1) page 485: Replace paragraph under Human Health Section for Methylmercury with the following: EPA is recommending that the Programs and Regions use 0.1 µg/kg/day as an interim RfD for methylmercury until the Agency has had an opportunity to review the work of the National Academy of Science (NAS). NAS is performing an independent assessment of the Agency's reference dose (RfD) for methylmercury (EPA 1999).
[U.S. EPA. 1999. Memo: Transmittal of Interim Agency Guidance on the Use of Methylmercury Reference Dose in Making Risk Management Decisions. From: Peter D. Robertson Acting Deputy Administrator, To: Assistant Administrators, General Counsel, Inspector General, Chief Financial Officer, Associate Administrators, Regional Administrators and Staff Office Directors (April 19, 1999)].

2) pages 7, 23, 35, 45, 61: Add to Human Health: Oral slope factor: 2.0 per mg/kg/d based on environmental mixtures of PCBs in aquatic organisms (EPA 1996)
[U.S. EPA. 1996. *Cancer Dose-Response Assessment for Application to Environmental Mixtures.* EPA/600/P-96/001F. Washington, DC].

3) The table below provides the latest World Health Organization (WHO) toxic equivalent factors (TEFs) for dioxins, furans, and coplanar PCBs. They are more recent than those cited in this document.

Congener	**Toxic Equivalent Factor (TEF)**
2,3,7,8-TCDD	1
1,2,3,7,8-PeCDD	1
1,2,3,4,7,8-HxCDD	0.1
1,2,3,6,7,8-HxCDD	0.1
1,2,3,7,8,9-HxCDD	0.1
1,2,3,4,6,7,8,-HpCDD	0.01
OCDD	0.0001
2,3,7,8-TCDF	0.1
1,2,3,7,8-PeCDF	0.05
2,3,4,7,8-PeCDF	0.5
1,2,3,4,7,8-HxCDF	0.1
1,2,3,6,7,8-HxCDF	0.1
1,2,3,7,8,9-HxCDF	0.1
2,3,4,6,7,8-HxCDF	0.1
1,2,3,4,6,7,8-HpCDF	0.01
1,2,3,4,7,8,9-HpCDF	0.01
OCDF	0.0001
3,4,4′,5-TCB(81)	0.0001
3,3′,4,4′-TCB(77)	0.0001
3,3′,4,4′,5-PeCB(126)	0.1
3,3′,4,4′,5,5′-HxCB(169)	0.01
2,3,3′,4,4′-PeCB(105)	0.0001
2,3,4,4′,5-PeCB(114)	0.0005
2,3′,4,4′,5-PeCB(118)	0.0001
2′,3,4,4′,5-PeCB(123)	0.0001
2,3,3′,4,4′,5-HxCB(156)	0.0005
2,3,3′,4,4′,5-HxCB(157)	0.0005
2,3′,4,4′,5,5′-HxCB(167)	0.00001
2,3,3′,4,4′,5,5′-HpCB(189)	0.0001

Van den Berg, et. al. 1998. Toxic Equivalency Factors (TEFs) for PCBs, PCDDs, PCDFs for Humans and Wildlife. *Environ. Health Perspect.* 106(12):775-792.

APPENDIX

Chemical-Specific Summary Tables

CONTENTS

Chemical Category: POLYNUCLEAR AROMATIC HYDROCARBON (low molecular weight)

Chemical Name (Common Synonyms): ACENAPHTHENE **CASRN:** 83-32-9

Chemical Characteristics

Solubility in Water: Insoluble [1]

Half-Life: No data [1,2]

Log K_{ow}: 3.92 [3]

Log K_{oc}: 3.85 L/kg organic carbon

Human Health

Oral RfD: 6 x 10^{-2} mg/kg/day [4]

Confidence: Low uncertainty factor = 3000

Critical Effect: Hepatotoxicity

Oral Slope Factor: No data [4]

Carcinogenic Classification: –

Wildlife

Partitioning Factors: Partitioning factors for acenaphthene in wildlife were not found in the literature.

Food Chain Multipliers: Food chain multipliers for acenaphthene in wildlife were not found in the literature.

Aquatic Organisms

Partitioning Factors: The water quality criterion tissue level (WQCTL) for acenaphthene, which is calculated by multiplying the water quality chronic value (710 µg/L) by the BCF (389.05), is 276,222 µg/kg [5].

Food Chain Multipliers: Food chain multipliers for acenaphthene in aquatic organisms were not found in the literature.

Toxicity/Bioaccumulation Assessment Profile

Most polynuclear aromatic hydrocarbons (PAHs) occur in sediment as complex mixtures. The toxicities of individual PAHs are additive and increase with increasing K_{ow}, whereas the bioavailabilities of PAHs decrease as a function of their K_{ow}s. The 10-day LC50s for *Eohaustorius estuarius* and *Leptocheirus plumulosus* in water were 374 µg/L and 678 µg/L, respectively [6]. Both amphipod species were exposed to acenaphthene-spiked sediments with total organic carbon ranging from 0.82 percent to 4.21 percent.

The 10-day LC50s ranged from 1,630 to 4,330 µg/g for *E. estuarius* and from 7,730 µg/g to >23,500 µg/g for *L. plumulosus*.

Bioaccumulation of low-molecular-weight PAHs including acenaphthene from sediments by *Rhepoxynius abronius* (amphipod) and *Armandia brevis* (polychaete) was similar; however, a large difference in tissue concentration between these two species was measured for high-molecular-weight PAHs [12]. Meador et al. [12] concluded that the low-molecular-weight PAHs were available to both species from interstitial water, while sediment ingestion was a much more important uptake route for the high-molecular-weight PAHs. The authors also indicated that bioavailability of the high-molecular weight-PAHs to amphipods was significantly reduced due to their partitioning to dissolved organic carbon.

Summary of Biological Effects Tissue Concentrations for Acenaphthene

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	Sediment µmol/g	Water µmol/L	Tissue (Sample Type) µmol/g	Effects	Log BCF	Log BAF	BSAF	Reference	Comments[3]
Invertebrates									
Nereis succinea, Polychaete worm	0.00003 0.001 0.0004 BDL BDL		BDL[4] BDL BDL 0.025 BDL					[7]	F
Corbicula fluminea, Asiatic clam		<0.003 <0.003	<0.0005 <0.0007					[8]	F
Mytilus edulis, Blue mussel						-0.35		[9]	F
Crassostrea virginica, Eastern oyster						-0.03		[9]	F
Macoma balthica, Baltic macoma	0.00003 0.001 0.0004		BDL BDL BDL					[7]	F
Mercenaria mercenaria, Northern quahog						-0.44 -0.09		[9]	F
Mya arenaria, Softshell						0.09		[9]	F

Summary of Biological Effects Tissue Concentrations for Acenaphthene

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	Sediment µmol/g	Water µmol/L	Tissue (Sample Type) µmol/g	Effects	Log BCF	Log BAF	BSAF	Reference	Comments[3]
Decapoda	0.034 0.041 0.675		0.001 0.017 0.027					[10]	F
Homarus americanus, American lobster						-0.89		[9]	F
Fishes									
Fundulus spp., Killifish						-0.33		[9]	F
Poecilia reticulata, Guppy		0.14-0.15	0.047 0.027 0.047 0.051					[11]	F
Lepomis sp., Sunfish	0.034 0.041 0.675		0.058 0.038 0.092					[10]	F
Tautogolabrus adspersus, Tautog						-1.22		[9]	F

[1] Concentration units based on wet weight unless otherwise noted.
[2] BCF = bioconcentration factor, BAF = bioaccumulation factor, BSAF = biota-sediment accumulation factor.
[3] L = laboratory study, spiked sediment, single chemical; F = field study, multiple chemical exposure; other unusual study conditions or observations noted.
[4] BDL = below detection limit.

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Chemical Category: POLYCHLORINATED BIPHENYLS

Chemical Name (Common Synonyms): Aroclor 1016 **CASRN:** 1336-36-3

Chemical Characteristics

Solubility in Water: 225-250 µg/L at 25°C [1]

Half-Life: No data [2,3]

Log K_{ow}: 5.6 [4]

Log K_{oc}: No data [4]

Human Health

Oral RfD: 7 x 10^{-5} mg/kg-day [5]

Confidence: Medium [5]

Critical Effect: PCBs have been shown to cause reproductive failure, birth defects, lesions, tumors, liver disorders, and death among sensitive species. Their toxicity is further enhanced by their ability to bioaccumulate and to biomagnify within the food chain due to extremely high lipophilicity [2].

Oral Slope Factor: No data [5]

Carcinogenic Classification: Unknown [5]

Wildlife

Partitioning Factors: No partitioning factors for Aroclor 1016 were identified for wildlife.

Food Chain Multipliers: For PCBs as a class the most toxic congeners have been shown to be selectively accumulated from organisms at one trophic level to the next [6]. At least three studies have concluded that PCBs have the potential to biomagnify in food webs based on aquatic organisms and predators that feed primarily on aquatic organisms [7,8,9]. The results from Biddinger and Gloss [7] and USACE [9] generally agreed that highly water-insoluble compounds (including PCBs) have the potential to biomagnify in these types of food webs. Thomann's [10] model also indicated that highly water-insoluble compounds (log K_{ow} values 5 to 7) showed the greatest potential to biomagnify. A biomagnification factor of 32 was determined for total PCBs from alewife to herring gull eggs in Lake Ontario [11]. No specific food chain multipliers were identified for Aroclor 1016.

Aquatic Organisms

Partitioning Factors: No partitioning factors for Aroclor 1016 were identified for aquatic organisms.

Food Chain Multipliers: Polychlorinated biphenyls as a class have been demonstrated to biomagnify through the food web. Oliver and Niimi [12], studying accumulation of PCBs in various organisms in the Lake Ontario food web, reported concentrations of total PCBs in phytoplankton, zooplankton, and several species of fish. Their data indicated a progressive increase in tissue PCB concentrations moving

from organisms lower in the food web to top aquatic predators. In a study of PCB accumulation in lake trout (*Salvelinus namaycush*) of Lake Ontario, Rasmussen et al. [13] reported that each trophic level contributed about a 3.5-fold biomagnification factor to the PCB concentrations in the trout. No specific food chain multipliers were identified for Aroclor 1016.

Toxicity/Bioaccumulation Assessment Profile

PCBs are a group (209 congeners/isomers) of organic chemicals, based on various substitutions of chlorine atoms on a basic biphenyl molecule. These manufactured chemicals have been widely used in various processes and products because of the extreme stability of many isomers, particularly those with five or more chlorines [14]. A common use of PCBs was as dielectric fluids in capacitors and transformers. In the United States, Aroclor is the most familiar registered trademark of commercial PCB formulations. Generally, the first two digits in the Aroclor designation indicate that the mixture contains biphenyls, and the last two digits give the weight percent of chlorine in the mixture. The exception to this code is Aroclor 1016, which contains mono- through hexachlorinated homologs with an average chlorine content of 41 percent [4].

As a result of their stability and their general hydrophobic nature, PCBs released to the environment have dispersed widely throughout the ecosystem [14]. PCBs are among the most stable organic compounds known, and chemical degradation rates in the environment are thought to be slow. As a result of their highly lipophilic nature and low water solubility, PCBs are generally found at low concentrations in water and at relatively high concentrations in sediment [15]. Individual PCB congeners have different physical and chemical properties based on the degree of chlorination and position of chlorine substitution, although differences with degree of chlorination are more significant [15]. Solubilities and octanol-water partition coefficients for PCB congeners range over several orders of magnitude [16]. Octanol-water partition coefficients, which are often used as estimators of the potential for bioconcentration, are highest for the most chlorinated PCB congeners.

Dispersion of PCBs in the aquatic environment is a function of their solubility [15] while PCB mobility within and sorption to sediment are a function of chlorine substitution pattern and degree of chlorination [17]. The concentration of PCBs in sediments is a function of the physical characteristics of the sediment, such as grain size [18,19] and total organic carbon content [18,19,20,21]. Fine sediments typically contain higher concentrations of PCBs than coarser sediments because of more surface area [15]. Mobility of PCBs in sediment is generally quite low for the higher chlorinated biphenyls [17]. Therefore, it is common for the lower chlorinated PCBs to have a greater dispersion from the original point source [15]. Limited mobility and high rates of sedimentation could prevent some PCB congeners in the sediment from reaching the overlying water via diffusion [17].

The persistence of PCBs in the environment is a result of their general resistance to degradation [16]. The rate of degradation of PCB congeners by bacteria decreases with increasing degree of chlorination [22]; other structural characteristics of the individual PCBs can affect susceptibility to microbial degradation to a lesser extent [16]. Photochemical degradation, via reductive dechlorination, is also known to occur in aquatic environments; the higher chlorinated PCBs appear to be most susceptible to this process [21].

Toxicity of PCB congeners is dependent on the degree of chlorination as well as the position of chlorine substitution. Lesser chlorinated congeners are more readily absorbed, but are metabolized more rapidly than higher chlorinated congeners [23]. PCB congeners with no chlorine substituted in the ortho (2 and 2′) positions but with four or more chlorine atoms at the meta (3 and 3′) and para (4 and 4′) positions can assume a planar conformation that can interact with the same receptor as the highly toxic 2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD) [24]. Examples of these more toxic, coplanar congeners are 3,3′,4,4′-tetrachlorobiphenyl (PCB 77), 3,3′,4,4′,5-pentachlorobiphenyl (PCB 126), and 3,3′,4,4′5,5′-hexachlorobiphenyl (PCB 169). A method that has been proposed to estimate the relative toxicity of mixtures is to use toxic equivalency factors (TEFs) [25]. With this method, relative potencies for individual congeners are calculated by expressing their potency in relation to 2,3,7,8-TCDD. The following TEFs have been recommended [25,26]:

Congener Class	Recommended TEF
3,3′,4,4′,5-PentaCB	0.1
3,3′,4,4′,5,5′-HexaCB	0.05
3,3′,4,4′-TetraCB	0.01
Monoortho coplanar PCBs	0.001
Diortho coplanar PCBs	0.00002

Due to the toxicity, high K_{ow} values, and highly persistent nature of many PCBs, they possess a high potential to bioaccumulate and exert reproductive effects in higher-trophic-level organisms. Aquatic organisms have a strong tendency to accumulate PCBs from water and food sources. The log bioconcentration factor for fish is approximately 4.70 [27]. This factor represents the ratio of concentration in tissue to the ambient water concentration. Aquatic organisms living in association with PCB-contaminated sediments generally have tissue concentrations equal to or greater than the concentration of PCB in the sediment [27]. Once taken up by an organism, PCBs partition primarily into lipid compartments [15]. Thus, differences in PCB concentration between species and between different tissues within the same species may reflect differences in lipid content [15]. PCB concentrations in polychaetes and fish have been strongly correlated to their lipid content [28]. Elimination of PCBs from organisms is related to the characteristics of the specific PCB congeners present. It has been shown that uptake and depuration rates in mussels are high for lower-chlorinated PCBs and much lower for higher-chlorinated congeners [29, 30]. In some species, tissue concentrations of PCBs in females can be reduced during gametogenesis because of PCB transfer to the more lipophilic eggs. Therefore, the transferred PCBs are eliminated from the female during spawning [31,32]. Fish and other aquatic organisms biotransform PCBs more slowly than other species, and they appear less able to metabolize, or excrete, the higher chlorinated PCB congeners [31]. Consequently, fish and other aquatic organisms may accumulate more of the higher chlorinated PCB congeners than is found in the environment [16].

The acute toxicity of PCBs appears to be relatively low, but results from chronic toxicity tests indicate that PCB toxicity is directly related to the duration of exposure [1]. Toxic responses have been noted to occur at concentrations of 0.03 and 0.014 µg/L in marine and freshwater environments, respectively [1]. The LC50 for grass shrimp exposed to PCBs in marine waters for 4 days was 6.1 to 7.8 µg/L [1]. Chronic toxicity of PCBs presents a serious environmental concern because of their resistance to degradation [33], although the acute toxicity of PCBs is relatively low compared to that of other chlorinated hydrocarbons. Sediment contaminated with PCBs has been shown to elicit toxic responses at relatively low concentrations. Sediment bioassays and benthic community studies suggest that chronic effects generally occur in sediment at total PCB concentrations exceeding 370 µg/kg [34].

A number of field and laboratory studies provide evidence of chronic sublethal effects on aquatic organisms at low tissue concentrations [16]. Field and Dexter [16] suggest that a number of marine and freshwater fish species have experienced chronic toxicity at PCB tissue concentrations of less than 1.0 mg/kg and as low as 0.1 mg/kg. Spies et al. [35] reported an inverse relationship between PCB concentrations in starry flounder eggs in San Francisco Bay and reproductive success, with an effective PCB concentration in the ovaries of less than 0.2 mg/kg. Monod [36] also reported a significant correlation between PCB concentrations in eggs and total egg mortality in Lake Geneva char. PCBs have also been shown to cause induction of the mixed function oxidase (MFO) system in aquatic animals, with MFO induction by PCBs at tissue concentrations within the range of environmental exposures [16].

Summary of Biological Effects Tissue Concentrations for Aroclor 1016

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	Sediment	Water	Tissue (Sample Type)	Effects	Log BCF	Log BAF	BSAF	Reference	Comments[3]
Invertebrates									
Crassostrea virginica, Oyster			4 mg/kg (whole body)[4]	Growth, ED10				[38]	L; reduction in shell growth
			32 mg/kg (whole body)[4]	Growth, NA				[38]	L; reduction in shell growth
			95 mg/kg (whole body)[4]	Growth, NA					L; reduction in shell growth
Limulus polyphemus, Horseshoe Crab			11.2 mg/kg (whole body)[4]	Growth, NA				[37]	L; delayed molting; less than 50% molted after 96 days starting with T2-stage crabs
			31.9 mg/kg (whole body)[4]	Growth, NA				[37]	L; delayed molting; less than 50% molted after 96 days starting with T1-stage crabs
			11.2 mg/kg (whole body)[4]	Mortality, NA				[37]	L; less than 50% mortality starting with T2-stage crabs
Fishes									
Lagodon rhomboides, Pinfish			38 mg/kg (muscle)[4]	Mortality, ED50				[38]	L; 50% mortality
			30 mg/kg (muscle)[4]	Mortality, ED50				[38]	L; 50% mortality
			72 mg/kg (muscle and skin)[4]	Mortality, ED50				[38]	L; 50% mortality

Summary of Biological Effects Tissue Concentrations for Aroclor 1016

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	Sediment	Water	Tissue (Sample Type)	Effects	Log BCF	Log BAF	BSAF	Reference	Comments[3]
			48 mg/kg (muscle and skin)[4]	Mortality, ED50				[38]	L; 50% mortality
			205 mg/kg (whole body)[4]	Mortality, ED50				[38]	L; 50% mortality
			106 mg/kg (whole body)[4]	Behavior, LOED				[38]	L; erratic swimming, stopped feeding, loss of equilibrium
			38 mg/kg (muscle)[4]	Behavior, LOED				[38]	L; erratic swimming, stopped feeding, loss of equilibrium
			72 mg/kg (muscle and skin)[4]	Behavior, LOED				[38]	L; erratic swimming, stopped feeding, loss of equilibrium
			205 mg/kg (whole body)[4]	Cellular, LOED				[38]	L; liver and pancreatic cell alterations
			30 mg/kg (muscle)[4]	Cellular, LOED				[38]	L; liver and pancreatic cell alterations
			48 mg/kg (muscle and skin)[4]	Cellular, LOED				[38]	L; liver and pancreatic cell alterations
			106 mg/kg (whole body)[4]	Morphology, LOED				[38]	L; darkened coloration
			38 mg/kg (muscle)[4]	Morphology, LOED				[38]	L; darkened coloration
			72 mg/kg (muscle and skin)[4]	Morphology, LOED				[38]	L; darkened coloration

Summary of Biological Effects Tissue Concentrations for Aroclor 1016

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	Sediment	Water	Tissue (Sample Type)	Effects	Log BCF	Log BAF	BSAF	Reference	Comments[3]
			205 mg/kg (whole body)[4]	Mortality, LOED				[38]	L; statistically significant increase in mortality
			140 mg/kg (muscle)[4]	Mortality, LOED				[38]	L; statistically significant increase in mortality
			30 mg/kg (muscle)[4]	Mortality, LOED				[38]	L; statistically significant increase in mortality
			180 mg/kg (muscle and skin)[4]	Mortality, LOED				[38]	L; statistically significant increase in mortality
			48 mg/kg (muscle and skin)[4]	Mortality, LOED				[38]	L; 5% mortality in 96 hours
			2.2 mg/kg (whole body)[4]	Mortality, LOED				[38]	L; statistically significant increase in mortality
			620 mg/kg (whole body)[4]	Mortality, LOED				[38]	L; statistically significant increase in mortality
			106 mg/kg (whole body)[4]	Mortality, NA				[38]	L; 18% mortality in 96 hours
			65 mg/kg (whole body)[4]	Cellular, NOED				[38]	L; no incidence of pathology (liver and pancreatic alterations)
			23 mg/kg (muscle)[4]	Cellular, NOED				[38]	L; no incidence of pathology (liver and pancreatic alterations)

Summary of Biological Effects Tissue Concentrations for Aroclor 1016

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	**Sediment**	**Water**	**Tissue (Sample Type)**	**Effects**	**Log BCF**	**Log BAF**	**BSAF**	**Reference**	**Comments[3]**
			49 mg/kg (muscle and skin)[4]	Cellular, NOED				[38]	L; no incidence of pathology (liver and pancreatic alterations)
			111 mg/kg (whole body)[4]	Mortality, NOED				[38]	L; no statistically significant increase in mortality
			63 mg/kg (muscle)[4]	Mortality, NOED				[38]	L; no statistically significant increase in mortality
			23 mg/kg (muscle)[4]	Mortality, NOED				[38]	L; no statistically significant increase in mortality
			76 mg/kg (muscle and skin)[4]	Mortality, NOED				[38]	L; no statistically significant increase in mortality
			49 mg/kg (muscle and skin)[4]	Mortality, NOED				[38]	L; no mortality in 96 hours
			21 mg/kg (whole body)[4]	Mortality, NOED				[38]	L; no statistically significant increase in mortality
			170 mg/kg (whole body)[4]	Mortality, NOED				[38]	L; no statistically significant increase in mortality
			111 mg/kg (whole body)[4]	Physiological, NOED				[38]	L; no reduced ability to survive osmotic stress after exposure

Summary of Biological Effects Tissue Concentrations for Aroclor 1016

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	Sediment	Water	Tissue (Sample Type)	Effects	Log BCF	Log BAF	BSAF	Reference	Comments[3]
			23 mg/kg (muscle)[4]	Physiological, NOED				[38]	L; no reduced ability to survive osmotic stress after exposure
			49 mg/kg (muscle and skin)[4]	Physiological, NOED				[38]	L; no reduced ability to survive osmotic stress after exposure
			111 mg/kg (whole body)[4]	Mortality, LOED				[38]	L; 33% mortality in 96 hours
			1.1 mg/kg (whole body)[4]	Mortality, NA				[38]	L; 38% mortality in 96 hours
			22 mg/kg (whole body)[4]	Mortality, NA				[38]	L; 93% mortality in 96 hours
			44 mg/kg (whole body)[4]	Mortality, LOED				[38]	L; 8% mortality in 96 hours
			3.8 mg/kg (whole body)[4]	Mortality, NA				[38]	L; 43% mortality in 96 hours
			42 mg/kg (whole body)[4]	Behavior, LOED				[38]	L; uncoordinated swimming, cessation of feeding
			1,100 mg/kg (whole body)[4]	Morphology, LOED				[39]	L; darkened body coloration, body lesions
			1,100 mg/kg (whole body)[4]	Mortality, LOED				[39]	L; lethal to 86% of fry in 28 days
			200 mg/kg (whole body)[4]	Mortality, LOED				[39]	L; 88% juvenile mortality in 28 days

Summary of Biological Effects Tissue Concentrations for Aroclor 1016

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	**Sediment**	**Water**	**Tissue (Sample Type)**	**Effects**	**Log BCF**	**Log BAF**	**BSAF**	**Reference**	**Comments[3]**
			1,100 mg/kg (whole body)[4]	Development, NOED				[39]	L; no effect on fertilization success, survival of embryos to hatching, and survival of fry two weeks after hatching
			4.2 mg/kg (whole body)[4]	Development, NOED				[39]	L; no effect on fertilization success, survival of embryos to hatching, and survival of fry two weeks after hatching
			17 mg/kg (whole body)[4]	Development, NOED				[39]	L; no effect on fertilization success, survival of embryos to hatching, and survival of fry two weeks after hatching
			66 mg/kg (whole body)[4]	Mortality, NOED				[39]	L; no effect on fry mortality in 28 days
			0.81 mg/kg (whole body)[4]	Mortality, NOED				[39]	L; no effect on fry mortality in 28 days
			4.9 mg/kg (whole body)[4]	Mortality, NOED				[39]	L; no effect on fry mortality in 28 days
			22 mg/kg (whole body)[4]	Mortality, NOED				[39]	L; no effect on fry mortality in 28 days
			38 mg/kg (whole body)[4]	Mortality, NOED				[39]	L; no effect on fry mortality in 28 days

Summary of Biological Effects Tissue Concentrations for Aroclor 1016

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	**Sediment**	**Water**	**Tissue (Sample Type)**	**Effects**	**Log BCF**	**Log BAF**	**BSAF**	**Reference**	**Comments[3]**
			5.9 mg/kg (whole body)[4]	Mortality, NOED				[39]	L; no effect on fry mortality in 28 days
			26 mg/kg (whole body)[4]	Mortality, NOED				[39]	L; no effect on fry mortality in 28 days
			57 mg/kg (whole body)[4]	Mortality, NOED				[39]	L; no effect on juvenile mortality in 28 days
			2.3 mg/kg (whole body)[4]	Mortality, NOED				[39]	L; no effect on juvenile mortality in 28 days
			8.9 mg/kg (whole body)[4]	Mortality, NOED				[39]	L; no effect on juvenile mortality in 28 days
			11 mg/kg (whole body)[4]	Mortality, NOED				[39]	L; no effect on juvenile mortality in 28 days
			79 mg/kg (whole body)[4]	Mortality, NOED				[39]	L; no effect on juvenile mortality in 28 days
			230 mg/kg (whole body)[4]	Mortality, NOED				[39]	L; no effect on juvenile mortality in 28 days
			10 mg/kg (whole body)[4]	Mortality, NOED				[39]	L; no effect on juvenile mortality in 28 days
			54 mg/kg (whole body)[4]	Mortality, NOED				[39]	L; no effect on juvenile mortality in 28 days
			220 mg/kg (whole body)[4]	Mortality, NOED				[39]	L; no effect on adult mortality in 28 days

Summary of Biological Effects Tissue Concentrations for Aroclor 1016

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	Sediment	Water	Tissue (Sample Type)	Effects	Log BCF	Log BAF	BSAF	Reference	Comments[3]
			0.84 mg/kg (whole body)[4]	Mortality, NOED				[39]	L; no effect on adult mortality in 28 days
			1.5 mg/kg (whole body)[4]	Mortality, NOED				[39]	L; no effect on adult mortality in 28 days
			12 mg/kg (whole body)[4]	Mortality, NOED				[39]	L; no effect on adult mortality in 28 days
			46 mg/kg (whole body)[4]	Mortality, NOED				[39]	L; no effect on adult mortality in 28 days
			100 mg/kg (whole body)[4]	Mortality, NOED				[39]	L; no effect on adult mortality in 28 days
			5.4 mg/kg (whole body)[4]	Mortality, NOED				[39]	L; no effect on adult mortality in 28 days
			22 mg/kg (whole body)[4]	Mortality, NOED				[39]	L; no effect on adult mortality in 28 days
			110 mg/kg (whole body)[4]					[39]	

1 Concentration units based on wet weight unless otherwise noted.
2 BCF = bioconcentration factor, BAF = bioaccumulation factor, BSAF = biota-sediment accumulation factor.
3 L = laboratory study, spiked sediment, single chemical; F = field study, multiple chemical exposure; other unusual study conditions or observations noted.
4 This entry was excerpted directly from the Environmental Residue-Effects Database (ERED, www.wes.army.mil/el/ered, U.S. Army Corps of Engineers and U.S. Environmental Protection Agency). The original publication was not reviewed, and the reader is strongly urged to consult the publication to confirm the information presented here.

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Chemical Category: POLYCHLORINATED BIPHENYLS

Chemical Name (Common Synonyms): Aroclor 1242 **CASRN:** 53469-21-9

Chemical Characteristics

Solubility in Water: 240 µg/L at 25°C [1]

Half-Life: No data [2,3]

Log K_{ow}: 5.6 [4]

Log K_{oc}: No data [4]

Human Health

Oral RfD: No data [5]

Confidence: —

Critical Effect: PCBs have been shown to cause reproductive failure, birth defects, lesions, tumors, liver disorders, and death among sensitive species. Their toxicity is further enhanced by their ability to bioaccumulate and to biomagnify within the food chain due to extremely high lipophilicity [2].

Oral Slope Factor: No data [5]

Carcinogenic Classification: A2 [5]

Wildlife

Partitioning Factors: No partitioning factors for Aroclor 1242 were identified for wildlife.

Food Chain Multipliers: For PCBs as a class the most toxic congeners have been shown to be selectively accumulated from organisms at one trophic level to the next [6]. At least three studies have concluded that PCBs have the potential to biomagnify in food webs based on aquatic organisms and predators that feed primarily on aquatic organisms [7,8,9]. The results from Biddinger and Gloss [7] and USACE [9] generally agreed that highly water-insoluble compounds (including PCBs) have the potential to biomagnify in these types of food webs. Thomann's [10] model also indicated that highly water-insoluble compounds (log K_{ow} values 5 to 7) showed the greatest potential to biomagnify. A biomagnification factor of 32 was determined for total PCBs from alewife to herring gull eggs in Lake Ontario [11]. No specific food chain multipliers were identified for Aroclor 1242.

Aquatic Organisms

Partitioning Factors: No partitioning factors for Aroclor 1242 were identified for aquatic organisms.

Food Chain Multipliers: Polychlorinated biphenyls as a class have been demonstrated to biomagnify through the food web. Oliver and Niimi [12], studying accumulation of PCBs in various organisms in the Lake Ontario food web, reported concentrations of total PCBs in phytoplankton, zooplankton, and several species of fish. Their data indicated a progressive increase in tissue PCB concentrations moving

from organisms lower in the food web to top aquatic predators. In a study of PCB accumulation in lake trout (*Salvelinus namaycush*) of Lake Ontario, Rasmussen et al. [13] reported that each trophic level contributed about a 3.5-fold biomagnification factor to the PCB concentrations in the trout. No specific food chain multipliers were identified for Aroclor 1242.

Toxicity/Bioaccumulation Assessment Profile

PCBs are a group (209 congeners/isomers) of organic chemicals, based on various substitutions of chlorine atoms on a basic biphenyl molecule. These manufactured chemicals have been widely used in various processes and products because of the extreme stability of many isomers, particularly those with five or more chlorines [14]. A common use of PCBs was as dielectric fluids in capacitors and transformers. In the United States, Aroclor is the most familiar registered trademark of commercial PCB formulations. Generally, the first two digits in the Aroclor designation indicate that the mixture contains biphenyls, and the last two digits give the weight percent of chlorine in the mixture (e.g., Aroclor 1242 contains biphenyls with approximately 42 percent chlorine).

