streambed sediments at the 22 sampling sites to three primary sources of contamination—industrial point sources, urban nonpoint sources, and orchard and agricultural nonpoint sources. In the following discussions, the upstream presence of one or more of these three primary sources is used to infer the possible cause of the contaminant concentrations that exceeded ERM values and most of the contaminant concentrations that exceeded ERL values (fig. 7). Additional sampling and detailed investigation would be necessary to determine the specific sources of contamination at each of these sampling sites.

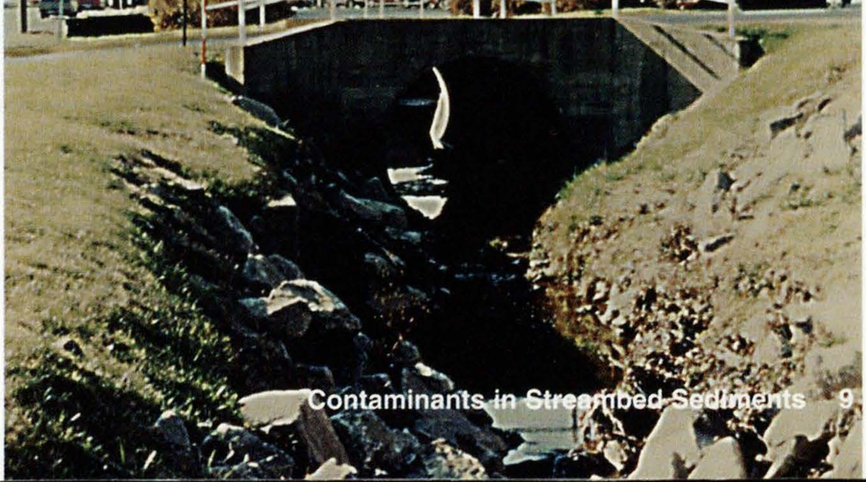
Industrial Point Sources

An industrial point source, which is known to have released mercury into the environment, is located near the headwaters of the South River in the Shenandoah River Basin. In 1977, mercury was discovered in soils at an industrial plant in Waynesboro, Va. (Brooks, 1977).

Historical records indicate that mercury was used in industrial processes at the plant until 1950. Two sampled sites (fig. 7) downstream from the industrial plant in Waynesboro—site 12 on the South River at Harriston, Va., and site 13 on the South Fork Shenandoah River at Front Royal, Va.—had mercury concentrations in streambed sediments that exceeded the ERM value for mercury. The mercury concentrations at these two sites, which were the highest measured in the Potomac River Basin, reflect the historical release of mercury into the environment at the industrial plant in Waynesboro.

Another industrial point source, which is known to have released PCB's into the environment, is located just upstream from site 13 on the South Fork Shenandoah River at Front Royal, Va. (fig. 7). Total PCB concentration in streambed sediments at site 13 was 468 ppb, which exceeded the ERM value for total PCB's of 180 ppb. The industrial plant located near the site was closed in 1989 after discovery of the release of PCB's into the South Fork Shenandoah River (Virginia Water Control Board, 1992). Two other sites where total PCB's in streambed sediments exceeded the ERL value may be related to industrial sources of PCB contamination. Site 18 on the Anacostia River drains a highly urban area with a major industrial plant in a nearby upstream area (fig. 7). Site 10 on the Potomac River at Shepherdstown, W. Va., has major industrial sources in its upper drainage area; however, no major

Runoff from urban areas is a possible source of lead and chlordane contamination in streambed sediments.



discharge points are located immediately upstream of the sampling site and no known PCB point sources are documented (fig. 7). The source of the high total PCB concentration at site 10 is unknown; further data collection and investigation is necessary to determine the source.

Urban Nonpoint Sources

The past use of chlordane for treatment of termite infestation in urban areas is a probable source of the high chlordane concentrations measured in streambed sediments in streams that drain urban areas. The four sites that have chlordane concentrations in streambed sediments that exceeded the ERM value for chlordane all drain major urban areas. Site 18 on the Anacostia River, site 20 on Accotink Creek, and site 21 on Bull Run all receive drainage from urban settings in the Washington, D.C., metropolitan area. Site 4 on the North Branch Potomac River receives drainage from the City of Cumberland, Md., which is the largest city in the western part of the Potomac River Basin (fig. 7). Urban nonpoint sources were identified by Wade and others (1994) as the probable sources of high chlordane concentrations in streambed sediments in the Anacostia River, and it is likely that similar types of urban sources are also responsible for the high concentrations of chlordane in streambed sediments at sites 4, 20, and 21 in this survey.

