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Occurrence of Organochlorine Compounds in Whole Fish Tissue from Streams of the Lower Susquehanna River Basin, Pennsylvania and Maryland, 1992

by Michael D. Bilger, Robin A. Brightbill, and Harry L. Campbell

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CONVERSION FACTORS AND ABBREVIATIONS

Multiply	By	To obtain
	Length	
centimeter (cm)	0.3937	inch
	Area	
square kilometer (km^2)	0.3861	square mile
	Volume	
milliliter (mL)	0.03382	ounce, fluid
	Mass	
gram (g)	0.03527	ounce, avoirdupois

Abbreviated water-quality units used in report:

mg/kg, milligrams per kilogram
µg/kg, micrograms per kilogram
pg/µL, picograms per microliter

OCCURRENCE OF ORGANOCHLORINE COMPOUNDS IN WHOLE FISH TISSUE FROM STREAMS OF THE LOWER SUSQUEHANNA RIVER BASIN, PENNSYLVANIA AND MARYLAND, 1992

by Michael D. Bilger, Robin A. Brightbill, and Harry L. Campbell

ABSTRACT

Tissue samples of whole body white sucker (Catostomus commersoni) were collected at 15 sites and smallmouth bass (Micropterus dolomieu) were collected at 5 sites during 1992 in the Lower Susquehanna River Basin to determine the occurrence and distribution of 28 selected organochlorine compounds as part of the U.S. Geological Survey's National Water-Quality Assessment (NAWQA) Program. Only 12 of the 28 compounds occurred at concentrations greater than the 5 µg/kg reporting limit (total PCB's reporting limit is <50 µg/kg and toxaphene is <200 µg/kg). The most frequently reported compounds were p,p'-DDE (reported in all tissue samples), total polychlorinated biphenyls (PCB's), and trans-nonachlor.

High concentrations of p,p'-DDE and low concentrations of the other DDT metabolites for the Lower Susquehanna River sites indicate no recent influx of DDT. Comparison with historical data from the Lower Susquehanna River Basin shows a decline of organochlorine concentrations within the basin. In 1987, Quittapahilla Creek had the highest concentrations of p,p'-DDE in a national survey of contaminant occurrence in fish tissue conducted by the U.S. Environmental Protection Agency. This stream ranked the highest for total DDT of the 20 NAWQA studies started nationally in 1991. Total DDT concentrations were higher in agriculture-dominated (>50 percent) sites than in forest-dominated (>50 percent) sites with the exception of Deer Creek and Big Beaver Creek. These two sites are located more in grazing areas that lack a substantial crop-land use. Concentrations of total PCB's were highest in basins with greater than 10 percent urban land use excluding the larger river sites. Concentrations of total chlordane were highest at sites with greater than 70 percent agricultural and 10 percent urban land use.

Regional comparisons of total DDT, total PCB's, and total chlordane in white sucker tissue from the Lower Susquehanna, Hudson (in New York), and Connecticut River Basins showed that median concentrations of total DDT were different (p=0.05), with the Lower Susquehanna Basin being the lowest. Total PCB's and total chlordane medians were similar. Comparison of the data from national and regional studies with data from this local study showed concentrations of p,p'-DDE in the Lower Susquehanna River Basin are similar to those nationwide and lower than the concentrations measured in the Northeast. PCB concentrations in the Lower Susquehanna River Basin and the Northeast were higher than those nationwide.

INTRODUCTION

The U.S. Geological Survey's (USGS) National Water-Quality Assessment (NAWQA) Program is a long-term effort designed to evaluate the status of, and trends in, the quality of surface- and groundwater resources in the United States through an integrated approach of physical, chemical, and biological factors (Hirsch and others, 1988; Leahy and others, 1990; Gurtz 1994; Gilliom and others, 1995). The program was designed to be conducted in 59 separate river basins and aquifer systems that account for about two-thirds of the water use and public water supply in the United States (Leahy and Wilber, 1991). These basins comprise the framework for regional- and national-level assessments. The Lower Susquehanna River Basin study (Breen and others, 1991) was among the first 20 NAWQA studies implemented.

The overall NAWQA Program includes bed-sediment and fish-tissue investigations; the objectives are to identify contaminant occurrence from a broad suite of compounds, determine any long-term trends in contaminant concentrations, describe spatial distribution of contaminants, and

examine the relations between contaminant concentrations and land use (Crawford and Luoma, 1993). Among these contaminants are PCB's and organochlorine compounds, which were in widespread use in the United States for nearly 40 years until banned or restricted in the 1970's and 1980's (Smith and others, 1988). Because of the low chemical reactivity, resistance to oxidation, and resistance to other degenerative processes of these compounds, residues of them have been shown to be widely persistent in the environment (Great Lakes Basin Commission, 1975). The extent of atmospheric deposition of long-lived, environmentally stable organochlorine compounds into surface waters is not well understood, but these compounds are known to accumulate in fish and mammals (including humans) at significant concentrations (Majewski and Capel, 1995).

During 1992, concentrations of 28 organochlorine compounds were determined in whole-body tissues of white sucker (*Catostomus commersoni*) and smallmouth bass (*Micropterus dolomieu*) collected in the Lower Susquehanna River Basin. This report discusses the compounds that were present above the method reporting limits (MRL): total dichlorodiphenyltrichloroethane (DDT), consisting of the sum of the *o,p*'- and *p,p*'- isomers of DDT and its metabolites dichlorodiphenyldichloroethane (DDD) and dichlorodiphenyldichloroethylene (DDE); total polychlorinated biphenyls (PCB's), consisting of Aroclors 1242, 1254, and 1260; and total chlordane, reported as the sum of *cis*- and *trans*-chlordane, *cis*- and *trans*-nonachlor, and oxychlordane. The organochlorine contaminants that occurred at concentrations below the 5 µg / kg MRL are in table 1. Toxaphene also occurred below its MRL, which is 200 µg / kg.

The nationally consistent design of NAWQA enables results from the Lower Susquehanna River Basin study to be compared with results from other river basins across the United States. Thus, an additional purpose of this report is to compare data on selected organochlorine contaminant concentrations in fish tissues of the Lower Susquehanna River Basin with data from (1) the U.S. Fish and Wildlife Service (USFWS) study in Pennsylvania (Rompala and others, 1984), (2) the U.S. Environmental Protection Agency's (USEPA) National Study of Chemical Residues in Fish (NSCRF) (U.S. Environmental Protection Agency, 1992), and (3) NAWQA studies in the Hudson River and Connecticut River Basins in the northeastern United States, (4) NAWQA studies across the United States, and (5) the USFWS National Contaminant Biomonitoring Program (NCBP) (Schmitt and others, 1990). Finally, data from the Lower Susquehanna River Basin were compared to established standards and guidelines for human consumption (Nowell and Resek, 1994) and protection of fish-eating wildlife (National Academy of Sciences and National Academy of Engineering, 1973).

DESCRIPTION OF STUDY AREA

The Lower Susquehanna River Basin (fig. 1) consists of 24,087 km^2 in Pennsylvania and Maryland, extending from near Sunbury, Pa., in the north downstream to Havre de Grace, Md., in the south. The basin is inhabited by about 1.9 million people, most of which (71 percent) reside in the southeastern part. For the analyses described in this report, the study area also included two sites north of Sunbury: the Susquehanna River at Danville, Pa., and the West Branch Susquehanna River at Lewisburg, Pa. Seven major tributaries drain about two-thirds of the Lower Susquehanna River Basin. The Juniata River, the largest tributary, drains about 8,800 km^2 (Breen and others, 1991).

Five physiographic provinces are present within the study area: the Ridge and Valley, the Blue Ridge, the Piedmont, the New England, and the Appalachian Plateaus. The Piedmont and

Table 1. *Compounds below method reporting limits in whole white sucker and smallmouth bass tissue in the Lower Susquehanna River Basin, Pa.*
[µg/kg, micrograms per kilogram]

Compounds below reporting limit of 5 µg/kg			
aldrin	alpha-hexachlorocyclohexane	heptachlor epoxide	hexachlorobenzene
dieldrin	beta-hexachlorocyclohexane	pentachloroanisole	*o,p*'-methoxychlor
endrin	delta-hexachlorocyclohexane	toxaphene[1]	*p,p*'-methoxychlor
lindane	heptachlor	dacthal (DCPA)	mirex

[1] Method reporting limit of 200 µg / kg.