As a result of their stability and their general hydrophobic nature, PCBs released to the environment have dispersed widely throughout the ecosystem [14]. PCBs are among the most stable organic compounds known, and chemical degradation rates in the environment are thought to be slow. As a result of their highly lipophilic nature and low water solubility, PCBs are generally found at low concentrations in water and at relatively high concentrations in sediment [15]. Individual PCB congeners have different physical and chemical properties based on the degree of chlorination and position of chlorine substitution, although differences with degree of chlorination are more significant [15]. Solubilities and octanol-water partition coefficients for PCB congeners range over several orders of magnitude [16]. Octanol-water partition coefficients, which are often used as estimators of the potential for bioconcentration, are highest for the most chlorinated PCB congeners.

Dispersion of PCBs in the aquatic environment is a function of their solubility [15] while PCB mobility within and sorption to sediment are a function of chlorine substitution pattern and degree of chlorination [17]. The concentration of PCBs in sediments is a function of the physical characteristics of the sediment, such as grain size [18,19] and total organic carbon content [18,19,20,21]. Fine sediments typically contain higher concentrations of PCBs than coarser sediments because of more surface area [15]. Mobility of PCBs in sediment is generally quite low for the higher chlorinated biphenyls [17]. Therefore, it is common for the lower chlorinated PCBs to have a greater dispersion from the original point source [15]. Limited mobility and high rates of sedimentation could prevent some PCB congeners in the sediment from reaching the overlying water via diffusion [17].

The persistence of PCBs in the environment is a result of their general resistance to degradation [16]. The rate of degradation of PCB congeners by bacteria decreases with increasing degree of chlorination [22]; other structural characteristics of the individual PCBs can affect susceptibility to microbial degradation to a lesser extent [16]. Photochemical degradation, via reductive dechlorination, is also known to occur in aquatic environments; the higher chlorinated PCBs appear to be most susceptible to this process [21].

Toxicity of PCB congeners is dependent on the degree of chlorination as well as the position of chlorine substitution. Lesser chlorinated congeners are more readily absorbed, but are metabolized more rapidly than higher chlorinated congeners [23]. PCB congeners with no chlorine substituted in the ortho (2 and

2′) positions but with four or more chlorine atoms at the meta (3 and 3′) and para (4 and 4′) positions can assume a planar conformation that can interact with the same receptor as the highly toxic 2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD) [24]. Examples of these more toxic, coplanar congeners are 3,3′,4,4′-tetrachlorobiphenyl (PCB 77), 3,3′,4,4′,5-pentachlorobiphenyl (PCB 126), and 3,3′,4,4′,5,5′-hexachlorobiphenyl (PCB 169). A method that has been proposed to estimate the relative toxicity of mixtures is to use toxic equivalency factors (TEFs) [25]. With this method, relative potencies for individual congeners are calculated by expressing their potency in relation to 2,3,7,8-TCDD. The following TEFs have been recommended [25,26]:

Congener Class	Recommended TEF
3,3′,4,4′,5-PentaCB	0.1
3,3′,4,4′,5,5′-HexaCB	0.05
3,3′4,4′-TetraCB	0.01
Monoortho coplanar PCBs	0.001
Diortho coplanar PCBs	0.00002

Due to the toxicity, high K_{ow} values, and highly persistent nature of many PCBs, they possess a high potential to bioaccumulate and exert reproductive effects in higher-trophic-level organisms. Aquatic organisms have a strong tendency to accumulate PCBs from water and food sources. The log bioconcentration factor for fish is approximately 4.70 [27]. This factor represents the ratio of concentration in tissue to the ambient water concentration. Aquatic organisms living in association with PCB-contaminated sediments generally have tissue concentrations equal to or greater than the concentration of PCB in the sediment [27]. Once taken up by an organism, PCBs partition primarily into lipid compartments [15]. Thus, differences in PCB concentration between species and between different tissues within the same species may reflect differences in lipid content [15]. PCB concentrations in polychaetes and fish have been strongly correlated to their lipid content [28]. Elimination of PCBs from organisms is related to the characteristics of the specific PCB congeners present. It has been shown that uptake and depuration rates in mussels are high for lower-chlorinated PCBs and much lower for higher-chlorinated congeners [29, 30]. In some species, tissue concentrations of PCBs in females can be reduced during gametogenesis because of PCB transfer to the more lipophilic eggs. Therefore, the transferred PCBs are eliminated from the female during spawning [31,32]. Fish and other aquatic organisms biotransform PCBs more slowly than other species, and they appear less able to metabolize, or excrete, the higher chlorinated PCB congeners [31]. Consequently, fish and other aquatic organisms may accumulate more of the higher chlorinated PCB congeners than is found in the environment [16].

The acute toxicity of PCBs appears to be relatively low, but results from chronic toxicity tests indicate that PCB toxicity is directly related to the duration of exposure [1]. Toxic responses have been noted to occur at concentrations of 0.03 and 0.014 µg/L in marine and freshwater environments, respectively [1]. The LC50 for grass shrimp exposed to PCBs in marine waters for 4 days was 6.1 to 7.8 µg/L [1]. Chronic toxicity of PCBs presents a serious environmental concern because of their resistance to degradation [33], although the acute toxicity of PCBs is relatively low compared to that of other chlorinated hydrocarbons. Sediment contaminated with PCBs has been shown to elicit toxic responses at relatively low concentrations. Sediment bioassays and benthic community studies suggest that chronic effects generally occur in sediment at total PCB concentrations exceeding 370 µg/kg [34].

A number of field and laboratory studies provide evidence of chronic sublethal effects on aquatic organisms at low tissue concentrations [16]. Field and Dexter [16] suggest that a number of marine and freshwater fish species have experienced chronic toxicity at PCB tissue concentrations of less than 1.0 mg/kg and as low as 0.1 mg/kg. Spies et al. [35] reported an inverse relationship between PCB concentrations in starry flounder eggs in San Francisco Bay and reproductive success, with an effective PCB concentration in the ovaries of less than 0.2 mg/kg. Monod [36] also reported a significant correlation between PCB concentrations in eggs and total egg mortality in Lake Geneva char. PCBs have also been shown to cause induction of the mixed function oxidase (MFO) system in aquatic animals, with MFO induction by PCBs at tissue concentrations within the range of environmental exposures [16].

Summary of Biological Effects Tissue Concentrations for Aroclor 1242

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	**Sediment**	**Water**	**Tissue (Sample Type)**	**Effects**	**Log BCF**	**Log BAF**	**BSAF**	**Reference**	**Comments[3]**
Invertebrates									
Hyalella azteca, Amphipod - freshwater			30 mg/kg (whole body)[4]	Mortality, NOED				[38]	L; radiolabeled compounds; Exp_conc = 3-100
Fishes									
Oncorhynchus mykiss; Rainbow trout			1.3 mg/kg (whole body)[4]	Mortality, LOED				[39]	L; 10% mortality
Salmo salar, Atlantic salmon			0.54 mg/kg (eggs)[4]	Mortality, ED75				[40]	L; estimated wet weight; eggs obtained from hatchery stock. 41 µg/g lipid
Ictalurus punctatus, Channel catfish			3.8 mg/kg (brain)[4]	Growth, LOED				[41]	L; 40% reduction in mean weight
			14.6 mg/kg (kidney)[4]	Growth, LOED				[41]	L; 40% reduction in mean weight
			11.9 mg/kg (muscle and skin)[4]	Growth, LOED				[41]	L; 40% reduction in mean weight
			14.3 mg/kg (whole body)[4]	Growth, LOED				[41]	L; 40% reduction in mean weight
			3.8 mg/kg (brain)[4]	Morphology; LOED				[41]	L; increased size of liver

Summary of Biological Effects Tissue Concentrations for Aroclor 1242

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	Sediment	Water	Tissue (Sample Type)	Effects	Log BCF	Log BAF	BSAF	Reference	Comments[3]
			14.6 mg/kg (kidney)[4]	Morphology; LOED				[41]	L; increased size of liver
			11.9 mg/kg (muscle and skin)[4]	Morphology; LOED				[41]	L; increased size of liver
			14.3 mg/kg (whole body)[4]	Morphology; LOED				[41]	L; increased size of liver
			1.16 mg/kg (blood)[4]	Cellular, NOED				[41]	L; no effect on histopathology of liver, brain, kidney
			3.8 mg/kg (brain)[4]	Cellular, NOED				[41]	L; no effect on histopathology of liver, brain, kidney
			14.6 mg/kg (kidney)[4]	Cellular, NOED				[41]	L; no effect on histopathology of liver, brain, kidney
			11.7 mg/kg (kidney)[4]	Cellular, NOED				[41]	L; no effect on histopathology of liver, brain, kidney
			11.9 mg/kg (muscle and skin)[4]	Cellular, NOED				[41]	L; no effect on histopathology of liver, brain, kidney
			11.4 mg/kg (muscle and skin)[4]	Cellular, NOED				[41]	L; no effect on histopathology of liver, brain, kidney

Summary of Biological Effects Tissue Concentrations for Aroclor 1242

Species:	**Concentration, Units in[1]:**			**Toxicity:**	**Ability to Accumulate[2]:**			**Source:**	
Taxa	**Sediment**	**Water**	**Tissue (Sample Type)**	**Effects**	**Log BCF**	**Log BAF**	**BSAF**	**Reference**	**Comments[3]**
			8.23 mg/kg (ovary)[4]	Cellular, NOED				[41]	L; no effect on histopathology of liver, brain, kidney
			5.76 mg/kg (testis)[4]	Cellular, NOED				[41]	L; no effect on histopathology of liver, brain, kidney
			14.3 mg/kg (whole body)[4]	Cellular, NOED				[41]	L; no effect on histopathology of liver, brain, kidney
			10.9 mg/kg (whole body)[4]	Cellular, NOED				[41]	L; no effect on histopathology of liver, brain, kidney
			1.16 mg/kg (blood)[4]	Mortality, NOED				[41]	L; no effect on mortality
			3.8 mg/kg (brain)[4]	Mortality, NOED				[41]	L; no effect on mortality
			14.6 mg/kg (kidney)[4]	Mortality, NOED				[41]	L; no effect on mortality
			11.7 mg/kg (kidney)[4]	Mortality, NOED				[41]	L; no effect on mortality
			11.9 mg/kg (muscle and skin)[4]	Mortality, NOED				[41]	L; no effect on mortality
			11.4 mg/kg (muscle and skin)[4]	Mortality, NOED				[41]	L; no effect on mortality

Summary of Biological Effects Tissue Concentrations for Aroclor 1242

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	Sediment	Water	Tissue (Sample Type)	Effects	Log BCF	Log BAF	BSAF	Reference	Comments[3]
			8.23 mg/kg (ovary)[4]	Mortality, NOED				[41]	L; no effect on mortality
			5.76 mg/kg (testis)[4]	Mortality, NOED				[41]	L; no effect on mortality
			14.3 mg/kg (whole body)[4]	Mortality, NOED				[41]	L; no effect on mortality
			10.9 mg/kg (whole body)[4]	Mortality, NOED				[41]	L; no effect on mortality

1 Concentration units based on wet weight unless otherwise noted.
2 BCF = bioconcentration factor, BAF = bioaccumulation factor, BSAF = biota-sediment accumulation factor.
3 L = laboratory study, spiked sediment, single chemical; F = field study, multiple chemical exposure; other unusual study conditions or observations noted.
4 This entry was excerpted directly from the Environmental Residue-Effects Database (ERED, www.wes.army.mil/el/ered, U.S. Army Corps of Engineers and U.S. Environmental Protection Agency). The original publication was not reviewed, and the reader is strongly urged to consult the publication to confirm the information presented here.

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Chemical Category: POLYCHLORINATED BIPHENYLS

Chemical Name (Common Synonyms): Aroclor 1248 **CASRN:** 12672-29-6

Chemical Characteristics

Solubility in Water: 54 µg/L at 25^0C [1]

Half-Life: No data [2,3]

Log K_{ow}: 6.2 [4]

Log K_{oc}: No data [4]

Human Health

Oral RfD: Inadequate data to calculate [5]

Confidence: —

Critical Effect: PCBs have been shown to cause reproductive failure, birth defects, lesions, tumors, liver disorders, and death among sensitive species. Their toxicity is further enhanced by their ability to bioaccumulate and to biomagnify within the food chain due to extremely high lipophilicity [2]. —

Oral Slope Factor: No data [5]

Carcinogenic Classification: A2 [5]

Wildlife

Partitioning Factors: No partitioning factors for Aroclor 1248 were identified for wildlife.

Food Chain Multipliers: For PCBs as a class the most toxic congeners have been shown to be selectively accumulated from organisms at one trophic level to the next [6]. At least three studies have concluded that PCBs have the potential to biomagnify in food webs based on aquatic organisms and predators that feed primarily on aquatic organisms [7,8,9]. The results from Biddinger and Gloss [7] and USACE [9] generally agreed that highly water-insoluble compounds (including PCBs) have the potential to biomagnify in these types of food webs. Thomann's [10] model also indicated that highly water-insoluble compounds (log K_{ow} values 5 to 7) showed the greatest potential to biomagnify. A biomagnification factor of 32 was determined for total PCBs from alewife to herring gull eggs in Lake Ontario [11]. No specific food chain multipliers were identified for Aroclor 1248.

Aquatic Organisms

Partitioning Factors: No partitioning factors for Aroclor 1248 were identified for aquatic organisms.

Food Chain Multipliers: Polychlorinated biphenyls as a class have been demonstrated to biomagnify through the food web. Oliver and Niimi [12], studying accumulation of PCBs in various organisms in the Lake Ontario food web, reported concentrations of total PCBs in phytoplankton, zooplankton, and several species of fish. Their data indicated a progressive increase in tissue PCB concentrations moving from organisms lower in the food web to top aquatic predators. In a study of PCB accumulation in lake trout (*Salvelinus namaycush*) of Lake Ontario, Rasmussen et al. [13] reported that each trophic level contributed about a 3.5-fold biomagnification factor to the PCB concentrations in the trout. No specific food chain multipliers were identified for Aroclor 1248.

Toxicity/Bioaccumulation Assessment Profile

PCBs are a group (209 congeners/isomers) of organic chemicals, based on various substitutions of chlorine atoms on a basic biphenyl molecule. These manufactured chemicals have been widely used in various processes and products because of the extreme stability of many isomers, particularly those with five or more chlorines [14]. A common use of PCBs was as dielectric fluids in capacitors and transformers. In the United States, Aroclor is the most familiar registered trademark of commercial PCB formulations. Generally, the first two digits in the Aroclor designation indicate that the mixture contains biphenyls, and the last two digits give the weight percent of chlorine in the mixture (e.g., Aroclor 1260 contains biphenyls with approximately 60 percent chlorine).

As a result of their stability and their general hydrophobic nature, PCBs released to the environment have dispersed widely throughout the ecosystem [14]. PCBs are among the most stable organic compounds known, and chemical degradation rates in the environment are thought to be slow. As a result of their highly lipophilic nature and low water solubility, PCBs are generally found at low concentrations in water and at relatively high concentrations in sediment [15]. Individual PCB congeners have different physical and chemical properties based on the degree of chlorination and position of chlorine substitution, although differences with degree of chlorination are more significant [15]. Solubilities and octanol-water partition coefficients for PCB congeners range over several orders of magnitude [16]. Octanol-water partition coefficients, which are often used as estimators of the potential for bioconcentration, are highest for the most chlorinated PCB congeners.

Dispersion of PCBs in the aquatic environment is a function of their solubility [15] while PCB mobility within and sorption to sediment are a function of chlorine substitution pattern and degree of chlorination [17]. The concentration of PCBs in sediments is a function of the physical characteristics of the sediment, such as grain size [18,19] and total organic carbon content [18,19,20,21]. Fine sediments typically contain higher concentrations of PCBs than coarser sediments because of more surface area [15]. Mobility of PCBs in sediment is generally quite low for the higher chlorinated biphenyls [17]. Therefore, it is common for the lower chlorinated PCBs to have a greater dispersion from the original point source [15]. Limited mobility and high rates of sedimentation could prevent some PCB congeners in the sediment from reaching the overlying water via diffusion [17].

The persistence of PCBs in the environment is a result of their general resistance to degradation [16]. The rate of degradation of PCB congeners by bacteria decreases with increasing degree of chlorination [22]; other structural characteristics of the individual PCBs can affect susceptibility to microbial degradation to a lesser extent [16]. Photochemical degradation, via reductive dechlorination, is also known to occur in aquatic environments; the higher chlorinated PCBs appear to be most susceptible to this process [21].

Toxicity of PCB congeners is dependent on the degree of chlorination as well as the position of chlorine substitution. Lesser chlorinated congeners are more readily absorbed, but are metabolized more rapidly than higher chlorinated congeners [23]. PCB congeners with no chlorine substituted in the ortho (2 and 2′) positions but with four or more chlorine atoms at the meta (3 and 3′) and para (4 and 4′) positions can assume a planar conformation that can interact with the same receptor as the highly toxic 2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD) [24]. Examples of these more toxic, coplanar congeners are 3,3′,4,4′-tetrachlorobiphenyl (PCB 77), 3,3′,4,4′,5-pentachlorobiphenyl (PCB 126), and 3,3′,4,4′,5,5′-hexachlorobiphenyl (PCB 169). A method that has been proposed to estimate the relative toxicity of mixtures is to use toxic equivalency factors (TEFs) [25]. With this method, relative potencies for individual congeners are calculated by expressing their potency in relation to 2,3,7,8-TCDD. The following TEFs have been recommended [25,26]:

Congener Class	Recommended TEF
3,3′,4,4′,5-PentaCB	0.1
3,3′,4,4′,5,5′-HexaCB	0.05
3,3′4,4′-TetraCB	0.01
Monoortho coplanar PCBs	0.001
Diortho coplanar PCBs	0.00002

Due to the toxicity, high K_{ow} values, and highly persistent nature of many PCBs, they possess a high potential to bioaccumulate and exert reproductive effects in higher-trophic-level organisms. Aquatic organisms have a strong tendency to accumulate PCBs from water and food sources. The bioconcentration factor for fish is approximately 50,000 [27]. This factor represents the ratio of concentration in tissue to the ambient water concentration. Aquatic organisms living in association with PCB-contaminated sediments generally have tissue concentrations equal to or greater than the concentration of PCB in the sediment [27]. Once taken up by an organism, PCBs partition primarily into lipid compartments [15]. Thus, differences in PCB concentration between species and between different tissues within the same species may reflect differences in lipid content [15]. PCB concentrations in polychaetes and fish have been strongly correlated to their lipid content [28]. Elimination of PCBs from organisms is related to the characteristics of the specific PCB congeners present. It has been shown that uptake and depuration rates in mussels are high for lower-chlorinated PCBs and much lower for higher-chlorinated congeners [29, 30]. In some species, tissue concentrations of PCBs in females can be reduced during gametogenesis because of PCB transfer to the more lipophilic eggs. Therefore, the transferred PCBs are eliminated from the female during spawning [31,32]. Fish and other aquatic organisms biotransform PCBs more slowly than other species, and they appear less able to metabolize, or excrete, the higher chlorinated PCB congeners [31]. Consequently, fish and other aquatic organisms may accumulate more of the higher chlorinated PCB congeners than is found in the environment [16].

The acute toxicity of PCBs appears to be relatively low, but results from chronic toxicity tests indicate that PCB toxicity is directly related to the duration of exposure [1]. Toxic responses have been noted to occur at concentrations of 0.03 and 0.014 µg/L in marine and freshwater environments, respectively [1]. The LC50 for grass shrimp exposed to PCBs in marine waters for 4 days was 6.1 to 7.8 µg/L [1]. Chronic toxicity of PCBs presents a serious environmental concern because of their resistance to degradation [33], although the acute toxicity of PCBs is relatively low compared to that of other chlorinated hydrocarbons. Sediment contaminated with PCBs has been shown to elicit toxic responses at relatively low concentrations. Sediment bioassays and benthic community studies suggest that chronic effects generally occur in sediment at total PCB concentrations exceeding 370 µg/kg [34].

A number of field and laboratory studies provide evidence of chronic sublethal effects on aquatic organisms at low tissue concentrations [16]. Field and Dexter [16] suggest that a number of marine and freshwater fish species have experienced chronic toxicity at PCB tissue concentrations of less than 1.0 mg/kg and as low as 0.1 mg/kg. Spies et al. [35] reported an inverse relationship between PCB concentrations in starry flounder eggs in San Francisco Bay and reproductive success, with an effective PCB concentration in the ovaries of less than 0.2 mg/kg. Monod [36] also reported a significant correlation between PCB concentrations in eggs and total egg mortality in Lake Geneva char. PCBs have also been shown to cause induction of the mixed function oxidase (MFO) system in aquatic animals, with MFO induction by PCBs at tissue concentrations within the range of environmental exposures [16].

Summary of Biological Effects Tissue Concentrations for Aroclor 1248

Species:	Concentration, Units in:			Toxicity:	Ability to Accumulate:			Source:	
Taxa	Sediment	Water	Tissue (Sample Type)	Effects	Log BCF	Log BAF	BSAF	Reference	Comments
Invertebrates			**[NO DATA FOUND]**						
Fishes			**[NO DATA FOUND]**						
Wildlife			**[NO DATA FOUND]**						

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Chemical Category: POLYCHLORINATED BIPHENYLS

Chemical Name (Common Synonyms): Aroclor 1254 **CASRN:** 11097-69-1

Chemical Characteristics

Solubility in Water: 12 µg/L at 25°C[1] **Half-Life:** No data [2,3]

Log K_{ow}: — **Log K_{oc}:** —

Human Health

Oral RfD: 2 x 10^{-5} mg/kg-day [4] **Confidence:** Medium; uncertainty factor = 300

Critical Effect: Ocular exudate, inflamed and prominent Meibomian glands, distorted growth of fingernails and toenails; decreased antibody (IgG and IgM) response to sheep erythrocyte

Oral Slope Factor: No data [4] **Carcinogenic Classification:** A2 [4]

Wildlife

Partitioning Factors: No partitioning factors for Aroclor 1254 were identified for wildlife.

Food Chain Multipliers: For PCBs as a class, the most toxic congeners have been shown to be selectively accumulated from organisms at one trophic level to the next [5]. At least three studies have concluded that PCBs have the potential to biomagnify in food webs based on aquatic organisms and predators that feed primarily on aquatic organisms [6,7,8]. The results from Biddinger and Gloss [6] and USACE [8] generally agreed that highly water-insoluble compounds (including PCBs) have the potential to biomagnify in these types of food webs. Thomann's [9] model also indicated that highly water-insoluble compounds (log K_{ow} values 5 to 7) showed the greatest potential to biomagnify. A biomagnification factor of 28 was calculated by [10] for transfer of total PCBs from fish to bald eagle eggs. Similarly, a biomagnification factor of 32 was determined for total PCBs from alewife to herring gull eggs in Lake Ontario [11]. No specific foot chain multipliers were identified for Aroclor 1254.

Aquatic Organisms

Partitioning Factors: BSAFs for Dover sole were approximately 0.96 for muscle and 1.14 for liver. Invertebrates collected from New Bedford, MA, and Long Island Sound, NY, had BSAFs ranging from 3.2 to 4.8. These data are presented in the attached summary table.

Food Chain Multipliers: Polychlorinated biphenyls as a class have been demonstrated to biomagnify through the food web. Oliver and Niimi [12], studying accumulation of PCBs in various organisms in the Lake Ontario food web, reported concentrations of total PCBs in phytoplankton, zooplankton, and several species of fish. Their data indicated a progressive increase in tissue PCB concentrations moving from organisms lower in the food web to top aquatic predators. In a study of PCB accumulation in lake trout (*Salvelinus namaycush*) of Lake Ontario, Rasmussen et al. [13] reported that each trophic level contributed about a 3.5-fold biomagnification factor to the PCB concentrations in the trout. No specific biomagnification data were identified for Aroclor 1254.

Toxicity/Bioaccumulation Assessment Profile

PCBs are among the most stable organic compounds known, and rates of chemical degradation in the environment are thought to be slow. Highly lipophilic, PCBs are generally found at low concentrations in water and at relatively high concentrations in sediment [14]. PCBs are a class of 209 discrete chemical compounds called congeners, in which one to ten chlorine atoms are attached to biphenyl. PCBs were commonly produced as complex mixtures of congeners for a variety of uses, including dielectric fluids in capacitors and transformers. In the United States, Aroclor is the most familiar requested trademark of commercial PCB formulations. The first two digits in the Aroclor designation (12) indicate that the mixture contains biphenyls, and the last two digits give the weight percent of chlorine in the mixture (e.g., Aroclor 1254 contains biphenyls with approximately 54 percent chlorine).

Individual PCB congeners have different physical and chemical properties based on the degree of chlorination and position of chlorine substitution, although differences in the degree of chlorination affect partitioning more significantly, but toxicity is more dependent on position [15]. Octanol-water partition coefficients, which are often used as estimators of the potential for bioconcentration, are highest for PCB congeners with the highest degree of chlorination. Solubilities and octanol-water partition coefficients range over several orders of magnitude. Due to their higher water solubility, lower-chlorinated PCBs might show greater dispersion from a point source, whereas the higher-chlorinated compounds might remain in the sediments closer to the source [15]. The mobility of PCBs in sediment is also a function of the chlorine substitution pattern and degree of chlorination and is generally quite low, particularly for the higher-chlorinated biphenyls [16]. Therefore, high rates of sedimentation could prevent PCBs in the sediment from reaching the overlying water via diffusion [16].

PCB concentrations in sediment are affected by physical characteristics of the sediment such as grain size and total organic carbon content [17,18]. Fine sediments typically contain higher concentrations of PCBs than coarser sediments [15]. Sorption to sediments is a function of total organic carbon content [19,20].

Toxicity of PCB congeners is dependent on the degree of chlorination as well as the isomer. Lesser chlorinated congeners are more readily absorbed, but are metabolized more rapidly than higher chlorinated congeners [21]. PCB congeners with no chlorine substituted in the ortho (2 and 2′) positions but with four or more chlorine atoms at the meta (3 and 3′) and para (4 and 4′) positions can assume a planar conformation that can interact with the same receptor as the highly toxic 2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD) [22]. Examples of these more toxic, coplanar congeners are 3,3′,4,4′-tetrachlorobiphenyl (PCB 77), 3,3′,4,4′,5-pentachlorobiphenyl (PCB 126), and 3,3′,4,4′,5,5′-hexachlorobiphenyl (PCB 169). A method that has been proposed to estimate the relative toxicity of mixtures is to use toxic equivalency factors (TEFs) [23]. With this method, relative potencies for individual congeners are calculated by expressing their potency in relation to 2,3,7,8-TCDD. The following TEFs have been recommended [23,24]:

Congener Class	Recommended TEF
3,3′,4,4′,5-TCB	0.1
3,3′,4,4′,5,5′-HCB	0.05
3,3′,4,4′-TeCB	0.01
Monoortho coplanar PCBs	0.001
Diortho coplanar PCBs	0.00002

Due to the toxicity, high K_{ow} values, and highly persistent nature of many PCBs, they possess a high potential to bioaccumulate and exert reproductive effects in higher-trophic-level organisms. Aquatic organisms have a strong tendency to accumulate PCBs from water and food sources. The bioconcentration factor for fish is approximately 50,000 [25]. This factor represents the ratio of concentration in tissue to the ambient water concentration. PCB concentrations in tissues of aquatic organisms will generally be greater than, or equal to, sediment concentrations [26]. PCB concentrations in fish have been strongly correlated to their lipid content. Elimination of PCBs from organisms is related to the characteristics of the specific PCB congeners present. It has been shown that uptake and depuration rates in mussels are high for lower-chlorinated PCBs and much lower for higher-chlorinated congeners [27,28]. Elimination of PCBs from the body can occur during egg production and spawning in females of some species [29,30]. There is a limited capacity for fish and other aquatic organisms to biotransform or metabolize PCBs.

Sediment contaminated with PCBs has been shown to elicit toxic responses at relatively low concentrations. Sediment bioassays and benthic community studies suggest that chronic effects generally occur in sediment at total PCB concentrations exceeding 370 µg/kg [31]. The LC50 for grass shrimp exposed to PCBs in marine waters for 4 days was 6.1 to 7.8 µg/L [1]. Chronic toxicity of PCBs presents a serious environmental concern because of their resistance to degradation [32], although the acute toxicity of PCBs is relatively low compared to that of other chlorinated hydrocarbons. Toxic responses have been noted to occur at concentrations of 0.03 and 0.014 µg/L in marine and freshwater environments, respectively [1].

Summary of Biological Effects Tissue Concentrations for Aroclor 1254

Species: Taxa	Concentration, Units in[1]: Sediment	Water	Tissue (Sample Type)	Toxicity: Effects	Ability to Accumulate[2]: Log BCF	Log BAF	BSAF	Source: Reference	Comments[3]
Nephtys incisa, Polychaete worm	New Bedford: 3,070-7,180 ng/g (TOC: 4.16-4.67%)						3.22 n = 3	[38]	F; New Bedford, MA; Long Island Sound, NY AF = $\frac{[\text{Organism}]_{(\text{ng/g lipic})}}{[\text{Sediment}]_{(\text{ng/g organ carbc})}}$
	Long Island: 40.3-48.3 ng/g (TOC: 2.39-2.62%)						4.29 n = 3		
Crassostrea virginica, Oyster			425 mg/kg (whole body)[4]	Cellular, LOED				[49]	L; atrophy of digestive diverticulata
			425 mg/kg (whole body)[4]	Growth, LOED				[49]	L; reduced growth
			101 mg/kg (whole body)[4]	Cellular, NOED				[49]	L; no effect on histopathology of digestive diverticulata
			101 mg/kg (whole body)[4]	Growth, NOED				[49]	L; no effect on growth
			425 mg/kg (whole body)[4]	Mortality, NOED				[49]	L; no effect on mortality
			101 mg/kg (whole body)[4]	Mortality, NOED				[49]	L; no effect on mortality
Crassostrea virginica, Oyster			33 mg/kg (whole body)[4]	Growth, NA				[46]	L; 41% reduction in rate of shell growth
			8.1 mg/kg (whole body)[4]	Growth, NA				[46]	L; 19% reduction in rate of shell growth

Summary of Biological Effects Tissue Concentrations for Aroclor 1254

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	**Sediment**	**Water**	**Tissue (Sample Type)**	**Effects**	**Log BCF**	**Log BAF**	**BSAF**	**Reference**	**Comments[3]**
			33 mg/kg (whole body)[4]	Mortality, NOED				[46]	L; no effect on survival in 96 hours
			8.1 mg/kg (whole body)[4]	Mortality, NOED				[46]	L; no effect on survival in 96 hours
Yoldia limatula, Bivalve	New Bedford: 3,070-7,180 ng/g (TOC: 4.16-4.67%)						4.07 n = 3	[38]	F; New Bedford, MA; Long Island Sound, NY
	Long Island: 40.3-48.3 ng/g (TOC: 2.39-2.62%)						4.79 n = 3		
Macoma nasuta, Clam			Concentrations at Stations:					[39]	L; standard bioassay with field collected sediments with multiple contaminants.

