Occurrence and Distribution of Organochlorine Pesticides, Polychlorinated Biphenyls, and Trace Elements in Fish Tissue in the Lower Tennessee River Basin, 1980-98

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FOREWORD

The U.S. Geological Survey (USGS) is committed to serve the Nation with accurate and timely scientific information that helps enhance and protect the overall quality of life, and facilitates effective management of water, biological, energy, and mineral resources. Information on the quality of the Nation's water resources is of critical interest to the USGS because it is so integrally linked to the long-term availability of water that is clean and safe for drinking and recreation and that is suitable for industry, irrigation, and habitat for fish and wildlife. Escalating population growth and increasing demands for the multiple water uses make water availability, now measured in terms of quantity *and* quality, even more critical to the long-term sustainability of our communities and ecosystems.

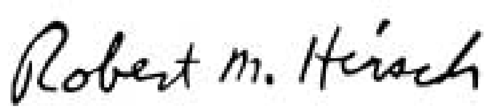
The USGS implemented the National Water-Quality Assessment (NAWQA) Program to support national, regional, and local information needs and decisions related to water-quality management and policy. Shaped by and coordinated with ongoing efforts of other Federal, State, and local agencies, the NAWQA Program is designed to answer: What is the condition of our Nation's streams and ground water? How are the conditions changing over time? How do natural features and human activities affect the quality of streams and ground water, and where are those effects most pronounced? By combining information on water chemistry, physical characteristics, stream habitat, and aquatic life, the NAWQA Program aims to provide science-based insights for current and emerging water issues and priorities. NAWQA results can contribute to informed decisions that result in practical and effective water-resource management and strategies that protect and restore water quality.

Since 1991, the NAWQA Program has implemented interdisciplinary assessments in more than 50 of the Nation's most important river basins and aquifers, referred to as Study Units. Collectively, these Study Units account for more than 60 percent of the overall water use and population served by public water supply, and are representative of the Nation's major hydrologic landscapes, priority ecological resources, and agricultural, urban, and natural sources of contamination.

Each assessment is guided by a nationally consistent study design and methods of sampling and analysis. The assessments thereby build local knowledge about water-quality issues and trends in a particular stream or aquifer while providing an understanding of how and why water quality varies regionally and nationally. The consistent, multi-scale approach helps to determine if certain types of water-quality issues are isolated or pervasive, and allows direct comparisons of how human activities and natural processes affect water quality and ecological health in the Nation's diverse geographic and environmental settings. Comprehensive assessments on pesticides, nutrients, volatile organic compounds, trace metals, and aquatic ecology are developed at the national scale through comparative analysis of the Study-Unit findings.

The USGS places high value on the communication and dissemination of credible, timely, and relevant science so that the most recent and available knowledge about water resources can be applied in management and policy decisions. We hope this NAWQA publication will provide you the needed insights and information to meet your needs, and thereby foster increased awareness and involvement in the protection and restoration of our Nation's waters.

The NAWQA Program recognizes that a national assessment by a single program cannot address all water-resource issues of interest. External coordination at all levels is critical for a fully integrated understanding of watersheds and for cost-effective management, regulation, and conservation of our Nation's water resources. The Program, therefore, depends extensively on the advice, cooperation, and information from other Federal, State, interstate, Tribal, and local agencies, non-government organizations, industry, academia, and other stakeholder groups. The assistance and suggestions of all are greatly appreciated.



Robert M. Hirsch
Associate Director for Water

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Multiply	By	To obtain
mile (mi)	1.609	kilometer
acre	0.4047	hectare
square mile (mi^2)	2.590	square kilometer
foot	0.3048	meter
inch (in.)	25.4	millimeter
pound (lb)	0.4536	kilogram

Temperature in degrees Fahrenheit (°F) may be converted to degrees Celsius (°C) as follows: °C = (°F-32)/1.8

Sea level: In this report, “sea level” refers to the National Geodetic Vertical Datum of 1929—a geodetic datum derived from a general adjustment of the first-order level nets of the United States and Canada, formerly called Sea Level Datum of 1929.

