U.S. DEPARTMENT OF THE INTERIOR
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# Organochlorine Compounds in Streambed Sediment and in Biological Tissue from Streams and Their Relations to Land Use, Central Arizona

Water-Resources Investigations Report 00–4041

*National Water-Quality Assessment Program*

USGS
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*By* J.B. Gebler

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NATIONAL WATER-QUALITY ASSESSMENT PROGRAM

Tucson, Arizona
2000

U.S. DEPARTMENT OF THE INTERIOR
BRUCE BABBITT, Secretary

U.S. GEOLOGICAL SURVEY
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## FOREWORD

The mission of the U.S. Geological Survey (USGS) is to assess the quantity and quality of the earth resources of the Nation and to provide information that will assist resource managers and policymakers at Federal, State, and local levels in making sound decisions. Assessment of water-quality conditions and trends is an important part of this overall mission.

One of the greatest challenges faced by water-resources scientists is acquiring reliable information that will guide the use and protection of the Nation's water resources. That challenge is being addressed by Federal, State, interstate, and local water-resources agencies and by many academic institutions. These organizations are collecting water-quality data for a host of purposes that include: compliance with permits and water-supply standards; development of remediation plans for a specific contamination problem; operational decisions on industrial, wastewater, or water-supply facilities; and research on factors that affect water quality. An additional need for water-quality information is to provide a basis on which regional and national-level policy decisions can be based. Wise decisions must be based on sound information. As a society we need to know whether certain types of water-quality problems are isolated or ubiquitous, whether there are significant differences in conditions among regions, whether the conditions are changing over time, and why these conditions change from place to place and over time. The information can be used to help determine the efficacy of existing water-quality policies and to help analysts determine the need for and likely consequences of new policies.

To address these needs, the Congress appropriated funds in 1986 for the USGS to begin a pilot program in seven project areas to develop and refine the National Water-Quality Assessment (NAWQA) program. In 1991, the USGS began full implementation of the program. The NAWQA program builds upon an existing base of water-quality studies of the USGS, as well as those of other Federal, State, and local agencies. The objectives of the NAWQA program are to:

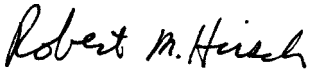
- Describe current water-quality conditions for a large part of the Nation's freshwater streams, rivers, and aquifers.
- Describe how water quality is changing over time.
- Improve understanding of the primary natural and human factors that affect water-quality conditions.

This information will help support the development and evaluation of management, regulatory, and monitoring decisions by other Federal, State, and local agencies to protect, use, and enhance water resources.

The goals of the NAWQA program are being achieved through ongoing and proposed investigations of 60 of the Nation's most important river basins and aquifer systems, which are referred to as study units. These study units are distributed throughout the Nation and cover a diversity of hydrogeologic settings. More than two-thirds of the people served by public water-supply systems live within their boundaries.

National synthesis of data analysis, based on aggregation of comparable information obtained from the study units, is a major component of the program. This effort focuses on selected water-quality topics using nationally consistent information. Comparative studies will explain differences and similarities in observed water-quality conditions among study areas and will identify changes and trends and their causes. The first topics addressed by the national synthesis are pesticides, nutrients, volatile organic compounds, and aquatic biology. Discussions on these and other water-quality topics will be published in periodic summaries of the quality of the Nation's ground and surface water as the information becomes available.

This report is an element of the comprehensive body of information developed as part of the NAWQA program. The program depends heavily on the advice, cooperation, and information from many Federal, State, interstate, Tribal, and local agencies and the public. The assistance and suggestions of all are greatly appreciated.



Robert M. Hirsch
Associate Director for Water

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## CONVERSION FACTORS

| Multiply | By | To obtain |
|---|---|---|
| centimeter (cm) | 0.3937 | inch |
| millimeter (mm) | 0.03937 | inch |
| meter (m) | 3.281 | foot |
| kilometer (km) | 0.6214 | mile |
| hectare (ha) | 2.471 | acre |
| square kilometer ($km^2$) | 0.3861 | square mile |
| liter (L) | 0.2642 | gallon |
| gram (g) | 0.03527 | ounce, avoirdupois |
| kilogram (kg) | 2.205 | pound, avoirdupois |

## ABBREVIATED WATER-QUALITY UNITS

Chemical concentration and water temperature are given only in metric units. Chemical concentration in water is given in milligrams per liter (mg/L) or micrograms per liter (µg/L). Milligrams per liter is a unit expressing solute mass (milligrams) per unit volume (liter) of water. One thousand micrograms per liter is equivalent to 1 milligram per liter. For concentrations less than 7,000 milligrams per liter, the numerical value is about the same as for concentrations in parts per million. Chemical concentration in bottom sediment is given in grams per kilogram (g/kg), micrograms per gram (µg/g), milligrams per kilogram (mg/kg), or micrograms per kilogram (µg/kg). Grams per kilogram is equal to parts per thousands (ppt). Milligrams per kilogram and micrograms per gram are equal to parts per million (ppm). Micrograms per kilogram are equal to parts per billion (ppb).

## VERTICAL DATUM

**Sea Level**: In this report, “sea level” refers to the National geodetic Vertical Datum of 1929 (NGVD of 1929)—A geodetic datum derived from a general adjustment of the first-order level nets of both the United States and Canada, formerly called the “Sea Level Datum of 1929”. **Elevation**, as used in this report, refers to distance above or below sea level.

# Organochlorine Compounds In Streambed Sediment and in Biological Tissue from Streams and Their Relations to Land Use, Central Arizona

*By* Joseph B. Gebler

## Abstract

Streambed-sediment samples from 13 sites and biological-tissue samples from 11 sites in the Gila River Basin in central Arizona were analyzed for 32 organochlorine compounds in streambed sediment and 28 compounds in biological tissue during 1996 as part of the United States Geological Survey's National Water-Quality Assessment program. The objectives of the study were to determine the occurrence and distribution of organochlorine compounds and their relation to land use. Sampling sites were categorized on the basis of major land uses in the basin or the source of water in the stream. Because land uses were mixed or had changed over time, some land-use categories were combined. Sites were categorized as forest/rangeland (6), forest/urban (1), urban (4), or agricultural/urban (2).

Thirteen organochlorine compounds were detected in streambed-sediment samples, and 10 were detected in tissue samples. The number of compounds found in streambed-sediment samples from individual sites ranged from 0 to 10, and the range for individual tissue samples was 0 to 7. Comparison of the number of detections in streambed-sediment samples to the number of detections in tissue samples from particular sites where both were sampled yielded five instances where more compounds were detected in streambed sediment, six instances where more compounds were detected in tissue, and five instances where the number of detections in streambed sediment and tissue were equal.

The frequency of detection of particular compounds for sites where both streambed sediment and tissue were sampled resulted in five compounds being detected more frequently in streambed sediment, five more frequently in tissue, and three compounds that were equally frequent in streambed sediment and in tissue. Few contaminants were detected in samples from the forest/rangeland sites; greater numbers of compounds were detected at the urban sites and at the forest/urban site. The greatest number of compounds and the highest concentrations of many contaminants were detected at agriculture/urban sites. The compound detected most frequently in streambed-sediment and tissue samples was *p,p*'-DDE.

Streambed-sediment guideline values for the protection of aquatic life for *p,p*'-DDE and total DDT were exceeded at both agricultural/urban sites, The streambed-sediment guideline value for the protection of aquatic life for total chlordane was exceeded at one agricultural/urban site, one urban site, and the forest/urban site. The streambed-sediment guideline value for the protection of aquatic life for total PCBs was exceeded at one agricultural/urban site.

Guideline values for the protection of fish-eating wildlife for total DDT and for toxaphene were exceeded only in samples from the two agricultural/urban sites. The guideline value for the protection of fish-eating wildlife for total PCB's was equaled or exceeded in samples from two sites—one urban and one agricultural/urban site.

Screening values established by the U.S. Environmental Protection Agency for the protection of human health for edible portions of fish were exceeded by total DDT and by toxaphene in fish-tissue samples from both agricultural/urban sites. The human-health criterion for total PCB's was exceeded in two fish-tissue samples from an agricultural site and from an urban site. Tissue samples analyzed in this study were for whole fish, and thus, concentration data are not entirely comparable to the screening values of the U.S. Environmental Protection Agency. Because these exceedences were an order of magnitude above the criteria, however, it is possible that concentrations in the edible portions of fish from these locations could present a human-health risk. Analyses of samples of edible portions of fish from these locations would be needed to adequately assess the presence or absence of a human-health risk.

The similarity of the results of this study to the results of other studies of organochlorine compounds in the environment suggests that there is a correlation between contaminants in sediment and biological-tissue samples and land uses. As with other studies of the occurrence and distribution of organochlorine contaminants in streambed sediments and biological tissue, this study shows that many organochlorine compounds continue to persist in the environment and thus could pose a threat to aquatic life, fish-eating wildlife, and possibly to humans who consume contaminated fish.