Summary of Biological Effects Tissue Concentrations for Aroclor 1254

Species: Taxa	Concentration, Units in[1]: Sediment	Water	Tissue (Sample Type)	Toxicity: Effects	Ability to Accumulate[2]: Log BCF	Log BAF	BSAF	Source: Reference	Comments[3]
	<20 µg/kg dw		21.4 µg/kg, (variance = 9.8, n=5)	100% survival					Tissue burdens and toxicity were determined in separate aquaria after 20 and 10 days, respectively.
	<20 µg/kg dw		35.2* µg/kg, (variance = 27.2, n=5)	100% survival					
	<20 µg/kg dw		20 µg/kg, (variance = 0, n=5)	100% survival					
	<20 µg/kg dw		27.8* µg/kg, (variance = 20.7, n=5) **statistically significant increase*	100% survival					
Daphnia magna, Cladoceran			10.4 mg/kg (whole body)[4]	Mortality, NOED				[52]	L; radiolabeled compound
Gammarus pseudolimnaeus, Amphipod			7.8 mg/kg (whole body)[4]	Mortality, NOED				[52]	L; radiolabeled compound
Gammarus tigrinus, Amphipod			4.64 mg/kg (whole body)[4]	Behavior, NOED				[51]	L; radiolabeled compound
Penaeus duorarum, Pink shrimp			3.9 mg/kg (whole body)[4]	Mortality, ED100				[46]	L; 100% mortality after 48 hours
Palaemonetes kadiakensis, Grass shrimp			3.2 mg/kg (whole body)[4]	Mortality, NOED				[52]	L; radiolabeled compound

Summary of Biological Effects Tissue Concentrations for Aroclor 1254

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	Sediment	Water	Tissue (Sample Type)	Effects	Log BCF	Log BAF	BSAF	Reference	Comments[3]
Orconectes nais, Crayfish			0.04 mg/kg (whole body)[4]	Mortality, NOED				[52]	L; radiolabeled compound
			16 mg/kg (whole body)[4]	Mortality, NA				[46]	L; lethal to 18 of 25 fish in 20 days
			33 mg/kg (whole body)[4]	Behavior, NOED				[46]	L; no effect on sense of equilibrium or behavior
			1.3 mg/kg (whole body)[4]	Mortality, NOED				[46]	L; no effect on survival in 48 hours
			33 mg/kg (whole body)[4]	Mortality, NOED				[46]	L; no effect on survival in 20 days
			0.14 mg/kg (whole body)[4]	Mortality, NOED				[46]	L; no effect on survival in 48 hours
Callinectes sapidus, Blue crab			23 mg/kg (whole body)[4]	Mortality, NOED				[46]	L; no effect on survival in 20 days
Culex tarsalis, Mosquito			5.4 mg/kg (whole body)[4]	Mortality, NOED				[52]	L; radiolabeled compound
Chaoborus punctipennis, Midge			1.2 mg/kg (whole body)[4]	Mortality, NOED				[52]	L; radiolabeled compound
Corydalus cornutus, Midge			1.02 mg/kg (whole body)[4]	Mortality, NOED				[52]	L; radiolabeled compound
Pteronarcys dorsata, Giant black stonefly			1.4 mg/kg (whole body)[4]	Mortality, NOED				[52]	L; radiolabeled compound

Summary of Biological Effects Tissue Concentrations for Aroclor 1254

Species:	**Concentration, Units in[1]:**			**Toxicity:**	**Ability to Accumulate[2]:**			**Source:**	
Taxa	**Sediment**	**Water**	**Tissue (Sample Type)**	**Effects**	**Log BCF**	**Log BAF**	**BSAF**	**Reference**	**Comments[3]**
Acheta domesticus, House cricket	Soil: 1,000 ppm 2,000 ppm		148.6 ppm 143.9 ppm	Signficant mortality (LC50 = 1,200 ppm)				[37]	L; 14-d soil bioassay; despite high mortality no significant differences were seen in growth rate or food consumption between surviving crickets and control crickets.
Fishes									
Oncorhynchus kisutch, Coho salmon			0.37 mg/kg (liver)	Mortality, ED10				[48]	L; 10% mortality of smolts
			0.15 mg/kg (whole body)[4]	Development, LOED				[48]	L; reduced ability of smolts to adapt to seawater
			0.5 mg/kg (liver)	Physiological, LOED				[48]	L; delayed increase in plasma thyroxine (T4) prior to smoltification by 30 days
Oncorhynchus mykiss, Rainbow trout			0.2 mg/kg (whole body)[4]	Physiological, LOED				[50]	L; increased ethoxyresorufin o-deethylase (EROD) activity

Summary of Biological Effects Tissue Concentrations for Aroclor 1254

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	**Sediment**	**Water**	**Tissue (Sample Type)**	**Effects**	**Log BCF**	**Log BAF**	**BSAF**	**Reference**	**Comments[3]**
Oncorhynchus mykiss, Rainbow trout			0.2 mg/kg (whole body)[4]	Physiological, LOED				[50]	L; increased ethoxyresorufin o-deethylase (EROD) activity
Oncorhynchus mykiss, Rainbow trout			Muscle or liver = 300 µg/kg	Elevated hepatic MFO (EROD) activity after 70 days				[40]	L
Pimephales promelas, Fathead minnow	0.82 µg/g dw 14-27 µg/g dw		5.25-11.6 µg/g 13.7-47.2 µg/g	No effect Reproduction inhibited. Frequency and fecundity 5-30% of control values.				[41]	L; organism survival and weight unaffected by PCB concentration. Increased lipid concentrations were seen with increased reproductive effects. Measurement endpoints for effects not well-defined.
Pleuronectes americanus, Winter flounder			Eggs = 7.1 µg/kg	Reduced growth in length and weight				[42]	F

Summary of Biological Effects Tissue Concentrations for Aroclor 1254

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	Sediment	Water	Tissue (Sample Type)	Effects	Log BCF	Log BAF	BSAF	Reference	Comments[3]
Microstomus pacificus, Dover sole	2.3* µg/kg, dw (median TOC - 7.6%)		Muscle = 1.1* µg/kg, dw (2.36 %lipids)				0.96	[43]	BSAFs are lipid and TOC normalized values reported in text.
			Liver = 12.0* µg/kg, (24.8% lipids)				1.4		
			**median concentration*						
Salvelinus fontinalis, Brook trout			39 mg/kg (fillet)	Physiological, LOED				[44]	L; 7 doses over 18-day period; effect at only exposure dose; hepatic enzyme induction
Cyprinus carpio, Common carp			0.1 mg/kg (whole body)[4]	Physiological, LOED				[50]	L; increased ethoxyresorufin o-deethylase (EROD) activity
Lagodon rhomboides, Pinfish			17 mg/kg (whole body)[4]	Mortality, NOED				[46]	L; no effect on survival in 48 hours
			3.8 mg/kg (whole body)[4]	Mortality, NOED				[46]	L; no effect on survival in 48 hours
			0.98 mg/kg (whole body)[4]	Mortality, NOED				[46]	L; no effect on survival in 48 hours
Ictalurus punctatus, Channel catfish			100 mg/kg (whole body)[4]	Physiological, NOED				[47]	L; no effect on neurotransmitters

Summary of Biological Effects Tissue Concentrations for Aroclor 1254

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	Sediment	Water	Tissue (Sample Type)	Effects	Log BCF	Log BAF	BSAF	Reference	Comments[3]
Platycephalus bassensis, Sand flathead			10 mg/kg (whole body)[4]	Physiological, ED50				[45]	L; 50% increase in activity of uridine diphosphoglucuro-nosyltransferase
			100 mg/kg (whole body)[4]	Physiological, LOED				[45]	L; induction (3x) of ethoxyresorufin o-deethylase (EROD) activity
			10 mg/kg (whole body)[4]	Physiological, NOED				[45]	L; no induction of ethoxyresorufin o-deethylase (EROD) activity

[1] Concentration units based on wet weight unless otherwise noted.
[2] BCF = bioconcentration factor, BAF = bioaccumulation factor, BSAF = biota-sediment accumulation factor.
[3] L = laboratory study, spiked sediment, single chemical; F = field study, multiple chemical exposure; other unusual study conditions or observations noted.
[4] This entry was excerpted directly from the Environmental Residue-Effects Database (ERED, www.wes.army.mil/el/ered, U.S. Army Corps of Engineers and U.S. Environmental Protection Agency). The original publication was not reviewed, and the reader is strongly urged to consult the publication to confirm the information presented here.

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Chemical Category: POLYCHLORINATED BIPHENYLS

Chemical Name (Common Synonyms): Aroclor 1260 **CASRN:** 11096-82-5

Chemical Characteristics

Solubility in Water: 0.027 mg/L at 25°C [1]

Half-Life: No data [2,3]

Log K_{ow}: 6.8 [4]

Log K_{oc}: No data [4]

Human Health

Oral RfD: No data [5]

Confidence: —

Critical Effect: PCBs have been shown to cause reproductive failure, birth defects, lesions, tumors, liver disorders, and death among sensitive species. Their toxicity is further enhanced by their ability to bioaccumulate and to biomagnify within the food chain due to extremely high lipophilicity [2].

Oral Slope Factor: No data [5]

Carcinogenic Classification: A2 [5]

Wildlife

Partitioning Factors: No partitioning factors for Aroclor 1260 were identified for wildlife.

Food Chain Multipliers: For PCBs as a class the most toxic congeners have been shown to be selectively accumulated from organisms at one trophic level to the next [6]. At least three studies have concluded that PCBs have the potential to biomagnify in food webs based on aquatic organisms and predators that feed primarily on aquatic organisms [7,8,9]. The results from Biddinger and Gloss [7] and USACE [9] generally agreed that highly water-insoluble compounds (including PCBs) have the potential to biomagnify in these types of food webs. Thomann's [10] model also indicated that highly water-insoluble compounds (log K_{ow} values 5 to 7) showed the greatest potential to biomagnify. A biomagnification factor of 32 was determined for total PCBs from alewife to herring gull eggs in Lake Ontario [11] No specific food chain multipliers were identified for Aroclor 1260.

Aquatic Organisms

Partitioning Factors: No partitioning factors for Aroclor 1260 were identified for aquatic organisms.

Food Chain Multipliers: Polychlorinated biphenyls as a class have been demonstrated to biomagnify through the food web. Oliver and Niimi [12], studying accumulation of PCBs in various organisms in the Lake Ontario food web, reported concentrations of total PCBs in phytoplankton, zooplankton, and several species of fish. Their data indicated a progressive increase in tissue PCB concentrations moving

from organisms lower in the food web to top aquatic predators. In a study of PCB accumulation in lake trout (*Salvelinus namaycush*) of Lake Ontario, Rasmussen et al. [13] reported that each trophic level contributed about a 3.5-fold biomagnification factor to the PCB concentrations in the trout. No specific food chain multipliers were identified for Aroclor 1260.

Toxicity/Bioaccumulation Assessment Profile

PCBs are a group (209 congeners/isomers) of organic chemicals, based on various substitutions of chlorine atoms on a basic biphenyl molecule. These manufactured chemicals have been widely used in various processes and products because of the extreme stability of many isomers, particularly those with five or more chlorines [14]. A common use of PCBs was as dielectric fluids in capacitors and transformers. In the United States, Aroclor is the most familiar registered trademark of commercial PCB formulations. Generally, the first two digits in the Aroclor designation indicate that the mixture contains biphenyls, and the last two digits give the weight percent of chlorine in the mixture (e.g., Aroclor 1260 contains biphenyls with approximately 60 percent chlorine).

As a result of their stability and their general hydrophobic nature, PCBs released to the environment have dispersed widely throughout the ecosystem [14]. PCBs are among the most stable organic compounds known, and chemical degradation rates in the environment are thought to be slow. As a result of their highly lipophilic nature and low water solubility, PCBs are generally found at low concentrations in water and at relatively high concentrations in sediment [15]. Individual PCB congeners have different physical and chemical properties based on the degree of chlorination and position of chlorine substitution, although differences with degree of chlorination are more significant [15]. Solubilities and octanol-water partition coefficients for PCB congeners range over several orders of magnitude [16]. Octanol-water partition coefficients, which are often used as estimators of the potential for bioconcentration, are highest for the most chlorinated PCB congeners.

Dispersion of PCBs in the aquatic environment is a function of their solubility [15] while PCB mobility within and sorption to sediment are a function of chlorine substitution pattern and degree of chlorination [17]. The concentration of PCBs in sediments is a function of the physical characteristics of the sediment, such as grain size [18,19] and total organic carbon content [18,19,20,21]. Fine sediments typically contain higher concentrations of PCBs than coarser sediments because of more surface area [15]. Mobility of PCBs in sediment is generally quite low for the higher chlorinated biphenyls [17]. Therefore, it is common for the lower chlorinated PCBs to have a greater dispersion from the original point source [15]. Limited mobility and high rates of sedimentation could prevent some PCB congeners in the sediment from reaching the overlying water via diffusion [17].

The persistence of PCBs in the environment is a result of their general resistance to degradation [16]. The rate of degradation of PCB congeners by bacteria decreases with increasing degree of chlorination [22]; other structural characteristics of the individual PCBs can affect susceptibility to microbial degradation to a lesser extent [16]. Photochemical degradation, via reductive dechlorination, is also known to occur in aquatic environments; the higher chlorinated PCBs appear to be most susceptible to this process [21].

Toxicity of PCB congeners is dependent on the degree of chlorination as well as the position of chlorine substitution. Lesser chlorinated congeners are more readily absorbed, but are metabolized more rapidly than higher chlorinated congeners [23]. PCB congeners with no chlorine substituted in the ortho (2 and 2′) positions but with four or more chlorine atoms at the meta (3 and 3′) and para (4 and 4′) positions can assume a planar conformation that can interact with the same receptor as the highly toxic 2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD) [24]. Examples of these more toxic, coplanar congeners are 3,3′,4,4′-tetrachlorobiphenyl (PCB 77), 3,3′,4,4′,5-pentachlorobiphenyl (PCB 126), and 3,3′,4,4′,5,5′-hexachlorobiphenyl (PCB 169). A method that has been proposed to estimate the relative toxicity of mixtures is to use toxic equivalency factors (TEFs) [25]. With this method, relative potencies for individual congeners are calculated by expressing their potency in relation to 2,3,7,8-TCDD. The following TEFs have been recommended [25,26]:

Congener Class	Recommended TEF
3,3′,4,4′,5-PentaCB	0.1
3,3′,4,4′,5,5′-HexaCB	0.05
3,3′,4,4′-TetraCB	0.01
Monoortho coplanar PCBs	0.001
Diortho coplanar PCBs	0.00002

Due to the toxicity, high K_{ow} values, and highly persistent nature of many PCBs, they possess a high potential to bioaccumulate and exert reproductive effects in higher-trophic-level organisms. Aquatic organisms have a strong tendency to accumulate PCBs from water and food sources. The bioconcentration factor for fish is approximately 50,000 [27]. This factor represents the ratio of concentration in tissue to the ambient water concentration. Aquatic organisms living in association with PCB-contaminated sediments generally have tissue concentrations equal to or greater than the concentration of PCB in the sediment [27]. Once taken up by an organism, PCBs partition primarily into lipid compartments [15]. Thus, differences in PCB concentration between species and between different tissues within the same species may reflect differences in lipid content [15]. PCB concentrations in polychaetes and fish have been strongly correlated to their lipid content [28]. Elimination of PCBs from organisms is related to the characteristics of the specific PCB congeners present. It has been shown that uptake and depuration rates in mussels are high for lower-chlorinated PCBs and much lower for higher-chlorinated congeners [29, 30]. In some species, tissue concentrations of PCBs in females can be reduced during gametogenesis because of PCB transfer to the more lipophilic eggs. Therefore, the transferred PCBs are eliminated from the female during spawning [31,32]. Fish and other aquatic organisms biotransform PCBs more slowly than other species, and they appear less able to metabolize, or excrete, the higher chlorinated PCB congeners [31]. Consequently, fish and other aquatic organisms may accumulate more of the higher chlorinated PCB congeners than is found in the environment [16].

The acute toxicity of PCBs appears to be relatively low, but results from chronic toxicity tests indicate that PCB toxicity is directly related to the duration of exposure [1]. Toxic responses have been noted to occur at concentrations of 0.03 and 0.014 µg/L in marine and freshwater environments, respectively [1]. The LC50 for grass shrimp exposed to PCBs in marine waters for 4 days was 6.1 to 7.8 µg/L [1]. Chronic toxicity of PCBs presents a serious environmental concern because of their resistance to degradation [33], although the acute toxicity of PCBs is relatively low compared to that of other chlorinated hydrocarbons. Sediment contaminated with PCBs has been shown to elicit toxic responses at relatively low concentrations. Sediment bioassays and benthic community studies suggest that chronic effects generally occur in sediment at total PCB concentrations exceeding 370 µg/kg [34].

A number of field and laboratory studies provide evidence of chronic sublethal effects on aquatic organisms at low tissue concentrations [16]. Field and Dexter [16] suggest that a number of marine and freshwater fish species have experienced chronic toxicity at PCB tissue concentrations of less than 1.0 mg/kg and as low as 0.1 mg/kg. Spies et al. [35] reported an inverse relationship between PCB concentrations in starry flounder eggs in San Francisco Bay and reproductive success, with an effective PCB concentration in the ovaries of less than 0.2 mg/kg. Monod [36] also reported a significant correlation between PCB concentrations in eggs and total egg mortality in Lake Geneva char. PCBs have also been shown to cause induction of the mixed function oxidase (MFO) system in aquatic animals, with MFO induction by PCBs at tissue concentrations within the range of environmental exposures [16].

Summary of Biological Effects Tissue Concentrations for Aroclor 1260

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	Sediment	Water	Tissue (Sample Type)	Effects	Log BCF	Log BAF	BSAF	Reference	Comments[3]
Invertebrates									
Clam, *Macoma nasuta*				Survival (out of 20):				[37]	L; standard bioassay with field collected sediments with multiple contaminants. Tissue burdens and toxicity were determined in separate aquaria after 20 and 10 days, respectively.
	1.2 mg/kg dw (reference station)		0.976 mg/kg (variance = 4.6x10^{6}, n=5)	19.8 (variance=0.2, n=5)					
	0.9 mg/kg dw		18.600 mg/kg (variance = na; n=5)	5.2 (variance=6.2, n=5)					
	3.8 mg/kg dw		9.170 mg/kg (variance = 3.96x10^{8}, n=5)	19.8 (variance=0.2, n=5)					

[1] Concentration units based on wet weight unless otherwise noted.
[2] BCF = bioconcentration factor, BAF = bioaccumulation factor, BSAF = biota-sediment accumulation factor.
[3] L = laboratory study, spiked sediment, single chemical; F = field study, multiple chemical exposure; other unusual study conditions or observations noted.

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Chemical Category: METAL

Chemical Name (Common Synonyms): ARSENIC **CASRN:** 7440-38-2

Chemical Characteristics

Solubility in Water: Insoluble [1] **Half-Life:** Not applicable, stable [1]

Log K_{ow}: – **Log K_{oc}:** –

Human Health

Oral RfD: 3×10^{-4} mg/kg/day [2] **Confidence:** Medium, uncertainty factor = 3

Critical Effect: Hyperpigmentation, keratosis, and possible vascular complications

Oral Slope Factor: $1.5 \times 10^{+0}$ per (mg/kg)/day [2] **Carcinogenic Classification:** A [2]

Wildlife

Partitioning Factors: Partitioning factors for arsenic in wildlife were not found in the literature.

Food Chain Multipliers: Food chain multipliers for arsenic in wildlife were not found in the literature.

Aquatic Organisms

Partitioning Factors: Arsenic is a metal that occurs in aquatic systems in a number of chemical forms. The most prevalent form is arsenate, followed by arsenite, which usually is present at lower concentrations. The arsenate ions can be methylated and form alkylated compounds (methylarsenic acid and dimethylarsenic acid). In any aquatic environment only a small portion of the total arsenic (approximately 0.1 percent) exists as methylated species. The arsenic methylation rate is strongly correlated with sediment organic matter content in sediments and amount of sulfate-reducing bacteria.

Food Chain Multipliers: The simplified trophic transfer experiment conducted by Lindsay and Sanders [11] effectively ended speculation of food chain transfer to the second trophic level. Arsenic is taken up by aquatic organisms primarily through dietary exposure [3]

Toxicity/Bioaccumulation Assessment Profile

Arsenic (As) is accumulated by aquatic organisms primarily through dietary exposure [3]. The most toxic form of arsenic in aquatic systems is As III, follow by As V, and the least toxic forms are organic complexes. The bioavailability of arsenic is not dependent on the concentration of acid-volatile sulfides

(AVS). Pore water concentrations of arsenic are two to three orders of magnitude higher than surface water concentrations [4], a factor that can be of considerable toxicological importance to some benthic organisms. It has been demonstrated that sediments are the major source of arsenic to the infaunal organisms and the body burden is related to the concentration of extractable (1N HCL) arsenic normalized for iron [5].

Summary of Biological Effects Tissue Concentrations for Arsenic

Species:	Concentration, Units in[1]:					Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	Sediment		Water		Tissue (Sample Type)	Effects	Log BCF	Log BAF	BSAF	Reference	Comments[3]
Invertebrates, field-collected	Total µg/g	SEM µg/g	Filt µg/L	Nonfit µg/L	µg/g					[8]	F
	404	202	57	1740	34						
	102	24	54	158	15						
	68	25	72	138	13						
	46	11	29	72	27						
	11	3	23	31	3						
	4	< 0.5	3	< 22	3						
Tubificidae	9.78 µg/g 1.15 µg/g 26 µg/g 18 µg/g 17 µg/g				6.96 mg/g 4.98 mg/g 7.38 mg/g 2.35 mg/g 5.95 mg/g					[7]	L
Helisoma campanulata, Snail					4.2 mg/kg (whole body)[4]	Mortality, ED16				[16]	L; mixture of 4 arsenic compounds, estimated body burden from graph
					16 mg/kg (whole body)[4]	Mortality, NOED				[16]	L; mixture of 4 arsenic compounds, estimated body burden from graph
					5.8 mg/kg (whole body)[4]	Mortality, NOED				[16]	L; mixture of 4 arsenic compounds, estimated body burden from graph
					4 mg/kg (whole body)[4]	Mortality, NOED				[16]	L; mixture of 4 arsenic compounds, estimated body burden from graph

Summary of Biological Effects Tissue Concentrations for Arsenic

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	Sediment	Water	Tissue (Sample Type)	Effects	Log BCF	Log BAF	BSAF	Reference	Comments[3]
Stagnicola emarginata, Snail			3.6 mg/kg (whole body)[4]	Mortality, NOED				[16]	L; mixture of 4 arsenic compounds, estimated body burden from graph
			3.6 mg/kg (whole body)[4]	Mortality, NOED				[16]	L; mixture of 4 arsenic compounds, estimated body burden from graph
			3.6 mg/kg (whole body)[4]	Mortality, NOED				[16]	L; mixture of 4 arsenic compounds, estimated body burden from graph
			3.6 mg/kg (whole body)[4]	Mortality, NOED				[16]	L; mixture of 4 arsenic compounds, estimated body burden from graph
Mytilus galloprovincialis, Mussel			0.44-0.51 mg/kg				0.047	[12]	F
Ceriodaphnia dubia, Cladoceran	1,120 µg/g	1295 µg/L		70% mortality				[4]	L
	2,720 µg/g	3580 µg/L		70% mortality					
	650 µg/g	901 µg/L		20% mortality/ no reproduction					
	569 µg/g	436 µg/L		0% mortality/ no reproduction					

Summary of Biological Effects Tissue Concentrations for Arsenic

Species:	**Concentration, Units in[1]:**			**Toxicity:**	**Ability to Accumulate[2]:**			**Source:**	
Taxa	**Sediment**	**Water**	**Tissue (Sample Type)**	**Effects**	**Log BCF**	**Log BAF**	**BSAF**	**Reference**	**Comments[3]**
Daphnia magna, Cladoceran			3.8 mg/kg (whole body)[4]	Mortality, NOED				[16]	L; mixture of 4 arsenic compounds, estimated body burden from graph, tissues exposed 21 d
			9.8 mg/kg (whole body)[4]	Mortality, NOED				[16]	L; mixture of 4 arsenic compounds, estimated body burden from graph, tissues exposed 21 d
			4.4 mg/kg (whole body)[4]	Mortality, NOED				[16]	L; mixture of 4 arsenic compounds, estimated body burden from graph, tissues exposed 21 d
			4 mg/kg (whole body)[4]	Mortality, NOED				[16]	L; mixture of 4 arsenic compounds, estimated body burden from graph, tissues exposed 21 d
			87 mg/kg (whole body)[4]	Mortality, ED50				[6]	L; lethal body burden after 21 d exposure
			33 mg/kg (whole body)[4]	Reproduction, ED10				[6]	L; 10% reduction in number of offspring
Hyallela azteca, Amphipod	3580 µg/g	1420 µg/L		Growth reduction				[4]	L

Summary of Biological Effects Tissue Concentrations for Arsenic

Species: Taxa	Concentration, Units in[1]: Sediment		Water		Tissue (Sample Type)	Toxicity: Effects	Ability to Accumulate[2]: Log BCF	Log BAF	BSAF	Source: Reference	Comments[3]
Hyallela azteca, Amphipod	Total μg/g	SEM μg/g	Filt μg/L	Nonfilt μg/L	μg/g					[8]	F
	404	202	57	1740	7						
	102	24	54	158	12						
	68	25	72	138	4						
	46	11	29	72	2						
	11	3	23	31	1						
	4	<0.5	3	<22	0.4						
Palaemonetes pugio, Grass shrimp					1.15 mg/kg (whole body)[4]	Growth, NOED				[11]	L; no effect on growth
					1.03 mg/kg (whole body)[4]	Growth, NOED				[11]	L; no effect on growth
					1.28 mg/kg (whole body)[4]	Growth, NOED				[11]	L; no effect on growth
					1.14 mg/kg (whole body)[4]	Growth, NOED				[11]	L; no effect on growth
Pteronarcys dorsata, Giant black stonefly					8.4 mg/kg (whole body)[4]	Mortality, NOED				[16]	L; mixture of 4 arsenic compounds, estimated body burden from graph
					6 mg/kg (whole body)[4]	Mortality, NOED				[16]	L; mixture of 4 arsenic compounds, estimated body burden from graph
					7 mg/kg (whole body)[4]	Mortality, NOED				[16]	L; mixture of 4 arsenic compounds, estimated body burden from graph

Summary of Biological Effects Tissue Concentrations for Arsenic

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	**Sediment**	**Water**	**Tissue (Sample Type)**	**Effects**	**Log BCF**	**Log BAF**	**BSAF**	**Reference**	**Comments[3]**
			8.4 mg/kg (whole body)[4]	Mortality, NOED				[16]	L; mixture of 4 arsenic compounds, estimated body burden from graph
Fishes									
Oncorhynchus mykiss, Rainbow trout		8.4 mg/L 18.1 mg/L 240 mg/L	1.8 mg/kg 3.5 mg/kg (0.18 mmol/kg)					[10]	F
Oncorhynchus mykiss, Rainbow trout			3 mg/kg (whole body)[4]	Growth, NOED				[14]	L; exposure to arsenic for 21 d did not affect growth at the longest time interval tested
			4.7 mg/kg (whole body)[4]	Mortality, LOED				[14]	L; pre-exposure to arsenic for 7 d produced significant increase in LC50 (reduced sensitivity to exposure) at shortest time interval tested
			8.6 mg/kg (whole body)[4]	Behavior, ED50				[15]	L; loss of equilibrium, mortality
			13.5 mg/kg (whole body)[4]	Behavior, ED50				[15]	L; loss of equilibrium, mortality

Summary of Biological Effects Tissue Concentrations for Arsenic

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	**Sediment**	**Water**	**Tissue (Sample Type)**	**Effects**	**Log BCF**	**Log BAF**	**BSAF**	**Reference**	**Comments[3]**
			8.1 mg/kg (whole body)[4]	Behavior, ED50				[15]	L; loss of equilibrium, mortality
			8.6 mg/kg (whole body)[4]	Behavior, ED50				[15]	L; loss of equilibrium, mortality
Lepisosteus osseus, Longnose gar	673 µg/g	186 µg/L	0.051 mg/kg					[9]	F
Esox lucius, Northern pike	673 µg/g	186 µg/L	0.025 mg/kg					[9]	F
Notemigonus crysoleucas, Golden shiner	673 µg/g	186 µg/L	0.167 mg/kg					[9]	F
Notropis atherinoides, Emerald shiner	673 µg/g	186 µg/L	0.036 mg/kg					[9]	F
Notropis hudsonius, Spottail shiner	673 µg/g	186 µg/L	0.03 mg/kg					[9]	F
Pimephales notatus, Bluntnose minnow	673 µg/g	186 µg/L	0.0513 mg/kg					[9]	F

Summary of Biological Effects Tissue Concentrations for Arsenic

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	Sediment	Water	Tissue (Sample Type)	Effects	Log BCF	Log BAF	BSAF	Reference	Comments[3]
Pimephales promelas, Fathead minnow	9.10 µg/g		1.39 mg/g					[7]	L
	9.78 µg/g		1.14 mg/g						
	1.25 µg/g		1.58 mg/g						
	26 µg/g		2.40 mg/g						
	15 µg/g		1.76 mg/g						
	18 µg/g		0.66 mg/g						
	17 µg/g		2.33 mg/g						
	17 µg/g		2.22 mg/g						
	11 µg/g		1.82 mg/g						
Semotilus atromaculatus, Creek chub	673 µg/g	186 µg/L	2.36 mg/kg					[9]	F
Catostomus commersoni, White sucker	673 µg/g	186 µg/L	0.132 mg/kg					[9]	F
Fundulus diaphanus, Banded killifish	673 µg/g	186 µg/L	0.101 mg/kg					[9]	F
Amblolites repestris, Rock bass	673 µg/g	186 µg/L	0.128 mg/kg					[9]	F
Lepomis gibbosus, Pumpkinseed	673 µg/g	186 µg/L	0.342 mg/kg					[9]	F

Summary of Biological Effects Tissue Concentrations for Arsenic

Species:	**Concentration, Units in[1]:**			**Toxicity:**	**Ability to Accumulate[2]:**			**Source:**	
Taxa	**Sediment**	**Water**	**Tissue (Sample Type)**	**Effects**	**Log BCF**	**Log BAF**	**BSAF**	**Reference**	**Comments[3]**
Lepomis macrochirus, Bluegill			0.52 mg/kg (whole body)[4]	Mortality, NOED				[13]	L; no effect on mortality
Micropterus salmoides Largemouth bass	673 µg/g	186 µg/L	0.083 mg/kg					[9]	F
Perca flavescens Yellow perch	673 µg/g	186 µg/L	0.077 mg/kg					[9]	F
Stizostedion vitreum vitreum, Walleye	673 µg/g	186 µg/L	0.080 mg/kg					[9]	F

[1] Concentration units based on wet weight unless otherwise noted.
[2] BCF = bioconcentration factor, BAF = bioaccumulation factor, BSAF = biota-sediment accumulation factor.
[3] L = laboratory study, spiked sediment, single chemical; F = field study, multiple chemical exposure; other unusual study conditions or observations noted.
[4] This entry was excerpted directly from the Environmental Residue-Effects Database (ERED, www.wes.army.mil/el/ered, U.S. Army Corps of Engineers and U.S. Environmental Protection Agency). The original publication was not reviewed, and the reader is strongly urged to consult the publication to confirm the information presented here.