Water-quality units

µg/g	micrograms per gram
mg/kg	milligrams per kilogram

Abbreviations and Acronyms

ADEM	Alabama Department of Environmental Management
BHC	Benzene hexachloride
DCPA	Dimethyl 2,3,5,6-tetrachloroterephthalate
DDD	Dichlorodiphenyldichloroethane
DDE	Dichlorodiphenyldichloroethylene
DDT	Dichlorodiphenyltrichloroethane
FDA	U.S. Food and Drug Administration
LTEN	Lower Tennessee River Basin
NAS/NAE	National Academy of Sciences and National Academy of Engineering
NAWQA	National Water-Quality Assessment Program
NCBP	National Contaminant Biomonitoring Program
NYDEC	New York Department of Environmental Conservation
PCB	Polychlorinated biphenyl
TDEC	Tennessee Department of Environment and Conservation
TVA	Tennessee Valley Authority
U.S. EPA	U.S. Environmental Protection Agency
USGS	U.S. Geological Survey

Occurrence and Distribution of Organochlorine Pesticides, Polychlorinated Biphenyls, and Trace Elements in Fish Tissue in the Lower Tennessee River Basin, 1980-98

By Rodney R. Knight *and* Jeffrey R. Powell

ABSTRACT

The U.S. Geological Survey, as part of the National Water-Quality Assessment Program, evaluated the occurrence and distribution of organochlorine pesticides, polychlorinated biphenyls, and trace elements in fish tissue in samples collected in the lower Tennessee River Basin study unit. Fish tissue analysis provides a time-averaged measurement of contaminants as well as a direct measurement of the contaminants that bioaccumulate in fish tissue. Bioaccumulation of contaminants in fish tissue may result in concentrations that can affect human, wildlife, or aquatic health. Data for two types of tissue analyses were evaluated to assess the occurrence and distribution of contaminants: whole fish for organochlorine pesticides and polychlorinated biphenyls and fish fillets for organochlorine pesticides, polychlorinated biphenyls, and trace elements. The fish tissue data analyzed for this study cover an 18-year span including data collected in 1998 by the U.S. Geological Survey as part of the National Water-Quality Assessment Program; data collected from 1980 through 1997 by the Tennessee Valley Authority; and data collected from 1992 through 1997 by the Tennessee Department of Environment and Conservation. Concentration data for constituents that are on the U.S. Environmental Protection Agency Priority Pollutant List were summarized and compared against existing action levels or guidelines.

From the list of organochlorine pesticide compounds analyzed, *p,p′*-dichlorodiphenyldichloroethylene (*p,p′*-DDE), a breakdown product of dichlorodiphenyltrichloroethane (DDT), was the most commonly detected compound with detections at 83 percent of the sites sampled. Eleven *p,p′*-DDE samples exceeded action levels or guidelines with concentrations ranging from 0.20 to 12.8 milligrams per kilogram. Five other organochlorine compounds, *p,p′*-dichlorodiphenyldichloroethane (*p,p′*-DDD), dieldrin, endrin, chlordane, and polychlorinated biphenyls, also exceeded action levels and guidelines, but the detection frequencies at sampling sites generally were less than 70 percent.

Mercury, the only trace element to exceed a guideline, was detected at 51 of 102 sites sampled for trace elements. Selenium was detected in fish fillet samples from 70 of 102 sites sampled, which was more sites than for any other trace element; however, selenium did not exceed the 50 micrograms per gram U.S. Environmental Protection Agency screening criteria. Arsenic and cadmium also were detected at 44 and 54 percent of the sampling sites, respectively.

INTRODUCTION

Water-quality assessment activities in the lower Tennessee (LTEN) River Basin study unit started in 1997. The LTEN River Basin (fig. 1) is one of 59 river basins selected for water-quality assessment as part of the U.S. Geological Survey (USGS) National Water-Quality Assessment (NAWQA) Program, which began in 1991. Initial assessment efforts in the LTEN River Basin included describing the occurrence and distribution of organochlorine pesticides, polychlorinated biphenyls (PCB's), and trace elements in fish tissue.