## INTRODUCTION

As part of the U.S. Geological Survey's (USGS) National Water-Quality Assessment (NAWQA) program, water-quality studies began in the Central Arizona Basins (CAZB) study area in 1994 (**fig. 1**). The goals of the NAWQA program are to describe current water-quality conditions, trends in water quality over time, and the effects of natural and human factors on water quality (Hirsch and others, 1988; Gurtz, 1994). One component of the NAWQA program is to determine the occurrence and distribution of organochlorine compounds in river systems.

Most organochlorine compounds are hydrophobic, which means they have low solubilities in water, and lipophillic, which means that they accumulate in the lipids of living organisms. In a stream environment, organochlorine compounds adsorb on sediment (Rinella and others, 1999). Benthic (bottom-dwelling) organisms, such as insects and other invertebrates, can be affected by organochlorine compounds through exposure and ingestion. As other aquatic organisms feed on these benthic animals, organochlorine compounds can biomagnify through each level of aquatic and terrestrial food webs. Consequently, streambed sediment and biological tissue usually are sampled to assess organochlorine compounds.

The organochlorine compounds analyzed in this study include organochlorine pesticides and total polychlorinated biphenyls (PCB's). The use of many of these compounds has been restricted or banned in the United States because they are toxic to wildlife and humans and are probable carcinogens (Carson, 1962). Other documented adverse environmental effects of certain organochlorine compounds are eggshell thinning and reproductive failure in birds of prey (Faber and Hickey, 1973) and the disruption of endocrine function and reproductive impairment of many kinds of organisms (Fry and Toon, 1981; Colburn and others, 1993; Kendall and others, 1998).

Despite the discontinuance of their use, many organochlorine compounds persist in the environment because of their resistance to degradation. Determining the occurrence and distribution of organochlorine compounds in streambed sediments and tissues of aquatic organisms is one way to assess the relation between land use and aquatic ecosystems. This information can aid in identifying those land uses that contribute organochlorine compounds to aquatic ecosystems and can be used for optimizing watershed management to minimize adverse effects on biota and humans.

### Purpose and Scope

This report summarizes the results of a study of the occurrence and distribution of organochlorine compounds in streambed sediment and the tissues of aquatic biota in streams in the CAZB. All samples were collected during 1996. Detected compounds and their concentrations are evaluated in relation to general land uses. In addition, the concentrations of detected compounds are compared to guidelines established for the protection of aquatic biota, fish-eating wildlife, and human health.

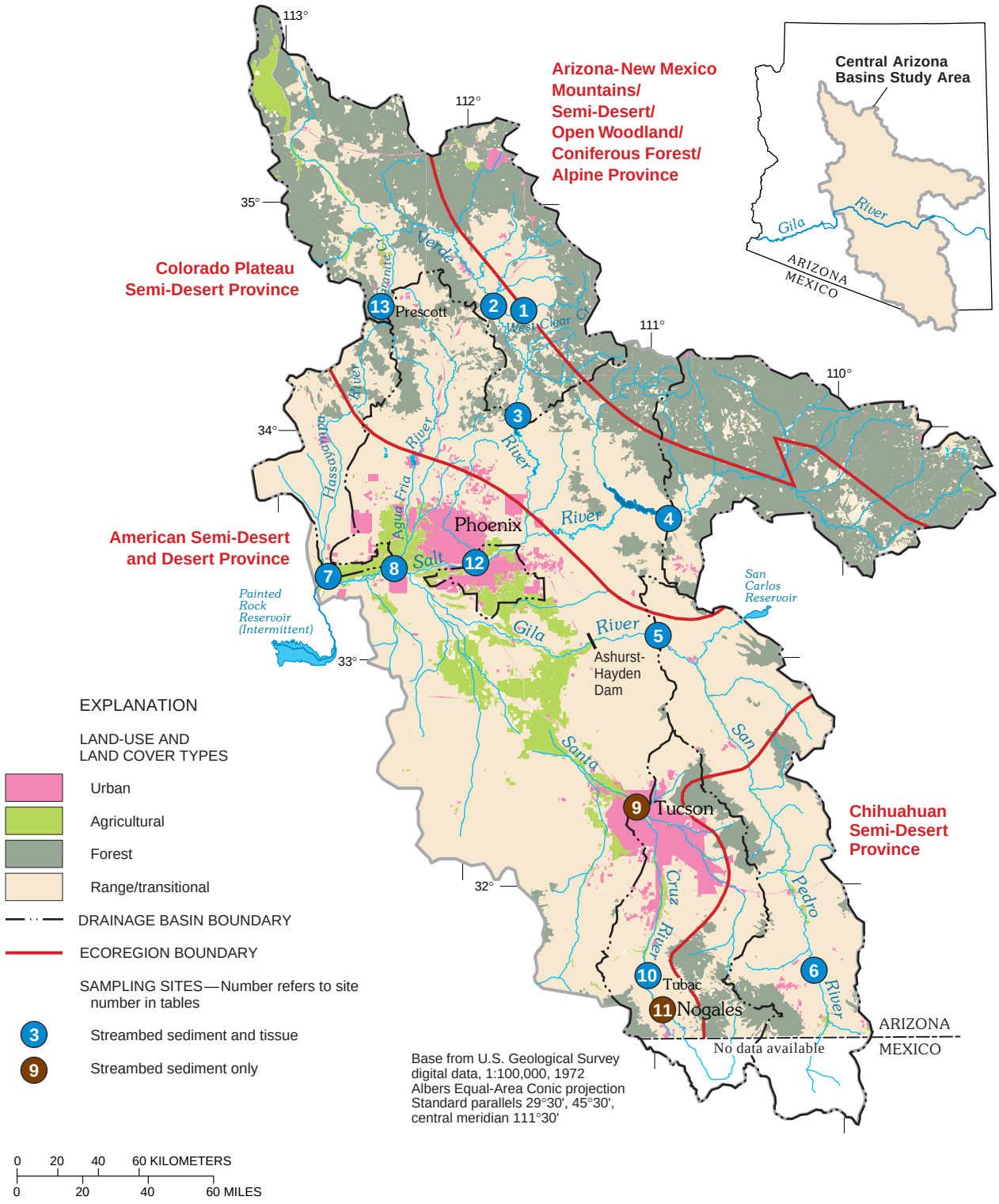


**Figure 1**. Streambed-sediment and biological-tissue sampling sites, and land-use and land-cover types in the Central Arizona Basins study area.

## Previous Studies

Several investigators have studied contaminants in the CAZB. Cordy and others (1998) summarized the findings of these studies. Two bioaccumulation studies were done in San Carlos Reservoir, which is just upstream from the CAZB study area on the Gila River. As such, the reservoir could potentially serve as an input source for contaminants to the river as the river enters the CAZB study area. As part of the National Contaminant Biomonitoring Program (NCBP) by the U.S. Fish and Wildlife Service, Schmitt and others (1990) reported six organochlorine compounds in fish-tissue samples (*p,p*'-DDD, *p,p*'-DDE, *p,p*'-DDT, Arochlor 1248 [a PCB mixture], *cis*-nonachlor, and toxaphene). DDD, DDE, and DDT are acronyms for dichlorodiphenyldichloroethane, dichlorodiphenyl-ethylene, and dichlorodiphenyltrichlorethane, respectively. Concentrations of the six compounds were low compared with national values of the same compounds. Contaminants reported by Baker and King (1994) in fish-tissue samples from the San Carlos Reservoir were heptachlor, *p,p*'-DDE, and *p,p*'-DDD, which were at low concentrations. King and Baker (1995) reported no organochlorine compounds in streambed sediment and low concentrations of *p,p*'-DDE in fish-tissue samples from the Gila River from the output of San Carlos Reservoir downstream to Ashurst-Hayden Dam.

King and others (1992) collected streambed-sediment and biota samples from nine sites in the San Pedro River Basin in 1987. Organochlorine compounds were not detected in streambed-sediment samples. Low concentrations of *p,p*'-DDE and the chlordane component, *trans*-nonachlor, were detected in some fish-tissue samples.

King and others (1991) collected fish samples from eight sites on various rivers near nesting sites of bald eagles (*Haliaeetus leucocephalus*) in order to assess contaminant levels in potential eagle prey. Seven of the eight sites are in the CAZB study area. Most organochlorine compounds were not detected. Low concentrations of chlordane were detected in some fish-tissue samples from five locations, and low concentrations of dieldrin and PCB's were detected in a few samples.