The many past and present uses of lead in urban areas, which include leaded fuel for vehicles, batteries, construction pipes, plumbing connections, and paint ingredients, probably are the major sources of the relatively high lead concentration detected in streambed sediments at site 18 on the Anacostia River (fig. 7). All sampled sites had lead concentrations in streambed sediments that exceeded the average crustal abundance of lead; the major reason for this probably is the widespread atmospheric deposition of lead in dust particles contaminated by vehicle exhaust fumes.

Although mostly used for agricultural purposes, DDT also was widely used to control mosquitoes in populated areas until it was banned in 1972. Residual concentrations of DDT in urban soils are a probable source of the relatively high concentration of total DDT in streambed sediments at site 18 on the Anacostia River (fig. 7).

Past pesticide applications in orchards are a possible source of DDT contamination in streambed sediments.

Orchard and Agricultural Nonpoint Sources

Total DDT concentrations in streambed sediments exceeded the ERL value for total DDT at sites 7, 8, and 15 in the north-central Great Valley (fig. 7). These three sites are near and downstream from areas where fruit orchards are most prevalent in the Potomac River Basin. In addition, the areas drained by these three sites have some of the most intensively cropped farmland in the basin. The past use of DDT to control insects in orchards and on cropland probably is the major source of the relatively high total DDT concentrations in streambed sediments measured at these three sites.

ENVIRONMENTAL IMPLICATIONS OF CONTAMINANTS IN STREAMBED SEDIMENTS

The occurrence of lead, mercury, chlordane, total DDT, and total PCB's in streambed sediments throughout the Potomac River Basin has several important implications for stream-ecosystem and human health. Factors such as the environmental persistence of the contaminants, their availability for downstream transport, their potential for bioaccumulation in aquatic organisms, and their possible effects on human health, are briefly discussed in the following sections.

Environmental Persistence

Once the contaminants are introduced into streambed sediments, they can remain there for long periods of time. While present, they can be available under certain environmental conditions to cause adverse effects on aquatic organisms. An example of the environmental persistence of contaminants in the Potomac River Basin is the occurrence of total DDT in streambed sediments at all sites sampled during the 1992 survey, two decades after the use of the pesticide was banned in 1972. Another even more compelling example is the presence of elevated mercury concentrations in streambed sediments at site 12 on the South River in 1992, more than four decades after the use of mercury was discontinued in the nearby industrial plant that released the mercury into the environment. The occurrence of total PCB's and chlordane in streambed sediments at sampled sites also are examples of the environmental persistence of contaminants years after their use was banned.

Availability for Downstream Transport

During high streamflow periods, streambed sediments are mobilized and transported downstream. Consequently, the contaminants stored in the sediments also are transported and redeposited in downstream reaches of the streams. Through this frequently recurring process, contaminants are introduced into new areas of the stream ecosystem, thereby becoming available for ingestion by greater numbers of aquatic organisms. An example of the transport of contaminants in streambed sediments is the occurrence of mercury in the Shenandoah River Basin. As noted earlier, the mercury was released into the environment along the South River in Waynesboro, Va. (fig. 8). Through decades of downstream transport of mercury-contaminated sediments, mercury has accumulated in high concentrations in streambed sediments at site 12 on the South River at Harriston, 16 river miles downstream from the industrial source; at site 13 on the South Fork Shenandoah River at Front Royal, 118 river miles downstream from the source; and at site 15 on the Shenandoah River at Millville, 171 river miles downstream from the source. Concentrations of mercury in streambed sediments at these sites decrease with distance downstream from the source in Waynesboro, Va. It also is possible that mercury released along the South River has reached the streambed sediments at site 19 on the Potomac River downstream from Washington, D.C.