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Chemical Category: POLYNUCLEAR AROMATIC HYDROCARBON (high molecular weight)

Chemical Name (Common Synonyms): BENZO(A)ANTHRACENE **CASRN:** 56-55-3

Chemical Characteristics

Solubility in Water: 0.014 mg/L at 25°C [1]

Half-Life: No data [2]

Log K_{ow}: 5.70 [3]

Log K_{oc}: 5.60 L/kg organic carbon

Human Health

Oral RfD: No data [4]

Confidence: —

Critical Effect: —

Oral Slope Factor (Reference): No data [4]

Carcinogenic Classification: No data [4]

Wildlife

Partitioning Factors: Partitioning factors for benzo(a)anthracene in wildlife were not found in the literature.

Food Chain Multipliers: Food chain multipliers for benzo(a)anthracene in wildlife were not found in the literature.

Aquatic Organisms

Partitioning Factors: Partitioning factors for benzo(a)anthracene in aquatic organisms were not found in the literature.

Food Chain Multipliers: Food chain multipliers (FCMs) for trophic level 3 aquatic organisms were 12.8 (all benthic food web), 1.4 (all pelagic food web), and 8.0 (benthic and pelagic food web). FCMs for trophic level 4 aquatic organisms were 20.2 (all benthic food web), 2.3 (all pelagic food web), and 10.2 (benthic and pelagic food web) [16].

Toxicity/Bioaccumulation Assessment Profile

The acute toxicity of hydrocarbons, including benzo(a)anthracene, to both fresh and salt water crustaceans is largely nonselective, i.e., it is not primarily influenced by molecular structure, but is rather controlled by organism-water partitioning which, for nonpolar organic chemicals, is in turn a reflection of aqueous solubility. The toxic effect is believed to occur at a relatively constant concentration within the organism [5]. Toxicity of benzo(a)anthracene, as well as chrysene and pyrene, to striped bass (*Morone saxatilis*) decreased as water salinity increased [6].

Bioavailability of sediment-associated polynuclear aromatic hydrocarbons (PAHs), e.g., benzo(a)anthracene, has been observed to decline with increased contact time [7]. The majority of investigations have shown that aquatic organisms are able to release PAHs from their tissues rapidly when they were returned to a clean environment. Mussels exposed to contaminated sediment rapidly accumulated benzo(a)anthracene reaching maximum concentrations at day 20 [8]. The concentration factors for mussels exposed to 675 ng/g of benzo(a)anthracene in sediment ranged from 2,470 to 35,700 [4]. Benzo(a)anthracene was rapidly taken up by the aquatic plant, *Fontinalis antipyretica* and the uptake kinetics plateaued between 48 and 168 h of exposure [9]. Roy et al. [9] suggested that slow elimination of benzo(a)anthracene from the plant tissue may be due to low aqueous solubility. Sediment-associated benzo(a)anthracene can be accumulated from two sources: interstital water and ingested particles. The accumulation kinetics of benzo(a)anthracene suggest that uptake occurs via the sediment interstitial water and ingested material and is controlled by desorption from sediment particles and dissolved organic matter [10]. Benzo(a)anthracene after 24 h exposure was accumulated by *Daphnia pulex* mostly from the water, while lower-molecular-weight PAHs like napththalene and phenanthrene were accumulated primarily through algal food [11].

Bioaccumulation of low-molecular-weight PAHs from sediments by *Rhepoxynius abronius* (amphipod) and *Armandia brevis* (polychaete) was similar, however, a large difference in tissue concentration between these two species was measured for high-molecular-weight PAHs including benzo(a)anthracene [12]. Meador et al. [12] concluded that the low-molecular-weight PAHs were available to both species from interstitial water, while sediment ingestion was a much more important uptake route for the high-molecular-weight PAHs. The authors also indicated that bioavailability of the high-molecular-weight PAHs to amphipods was significantly reduced due to their partitioning to dissolved organic carbon.

Summary of Biological Effects Tissue Concentrations for Benzo(a)anthracene

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	**Sediment**	**Water**	**Tissue (Sample Type)**	**Effects**	**Log BCF**	**Log BAF**	**BSAF**	**Reference**	**Comments[3]**
Invertebrates									
Corbicula fluminea, Asian clam	59 µg/kg OC		508 µg/kg lipid				8.643	[15]	F; %lipid = 0.61; %sed OC = 1.19
	3,613 µg/kg OC		1,049 µg/kg lipid				0.290	[15]	F; %lipid = 0.61; %sed OC = 1.19
Macoma nasuta, Clam	4.13 ng/g		16.5 ng/g			-0.21		[13]	F
	6.19 ng/g		6.1 ng/g			-0.82		[13]	F
	39.9 ng/g		14 ng/g			-0.62		[13]	F
	39.5 ng/g		11 ng/g			-0.68		[13]	F
	138 ng/g		66 ng/g			-0.36		[13]	F
	146 ng/g		53 ng/g			-0.32		[13]	F
Daphnia pulex, Cladoceran		5.27 µg/L	1.6 ng/g		3.04			[11]	L
Pontoporeia hoyi, Amphipod	28 ng/g		72 ng/g					[10]	L

Summary of Biological Effects Tissue Concentrations for Benzo(a)anthracene

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	Sediment	Water	Tissue (Sample Type)	Effects	Log BCF	Log BAF	BSAF	Reference	Comments[3]
Fishes									
Leuciscus idus, Golden ide			17.5 mg/kg (whole body)	Mortality, NOED				[14]	L; no effect on survivorship in 3 days

[1] Concentration units based on wet weight unless otherwise noted.
[2] BCF = bioconcentration factor, BAF = bioaccumulation factor, BSAF = biota-sediment accumulation factor.
[3] L = laboratory study, spiked sediment, single chemical; F = field study, multiple chemical exposure; other unusual study conditions or observations noted.
[4] This entry was excerpted directly from the Environmental Residue-Effects Database (ERED, www.wes.army.mil/el/ered, U.S. Army Corps of Engineers and U.S. Environmental Protection Agency). The original publication was not reviewed, and the reader is strongly urged to consult the publication to confirm the information presented here.

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Chemical Category: POLYNUCLEAR AROMATIC HYDROCARBON (high molecular weight)

Chemical Name (Common Synonyms): BENZO(A)PYRENE **CASRN:** 50-32-8

Chemical Characteristics

Solubility in Water: 0.0038 mg/L at 25°C [1]

Half-Life: 5.7 d - 1.45 yrs based on aerobic soil die-away test data at 10-30°C [2]

Log K_{ow}: 6.11 [3]

Log K_{oc}: 6.01 L/kg organic carbon

Human Health

Oral RfD: No Data [4]

Confidence: —

Critical Effect: Forestomach cancer in mice

Oral Slope Factor: $7.3 \times 10^{+0}$ per (mg/kg)/day [4]

Carcinogenic Classification: B2 [4]

Wildlife

Partitioning Factors: Partitioning factors for benzo(a)pyrene in wildlife were not found in the literature.

Food Chain Multipliers: Food chain multipliers for benzo(a)pyrene in wildlife were not found in the literature.

Aquatic Organisms

Partitioning Factors: Partitioning factors for benzo(a)pyrene in aquatic organisms were not found in the literature.

Food Chain Multipliers: Trophic tranfer of benzo(a)pyrene metabolites has been demonstrated between polychaetes and bottom-feeding fish [5]. The diatom *Thalassiosira pseudonana* cultured in 10 µg/L of benzo(a)pyrene and subsequently fed to larvae of the hard clam *Mercenaria mercenaria* accumulated 42.2 µg/g while clams accumulated only 18.6 µg/g [6]. The rate of direct uptake by the algae was thus approximately 20 times faster than the rate of trophic transfer. Dobroski and Epifanio [6] concluded that direct uptake and trophic transfer (2 µg/g/day) are equally important in accumulation of benzo(a)pyrene. Food chain multipliers (FCMs) for trophic level 3 aquatic organisms were 18.5 (all benthic food web), 1.6 (all pelagic food web), and 11.3 (benthic and pelagic food web). FCMs for trophic level 4 aquatic organisms were 37.4 (all benthic food web), 3.1 (all pelagic food web), and 17.8 (benthic and pelagic food web) [42].

Toxicity/Bioaccumulation Assessment Profile

Bioavailability of sediment-associated polynuclear aromatic hydrocarbon (PAHs), including benzo(a)pyrene has been observed to decline with increased contact time [7]. Oikari and Kukkonene [8] established a relationship between dissolved organic matter including the percentage of hydrophobic acids and accumulation of benz(a)pyrene. They observed that the bioavailability of benzo(a)pyrene decreases in waters with dissolved organic carbon having more high-molecular-weight hydrophobic acids. The reduced bioavailability has been observed for benzo(a)pyrene accumulation from field-collected sediments compared with laboratory spiked sediments [9]. Mean accumulation of benzo(a)pyrene declined by a factor of three in *Chironomus riparius* exposed to sediment stored one week versus the sediment stored for eight weeks [10]. The concentrations of benzo(a)pyrene in whole sediment and pore water were 0.27-80.9 ng/g and 0.004-0.913 mg/mL, respectively [10].

Short-term exposures (24-h) to 1 mg/L benzo(a)pyrene averaged 8.27 nmol in fish tissue. Of this total, 67 percent was accumulated in the gallbladder or gut, indicating rapid metabolism and excretion [11]. The bioaccumulation of benzo(a)pyrene can be influenced by the lipid reserves [12]. In an experiment conducted by Clements et al. [13], chironomidae larvae rapidly accumulated benzo(a)pyrene from spiked sediment and tissue concentrations were directly proportional to sediment concentrations. However, the level of benzo(a)pyrene in bluegill that were fed contaminated chironomids was generally low, indicating either low uptake or rapid metabolism. According to McCarthy [14], accumulation of hydrophobic chemicals like benzo(a)pyrene in aqueous systems appears to depend on the amount of chemical in solution and on the amount sorbed to particles entering the food chain. Uptake and accumulation of benzo(a)pyrene was reduced by 97 percent due to sorption to organic matter [14].

Studies that report body burdens of the parent compound may, depending on the species, grossly underestimate total bioaccumulation of benzo(a)pyrene and their metabolites [15]. Kane-Driscoll and McElroy [15] concluded that the body burden of the parent compound may represent less than 10 percent of the actual total body burden of parent plus metabolites. The accumulation kinetics of benzo(a)pyrene suggest that uptake occurs largely via the sediment interstitial water and is controlled by desorption from sediment particles and dissolved organic matter [16]. Accumulation of benzo(a)pyrene from water was not affected by the simultaneous presence of naphthalene or PCB [17].

Kolok et al. [18] showed that the concentration of benzo(a)pyrene equivalents in shad (*Dorosoma cepedianum*) increases when the fish ventilate water turbid with benzo(a)pyrene spiked sediments. Also the turbid water, not sediment ingestion, appears to be a significant source of benzo(a)pyrene for gizzard shad.

Bioaccumulation of low-molecular-weight PAHs from sediments by *Rhepoxynius abronius* (amphipod) and *Armandia brevis* (polychaete) was similar, however, a large difference in tissue concentration between these two species was measured for high-molecular-weight PAHs including benzo(a)pyrene [19]. Meador et al. [19] concluded that the low-molecular-weight PAHs were available to both species from interstitial water, while sediment ingestion was a much more important uptake route for the high-molecular-weight PAHs. The authors also indicated that bioavailability of the high-molecular-weight PAHs to amphipods was significantly reduced due to their partitioning to dissolved organic carbon.

Summary of Biological Effects Tissue Concentrations for Benzo(a)pyrene

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	**Sediment**	**Water**	**Tissue (Sample Type)**	**Effects**	**Log BCF**	**Log BAF**	**BSAF**	**Reference**	**Comments[3]**
Invertebrates									
Nereis diversicolor, Polychaeta worm	236.6 pmol/g		95.2 pmol/g					[15]	F
Scolecolepides viridis, Polychaeta worm	184.2 pmol/g		119 pmol/g					[15]	F
Leitoscoloplos fragilis, Polychaeta worm	475.8 pmol/g		3540 pmol/g					[15]	F
Thais haemostoma, Snail		BDL	1.45-3.89 µg/kg					[23]	F
Physa sp., Snail		3.39 µg/L	259.6 µg/kg					[20]	L
Dreissena polymorpha, Zebra mussel			3.1 - 4.7 x 10^6 mg/g					[12]	L; depending on the lipid content
Mytilus edulis, Mussel			3.2 mg/kg (whole body)[4]	Physiological, ED50				[30]	L; 50% reduction in feeding, clearance rate, and tolerance to aerial exposure

Summary of Biological Effects Tissue Concentrations for Benzo(a)pyrene

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	Sediment	Water	Tissue (Sample Type)	Effects	Log BCF	Log BAF	BSAF	Reference	Comments[3]
			0.161 mg/kg (whole body)[4]	Physiological, LOED				[30]	L; elevated activity of superoxide dismutase (SOD)
			3.2 mg/kg (whole body)[4]	Physiological, LOED				[30]	L; inhibition of superoxide dismutase (SOD) and catalase activity
			3.2 mg/kg (whole body)[4]	Reproduction, LOED				[30]	L, reduced gametogenesis, reproductive success rate
Macoma nasuta, Clam	9.2 ng/g		50 ng/g			-0.07		[12]	F
Macoma nasuta, Clam	4.7 ng/g		1.4 ng/g			-1.30		[21]	F
	70 ng/g		22 ng/g			-0.68		[21]	F
	99 ng/g		45 ng/g			-0.48		[21]	F
	228 ng/g		62 ng/g			-0.70		[21]	F
	440 ng/g		66 ng/g			-0.70		[21]	F
Macomona liliana, Mollusc	3,533 µg/kg OC		189.2 µg/kg lipid				0.0536	[40]	F, %lipid = 2.95; %sed OC = 0.30

Summary of Biological Effects Tissue Concentrations for Benzo(a)pyrene

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	**Sediment**	**Water**	**Tissue (Sample Type)**	**Effects**	**Log BCF**	**Log BAF**	**BSAF**	**Reference**	**Comments[3]**
	68,767 µg/kg OC		845.5 µg/kg lipid				0.0123	[40]	F, %lipid = 2.33; %sed OC = 0.73
	2,864 µg/kg OC		166.9 µg/kg lipid				0.0583	[40]	F, %lipid = 2.57; %sed OC = 0.22
	2,440 µg/kg OC		261.8 µg/kg lipid				0.1073	[40]	F, %lipid = 2.04; %sed OC = 0.25
	1,021 µg/kg OC		48.6µg/kg lipid				0.0476	[40]	F, %lipid = 3.13; %sed OC = 0.48
Austrovenus stutchburyi, Mollusc	3,533 µg/kg OC		19.2 µg/kg lipid				0.0054	[40]	F, %lipid = 5.62; %sed OC = 0.30
	68,767 µg/kg OC		24.6 µg/kg lipid				0.0004	[40]	F, %lipid = 5.21; %sed OC = 0.73
	2,864 µg/kg OC		18.8 µg/kg lipid				0.0066	[40]	F, %lipid = 4.85; %sed OC = 0.22
	2,440 µg/kg OC		14.5 µg/kg lipid				0.0059	[40]	F, %lipid = 3.87; %sed OC = 0.25
	1,021 µg/kg OC		11.0 µg/kg lipid				0.0108	[40]	F, %lipid = 4.27; %sed OC = 0.48
Sphaerium corneum, Fingernail Clam			1.25 mg/kg (whole body)[4]	Mortality, NOED				[28]	L; no effect on survivorship in 120 hours

Summary of Biological Effects Tissue Concentrations for Benzo(a)pyrene

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	Sediment	Water	Tissue (Sample Type)	Effects	Log BCF	Log BAF	BSAF	Reference	Comments[3]
Corbicula fluminea, Asian Clam	84 µg/kg OC		180.3 µg/kg lipid				2.146	[41]	F, %lipid =0.61; %sed OC = 1.19
	6,387 µg/kg OC		245.9 µg/kg lipid				0.039	[41]	F, %lipid =0.61; %sed OC = 1.19
Mercenaria mercenaria, Quahog Clam,			0.00221 mg/kg (whole body)[4]	Physiological, LOED				[27]	L;impaired ability to clear flavobacterium, exp_conc = < 0.001
			0.00221 mg/kg (whole body)[4]	Mortality, NOED				[27]	L; no effect on mortality, exp_conc = <0.001
Daphnia magna, Cladoceran					3.90 (without organic matter)			[14]	L
Daphnia magna, Cladoceran					3.00 (with organic matter)			[14]	L

Summary of Biological Effects Tissue Concentrations for Benzo(a)pyrene

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	Sediment	Water	Tissue (Sample Type)	Effects	Log BCF	Log BAF	BSAF	Reference	Comments[3]
Pontoporeia hoyi, Amphipod	15.5 ng/g		32 ng/g					[16]	L
	410 ng/g	3 ng/mL	600 ng/g			4.74		[22]	L
	40 ng/g	3.5 ng/mL	400 ng/g						
	30 ng/g	2.2 ng/mL	270 ng/g						
Chironomus riparius, Midge	3,920 µg/kg	2,160 ng/L	720 µg/kg					[13]	L
	4,290 µg/kg	1,680 ng/L	252 µg/kg					[13]	L
	4,035 µg/kg	2,640 ng/L	720 µg/kg					[13]	L
Chironomus riparius, Midge			0.23 mg/kg (whole body)[4]	Behavior, NOED				[38]	L; no effect on swimming behavior
			0.09 mg/kg (whole body)[4]	Behavior, NOED				[38]	L; no effect on swimming behavior
			0.04 mg/kg (whole body)[4]	Behavior, NOED				[38]	L; no effect on swimming behavior
Chironomus riparius, Midge			1.9 mg/kg (whole body)[4]	Mortality, NOED				[28]	L; no effect on survivorship in 120 hours
Culex pipiens quinquefasciatus, Mosquito larva		3.39 µg/L	73.1 µg/kg					[21]	L

Summary of Biological Effects Tissue Concentrations for Benzo(a)pyrene

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	Sediment	Water	Tissue (Sample Type)	Effects	Log BCF	Log BAF	BSAF	Reference	Comments[3]
Asterias rubens, Starfish			37.8 mg/kg (pyloric caeca)[4]	Physiological, ED100				[29]	L; 346% induction of benzo(a)pyrene hydroxylase activity
			40 mg/kg (whole body)[4]	Physiological, ED100				[29]	L; 346% induction of benzo(a)pyrene hydroxylase activity
			2.15 mg/kg (pyloric caeca)[4]	Physiological, LOED				[29]	L; 200% induction of benzo(a)pyrene hydroxylase activity
			13.2 mg/kg (pyloric caeca)[4]	Physiological, LOED				[29]	L; 200% induction of benzo(a)pyrene hydroxylase activity
			2.5 mg/kg (whole body)[4]	Physiological, LOED				[29]	L; 200% induction of benzo(a)pyrene hydroxylase activity
			10 mg/kg (whole body)[4]	Physiological, LOED				[29]	L; 200% induction of benzo(a)pyrene hydroxylase activity
			0.5 mg/kg (whole body)[4]	Mortality, NOED				[29]	L; no effect on mortality
			10 mg/kg (whole body)[4]	Mortality, NOED				[29]	L; no effect on mortality
			2.5 mg/kg (whole body)[4]	Mortality, NOED				[29]	L; no effect on mortality

Summary of Biological Effects Tissue Concentrations for Benzo(a)pyrene

Taxa	Sediment	Water	Tissue (Sample Type)	Effects	Log BCF	Log BAF	BSAF	Reference	Comments[3]
Species:	**Concentration, Units in[1]:**			**Toxicity:**	**Ability to Accumulate[2]:**			**Source:**	
			10 mg/kg (whole body)[4]	Mortality, NOED				[29]	L; no effect on mortality
			40 mg/kg (whole body)[4]	Mortality, NOED				[29]	L; no effect on mortality
			0.053 mg/kg (pyloric caeca)[4]	Physiological, NOED				[29]	L; no effect on benzo(a)pyrene hydroxylase activity
			0.5 mg/kg (whole body)[4]	Physiological, NOED				[29]	L; no effect on benzo(a)pyrene hydroxylase activity
Fishes									
Poeciliopsis monoacha, Viviparius	3.96 µmol/L		8.27 nmol	48-h LC50 3.75 mg/L				[11]	L
Oncorhynchus mykiss (Salmo gairdneri), Rainbow trout		5 µg/egg injection	32,090 cpm (egg) 25,448 cpm (fry)					[24]	L
			14-day 21,839 cpm fry) 35-day 8,922 cpm (fry)						

Summary of Biological Effects Tissue Concentrations for Benzo(a)pyrene

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	Sediment	Water	Tissue (Sample Type)	Effects	Log BCF	Log BAF	BSAF	Reference	Comments[3]
Oncorhynchus mykiss, Rainbow trout			0.35 mg/kg (whole body)[4]	Physiological, LOED				[34]	L; hepatic enzyme induction
			30 mg/kg (whole body)[4]	Physiological, LOED				[34]	L; induction of hepatic mixed function oxidases
			12.3 mg/kg (whole body)[4]	Development, NA				[35]	L; gross abnormalities in alevins noted at all test concentrations 0.08 mg/L and above, significant increase relative to the control
			1.93 mg/kg (whole body)[4]	Reproduction, NA				[35]	L; hatchability not significantly reduced
			7.18 mg/kg (whole body)[4]	Reproduction, NA				[35]	L; hatchability not significantly reduced
			10.2 mg/kg (whole body)[4]	Reproduction, NA				[35]	L; hatchability not significantly reduced
			12.3 mg/kg (whole body)[4]	Reproduction, NA				[35]	L; hatchability not significantly reduced

Summary of Biological Effects Tissue Concentrations for Benzo(a)pyrene

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	Sediment	Water	Tissue (Sample Type)	Effects	Log BCF	Log BAF	BSAF	Reference	Comments[3]
Cyprinus carpio, Common carp			155 mg/kg (liver)[4]	Physiological, NA				[39]	L; significant increase in EROD enzyme and P450 1A protein content
Gambusia affinis, Mosquito fish		3.39 µg/L	14.1 µg/kg					[20]	L
Lepomis macrochirus, Bluegill sunfish		1 µg/L	39,000 ng/g (gall bladder)		4.15			[25]	L
		1 µg/L	4,600 ng/g (liver)		3.20			[25]	L
		1 µg/L	2,200 ng/g (viscera)		2.89			[25]	L
		1 µg/L	250 ng/g (brain)		1.95			[25]	L
		1 µg/L	370 ng/g (carcass)		2.11			[25]	L
Dorosoma cepedianum, Gizzard shad					3.62			[18]	L

Summary of Biological Effects Tissue Concentrations for Benzo(a)pyrene

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	Sediment	Water	Tissue (Sample Type)	Effects	Log BCF	Log BAF	BSAF	Reference	Comments[3]
Dorosoma cepedianum, Gizzard shad			10 mg/kg (whole body)[4]	Physiological, LOED				[37]	L; statistically significant, maximum (11x) induction of ethoxyresorufin-o-deethylase (EROD)
			0.0289 mg/kg (whole body)[4]	Physiological, LOED				[37]	L; statistically significant induction of ethoxyresorufin-o-deethylase (EROD)
			0.0283 mg/kg (whole body)[4]	Physiological, LOED				[37]	L; statistically significant induction of ethoxyresorufin-o-deethylase (EROD)
			50 mg/kg (whole body)[4]	Physiological, NA				[37]	L; 10x induction of ethoxyresorufin-o-deethylase (EROD)
			0.0257 mg/kg (whole body)[4]	Physiological, NA				[37]	L; statistically significant induction of ethoxyresorufin-o-deethylase (EROD)

Summary of Biological Effects Tissue Concentrations for Benzo(a)pyrene

Species:	**Concentration, Units in[1]:**			**Toxicity:**	**Ability to Accumulate[2]:**			**Source:**	
Taxa	**Sediment**	**Water**	**Tissue (Sample Type)**	**Effects**	**Log BCF**	**Log BAF**	**BSAF**	**Reference**	**Comments[3]**
			0.0265 mg/kg (whole body)[4]	Physiological, NA				[37]	L; statistically significant induction of ethoxyresorufin-o-deethylaste (EROD)
			0.1 mg/kg (whole body)[4]	Physiological, NOED				[37]	L; no induction of ethoxyresorufin-o-deethylase (EROD)
			0.0337 mg/kg (whole body)[4]	Physiological, NOED				[37]	L; no induction of ethoxyresorufin-o-deethylase (EROD)
			0.0201 mg/kg (whole body)[4]	Physiological, NOED				[37]	L; no induction of ethoxyresorufin-o-deethylase (EROD)
			1 mg/kg (whole body)[4]	Physiological, NOED				[37]	L; no induction of ethoxyresorufin-o-deethylase (EROD)
			0.0239 mg/kg (whole body)[4]	Physiological, NOED				[37]	L; no induction of ethoxyresorufin-o-deethylase (EROD)
			0.0196 mg/kg (whole body)[4]	Physiological, NOED				[37]	L; no induction of ethoxyresorufin-o-deethylase (EROD)

Summary of Biological Effects Tissue Concentrations for Benzo(a)pyrene

Species:	**Concentration, Units in[1]:**			**Toxicity:**	**Ability to Accumulate[2]:**			**Source:**	
Taxa	**Sediment**	**Water**	**Tissue (Sample Type)**	**Effects**	**Log BCF**	**Log BAF**	**BSAF**	**Reference**	**Comments[3]**
Ictalurus punctatus, Channel catfish			100 mg/kg (whole body)[4]	Physiological, LOED				[31]	L; significant decrease in neurotransmitter levels
			0.1 mg/kg (whole body)[4]	Physiological, LOED				[32]	L; five to six-fold induction of cytochrome P450
Leuciscus idus, Golden ide			24 mg/kg (whole body)[4]	Mortality, NOED				[33]	L; no effect on survivorship in 3 days
Citharichthys stigmaeus, Sand dab		3 µg/L	130 ng/g (liver), 10 ng/g (gut), 400 ng/g (gill), 30 ng/g (flesh), 150 ng/g (heart)					[25]	L; accumulation within 1 h
Psettichthys melanostictus, Sand sole			2.1 mg/kg (whole body)[4]	Reproduction, ED50				[36]	L; reduced hatching success
			2.1 mg/kg (whole body)[4]	Development, LOED				[36]	L; larval abnormalities

Summary of Biological Effects Tissue Concentrations for Benzo(a)pyrene

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	Sediment	Water	Tissue (Sample Type)	Effects	Log BCF	Log BAF	BSAF	Reference	Comments[3]
Oligocottus maculosus, Tidepool sculpins		0.5 µg/L	120 ng/g (liver), 160 ng/g (gut), 200 ng/g (gill), 130 ng/g (flesh), 70 ng/g (heart)					[25]	L; accumulation within 1 h

[1] Concentration units based on wet weight unless otherwise noted.

[2] BCF = bioconcentration factor, BAF = bioaccumulation factor, BSAF = biota-sediment accumulation factor.

[3] L = laboratory study, spiked sediment, single chemical; F = field study, multiple chemical exposure; other unusual study conditions or observations noted.

[4] This entry was excerpted directly from the Environmental Residue-Effects Database (ERED, www.wes.army.mil/el/ered, U.S. Army Corps of Engineers and U.S. Environmental Protection Agency). The original publication was not reviewed, and the reader is strongly urged to consult the publication to confirm the information presented here.

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Chemical Category: POLYNUCLEAR AROMATIC HYDROCARBON (high molecular weight)

Chemical Name (Common Synonyms): BENZO(B)FLUORANTHENE **CASRN:** 205-99-2

Chemical Characteristics

Solubility in Water: 0.0012 mg/L [1]

Half-Life: 360 days - 1.67 yrs based on aerobic soil die-away test data [2]

Log K_{ow}: 6.20 [3]

Log K_{oc}: 6.09 L/kg organic carbon

Human Health

Oral RfD: No data [4]

Confidence: —

Critical Effect: —

Oral Slope Factor (Reference): No data [4]

Carcinogenic Classification: No data [4]

Wildlife

Partitioning Factors: Partitioning factors for benzo(b)fluoranthene in wildlife were not found in the literature.

Food Chain Multipliers: Food chain multipliers for benzo(b)fluoranthene in wildlife were not found in the literature.

Aquatic Organisms

Partitioning Factors: Partitioning factors for benzo(b)fluoranthene in aquatic organisms were not found in the literature.

Food Chain Multipliers: Food chain multipliers for benzo(b)fluoranthene in aquatic organisms were not found in the literature.

Toxicity/Bioaccumulation Assessment Profile

The acute toxicity of hydrocarbons, including benzo(b)fluoranthene, to both fresh and salt water crustaceans is largely nonselective, i.e., it is not primarily influenced by molecular structure, but is rather controlled by organism-water partitioning which, for nonpolar organic chemicals, is in turn a reflection of aqueous solubility. The toxic effect is believed to occur at a relatively constant concentration within the organism [5].

Bioavailability of sediment-associated polynuclear aromatic hydrocarbons (PAHs), e.g., benzo(b)fluoranthene, has been observed to decline with increased contact time [6]. The majority of investigations have shown that aquatic organisms are able to release PAHs from their tissues rapidly when they were returned to a clean environment. The apparent effects threshold concentration of 4,500 ng/g was established for benzo(b)fluoranthene based on effects observed in the marine amphipod *Rhepoxynius abronius* [7].

Bioaccumulation of low- molecular-weight PAHs from sediments by *Rhepoxynius abronius* (amphipod) and *Armandia brevis* (polychaete) was similar, however, a large difference in tissue concentration between these two species was measured for high-molecular-weight PAHs including benzo(b)fluoranthene [8]. Meador et al. [8] concluded that the low-molecular-weight PAHs were available to both species from interstitial water, while sediment ingestion was a much more important uptake route for the high-molecular-weight PAHs. The authors also indicated that bioavailability of the high-molecular-weight PAHs to amphipods was significantly reduced due to their partitioning to dissolved organic carbon.

Summary of Biological Effects Tissue Concentrations for Benzo(b)fluoranthene

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	**Sediment**	**Water**	**Tissue (Sample Type)**	**Effects**	**Log BCF**	**Log BAF**	**BSAF**	**Reference**	**Comments[3]**
Invertebrates									
Crassostrea virginica, Oyster	18 ng/g		18 ng/g					[9]	F
	2.9 ng/g		27 ng/g					[9]	F
	9.9 ng/g		40 ng/g					[9]	F
Diporeia spp, Amphipod	27 nmol/g		321 nmol/g					[6]	L

[1] Concentration units based on wet weight unless otherwise noted.
[2] BCF = bioconcentration factor, BAF = bioaccumulation factor, BSAF = biota-sediment accumulation factor.
[3] L = laboratory study, spiked sediment, single chemical; F = field study, multiple chemical exposure; other unusual study conditions or observations noted.

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Chemical Category: POLYNUCLEAR AROMATIC HYDROCARBON (high molecular weight)

Chemical Name (Common Synonyms): BENZO(G,H,I)PERYLENE **CASRN:** 191-24-2

Chemical Characteristics

Solubility in Water: Insoluble in water [1]

Half-Life: 590 d - 650 days based on aerobic soil die-away test data at 30°. [2]

Log K_{ow}: 6.70 [3]

Log K_{oc}: 6.59 L/kg organic carbon

Human Health

Oral RfD: No data [4]

Confidence: —

Critical Effect: —

Oral Slope Factor (Reference): No data [4]

Carcinogenic Classification: No data [4]

Wildlife

Partitioning Factors: Partitioning factors for benzo(g,h,i)perylene in wildlife were not found in the literature.