Johnson and Lew (1970) collected samples of fish tissue from canals associated with the Gila and Salt Rivers in the Phoenix area between 1965 and 1967. They reported residues of DDT and metabolites that exceeded the Food and Drug Administration's interim guideline for fish shipped in interstate commerce [5 ppm (5 μg/g)] in 12 of 23 fish-tissue samples.

Kepner (1987) reported high concentrations of *p,p*'-DDE and toxaphene in fish from the lower Gila River and associated agricultural canals for samples collected in 1985. In a followup to Kepner's study, King and others (1997) sampled fish at six locations along 142 km of the lower Gila River and associated canals from Phoenix to Painted Rock Reservoir in 1994 and 1995. The highest geometric mean concentration of *p,p*'-DDE (11,170 μg/kg) was in a sample of common carp from the Buckeye Canal. King and others (1997) noted that this was the highest agriculturally associated concentration of DDE in the United States. King and others (1997) also reported high concentrations of toxaphene in fish samples from the Buckeye Canal (2,600 and 5,400 μg/kg) and lower concentrations of PCB's, chlordane, and dieldrin.


## Acknowledgements

Field assistance was provided by Ken Galyean, Steven L. Goodbred, Julie Rees, and Terry Short of the USGS, and by volunteers Brian Popadac and Tom Rees. Steven L. Goodbred, Kirke King (U.S. Fish and Wildlife Service), and Kirk Young (Arizona Game and Fish Department) provided valuable advice. Julie Rees compiled geographic information system data. Lisa H. Nowell provided invaluable information on guideline values and criteria.


## Description of Study Area

The CAZB study area encompasses 89,900 $km^2$ in central and southern Arizona and northern Mexico (**fig. 1**). Elevations range from about 245 m to about 3,475 m. The climate is arid to semiarid. Average annual precipitation ranges from about 64 cm to 102 cm at the higher elevations in the northern part of the study area and from about 15 cm to 25 cm in the lower elevations in the southern part. About 90 to 99 percent of precipitation is evaporated or transpired by plants (Cordy, 1994). Consequently, many water courses in the area are intermittent or ephemeral. Southern parts of the area are in the American Semi-Desert and Desert Province and the Chihuahuan Semi-Desert Province ecoregions; whereas, northern parts are in the Colorado Plateau Semi-Desert Province and the Arizona-New Mexico Mountains Semi-Desert-Open Woodland-Coniferous Forest- Alpine Meadow Province ecoregions (Bailey, 1995). The Gila River is the primary surface-water system that drains the area; major tributaries are the Hassayampa, Agua Fria, Verde, Salt, San Pedro, and Santa Cruz Rivers (fig. 1).

Of these, only the Verde and Salt Rivers are perennial. Dams on several of these rivers regulate flow that is discharged into a complex system of canals for irrigation, predominantly in agricultural lands near Phoenix.

Water use in the study area is dominated by agriculture. Although agriculture is the primary land-use type in only 5 percent of the study area, about 73 percent of the ground water and surface water withdrawn is used for agriculture (Cordy and others, 1998). The major crop is cotton; gravity irrigation with furrows is the principal irrigation technique (Cordy and others, 1998).

Increasing human population in the study area is resulting in increases in domestic water use. Urbanized land more than doubled from 2,540 $km^2$ in 1976 to 4,660 $km^2$ in 1990—the latter value represents about 5 percent of the study area (Cordy and others, 1998). Treated sewage effluent is the source of perennial flow for certain stream reaches, especially in the southern part of the study area. Except during floods, effluent composes 100 percent of the flow in these streams. The water quality of such streams generally is poor (Gebler, 1998). In addition, effluent augmented by ground water is used for irrigation in the Salt River Valley, west of Phoenix, where the principal crop is cotton (Arizona Agricultural Statistics Service, 1997). The environmental setting of the study area is discussed in detail by Cordy and others (1998).

## METHODS OF INVESTIGATION

### Site Selection and Classification

Thirteen sampling sites (**fig. 1**) were selected on perennial reaches of streams in the CAZB study area to represent urban, agricultural, and minimally developed (forest, rangeland) land uses (table 1). Sites with primary and secondary land use of forest or rangeland are referred to as forest/rangeland, regardless of which of the two land uses predominate. Land use in the drainage basin upstream from most sites was determined using Anderson Level I classification modified from Geographical Information Retrieval and Analysis System (GIRAS) data from 1974–83 at a scale of 1:250,000 (Anderson and others, 1976).

**Table 1**. Land uses for streambed-sediment and biological-tissue sampling sites, Central Arizona Basins study area, 1996

[Land use: F, forest; R, rangeland; A, agriculture; U, urban. NA, not applicable]

| Site number (see fig. 1) | Site name | Primary and secondary land use | Land use, in percent | | | | |
|---|---|---|---|---|---|---|---|
| | | | Urban | Agricultural | Rangeland | Forest | Other |
| 1 | West Clear Creek | F/R | 0 | 0 | 21 | 79 | 0 |
| 2 | Verde River above West Clear Creek, near Camp Verde | F/R | 2 | 5 | 32 | 59 | 2 |
| 3 | Verde River below Tangle Creek, above Horseshoe Dam | F/R | 2 | 4 | 33 | 60 | 1 |
| 4 | Salt River near Roosevelt | F/R | 1 | 0 | 16 | 83 | 0 |
| 5 | Gila River at Kelvin | F/R | 1 | 1 | 84 | 13 | 1 |
| 6 | San Pedro River at Charleston | F/R | 3 | 2 | 76 | 18 | 1 |
| 7 | Buckeye Canal near Hassayampa | [1]A/U | NA | NA | NA | NA | NA |
| 8 | 91st Avenue wastewater-treatment plant outfall near Phoenix | [1]A/U | NA | NA | NA | NA | NA |
| 9 | Santa Cruz River at Cortaro | [2]U | NA | NA | NA | NA | NA |
| 10 | Santa Cruz River at Tubac | [2]U | NA | NA | NA | NA | NA |
| 11 | Santa Cruz River near Nogales Wastewater-Treatment Plant | [2]U | NA | NA | NA | NA | NA |
| 12 | 48th Street Drain near Interstate 10 | [3]U | NA | NA | NA | NA | NA |
| 13 | Granite Creek at Prescott | F/U | 26 | 0 | 3 | 70 | 1 |

[1]Primary land use for sites 7 and 8 was defined as agricultural because of past agricultural activities; secondary land use was defined as urban because almost all flow is effluent.
[2]Land use for sites 9–11 was defined as urban because almost all flow is effluent. Secondary land use was not defined for these sites.
[3]Land use for site 12 was defined as urban because all flow is urban runoff.

Land-use information was updated for Maricopa County using 1990 data from the Maricopa Association of Governments, and for the metropolitan Tucson area using 1990 data from Pima County and the University of Arizona (Cordy and others, 1998). Land-use information for one sampling site—San Pedro River at Charleston—was limited to 1,323 $km^2$ of the watershed total of 3,257 $km^2$ because of a lack of land-use information for Mexico. Land-use percentages determined from the part of the basin in Arizona probably are representative of the entire basin because no major urban nor agricultural areas are in the part of the basin in Mexico (Commission for Environmental Cooperation, 1998; D.W. Anning, hydrologist, USGS, oral commun., 1998).

The primary land use for effluent-dependent sampling reaches was defined as urban because all water at these sites is derived from sewage effluent except during floods, which typically are of short duration. Reaches at the Buckeye Canal near Hassayampa (site 7, **fig. 1**) and the 91st Avenue wastewater-treatment plant (site 8, fig. 1) also have surface water derived primarily from wastewater; however, historical agricultural activities are thought to be the primary source of organochlorine compounds at these locations. About 772,700 kg of DDT were applied to 13,355 ha between 1958 and 1960 in the area of these two sites (King and others, 1997). Historically, this area has been among the most contaminated in the Nation (King and others, 1997). Consequently, agriculture was deemed to be the primary land use for these sites, and urban land use was deemed the secondary land use.

## Sample Collection and Processing

Streambed-sediment samples were collected from 13 sites in 1996 (fig. 1; **table 1**), including two sites where targeted biota were absent. Each streambed-sediment sample was a composite of 5 to 10 individual samples collected with a Teflon spoon from the upper 2 cm of depositional zones throughout each 120- to 582-meter sampling reach. Samples were homogenized in a glass bowl and then passed through a 2.0-millimeter stainless-steel sieve into a 1,000-milliliter glass jar. Streambed- sediment samples were packed in wet ice and shipped to the U.S. Geological Survey's National Water-Quality Laboratory (NWQL) in Arvada, Colorado, by overnight carrier. Before samples were collected at each site, all equipment used for sample collection and processing was cleaned with 0.2 percent phosphate-free detergent, then rinsed with tap water, deionized water, and reagent-grade methanol. Equipment was air dried and wrapped in aluminium foil. Additional information about streambed-sediment sampling in the NAWQA program is provided by Shelton and Capel (1994).