Potential for Bioaccumulation in Aquatic Organisms

The presence of these contaminants in streambed sediments can have a significant adverse effect on aquatic organisms. Organisms that live in the sediments can ingest the contaminants and accumulate them in their tissues. The bioaccumulation of the contaminants in these aquatic organisms has been shown to cause various physiological problems and even death of the organisms when contaminant concentrations exceed ERL and ERM guidelines (Long and others, 1995). In addition, these accumulated concentrations can be passed on to higher organisms in the food chain as a result of the higher organisms ingesting contaminated organisms that live in the sediments. One example of the relation of streambed-sediment contamination to the resulting contamination of higher organisms is shown in figure 9. As part of the 1992 survey, tissues from catfish (yellow bullheads) were collected at eight of the sites where streambed sediments were collected. The correlation coefficient (Spearman's rho) between chlordane concentrations in sediments and chlordane concentrations in catfish tissues is 0.94, indicating a strong direct relation between the occurrence of the contaminant in streambed sediments and the presence of the contaminant in fish tissues.

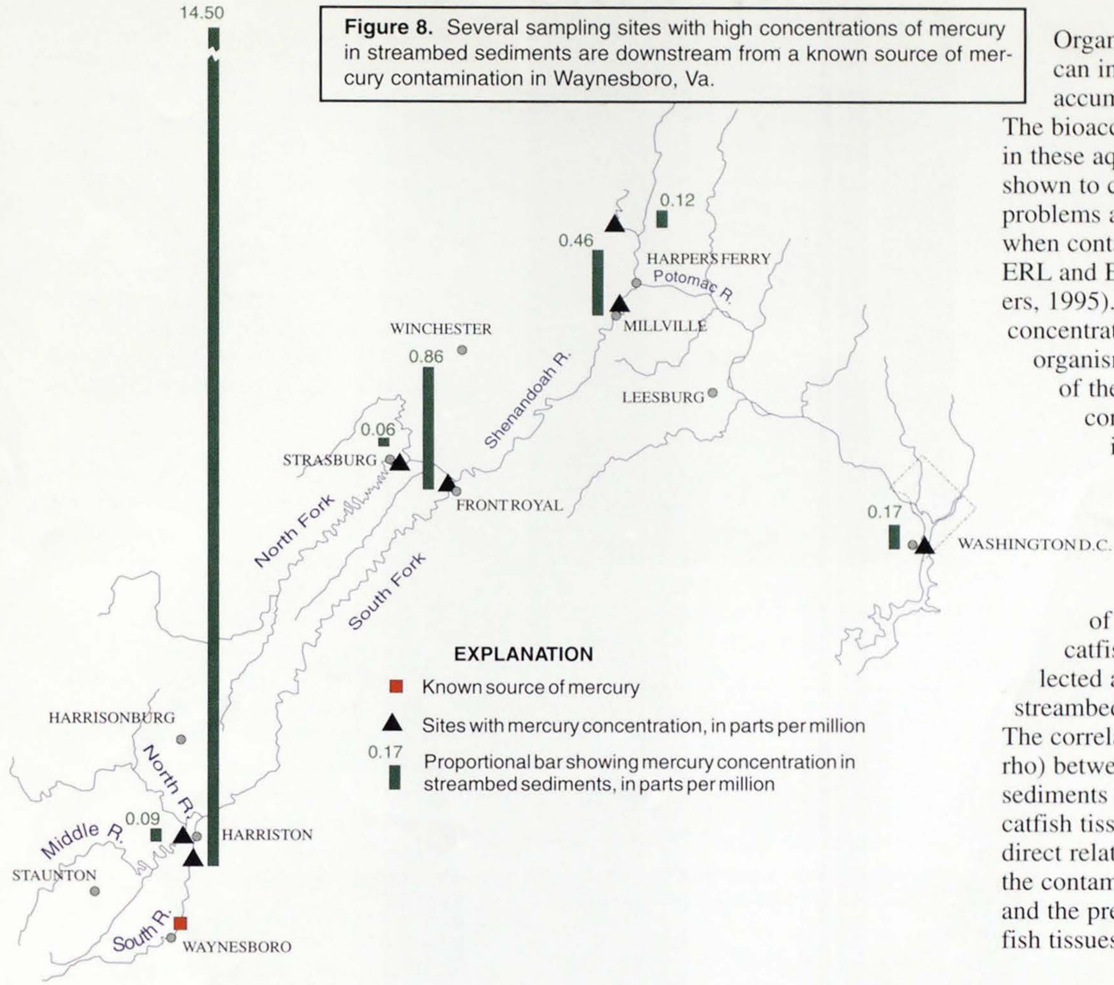


Figure 8. Several sampling sites with high concentrations of mercury in streambed sediments are downstream from a known source of mercury contamination in Waynesboro, Va.