Figure 1. Location of the lower Tennessee River Basin study unit.

According to Crawford and Luoma (1993), four advantages exist for using fish tissues in water-quality assessments when compared to using standard water chemistry sampling. First, tissue analysis can increase the probability of detecting trace amounts of some contaminants that tend to bioaccumulate in tissue. Second, tissues provide a time-averaged assessment or record of the presence of contaminants in the environment. Third, tissue analyses provide direct measurements of bioavailability of contaminants to other living organisms. Finally, by integrating tissue, water, and sediment analyses, complementary or multiple lines of evidence are provided to assist in the understanding of contaminant fate, distribution, and effects.

Industrial and municipal effluents, nonpoint-source runoff, and atmospheric deposition are all potential sources of organochlorine pesticides, PCB’s, and trace elements that may accumulate in fish tissue. Accumulation of organochlorine pesticides and PCB’s in fish tissue is a direct result of human activity because these compounds are synthetic. While dichlorodiphenyltrichloroethane (DDT) use was banned by the U.S. Environmental Protection Agency (U.S. EPA) in 1973, production and use of most organochlorine pesticides were discontinued in the United States by the mid-1980’s; nevertheless, many of the organochlorine pesticides and their metabolites (breakdown products) can still be found in water, sediment, and fish tissue. Trace elements occur naturally in the environment and reflect soil type, geology, and land use in the watershed.

Purpose and Scope

The purpose of this report is to summarize the occurrence and distribution of organochlorine pesticides, PCB’s, and trace elements in fish tissue in the LTEN River Basin. Existing fish tissue data were compared with action levels and guidelines from the Niagara River Biota Contamination Project (Newell and others, 1987), National Academy of Sciences and National Academy of Engineering (1973), U.S. Food and Drug Administration (1989), and U.S. EPA (1995) to place the data in a human and aquatic health context. This report is limited to the occurrence and distribution of organic compounds and trace elements that are listed on the U.S. EPA Priority Pollutant List (U.S. Environmental Protection Agency, 1994) and that have an action level or guideline available. Analyses presented in this report were based on fish tissue data collected by the USGS during August and September 1998, by the Tennessee Valley Authority (TVA) from 1980 through 1997, and by the Tennessee Department of Environment and Conservation (TDEC) from 1992 through 1997. This report summarizes existing data for organochlorine pesticides, PCB’s, and trace elements in fish tissue collected from sampling sites primarily located along the main stem of the Tennessee River within the LTEN River Basin, and does not supersede fish consumption advisories issued by State agencies.

Consumption Advisories

The LTEN River Basin contains approximately 26,700 stream miles and 382,500 lake acres. In 1998, less than 4 percent of the lake acres and less than 1 percent of the stream miles in the LTEN River Basin had consumption advisories posted for the consumption of fish by humans. Currently (2000), advisories issued by TDEC exist for Woods and Nickajack Lakes in Tennessee because of elevated concentrations of PCB’s (Freeman and Denton, 1997). The Alabama Department of Environmental Management (ADEM) has current consumption advisories for the Tennessee River, Indian Creek, and Huntsville Spring Branch in Alabama because of elevated DDT concentrations (Alabama Department of Environmental Management, 1996). Current fish advisories exist for streams, rivers, and reservoirs in Tennessee (Tennessee Department of Environment and Conservation, 2000) and Alabama (Alabama Department of Public Health, 2000).