Food Chain Multipliers: Food chain multipliers for benzo(g,h,i)perylene in wildlife were not found in the literature.

Aquatic Organisms

Partitioning Factors: Partitioning factors for benzo(g,h,i)perylene in aquatic organisms were not found in the literature.

Food Chain Multipliers: An ecotoxicological in situ study conducted at the Baltic Sea, showed that the tissue residue concentration of benzo(g,h,i)perylene decreased with increasing trophic level [5]. The relatively high theoretical flux through the food chain was not possible to detect.

Toxicity/Bioaccumulation Assessment Profile

The acute toxicity of hydrocarbons, including benzo(g,h,i)perylene, to both fresh and salt water crustaceans is largely nonselective, i.e., it is not primarily influenced by molecular structure, but is rather controlled by organism-water partitioning which, for nonpolar organic chemicals, is in turn a reflection of aqueous solubility. The toxic effect is believed to occur at a relatively constant concentration within the organism [5].

The majority of investigations have shown that aquatic organisms are able to release polynuclear aromatic hydrocarbons (PAHs), e.g., benzo(g,h,i)perylene, from their tissues rapidly when they were returned to clean environment. Tanacredl and Cardenas [6] reported that *Mercenaria mercenaria* exposed to PAHs accumulated them to high levels in their tissues and failed to release them when returned to clean seawater over the 45-day depuration period. Unlike other marine organisms, this "sequestering" in molluscs may support the apparent inability to metaboilize PAHs to more water soluble and thus easily secreted polar metabolites.

Bioaccumulation of low-molecular-weight PAHs from sediments by *Rhepoxynius abronius* (amphipod) and *Armandia brevis* (polychaete) was similar; however, a large difference in tissue concentration between these two species was measured for high-molecular-weight PAHs including benzo(g,h,i)perylene [7]. Meador et al. [7] concluded that the low-molecular-weight PAHs were available to both species from interstitial water, while sediment ingestion was a much more important uptake route for the high-molecular-weight PAHs. The authors also indicated that bioavailability of the high-molecular-weight PAHs to amphipods was significantly reduced due to their partitioning to dissolved organic carbon.

Summary of Biological Effects Tissue Concentrations for Benzo(g,h,i)perylene									
Species:	**Concentration, Units in[1]:**			**Toxicity:**	**Ability to Accumulate[2]:**			**Source:**	
Taxa	**Sediment**	**Water**	**Tissue (Sample Type)**	**Effects**	**Log BCF**	**Log BAF**	**BSAF**	**Reference**	**Comments[3]**
Invertebrates									
Mytilus edulis, Mussels			13 ng/g					[8]	F
Crassostrea virginica, Oyster	0.4 ng/g		10 ng/g					[10]	
	122.1 ng/g		16 ng/g					[10]	F
	31.1 ng/g		27 ng/g					[10]	F
	75.1 ng/g		12 ng/g					[10]	F
	5.4 ng/g		14 ng/g					[10]	F
	5.7 ng/g		18 ng/g					[10]	F
	6.2 ng/g		10 ng/g					[10]	F
	6.7 ng/g		10 ng/g					[10]	F
	0.4 ng/g		10 ng/g					[10]	F
	16.1 ng/g		16 ng/g					[10]	F
Pontoporeia hoyi, Amphipod	400 ng/g	5 ng/mL	BDL					[9]	L
Fishes									
Cyprinus carpio, Common carp			29.6 mg/kg (liver)[4]	Physiological, NOED				[11]	L; no significant increase in EROD enzyme and P450 1a protein content

Summary of Biological Effects Tissue Concentrations for Benzo(g,h,i)perylene

Species:	**Concentration, Units in[1]:**			**Toxicity:**	**Ability to Accumulate[2]:**			**Source:**	
Taxa	**Sediment**	**Water**	**Tissue (Sample Type)**	**Effects**	**Log BCF**	**Log BAF**	**BSAF**	**Reference**	**Comments[3]**
Wildlife									
Somateria mollissima, Eider duck			2 ng/g					[8]	F

[1] Concentration units based on wet weight unless otherwise noted.

[2] BCF = bioconcentration factor, BAF = bioaccumulation factor, BSAF = biota-sediment accumulation factor.

[3] L = laboratory study, spiked sediment, single chemical; F = field study, multiple chemical exposure; other unusual study conditions or observations noted.

[4] This entry was excerpted directly from the Environmental Residue-Effects Database (ERED, www.wes.army.mil/el/ered, U.S. Army Corps of Engineers and U.S. Environmental Protection Agency). The original publication was not reviewed, and the reader is strongly urged to consult the publication to confirm the information presented here.

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Chemical Category: POLYNUCLEAR AROMATIC HYDROCARBON (high molecular weight)

Chemical Name (Common Synonyms): BENZO(K)FLUORANTHENE **CASRN:** 207-08-9

Chemical Characteristics

Solubility in Water: Insoluble in water [1]

Half-Life: 2.49 yrs - 5.86 yrs based on aerobic soil die-away test data [2]

Log K_{ow}: 6.20 [3]

Log K_{oc}: 6.09 L/kg organic carbon

Human Health

Oral RfD: No data [4]

Confidence: —

Critical Effect: —

Oral Slope Factor (Reference): Not available [4]

Carcinogenic Classification: B2 [4]

Wildlife

Partitioning Factors: Partitioning factors for benzo(k)fluoranthene in wildlife were not found in the literature.

Food Chain Multipliers: Food chain multipliers for benzo(k)fluoranthene in wildlife were not found in the literature.

Aquatic Organisms

Partitioning Factors: The only partitioning factors for benzo(k)fluoranthene in aquatic organisms found in the literature were log BAFs of -0.68 to 0.01 for the clam *Macoma nasuta* [9].

Food Chain Multipliers: An ecotoxicological in situ study conducted at the Baltic Sea [5] showed that the tissue residue concentration of benzo(k)fluoranthene decreased with increasing trophic level. The relatively high theoretical flux through the food chain was not possible to detect.

Toxicity/Bioaccumulation Assessment Profile

The acute toxicity of hydrocarbons, including benzo(k)fluoranthene, to both fresh and salt water crustaceans is largely nonselective, i.e., it is not primarily influenced by molecular structure, but is rather controlled by organism-water partitioning which, for nonpolar organic chemicals, is in turn a reflection of aqueous solubility. The toxic effect is believed to occur at a relatively constant concentration within the organism [6].

The majority of investigations have shown that aquatic organisms are able to release polynuclear aromatic hydrocarbons (PAHs), e.g., benzo(k)fluoranthene, from their tissues rapidly when they were returned to clean environment. The apparent effects threshold concentration of 4500 ng/g for benzo(k)fluoranthene was established based on effects observed in the marine amphipod *Rhepoxynius abronius* [7].

Bioaccumulation of low-molecular-weight PAHs from sediments by *Rhepoxynius abronius* (amphipod) and *Armandia brevis* (polychaete) was similar, however, a large difference in tissue concentration between these two species was measured for high-molecular-weight PAHs including benzo(k)fluoranthene [8]. Meador et al. [8] concluded that the low-molecular-weight PAHs were available to both species from interstitial water, while sediment ingestion was a much more important uptake route for the high-molecular-weight PAHs. The authors also indicated that bioavailability of the high-molecular-weight PAHs to amphipods was significantly reduced due to their partitioning to dissolved organic carbon.

Summary of Biological Effects Tissue Concentrations for Benzo(k)fluoranthene

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	Sediment	Water	Tissue (Sample Type)	Effects	Log BCF	Log BAF	BSAF	Reference	Comments[3]
Invertebrates									
Mytilus edulis, Blue mussel			44 ng/g					[5]	F
Crassostrea virginica, Eastern oyster	1.5 ng/g		14 ng/g					[10]	F
	36 ng/g		85 ng/g					[10]	F
	59.6 ng/g		65 ng/g					[10]	F
	127.5 ng/g		61 ng/g						
Macoma nasuta, Clam	14.1 ng/g		92 ng/g			0.009 or 0.01		[9]	F
	17 ng/g		24 ng/g			-0.66		[9]	F
	121 ng/g		59 ng/g			-0.48		[9]	F
	156 ng/g		87 ng/g			-0.39		[9]	F
	390 ng/g		128 ng/g			-0.51		[9]	F
	610 ng/g		96 ng/g			-0.68		[9]	F
Wildlife									
Somateria mollissima, Eider duck			4.3 ng/g					[5]	F

[1] Concentration units based on wet weight unless otherwise noted.
[2] BCF = bioconcentration factor, BAF = bioaccumulation factor, BSAF = biota-sediment accumulation factor.
[3] L = laboratory study, spiked sediment, single chemical; F = field study, multiple chemical exposure; other unusual study conditions or observations noted.
[4] This entry was excerpted directly from the Environmental Residue-Effects Database (ERED, www.wes.army.mil/el/ered, U.S. Army Corps of Engineers and U.S. Environmental Protection Agency). The original publication was not reviewed, and the reader is strongly urged to consult the publication to confirm the information presented here.

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Chemical Category: METAL (Divalent)

Chemical Name (Common Synonyms): CADMIUM **CASRN:** 7440-43-9

Chemical Characteristics

Solubility in Water: Insoluble [1]

Half-Life: Not applicable, stable [1]

Log K_{ow}: –

Log K_{oc}: –

Human Health

Oral RfD: 5 x 10^{-4} mg/kg-day [2]

Confidence: High, uncertainty factor = 10

Critical Effect: Significant proteinuria, presence of protein in urine

Oral Slope Factor: Not available [2]

Carcinogenic Classification: B1 [2]

Wildlife

Partitioning Factors: Partitioning factors for cadmium in wildlife were not found in the literature.

Food Chain Multipliers: Food chain multipliers for cadmium in wildlife were not found in the literature.

Aquatic Organisms

Partitioning Factors: Cadmium in the water column can partition to dissolved and particulate organic carbon. The more important issues related to water column concentrations of cadmium are water hardness (i.e., calcium concentration), pH, and metal speciation since the divalent cadmium ion is believed to be responsible for observed biological effects. Cadmium speciation yields primarily the divalent form of the metal, Cd^{+2}, between pH values of 4.0 and 7.0 [3]. In addition, the concentration of acid-volatile sulfides is known to be an important factor controlling the toxicity and bioaccumulation of cadmium in sediments.

Food Chain Multipliers: Most studies reviewed contained data which suggest that cadmium is not a highly mobile element in aquatic food webs, and there appears to be little evidence to support the general occurrence of biomagnification of cadmium within marine or freshwater food webs [4,5,6,7].

Toxicity/Bioaccumulation Assessment Profile

Cadmium does not appear to be a highly mobile element under typical conditions in most aquatic habitats [4]. Additional studies reviewed by Kay [4] indicated that no maternal transfer of cadmium was observed in zebrafish and that the cadmium content of bird eggs did not appear to be a good indicator of environmental exposure to cadmium. Tissue residue-toxicity relationships can also be variable because organisms might sequester metal in various forms that can be analytically measurable as tissue residue but might actually be stored in unavailable forms within the organism as a form of detoxification [8]. Whole body residues might also not be indicative of effects concentrations at the organ level because concentrations in target organs, such as the kidneys and liver, may be 20 times higher than whole body residues [9]. The application of "clean" chemical analytical and sample preparation techniques is also critical in the measurement of metal tissue residues. After evaluating the effects of sample preparation techniques on measured concentrations of metals in the edible tissue of fish, Schmitt and Finger [10] concluded that there was little direct value in measuring copper, zinc, iron, or manganese tissue residues in fish because they do not bioaccumulate to any appreciable extent. Cadmium and lead were the only ones found to be of potential concern in edible fish tissue based on the results from Schmitt and Finger's study of "clean" chemical techniques, although Wiener and Stokes [11] suggested that cadmium did not generally accumulate to any appreciable extent in the edible muscle tissue of fish.

Rule and Alden [26] studied the relationship between uptake of cadmium and copper from the sediment by the blue mussel (*Mytilus edulis*), grass shrimp (*Palaemonetes pugio*), and hard clam (*Mercenaria mercenaria*). The uptake of cadmium by the blue mussel significantly increased as a function of increasing cadmium concentration in sediment. However, the uptake of cadmium increased when copper was added to the sediments. The uptake of cadmium by the grass shrimp exhibited a pattern similar to that of the mussel, while the uptake of cadmium by the hard clam was low compared to the other two species and related only to the cadmium concentration in sediment.

The experiments performed by Meador [28] revealed that the response of the amphipods *Rhepoxynius abronius* and *Eohaustorius estuarius* to cadium decreased two- to threefold for animals held in the laboratory for several weeks compared to organisms recently collected from the field.

Summary of Biological Effects Tissue Concentrations for Cadmium

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]			Source:	
Taxa	Sediment	Water	Tissue (Sample Type)	Effects	Log BCF	Log BAF	BSAF	Reference	Comments[3]
Plants									
Scenedesmus obliquus, Freshwater colonial green algae			2,340 mg/kg (whole body)[5]	Growth, LOED				[31]	L; significant inhibition of growth (27% reduction from control)
			658 mg/kg (whole body)[5]	Growth, LOED				[31]	L; 39% reduction in population growth from controls
			3,030 mg/kg (whole body)[5]	Growth, NOED				[31]	L; no significant inhibition of growth
Eichhornia crassipes, Water hyacinth			11.4 mg/kg (leaf)[5]	Growth, LOED				[47]	F; reduced growth rate, chlorosis
			262 mg/kg (root)[5]	Growth, LOED				[47]	F; reduced growth rate, chlorosis
			49.6 mg/kg (stem)[5]	Growth, LOED				[47]	F; reduced growth rate, chlorosis

Summary of Biological Effects Tissue Concentrations for Cadmium

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]			Source:	
Taxa	**Sediment**	**Water**	**Tissue (Sample Type)**	**Effects**	**Log BCF**	**Log BAF**	**BSAF**	**Reference**	**Comments[3]**
			11.4 mg/kg (leaf)[5]	Morphology, LOED				[47]	F; chlorosis, browning, necrosis, waterlogging of tissues
			262 mg/kg (root)[5]	Morphology, LOED				[47]	F; chlorosis, browning, necrosis, waterlogging of tissues
			49.6 mg/kg (stem)[5]	Morphology, LOED				[47]	F; chlorosis, browning, necrosis, waterlogging of tissues
			20.8 mg/kg (leaf)[5]	Growth, NA				[47]	F; reduced growth rate, chlorosis
			45.8 mg/kg (leaf)[5]	Growth, NA				[47]	F; reduced growth rate, chlorosis
			578 mg/kg (root)[5]	Growth, NA				[47]	F; reduced growth rate, chlorosis
			1,300 mg/kg (root)[5]	Growth, NA				[47]	F; reduced growth rate, chlorosis

Summary of Biological Effects Tissue Concentrations for Cadmium

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]			Source:	
Taxa	Sediment	Water	Tissue (Sample Type)	Effects	Log BCF	Log BAF	BSAF	Reference	Comments[3]
			84.8 mg/kg (stem)[5]	Growth, NA				[47]	F; reduced growth rate, chlorosis
			159 mg/kg (stem)[5]	Growth, NA				[47]	F; reduced growth rate, chlorosis
			20.8 mg/kg (leaf)[5]	Morphology, NA				[47]	F; chlorosis, browning, necrosis, waterlogging of tissues
			45.8 mg/kg (leaf)[5]	Morphology, NA				[47]	F; chlorosis, browning, necrosis, waterlogging of tissues
			578 mg/kg (root)[5]	Morphology, NA				[47]	F; chlorosis, browning, necrosis, waterlogging of tissues
			1,300 mg/kg (root)[5]	Morphology, NA				[47]	F; chlorosis, browning, necrosis, waterlogging of tissues

Summary of Biological Effects Tissue Concentrations for Cadmium

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]			Source:	
Taxa	Sediment	Water	Tissue (Sample Type)	Effects	Log BCF	Log BAF	BSAF	Reference	Comments[3]
			84.8 mg/kg (stem)[5]	Morphology, NA				[47]	F; chlorosis, browning, necrosis, waterlogging of tissues
			159 mg/kg (stem)[5]	Morphology, NA				[47]	F; chlorosis, browning, necrosis, waterlogging of tissues
			8 mg/kg (leaf)[5]	Growth, NOED				[47]	F; no effect on growth
			142 mg/kg (root)[5]	Growth, NOED				[47]	F; no effect on growth
			27.8 mg/kg (stem)[5]	Growth, NOED				[47]	F; no effect on growth
			8 mg/kg (leaf)[5]	Morphology, NOED				[47]	F; no effect on plant appearance
			142 mg/kg (root)[5]	Morphology, NOED				[47]	F; no effect on plant appearance
			27.8 mg/kg (stem)[5]	Morphology, NOED				[47]	F; no effect on plant appearance

Summary of Biological Effects Tissue Concentrations for Cadmium

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]			Source:	
Taxa	Sediment	Water	Tissue (Sample Type)	Effects	Log BCF	Log BAF	BSAF	Reference	Comments[3]
Invertebrates									
Lumbriculus variegatus, Oligochaete			670 mg/kg (whole body)[5]	Mortality, LOED				[32]	L; 40% mortality
			310 mg/kg (whole body)[5]	Mortality, NOED				[32]	L; no effect on mortality
Najas quadulepensis, Southern naiad			10.3 mg/kg (whole body)[5]	Development, LOED				[35]	L; reductions in chlorophyll and stolon development
Neanthes arenaceodentata, Polychaete			67 mg/kg (whole body)[5]	Reproduction, ED100				[46]	L; reproductive failure
			67 mg/kg (whole body)[5]	Behavior, LOED				[46]	L; reduced tube building, sluggish behavior
			4.5 mg/kg (whole body)[5]	Behavior, NOED				[46]	L; no effect on behavior
			0.22 mg/kg (whole body)[5]	Behavior, NOED				[46]	L; no effect on behavior
			0.028 mg/kg (whole body)[5]	Behavior, NOED				[46]	L; no effect on behavior

Summary of Biological Effects Tissue Concentrations for Cadmium

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]			Source:	
Taxa	Sediment	Water	Tissue (Sample Type)	Effects	Log BCF	Log BAF	BSAF	Reference	Comments[3]
			0.0028 mg/kg (whole body)[5]	Behavior, NOED				[46]	L; no effect on behavior
			67 mg/kg (whole body[5]	Mortality, NOED				[46]	L; no effect on survival
			4.5 mg/kg (whole body)[5]	Mortality, NOED				[46]	L; no effect on survival
			0.22 mg/kg (whole body)[5]	Mortality, NOED				[46]	L; no effect on survival
			0.028 mg/kg (whole body)[5]	Mortality, NOED				[46]	L; no effect on survival
			0.0028 mg/kg (whole body)[5]	Mortality, NOED				[46]	L; no effect on survival
			4.5 mg/kg (whole body)[5]	Reproduction, NOED				[46]	L; no effect on reproduction
			0.22 mg/kg (whole body)[5]	Reproduction, NOED				[46]	L; no effect on reproduction
			0.028 mg/kg (whole body)[5]	Reproduction, NOED				[46]	L; no effect on reproduction
			0.0028 mg/kg (whole body)[5]	Reproduction, NOED				[46]	L; no effect on reproduction

Summary of Biological Effects Tissue Concentrations for Cadmium

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]			Source:	
Taxa	**Sediment**	**Water**	**Tissue (Sample Type)**	**Effects**	**Log BCF**	**Log BAF**	**BSAF**	**Reference**	**Comments[3]**
Neanthes virens, Polychaete - Sandworm			106 mg/kg (whole body)[5]	Behavior, LOED				[33]	L; lethargy
			78 mg/kg (whole body)[5]	Physiological, LOED				[33]	L; total glycogen reduced, increase in ascorbic acid
			290 mg/kg (whole body)[5]	Physiological, LOED				[33]	L; increase in ascorbic acid content
Helisoma sp., Snail			625 mg/kg (whole body)[5]	Mortality, ED50				[32]	L; 50% mortality
			300 mg/kg (whole body)[5]	Mortality, NOED				[32]	L; no effect on mortality
			460 mg/kg (whole body)[5]	Mortality, NOED				[32]	L; no effect on mortality
Dreissena polymorpha, Zebra mussel			Day 27: 539-598 µg/g 0.96-1.06 mmol/kg	50% mortality				[19]	L
Mytilus edulis, Blue mussel			30 mg/kg (whole body)[5]	Growth, NOED				[53]	L

Summary of Biological Effects Tissue Concentrations for Cadmium

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]			Source:	
Taxa	**Sediment**	**Water**	**Tissue (Sample Type)**	**Effects**	**Log BCF**	**Log BAF**	**BSAF**	**Reference**	**Comments[3]**
			30 mg/kg (whole body)[5]	Mortality, NOED				[53]	L; highest body burden reported
			6.45 mg/kg (whole body)[5]	Mortality, NOED				[26]	L; estimated wet weight
			4.22 mg/kg (whole body)[5]	Mortality, NA				[60]	L; decreased anoxic survival time (Control 10.7 days)
			8.06 mg/kg (whole body)[5]	Mortality, NA				[60]	L; decreased anoxic survival time (Control 10.7 days)
			3.74 mg/kg (whole body)[5]	Mortality, NA				[60]	L; decreased anoxic survival time (Control 13 days)
			8.06 mg/kg (whole body)[5]	Mortality, NA				[60]	L; decreased anoxic survival time (Control 10.7 days)
			8.06 mg/kg (whole body)[5]	Physiological, NOED				[60]	L; no significant changes in adenylate energy charge or glycogen content

Summary of Biological Effects Tissue Concentrations for Cadmium

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]			Source:	
Taxa	Sediment	Water	Tissue (Sample Type)	Effects	Log BCF	Log BAF	BSAF	Reference	Comments[3]
Mytilus galloprovincialis, Mussel			0.57-0.92 mg/kg				0.416	[27]	F
Crassostrea virginica, Oyster			18.2 mg/kg (whole body)[5]	Reproduction, NOED				[62]	L; no reduced viability of gametes after exposure of adults in 21 ppt seawater
			54 mg/kg (whole body)[5]	Reproduction, NOED				[62]	L; 24% reduction in viability of gametes after exposure of adults in 21 ppt seawater
Daphnia magna, Cladoceran			Day 21: 2.36 µg/g	LOEC				[20]	F
			Week 20: 17.4 µg/g	LOEC				[17]	L
			Day 21: 2.0 mmol/kg	10% mortality				[21]	L

Summary of Biological Effects Tissue Concentrations for Cadmium

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]			Source:	
Taxa	Sediment	Water	Tissue (Sample Type)	Effects	Log BCF	Log BAF	BSAF	Reference	Comments[3]
Daphnia magna, Cladoceran			1.7 mg/kg (whole body)[5]	Reproduction, ED10				[21]	L; 10% reduction in number of offspring
			221 mg/kg (whole body)[5]	Mortality, ED50				[21]	L; lethal body burden after 21-day exposure
Daphnia galeata mendotae, Cladoceran			10.3 mg/kg (whole body)[5]	Growth, LOED				[48]	L; increased weight of individual animals
			3.5 mg/kg (whole body)	Mortality, LOED				[48]	L; reduced longevity, increased prenatal mortality
			5.7 mg/kg (whole body)[5]	Mortality, NA				[48]	L; reduced longevity, increased prenatal mortality
			8.6 mg/kg (whole body)[5]	Mortality, NA				[48]	L; reduced longevity, increased prenatal mortality

Summary of Biological Effects Tissue Concentrations for Cadmium

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]			Source:	
Taxa	Sediment	Water	Tissue (Sample Type)	Effects	Log BCF	Log BAF	BSAF	Reference	Comments[3]
			10.3 mg/kg (whole body)[5]	Mortality, NA				[48]	L; reduced longevity, increased prenatal mortality
			3.5 mg/kg (whole body)[5]	Growth, NOED				[48]	L; no effect on individual weight
			5.7 mg/kg (whole body)[5]	Growth, NOED				[48]	L; no effect on individual weight
			8.6 mg/kg (whole body)[5]	Growth, NOED				[48]	L; no effect on individual weight
Folsomia candida, Cladoceran			60 µg/g	LOEC				[22]	F
Gammarus fossarum, Amphipod			Day 14: 60-70 µg/g	50% mortality				[18]	L
Moina macrocopa, Cladoceran			16.4 mg/kg (whole body)[5]	Reproduction, ED100				[42]	L; no reproduction after 12 days
			16.4 mg/kg (whole body)[5]	Growth, LOED				[42]	L; reduced growth

Summary of Biological Effects Tissue Concentrations for Cadmium

Species:	**Concentration, Units in[1]:**			**Toxicity:**	**Ability to Accumulate[2]**			**Source:**	
Taxa	**Sediment**	**Water**	**Tissue (Sample Type)**	**Effects**	**Log BCF**	**Log BAF**	**BSAF**	**Reference**	**Comments[3]**
			16.4 mg/kg (whole body)[5]	Mortality, LOED				[42]	L; reduced survival
			10.6 mg/kg (whole body)[5]	Reproduction, LOED				[42]	L; reduced brood size
			10.6 mg/kg (whole body)[5]	Mortality, NOED				[42]	L; no effect on survival
			8 mg/kg (whole body)[5]	Reproduction, NOED				[42]	L; no effect on brood size
Hyallela azteca, Amphipod			Week 6: 15.2 µg/g	LOAEC				[17]	L
Pontoporeia affinis, Amphipod (juveniles, 105-460 d)			Day 460: 80-90 µg/g (0.14 mmol/kg)	LOEC				[16]	L
Pontoporeia affinis, Amphipod			11 mg/kg (whole body)[5]	Mortality, LOED				[58]	L
			6 mg/kg (whole body)[5]	Reproduction, LOED				[58]	L; percent malformed eggs
			6 mg/kg (whole body)[5]	Mortality, NOED				[58]	L

Summary of Biological Effects Tissue Concentrations for Cadmium

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]			Source:	
Taxa	Sediment	Water	Tissue (Sample Type)	Effects	Log BCF	Log BAF	BSAF	Reference	Comments[3]
			3 mg/kg (whole body)[5]	Reproduction, NOED				[58]	L; Percent malformed eggs
			2 mg/kg (whole body)[5]	Mortality, NOED				[59]	L; body burden estimated from graph
			10 mg/kg (whole body)[5]	Mortality, NOED				[59]	L; body burden estimated from graph
Balanus crenatus, Barnacle			52 mg/kg (whole body)[5]	Behavior, NOED				[55]	L; regulation of metals endpoint - summer experiment
Mysidopsis bahia, Mysid			1.29 mg/kg (whole body)[5]	Growth, LOED				[34]	L; reduction in growth, mean dry weight of animals
			1.29 mg/kg (whole body)[5]	Physiological, LOED				[34]	L; altered O:N ratio, shift towards lipid utilization with increasing cadmium concentration

Summary of Biological Effects Tissue Concentrations for Cadmium

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]			Source:	
Taxa	**Sediment**	**Water**	**Tissue (Sample Type)**	**Effects**	**Log BCF**	**Log BAF**	**BSAF**	**Reference**	**Comments[3]**
			2.38 mg/kg (whole body)[5]	Growth, NA				[34]	L; reduction in growth, mean dry weight of animals
			4.36 mg/kg (whole body)[5]	Growth, NA				[34]	L; reduction in growth, mean dry weight of animals
			2.38 mg/kg (whole body)[5]	Physiological, NA				[34]	L; altered O:N ratio, shift towards lipid utilization with increasing cadmium concentration
			4.36 mg/kg (whole body)[5]	Physiological, NA				[34]	L; altered O:N ratio, shift towards lipid utilization with increasing cadmium concentration
Oniscus asellus, Isopod			Day 91: 8.15 mmol/kg	50% mortality				[23]	F
Porcellio scaber, Isopod			Day 63: 5.40 mmol/kg 3.77 mmol/kg	50% mortality 50% mortality				[23]	F

Summary of Biological Effects Tissue Concentrations for Cadmium

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]			Source:	
Taxa	Sediment	Water	Tissue (Sample Type)	Effects	Log BCF	Log BAF	BSAF	Reference	Comments[3]
Palaemonetes pugio, Grass shrimp			0.9 mg/kg (whole body)[5]	Mortality, NOED				[26]	L; estimated wet weight
			2.6 mg/kg (whole body)[5]	Mortality, NA				[61]	L; 20% increased mortality over control in 5 ppt water; no statistical analysis
			5.8 mg/kg (whole body)[5]	Mortality, NA				[61]	L; 22% increased mortality over control in 5 ppt water; no statistical analysis
			7 mg/kg (whole body)[5]	Mortality, NA				[61]	L; 25% increased mortality over control in 5 ppt water; no statistical analysis
Palaemonetes pugio, Grass shrimp			Day 21: 4.0 µg/g	25% mortality				[14]	L

Summary of Biological Effects Tissue Concentrations for Cadmium

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]			Source:	
Taxa	Sediment	Water	Tissue (Sample Type)	Effects	Log BCF	Log BAF	BSAF	Reference	Comments[3]
Callianassa australiensis, Mole shrimp			Day 14: 4.8 µg/g	50% mortality				[15]	L
Cambarus latimanus, Crayfish			14.9 mg/kg (whole body)[5]	Growth, NOED				[13]	L; no significant difference from control growth at lowest test concentration
			14.9 mg/kg (whole body)[5]	Mortality, NOED				[13]	L; no significant difference from control mortality
			14.9 mg/kg (whole body)[5]	Physiological, NOED				[13]	L; no significant difference from control temperature sensitivity at lowest test concentration
Cambarus latimanus, Crayfish			Month 5: 4.4 µg/g	LOEC				[13]	L

Summary of Biological Effects Tissue Concentrations for Cadmium

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]			Source:	
Taxa	**Sediment**	**Water**	**Tissue (Sample Type)**	**Effects**	**Log BCF**	**Log BAF**	**BSAF**	**Reference**	**Comments[3]**
Orconectes virilis, Crayfish			Day 14: 5.6 µg/g	25% mortality				[12]	L
Orconectes propinquus, Crayfish			534 mg/kg (whole body)[5]	Mortality, NOED				[39]	L; 7% mortality after 190.5 hours, probably not significant
Chironomus gr. thummi, Midge			0.156 mg/kg (whole body)[5]	Morphology, NOED				[45]	F; 4th instar larvae
Glyptotendipes pallens, Midge			20 mg/kg (whole body)[5]	Behavior, LOED				[44]	L; modified feeding behavior, reduced net spinning activity
			20 mg/kg (whole body)[5]	Growth, LOED				[44]	L; reduced biomass
			30 mg/kg (whole body)[5]	Behavior, NA				[44]	L; modified feeding behavior, reduced net spinning activity
			50 mg/kg (whole body)[5]	Behavior, NA				[44]	L; lethargy