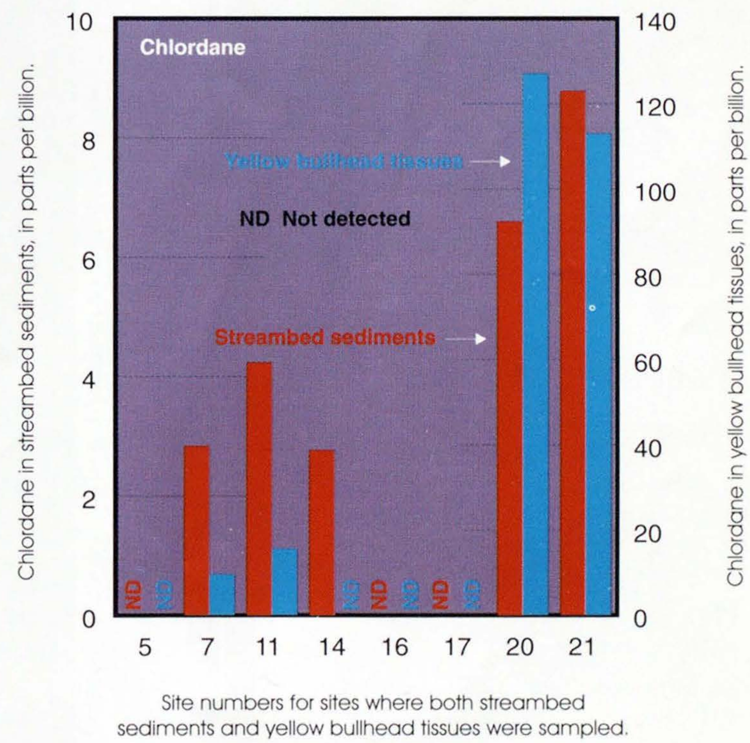
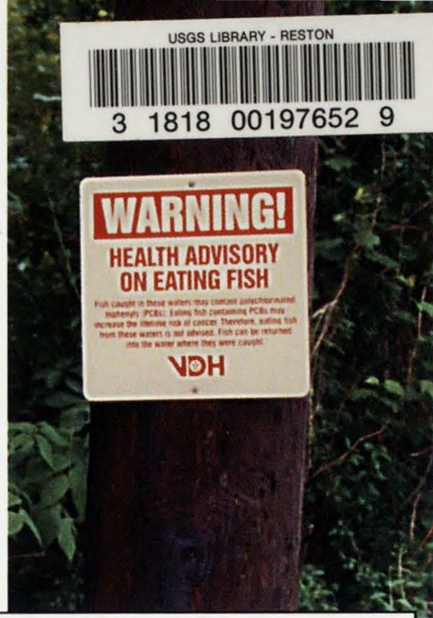


Figure 9. Chlordane concentrations in catfish tissues are closely correlated with chlordane concentrations in streambed sediments at eight sampling sites where both media were sampled.

Possible Effects on Human Health

Some of the possible effects of the contaminants on human health are documented in table 2. One way that humans can be exposed to the contaminants is through the food chain. The human consumption of fish from streams with contaminated sediments and the human consumption of terrestrial animals who prey on contaminated fish can lead to the bioaccumulation of the contaminants in human tissues. Fish surveys conducted in the Potomac River Basin have detected unacceptable levels of mercury, chlordane, and total PCB's in fish tissues in selected streams and, as a result, have prompted State regulatory agencies to issue bans or restrictions on the human consumption of fish from certain reaches of the streams.



PCB contamination in the South Fork Shenandoah River has caused contamination of fish, resulting in restrictions on human consumption of fish.

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