Description of the Lower Tennessee River Basin Study Unit

The LTEN River Basin study unit extends from Chattanooga, Tennessee, to near Paducah, Kentucky, at the confluence of the Tennessee and Ohio Rivers and encompasses approximately 19,500 square miles. Most of the study unit is in Middle Tennessee and northern Alabama, with smaller parts in southwestern Kentucky, northeastern Mississippi, and northwestern Georgia. Approximately 57 percent of the study unit is in Tennessee, 35 percent in Alabama, 5 percent in Kentucky, 2 percent in Mississippi, and 1 percent in Georgia. Population in the study unit is about 1.5 million (U.S. Department of Commerce, 1997). The most populated cities in the study unit are Huntsville, Alabama (population 160,000), Chattanooga, Tennessee (population 152,000), and Decatur, Alabama (population 52,000) (Woodside and Mitchell, 1998). Land-surface elevations in the study unit range from about 300 feet above sea level near Paducah, Kentucky, to more than 2,900 feet above sea level along the eastern edge of the Sequatchie River Basin. Annual precipitation varies from 47 to 63 inches, with higher precipitation amounts recorded in the northeastern area of the study unit. Average runoff ranges from 18 inches in the northwest to 30 inches in the southeast. The study unit has a temperate climate with an average annual temperature of about 58 °F.

The main stem of the lower Tennessee River is highly regulated with few free-flowing stream reaches. Six major reservoirs were constructed along the main stem from the 1920's through the 1940's for purposes of power generation, navigation, and flood control. Today, these reservoirs also are used extensively for sources of drinking water and recreational activities such as fishing, swimming, and boating.

Land use varies in the study unit. Forest covers about 51 percent of the study unit (Tennessee Valley Authority, written commun., 1992). Additional land uses include row crops and pasture land (40 percent), urban (1 percent), and other land uses (8 percent), such as wetlands, water, and barren land. Row-crop cultivation is present predominantly along the main stem and tributaries of the Tennessee River in northern Alabama and along the western edge of the study area. Cotton, corn, and soybeans are the primary row crops. Areas of confined-animal feeding operations are concentrated primarily in northern Alabama.

Kingsbury and others (1999) describe three hydrogeologic regions in the LTEN River Basin study unit. These hydrogeologic regions lie within three physiographic provinces (Kingsbury and others, 1999, fig. 1). Along the western edge of the study unit, the Coastal Plain Physiographic Province encompasses about 18 percent of the LTEN River Basin area and generally consists of a thick series of unconsolidated sands, gravels, silts, and clays. Shallow ground water occurs primarily in these gravels and sands and is an important source of drinking water. The Interior Low Plateaus Physiographic Province is centrally located and encompasses about 59 percent of the LTEN River Basin. In this province, ground water moves through an overburden consisting of 10 to more than 200 feet of regolith, a mixture of soil and weathered rock, and subsequently into an underlying carbonate aquifer. Carbonate aquifers are important sources of drinking water in many areas throughout the LTEN River Basin study unit. Thin regolith, caves, and sinkholes in this province increase the susceptibility of ground-water contamination from surface water. The Cumberland Plateau section of the Appalachian Plateaus Physiographic Province is located along the eastern edge of the study unit and encompasses about 23 percent of the LTEN River Basin. Most of this area is underlain by sandstones with ground water occurring primarily in interconnected fractures.

Acknowledgments

The authors thank Wade Bryant of the USGS for field assistance as well as technical guidance; Lisa Nowell and Rod DeWeese of the USGS for their help in locating action levels and guidelines for comparisons; Don Dycus, Tyler Baker, and Kenny Gardner of the Tennessee Valley Authority for providing fish tissue data and information about sample methodology; and Greg Denton of the Tennessee Department of Environment and Conservation for providing assistance concerning fish tissue information.

METHODS

Various field collection and sampling protocols were used by the USGS, TVA, and TDEC. In addition, different action levels and guidelines were used as they apply to the analysis of whole fish and fish fillets. The analysis of organochlorine pesticides in fish tissue samples collected by the USGS involved the homogenization of whole fish and the use of gas chromatography and mass spectrometry. Analytical methods used for the determination of concentrations of organochlorine pesticides can be found in Crawford and Luoma (1993) and Leiker and others (1995). Methods used by TVA and TDEC can be found in Williams and Dycus (1993) and Freeman and Denton (1997), respectively.