Chemical analyses of streambed-sediment samples were performed by the NWQL for 32 compounds using dual-column gas chromatography with electron-capture detection (Foreman and others, 1995). Analytes and method-detection limits are listed in **table 2**.

Biological-tissue samples were collected from 11 sites (fig. 1; table 1). No single taxon was available at all sampling locations because of the wide variety of stream types and environments that were sampled and because of species-specific distributional limits.
Five species of fish were collected using electrofishing or seine netting— desert sucker (*Catostomus clarki*), red shiner (*Cyprinella lutrensis*), redbelly tilapia (*Tilapia zilli*), common carp (*Cyprinus carpio*), and fathead minnow (*Pimephales promelas*).
Two invertebrate species also were collected at certain sites—asiatic clam (*Corbicula sp.*) and a crayfish species (*Orconectes causeyi*). Multiple species were collected from four sites to examine interspecific differences in bioaccumulated contaminants. Tissue samples were composites of multiple individuals of the same species.

After weighing and measuring organisms, composite samples were wrapped in aluminum foil, placed in a polyethylene bag, frozen on dry ice, and shipped to the NWQL by overnight carrier. Additional information on NAWQA tissue sampling is given by Crawford and Luoma (1993).

The NWQL analyzed tissue from whole organisms for 28 organochlorine compounds using dual-column gas chromatography with electron-capture detection (table 2). Leiker and others (1995) describe analytical methodology, performance, quality assurance, and quality control for tissue analyses.

**Table 2**. Method-detection limits for organochlorine compounds analyzed in streambed-sediment and biological-tissue samples, Central Arizona Basins study area, 1996

[Values for streambed sediment, in micrograms per kilogram, dry weight. Values for biological tissue, in micrograms per kilogram, wet weight. NA, not analyzed]

| Analyte | Streambed sediment | Biological tissue | Analyte | Streambed sediment | Biological tissue |
|---|---|---|---|---|---|
| Aldrin | 1.0 | 5.0 | Hexachlorocyclohexane (HCH, γ) | 1.0 | 5.0 |
| Chlordane, *cis*- | 1.0 | 5.0 | Heptachlor | 1.0 | 5.0 |
| Chlordane, *trans*- | 1.0 | 5.0 | Heptachlor epoxide | 1.0 | 5.0 |
| Chlorneb | 5.0 | NA | Hexachlorobenzene | 1.0 | 5.0 |
| Dimethyl 2, 3, 5, 6-tetrachloro-1, 4-benzenedicarboxylate (DCPA) | 5.0 | 5.0 | Isodrine | 1.0 | NA |
| Dichlorodiphenyldichloroethane (*o,p*'-DDD) | 1.0 | 5.0 | Methoxychlor, *o,p*'- | 5.0 | 5.0 |
| Dichlorodiphenyldichloroethane (*p,p*'-DDD) | 1.0 | 5.0 | Methoxychlor, *p,p*'- | 5.0 | 5.0 |
| Dichlorodiphenylethylene (*o,p*'-DDE) | 1.0 | 5.0 | Mirex | 1.0 | 5.0 |
| Dichlorodiphenylethylene (*p,p*'-DDE) | 1.0 | 5.0 | Nonachlor, *cis*- | 1.0 | 5.0 |
| Dichlorodiphenyltrichloroethane (*o,p*'-DDT) | 2.0 | 5.0 | Nonachlor, *trans*- | 1.0 | 5.0 |
| Dichlorodiphenyltrichloroethane (*p,p*'-DDT) | 2.0 | 5.0 | Oxychlordane | 1.0 | 5.0 |
| Dieldrin | 1.0 | 5.0 | Pentachloroanisole | 1.0 | 5.0 |
| Endosulfan | 1.0 | NA | Permethrin, *cis*- | 5.0 | NA |
| Endrin | 2.0 | 5.0 | Permethrin, *trans*- | 5.0 | NA |
| Hexachlorocyclohexane (HCH, α) | 1.0 | 5.0 | Toxaphene | 200 | 200 |
| Hexachlorocyclohexane (HCH, β) | 1.0 | 5.0 | Polychlorinated biphenyls, total | 50 | 50 |
| Hexachlorocyclohexane (HCH, δ) | NA | 5.0 | | | |

## Comparisons of Results with Sediment- and Tissue-Contaminant Guidelines

Many comparisons can be made to evaluate the potential for adverse effects of contaminants in streambed sediment and biological tissue. Streambed-sediment guidelines for the protection of aquatic life have been proposed by various researchers, certain States in the United States, as well as the Province of Ontario in Canada and the Federal government of Canada. Concentrations of contaminants in the tissues of aquatic organisms can be compared with guidelines for the protection of fish-eating wildlife or guidelines proposed to protect human health. In this report, comparisons were made with both types of tissue guidelines as well as with the streambed-sediment guidelines, and the most current guidelines were used. In most cases, these guidelines also were the most stringent.

Concentrations of detected compounds in streambed-sediment samples were compared with sediment-quality guidelines compiled by Gilliom and others (1998). Gilliom and others (1998) selected guidelines using procedures developed and used by the U.S. Environmental Protection Agency (U.S. Environmental Protection Agency, 1997) to analyze data in the National Sediment Quality Survey. These procedures use the available sediment-quality guidelines for a given contaminant to classify sites

according to the probability of adverse effects on aquatic life. The values used here are those that have a high probability of adverse effects on aquatic life.

Concentrations of detected compounds in tissue samples, with the exception of toxaphene, were compared with criteria for the protection of fish-eating wildlife for the State of New York (Newell and others, 1987). The criteria of the State of New York are for noncancerous effects. Toxaphene concentrations in tissue were compared with the National Academy of Science/National Academy of Engineering (NAS/NAE; 1973) criterion for the protection of fish-eating wildlife because Newell and others (1987) do not list a criterion for this compound. Although the NAS/NAE guidelines are commonly used, they are more than 25 years old and were considered preliminary even at the time they were promulgated. Unlike the guidelines of the State of New York, which were derived using explicitly stated risk-assessment methodology, the NAS/NAE (1973) provided little information on how their guideline values were derived. The NAS/NAE guidelines were intended to protect fish-eating predators from adverse effects (such as mortality and reproductive effects) due to bioaccumulation of manmade chemicals (Nowell and Resek, 1994; L.H. Nowell, chemist, U.S. Geological Survey, oral commun., 1999).

Concentrations in tissues also were compared with screening values for edible fish (U.S. Environmental Protection Agency, 1995). These screening values are for the protection of human health and are based on a $1 \times 10^{-5}$ risk factor for an adult of average size (70 kg) and a consumption rate of 6.5 g/day of fish (U.S. Environmental Protection Agency, 1995). Although contaminant concentrations in whole organisms cannot be compared directly with guidelines based on samples of edible portions of aquatic organisms (fish fillets), these guidelines may be useful in determining if additional sampling of edible portions of fish is warranted.

One guideline used for both sediment and tissue samples is total DDT. Total DDT is the sum of *o,p*'- and *p,p*'-DDD, *o,p*'- and *p,p*'-DDE, and o,*p*'- and *p,p*'-DDT. Similarly, a guideline used for both sediment and tissue is total chlordane. Total chlordane is the sum of *trans*-nonachlor, *cis*-nonachlor, *trans*-chlordane, *cis*-chlordane, and oxychlordane. All PCB congeners are included in the guideline for total PCB's. Guideline values have not been established for many of the compounds analyzed.

## ORGANOCHLORINE COMPOUNDS IN STREAMBED SEDIMENT AND BIOLOGICAL TISSUE

Of the 32 compounds analyzed in streambed-sediment samples and 28 compounds analyzed in biological-tissue samples, 13 were detected in streambed sediment, 10 in tissue, and 7 in both (**tables 3** and **4**). Of the compounds analyzed in both sample media, *o,p*'-DDD, *o,p*'-DDT, and *p,p*'-DDT were found only in streambed sediments; and toxaphene and pentachloroanisole were found only in tissue.

The most frequently detected compound in streambed sediment and tissue was *p,p*'-DDE, which was found in sediment samples from 7 sites and in 13 tissue samples from 9 sites. The next most frequently detected compounds in streambed sediment were *p,p*'-DDD, *trans*-nonachlor, *trans*-chlordane, and *cis*-chlordane (4 sites each; table 3). In tissue, *trans*-nonachlor was the next most frequently detected compound and was found in six samples from four sites (table 4).