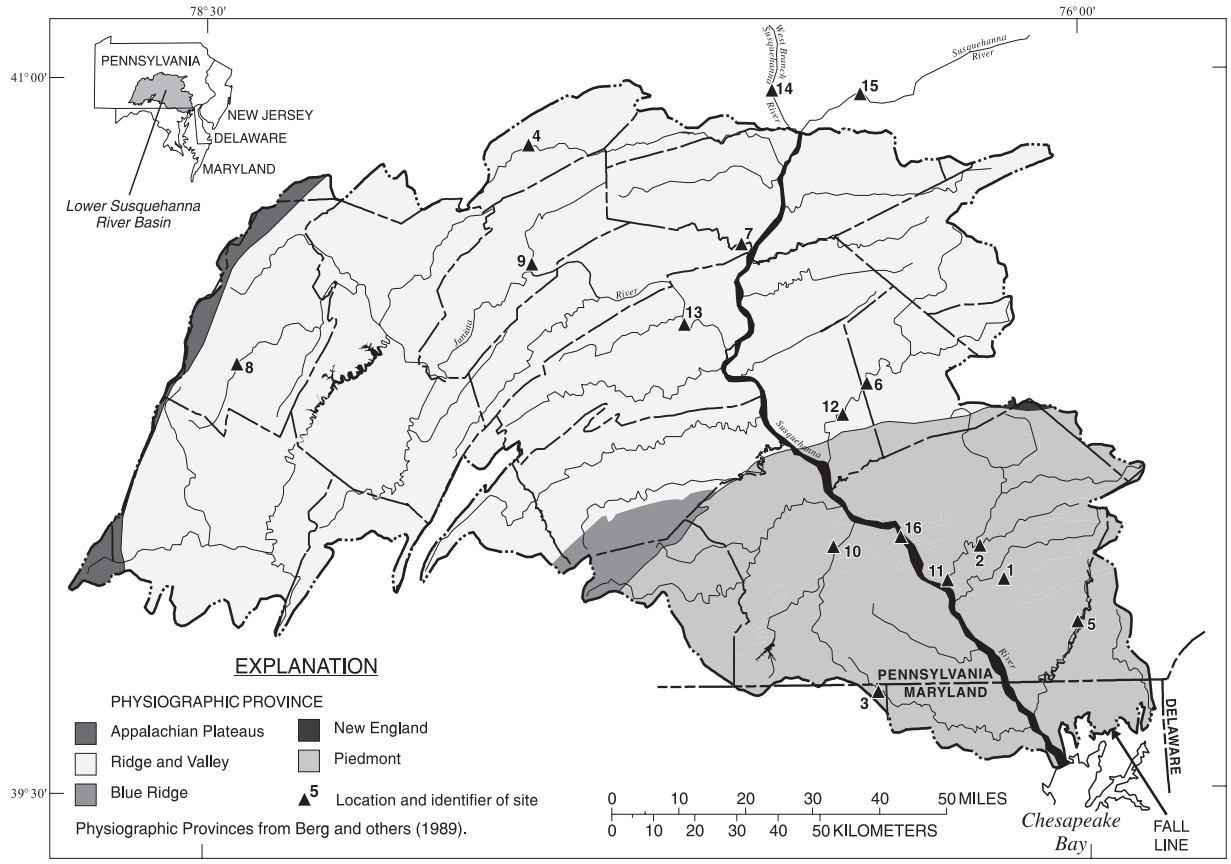

Figure 1. Location of fish-tissue collection sites in the Lower Susquehanna River Basin NAWQA Program. Names and exact locations of sites are given in table 1.

Ridge and Valley Physiographic Provinces comprise most of the area (Risser and Siwiec, 1996). Many natural and anthropogenic factors influence the water quality within the basin: climate, physiography, geology, water use, land use, and population density (Breen and others, 1991). In terms of land use, the study area is about 47 percent forested and 47 percent agricultural. The remaining 6 percent consists of urban and built-up areas (4 percent) and bodies of water and barren land (2 percent) (Risser and Siwiec, 1996).

ACKNOWLEDGMENTS

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STUDY METHODS

SITE SELECTION

Sites in the Lower Susquehanna River Basin were chosen to define what and where organochlorine compounds occur in fish tissue (Crawford and Luoma, 1993). State and local agencies met with the Lower Susquehanna River study group to determine sites where contamination has occurred in the past or is likely to occur. Sites were not selected randomly but rather on the basis of historical contamination except for two, Deer Creek and Penns Creek, which were known to have little or no contaminant sources. A total of 16 sites were chosen (table 2).

Table 2. *Characteristics of sites and basins selected for 1992 survey of contaminants in fish tissue by the National Water-Quality Assessment Program, Lower Susquehanna River Basin, Pa.*

[km^2, square kilometers]

Stream name and location	Site identifier on figure 1	Drainage area at sampling site (km^2)	Number of known upstream point sources	Designated use	Land use (percent)[1]		
					Agriculture	Forest	Urban
Big Beaver Creek at Refton, Pa.	1	51.3	1	Trout stocking	82.3	13.5	4.2
Mill Creek near Lyndon, Pa.	2	51.3	5	Warm-water fishes	84.5	7.3	8.2
Deer Creek at Gorsuch Mills, Md.	3	66.3	1	Cold-water fishes	75.2	21.8	3.0
Penns Creek at Spring Mills, Pa.	4	106	1	Cold-water fishes	46.9	50.9	2.2
East Branch Octoraro Creek near Kirkwood, Pa.	5	142	6	Trout stocking	79.4	17.2	3.6
Quittapahilla Creek near Palmyra, Pa.	6	200	13	Trout stocking	70.1	11.2	18.7
West Mahantango Creek near Liverpool, Pa.	7	217	4	Trout stocking	43.5	56.3	.2
Frankstown Branch Juniata River near Hollidaysburg, Pa.	8	350	15	Warm-water fishes	36.2	60.2	3.4
Kishacoquillas Creek at Lewistown, Pa.	9	490	6	Cold-water fishes	35.8	62.7	1.5
Codorus Creek at Pleasureville, Pa.	10	627	28	Warm-water fishes	73.2	16.4	10.4
Conestoga River near Safe Harbor, Pa.	11	1,235	55	Warm-water fishes	73.9	19.6	6.5
Swatara Creek near Hershey, Pa.	12	1,250	38	Warm-water fishes	56.8	36.7	6.5
Juniata River at Newport, Pa.	13	8,650	110	Warm-water fishes	29.5	68.2	2.3
West Branch Susquehanna River at Lewisburg, Pa.	14	17,700	Many	Warm-water fishes	13.9	81.0	5.1
Susquehanna River at Danville, Pa.	15	29,100	Many	Warm-water fishes	26.4	59.8	13.8
Susquehanna River at Columbia, Pa.	16	67,300	Many	Warm-water fishes	34.9	64.7	.4

[1] Mitchell and others, 1977

SAMPLE COLLECTION

Fish were collected at these sites by electrofishing, in accordance with NAWQA guidelines. To maintain a national consistency in species selection, the white sucker (*Catostomus commersoni*) (a bottom feeder) was chosen as the target taxon (Crawford and Luoma, 1993). The smallmouth bass (*Micropterus dolomieu*) (a predator), although not listed as a national target taxon, was chosen because of its importance as a recreational species that is consumed by anglers in this study area. An attempt was made to include both species at each site during the site-selection process; however, at 12 sites, only one target taxon could be captured in sufficient numbers to meet the minimum criterion for sample size. Most samples were collected during the late summer and early fall to minimize interference with the reproductive periods of target and nontarget fish species.

A sample constituted a composite of 5 to 10 fish, ideally 8. Each fish was sacrificed, weighed, and measured for total and standard length. External anomalies were recorded, and gender was determined. For age determination, a scale sample and pectoral fin-ray were removed from each white sucker and scales were removed from each smallmouth bass. Whole fish were individually wrapped in aluminum foil, and all individuals were placed into a polyethylene bag, frozen with dry ice, and sent to the laboratory.

White suckers were collected at 15 sites and smallmouth bass at 5 sites. A summary of the composite physical characteristics of white sucker and smallmouth bass collected for tissue analysis is given in table 3.

LABORATORY PROCEDURES

Analyses of organochlorine compounds and PCB's for both fish species were done by the USGS National Water Quality Laboratory (NWQL) in Arvada, Colo. A brief summary of the methods follows. A more detailed description can be found in Leiker and others (1995).

Whole fish were homogenized with a meat grinder to form a single composite. An aliquot of 10 g was extracted and homogenized with 100 g of granular anhydrous sodium sulfate to remove

residual water. Next, two surrogates, α-hexachlorocyclohexane d6 (α-HCH d6) and 3,5-dichlorobiphenyl (3,5-DCB), were added to the sample, which was Soxhlet extracted overnight in methylene chloride. The extract was then filtered through granular anhydrous sodium sulfate and concentrated to a 5.0-mL volume. A 1.0-mL sample of the concentrated extract was removed for determination of percent lipid. A 2.0-mL sample of the extract was injected into an automated gel permeation chromatograph to isolate the analytes from the lipid material that was coextracted. The extract was then solvent exchanged into hexane and further concentrated to a 1.0-mL volume. The extract was fractionated into two components by use of alumina/silica adsorption chromatography: nonpolar organics such as PCB's and DDE, hexachlorobenzene (HCB), heptachlor, aldrin, and 3,5-DCB surrogate; and polar organics such as chlordanes, toxaphene, DDT, and DDD. The fractions were then concentrated to a 1.0-mL volume and analyzed by dual capillary column gas chromatography (GC) with electron capture detector (Leiker and others, 1995).