Field Collection

The USGS NAWQA Program recommends several fish species for fish tissue contaminant analysis. Species selection for this study was based on a targeted taxa list of recommended fish species, which was developed by Crawford and Luoma (1993). Because of geographic distribution of some fish species on the targeted taxa list, some species were

A variety of stream habitats were sampled (pools, undercut banks, logjams) to obtain a sufficient number of fish from the targeted species.

unavailable or impractical to collect. Top predator species, such as largemouth bass (*Micropterus salmoides*), smallmouth bass (*Micropterus dolomieu*), redeye bass (*Micropterus coosae*), spotted bass (*Micropterus punctatus*), and rock bass (*Ambloplites rupestris*), were the indicator species collected for analysis. Fish were collected using electrofishing techniques in accordance with NAWQA sampling protocols as described by Crawford and Luoma (1993).

Whole fish were analyzed to determine what pesticides were present and the areal distribution of their occurrence, and to assess the concentration levels of certain pesticides that wildlife may ingest as a result of eating fish. Approximately 10 fish of the same species were collected at each site to gain a representative sample. Once collected, both external and internal observations were recorded (for example, sex, coloration of organs, mesentaric fat, tumors, lesions, and parasites). In addition, scales or pectoral spines and length and weight data were collected to determine the

Prior to dissection, the exterior, entrails, and gills of fish were visually examined for discoloration, tumors, parasites, or other anomalies that might be indicative of degraded water-quality conditions.

age and size of individual specimens. Whole fish were shipped frozen to the USGS National Water-Quality Laboratory in Lakewood, Colorado, for analysis.

The primary indicator species collected by the TVA was channel catfish (*Ictalurus punctatus*). The channel catfish is highly sought by commercial and sport fishermen and was selected by the TVA because individual channel catfish tend to concentrate contaminants more so than other fish species due to the higher lipid content in catfish. Other important species collected by TVA included largemouth bass, striped bass (*Morone saxitilis*), buffalo (*Ictiobus* spp.), and crappie (*Pomoxis* spp.). Fish fillets, including the “belly flap” (a layer of fat associated with the fillet), were sampled in an effort to define which species are affected by contaminants, the geographical boundaries of contamination, and to document trends in contaminant concentrations. The information collected by TVA is shared with public health agencies such as TDEC and ADEM for their determination of any possible restrictions or consumption advisories that may need to be issued on fish consumption. Five specimens were collected by TVA using electrofishing equipment and commercial fishing gear such as seines and other nets. Black bass (*Micropterus* spp.) collected for analysis had to be at least 10 inches in length; channel catfish collected for analysis had to weigh at least 1 pound, and striped bass had to weigh at least 2 pounds. Upon collection, the fish were examined both internally and externally for physical abnormalities. Any fish having tissue unsuitable for human consumption was not included in a sample. The fish were placed on wet ice and shipped to the TVA laboratory for analysis (Williams and Dycus, 1993).

Largemouth bass (*Micropterus salmoides*), channel catfish (*Ictalurus punctatus*), and common carp (*Cyprinus carpio*) were the preferred indicator species collected for analysis by TDEC. At least five fish from each of these species were preferred, but when these fish were not available, smallmouth bass (*Micropterus dolomieu*), sunfish (*Ambloplites rupestris* and *Lepomis* spp.), suckers (*Moxostoma* spp. and *Hypentelium nigricans*), buffalo (*Ictiobus* spp.), flathead catfish (*Pylodictis olivaris*), and bullhead catfish (*Ameiurus* spp.) were substituted. Samples were collected with either electrofishing equipment or nets. Fish fillets with the belly flap (edible portion) were analyzed by TDEC to assist in the development of fish consumption advisories.