The frequencies of detection of organochlorine compounds in streambed sediment and in tissue were compared to determine if either of these sampling media was more effective than the other in assessing the occurrence of these compounds. The number of compounds found in a streambed-sediment sample from a particular site ranged from 0 to 10, and the range for particular tissue samples was 0 to 7. Comparison of the number of detections in streambed-sediment samples to detections in tissue samples from particular sites where both media were sampled yielded five instances in which more compounds were detected in streambed sediment, six instances in which more compounds were detected in tissue, and five instances in which the number of detections in streambed sediment and tissue were equal (**fig. 2**). The similar number of detections indicate that neither sample media was clearly superior to the other in evaluating the occurrence of organochlorine compounds in the CAZB study area.

**Table 3**. Organochlorine compounds detected in streambed-sediment samples, Central Arizona Basins study area, 1996

[Site number refers to figure 1. F, forested; U, urban; A, agriculture; R, rangeland; DDD, dichlorodiphenyldichloroethane; DDE, dichlorodiphenylethylene; DDT, dichlorodiphenyltrichloroethane; PCB's polychlorinated biphenyls. Values are in micrograms per kilogram, dry weight except total organic carbon, which is in grams per kilogram. Dashes indicate analyte not detected. Total DDT is equal to the sum of *o,p*'-DDD, *p,p*'-DDD, *p,p*'-DDE, *o,p*'-DDT, and *p,p*'-DDT; and total chlordane is equal to the sum of *trans*-nonachlor, *cis*-nonachlor, *trans*-chlordane, and *cis*-chlordane. *o,p*'-DDE and oxychlordane were not detected. Values in red exceed sediment-quality criteria. NA, not applicable]

| Site number | Station number | Site name | Land use | Date of sample | *o,p*'-DDD | *p,p*'-DDD | *p,p*'-DDE[1] | *o,p*'-DDT | *p,p*'-DDT | Total DDT[1] | Dieldrin |
|---|---|---|---|---|---|---|---|---|---|---|---|
| NA | NA | Sediment-quality guidelines[1] | NA | NA | --- | --- | 15 | --- | --- | 46.1 | 110 |
| 1 | 09505800 | West Clear Creek near Camp Verde | F/R | 04–06–96 | --- | --- | --- | --- | --- | --- | --- |
| 2 | 09505570 | Verde River above West Clear Creek, near Camp Verde | F/R | 05–22–96 | --- | --- | --- | --- | --- | --- | --- |
| 3 | 09508500 | Verde River below Tangle Creek, near Horseshoe Dam | F/R | 06–19–96 | --- | --- | --- | --- | --- | --- | --- |
| 4 | 09498500 | Salt River near Roosevelt | F/R | 05–10–96 | --- | --- | --- | --- | --- | --- | --- |
| 5 | 09474000 | Gila River at Kelvin | R/F | 05–09–96 | --- | --- | --- | --- | --- | --- | --- |
| 6 | 09471000 | San Pedro River at Charleston | R/F | 05–08–96 | --- | --- | --- | --- | --- | --- | --- |
| 7 | 332136112434201 | Buckeye Canal near Hassayampa | A/U | 06–07–96 | --- | 3.2 | 440 | 2.6 | 7.2 | 453 | --- |
| 8 | 09512407 | 91st Avenue wastewater-treatment plant outfall, near Phoenix | A/U | 06–05–96 | 2.1 | 3.8 | 160 | --- | 2.8 | 168.7 | 7.9 |
| 9 | 09486500 | Santa Cruz River at Cortaro | U | 05–06–96 | --- | --- | 1.6 | --- | --- | 1.6 | --- |
| 10 | 09481740 | Santa Cruz River at Tubac | U | 05–07–96 | --- | --- | 1.1 | --- | --- | 1.1 | --- |
| 11 | 312731110573901 | Santa Cruz River near Nogales Wastewater-Treatment Plant | U | 05–09–96 | --- | 3.9 | 7.5 | --- | --- | 11.4 | --- |
| 12 | 332516111562001 | 48th Street Drain near Interstate 10 | U | 06–06–96 | --- | --- | 6.3 | --- | --- | 6.3 | 1.5 |
| 13 | 09502960 | Granite Creek at Prescott | F/U | 06–18–96 | --- | 1.8 | 2.4 | --- | --- | 4.2 | 1.1 |

| Site number | Station name | Station name | *Trans*-nonachlor | *Cis*-nonachlor | *Trans*-chlordane | *Cis*-chlordane | Total chlordane[1] | PCB's[1] | *Trans*-permethrin | *Cis*-permethrin | Total organic carbon |
|---|---|---|---|---|---|---|---|---|---|---|---|
| NA | NA | Sediment-quality guidelines[1] | --- | --- | --- | --- | 6 | 189 | --- | --- | --- |
| 1 | 09505800 | West Clear Creek near Camp Verde | --- | --- | --- | --- | --- | --- | --- | --- | 39 |
| 2 | 09505570 | Verde River above West Clear Creek, near Camp Verde | --- | --- | --- | --- | --- | --- | --- | --- | 18 |
| 3 | 09508500 | Verde River below Tangle Creek, near Horseshoe Dam | --- | --- | --- | --- | --- | --- | --- | --- | 21 |
| 4 | 09498500 | Salt River near Roosevelt | --- | --- | --- | --- | --- | --- | --- | --- | 14 |
| 5 | 09474000 | Gila River at Kelvin | --- | --- | --- | --- | --- | --- | --- | --- | 10 |
| 6 | 09471000 | San Pedro River at Charleston | --- | --- | --- | --- | --- | --- | --- | --- | 10 |
| 7 | 332136112434201 | Buckeye Canal near Hassayampa | --- | --- | --- | --- | --- | --- | --- | --- | 8.8 |
| 8 | 09512407 | 91st Avenue wastewater-treatment plant outfall, near Phoenix | 3.6 | 3.6 | 6.9 | 8.2 | 22.3 | 290 | --- | --- | 14 |
| 9 | 09486500 | Santa Cruz River at Cortaro | --- | --- | 1.2 | --- | 1.2 | --- | 7.0 | 8.6 | 8.7 |
| 10 | 09481740 | Santa Cruz River at Tubac | --- | --- | --- | --- | --- | --- | --- | --- | 6.9 |
| 11 | 312731110573901 | Santa Cruz River near Nogales Wastewater-Treatment Plant | 3.3 | --- | 3.6 | 3.2 | 10.1 | --- | --- | --- | 44 |
| 12 | 332516111562001 | 48th Street Drain near Interstate 10 | 1.6 | --- | --- | 1.4 | 3.0 | --- | --- | --- | 21 |
| 13 | 09502960 | Granite Creek at Prescott | 2.3 | --- | 4.1 | 2.6 | 9.0 | --- | --- | --- | 24 |

[1]Sediment-quality guidelines for organochlorine compounds in streambed sediment from Gilliom and others (1998).

**Table 4**. Organochlorine compounds detected in biological-tissue samples, Central Arizona Basins study area, 1996

[Site number refers to figure 1. F, forested; U, urban; A, agriculture; R, rangeland; DDD, dichlorodiphenyldichloroethane; DDE, dichlorodiphenylethylene; DDT, dichlorodiphenyltrichloroethane; PCB's polychlorinated biphenyls. Values are in micrograms per kilogram, wet weight. Dashes indicate analyte not detected. Total DDT is equal to the sum of *o,p'*-DDD, *p,p'*-DDD, p,p'-DDE, *o,p'*-DDT, and *p,p'*-DDT; and total chlordane is equal to the sum of *trans*-nonachlor, *cis*-nonachlor, *trans*-chlordane, *cis*-chlordane. Values in red exceed one or both of the listed tissue criteria. NA, not applicable]