Identification of compounds was based on the GC retention times on both capillary columns compared to those obtained by use of external standard mixtures. The compound quantitation curve is based on the calibration curves of 5, 10, 20, 50, 100, and 200 pg/μL for chlorinated pesticides, 600 pg/μL for mixed Aroclor standards for PCB's, and 800 pg/μL for toxaphene. The lower of the two observed concentrations from the two GC columns was reported except where recognized compound coelutions or interferences resulted in single-column quantification (Leiker and others, 1995).

The 12 compounds and 2 surrogates discussed in this report are listed in table 4. The MRL's for fish tissue are 5.0 μg/kg on a wet-weight, whole-fish basis for all organochlorine compounds and 50 μg/kg for PCB's. The mean recovery for five reagent spikes, the ranges of the reagent recoveries, and their reagent-spike recovery ranges also

Table 3. *Mean total length, weight, age, number of fish, and percent lipid content per composite sample for survey of contaminants in fish tissue by the National Water-Quality Assessment Program, Lower Susquehanna River Basin, Pa.*

Site name	Mean total length (millimeters)	Mean weight (grams)	Mean age (years)[1]	Number of fish in composite	Percent lipid content by wet weight
		White sucker			
Big Beaver Creek	355	463	12	8	4.4
Mill Creek	290	240	10	10	3.0
Deer Creek	276	234	8	10	3.1
Penns Creek	348	441	13	8	5.3
East Branch Octararo Creek	342	406	11	8	6.4
Quittapahilla Creek	400	740	14	8	6.9
West Mahantango Creek	303	316	10	8	2.9
Frankstown Branch Juniata River	319	354	12	8	4.4
Kishacoquillas Creek	364	522	12	8	5.8
Codorus Creek	366	568	12	8	6.0
Conestoga River	347	453	13	6	5.0
Swatara Creek	347	531	11	8	7.6
Juniata River	267	235	8	8	12
West Branch Susquehanna River	436	961	17	8	14
Susquehanna River at Danville	391	733	14	8	8.5
		Smallmouth bass			
Conestoga River	273	224	2 +	5	1.3
Juniata River	208	116	1 +	8	3.9
West Branch Susquehanna River	368	669	3 +	8	5.1
Susquehanna River at Danville	377	681	4 +	8	1.6
Susquehanna River at Columbia	311	371	3 +	8	3.2

[1] Data from Cooperative Fish and Wildlife Research Unit, Pennsylvania State University, University Park, Pa.

are listed in table 4. Detailed information on MRL's and quality-assurance procedures is given by Leiker and others (1995).

One duplicate sample was collected for white sucker. The duplicate sample had concentrations of *o,p'*-DDD, *o,p'*-DDE, *o,p'*-DDT, *p,p'*-DDT, *cis*-chlordane, *trans*-chlordane, *cis*-nonachlor, *trans*-nonachlor, and oxychlordane below the MRL. The percentage differences between the reported compound and the duplicate was 30 percent for PCB's, 232 percent for *p,p*'-DDD, and 16 percent for *p,p'*-DDE. The percentage difference for *p,p'*-DDD may be exaggerated because the first sample was below the MRL of 5 µg / kg and the duplicate was 8.3 µg / kg.

FISH AGE DETERMINATION

The ages of white suckers were determined by analysis of pectoral fin-ray samples (scale samples were not reliable) by the Cooperative Fish and Wildlife Research Unit, Pennsylvania State University, University Park, Pa., using a modification of the method described in Deelder and Willemse (1973). The ages of smallmouth bass were determined by reading annual rings from a sample of about 20 scales taken from below the lateral line, near the tip of the oppressed pectoral fin (Crawford and Luoma, 1993).

DATA ANALYSIS

For the Lower Susquehanna River Basin analysis, ranges of concentrations for individual compounds were reported. For concentrations below the MRL, a value of one-half the MRL was used in computing concentrations of total DDT and total chlordane (Harrison and Klaverkamp, 1990; Tate and Heiny, 1996).

Comparisons of regional data from the Hudson (Firda and others, 1993), Connecticut (Coles, 1996), and Lower Susquehanna River Basins were based on median concentrations. Concentrations were computed in the same manner as those for the Lower Susquehanna River Basin. A median test (Zar, 1984), which is used to test for differences between median values, was used to compare

Table 4. *Reporting limits, spike recoveries, and surrogate recoveries for organochlorine compounds detected in whole white sucker and smallmouth bass tissue for samples collected in 1992-94 in the Lower Susquehanna River Basin NAWQA study*

[Analyses by U.S. Geological Survey National Water Quality Laboratory (NWQL); µg/kg, micrograms per kilogram; n, sample size; <, less than; —, not applicable]

Compound	Chemical Abstracts number	Method reporting limit for fish tissue (µg/kg)	Mean recovery of five reagent spikes for samples from this study (percent)	Range of recoveries of reagent spikes for samples from this study (percent)	NWQL range for reagent spikes (percent), n
Total PCB's	—	<50	—	—	—
o,p'-DDT	789-02-6	<5.0	89	76-107	76-102,33
p,p'-DDT	50-29-3	<5.0	96	82-110	73-99,34
o,p'-DDD	53-19-0	<5.0	94	86-107	76-100,34
p,p'-DDD	72-54-8	<5.0	102	88-111	69-115,22
o,p'-DDE	3424-82-6	<5.0	79	66-108	67-95,34
p,p'-DDE	72-55-9	<5.0	88	74-105	76-104,34
cis-chlordane	5103-71-9	<5.0	86	78-103	71-93,34
trans-chlordane	5103-74-2	<5.0	90	76-100	74-98,34
cis-nonachlor	5103-73-1	<5.0	83	62-100	67-97,34
trans-nonachlor	39765-80-5	<5.0	90	80-101	74-96,34
oxychlordane	27304-13-8	<5.0	86	75-100	73-101,34
α-d6-HCH surrogate	—	—	60	35-109	51-77,33
3,5-dichlorobiphenyl surrogate	34883-41-5	—	61	30-83	42-68,33

medians from the Lower Susquehanna (n=15), Hudson (n=7), and Connecticut River Basins (n=31). The procedure for this test is to 1) determine the grand median for all data in two samples and 2) set up a 2 X 2 contingency table. This table can be analyzed using chi-square.

For comparisons of national to regional and local results, the same method of using half the MRL to compute median values was used. A regional median for PCB's, total DDT, and total chlordane was computed by combining the 1992 data from the Connecticut, Hudson, and Lower Susquehanna River Basin studies. A median test (Zar, 1984) was used to compare medians between the local, regional, and national studies.

ORGANOCHLORINE COMPOUNDS IN FISH TISSUE

Organochlorine compounds were detected in white suckers and smallmouth bass tissue. The compounds most frequently detected in both species were total PCB's, *p,p'*-DDT, and *trans*-nonachlor.

CONCENTRATIONS IN WHITE SUCKER TISSUE

White suckers were sampled at 15 sites. The mean total length of fish from the composited samples was 34.3 cm (range = 27.6-43.6 cm), mean weight was 480 g (range = 234-961 g), and mean percent lipid was 6.4 (range = 2.9-14). Mean age was 12 years (range = 8-17 years). The most frequently reported compounds from the 15 samples of whole fish were *p,p'*-DDE (15 samples), total PCB's (12 samples), *trans*-nonachlor (10 samples), *p,p'*-DDT (9 samples), *cis*-chlordane (8 samples), and *p,p'*-DDD (6 samples). Compounds also reported were *cis*-nonachlor (5 samples), oxychlordane (3 samples), *trans*-chlordane (3 samples), *o,p'*-DDD (3 samples), *o,p'*-DDE (2 samples), and *o,p'*-DDT (1 sample). Results are listed in table 5.

Reported DDT metabolite concentrations varied widely among the sites. All DDT metabolites were reported at Quittapahilla Creek, and the fewest at Penns Creek, Deer Creek, Big Beaver Creek, Frankstown Branch Juniata River, and the Juniata River (table 5). A metabolite of total DDT, *p,p'*-DDE, was reported in all 15 samples.

Concentrations of total DDT in white sucker tissue ranged from 18 µg / kg at Juniata River to 3,400 µg / kg at Quittapahilla Creek. The highest single metabolite concentration, also recorded at Quittapahilla Creek, was 1,600 µg / kg for *p,p'*-DDE (table 5). The percentage of total DDT measured as *p,p'*-DDE ranged from 27 percent to 81 percent; the mean percentage for the basin was 57 percent.