Action Levels and Guidelines

Fish tissue data from over 200 sites in the LTEN River Basin were compared with action levels and guidelines in order to place the fish tissue data in a human and aquatic health context. Different action levels or guidelines are available for analyzing tissue from fillets and whole fish. The most recent fish tissue sample concentration data from sites that were sampled multiple times were used to depict the areal distribution of organochlorine compounds and trace elements in the study unit. By allowing for the most recent concentration data to be used in action level and guideline comparisons, maps illustrating sampling sites can be presented as the most recent information available for each site for each organochlorine compound and trace element. Whole fish organochlorine pesticide and PCB concentrations were compared to guidelines developed by the National Academy of Sciences and National Academy of Engineering (NAS/NAE) in 1973. The NAS/NAE guidelines were developed to provide a measure of nonlethal levels of contaminants. Additionally, organochlorine pesticide and PCB concentrations were compared to criteria developed by the New York Department of Environmental Conservation (NYDEC). The criteria presented by NYDEC were designed to protect piscivorous (fish-eating) wildlife and are based on studies of 18 different species of mammals, reptiles, and birds living along the Niagara River (Newell and others, 1987). Fish fillet data were compared to action levels developed by the U.S. Food and Drug Administration (FDA) (1989). FDA action levels for pesticides in fish fillets are available only for those pesticides that are either no longer registered for use or are severely limited in their application, but are persistent in the environment and may be unavoidable in fish tissue. Some of the action levels and guidelines used for comparison in this report were developed for use with the sum of concentrations for members within a particular group. For example, the action levels for aldrin concentrations in fish fillets are meant to be used for the sum of the concentrations of aldrin and dieldrin. Guidelines for aldrin concentrations in whole fish are meant to be used for the sum of concentrations for aldrin, chlordane, dieldrin, endosulfan, endrin, heptachlor, heptachlor epoxide, lindane, toxaphene, and benzene hexachloride (BHC). This same use of the guidelines also is true for the diphenyl aliphatic pesticides (Nowell and Resek, 1994). In this report, the action levels and guidelines are compared to pesticides singly, not to the additive sum of the other compounds of the group. Application of the action levels and guidelines to single pesticides was chosen because of the abundance of records available for the LTEN River Basin. The application of the action level to the sum of concentrations for a group of pesticides was completed for a limited number of sites and resulted in no change in the detection frequency.

Trace element data from fish fillets were compared against FDA action levels for mercury (U.S. Food and Drug Administration, 1989). These same data were compared to U.S. EPA screening values for the protection of human health for mercury, cadmium, selenium, and arsenic (U.S. Environmental Protection Agency, 1995).

OCCURRENCE AND DISTRIBUTION OF ORGANOCHLORINE PESTICIDES IN FISH TISSUE

Organochlorine pesticides listed on the U.S. EPA Priority Pollutant List that have an action level or guideline available for either whole fish or fish fillets are discussed in this section. The organochlorine pesticides discussed are divided into five subgroups: cyclodienes, chlorinated benzene derivatives, polychloroterpenes, diphenyl aliphatics, and polychlorinated biphenyls. Each of the five subgroups is presented with background information about past uses and properties as well as the occurrence of the compound in the study unit. Throughout the study unit, 101 sites were sampled for organochlorine pesticides.

The five organochlorine pesticide subgroups are further divided into three subgroups: (1) cyclodienes, chlorinated benzene derivatives, and polychloroterpenes (aldrin, chlordane, dieldrin, endrin, mirex, heptachlor, heptachlor epoxide, hexachlorobenzene, and toxaphene); (2) diphenyl aliphatics (DDT and breakdown products); and (3) polychlorinated biphenyls (PCB’s) for discussion in this report. The 13 organochlorine pesticides that have action levels or guidelines and that are listed on the U.S. EPA Priority Pollutant List are aldrin, chlordane, dieldrin, endrin, heptachlor, heptachlor epoxide, hexachlorobenzene, toxaphene, mirex, DDT, DDD, DDE, and PCB’s (table 1). Chlordane in this report refers to the summation of *cis*- and *trans*-chlordane, *cis*- and *trans*-nonachlor, and oxychlordane either singly or in combination (L.H. Nowell, U.S. Geological Survey, written commun., 2000). Individual concentration information for these compounds as well as those not detected above action levels or guidelines is included in table 1.

Eleven additional organochlorine compounds were analyzed in fish tissue, but either these compounds did not have an existing action level for comparison or they are not listed on the U.S. EPA Priority Pollutant List. Of the 11 compounds without an existing action level or guideline, 5 compounds were detected at less than 10 percent of the sites sampled. These compounds included dimethyl 2,3,5,6-tetrachloroterephthalate (DCPA), lindane, *p,p′*-methoxychlor, *o,p′*-methoxychlor, and pentchloroanisol. The remaining three compounds, *o,p′*-DDT, *o,p′*-DDD, and *o,p′*-DDE, were detected at almost 100 percent of fish fillet sites and 10 percent of whole fish sites.