| Site number | Site name | Land use | Species collected | Date of sample | Number of individuals in composite sample | Average total length, in millimeters | Percent lipid | *p,p'* -DDD | *p,p'* -DDE | Total DDT |
|---|---|---|---|---|---|---|---|---|---|---|
| NA | Tissue criteria, fish-eating wildlife[1] | NA | NA | NA | NA | NA | NA | --- | --- | 200 |
| NA | Tissue criteria, human health[2] | NA | NA | NA | NA | NA | NA | --- | --- | 300 |
| 1 | West Clear Creek, near Camp Verde | F/R | Desert sucker | 04–06–96 | 8 | 171 | 8.4 | --- | --- | --- |
| 2 | Verde River above West Clear Creek, near Camp Verde | F/R | Desert sucker | 05–22–96 | 8 | 244 | 15.0 | --- | 5.3 | 5.3 |
| 3 | Verde River below Tangle Creek, above Horseshoe Dam | F/R | Red shiner | 06–19–96 | 14 | 59 | 6.4 | --- | 21 | 21 |
| | | do. | Asiatic clam | do. | 146 | 14 | 1.3 | --- | --- | --- |
| 4 | Salt River near Roosevelt | F/R | Red shiner | 05–10–96 | 27 | 48 | 6.9 | --- | 8.6 | 8.6 |
| 5 | Gila River at Kelvin | R/F | Desert sucker | 05–09–96 | 8 | 165 | 11.0 | --- | 13 | 13 |
| 6 | San Pedro River at Charleston | R/F | Desert sucker | 05–08–96 | 8 | 83.6 | 6.9 | --- | --- | --- |
| 7 | Buckeye Canal near Hassayampa | A/U | Red shiner | 06–07–96 | 16 | 49 | 8.1 | --- | 7,200 | 7,200 |
| | Do. | do. | Redbelly tilapia | do. | 3 | 129 | 4.2 | --- | 40 | 40 |
| | Do. | do. | Common carp | do. | 8 | 128 | 6.6 | --- | [3]3,700 | [3]3,700 |
| 8 | 91st Avenue wastewater-treatment plant at outfall | A/U | Redbelly tilapia | 06–05–96 | 8 | 118 | 4.8 | --- | [3]2,200 | [3]2,200 |
| 10 | Santa Cruz River at Tubac | U | Desert sucker | 05–07–96 | 8 | 97 | 12.0 | 20 | 46 | 66 |
| 12 | 48th Street Drain near Interstate 10 | U | Redbelly tilapia | 06–06–96 | 8 | 158 | 4.8 | --- | 22 | 22 |
| | Do. | do. | Asiatic clam | do. | 110 | 18 | 1.9 | --- | 16 | 16 |
| 13 | Granite Creek at Prescott | F/U | Fathead minnow | 06–18–96 | 14 | 60 | 4.1 | 6.2 | 20 | 26.2 |
| | Do. | do. | Crayfish | do. | 8 | 47 | 2.5 | --- | 8.1 | 8.1 |

| Site number | Site name | Dieldrin[1] | *Trans*-nonachlor | *Cis*-nonachlor | Trans-chlordane | Cis-chlordane | Total chlordane | PCB's | Toxaphene | Pentachloroanisole |
|---|---|---|---|---|---|---|---|---|---|---|
| NA | Tissue criteria, fish-eating wildlife[1] | 120 | --- | --- | --- | --- | 500 | 110 | [4]100 | --- |
| NA | Tissue criteria, human health[2] | 7 | --- | --- | --- | --- | 80 | 10 | 100 | --- |
| 1 | West Clear Creek, near Camp Verde | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 2 | Verde River above West Clear Creek, near Camp Verde | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 3 | Verde River below Tangle Creek, above Horseshoe Dam | --- | --- | --- | ---. | --- | --- | --- | --- | --- |
| | | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 4 | Salt River near Roosevelt | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 5 | Gila River at Kelvin | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 6 | San Pedro River at Charleston | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 7 | Buckeye Canal near Hassayampa | 17 | 13 | --- | 9.6 | 13 | 35.6 | 82 | [3]7,200 | --- |
| | Do. | 5.8 | 21 | --- | --- | --- | 21 | 110 | --- | 78 |
| | Do. | --- | --- | --- | --- | --- | --- | --- | [3]3,300 | --- |
| 8 | 91st Avenue wastewater-treatment plant at outfall | --- | --- | --- | --- | --- | --- | --- | [3]1,800 | --- |
| 10 | Santa Cruz River at Tubac | --- | 23 | --- | --- | 12 | 35 | 120 | --- | --- |
| 12 | 48th Street Drain near Interstate 10 | --- | 5 | --- | --- | --- | 5 | --- | --- | --- |
| | Do. | --- | --- | 6.8 | --- | --- | 6.8 | --- | --- | --- |
| 13 | Granite Creek at Prescott | 7.9 | 9.5 | --- | 6.9 | 9.3 | 25.7 | --- | --- | --- |
| | Do. | --- | 5.3 | --- | --- | --- | 5.3 | --- | --- | --- |

[1]Criteria for the protection of fish-eating wildlife from Newell and others (1987).
[2]Screening criteria for edible fish for the protection of human health from U.S. Environmental Protection Agency (1995).
[3]Estimated because of matrix interference.
[4]Criteria for the protection of fish-eating wildlife from National Academy of Science/National Academy of Engineers (1973).

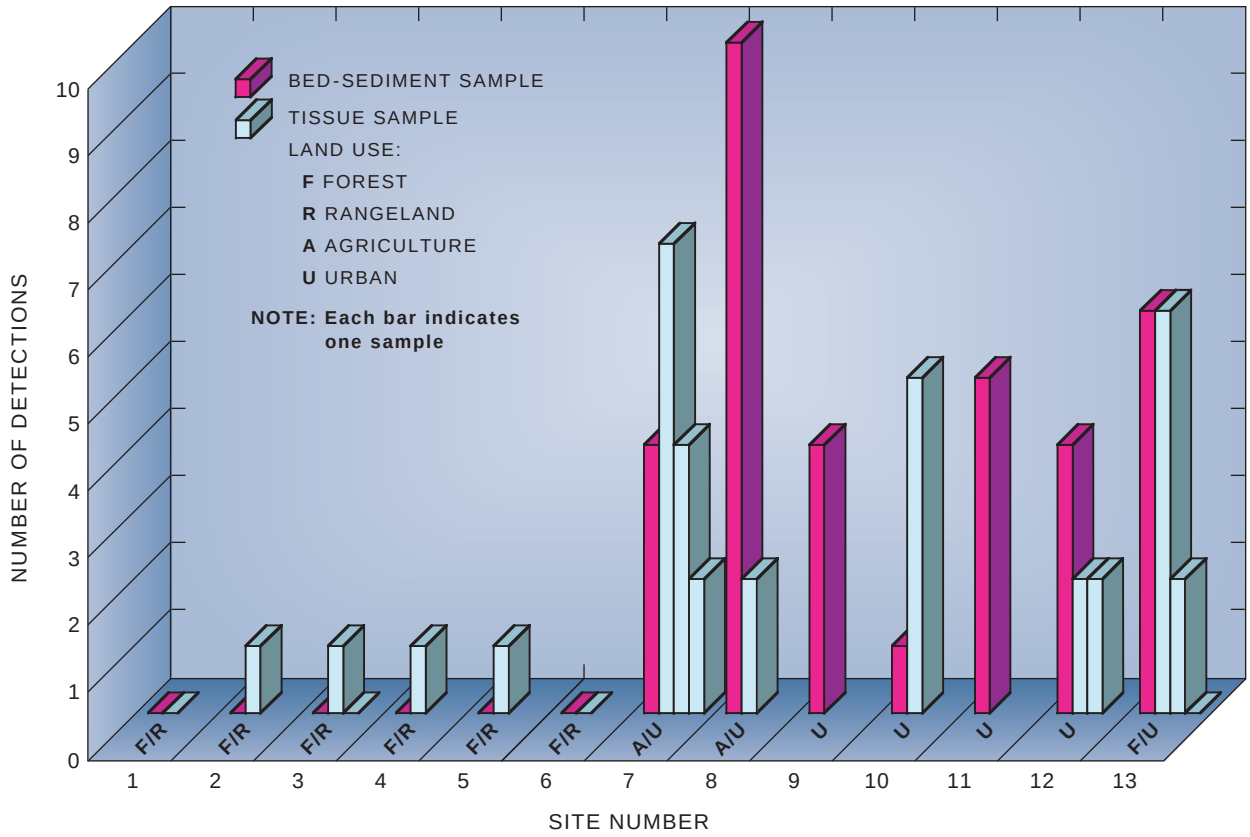


**Figure 2**. Number of organochlorine compounds detected in streambed-sediment and biological-tissue samples from various land-use categories for sites in the Central Arizona Basins study area, 1996.

The frequency of detection of particular compounds for sites where both media were sampled resulted in five compounds being detected more frequently in streambed sediment, five more frequently in tissue, and three compounds that were equally frequent (**fig. 3**). Because more than one tissue sample was collected at certain sites, a detection was tallied for the preceding comparisons if at least one of the tissue samples contained the compound. Detections in more than one tissue sample from a site, however, were not counted. The similar frequency of detections also indicate that neither sample media was superior to the other in this study.

In some instances, organochlorine compounds do differ in their occurrence in streambed sediment and biological tissue. Maret and Ott (1997) reported that organochlorine compounds were found more frequently in fish tissue than streambed sediment in the upper Snake River Basin in Idaho and western Wyoming. Stephens and Deacon (1998) found organochlorine compounds more frequently in fish tissue than in streambed sediment in the upper Colorado River Basin, Colorado. Moring (1997) found more detections of organochlorine compounds in streambed sediment than in tissue samples from the Trinity River Basin, Texas. Brown (1998), however, concluded that it was not clear that either sampling medium was superior to the other in the San Joaquin River drainage in California. The similarity of results from the two media in this study indicates that monitoring programs that target organochlorine compounds in central Arizona streams obtain a more complete evaluation by sampling both streambed sediment and biological tissue.