Data collected in this study indicate a widespread occurrence of PCB's, in that they were reported in 80 percent of the white sucker samples collected (table 5). The concentrations of total PCB's ranged from <50 µg / kg at Penns Creek, Deer Creek, and West Mahantango Creek to 1,500 µg / kg at Codorus Creek.

Chlordane and its related components (U.S. Environmental Protection Agency, 1993) were reported in tissues collected from 67 percent of the sites (table 5). All five components of total chlordane were reported in tissues collected from Quittapahilla Creek and Codorus Creek. No chlordane components were above the MRL in samples from Penns Creek, Deer Creek, West Mahantango Creek, Frankstown Branch of the Juniata River, or the mainstem Juniata River.

Concentrations of total chlordane ranged from 13 µg / kg (calculated using 1 / 2 MRL) at the five sites listed above to 120 µg / kg at Quittapahilla Creek. The highest single-component concentration was at Quittapahilla Creek, where the concentration of *cis*-chlordane was 38 µg / kg. The final degradation product of chlordane, *trans*-nonachlor, ranged from 19 percent to 48 percent of the total; the mean for the basin was 32 percent.

CONCENTRATIONS IN SMALLMOUTH BASS TISSUE

Smallmouth bass were sampled at five sites, four of which coincided with white sucker collections. The mean total length of fish from the composited samples was 30.7 cm (range = 20.8-37.7 cm), mean weight was 412 g (range = 116-681 g), and mean percent lipid was 3.0 (range = 1.3-5.1). Mean age of each composite ranged from 1+ to 4+ years. The most frequently reported organochlorine contaminants were total PCB's (5 samples), *p,p'*-DDE (5 samples), and *trans*-nonachlor (5 samples) (table 6).

DDT metabolites were reported at the three Susquehanna River mainstem sites (table 6). Samples from all sites contained *p,p'*-DDE at levels above the MRL. Concentrations of total DDT ranged from 30 µg / kg at the Juniata River to 77 µg / kg at the Susquehanna River at Columbia. The highest concentration of a metabolite,

Table 5. *Concentrations of total PCB's, total DDT and metabolites, and total chlordane and components in white sucker samples collected in 1992 from the Lower Susquehanna River Basin, Pa.*

[—, missing data; <, value is less than method reporting limit; µg/kg, micrograms per kilogram]

Site name	Concentration in whole fish, wet weight basis (µg/kg)													
	Total PCB's	*o,p'*-DDT	*p,p'*-DDT	*o,p'*-DDD	*p,p'*-DDD	*o,p'*-DDE	*p,p'*-DDE	Total DDT	*cis*-chlordane	*trans*-chlordane	*cis*-nonachlor	*trans*-nonachlor	oxy-chlordane	Total chlordane
Big Beaver Creek	57	<5	< 5	<5	<5	<5	16	29	< 5	< 5	< 5	9.0	< 5	19
Mill Creek	130	<5	6.0	<5	16	<5	100	123	9.9	< 5	6.5	13	< 5	34
Deer Creek	<50	<5	<5	<5	<5	<5	29	42	< 5	< 5	< 5	< 5	< 5	13
Penns Creek	<50	<5	<5	<5	<5	<5	13	26	< 5	< 5	< 5	< 5	< 5	13
East Branch Octoraro Creek	84	<5	7.7	<5	7.4	<5	96	120	12	< 5	11	20	5.5	51
Quittapahilla Creek	730	17	120	360	1,200	130	1,600	3,400	38	17	11	37	17	120
West Mahantango Creek	<50	<5	5.2	<5	—	<5	37	50	< 5	< 5	< 5	< 5	< 5	13
Frankstown Branch Juniata River	120	<5	<5	<5	<5	<5	31	44	< 5	< 5	< 5	< 5	< 5	13
Kishacoquillas Creek	360	<5	<5	6.9	6.6	<5	7.9	29	5.1	< 5	< 5	7.6	< 5	20
Codorus Creek	1,500	<5	20	<5	18	<5	140	190	21	10	9.4	18	10	68
Conestoga River	230	<5	5.7	<5	—	<5	54	67	11	< 5	6.0	13	< 5	35
Swatara Creek	180	<5	19	53	220	21	300	620	12	5.1	< 5	12	< 5	34
Juniata River	93	<5	<5	<5	<5	<5	5.3	18	< 5	< 5	< 5	< 5	< 5	13
West Branch Susquehanna River	160	<5	12	<5	—	<5	34	54	8.4	< 5	—	12	< 5	25
Susquehanna River at Danville	250	<5	8.3	<5	—	<5	39	55	< 5	< 5	< 5	8.2	< 5	18

Table 6. *Concentrations of total PCB's, total DDT and metabolites, and total chlordane and components in smallmouth bass samples collected in 1992 in the Lower Susquehanna River Basin, Pa.*
[—, missing data; <, value is less than method reporting limit; µg/kg, micrograms per kilogram]

Site name	Concentration in whole fish, wet weight basis (µg/kg)													
	Total PCB's	*o,p'*-DDT	*p,p'*-DDT	*o,p'*-DDD	*p,p'*-DDD	*o,p'*-DDE	*p,p'*-DDE	Total DDT	*cis*-chlordane	*trans*-chlordane	*cis*-nonachlor	*trans*-nonachlor	oxy-chlordane	Total chlordane
Conestoga River	180	<5	<5	<5	—	<5	53	63	6.6	<5	13	25	<5	50
Juniata River	270	<5	<5	<5	<5	<5	17	30	<5	<5	<5	6.7	<5	17
West Branch Susquehanna River	190	<5	9.6	<5	—	<5	48	65	<5	<5	11	21	<5	40
Susquehanna River at Danville	190	<5	5.6	<5	—	<5	40	53	<5	<5	<5	6.7	<5	17
Susquehanna River at Columbia	650	<5	6.1	<5	<5	<5	61	77	<5	<5	6.1	14	<5	28

61 µg / kg for *p,p*'-DDE, was at the Susquehanna River at Columbia (table 6). The percentage of total DDT measured as *p,p*'-DDE ranged from 57 to 84 percent; the mean for the basin was 74 percent.

PCB's were reported in all samples of smallmouth bass. Concentrations ranged from 180 µg / kg at the Conestoga River near Safe Harbor to 650 µg / kg at the Susquehanna River near Columbia (table 6).

Chlordane components were reported in smallmouth bass tissue from all five sites (table 6). Three of the five components were reported at the Conestoga River near Safe Harbor, whereas only one component was reported at sites on the Juniata River and the Susquehanna River at Danville. Concentrations of total chlordane ranged from 17 µg / kg at the Juniata River and the Susquehanna River at Danville to 50 µg / kg at the Conestoga River. The highest component concentration was for *trans*-nonachlor, 25 µg / kg, at the Conestoga River (table 6). Concentrations of *trans*-nonachlor ranged from 39 to 53 percent of the total; the mean for the basin was 46 percent.

Occurrence of Compounds in the Lower Susquehanna River Basin

Fish readily absorb DDT from water, so a high proportion of DDE in tissues would indicate low DDT uptake and high DDT metabolism (Haynes and Laws, 1991). The composition of total DDT as a mean percentage of *p,p*'-DDE was 62 percent and 74 percent in white sucker and smallmouth bass, respectively. Technical DDT is approximately 77 percent *p,p*'-DDT, which is a parent compound of *p,p*'-DDE. Moreover, *o,p*'- metabolites of DDT are more readily excreted than are *p,p*'- metabolites (Haynes and Laws, 1991). Because the greatest percentage of total DDT is in the form of *p,p*'-DDE, concentrations within the study area may be in the final stages of degradation. This finding suggests no recent influx of total DDT into the basin.

PCB's comprise a class of compounds with wide variations in physical, chemical, and biological behavior. The distribution of PCB's in the environment seems to be regulated by volatilization for the less chlorinated congeners and adsorption onto sediments and biota for the highly chlorinated congeners (U.S. Environmental Protection Agency, 1979; McFarland and Clarke, 1989). This potential for more highly chlorinated congeners to accumulate in tissues is explained by the high octanol / water (K_{ow}) coefficient of PCB's (U.S. Environmental Protection Agency, 1979). Among congeners containing four or fewer chlorine atoms per molecule, biodegradation appears to be the primary fate process; more highly chlorinated congeners (five or greater chlorine atoms per molecule) appear to photolyze. Evidence indicates that PCB's with four or more chlorines are most persistent in the environment. Of the smaller streams sampled in the Lower Susquehanna River Basin, Codorus and Quittapahilla Creeks had the highest PCB concentrations. PCB's are known to occur in high concentrations in urbanized areas. Both these creeks receive discharge from more than 10 permitted point sources, and both have greater than 10 percent urban land use within their respective basins.