Cyclodienes, Polychloroterpenes, and Chlorinated Benzene Derivatives

Cyclodienes, which include aldrin, chlordane, dieldrin, endrin, heptachlor, heptachlor epoxide, and mirex, are stable in soil (up to 40 years for some pesticides), insoluble in water, and resistant to ultraviolet breakdown. Consequently, these pesticides, patented between 1948 and 1951 and used extensively to kill insect larvae that feed on root systems, were still in use as late as 1988 as termite insecticides (Ware, 1989).

The characteristic resistance of chlorinated cyclodienes to breakdown in soil or water leads one to suspect that these pesticides might be present in fish tissue. The information presented in this report confirms these expectations because, not only were these pesticides detected in fish fillets collected throughout the 1980’s and early 1990’s, but they were also detected in whole fish samples collected as recently as the summer of 1998. Neither aldrin, heptachlor, nor mirex were detected in whole fish samples (table 1); however, these compounds were detected in less than 3 percent of the fish fillet samples (figs. 2, 3, and 4, respectively). Aldrin is stored in the fat of animal tissue where it metabolizes into dieldrin. No method exists to measure the amount of dieldrin that originated as aldrin for the initial application. Dieldrin, heptachlor epoxide, and endrin (figs. 5, 6, and 7, respectively) each were detected in whole fish and fish fillet samples. Approximately 300 samples were collected and analyzed for the 6 cyclodiene pesticides discussed here. Only 2 of the 300 samples had concentrations that equaled or exceeded the action levels or guidelines used herein for comparison.

Table 1. Summary of organochlorine compounds in fish fillet and whole fish samples collected in the lower Tennessee River Basin, 1980-98

[Compounds in **bold** were detected at or above established action levels or guidelines; F, fish fillets; W, whole fish; mg/kg, milligram per kilogram; <, less than; ---, no information; DCPA, dimethyl 2,3,5,6-tetrachloroterephthalate; BHC, benzene hexachloride; PCB, polychlorinated biphenyl; DDT, dichlorodiphenyltrichloroethane; DDD, dichlorodiphenyldichloroethane; DDE, dichlorodiphenyldichloroethylene]

Compound	Tissue type	Number of samples	Number of detections	Number of sites sampled for contaminant	Number of sites with detections	Range of data (mg/kg)	Action level (mg/kg)	Guideline (mg/kg)	Number of sites with detections above lowest action level
Cyclodienes, chlorinated benzene derivatives, and polychloroterpenes									
Aldrin	F	273	4	82	4	0.01	[d]0.3	---	0
	W	11	0	10	0	<.005	---	[a]0.1	0
Chlordane (total)	**F**	**340**	**153**	**86**	**26**	**<.01 - .36**	**[d].3**	**---**	**1**
	W	**11**	**2**	**10**	**2**	**<.005 - .149**	**---**	**[a].1**	**1**
cis-Chlordane	F	375	38	96	31	.01 - .15	---	---	---
	W	11	2	10	2	<.005 - .031	---	---	---
trans-Chlordane	F	252	48	68	24	.01 - .1	---	---	---
	W	11	1	10	1	<.005 - .018	---	---	---
cis-Nonachlor	F	245	16	63	11	.01 - .26	---	---	---
	W	11	2	10	2	<.005 - .029	---	---	---
trans-Nonachlor	F	245	67	63	33	.01 - .11	---	---	---
	W	11	1	10	1	<.005 - .140	---	---	---
Oxychlordane	F	148	2	60	2	.01	---	---	---
	W	11	2	10	2	<.005 - .030	---	---	---
Dieldrin	F	256	10	75	8	<.01 - .05	[d].3	---	0
	W	**11**	**5**	**10**	**5**	**<.005 - .10**	**---**	**[a].1/[b].12**	**1**
Endrin	F	272	34	82	29	<0.01 - 0.03	[d].3	---	0
	W	**11**	**1**	**10**	**1**	**<.005 - .027**	**---**	**[a].1/[b].025**	**1**
Heptachlor	F	258	4	75	4	.01	[d].3	---	0
	W	11	0	10	0	<.005			
Heptachlor epoxide	F	260	9	75	8	<.01 - .07	[d].3	---	0
	W	11	2	10	2	<.005 - .017	---	[a].1/[b].20	0
Lindane	F	262	4	75	4	0.01	---	---	---
	W	11	0	10	0	<.005	---	---	---