Summary of Biological Effects Tissue Concentrations for Cadmium

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]			Source:	
Taxa	Sediment	Water	Tissue (Sample Type)	Effects	Log BCF	Log BAF	BSAF	Reference	Comments[3]
			72 mg/kg (whole body)[5]	Behavior, NA				[44]	L; lethargy
			138 mg/kg (whole body)[5]	Behavior, NA				[44]	L; lethargy
			30 mg/kg (whole body)[5]	Growth, NA				[44]	L; reduced biomass
			50 mg/kg (whole body)[5]	Growth, NA				[44]	L; reduced biomass
			72 mg/kg (whole body)[5]	Growth, NA				[44]	L; reduced biomass
			138 mg/kg (whole body)[5]	Growth, NA				[44]	L; reduced biomass
			10 mg/kg (whole body)[5]	Behavior, NOED				[44]	L; no effect on feeding behavior or activity level
			18 mg/kg (whole body)[5]	Behavior, NOED				[44]	L; no effect on feeding behavior or activity level
			10 mg/kg (whole body)[5]	Growth, NOED				[44]	L; no effect on biomass
			18 mg/kg (whole body)[5]	Growth, NOED				[44]	L; no effect on biomass

Summary of Biological Effects Tissue Concentrations for Cadmium

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]			Source:	
Taxa	**Sediment**	**Water**	**Tissue (Sample Type)**	**Effects**	**Log BCF**	**Log BAF**	**BSAF**	**Reference**	**Comments[3]**
			10 mg/kg (whole body)[5]	Mortality, NOED				[44]	L; no effect on mortality in 96 hours
			18 mg/kg (whole body)[5]	Mortality, NOED				[44]	L; no effect on mortality in 96 hours
			20 mg/kg (whole body)[5]	Mortality, NOED				[44]	L; no effect on mortality in 96 hours
			30 mg/kg (whole body)[5]	Mortality, NOED				[44]	L; no effect on mortality in 96 hours
			50 mg/kg (whole body)[5]	Mortality, NOED				[44]	L; no effect on mortality in 96 hours
			72 mg/kg (whole body)[5]	Mortality, NOED				[44]	L; no effect on mortality in 96 hours
			138 mg/kg (whole body)[5]	Mortality, NOED				[44]	L; no effect on mortality in 96 hours
Orchesella cincta, Springtail			Day 49: 0.07 mmol/kg	50% mortality				[23]	F
Tomocerus minor, Springtail			Day 63: 0.13 mmol/kg	50% mortality				[23]	F

Summary of Biological Effects Tissue Concentrations for Cadmium

Species: Taxa	Concentration, Units in[1]: Sediment	Water	Tissue (Sample Type)	Toxicity: Effects	Ability to Accumulate[2]: Log BCF	Log BAF	BSAF	Source: Reference	Comments[3]
Platynothrus peltifer, Oribatid mite			Day 63: 0.42 mmol/kg	50% mortality				[23]	F
Classenia sabulosa, Stonefly	<0.3 µg/g 3.5 µg/g 6.6 µg/g		0.1 µg/g ND 1.4 µg/g					[24]	F
Hesperoperla pacifica, Stonefly	<0.3 µg/g 3.5 µg/g 6.6 µg/g		0.2 µg/g ND 1.0 µg/g					[24]	F
Isogenoides sp., Stonefly	<0.3 µg/g 3.5 µg/g 6.6 µg/g		<0.4 µg/g 1.4 µg/g 1.8 µg/g					[24]	F
Pteronarcys californica, Stonefly	<0.3 µg/g 3.5 µg/g 6.6 µg/g		0.1 µg/g ND 1.0 µg/g					[24]	F
Hydropsyche sp., Caddisfly			9.8 mg/kg (whole body)[5]	Mortality, LOED				[38]	L; mortality in one day
			17.4 mg/kg (whole body)[5]	Mortality, LOED				[38]	L; mortality in two days
			29.8 mg/kg (whole body)[5]	Mortality, LOED				[38]	L; mortality in four days

Summary of Biological Effects Tissue Concentrations for Cadmium

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]			Source:	
Taxa	Sediment	Water	Tissue (Sample Type)	Effects	Log BCF	Log BAF	BSAF	Reference	Comments[3]
			0.118 mg/kg (whole body)[5]	Mortality, LOED				[38]	L; mortality in one day
			0.0934 mg/kg (whole body)[5]	Mortality, LOED				[38]	L; mortality in two days
			16 mg/kg (whole body)[5]	Mortality, NOED				[38]	L; no effect on mortality in one day
			24.8 mg/kg (whole body)[5]	Mortality, NOED				[38]	L; no effect on mortality in one day
			41.8 mg/kg (whole body)[5]	Mortality, NOED				[38]	L; no effect on mortality in one day
			0.202 mg/kg (whole body)[5]	Mortality, NOED				[38]	L; no effect on mortality in one day
			0.284 mg/kg (whole body)[5]	Mortality, NOED				[38]	L; no effect on mortality in one day
Hydropsyche spp., Caddisfly	<0.3 µg/g 3.5 µg/g 6.6 µg/g		0.2 µg/g 2.2 µg/g 2.8 µg/g					[24]	F
Arctopsyche grandis, Caddisfly	<0.3 µg/g 3.5 µg/g 6.6 µg/g		0.2 µg/g ND[4] 1.4 µg/g					[24]	F

Summary of Biological Effects Tissue Concentrations for Cadmium

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]			Source:	
Taxa	**Sediment**	**Water**	**Tissue (Sample Type)**	**Effects**	**Log BCF**	**Log BAF**	**BSAF**	**Reference**	**Comments[3]**
Asterias rubens, Starfish			0.03 mg/kg (gonad)[5]	Development, LOED				[37]	combined, estimated wet weight adult males
			0.14 mg/kg (gonad)[5]	Development, LOED				[37]	combined, estimated wet weight adult females
Fishes									
Oncorhynchus mykiss, Rainbow trout			16.4 mg/kg (whole body)[5]	Mortality, ED100				[29]	L; complete mortality of alevins within 10 hours
			101 mg/kg (whole body)[5]	Mortality, ED100				[29]	L; complete mortality of eggs within 32 hours
			0.84 mg/kg (whole body)[5]	Mortality, ED100				[29]	L; complete mortality of alevins within 320 hours
			0.71 mg/kg (whole body)[5]	Behavior, LOED				[29]	L; erratic swimming
			0.21 mg/kg (whole body)[5]	Morphology, LOED				[29]	L; deformed vertebrae, blood clots in fins

Summary of Biological Effects Tissue Concentrations for Cadmium

Species:	**Concentration, Units in[1]:**			**Toxicity:**	**Ability to Accumulate[2]**			**Source:**	
Taxa	**Sediment**	**Water**	**Tissue (Sample Type)**	**Effects**	**Log BCF**	**Log BAF**	**BSAF**	**Reference**	**Comments[3]**
			0.21 mg/kg (whole body)[5]	Mortality, LOED				[29]	L; hatching alevins unable to break free from egg membrane, died
			10 mg/kg (whole body)[5]	Physiological, LOED				[30]	L; induction of metallothionein
			0.0599 mg/kg (whole body)[5]	Mortality, NOED				[41]	L; no effect on mortality
			6.4 mg/kg (whole body)[5]	Mortality, ED50				[51]	L; hardness: 279 mg/L $CaCO_3$
			3.74 mg/kg (whole body)[5]	Mortality, ED50				[51]	L; Hardness: 279 Mg/L $CaCO_3$
			4 mg/kg (whole body)[5]	Mortality, ED50				[51]	L; hardness: 70 mg/L $CaCO_3$
			2.2 mg/kg (whole body)[5]	Mortality, ED50				[51]	L; hardness: 70 mg/L $CaCO_3$

Summary of Biological Effects Tissue Concentrations for Cadmium

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]			Source:	
Taxa	Sediment	Water	Tissue (Sample Type)	Effects	Log BCF	Log BAF	BSAF	Reference	Comments[3]
Salmo salar, Atlantic Salmon			0.26 mg/kg (yolk sac/stomach)[5]	Growth, LOED				[52]	L; yolk sac/stomach weight - graph and table interpretation
			0.26 mg/kg (yolk sac/stomach)[5]	Mortality, LOED				[52]	L; yolk sac/stomach weight - graph and table interpretation
			0.05 mg/kg (yolk sac/stomach)[5]	Growth, NOED				[52]	L; yolk sac/stomach weight - graph and table interpretation
			0.05 mg/kg (yolk sac/stomach)[5]	Mortality, NOED				[52]	L; yolk sac/stomach weight - graph and table interpretation
Salvelinus fontinalis, Brook trout		3.4 µg/g	Week 38: 10 µg/g, kidney 2 µg/g, liver					[25]	L

Summary of Biological Effects Tissue Concentrations for Cadmium

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]			Source:	
Taxa	Sediment	Water	Tissue (Sample Type)	Effects	Log BCF	Log BAF	BSAF	Reference	Comments[3]
Salvelinus fontinalis, Brook Trout			0.175 mg/kg (liver)[5]	Mortality, LOED				[40]	L; significant mortality in 10.5 µg/L at 15 days and 1.91 µg/L at 7 days, but no body burdens measured
			0.232 mg/kg (liver)[5]	Growth, NA				[40]	L; no significant effect on growth
			0.203 mg/kg (liver)[5]	Mortality, NOED				[40]	L
			144 mg/kg (whole body)[5]	Mortality, LOED				[40]	L; significantly reduced survival at lowest test concentration, exp_conc = <3.6

Summary of Biological Effects Tissue Concentrations for Cadmium

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]			Source:	
Taxa	Sediment	Water	Tissue (Sample Type)	Effects	Log BCF	Log BAF	BSAF	Reference	Comments[3]
			0.742 mg/kg (liver)[5]	Physiological, LOED				[40]	L; significantly increased metallothionein in whole body tissues at lowest test concentration; no correlation between metallothionein concentration and mortality or whole body tissue residues, exp_conc = < 3.6
			144 mg/kg (whole body)[5]	Physiological, LOED				[40]	L; significantly increased metallothionein in whole body tissues at lowest test concentration; no correlation between metallothionein and mortality or whole body tissue residues, exp_conc = < 3.6

Summary of Biological Effects Tissue Concentrations for Cadmium

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]			Source:	
Taxa	Sediment	Water	Tissue (Sample Type)	Effects	Log BCF	Log BAF	BSAF	Reference	Comments[3]
Jordanella floridae, American flagfish			0.4 mg/kg (whole body)[5]	Mortality, LOED				[56]	L; body burden estimated from graph, fish initially exposed as embryos
			0.4 mg/kg (whole body)[5]	Mortality, LOED				[56]	L; body burden estimated from graph, fish not exposed as embryos
			6 mg/kg (whole body)[5]	Growth, NOED				[56]	L; body burden estimated from graph
			0.4 mg/kg (whole body)[5]	Mortality, NOED				[56]	L; body burden estimated from graph, fish not exposed as embryos
			0.09 mg/kg (whole body)[5]	Mortality, NOED				[56]	L; body burden estimated from graph, fish initially exposed as embryos
			6 mg/kg (whole body)[5]	Reproduction, NOED				[56]	L; body burden estimated from graph

Summary of Biological Effects Tissue Concentrations for Cadmium

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]			Source:	
Taxa	Sediment	Water	Tissue (Sample Type)	Effects	Log BCF	Log BAF	BSAF	Reference	Comments[3]
			20 mg/kg (whole body)[5]	Growth, LOED				[57]	L; total length of females
			10 mg/kg (whole body)[5]	Growth, NOED				[57]	L; total length of females
			35 mg/kg (whole body)[5]	Mortality, NOED				[57]	L
Poecilia reticulata, Guppy			8 mg/kg (whole body)[5]	Mortality, ED50				[43]	L; 50% reduction in survival
			0.5 mg/kg (whole body)[5]	Growth, LOED				[43]	L; reduction in body length within 10 days
			1.2 mg/kg (whole body)[5]	Mortality, LOED				[43]	L; 14% reduction in survival
			0.8 mg/kg (whole body)[5]	Growth, NA				[43]	L; reduction in body length within 10 days
Cyprinodon variegatus, Sheepshead minnow			0.9 mg/kg (whole body)[5]	Development, LOED				[49]	L; decreased time to hatch

Summary of Biological Effects Tissue Concentrations for Cadmium

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]			Source:	
Taxa	Sediment	Water	Tissue (Sample Type)	Effects	Log BCF	Log BAF	BSAF	Reference	Comments[3]
Platichthys flesus, European flounder			17.2 mg/kg (kidney)[5]	Biochemical, LOED				[54]	L; females - Cd + estradiol injection: RNA:DNA ratio
			21.6 mg/kg (liver)[5]	Biochemical, LOED				[54]	L; females - Cd + estradiol injection: RNA:DNA ratio
			1.82 mg/kg (ovary)[5]	Biochemical, LOED				[54]	L; females - Cd + estradiol injection: RNA:DNA ratio
			33.2 mg/kg (kidney)[5]	Biochemical, NOED				[54]	L; males - Cd + estradiol injection: RNA:DNA ratio
			43.8 mg/kg (liver)[5]	Biochemical, NOED				[54]	L; males - Cd + estradiol injection: RNA:DNA ratio

Summary of Biological Effects Tissue Concentrations for Cadmium

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]			Source:	
Taxa	Sediment	Water	Tissue (Sample Type)	Effects	Log BCF	Log BAF	BSAF	Reference	Comments[3]
			4.66 mg/kg (ovary)[5]	Biochemical, NOED				[54]	L; males - Cd + estradiol injection: RNA:DNA ratio
			17.2 mg/kg (kidney)[5]	Mortality, NOED				[54]	L; females - Cd + estradiol injection: survival
			33.2 mg/kg (kidney)[5]	Mortality, NOED				[54]	L; males - Cd + estradiol injection: survival
			43.8 mg/kg (liver)[5]	Mortality, NOED				[54]	L; males - Cd + estradiol injection: survival
			21.6 mg/kg (liver)[5]	Mortality, NOED				[54]	L; females - Cd + estradiol injection: survival
			4.66 mg/kg (ovary)[5]	Mortality, NOED				[54]	L; males - Cd + estradiol injection: survival
			1.82 mg/kg (ovary)[5]	Mortality, NOED				[54]	L; females - Cd + estradiol injection: survival

Summary of Biological Effects Tissue Concentrations for Cadmium

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]			Source:	
Taxa	Sediment	Water	Tissue (Sample Type)	Effects	Log BCF	Log BAF	BSAF	Reference	Comments[3]
Pleuronectes americanus, Winter flounder			1 mg/kg (whole body)[5]	Physiological, LOED				[36]	L; induction of metallothionein
Wildlife									
Ambystoma gracile, Salamander			140 mg/kg (whole body)[5]	Behavior, LOED				[50]	L; significant reduction in regurgitation/ food retention
			6.28 mg/kg (whole body)[5]	Growth, LOED				[50]	L; significant reduction in both length and weight
			4.7 mg/kg (whole body)[5]	Growth, LOED				[50]	L; significant reduction in both length and weight
			71.7 mg/kg (whole body)[5]	Behavior, NOED				[50]	L; no significant increase in regurgitation/ food retention

Summary of Biological Effects Tissue Concentrations for Cadmium

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]			Source:	
Taxa	Sediment	Water	Tissue (Sample Type)	Effects	Log BCF	Log BAF	BSAF	Reference	Comments[3]
			43.5 mg/kg (whole body)[5]	Growth, NOED				[50]	L; no significant reduction in length or weight at highest test concentration
			3.75 mg/kg (whole body)[5]	Growth, NOED				[50]	L; no significant reduction in length or weight
			145 mg/kg (whole body)[5]	Growth, NOED				[50]	L; no significant reduction in length or weight at highest test concentration
			1.62 mg/kg (whole body)[5]	Growth, NOED				[50]	L; no significant reduction in length or weight
			43.5 mg/kg (whole body)[5]	Mortality, NOED				[50]	L; no significant increase in mortality at highest test concentration

Summary of Biological Effects Tissue Concentrations for Cadmium

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]			Source:	
Taxa	Sediment	Water	Tissue (Sample Type)	Effects	Log BCF	Log BAF	BSAF	Reference	Comments[3]
			145 mg/kg (whole body)[5]	Mortality, NOED				[50]	L; no significant increase in mortality at highest test concentration
			4.13 mg/kg (whole body)[5]	Mortality, NOED				[50]	L; no significant increase in mortality at highest test concentration

[1] Concentration units based on wet weight unless otherwise noted.
[2] BCF = bioconcentration factor, BAF = bioaccumulation factor, BSAF = biota-sediment accumulation factor.
[3] L = laboratory study, spiked sediment, single chemical; F = field study, multiple chemical exposure; other unusual study conditions or observations noted.
[4] ND = not detected.
[5] This entry was excerpted directly from the Environmental Residue-Effects Database (ERED, www.wes.army.mil/el/ered, U.S. Army Corps of Engineers and U.S. Environmental Protection Agency). The original publication was not reviewed, and the reader is strongly urged to consult the publication to confirm the information presented here.

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Chemical Category: PESTICIDE (ORGANOCHLORINE)

Chemical Name (Common Synonyms): CHLORDANE **CASRN:** 57-74-9

Chemical Characteristics

Solubility in Water: 0.1 mg/L at 20 - 30°C [1]

Half-Life: 283 days - 3.8 yrs based on unacclimated aerobic river die-away test and reported soil grab sample data [2]

Log K_{ow}: 6.32 [3]

Log K_{oc}: 6.21 L/kg organic carbon

Human Health

Oral RfD: 6×10^{-5} mg/kg/day [4]

Confidence: Low, uncertainty factor = 1000

Critical Effect: Regional liver hypertrophy in female rats; hepatocellular carcinomas in mice

Oral Slope Factor: $1.3 \times 10^{+0}$ per (mg/kg)/day [4]

Carcinogenic Classification: B2 [4]

Wildlife

Partitioning Factors: Partitioning factors for chlordane in wildlife were not found in the literature.

Food Chain Multipliers: Food chain multipliers for chlordane in wildlife were not found in the literature.

Aquatic Organisms

Partitioning Factors: The major components of technical chlordane include gamma chlordane (24 percent), alpha chlordane (19 percent), and *trans*-nonachlor (7 percent). Alpha chlordane is environmentally more stable and therefore more persistent than gamma chlordane. Oxychlordane is an epoxide metabolite formed in mammalian liver. It is persistent and much more toxic than its parent chemicals [5].

Food Chain Multipliers: In a marine ecosystem the chlordane compounds (nonachlor and oxychlordane) increased significantly with trophic levels from zooplankton to marine mammals [6]. Although the results of the study reported by Kawano et al. [6] indicated a small difference in the chlordane composition in zooplankton from the North Pacific, Bering Sea, and Antarctic, they also revealed a significant difference in chlordane composition between Dall's porpoise and the Weddell seal. *Trans*-chlordane was present in the seal but not in the porpoise, and the percentage composition of oxychlordane in the seal was larger than that in the porpoise. Furthermore, the compositional percentage of oxychlordane in the Adelie penguin and thick-billed murre was much higher than that in the other organisms. Marine mammals and seabirds accumulated chlordane via food. Biomagnification of total chlordanes through the food chain is strongly evident in marine mammals. Chlordanes are concentrated gradually from zooplankton, through squid and fish, to porpoises and dolphins [7,8]. Chlordane residues in marine mammals are positively correlated with lipid content and not with the age of the animal [9]. Food chain multipliers (FCMs) for *cis*- or *trans*-chlordane for trophic level 3 aquatic organisms were 21.7 (all benthic food web), 1.6 (all pelagic food web), and 13.2 (benthic and pelagic food web). FCMs for trophic level 4 aquatic organisms were 49.5 (all benthic food web), 3.5 (all pelagic food web), and 23.3 (benthic and pelagic food web) [26].

Toxicity/Bioaccumulation Assessment Profile

Chlordane adversely affected sensitive species of fish and aquatic invertebrates at concentrations of 0.2 to 2.0 µg/L. Specifically, survival of shrimp and crabs was reduced at water concentrations of 0.2 to 2.0 µg/L, while survival of freshwater and marine fishes was reduced between 1.7 and 3.0 µg/L. Generally, the uptake of chlordane by aquatic organisms is high, ranging from 216.8 µg organic carbon cleared per gram organism per hour for *Diporeia* spp. to 358 µg organic carbon cleared per gram organism per hour for *Chironomus riparius* [10]. Accumulation of chlordane by *Diporeia* spp., *C. riparius,* or *Lumbriculus variegatus* from whole sediment exposures was greater than that from the elutriate or pore water. Neither species was able to metabolize chlordane. A study by Wilcock et al. [11] has shown that the bivalve *Macomona liliana* can accumulate chlordane bound to sediment at depths below 2 cm. Animals constantly exposed to contaminated sediment accumulated more (5,728 ppb lipid) than those able to feed alternatively on contaminated and uncontaminated sediments (3,617 and 2,756 ppb). An in situ study of the uptake and elimination by adult intertidal benthic infauna of chlordane from contaminated sediment has shown large differences in accumulation between deposit- and suspension-feeding species [12]. In the case of surface feeders, these differences can be attributed to direct exposure to high initial concentration of chlordane in surficial sediments. The extract from the chlordane residues obtained from Lake Michigan lake trout was significantly more toxic (3 to 5 times) than the chlordane used in agricultural applications. Gooch et al. [13] suggested that the increased toxicity of these extracts was due to the presence of the stable metabolite heptachlor epoxide and oxychlordane. Chlordane is persistent in the environment; measurable residues in sediment were found 2.8 years after application to the overlying water column [5]. More than 80 percent of the fish sampled from the Kansas River had detectable chlordanes in their tissue [14]. Residues of *cis*-chlordane and *trans*-chlordane were the most abundant and persistent of the chlordane components measured in fish tissues in a U.S. study conducted aproximately 10 years after the termination of the agricultural use of chlordanes [15]. In birds, technical chlordane and its metabolite oxychlordane are frequently elevated in tissues with high lipid content. In northern gannets, the half-time persistence of *cis*-chlordane, *cis*-nonachlor, and oxychlordane was estimated at 11, 199, and 35 years [16].

Summary of Biological Effects Tissue Concentrations for Chlordane

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	**Sediment**	**Water**	**Tissue (Sample Type)**	**Effects**	**Log BCF**	**Log BAF**	**BSAF**	**Reference**	**Comments[3]**
Invertebrates									
Lumbriculus variegatus, Oligochaete worm	125 ng/g		28,197 ng/g					[10]	F
	1,406 ng/g		23,031 ng/g[3]						
		BDL[4]	0.03 µ/kg					[17]	F
Crassostrea virginica, Eastern oyster			0.02 mg/kg (whole body)[5]	Growth, ED18				[22]	L; exposure media 65% heptachlor (technical grade)
			2.2 mg/kg (whole body)[5]	Growth, ED28				[22]	L; exposure media 65% heptachlor (technical grade)
			0.3 mg/kg (whole body)[5]	Growth, ED28					L; exposure media 65% heptachlor (technical grade)
			0.075 mg/kg (whole body)[5]	Growth, ED30				[22]	L; exposure media 65% heptachlor (technical grade)
			0.6 mg/kg (whole body)[5]	Growth, ED30				[22]	L; exposure media 65% heptachlor (technical grade)
			0.78 mg/kg (whole body)[5]	Growth, ED33				[22]	L; exposure media 65% heptachlor (technical grade)
			6.5 mg/kg (whole body)[5]	Growth, ED33				[22]	L; exposure media 65% heptachlor (technical grade)

Summary of Biological Effects Tissue Concentrations for Chlordane

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	Sediment	Water	Tissue (Sample Type)	Effects	Log BCF	Log BAF	BSAF	Reference	Comments[3]
			1.9 mg/kg (whole body)[5]	Growth, ED78				[22]	L; exposure media 65% heptachlor (technical grade)
			14 mg/kg (whole body)[5]	Growth, ED78				[22]	L; exposure media 65% heptachlor (technical grade)
			5.6 mg/kg (whole body)[5]	Growth, ED95				[22]	L; exposure media 65% heptachlor (technical grade)
			47 mg/kg (whole body)[5]	Growth, ED95				[22]	L; exposure media 65% heptachlor (technical grade)
			0.022 mg/kg (whole body)[5]	Growth, NOED				[22]	L; exposure media 65% heptachlor (technical grade)
Crassostrea virginica, Eastern oyster			27 mg/kg (whole body)[5]	Growth, LOED				[23]	L; estimated LOED - no statistical summary in text
			11 mg/kg (whole body)[5]	Growth, NOED				[23]	L; estimated NOED - no statistical summary in text
Corbicula fluminea, Asian clam	21.7 µg/kg OC		2,400 µg/kg lipid				2.04	[21]	F; *trans*-chlordane; %lipid not reported; %sed OC = 2.30

Summary of Biological Effects Tissue Concentrations for Chlordane

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	Sediment	Water	Tissue (Sample Type)	Effects	Log BCF	Log BAF	BSAF	Reference	Comments[3]
Gonatopsis borealis, Eight-armed squid			*cis*-chlordane: 15 (11-18) µg/kg *trans*-chlordane: 8.1 (6.3-9.9) µg/kg *cis*-nonachlor: 2.4 (2.2-2.8) µg/kg *trans*-nonachlor: 18 (14-20) µg/kg oxychlordane: 1.2 (0.8-1.60) µg/kg total chlordanes: 44 (35-52) µg/kg					[5]	F; lipid samples
Diporeia sp., Amphipod	493 ng/g 430 ng/g		23,729 ng/g 40,086 ng/g					[10]	F
Euphasia superba, Krill			*cis*-chlordane: 0.58 µg/kg *trans*-chlordane: 0.51 µg/kg *cis*-nonachlor: 0.22 µg/kg *trans*-nonachlor: 0.8 µg/kg oxychlordane: 0.1 µg/kg					[6]	F
Palaemonetes pugio, Grass shrimp			4.5 mg/kg (whole body)[5]	Mortality, LOED				[23]	L; estimated LOED - no statistical summary in text

Summary of Biological Effects Tissue Concentrations for Chlordane

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	**Sediment**	**Water**	**Tissue (Sample Type)**	**Effects**	**Log BCF**	**Log BAF**	**BSAF**	**Reference**	**Comments[3]**
			4.8 mg/kg (whole body)[5]	Mortality, NOED				[23]	L; estimated NOED - no statistical summary in text
Penaeus duorarum, Pink shrimp			1.7 mg/kg (whole body)[5]	Mortality, LOED				[23]	L; estimated LOED - no statistical summary in text
			0.71 mg/kg (whole body)[5]	Mortality, NOED				[23]	L; estimated NOED - no statistical summary in text
Homarus americanus, American lobster			*cis*-chlordane: 80-100 µg/kg, hepatopancreas *trans*-chlordane: 80-100 µg/kg, hepatopancreas *cis*-nonachlor: 30 µg/kg, hepatopancreas *trans*-nonachlor: (380-440) µg/kg, hepatopancreas					[5]	F
Chironomus riparius, Midge	1,663 ng/g 1,741 ng/g		16,224 ng/g 8,417 ng/g					[10]	F

Summary of Biological Effects Tissue Concentrations for Chlordane

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	Sediment	Water	Tissue (Sample Type)	Effects	Log BCF	Log BAF	BSAF	Reference	Comments[3]
Fishes									
Oncorhynchus, Salmo, Salvelinus sp., Salmonids		0.000034 µg/L	19 µg/kg			5.75		[20]	F; *trans*-chlordane, % lipid = 11
	77.8 µg/kg OC		172.7 µg/kg lipid				2.22	[20]	F; *trans*-chlordane; %lipid = 11; %sed OC = 2.70
Salmonids							2.00	[25]	F; *trans*-chlordane
							4.77	[25]	F; *cis*-chlordane
Osmerus mordax, Smelt; *Oncorhynchus velinus,* Coho salmon	2.1 ng/g	34 pg/L	3.6 ng/g 19 ng/g					[18,20]	F; median BSAFs calculated in [18] from field data in [20]
Cyprinus carpio, Carp	2.5 ng/g		18 ng/g				46.3 33.4	[18,19]	F; median BSAFs calculated in [18] from field data in [19]
Cyprinus carpio, Carp	437.5 µg/kg OC		217.9 µg/kg lipid				0.498	[24]	F; *trans*-chlordane; %lipid = 7.8; %sed OC = 0.80
	145.3 µg/kg OC		110.7 µg/kg lipid				0.762	[24]	F; *trans*-chlordane; %lipid = 8.4; %sed OC = 1.79
	112.1 µg/kg OC		161.3 µg/kg lipid				1.439	[24]	F; *trans*-chlordane; %lipid = 9.3; %sed OC = 1.16

Summary of Biological Effects Tissue Concentrations for Chlordane

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	Sediment	Water	Tissue (Sample Type)	Effects	Log BCF	Log BAF	BSAF	Reference	Comments[3]
Cyprinus carpio, Carp	212.5 µg/kg OC		294.9 µg/kg lipid				1.3878	[24]	F; *cis*-chlordane; %lipid = 7.8; %sed OC = 0.80
	128.5 µg/kg OC		190.5 µg/kg lipid				1.4825	[24]	F; *cis*-chlordane; %lipid = 8.4; %sed OC = 1.79
	86.21 µg/kg OC		258.1 µg/kg lipid				2.9939	[24]	F; *cis*-chlordane; %lipid = 9.3; %sed OC = 1.16
Catastomus commersoni, White sucker	437.5 µg/kg OC		132.5 µg/kg lipid				0.301	[24]	F; *trans*-chlordane; %lipid = 8.3; %sed OC = 0.8
	145.3 µg/kg OC		189.9 µg/kg lipid				1.307	[24]	F; *trans*-chlordane; %lipid = 7.9; %sed OC = 1.79
	112.1 µg/kg OC		266.7 µg/kg lipid				2.379	[24]	F; *trans*-chlordane; %lipid = 4.5; %sed OC = 1.16
Catastomus commersoni, White sucker	212.5 µg/kg OC		192.8 µg/kg lipid				0.9073	[24]	F; *cis*-chlordane; %lipid = 8.3; %sed OC = 0.8
	128.5 µg/kg OC		519 µg/kg lipid				4.0389	[24]	F; *cis*-chlordane; %lipid = 7.9; %sed OC = 1.79
	86.21 µg/kg OC		533.3 µg/kg lipid				6.1861	[24]	F; *cis*-chlordane; %lipid = 4.5; %sed OC = 1.16

Summary of Biological Effects Tissue Concentrations for Chlordane

Species: Taxa	Concentration, Units in[1]: Sediment	Water	Tissue (Sample Type)	Toxicity: Effects	Ability to Accumulate[2]: Log BCF	Log BAF	BSAF	Source: Reference	Comments[3]
Cyprinodon variegatus, Sheepshead minnow			909 mg/kg (whole body)	Mortality, ED35				[22]	L; exposure media 65% heptachlor (technical grade)
			1.2 mg/kg (whole body)[5]	Mortality, ED35				[22]	L; exposure media 65% heptachlor (technical grade)
			0.019 mg/kg (whole body)[5]	Mortality, ED5				[22]	L; exposure media 65% heptachlor (technical grade)
			0.01 mg/kg (whole body)[5]	Mortality, ED5				[22]	L; exposure media 65% heptachlor (technical grade)
			17.5 mg/kg (whole body)[5]	Mortality, ED50				[22]	L; exposure media 65% heptachlor (technical grade)
			2 mg/kg (whole body)[5]	Mortality, ED50				[22]	L; exposure media 65% heptachlor (technical grade)
			3.9 mg/kg (whole body)[5]	Mortality, ED60				[22]	L; exposure media 65% heptachlor (technical grade)
			32 mg/kg (whole body)[5]	Mortality, ED60				[22]	L; exposure media 65% heptachlor (technical grade)
			47 mg/kg (whole body)[5]	Mortality, ED85				[22]	L; exposure media 65% heptachlor (technical grade)
			6.1 mg/kg (whole body)[5]	Mortality, ED85				[22]	L; exposure media 65% heptachlor (technical grade)