Chlordane is a pesticide that was commonly used in the United States from about 1948 until it was banned in the 1980's (U.S. Environmental Protection Agency, 1992). Fish collected from this study contained *trans*-chlordane concentrations that were roughly half that of *cis*-chlordane, perhaps because *trans*-chlordane is eliminated from fish (redhorse sucker and white sucker) 1.8 times faster than the *cis*-isomer; moreover, the half-life for the *cis*-isomer has been reported to be 60 days as opposed to 30 days for the *trans*-isomer (U.S. Environmental Protection Agency, 1979). Oxychlordane, which has a low potential for bioaccumulation, was detected in fish from only three sites. The most frequently detected chlordane component in white sucker and smallmouth bass was *trans*-nonachlor, an indication that chlordane is probably approaching the final stages of degradation (Schmitt and others, 1990).

Association of Compound Concentrations to Land Use

Concentrations of organochlorine compounds detected in whole-body white sucker tissue showed only weak associations with major land-use categories within the Lower Susquehanna River Basin. Samples from all sites had concentrations reported for one or more compounds in at least one of the organochlorine groups—total PCB's, total DDT, and total chlordane.

Total PCB concentrations in tissue were expected to be comparatively high at the large-river sites near urban centers; however, samples from small streams like Codorus Creek and Quittapahilla Creek had concentrations that exceeded 500 µg/kg (table 5). Samples from the mainstem sites had slightly elevated concentrations, especially at Danville. Quittapahilla Creek, Codorus Creek, and the Susquehanna River at Danville have the greatest percentage of urban land use (>10 percent) of the 15 sites (table 2), and their tissue-analysis results appear to be affected by the urban land use.

Total DDT was reported at all sites within the Lower Susquehanna River Basin. The basin is known for its agricultural land use. The five sites with the highest concentrations of total DDT (≥120 µg/kg) were all agriculture-dominated (>50 percent) (table 2) sites (table 5). The lowest concentrations of DDT were at agriculture-dominated sites on Deer Creek and Big Beaver Creek. These two sites are in areas of grazing lands and are not dominated by crop growing as are the other agricultural sites. Samples from the forest-dominated (>50 percent) sites, exclusive of the mainstem, had the lowest concentrations.

Concentration patterns of total chlordane closely resembled those for total DDT and total PCB's (table 5). Samples from Quittapahilla Creek and Codorus Creek had the highest concentrations (>700 µg/kg) (table 5). Drainage basins of these sites have more than 70 percent agricultural land use and more than 10 percent urban land use. Chlordane has been used as a residential and commercial termiticide, and its presence at these agriculturally dominated land-use sites was not expected. The urban land use at these sites has appeared to influence the water quality. The predominantly forested (>50 percent) sites have the lowest concentrations of chlordane in the basin.

Comparison of Lower Susquehanna River Basin Results With Results of Other Studies and With Established Standards and Guidelines

Two major national studies were previously conducted and included the Lower Susquehanna River Basin. The earlier findings are compared to the results from the Lower Susquehanna River NAWQA in the following section. Regional comparisons also are made to the Hudson River and Connecticut River NAWQA Programs as well as the other NAWQA studies across the United States. Trends of organochlorine compound concentrations are discussed as well as how the Lower Susquehanna River Basin compares to established standards and guidelines as determined by the National Academy of Science (NAS) and the National Academy of Engineers (NAE).

Comparison With Previous Studies in the Basin

Two major studies of contaminants in fish were previously done that included samples within the Lower Susquehanna River Basin, the USFWS (Rompala and others, 1984) and the NSCRF by the USEPA (1992). Results from these studies were compared to DDT, PCB's, and chlordane concentrations from the Lower Susquehanna River Basin NAWQA study, hereafter termed "this study." In looking at these comparisons, one must consider the differences in fish species, tissue type (whole body or edible portion (fillets)), analytical capability and quality of the

laboratory, MRL's, and the reproducibility of results. No lipid normalizations, fish gender, or age determination were done in the USFWS or NSCRF studies.

The objective of the USFWS study was to determine how widespread certain contaminants were in selected fish species in Pennsylvania (Rompala and others, 1984). In the USFWS study, three site locations were similar to those of this study. These sites were on Kishacoquillas Creek, West Mahantango Creek, and the Juniata River; however, only the sampling from the Juniata River site had a potentially comparable species, the rock bass (*Ambloplites rupestris*).

Organochlorine compound	USFWS whole-body rock bass (micrograms per kilogram)	LSUS whole-body smallmouth bass (micrograms per kilogram)
DDT	<50	<5.0
DDD	<50	<5.0
DDE	30	20
PCB's	420	270
trans-nonachlor	20	6.7

The USFWS study did not differentiate between the *o,p'*- and *p,p'*- forms of DDT, DDD, or DDE and reported PCB concentrations as three Aroclors: 1242, 1254, and 1260. For samples from the Juniata River, DDT and DDD concentrations were below the MRL (<50 µg / kg) in whole-body rock bass (USFWS) and below the MRL of 5.0 µg / kg in smallmouth bass (this study). The concentration of DDE was recorded as 30 µg / kg in rock bass (USFWS) and 20 µg / kg in smallmouth bass (this study). PCB concentration in rock bass tissue was 420 µg / kg and 270 µg / kg in smallmouth bass. *Trans*-nonachlor was detected at a concentration of 20 µg / kg in rock bass (USFWS) and 6.7 µg / kg in smallmouth bass (this study).

Although the differences between the studies preclude any definitive statement concerning changes in concentrations of DDT and its metabolites, PCB's, and chlordane during the decade between collections, DDE, PCB's, and *trans*-chlordane still persist in detectable concentrations in Juniata River fish.

The NSCRF study was designed as a one-time screening investigation to determine the prevalence of selected bioaccumulative pollutants in fish, to identify correlations with sources of these pollutants, and to make estimates of human health risks of these selected pollutants. Samples of fish tissue (whole body for bottom feeders and fillets for predators) were collected at four sites: Codorus Creek, Frankstown Branch of the Juniata River, Susquehanna River at Columbia, and Union Canal in Lebanon, Pa., during 1984-87 (U.S. Environmental Protection Agency, 1992). The Union Canal site is upstream of the Quittapahilla Creek site of the Lower Susquehanna River Basin study and had the highest concentrations of *p,p'*-DDE in carp (*Cyprinus carpio*) tissue nationwide in the NSCRF study. The Quittapahilla site had the highest concentrations of total DDT in any white sucker fish tissue found in the 20 NAWQA studies that began in 1991 (Lindsey and others, 1998).

White suckers were collected only at Frankstown Branch of the Juniata River allowing for a direct species comparison between the two studies. The only DDT metabolite analyzed for in the NSCRF study, *p,p'*-DDE, was measured in white sucker whole-fish tissue at a concentration of 22.2 µg / kg at the Frankstown Branch in 1987, as compared to 31 µg / kg during this study in 1992. The concentration of PCB was 51.5 µg / kg in 1987 compared to 120 µg / kg in 1992. The *trans*-nonachlor concentration was 5.56 µg / kg in 1987, whereas in 1992 the concentration was below the MRL of 5 µg / kg. Oxychlordane and *cis*-nonachlor were not detected in either study (< 2.5 µg / kg for NSCRF study and <5 µg / kg for this study). The *p,p'*-DDE and *trans*-nonachlor concentrations did not appear to change notably over a 15-year period; however, the PCB concentration from this study was more than twice that of the NSCRF result at the same site.

Comparison of NAWQA Studies in the Northeastern United States

Other NAWQA studies in the northeastern United States include the Hudson River Basin and the Connecticut River Basin. Sampling techniques and NWQL procedures were identical to those used in this study. For comparison, only sites with white sucker tissue data were used.