[a] Water Quality Criteria 1972 (National Academy of Sciences and National Academy of Engineering, 1973).
[b]Niagara River Biota Contamination Project, New York State Department of Environmental Conservation (Newell and others, 1987).
[c]Compilation of legal limits for hazardous substances in fish and fishery products (Nauen, 1983).
[d] FDA tolerance level (U.S. Food and Drug Administration, 1989).

Table 1. Summary of organochlorine compounds in fish fillet and whole fish samples collected in the lower Tennessee River Basin, 1980-98—Continued

Compound	Tissue type	Number of samples	Number of detec-tions	Number of sites sam-pled for contaminant	Number of sites with detections	Range of data (mg/kg)	Action level (mg/kg)	Guideline (mg/kg)	Number of sites with detections above lowest action level
Hexachlorobenzene	W	11	0	10	0	<0.005	---	[b]0.33	0
Toxaphene	F	262	6	75	5	.5	[d]5.0	---	0
Mirex	F	196	5	46	5	.008	[c].1	[b].33	0
	W	11	0	10	0	<.005	---	---	---
p,p′-Methoxychlor	W	11	0	10	0	<.005	---	---	---
o,p′-Methoxychlor	W	11	1	10	1	<.005 - .022	---	---	---
DCPA	W	11	0	10	0	<.005	---	---	---
Pentchloroanisol	W	11	0	10	0	<.005	---	---	---
Alpha-BHC	W	11	0	10	0	<0.005	---	---	---
Beta-BHC	W	11	0	10	0	<.005	---	---	---
Delta-BHC	W	11	0	10	0	<.005	---	---	---
Diphenyl aliphatics									
p,p′-DDT	F	357	120	91	55	<.01 - .6	[d]5.0	---	0
	W	11	5	10	5	<.005 - .014	---	[a]1.0/[b].20	0
o,p′-DDT	F	109	16	7	6	.01 - 6.7	---	---	---
	W	11	1	10	1	<.005 - .019	---	---	---
***p,p′*-DDD**	**F**	**357**	**240**	**91**	**65**	**<.01 - 20.1**	**[d]5.0**	**---**	**2**
	W	11	5	10	5	<.005 - .15	---	[a]1.0/[b].20	0
o,p′-DDD	F	109	81	7	7	.01 - 2.1	---	---	---
	W	11	1	10	1	<5 - .022	---	---	---
***p,p′*-DDE**	**F**	**357**	**295**	**91**	**77**	**<.01 - 12.8**	**[d]5.0**	**---**	**1**
	W	**11**	**7**	**10**	**7**	**<.005 - 1.2**	**---**	**[a]1.0/[b].20**	**4**
o,p′-DDE	F	109	59	7	7	0.01 - 1.5	---	---	---
	W	11	1	10	1	<.005 - .0058	---	---	---
Polychlorinated biphenyls									
Total PCB's	**F**	**202**	**161**	**75**	**63**	**.1 - 85**	**[d]2.0**	**---**	**6**
	W	**11**	**3**	**10**	**3**	**<.05 - .30**	**---**	**[a].5/[b].13**	**2**

[a] Water Quality Criteria 1972 (National Academy of Sciences and National Academy of Engineering, 1973).
[b]Niagara River Biota Contamination Project, New York State Department of Environmental Conservation (Newell and others, 1987).
[c]Compilation of legal limits for hazardous substances in fish and fishery products (Nauen, 1983).
[d] FDA tolerance level (U.S. Food and Drug Administration, 1989).