Summary of Biological Effects Tissue Concentrations for Chlordane

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	Sediment	Water	Tissue (Sample Type)	Effects	Log BCF	Log BAF	BSAF	Reference	Comments[3]
Cyprinodon variegatus, Sheepshead minnow			281 mg/kg (whole body)[5]	Mortality, LOED				[23]	L; estimated LOED - no statistical summary in text
			3.18 mg/kg (whole body)[5]	Mortality, LOED				[23]	L
			3.18 mg/kg (whole body)[5]	Reproduction, LOED				[23]	L; hatching success of fry from exposed parents
			0.6 mg/kg (whole body)[5]	Mortality, NOED				[23]	L; estimated NOED - no statistical summary in text
			87 mg/kg (whole body)[5]	Mortality, NOED				[23]	L; estimated NOED - no statistical summary in text
			1.38 mg/kg (whole body)[5]	Mortality, NOED				[23]	L
			1.38 mg/kg (whole body)[5]	Reproduction, NOED				[23]	L; hatching success of fry from exposed parents
Lagodon rhomboides, Pinfish			16.6 mg/kg (whole body)[5]	Mortality, LOED				[23]	L; estimated LOED - no statistical summary in text
Leiostomus xanthurus, Spot			0.16 mg/kg (whole body)[5]	Mortality, ED25				[22]	L; exposure media 65% heptachlor (technical grade)

Summary of Biological Effects Tissue Concentrations for Chlordane

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	Sediment	Water	Tissue (Sample Type)	Effects	Log BCF	Log BAF	BSAF	Reference	Comments[3]
			0.55 mg/kg (whole body)[5]	Mortality, ED25				[22]	L; exposure media 65% heptachlor (technical grade)
			0.89 mg/kg (whole body)[5]	Mortality, ED35				[22]	L; exposure media 65% heptachlor (technical grade)
			0.22 mg/kg (whole body)[5]	Mortality, ED35				[22]	L; exposure media 65% heptachlor (technical grade)
			3.3 mg/kg (whole body)[5]	Mortality, ED40				[22]	L; exposure media 65% heptachlor (technical grade)
			0.94 mg/kg (whole body)[5]	Mortality, ED40				[22]	L; exposure media 65% heptachlor (technical grade)
			1.6 mg/kg (whole body)[5]	Mortality, ED70				[22]	L; exposure media 65% heptachlor (technical grade)
			7.1 mg/kg (whole body)[5]	Mortality, ED70				[22]	L; exposure media 65% heptachlor (technical grade)
			0.7 mg/kg (whole body)[5]	Mortality, ED85				[22]	L; exposure media 65% heptachlor (technical grade)
			3.5 mg/kg (whole body)[5]	Mortality, ED85				[22]	L; exposure media 65% heptachlor (technical grade)
			0.01 mg/kg (whole body)[5]	Mortality, NOED				[22]	L; exposure media 65% heptachlor (technical grade)

Summary of Biological Effects Tissue Concentrations for Chlordane

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	Sediment	Water	Tissue (Sample Type)	Effects	Log BCF	Log BAF	BSAF	Reference	Comments[3]
			0.01 mg/kg (whole body)[5]	Mortality, NOED				[22]	L; exposure media 65% heptachlor (technical grade)
			0.01 mg/kg (whole body)[5]	Mortality, NOED				[22]	L; exposure media 65% heptachlor (technical grade)
			0.01 mg/kg (whole body)[5]	Mortality, NOED				[22]	L; exposure media 65% heptachlor (technical grade)
Cottus cognatus, Slimy sculpin	2.1 ng/g	34 g/L	30 µg/kg			5.95	2.47	[18,20]	F; *trans*-chlordane, % lipid = 8
	77.8 µg/kg OC		375 µg/kg lipid				4.821	[20]	F; *trans*-chlordane; %lipid = 8; %sed OC = 2.70
Pimelodus albicans, Oligosarcus jenynsi, Prochilodus platensis	3.4 ng/g	0.8 ng/L	2.9 µg/g				20	[18,21]	F; median BSAFs calculated in [18] from field data in [21]
Prochilodus platensis, Curimata	20 µg/kg OC		4,600 µg/kg lipid				230	[21]	F; *trans*-chlordane; %lipid not reported; %sed OC = 1
Pimelodus albicans, Mandi	20 µg/kg OC		1,000 µg/kg lipid				50	[21]	F; *trans*-chlordane; %lipid not reported; %sed OC = 1

Summary of Biological Effects Tissue Concentrations for Chlordane

Species:	**Concentration, Units in[1]:**			**Toxicity:**	**Ability to Accumulate[2]:**			**Source:**	
Taxa	**Sediment**	**Water**	**Tissue (Sample Type)**	**Effects**	**Log BCF**	**Log BAF**	**BSAF**	**Reference**	**Comments[3]**
Wildlife									
Ducks							0.83 19.5	[18,19]	F; median BSAFs calculated in [18] from field data in [19]

1 Concentration units based on wet weight unless otherwise noted.
2 BCF = bioconcentration factor, BAF = bioaccumulation factor, BSAF = biota-sediment accumulation factor.
3 L = laboratory study, spiked sediment, single chemical; F = field study, multiple chemical exposure; other unusual study conditions or observations noted.
4 BDL = Below detection limit.
5 This entry was excerpted directly from the Environmental Residue-Effects Database (ERED, www.wes.army.mil/el/ered, U.S. Army Corps of Engineers and U.S. Environmental Protection Agency). The original publication was not reviewed, and the reader is strongly urged to consult the publication to confirm the information presented here.

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Chemical Category: PESTICIDE (ORGANOPHOSPHATE)

Chemical Name (Common Synonyms): CHLORPYRIFOS **CASRN:** 2921-88-2

Chemical Characteristics

Solubility in Water: 0.7 ppm at 20°C [1]

Half-Life: No data [2]

Log K_{ow}: 5.26 [3]

Log K_{oc}: 5.17 L/kg organic carbon

Human Health

Oral RfD: 3×10^{-3} mg/kg/day [4]

Confidence: Medium, uncertainty factor =10[4]

Critical Effect: Decreased plasma cholinesterase activity after 9 days of 20-day human feeding study

Oral Slope Factor): No data [4]

Carcinogenic Classification: No data [4], D[5]

Wildlife

Partitioning Factors: Partitioning factors for chlorpyrifos in wildlife were not found in the literature.

Food Chain Multipliers: Food chain multipliers for chlorpyrifos in wildlife were not found in the literature.

Aquatic Organisms

Partitioning Factors: The only partitioning factors for chlorpyrifos in aquatic organisms found in the literature were log BCF of 3.23 for an isopod [14].

Food Chain Multipliers: Food chain multipliers for chlorpyrifos in aquatic organisms were not found in the literature.

Toxicity/Bioaccumulation Assessment Profile

Chlorpyrifos or Dursban is an organophosphorus insecticide which is used to control both adult and larval mosquitoes [6]. It is more toxic to nontarget organisms like cladocerans, amphipods, and other organisms than to mosquito larvae, however. The increase of chlorpyrifos concentration in water proportionally increased the bioconcentration factor in fish [7]. A low recovery (20 percent or lower) of chlorpyrifos from C-18 columns was attributed to its high binding affinity [8]. Also, acidic or basic conditions were not effective in reducing its concentration in water [9]. Because of the binding capacity and the high K_{ow}, chlorpyrifos does not remain in aqueous solution or suspension but is bound to the organic and clay fractions of sediments. The time for sediment-associated pesticides to degrade and reach nontoxic states is much greater than for aqueous phases [10]. The responses to chlorpyrifos from single-species tests were compared to responses observed in a field mesocosm [11]. The EC50 for seven species in the mesocosms ranged from 0.1 to 3.4 µg/L and were within the same order of magnitude as the laboratory data. Toxicity to the most sensitive test species, *D. magna* , at 1 µg/L was representative of sensitive indigenous species.

The results of toxicity tests exposing *Chironomus tentans* to sediments with differing organic carbon content spiked with chlorpyrifos revealed that an organic carbon partitioning model can be reasonably used to predict the toxicity of chlorpyrifos to benthic macroinvertebrates [12]. The TOC-normalized, solid-phase concentration of chlorpyrifos was no better predictor of the toxicity of the pesticide to *C. tentans* than the sediment dry-weight concentration of chlorpyrifos. The effects based on predicted pore-water concentrations were accurate to within a factor of two of expected effects based on water-only toxicity tests with the midge.

Distinct pulses of pesticides, including chlorpyrifos, were detected in the San Joaquin River and in the Sacramento River following rainfall events [13]. The results of short-term chronic tests with *Ceriodaphnia dubia* indicated that Sacramento River water at Rio Vista was acutely toxic for three consecutive days, while San Joaquin River water at Vernalis was toxic for 12 consecutive days.

Summary of Biological Effects Tissue Concentrations for Chlorpyrifos

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	**Sediment**	**Water**	**Tissue (Sample Type)**	**Effects**	**Log BCF**	**Log BAF**	**BSAF**	**Reference**	**Comments[3]**
Invertebrates									
Mytilus galloprovincialis, Mediterranean mussel			42 mg/kg (whole body)[4]	Mortality, ED50				[19]	L; estimated from table 4
			4 mg/kg (whole body)[4]	Morphology, LOED				[19]	L; presence of functional byssus
			1.9 mg/kg (whole body)[4]	Morphology, NOED				[19]	
			4 mg/kg (whole body)[4]	Mortality, NOED				[19]	L; estimated from table 4
Asellus aquaticus, Isopod		0.7 µg/L 5.0 µg/L	140,000 µg/kg 260,000 µg/kg		3.23			[14]	F
Fishes									
Pimephales promelas, Fathead minnow			2 mg/kg (whole body)[4]	Growth, LOED				[21]	L; significant reduction in growth
			4.5 mg/kg (whole body)[4]	Morphology, LOED				[21]	L; body constriction behind opercula, shortening of caudal peduncle
			4.5 mg/kg (whole body)[4]	Mortality, LOED				[21]	L; significant reduction in survival

Summary of Biological Effects Tissue Concentrations for Chlorpyrifos

Species: Taxa	Concentration, Units in[1]: Sediment	Water	Tissue (Sample Type)	Toxicity: Effects	Ability to Accumulate[2]: Log BCF	Log BAF	BSAF	Source: Reference	Comments[3]
			0.45 mg/kg (whole body)[4]	Physiological, LOED				[21]	L; inhibition of acetylcholinesterase (ACHE) activity
			4.5 mg/kg (whole body)[4]	Growth, NA				[21]	L; significant reduction in growth
			4.5 mg/kg (whole body)[4]	Physiological, NA				[21]	L; inhibition of acetylcholinesterase (ACHE) activity
			2 mg/kg (whole body)[4]	Physiological, NA				[21]	L; inhibition of acetylcholinesterase (ACHE) activity
			1.1 mg/kg (whole body)[4]	Physiological, NA				[21]	L; inhibition of acetylcholinesterase (ACHE) activity
			1.1 mg/kg (whole body)[4]	Growth, NOED				[21]	L; no effect on growth
			0.45 mg/kg (whole body)[4]	Growth, NOED				[21]	L; no effect on growth
			0.2 mg/kg (whole body)[4]	Growth, NOED				[21]	L; no effect on growth
			2 mg/kg (whole body)[4]	Morphology, NOED				[21]	L; no effect on appearance or development
			1.1 mg/kg (whole body)[4]	Morphology, NOED				[21]	L; no effect on appearance or development

Summary of Biological Effects Tissue Concentrations for Chlorpyrifos

Species: Taxa	Concentration, Units in[1]: Sediment	Water	Tissue (Sample Type)	Toxicity: Effects	Ability to Accumulate[2]: Log BCF	Log BAF	BSAF	Source: Reference	Comments[3]
			0.45 mg/kg (whole body)[4]	Morphology, NOED				[21]	L; no effect on appearance or development
			0.2 mg/kg (whole body)[4]	Morphology, NOED				[21]	L; no effect on appearance or development
			2 mg/kg (whole body)[4]	Mortality, NOED				[21]	L; no effect on survival
			1.1 mg/kg (whole body)[4]	Mortality, NOED				[21]	L; no effect on survival
			0.45 mg/kg (whole body)[4]	Mortality, NOED				[21]	L; no effect on survival
			0.2 mg/kg (whole body)[4]	Mortality, NOED				[21]	L; no effect on survival
			0.2 mg/kg (whole body)[4]	Physiological, NOED				[21]	L; inhibition of acetylcholinesterase (ACHE) activity
Gambusia affinis, Mosquito fish			0.0352 mg/kg (whole body)[4]	Mortality, NOED				[22]	L; no effect on survivorship after 3 days
Poecilia reticulata, Guppy		0.9 µg/L 1.9 µg/L 3.9 µg/L 10 µg/L 19 µg/L 37 µg/L	6 µg/g lipid 33 µg/g lipid 66 µg/g lipid 350 µg/g lipid 710 µg/g lipid 2,100 µg/g lipid					[15]	L

Summary of Biological Effects Tissue Concentrations for Chlorpyrifos

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	**Sediment**	**Water**	**Tissue (Sample Type)**	**Effects**	**Log BCF**	**Log BAF**	**BSAF**	**Reference**	**Comments[3]**
Poecilia reticulata, Guppy			2,810 mg/kg (whole body)[4]	Mortality, ED100				[18]	L; lifestage: 2-3 months
Gasterosteus aculeatus, Three-spined stickleback		0.12 µg/L 0.46 µg/L 1.0 µg/L	8.1 µg/g lipid 31.2 µg/g lipid 125 µg/g lipid					[16]	L
Cyprinodon variegatus, Sheepshead minnow		series 1 0.78µg/L 1.7 µg/L 3.0 µg/L 6.8 µg/L	 0.033 µg/g 0.22 µg/g 0.45 µg/g 4.8 µg/g					[17]	L (low feeding: 20 *Artemia*/fish/ feeding)
Cyprinodon variegatus, Sheepshead minnow		series 1 0.78µg/L 1.7 µg/L 3.0 µg/L 6.8 µg/L	 0.054 µg/g 0.12 µg/g 0.78 µg/g 2.9 µg/g					[17]	L (medium feeding: 110 *Artemia*/fish/ feeding)
		series 1 0.78µg/L 1.7 µg/L 3.0 µg/L 6.8 µg/L	 0.66 µg/g 0.19 µg/g 2.9 µg/g 7.3 µg/g					[17]	L (high feeding: 550 *Artemia*/ fish/feeding)
		series 2 3.1 µg/L 7.2 µg/L 14 µg/L 26 µg/L 52 µg/L	 0.67 µg/g 1.8 µg/g 4.3 µg/g 17 µg/g 34 µg/g					[17]	L (low feeding: 20 *Artemia*/fish/ feeding)

Summary of Biological Effects Tissue Concentrations for Chlorpyrifos

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	Sediment	Water	Tissue (Sample Type)	Effects	Log BCF	Log BAF	BSAF	Reference	Comments[3]
		series 2 3.1 µg/L 7.2 µg/L 14 µg/L 26 µg/L 52 µg/L	 0.82 µg/g 2.9 µg/g 5.5 µg/g 15.9 µg/g 52 µg/g					[17]	L (medium feeding: 110 *Artemia*/fish/ feeding)
		series 2 3.1 µg/L 7.2 µg/L 14 µg/L 26 µg/L 52 µg/L	 2.2 µg/g 5.3 µg/g 13.9 µg/g 37 µg/g 95 µg/g					[17]	L (high feeding: 550 *Artemia*/ fish/feeding)
Leuresthes tenuis, California grunion			0.21 mg/kg (whole body)[4]	Behavior, LOED				[23]	L; reduced activity
			0.038 mg/kg (whole body)[4]	Growth, LOED				[23]	L; significant reduction in weight of fry
			0.21 mg/kg (whole body)[4]	Growth, LOED				[23]	L; significant reduction in mean fish weight
			0.21 mg/kg (whole body)[4]	Morphology, LOED				[23]	L; fish appeared darker, abnormal lateral flexure of the back
			0.58 mg/kg (whole body)[4]	Mortality, LOED				[23]	L; nearly 40% reduction in fry survival
			0.39 mg/kg (whole body)[4]	Mortality, LOED				[23]	L; 38% reduction in fry survival

Summary of Biological Effects Tissue Concentrations for Chlorpyrifos

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	**Sediment**	**Water**	**Tissue (Sample Type)**	**Effects**	**Log BCF**	**Log BAF**	**BSAF**	**Reference**	**Comments[3]**
			0.58 mg/kg (whole body)[4]	Growth, NA				[23]	L; significant reduction in weight of fry
			0.15 mg/kg (whole body)[4]	Behavior, NOED				[23]	L; no effect on behavior
			0.015 mg/kg (whole body)[4]	Growth, NOED				[23]	L; no effect on weight of fry
			0.15 mg/kg (whole body)[4]	Growth, NOED				[23]	L; no effect on growth
			0.15 mg/kg (whole body)[4]	Morphology, NOED				[23]	L; no effect on morphology
			0.015 mg/kg (whole body)[4]	Mortality, NOED				[23]	L; no effect on fry mortality
			0.15 mg/kg (whole body)[4]	Mortality, NOED				[23]	L; no effect on fry survival
			0.038 mg/kg (whole body)[4]	Mortality, NOED				[23]	L; no effect on fry mortality
			0.21 mg/kg (whole body)[4]	Mortality, NOED				[23]	L; no effect on fry survival
Opsanus beta, Gulf toadfish			770 mg/kg (whole body)[4]	Development, ED25				[20]	L; delayed development of 25% of sac fry
			12 mg/kg (whole body)[4]	Growth, ED25				[20]	L; 25% reduction in average weight of fry
			175 mg/kg (whole body)[4]	Growth, ED50				[20]	L; 50% reduction in average weight of fry

Summary of Biological Effects Tissue Concentrations for Chlorpyrifos

Species: Taxa	Concentration, Units in[1]: Sediment	Water	Tissue (Sample Type)	Toxicity: Effects	Ability to Accumulate[2]: Log BCF	Log BAF	BSAF	Source: Reference	Comments[3]
			770 mg/kg (whole body)[4]	Behavior, LOED				[20]	L; hyperactivity, hyperventilation
			0.95 mg/kg (whole body)[4]	Growth, LOED				[20]	L; 9% reduction in fry weight
			770 mg/kg (whole body)[4]	Mortality, LOED				[20]	L; significant increase in fry mortality
			2.2 mg/kg (whole body)[4]	Growth, NA				[20]	L; 19% reduction in fry weight
			4.7 mg/kg (whole body)[4]	Growth, NA				[20]	L; 21% reduction in fry weight
			15 mg/kg (whole body)[4]	Growth, NA				[20]	L; 37% reduction in fry weight
			30 mg/kg (whole body)[4]	Growth, NA				[20]	L; 42% reduction in fry weight
			9.9 mg/kg (whole body)[4]	Growth, NA				[20]	L; 21% reduction in average weight of fry
			45 mg/kg (whole body)[4]	Growth, NA				[20]	L; 35% reduction in average weight of fry
			770 mg/kg (whole body)[4]	Growth, NA				[20]	L; 62% reduction in average weight of fry
			0.14 mg/kg (whole body)[4]	Growth, NOED				[20]	L; no effect on growth
			12 mg/kg (whole body)[4]	Mortality, NOED				[20]	L; no effect on fry mortality
			9.9 mg/kg (whole body)[4]	Mortality, NOED				[20]	L; no effect on fry mortality

Summary of Biological Effects Tissue Concentrations for Chlorpyrifos

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	Sediment	Water	Tissue (Sample Type)	Effects	Log BCF	Log BAF	BSAF	Reference	Comments[3]
			45 mg/kg (whole body)[4]	Mortality, NOED				[20]	L; no effect on fry mortality
			175 mg/kg (whole body)[4]	Mortality, NOED				[20]	L; no effect on fry mortality

1 Concentration units based on wet weight unless otherwise noted.

2 BCF = bioconcentration factor, BAF = bioaccumulation factor, BSAF = biota-sediment accumulation factor.

3 L = laboratory study, spiked sediment, single chemical; F = field study, multiple chemical exposure; other unusual study conditions or observations noted.

4 This entry was excerpted directly from the Environmental Residue-Effects Database (ERED, www.wes.army.mil/el/ered, U.S. Army Corps of Engineers and U.S. Environmental Protection Agency). The original publication was not reviewed, and the reader is strongly urged to consult the publication to confirm the information presented here.

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Chemical Category: METAL

Chemical Name (Common Synonyms): CHROMIUM (hexavalent) **CASRN:** 18540-29-9

Chemical Characteristics

Solubility in Water: Insoluble [1]

Half-Life: Not applicable, stable [1]

Log K_{ow}: –

Log K_{oc}: –

Human Health

Oral RfD: 5×10^{-3} mg/kg/day [2]

Confidence: Low, uncertainty factor = 500

Critical Effect: No effects observed (Currently under review by RfD/RfC Work Group)

Oral Slope Factor: Not available [2]

Carcinogenic Classification: A [2]

Wildlife

Partitioning Factors: Partitioning factors for chromium in wildlife were not found in the literature.

Food Chain Multipliers: Food chain multipliers for chromium in wildlife were not found in the literature.

Aquatic Organisms

Partitioning Factors: In aqueous solutions, within a pH range of 6 to 8, hexavalent chromium is distributed between two species: monovalent hydrochromate anion and divalent chromate anion. Hexavalent chromium may account for 75 to 85 percent of the dissolved chromium while trivalent chromium is generally below detection limits in most oxic surface waters [3]. In some surface waters, as much as 10 to 15 percent of the dissolved chromium may be present in the colloidal/organic form. A log BCF of 2.74 was reported for *Daphia magna* [9].

Food Chain Multipliers: Little evidence exists for the bioaccumulation/biomagnification of chromium in aquatic food webs, although sediments frequently contain elevated concentrations of trivalent chromium [4].

Toxicity/Bioaccumulation Assessment Profile

Chromium appears to have limited mobility under typical conditions in most aquatic habitats because the trivalent form tends to bind to sediments. Plants can, however, bioaccumulate and reduce chromium.

Tissue residue-toxicity relationships can also be variable because organisms might sequester metal in various forms that might be analytically measurable as tissue residue but are actually stored in unavailable forms within the organism as a form of detoxification [5]. Whole body residues might also not be indicative of effects concentrations at the organ level because concentrations in target organs, such as the kidneys and liver, may be 20 times more than whole body residues [6]. The application of "clean" chemical analytical and sample preparation techniques is critical for the accurate measurement of metal tissue residues [7]. Accumulation of hexavalent chromium in the gills of rainbow trout was significantly higher at pH 6.5 than at 8.1 and is directly coupled with oxygen transfer, irrespective of exposure time or concentration [8]. The authors of that study suggested that chromium uptake might be related to the $HCr0_4$ to $Cr0_4$ ratio, whereby the monovalent hydrochromate anion is taken up more readily by the gill tissue.

Summary of Biological Effects Tissue Concentrations for Chromium

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	Sediment	Water	Tissue (Sample Type)	Effects	Log BCF	Log BAF	BSAF	Reference	Comments[3]
Invertebrates									
Mytilus galloprovincialis, Mussel			0.73-1.04 mg/kg				0.018	[13]	F
Daphnia magna, Cladoceran			Day 21: 1.1 mmol/kg	10% mortality	2.74			[9]	F
Xantho hydrophilus, Mud crab		1 µg/L	0.2 µg/g (whole body) 0.2 µg/g (hepatopancreas) 0.4 µg/g (gill) 0.05 µg/g (muscle)					[12]	F
Fishes									
Oncorhynchus mykiss (*Salmo gairdneri*), Rainbow trout		2.5 mg/L	Day 22: 171 µg/g (skin) 187 µg/g (muscle) 132 µg/g (gastro-intestinal) 49.8 µg/g (bone) 75.4 µg/g (kidney) 77.2 µg/g (blood) 41.4 µg/g (gill) 16.9 µg/g (fat) 27.3 µg/g (liver)					[10]	L
		10.0 µg/L 1.3 µg/L	133.6 µg/g 16.6 µg/g					[11]	L

Summary of Biological Effects Tissue Concentrations for Chromium

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	**Sediment**	**Water**	**Tissue (Sample Type)**	**Effects**	**Log BCF**	**Log BAF**	**BSAF**	**Reference**	**Comments[3]**
Oncorhynchus mykiss Salmo gairdneri), Rainbow trout		2.0 mg/L	2.0 µg/g (whole body) 31.7 µg/g (gill) 6.2 µg/g (digestive tract) 2.0 µg/g (liver) 6.7 µg/g (kidney)	100% survival				[8]	L; pH = 6.5
		2.0 mg/L	0.9 µg/g (whole body) 5.1 µg/g (gill) 7.4 µg/g (digestive tract) 3.4 µg/g (liver) 8.5 µg/g (kidney)	100% survival				[8]	L; pH = 7.8
		5.0 mg/L	5.5 µg/g (whole body) 51.8 µg/g (gill) 9.5 µg/g (digestive tract) 3.8 µg/g (liver) 10.7 µg/g (kidney)	100% survival				[8]	L; pH = 6.5
		5.0 mg/L	2.3 µg/g (whole body) 10.6 µg/g (gill) 11.2 µg/g (digestive tract) 5.1 µg/g (liver) 12.2 µg/g (kidney)	100% survival				[8]	L; pH = 7.8
		16.5 mg/L	8.7 µg/g (whole body) 139 µg/g (gill) 23.4 µg/g (digestive tract) 24.8 µg/g (liver) 43.2 µg/g (kidney)	25% survival				[8]	L; pH = 6.5

Summary of Biological Effects Tissue Concentrations for Chromium

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	**Sediment**	**Water**	**Tissue (Sample Type)**	**Effects**	**Log BCF**	**Log BAF**	**BSAF**	**Reference**	**Comments[3]**
Oncorhynchus mykiss (Salmo gairdneri), Rainbow trout		16.5 mg/L	8.9 µg/g (whole body) 35.3 µg/g (gill) 22.6 µg/g (digestive tract) 25.9 µg/g (liver) 24.6 µg/g (kidney)	63% survival				[8]	L; pH = 7.8
		50 mg/L		0% survival				[8]	L; pH = 6.5
		50 mg/L	10.5 µg/g (whole body) 37.6 µg/g (gill) 45.0 µg/g (digestive tract) 84.6 µg/g (liver) 70.3 µg/g (kidney)	50% survival				[8]	L; pH = 7.8
Oncorhynchus mykiss, Rainbow trout			45 mg/kg (digestive tract)[4]	Mortality, ED50				[14]	L; pH 7.8; increased mortality relative to control
			37.6 mg/kg (gill)[4]	Mortality, ED50				[14]	L; pH 7.8; increased mortality relative to control
			70.3 mg/kg (kidney)[4]	Mortality, ED50				[14]	L; pH 7.8; increased mortality relative to control
			85.6 mg/kg (liver)[4]	Mortality, ED50				[14]	L; pH 7.8; increased mortality relative to control

Summary of Biological Effects Tissue Concentrations for Chromium

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	**Sediment**	**Water**	**Tissue (Sample Type)**	**Effects**	**Log BCF**	**Log BAF**	**BSAF**	**Reference**	**Comments[3]**
			10.5 mg/kg (whole body)[4]	Mortality, ED50				[14]	L; pH 7.8; increased mortality relative to control
			23.4 mg/kg (digestive tract)[4]	Mortality, ED75				[14]	L; pH 6.5; increased mortality relative to control
			139 mg/kg (gill)[4]	Mortality, ED75				[14]	L; pH 6.5; increased mortality relative to control
			43.1 mg/kg (kidney)[4]	Mortality, ED75				[14]	L; pH 6.5; increased mortality relative to control
			24.8 mg/kg (liver)[4]	Mortality, ED75				[14]	L; pH 6.5; increased mortality relative to control
			8.7 mg/kg (whole body)[4]	Mortality, ED75				[14]	L; pH 6.5; increased mortality relative to control
			22.6 mg/kg (digestive tract)[4]	Mortality, NA				[14]	L; pH 7.8; increased mortality relative to control
			35.3 mg/kg (gill)[4]	Mortality, NA				[14]	L; pH 7.8; increased mortality relative to control

Summary of Biological Effects Tissue Concentrations for Chromium

Species:	**Concentration, Units in[1]:**			**Toxicity:**	**Ability to Accumulate[2]:**			**Source:**	
Taxa	**Sediment**	**Water**	**Tissue (Sample Type)**	**Effects**	**Log BCF**	**Log BAF**	**BSAF**	**Reference**	**Comments[3]**
			24.6 mg/kg (kidney)[4]	Mortality, NA				[14]	L; pH 7.8; increased mortality relative to control
			25.9 mg/kg (liver)[4]	Mortality, NA				[14]	L; pH 7.8; increased mortality relative to control
			8.9 mg/kg (whole body)[4]	Mortality, NA				[14]	L; pH 7.8; increased mortality relative to control
			9.5 mg/kg (digestive tract)[4]	Mortality, NOED				[14]	L; pH 6.5; no increased mortality relative to control
			11.2 mg/kg (digestive tract)[4]	Mortality, NOED				[14]	L; pH 7.8; no increased mortality relative to control
			51.8 mg/kg (gill)[4]	Mortality, NOED				[14]	L; pH 6.5; no increased mortality relative to control
			10.6 mg/kg (gill)[4]	Mortality, NOED				[14]	L; pH 7.8; no increased mortality relative to control
			10.7 mg/kg (kidney)[4]	Mortality, NOED				[14]	L; pH 6.5; no increased mortality relative to control

Summary of Biological Effects Tissue Concentrations for Chromium

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	Sediment	Water	Tissue (Sample Type)	Effects	Log BCF	Log BAF	BSAF	Reference	Comments[3]
			12.2 mg/kg (kidney)[4]	Mortality, NOED				[14]	L; ph 7.8; no increased mortality relative to control
			3.8 mg/kg (liver)[4]	Mortality, NOED				[14]	L; pH 6.5; no increased mortality relative to control
			5.1 mg/kg (liver)[4]	Mortality, NOED				[14]	L; pH 7.8; no increased mortality relative to control
			5.5 mg/kg (whole body)[4]	Mortality, NOED				[14]	L; pH 6.5; no increased mortality relative to control
			2.3 mg/kg (whole body)[4]	Mortality, NOED				[14]	L; pH 7.8; no increased mortality relative to control

1 Concentration units based on wet weight unless otherwise noted.

2 BCF = bioconcentration factor, BAF = bioaccumulation factor, BSAF = biota-sediment accumulation factor.

3 L = laboratory study, spiked sediment, single chemical; F = field study, multiple chemical exposure; other unusual study conditions or observations noted.

4 This entry was excerpted directly from the Environmental Residue-Effects Database (ERED, www.wes.army.mil/el/ered, U.S. Army Corps of Engineers and U.S. Environmental Protection Agency). The original publication was not reviewed and the reader is strongly urged to consult the publication to confirm the information presented here.

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Chemical Category: POLYNUCLEAR AROMATIC HYDROCARBON (high molecular weight)

Chemical Name (Common Synonyms): CHRYSENE **CASRN:** 218-01-9

Chemical Characteristics

Solubility in Water: 0.0020 mg/L at 25°C [1]

Half-Life: 1.02 yrs - 2.72 yrs based on aerobic soil die-away test data. [2]

Log K_{ow}: 5.70 [3]

Log K_{oc}: 5.60 L/kg organic carbon

Human Health

Oral RfD: No data [4]

Confidence: —

Critical Effect: —

Oral Slope Factor (Reference): Not available [4]

Carcinogenic Classification: B2 [4]

Wildlife

Partitioning Factors: Partitioning factors for chrysene in wildlife were not found in the literature.