Comparison of total DDT among the three basins shows the median concentrations are significantly different at p=0.05 (fig. 2). Although the median concentration in the Lower Susquehanna River Basin was lower than either the Hudson River Basin or the Connecticut River Basin, concentrations at two sites in the Lower Susquehanna River Basin were the highest of all three study

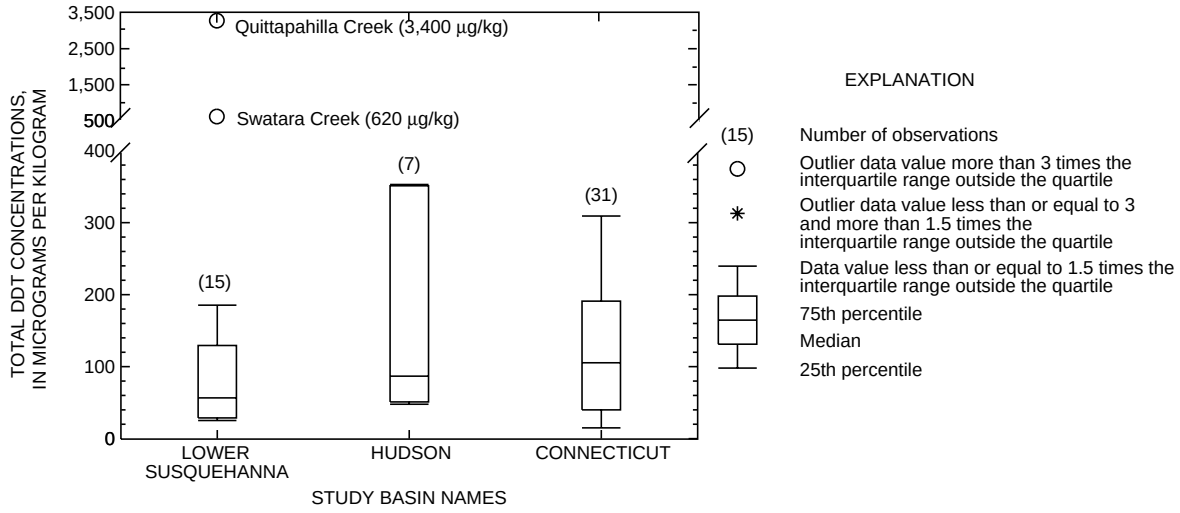

Figure 2. Concentrations of total DDT in white sucker whole fish tissue for the Lower Susquehanna, Hudson, and Connecticut River Basins.

units together. The data for each basin indicates that *p,p'*-DDE was the most frequently reported form of total DDT. This finding may indicate that no significant influx of DDT has recently occurred in these basins and that the degradation of DDT has taken similar pathways throughout these areas of the northeastern United States.

The PCB medians were not significantly different (p=0.05) among the three basins (fig. 3). The highest concentration in the Lower Susquehanna River Basin was at Codorus Creek (1,500 µg / kg). This outlier was dwarfed by concentrations at three sites in the Connecticut River Basin. All other samples are below 5,000 µg / kg for PCB's. PCB occurrence is widespread in the basins; the highest concentrations of PCB's center on known historical sources and urban areas at large-river sites (K.R. Murray, U.S. Geological Survey, oral commun. 1996). Some samples from the Connecticut River Basin had high PCB concentrations, which may be related to the known industrial point sources in the basin and may also include hydroelectric power generating facilities as a significant source (J.F. Coles, U.S. Geological Survey, oral commun. 1996). The Lower Susquehanna River Basin generally does not have these types of point sources.

Median values of total chlordane (consisting of *cis*- and *trans*-chlordane, *cis*- and *trans*-nonachlor, and oxychlordane) were not significantly different (p=0.05) among the basins (fig. 4). All three basins had outliers. The most commonly reported chlordane components in all three studies were *cis*-chlordane and *trans*-nonachlor. *Trans*-nonachlor concentrations were similar among the basins indicating that the concentrations of chlordane components in whole-body white sucker tissue were also similar.

Comparison with NAWQA Studies Across the United States

The NAWQA program in 1991 began studies of fish tissue organochlorine compounds in 18 river basins. The Lower Susquehanna River Basin study was included in the 18 studies. Compared to the other 17 studies, median concentrations of total PCB's in the Lower Susquehanna River Basin were the third highest, and the maximum concentration was the fifth highest (table 7). The Lower Susquehanna River Basin had the fifth highest median concentration and the highest maximum concentration of total DDT compared to the other studies (table 7). The median concentration of total chlordane in the Lower Susquehanna River Basin was the third highest and the maximum concentration was the fifth highest of the 18 studies (table 7). Concentrations of organochlorine compounds in

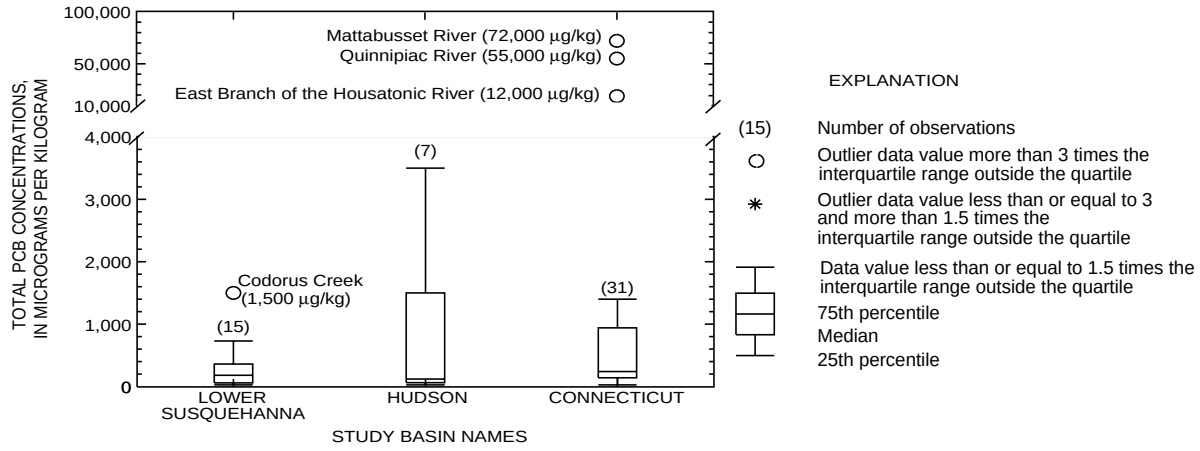

Figure 3. Concentrations of total PCB's in white sucker whole fish tissue for the Lower Susquehanna, Hudson, and Connecticut River Basins.

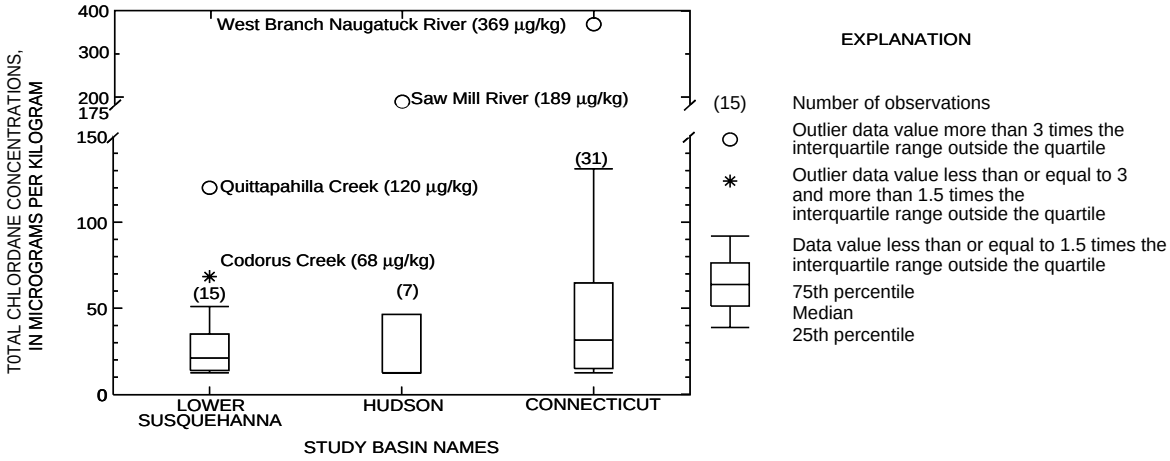

Figure 4. Concentrations of total chlordane in white sucker whole fish tissue for the Lower Susquehanna, Hudson, and Connecticut River Basins.

Table 7. *Comparison of median concentrations of total PCB's, total DDT, and total chlordane for the NAWQA study basins started in 1991*

[all concentrations are in micrograms per kilogram; L.H. Nowell, written commun., 1999]

Study basin	Total PCB		Total DDT		Total chlordane	
	Median concentration	Maximum concentration	Median concentration	Maximum concentration	Median concentration	Maximum concentration
Apalachicola-Chattahoochee-Flint River Basin	0	63	11	38	0	84
Albemarle-Pamlico Drainage	0	0	21	145	0	8
Central Columbia Plateau	0	820	157	2,998	0	46
Central Nebraska Basins	0	160	10	78	0	43
Connecticut, Housatonic, and Thames River Basins	220	72,000	80	304	23	369
Hudson River Basin	120	33,000	48	458	0	189
Lower Susquehanna River Basin	107	1,500	68	3,427	10	120
Ozark Plateaus	0	0	0	1	0	0
Potomac River Basin	83	390	0	255	0	127
Red River of the North	0	320	44	207	0	86
Rio Grande Valley	0	410	47	179	0	21
San Joaquin-Tulare Basins	0	52	90	510	0	0
South Platte River Basin	41	580	22	955	0	112
Trinity River Basin	48	640	103	449	5	292
Upper Snake River Basin	0	1,900	61	590	0	13
White River Basin	0	0	9	9	50	50
Willamette Basin	0	1,200	9	560	0	60
Western Lake Michigan Drainages	0	3,000	6	116	0	51