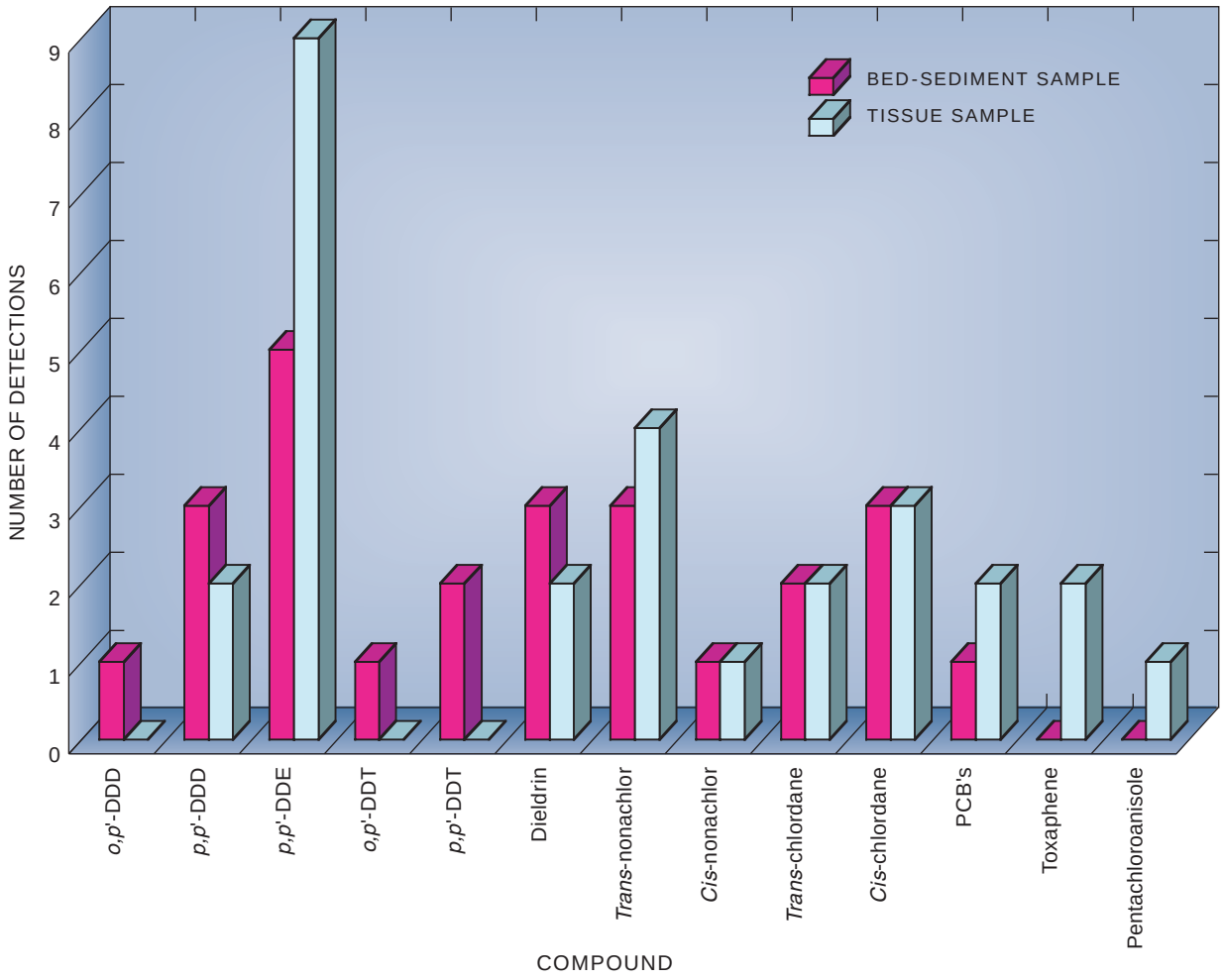


**Figure 3**. Number of detections by compound for streambed-sediemnt and biological-tissue samples, Central Arizona Basins study are, 1996.

## Comparisons of Results with Guidelines and with Results from Previous Studies

Concentrations of detected organochlorine compounds in some streambed-sediment samples exceeded the guideline values presented by Gilliom and others (1998; **table 3**, this report). One or more exceedences were found at 4 of the 13 streambed-sediment sites—two agricultural sites (sites 7 and 8), one urban site (site 11), and the forest/urban site (site 13). The aquatic-life criteria for sediments for *p,p*'-DDE (15 μg/kg) and for total DDT (46.1 μg/kg) were exceeded at the two agriculture/urban sites (sites 7 and 8). Site 8 also was the only site where the PCB criterion (189 μg/kg) was exceeded. The criterion for total chlordane (6 μg/kg) was exceeded at site 8 where two of the constituents of total chlordane (*trans*- and *cis*-chlordane) exceeded the criterion. The chlordane criterion also was exceeded at an urban site (site 11) and at the forest/urban site (site 13).

Concentrations in a few tissue samples exceeded the criteria for the protection of fish-eating wildlife presented by Newell and others (1987; **table 4**, this report). One or more exceedences were found at 3 of the 11 sites that had tissue data—two agricultural/urban sites (sites 7 and 8) and one urban site (site 10). The total DDT criterion (200 μg/kg) was exceeded in two tissue samples from site 7 and in the tissue sample from site 8. The total PCB criterion (110 μg/kg) was equaled in one tissue sample from site 7 and was exceeded in the tissue sample from site 10. The toxaphene guideline (100 μg/kg) was exceeded in two samples from site 7 and in the sample from site 8.

The screening values for the protection of human health (U.S. Environmental Protection Agency, 1995) for total DDT and for toxaphene were exceeded in two tissue samples from site 7 and in the tissue sample from site 8. The human-health criterion for total PCB's was exceeded in two tissue samples from site 7 and in the sample from site 10. The human-health criterion for dieldrin was exceeded in one tissue sample from site 7 and in one tissue sample from site 13. Although by no means certain, concentrations in the edible portions of fish from these locations could present a human-health risk. People were observed fishing at site 7 despite posted health advisories. It is unknown if people fish at site 8, and unlikely that people fish at sites 10 and 13 because fish species at these locations generally are not those that are consumed by humans. Analyses of samples of edible portions of fish from these locations would be needed to adequately assess whether a human-health risk exists.

The results of this study are similar to the findings of other studies in the CAZB area. Streambed-sediment and tissue samples collected from areas with minimal anthropogenic land uses generally had low numbers of detections and low concentrations of organochlorine compounds (King and others, 1991; King and others, 1992; King and Baker, 1995); whereas, samples collected from sites with historic agricultural land use were characterized by higher numbers of detections and higher concentrations of organochlorine compounds (Kepner, 1987; King and others, 1997). In particular, the high concentrations of organochlorine compounds detected from sites 7 and 8 of this study corroborate the results of King and others (1997) and Kepner (1987) from the same parts of the lower Gila River. Exceedences of sediment- and tissue-guideline values at these sites indicate that aquatic life in these areas and fish-eating wildlife that use these areas may be adversely affected by organochlorine compounds. Exceedences of human-health screening values could indicate potential risks to people although this risk cannot be adequately assessed without analyses of edible portions of fish from these locations.

DDE and chlordane were among the most frequently detected organochlorine compounds in streambed sediment in a national study of pesticides in rivers by Gilliom and others (1985), and DDE was the most frequently detected organochlorine compound in tissue samples in studies of many basins (Tate and Heiny, 1996; Moring, 1997; Munn and Gruber, 1997; Maret and Ott, 1997; Coles, 1998), as well as in a national study (Schmitt and others, 1990). The results of the CAZB study are consistent with the results from these other basin studies and with national results.

## Comparisons of Bioaccumulation Among Species

The fish species collected from site 13 (fathead minnow) contained higher concentrations of all detected compounds (six analytes) than did the invertebrate species (crayfish) from the same site (**table 4**). Fish species collected at sites 3 and 12 bioaccumulated more *p,p*'-DDE than did asiatic clams; however, the invertebrate species from site 12 (asiatic clam) contained a higher concentration of *cis*-nonachlor than did the fish. In general, these observations indicate that vertebrates are better "bioaccumulators" than invertebrates. This difference may be due to the greater lipid content of the fish compared with the invertebrates. Indeed, fish usually have greater bioconcentration factors than aquatic invertebrates (U.S. Environmental Protection Agency, 1980).