Table 8. *Concentrations of total PCB's, DDT metabolites, and chlordane components in whole fish tissue from national surveys of contaminant concentrations*

[NA, not analyzed; mixed, several game and bottom-feeding species collected to determine mean concentrations; USEPA-NSCRF, U.S. Environmental Protection Agency, National Study of Chemical Residues in Fish; NCBP, National Contaminant Biomonitoring Program; µg/kg, micrograms per kilogram]

Study	Fish species	Total number of sites	Mean concentrations in whole fish (µg/kg)								
			Total PCB[1]	*p,p'*-DDT	*p,p'*-DDD	*p,p'*-DDE	*cis*-chlordane	*trans*-chlordane	*cis*-nonachlor	*trans*-nonachlor	Oxy-chlordane
NCBP:											
1970-74[2]	Mixed	113	1,200	270	340	470	NA	NA	NA	NA	NA
1976-77[3]	Mixed	112	890	50	80	260	60	20	10	30	NA
1978-79[3]	Mixed	106	840	40	80	240	70	20	30	50	10
1980-81[3]	Mixed	108	530	50	70	200	30	20	20	40	10
1984[3]	Mixed	112	390	30	60	190	30	20	20	30	10
USEPA-NSCRF:											
1987[4]	Mixed	362	1,890	NA	NA	295	21.0	16.7	8.77	31.2	4.75
LOWER SUSQUEHANNA RIVER BASIN:											
1992	Mixed	16	266	12	107	131	7.3	3.7	5.4	12	3.7

[1] The NCBP study measured concentrations of only three Aroclors; the EPA-NSCRF study measured all chlorinated PCB compounds.
[2] Schmitt and others, 1981.
[3] Schmitt and others, 1990.
[4] U.S. Environmental Protection Agency, 1992.

the Lower Susquehanna River Basin appear to be higher than many of the 18 basins studied by the 1991 NAWQA studies.

Comparison with Studies across the United States

The NSCRF reported concentrations of contaminants in whole fish for a nationwide network of sampling sites (U.S. Environmental Protection Agency, 1992). A majority of these sites were sampled in 1987. Protocols called for the collection of three to five adult fish of the same species and of similar size. Fish age and gender were not determined. At nearly all sites, a composite sample of a bottom-feeding fish species and a game fish species was collected. Targeted sites were selected at 314 locations on the basis of the expected presence of contaminants from various point and nonpoint sources. In addition, 39 sites were chosen from the USGS National Stream Quality Accounting Network (NASQAN) and 35 were representative of background sites. NSCRF used single-species composites consisting of carp, channel catfish, white sucker, white bass, northern pike, walleye, smallmouth bass, largemouth bass, or crappie. Although the NSCRF-reported concentrations are based on combining all these single-species composites (no differentiation by species) and the site-selection process was in part based on known pollutant sources, a general assessment of contaminant occurrences (including national and regional contaminant concentrations) can be attempted. White suckers were sampled at 41 sites by NSCRF. Median concentrations were calculated from these 41 samples and were compared to northeastern regional and Lower Susquehanna River Basin median concentrations (table 8).

Total DDT was not reported by NSCRF; only the *p,p'*-DDE form was reported in measurable concentrations at 357 of 362 sites sampled nationwide, which included species other than white sucker. This was the most reported contaminant for all species at all sites. White sucker were analyzed for *p,p'*-DDE at 41 sites. Median concentrations show the northeastern region and the Lower Susquehanna River Basin as having higher concentrations of *p,p'*-DDE than the nation. The medians for the NSCRF and the Lower Susquehanna River Basin are not significantly different (p=0.05); the medians for the Lower Susquehanna and the northeastern region are different (p=0.05). The medians for the northeastern region were significantly higher than those for the nation and the Lower Susquehanna River Basin (table 9).

PCB analysis by NSCRF was for all chlorinated PCB compounds (U.S. Environmental Protection Agency, 1992) and not specific Aroclors as in the regional and local studies. Total PCB concentrations were detected at 331 of 362 sites sampled for numerous species for the NSCRF. The white sucker median for NSCRF was below the MRL. The medians for the Lower Susquehanna Basin

and the northeastern region were above the MRL and were not significantly different (p=0.05).

Chlordane and related compounds in the NSCRF study were reported at 278 of the 362 sites surveyed for all fish species. Oxychlordane, a metabolic breakdown product of chlordane, was reported at 98 of the 362 sites. The median concentration for this component of chlordane in white sucker was below the MRL for all studies.

The National Contaminant Biomonitoring Program (NCBP) was implemented in 1967 by the USFWS in an attempt to establish temporal and geographic trends in concentrations of environmental contaminants that may threaten fish and wildlife resources on a nationwide basis (Schmitt and others, 1981). As part of this program, fish were sampled during four collection periods: 1970 to 1974, 1976 to 1979, 1980 to 1981, and 1984 (Schmitt and others, 1990).

The most frequently collected taxa throughout all the years of study were common carp (*Cyprinus carpio*), white sucker (*Catostomus commersoni*), largemouth bass (*Micropterus salmoides*), and other members of the families Cyprinidae, Catostomidae, and Centrarchidae. Three to five adults of a single species, usually collected in the autumn, constituted a composite. Data were presented as means of contaminant concentrations for every species at every site to give overall nationwide contaminant concentrations. The *p,p'*- forms of total DDT were the only metabolites that were analyzed for in the fish (Schmitt and others, 1990).

The only DDT form comparable between the two studies was *p,p*'-DDE. NCBP data show a decline over time in concentration of *p,p*'-DDE. The NSCRF shows concentrations comparable to the 1976-77 NCBP data.

The NCBP data show a decline of total PCB concentrations between 1970 and 1984. The NSCRF study from 1987 showed concentrations higher than the 1970-84 concentrations. NSCRF was designed to target sites where PCB's were expected to occur and NCBP was designed to show trends.

The combination of these two studies has shown a decline in chlordane concentrations. *Trans*-nonachlor, the final degradation product of chlordane, has remained relatively constant while the other chlordane components concentrations have decreased. The Lower Susquehanna River Basin mean concentrations were lower for total PCB's, *p,p*'-DDE, and t*rans*-nonachlor than either of the national studies, which perpetuates the theory that organochlorine compound concentrations are declining in fish.

Comparison With Established Standards and Guidelines

Concentrations of organochlorine compounds from this study exceeded established standards and guidelines (Nowell and Resek, 1994) for whole-fish tissue at only a few sites. The NAS and the NAE guideline for the protection of fish-eating birds and wildlife for total chlordane (100 µg/kg) was exceeded for white sucker at one site, Quittapahilla Creek. The U.S. Food and Drug Administration (USFDA) action level for human consumption for total chlordane in the edible portion (300 µg/kg) was not exceeded at any sites selected within the basin. Although concentrations in whole fish and edible portions (fillets) are not directly comparable, the collection of fillet data in future studies might aid in identifying problem sites.

Table 9. *Concentrations of total PCB's, p,p'-DDE and oxychlordane in white sucker whole-fish tissue from a national survey, a regional survey, and this study of the Lower Susquehanna River Basin, Pa.*
[USEPA-NSCRF, U.S. Environmental Protection Agency, National Study of Chemical Residues in Fish; nd, no detects; µg/kg, micrograms per kilogram]

Study	Number of sites	Median concentrations of whole fish (µg/kg)		
		Total PCB's[1]	*p,p'*-DDE	oxychlordane
USEPA-NSCRF[2]	41	nd	24	nd
Northeastern Region[3]	53	191	525	nd
Lower Susquehanna River Basin	15	150	36	nd

[1] The USEPA-NSCRF study measured all chlorinated PCB compounds; the Lower Susquehanna, Hudson, and Connecticut studies measured only three Aroclors.
[2] U.S. Environmental Protection Agency, 1992.
[3] Lower Susquehanna, Hudson, and Connecticut studies data combined.

There is no guideline for total PCB's from NAS, NAE (1973). The USFDA action level (2,000 µg / kg) was not exceeded. Because only Aroclors 1242, 1254, and 1260 were determined by the NWQL as the total PCB concentration, it is difficult to speculate on the toxicological significance of these reported values.

The total DDT guideline from NAS, NAE (1973; 1,000 µg / kg) was exceeded at only one site, Quittapahilla Creek. No exceedances were reported for the USFDA action level (5,000 µg / kg) at any of the sampling locations.

CONCLUSIONS

Most organochlorine pesticides and PCB's were banned from use in the United States in the 1970's and 1980's, yet, because of their inherent stability, measurable concentrations still persist in whole-body fish tissue. This paper gives the concentrations of 12 selected organochlorine contaminants in samples of whole-body white sucker and smallmouth bass tissue collected from 16 sites in the Lower Susquehanna River Basin in 1992.

The most frequently reported compounds for both white sucker and smallmouth bass were *p,p'*-DDT, *p,p'*-DDE (found in all tissue samples in the study), total PCB's, and *trans*-nonachlor. Similar results were observed at regional and national scales.

Comparisons of concentrations of organochlorine compounds detected in whole-body white sucker tissue to major land-use categories within the Lower Susquehanna River Basin study show that total DDT concentrations were highest at the agriculture-dominated (>50 percent) sites that had more than one permitted point source. Total PCB concentrations in tissue were higher at the small stream sites than at the Susquehanna River main-stem sites. These small streams had the greatest area of urban land use (> 10 percent) and thus PCB's seemed to represent an urban signature. Concentrations of total chlordane were highest at sites with greater than 70 percent agricultural land use and an urban signature. Tissue samples from sites categorized as forest dominated (>50 percent) had the lowest concentrations of organochlorine compounds overall.

Median concentrations of total DDT were significantly lower in the Lower Susquehanna River Basin than the Hudson and Connecticut River Basins (p=0.05), although the highest concentration in any of the Basins was measured in the sample of white suckers from the Quittapahilla Creek in the Lower Susquehanna River Basin. The fact that the *p,p'*-DDE form of total DDT was the most prevalent for the three studies indicates there has been no recent significant influx of DDT to the basins and that the degradation of DDT has taken similar pathways throughout the northeastern United States. Median concentrations of total PCB's and total chlordane were not significantly different among the three basins. The most commonly detected chlordane component and the most persistent was *trans*-nonachlor.

The median concentration of total PCB's in white sucker reported in the NSCRF in fish by USEPA were lower than those reported from the Lower Susquehanna River Basin and the northeastern region of the United States. The median concentration of *p,p'*-DDE in the Lower Susquehanna River Basin was not significantly different from the national median but was significantly lower than the northeastern regional median (p=0.05). The median concentrations of oxychlordane detected in the Lower Susquehanna River Basin, as well as those reported in the Northeast and in the national study were all below the MRL.

REFERENCES CITED

Berg, T.M., Barnes, J.H., Sevon, W.D., Skema, V.W., Wilshusen, J.P., and Yannacci, D.W., 1989, Physiographic provinces of Pennsylvania: Pennsylvania Geological Survey, 4th ser., Map 13 (color), scale 1:2,000,000, 8.5 x 11 inches.

Breen, K.J., Hainly, R.A., and Hoffman, S.A., 1991, National Water-Quality Assessment Program—the Lower Susquehanna River Basin: U.S. Geological Survey Open-File Report 91-168, 2 p.

Coles, J.F., 1996, Organochlorine compounds and trace elements in fish tissue and ancillary data for the Connecticut, Housatonic, and Thames River Basins Study Unit, 1992-94: U.S. Geological Survey Open-File Report 96-358.

Crawford, J.K., and Luoma S.N., 1993, Guidelines for studies of contaminants in biological tissues for the National Water-Quality Assessment Program: U.S. Geological Survey Open-File Report 92-494, 69 p.

Deelder, C.L., and Willemse, J.J., 1973, Age determination in fresh-water teleosts, based on annular structures in fin-rays: Aquaculture 1, p. 365-371.

Firda, C.D., Lumis, K., Murray, P.M., and Freeman, W.O., 1993, Water Resources Data, New York, Water Year 1993, vol. 1.: U.S. Geological Survey Water-Data Report NY-93-1, p. 377-379.

Gilliom, R.J., Alley, W.M., and Gurtz, M.E., 1995, Design of the National Water-Quality Assessment Program—Occurrence and distribution of water-quality conditions: U.S. Geological Survey Circular 1112, 33 p.

Great Lakes Basin Commission, 1975, Great Lakes Basin framework study, Appendix 8: Ann Arbor, Mich., Great Lakes Basin Commission, p. 47-49.

Gurtz, M.E., 1994, Design of biological components of the National Water-Quality Assessment (NAWQA) Program *in* Loeb, S.L., and Spacie, A., eds., Biological monitoring of aquatic systems: Boca Raton, Fla., Lewis Publishers, p. 323-354.

Harrison, S.E., and Klaverkamp, J.F., 1990, Metal contamination in liver and muscle of northern pike (*Exos lucius*) and white sucker (*Catostomus commersoni*) and in sediments from lakes near the smelter at Flin Flon, Manitoba: Environmental Toxicology and Chemistry., vol. 9, p. 941-956.

Haynes, W.J., and Laws, E.R., 1991, Handbook of pesticide toxicology, vols. 1 and 2: San Diego, Calif., Academic Press.

Hirsch, R.M., Alley, W.M., and Wilber, W.G., 1988, Concepts for National Water-Quality Assessment Program: U.S. Geological Survey Circular 1021, 42 p.

Leahy, P.P., Rosenshein, J.S., and Knopman, D.S., 1990, Implementation plan for the National Water-Quality Assessment Program: U.S. Geological Survey Open-File Report 90-174, 10 p.

Leahy, P.P., and Wilber, W.G., 1991, National Water-Quality Assessment Program: U.S. Geological Survey Open-File Report 91-54, 2 p.

Leiker, T.J., Madsen, J.E., Deacon, J.R., and Foreman, W.T., 1995, Methods of analysis by the U.S. Geological Survey National Water Quality Laboratory—Determination of chlorinated pesticides in aquatic tissue by capillary-column gas chromatography with electron-capture detection: U.S. Geological Survey Open-File Report 94-710, 42 p.

Lindsey, B.D., Breen, K.J., Bilger, M.D., and Brightbill, R.A., 1998, Water quality in the Lower Susquehanna River Basin, Pennsylvania and Maryland, 1992-95: U.S. Geological Survey Circular 1168, 38 p.

Majewski, M.S., and Capel, P.D., 1995, Pesticides in the atmosphere—Distribution, trends, and governing factors: Ann Arbor, Mich., Ann Arbor Press, 214 p.

McFarland, V.A., and Clarke, J.U., 1989, Environmental occurrence, abundance, and potential toxicity of polychlorinated biphenyl congeners—Considerations for a congener-specific analysis: Environ Health Perspectives. 81, p. 225-239.

National Academy of Sciences & National Academy of Engineering, 1973, Water quality criteria 1972: Ecological Research Series, EPA-R3-73-033, 594 p.

Nowell, L.H., and Resek, E.A., 1994, National standards and guidelines for pesticides in water, sediment, and aquatic organisms—Application to water-quality assessments *in* Reviews of Environmental Contamination and Toxicology: New York, N.Y., Springer-Verlang, vol. 140, 221 p.

Risser, D.W., and Siwiec, S.F., 1996, Water-quality assessment of the Lower Susquehanna River Basin—Environmental setting: U.S. Geological Survey Water-Resources Investigations Report 94-4245, 50 p.

Rompala, J.M., Rutkosky, F.W., Putnam, D.J., and Kulp, C.J., 1984, Concentrations of environmental contaminants in fish from selected waters in Pennsylvania: State College, Pa., U.S. Fish and Wildlife Service, p. 1-9, 13, 39-47, 65-69.

Schmitt, C.J., Ludke, J.L., and Walsh, D.F., 1981, Organochlorine residues in fish—National Pesticide Monitoring Program 1970-74: Pesticide Monitoring Journal, 14(4), p 136-206.

Schmitt, C.J., Zajicek, J.L., and Peterman, P.H., 1990, National Contaminant Biomonitoring Program:—Residues of organochlorine chemicals in U.S. freshwater fish, 1976-1984: Archives of Environmental Contamination and Toxicology, vol. 19, p. 748-781.

Smith, J.A., Witkowski, P.J., and Fusillo, T.V., 1988, Manmade organic compounds in the surface waters of the United States—A review of current understanding: U.S. Geological Survey Circular 1007, 92 p.

Tate, C.M., and Heiny, J.S., 1996, Organochlorine compounds in bed sediment and fish tissue in the South Platte River Basin USA, 1992-1993: Archives of Environmental Contamination and Toxicology, vol. 30, 62-78.

U.S. Environmental Protection Agency, 1979, Water-related environmental fate of 129 priority pollutants, vol. 1, Introduction and technical background, metals and inorganics, pesticides and PCB's: Washington, D.C., U.S. Environmental Protection Agency, p. 22/1-25/21, 36/1-36/18.

_____1992, National study of chemical residues in fish (vols. I and II): Office of Science and Technology, Standards and Applied Science Division, EPA 823-R-92-008 a and b, 166 p.

_____1993, Guidance for assessing chemical contaminant data for use in fish advisories (vol. I), Fish sampling and analysis: Office of Water, EPA 823-R-93-002, 327 p.

Zar, J.H., 1984, Biostatistical analysis (2nd ed.): Englewood Cliffs, N.J., Prentice-Hall, Inc., 718 p.