Samples of red shiner (sites 3 and 7) contained higher concentrations of most compounds than other species collected from the same sites (table 4). Of particular interest, red shiners from site 7 contained higher concentrations of *p,p*'-DDE and toxaphene than did the sample of common carp (table 4), and concentrations of these compounds were two orders of magnitude higher in the red shiner sample than in the sample of redbelly tilapia. Red shiners are small, short-lived species. The red shiner sample from site 7 contained a greater percentage of lipid than the other fish samples (table 4), which may partly explain the higher concentrations. On the basis of age/length relations (Carlander, 1969), the ages of the fish were similar; therefore, the higher concentrations in the red shiner apparently are not the result of exposure time due to age. Although most studies of bioaccumulation focus on species that are large and long-lived, this result shows that small, short-lived species can provide useful information on bioaccumulation of organochlorine compounds in aquatic systems.

Conversely, the redbelly tilapia sample from the same location (site 7) contained a somewhat higher concentration of total PCB's than the red shiner sample, and total PCB's were not detected (method-detection limit of 50 μg/kg) in the common carp sample (table 4). The percent lipid of the tilapia was less than

that of the other species; therefore, percent lipid does not explain this result. Several explanations can be postulated to explain the different concentrations of PCB's in the samples of different species (Huckle and Milburn, 1990). The physiological ability to breakdown and eliminate contaminants varies among species. Differing feeding habits could result in different uptake routes for different compounds. Finally, different microhabitat preferences could result in different exposures to contaminants. These possible factors are not mutually exclusive.

In this study, the collection of multiple species from certain locations increased the ability to evaluate the occurrence of organochlorine contaminants at those locations. Because small sample sizes (multiple species were collected from only four sites) preclude rigorous analyses of the between-species data, these observations should be viewed as potential starting places for future investigation and not as conclusive evidence of a biological pattern.

## ASSOCIATIONS BETWEEN THE OCCURRENCE OF ORGANOCHLORINE COMPOUNDS AND LAND USES

As with many similar studies throughout the United States (Tate and Heiny, 1996; Moring, 1997; Munn and Gruber, 1997; Maret and Ott, 1997; Coles, 1998), most organochlorine compounds detected in samples of streambed sediment and biological tissue in the CAZB study area were found in samples from sites that have anthropogenic land uses. The greatest number of detections and the highest concentrations of many organochlorine compounds in streambed-sediment and biological-tissue samples were from agriculture/urban sites (sites 7 and 8; **tables 3** and **4**). Site 8 had the highest number of detections in streambed sediment (10) of any site. Concentrations of *p,p*'-DDE in streambed sediment at these agriculture/urban sites were high compared with concentrations in other land-use categories. PCB's were found in streambed sediment only at site 8. As with streambed-sediment samples, the highest concentrations of *p,p*'-DDE in tissue were found at the two agriculture/urban sites (sites 7 and 8). Toxaphene, which was not detected in any streambed-sediment samples, was detected at high concentrations in tissue samples only from sites 7 and 8. Multiple organochlorine compounds also were detected in tissue samples from these agriculture/urban sites. The red shiner sample from site 7 had the greatest number of detected compounds (seven); five compounds were detected in the redbelly tilapia sample.

The concentrations of toxaphene and *p,p*'- DDE detected in tissue samples at the agriculture/urban sites (sites 7 and 8) were high relative to concentrations at other sites and may be the result of past agricultural practices near these sites rather than influences of effluent. These sites are in an area of intensive cotton production. Before the ban on the use of DDT in Arizona in 1969 (Johnson and Lew, 1970), DDT was the predominant insecticide used to combat insect pests of cotton. After the ban on DDT, toxaphene became the most heavily used pesticide in the United States, especially for cotton (Schmitt and others, 1990), until it was banned for most uses in 1982. Some evidence suggests that DDT degrades slowly in certain soils in the Southwest (Hitch and Day, 1992). Slow degradation along with the persistence of DDT metabolites and sediment transport from agricultural soils (Gilliom and Clifton, 1990), may explain the high concentrations of these compounds in tissue samples from sites 7 and 8.

Sites classified as urban because they are on effluent-dependent streams had more detections of organochlorine compounds than sites without anthropogenic influences. Between one and five compounds were detected in streambed-sediment samples from the urban sites (9–12). Concentrations of most detected compounds at urban sites, however, were low compared with concentrations at agricultural sites. Because of the lack of targeted taxa, tissue samples were collected from only two of the four urban sites (sites 10 and 12). Five compounds were detected in the tissue sample from site 10, and two compounds were detected in each of the two tissue samples from site 12. Concentrations of most detected compounds were low at urban sites compared with concentrations found at the agriculture/urban sites (tables 3 and 4). The greatest concentration of PCB's in tissue samples (120 μg/kg), however, was at urban site 10.

Total PCB's were the only nonpesticides analyzed in this study. Before being banned in 1979, PCB's were used primarily in industrial processes and thus, are usually associated with urban land uses. PCB's were found in streambed sediment only from site 8, and in tissue samples only from sites 7 and 10 (three samples). All of these sites are on effluent-dependent streams and thus, are subjected to urban influences.

Chlordane components (*trans*-nonachlor, *cis*-nonachlor, *trans*-chlordane, *cis*-chlordane) and dieldrin in both sample media also were associated with the sites where either the primary or secondary land use was urban. Chlordane was used to control termites, in agriculture, and also had significant home, lawn, and

garden use (Eisler, 1990). Chlordane's association with urban land use, therefore, was not unexpected. Determining the source of chlordane at the agriculture/urban sites is confounded, however, because it could be derived from either agricultural or urban land uses or both. Dieldrin, which was used as an insecticide, also is a breakdown product of another insecticide—aldrin, which also was used in termite control and agriculture. Detections of dieldrin followed patterns similar to detections of chlordane. Although home and garden use of this compound has not been recorded, it has been associated with urban uses (Van Metre and Callendar, 1997).

Multiple compounds also were detected in samples from site 13, which was classified as forest/urban, compared with sites that had no anthropogenic influences. Six compounds were detected in the streambed-sediment sample from site 13. Concen-trations were low compared to concentrations in sediment from the agriculture/ urban sites. Tissue samples from site 13 contained the second greatest number of detected compounds (six) in tissue samples. Again, concentrations generally were low compared with concentrations in tissue samples from agriculture/urban sites. Although about 70 percent of the basin upstream from this site is forested and only about 26 percent is urban, the sampling site is in the urban part. Localized land use near this site appears to be the primary factor influencing the occurrence of contaminants. Munn and Gruber (1997) noted the same phenomenon for sites affected by point sources in their study.

In contrast to sites associated with agriculture and urban land uses, sites with minimal anthropogenic influence were found to be free of most organochlorine compounds. Only *p,p*'-DDE in low concentrations was found in tissue from four of six sites whose major land uses were forest and rangeland. DDE is the primary breakdown product of DDT. *p,p*'-DDE has been found to be ubiquitous in many areas (Tate and Heiny, 1996; Moring, 1997; Munn and Gruber, 1997; Maret and Ott, 1997; Coles, 1998) probably because of past wide-spread use of DDT for many purposes, its persistence in the environment, and atmospheric transport of chemical spray (Majewski and Capel, 1995).

The association between the occurrence of organochlorine compounds and land uses affected by anthropogenic activities documented in this study is similar to the findings of many other studies (Tate and Heiny, 1996; Moring, 1997; Munn and Gruber, 1997; Maret and Ott, 1997; Coles, 1998). As patterns of association between organochlorine compounds and land uses are repeated in an increasing number of investigations, the probability increases that such patterns represent a cause-and-effect relation.

## SUMMARY AND CONCLUSIONS

As with many other studies of the distribution and occurrence of organochlorine contaminants in streambed sediment and biological tissue, this study shows that many organochlorine compounds continue to persist in the environment long after their use has been discontinued and thus, could pose a threat to aquatic life and fish-eating wildlife. At certain sites, exceedences of human-health screening values could indicate potential risks to people although this cannot be adequately assessed without additional analyses of edible portions of fish from those locations.

At sites where multiple species were collected, smaller-sized, short-lived fish species often contained higher concentrations of organochlorine compounds than larger, long-lived species. Although based on a limited number of samples, this indicates that such small, short-lived species provide useful information on bioaccumulation of organochlorine compounds in aquatic systems. Further, the collection of multiple species at certain sites in this study increased the ability to evaluate the occurrence of organochlorine contaminants.

In general, the results of this study indicate that organochlorine contaminants are associated with anthropogenically altered landscapes. The greatest number and highest concentration of organochlorine compounds were detected at agricultural/ urban sites. Organochlorine compounds also were at sites in basins that had urban land uses, although urban sites had fewer detections, and concentrations were lower than at the agricultural/urban sites. Sites that were in basins that had predominantly forest/rangeland land uses had few detections of organochlorine compounds.

The patterns of association between contaminants and land uses documented in this study are similar to the patterns observed in many similar studies. The similarity of the results of this study and many other studies of organochlorine compounds in the environment suggests that there is a correlation between contaminants and land uses. As these patterns are repeated in an increasing number of investigations, the probability increases that such patterns represent a cause-and-effect relation.

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