Food Chain Multipliers: Food chain multipliers for chrysene in wildlife were not found in the literature.

Aquatic Organisms

Partitioning Factors: Partitioning factors for chrysene in aquatic organisms were not found in the literature.

Food Chain Multipliers: Food chain multipliers for chrysene in aquatic organisms were not found in the literature. Log BAF values found in the literature ranged from -0.68 for the clam *Macoma nasuta* [7] to 4.31 for the amphipod *Pontoporeia hoyi* [9].

Toxicity/Bioaccumulation Assessment Profile

The results from the laboratory experiments performed by Harkey [5] indicated that accumulation of chrysene from elutriates was significantly lower than that from whole sediment, and the elutriate-sediment accumulations followed a downward curve over time. A similar curve was observed for pore water-to-sediment accumulation ratios. The concentrations of chrysene in whole sediment and pore water were 34.2 ng/g and 0.305 mg/mL, respectively [5]. Uptake rate coefficients for *Diporeia* spp. were highest in pore water (244.3 µg/g_{oc}/h) and lowest in elutriate (55.2 µg/g_{oc}/h). The authors concluded that aqueous extracts of whole sediment did not accurately represent the exposure observed in whole sediment [5]. The aqueous extracts of whole sediment underexposed organisms, compared to whole sediment, even after adjusting accumulation to the fraction of organic carbon contained in the test media. While the total chrysene concentration in the sediment stayed constant, total concentration decreased appreciably in pore water and elutriate over the course of the exposure, and it is likely that the bioavailability concentrations in these media also decreased. Benthic amphipods, *Gammarus pulex,* exposed to sediments containing polynuclear aromatic hydrocarbons (PAHs) and water spiked with sediment extract from PAH-contaminated sediment, accumulated chrysene in direct proportion to exposure concentrations [6].

Summary of Biological Effects Tissue Concentrations for Chrysene

Species:	**Concentration, Units in[1]:**			**Toxicity:**	**Ability to Accumulate[2]:**			**Source:**	
Taxa	**Sediment**	**Water**	**Tissue (Sample Type)**	**Effects**	**Log BCF**	**Log BAF**	**BSAF**	**Reference**	**Comments[3]**
Invertebrates									
Macoma nasuta, Clam	7.4 ng/g		29 ng/g			-0.21		[7]	F
	5.9 ng/g		8.1 ng/g			-0.68		[7]	F
	50 ng/g		29.8 ng/g			-0.40		[7]	F
	41 ng/g		30 ng/g			-0.28		[7]	F
	174 ng/g		88 ng/g			-0.33		[7]	F
	249 ng/g		72 ng/g			-0.41		[7]	F
Diporeia spp., Amphipod	15 nmol/g		213 nmol/g					[8]	L
Diporeia spp., Amphipod			2.6 mg/kg (whole body)[4]	Mortality, NOED				[5]	L; no increase in mortality in 96 hours
Pontoporeia hoyi, Amphipod	50 ng/g	7 ng/mL	600 ng/g			4.31		[9]	L
	30 ng/g	1.5 ng/mL	180 ng/g					[9]	L

Summary of Biological Effects Tissue Concentrations for Chrysene

Species:	**Concentration, Units in[1]:**			**Toxicity:**	**Ability to Accumulate[2]:**			**Source:**	
Taxa	**Sediment**	**Water**	**Tissue (Sample Type)**	**Effects**	**Log BCF**	**Log BAF**	**BSAF**	**Reference**	**Comments[3]**
Fishes									
Oncorhynchus mykiss, Rainbow trout			30 mg/kg (whole body)[4]	Physiological, LOED				[11]	L; induction of hepatic mixed function oxidases
Cyprinus carpio, Common carp			109 mg/kg (liver)[4]	Physiological, NA				[10]	L; significant increase in EROD enzyme and P450 1a protein content

1 Concentration units based on wet weight unless otherwise noted.
2 BCF = bioconcentration factor, BAF = bioaccumulation factor, BSAF = biota-sediment accumulation factor.
3 L = laboratory study, spiked sediment, single chemical; F = field study, multiple chemical exposure; other unusual study conditions or observations noted.
4 This entry was excerpted directly from the Environmental Residue-Effects Database (ERED, www.wes.army.mil/el/ered, U.S. Army Corps of Engineers and U.S. Environmental Protection Agency). The original publication was not reviewed, and the reader is strongly urged to consult the publication to confirm the information presented here.

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Chemical Category: METAL

Chemical Name (Common Synonyms): COPPER **CASRN:** 7440-50-8

Chemical Characteristics

Solubility in Water: Insoluble [1]

Half-Life: Not applicable, stable [1]

Log K_{ow}: —

Log K_{oc}: —

Human Health

Oral RfD: Not available [2]

Confidence: —

Critical Effect: —

Oral Slope Factor: No data [2]

Carcinogenic Classification: D [2]

Wildlife

Partitioning Factors: Partitioning factors for copper in wildlife were not found in the literature.

Food Chain Multipliers: Food chain multipliers for copper in wildlife were not found in the literature.

Aquatic Organisms

Partitioning Factors: Up to 29 different species of copper can be present in aqueous solution in the pH range from 6 to 9. Aqueous copper speciation and toxicity depend on the ionic strength of the water. The hydroxide species and free copper ions are mostly responsible for toxicity, while copper complexes consisting of carbonates, phosphates, nitrates, ammonia, and sulfates are weakly toxic or nontoxic. Copper in the aquatic environment can partition to dissolved and particulate organic carbon. The bioavailability of copper also can be influenced to some extent by total water hardness. Bioavailability of copper in sediments is controlled by the acid-volatile sulfide (AVS) concentration [12]. A log BCF of 3.77 was reported for the midge [4].

Food Chain Multipliers: Little evidence exists to support the general occurrence of biomagnification of copper in the aquatic environment [3]. Copper is taken up by aquatic organisms primarily through dietary exposure.

Toxicity/Bioaccumulation Assessment Profile

The free copper ions are the most bioavailable inorganic forms, although they might account for only a minor proportion of the total dissolved metal. The concentration of copper found in interstitial water is usually much lower than that in surface water. The amount of bioavailable copper in sediment is controlled in large part by the concentration of AVS and organic matter. A considerable number of aquatic species are sensitive to dissolved concentrations of copper in the range of 1-10 µg/L. Metal metabolism by aquatic biota has significant affects on metal accumulation, distribution in tissues, and toxic effects. Concentration of copper in benthic organisms from contaminated areas can be one to two orders of magnitude higher than normal. Copper is accumulated by aquatic organisms primarily through dietary exposure [3]. However, most organisms retain only a small proportion of the heavy metals ingested with their diet.

Rule and Alden [13] studied the relationship between uptake of cadmium and copper from the sediment by blue mussel (*Mytilus edulis*), grass shrimp (*Palaemonetes pugio*), and hard clam (*Mercenaria mercenaria*). The uptake of copper by all organisms was related only to copper concentration in sediment.

Summary of Biological Effects Tissue Concentrations for Copper									
Species:	**Concentration, Units in[1]:**			**Toxicity:**	**Ability to Accumulate[2]:**			**Source:**	
Taxa	**Sediment**	**Water**	**Tissue (Sample Type)**	**Effects**	**Log BCF**	**Log BAF**	**BSAF**	**Reference**	**Comments[3]**
Plants									
Eichhornia crassipes, Water Hyacinth			11.4 mg/kg (leaf)	Growth, LOED				[22]	L; reduced growth rate, chlorosis
			549 mg/kg (root)	Growth, LOED				[22]	L; reduced growth rate, chlorosis
			37.8 mg/kg (stem)	Growth, LOED				[22]	L; reduced growth rate, chlorosis
			11.4 mg/kg (leaf)	Morphology, LOED				[22]	L; chlorosis, browning, necrosis, waterlogging of tissues
			549 mg/kg (root)	Morphology, LOED				[22]	L; chlorosis, browning, necrosis, waterlogging of tissues
			37.8 mg/kg (stem)	Morphology, LOED				[22]	L; chlorosis, browning, necrosis, waterlogging of tissues
			13.8 mg/kg (leaf)	Growth, NA				[22]	L; reduced growth rate, chlorosis
			1,750 mg/kg (root)	Growth, NA				[22]	L; reduced growth rate, chlorosis
			74.4 mg/kg (stem)	Growth, NA				[22]	L; reduced growth rate, chlorosis

Summary of Biological Effects Tissue Concentrations for Copper

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	**Sediment**	**Water**	**Tissue (Sample Type)**	**Effects**	**Log BCF**	**Log BAF**	**BSAF**	**Reference**	**Comments[3]**
			13.8 mg/kg (leaf)	Morphology, NA				[22]	L; chlorosis, browning, necrosis, waterlogging of tissues
			1,750 mg/kg (root)	Morphology, NA				[22]	L; chlorosis, browning, necrosis, waterlogging of tissues
			74.4 mg/kg (stem)	Morphology, NA				[22]	L; chlorosis, browning, necrosis, waterlogging of tissues
			4.6 mg/kg (leaf)	Growth, NOED				[22]	L; no effect on growth
			7.8 mg/kg (leaf)	Growth, NOED				[22]	L; no effect on growth
			20.8 mg/kg (root)	Growth, NOED				[22]	L; no effect on growth
			82.8 mg/kg (root)	Growth, NOED				[22]	L; no effect on growth
			10 mg/kg (stem)	Growth, NOED				[22]	L; no effect on growth
			15.2 mg/kg (stem)	Growth, NOED				[22]	L; no effect on growth
			4.6 mg/kg (leaf)	Morphology, NOED				[22]	L; no effect on plant appearance

Summary of Biological Effects Tissue Concentrations for Copper

Species: Taxa	Concentration, Units in[1]: Sediment	Water	Tissue (Sample Type)	Toxicity: Effects	Ability to Accumulate[2]: Log BCF	Log BAF	BSAF	Source: Reference	Comments[3]
			7.8 mg/kg (leaf)	Morphology, NOED				[22]	L; no effect on plant appearance
			20.8 mg/kg (root)	Morphology, NOED				[22]	L; no effect on plant appearance
			82.8 mg/kg (root)	Morphology, NOED				[22]	L; no effect on plant appearance
			10 mg/kg (stem)	Morphology, NOED				[22]	L; no effect on plant appearance
			15.2 mg/kg (stem)	Morphology, NOED				[22]	L; no effect on plant appearance
Invertebrates									
Invertebrates field-collected	Total µg/g / SEM µg/g	Filt µg/L / Nonfilt µg/L	Body					[10]	F
	7,820 / 6,971	79 / 11,080	1,382 µg/g						
	583 / 325	36 / 698	122 µg/g						
	480 / 287	16 / 274	181 µg/g						
	478 / 251	9 / 184	266 µg/g						
	128 / 77	9 / 58	48 µg/g						
	16 / <12	2 / 35	26 µg/g						
Tubificidae	172 µg/g		17.14 mg/g					[9]	F
	185 µg/g		10.23 mg/g						
	175 µg/g		16.11 mg/g						
	125 µg/g		20.12 mg/g						
	130 µg/g		14.73 mg/g						

Summary of Biological Effects Tissue Concentrations for Copper

Species: Taxa	Concentration, Units in[1]: Sediment	Water	Tissue (Sample Type)	Toxicity: Effects	Ability to Accumulate[2]: Log BCF	Log BAF	BSAF	Source: Reference	Comments[3]
Nereis diversicolor, Polychaete worm	41 µg/g		28 µg/g					[5]	L
	44 µg/g		22 µg/g						
	52 µg/g		33 µg/g						
	73 µg/g		31 µg/g						
	436 µg/g		106 µg/g						
	591 µg/g		257 µg/g						
	3,020 µg/g		1,142 µg/g						
Meretrix casta, Marine clam			201 mg/kg (whole body)[4]	Mortality, ED50				[25]	L; lethal body burden
Mytilus edulis, Mussel			67.4 mg/kg (whole body)[4]	Mortality, ED50				[21]	L; lethal body burden after 7 - 8 days
			67.4 mg/kg (whole body)[4]	Behavior, LOED				[21]	L; total valve closure, increased mucus production, reduced byssus production
			80 mg/kg (whole body)[4]	Mortality, ED100				[26]	L; lethal body burden
			36 mg/kg (whole body)[4]	Mortality, ED100				[26]	L; lethal body burden
			23 mg/kg (whole body)[4]	Mortality, ED100				[26]	L; lethal body burden
			15 mg/kg (whole body)[4]	Mortality, ED100				[26]	L; lethal body burden

Summary of Biological Effects Tissue Concentrations for Copper

Species: Taxa	Concentration, Units in[1]: Sediment	Water	Tissue (Sample Type)	Toxicity: Effects	Ability to Accumulate[2]: Log BCF	Log BAF	BSAF	Source: Reference	Comments[3]
			12 mg/kg (whole body)[4]	Mortality, ED100				[26]	L; lethal body burden
			12 mg/kg (whole body)[4]	Mortality, ED100				[26]	L; lethal body burden
			12 mg/kg (whole body)[4]	Mortality, ED100				[26]	L; lethal body burden
			56 mg/kg (whole body)[4]	Mortality, ED100				[26]	L; lethal body burden
Mytilus galloprovincialis, Mussel			1.9-3.1 mg/kg				0.04	[14]	F
Dreissena polymorpha, Zebra mussel			8.1 mg/kg (whole body)[4]	Physiological; LOED				[24]	L; indicative of breakdown of internal Cu regulatory process
			2.7 mg/kg (whole body)[4]	Physiological, NOED				[24]	L; no effect on internal Cu regulatory process

Summary of Biological Effects Tissue Concentrations for Copper

Species: Taxa	Concentration, Units in[1]: Sediment	Water	Tissue (Sample Type)	Toxicity: Effects	Ability to Accumulate[2]: Log BCF	Log BAF	BSAF	Source: Reference	Comments[3]
Elliptio complanata, Freshwater mussel	0.1-23.7 µg/g		5.4 µg/g (foot)					[11]	F
			2.4 µg/g (muscle)						
			8.5 µg/g (visceral)						
			29.0 µg/g (hepatopancreas)						
			29.5 µg/g (gill)						
			17.6 µg/g (mantle)						
	0.1-40.7 µg/g		5.4 µg/g (foot)						
			2.7 µg/g (muscle)						
			10.5 µg/g (visceral)						
			28.8 µg/g (hepatopancreas)						
			27.8 µg/g (gill)						
			11.8 µg/g (mantle)						
	0.2-106 µg/g		12.7 µg/g (foot)						
			11.7 µg/g (muscle)						
			16.5 µg/g (visceral)						
			44.5 µg/g (hepatopancreas)						
			214 µg/g (gill)						
			94 µg/g (mantle)						

Summary of Biological Effects Tissue Concentrations for Copper									
Species:	**Concentration, Units in[1]:**			**Toxicity:**	**Ability to Accumulate[2]:**			**Source:**	
Taxa	**Sediment**	**Water**	**Tissue (Sample Type)**	**Effects**	**Log BCF**	**Log BAF**	**BSAF**	**Reference**	**Comments[3]**
Elliptio complanata, Freshwater mussel	0.3-142 µg/g		13.1 µg/g (foot) 10.7 µg/g (muscle) 16.1 µg/g (visceral) 72.9 µg/g (hepatopancreas) 132 µg/g (gill) 81.7 µg/g (mantle)						
Unio pictorum, Freshwater mussel			6.5 mg/kg (digestive gland)[4]	Physiological; LOED				[24]	L; indicative of breakdown of internal Cu regulatory process
			10 mg/kg (gill)[4]	Physiological; LOED				[24]	L; indicative of breakdown of internal Cu regulatory process
			4.6 mg/kg (mantle)[4]	Physiological; LOED				[24]	L; indicative of breakdown of internal Cu regulatory process
			2.7 mg/kg (digestive gland)[4]	Physiological; NOED				[24]	L; no effect on internal Cu regulatory process

Summary of Biological Effects Tissue Concentrations for Copper

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	Sediment	Water	Tissue (Sample Type)	Effects	Log BCF	Log BAF	BSAF	Reference	Comments[3]
			1.9 mg/kg (gill)[4]	Physiological; NOED				[24]	L; no effect on internal Cu regulatory process
			1.7 mg/kg (gonad)[4]	Physiological; NOED				[24]	L; no effect on internal Cu regulatory process
			4 mg/kg (gonad)[4]	Physiological; NOED				[24]	L; no effect on internal Cu regulatory process
			2 mg/kg (kidney)[4]	Physiological; NOED				[24]	L; no effect on internal Cu regulatory process
			3.7 mg/kg (kidney)[4]	Physiological; NOED				[24]	L; no effect on internal Cu regulatory process
			1.1 mg/kg (mantle)[4]	Physiological; NOED				[24]	L; no effect on internal Cu regulatory process

Summary of Biological Effects Tissue Concentrations for Copper

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	Sediment	Water	Tissue (Sample Type)	Effects	Log BCF	Log BAF	BSAF	Reference	Comments[3]
Daphnia magna, Cladoceran			5.8 mg/kg (whole body)[4]	Reproduction, ED10				[7]	L; 10% reduction in number of offspring
			68 mg/kg (whole body)[4]	Mortality, ED50				[7]	L; lethal body burden after 21 day exposure
Hyalella azteca, Amphipod		7.7 µg/L	91 µg/g	54% survival				[6]	L
		10.7 µg/L	92 µg/g	50% survival					
		16.7 µg/L	95 µg/g	40% survival					
		25.4 µg/L	88 µg/g	29% survival					
		43.8 µg/L	80 µg/g	6% survival					
		81.3 µg/L	—	0% survival					

Taxa	Sediment: Total µg/g	Sediment: SEM µg/g	Water: Filt µg/L	Water: Nonfilt µg/L	Tissue: Body;	Reference	Comments
Hyalella azteca, Amphipod	7,820	6,971	79	11,080	249 µg/g	[10]	F
	583	325	36	698	87 µg/g		
	480	287	16	274	124 µg/g		
	478	251	9	184	127 µg/g		
	128	77	9	58	124 µg/g		
	16	<12	2	35	84 µg/g		

Summary of Biological Effects Tissue Concentrations for Copper

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	**Sediment**	**Water**	**Tissue (Sample Type)**	**Effects**	**Log BCF**	**Log BAF**	**BSAF**	**Reference**	**Comments[3]**
Corophium volutator, Amphipod			16.9 mg/kg (whole body)[4]	NA, LOED				[18]	L; 100% dissolved oxygen saturation during test
Balanus crenatus, Barnacle			80 mg/kg (whole body)[4]	Behavior, NOED				[29]	L; regulation of metals endpoint-summer experiment
Orconectes rusticus, Crayfish			24 mg/kg (abdomen)[4]	Mortality, NOED				[19]	L; no effect on survivorship
			26 mg/kg (abdomen)[4]	Mortality, NOED				[19]	L; no effect on survivorship
			32 mg/kg (abdomen)[4]	Mortality, NOED				[19]	L; no effect on survivorship
			42 mg/kg (abdomen)[4]	Mortality, NOED				[19]	L; no effect on survivorship
			52 mg/kg (abdomen)[4]	Mortality, NOED				[19]	L; no effect on survivorship
			17.8 mg/kg (claw)[4]	Mortality, NOED				[19]	L; no effect on survivorship
			24 mg/kg (claw)[4]	Mortality, NOED				[19]	L; no effect on survivorship
			24 mg/kg (claw)[4]	Mortality, NOED				[19]	L; no effect on survivorship
			30 mg/kg (claw)[4]	Mortality, NOED				[19]	L; no effect on survivorship

Summary of Biological Effects Tissue Concentrations for Copper

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	Sediment	Water	Tissue (Sample Type)	Effects	Log BCF	Log BAF	BSAF	Reference	Comments[3]
			34 mg/kg (claw)[4]	Mortality, NOED				[19]	L; no effect on survivorship
			42 mg/kg (thorax)[4]	Mortality, NOED				[19]	L; no effect on survivorship
			50 mg/kg (thorax)[4]	Mortality, NOED				[19]	L; no effect on survivorship
			56 mg/kg (thorax)[4]	Mortality, NOED				[19]	L; no effect on survivorship
			60 mg/kg (thorax)[4]	Mortality, NOED				[19]	L; no effect on survivorship
			70 mg/kg (thorax)[4]	Mortality, NOED				[19]	L; no effect on survivorship
			2 mg/kg (whole body)[4]	Mortality, NOED				[19]	L; no effect on survivorship
			9 mg/kg (whole body)[4]	Mortality, NOED				[19]	L; no effect on survivorship
			11.2 mg/kg (whole body)[4]	Mortality, NOED				[19]	L; no effect on survivorship
			19.2 mg/kg (whole body)[4]	Mortality, NOED				[19]	L; no effect on survivorship
			26 mg/kg (whole body)[4]	Mortality, NOED				[19]	L; no effect on survivorship

Summary of Biological Effects Tissue Concentrations for Copper

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	**Sediment**	**Water**	**Tissue (Sample Type)**	**Effects**	**Log BCF**	**Log BAF**	**BSAF**	**Reference**	**Comments[3]**
Chironomus riparius, Midge		0.087 mg/L	500 µg/g		3.77			[4]	F
Chironomus thummi, Midge	12.55 mg/kg		35.7 mg/kg 39.7 mg/kg	Normal larvae Deformed larvae				[8]	F
Chironomus decorus, Midge			1,000 mg/kg (whole body)[4]	Mortality, ED100				[23]	L; 100% mortality
			142 mg/kg (whole body)[4]	Mortality, ED50				[23]	L; ED50
			107 mg/kg (whole body)[4]	Mortality, LOED				[23]	L; significant mortality
			126 mg/kg (whole body)[4]	Mortality, LOED				[23]	L; significant mortality
			86.2 mg/kg (whole body)[4]	Mortality, NOED				[23]	L; no effect on mortality
			130 mg/kg (pupal exuviae)[4]	Development, LOED				[23]	L; increased time to adult emergence by 10 days
			18 mg/kg (whole body)[4]	Development, LOED				[23]	L; increased time to adult emergence by 10 days
			14.8 mg/kg (pupal exuviae)[4]	Development, NOED				[23]	L; no effect on time to adult emergence

Summary of Biological Effects Tissue Concentrations for Copper									
Species:	**Concentration, Units in[1]:**			**Toxicity:**	**Ability to Accumulate[2]:**			**Source:**	
Taxa	**Sediment**	**Water**	**Tissue (Sample Type)**	**Effects**	**Log BCF**	**Log BAF**	**BSAF**	**Reference**	**Comments[3]**
			75.6 mg/kg (pupal exuviae)[4]	Development, NOED				[23]	L; no effect on time to adult emergence
			2.28 mg/kg (whole body)[4]	Development, NOED				[23]	L; no effect on time to adult emergence
			7.2 mg/kg (whole body)[4]	Development, NOED				[23]	L; no effect on time to adult emergence
			13 mg/kg (whole body)[4]	Development, NOED				[23]	L; no effect on time to adult emergence
			7.14 mg/kg (whole body)[4]	Morphology, NOED				[8]	L; 4th instar larvae
Fishes									
Oncorhynchus mykiss, Rainbow trout			40 mg/kg (whole body)[4]	Physiological; LOED				[16]	L; induction of metallothionein
			1.6 mg/kg (whole body)[4]	Mortality, ED100				[17]	L; 100% mortality in non-metallo-thionein-induced fish
			6.8 mg/kg (whole body)[4]	Physiological, LOED				[17]	L; induction of metallothionein
			2.22 mg/kg (whole body)[4]	Mortality, LOED				[20]	L; 50% mortality in 7 hours

Summary of Biological Effects Tissue Concentrations for Copper

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	**Sediment**	**Water**	**Tissue (Sample Type)**	**Effects**	**Log BCF**	**Log BAF**	**BSAF**	**Reference**	**Comments[3]**
			4.48 mg/kg (whole body)[4]	Survival, LOED				[27]	L
			3.92 mg/kg (whole body)[4]	Not applicable, NOED				[27]	L
Pimephales promelas, Fathead minnow	78.9 µg/g		10.28 mg/g					[9]	F
	110 µg/g		9.32 mg/g						
	125 µg/g		9.13 mg/g						
	130 µg/g		9.70 mg/g						
	130 µg/g		9.86 mg/g						
	172 µg/g		6.92 mg/g						
	175 µg/g		7.28 mg/g						
	175 µg/g		10.96 mg/g						
	185 µg/g		9.37 mg/g						
Cyprinus carpio, Common carp			12.1 mg/kg (whole body)[4]	Morphology, LOED				[29]	L; larval deformation, pH 6.3, body burden from graph
			12.1 mg/kg (whole body)[4]	Morphology, LOED				[29]	L; larval deformation, pH 7.6, body burden from graph
			12.1 mg/kg (whole body)[4]	Mortality, LOED				[29]	L; larval mortality, pH 6.3, body burden from graph

Summary of Biological Effects Tissue Concentrations for Copper									
Species:	**Concentration, Units in[1]:**			**Toxicity:**	**Ability to Accumulate[2]:**			**Source:**	
Taxa	**Sediment**	**Water**	**Tissue (Sample Type)**	**Effects**	**Log BCF**	**Log BAF**	**BSAF**	**Reference**	**Comments[3]**
			12.1 mg/kg (whole body)[4]	Mortality, LOED				[29]	L; larval mortality, pH 7.6, body burden from graph
			24.1 mg/kg (whole body)[4]	Reproduction, LOED				[29]	L; egg mortality, pH 6.3, body burden from graph
			7.62 mg/kg (whole body)[4]	Morphology, NOED				[29]	L; larval deformation, pH 7.6, body burden from graph
			7.62 mg/kg (whole body)[4]	Mortality, NOED				[29]	L; larval mortality, pH 7.6, body burden from graph
			12.1 mg/kg (whole body)[4]	Reproduction, NOED				[29]	L; egg mortality, pH 7.6, body burden from graph
			12.1 mg/kg (whole body)[4]	Reproduction, NOED				[29]	L; egg mortality, pH 6.3, body burden from graph
Lepomis macrochirus, Bluegill			13 mg/kg (gill)[4]	Growth, LOED				[15]	L; duration = 22 months or 660 days

Summary of Biological Effects Tissue Concentrations for Copper

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	Sediment	Water	Tissue (Sample Type)	Effects	Log BCF	Log BAF	BSAF	Reference	Comments[3]
			44 mg/kg (kidney)[4]	Growth, LOED				[15]	L; duration = 22 months or 660 days
			480 mg/kg (liver)[4]	Growth, LOED				[15]	L; duration = 22 months or 660 days
			13 mg/kg (gill)[4]	Mortality, LOED				[15]	L; duration = 22 months or 660 days
			44 mg/kg (kidney)[4]	Mortality, LOED				[15]	L; duration = 22 months or 660 days
			480 mg/kg (liver)[4]	Mortality, LOED				[15]	L; duration = 22 months or 660 days
			13 mg/kg (gill)[4]	Reproduction, LOED				[15]	L; duration = 22 months or 660 days
			44 mg/kg (kidney)[4]	Reproduction, LOED				[15]	L; duration = 22 months or 660 days
			480 mg/kg (liver)[4]	Reproduction, LOED				[15]	L; duration = 22 months or 660 days
			6 mg/kg (gill)[4]	Growth, NOED				[15]	L; duration = 22 months or 660 days
			12 mg/kg (kidney)[4]	Growth, NOED				[15]	L; duration = 22 months or 660 days

Summary of Biological Effects Tissue Concentrations for Copper

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	Sediment	Water	Tissue (Sample Type)	Effects	Log BCF	Log BAF	BSAF	Reference	Comments[3]
			57 mg/kg (liver)[4]	Growth, NOED				[15]	L; duration = 22 months or 660 days
			6 mg/kg (gill)[4]	Mortality, NOED				[15]	L; duration = 22 months or 660 days
			12 mg/kg (kidney)[4]	Mortality, NOED				[15]	L; duration = 22 months or 660 days
			57 mg/kg (liver)[4]	Mortality, NOED				[15]	L; duration = 22 months or 660 days
			6 mg/kg (gill)[4]	Reproduction, NOED				[15]	L; duration = 22 months or 660 days
			12 mg/kg (kidney)[4]	Reproduction, NOED				[15]	L; duration = 22 months or 660 days
			57 mg/kg (liver)[4]	Reproduction, NOED				[15]	L; duration = 22 months or 660 days

[1] Concentration units based on wet weight unless otherwise noted.
[2] BCF = bioconcentration factor, BAF = bioaccumulation factor, BSAF = biota-sediment accumulation factor.
[3] L = laboratory study, spiked sediment, single chemical; F = field study, multiple chemical exposure; other unusual study conditions or observations noted.
[4] This entry was excerpted directly from the Environmental Residue-Effects Database (ERED, www.wes.army.mil/el/ered, U.S. Army Corps of Engineers and U.S. Environmental Protection Agency). The original publication was not reviewed, and the reader is strongly urged to consult the publication to confirm the information presented here.

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Chemical Category: POLYCHLORINATED DIBENZO-*p*-DIOXINS

Chemical Name (Common Synonyms): **CASRN:** 35822-46-9
1,2,3,4,6,7,8-HEPTACHLORO DIBENZO-*p*-DIOXIN

Chemical Characteristics

Solubility in Water: No data [1], 2.4 mg/L [2]

Half-Life: No data [2,3]

Log K_{ow}: No data [4], 8.00 [2]

Log K_{oc}: 7.86 L/kg organic carbon

Human Health

Oral RfD: No data [5]

Confidence: —

Critical Effect: —

Oral Slope Factor: No data [5]

Carcinogenic Classification: —

Wildlife

Partitioning Factors: Partitioning factors for 1,2,3,4,6,7,8-heptaCDD in wildlife were not found in the studies reviewed.

Food Chain Multipliers: Limited information was found on specific biomagnification factors of PCDDs and PCDFs through terrestrial wildlife. Due to the toxicity, high K_{ow} values, and highly persistent nature of the PCDDs and PCDFs, they possess a high potential to bioaccumulate and biomagnify through the food web. PCDDs and PCDFs have been identified in fish and wildlife throughout the global aquatic and marine environments [6]. Studies conducted in Lake Ontario indicated that biomagnification of 2,3,7,8-tetrachlorodibenzo-*p*-dioxin (2,3,7,8-TCDD) appears to be significant between fish and fish-eating birds but not between fish and their food. When calculated for older predaceous fish such as lake-trout-eating young smelt, the biomagnification factor (BMF) can equal 3. The log BMF from alewife to herring gulls in Lake Ontario was 1.51 for 2,3,7,8-TCDD [7]. Log BMFs of 1.18 to 1.70 were determined for mink fed 1,2,3,4,6,7,8-Hepta CDD in the diet [18].

EPA has developed risk-based concentrations of 2,3,7,8-TCDD in different media that present low and high risk to fish, mammalian, and avian wildlife. These concentrations were developed based on toxic effects of 2,3,7,8-TCDD and its propensity to bioaccumulate in fish, mammals, and birds.

Environmental Concentrations Associated With 2,3,7,8-TCDD Risk to Aquatic Life and Associated Wildlife [8]

Organism	Fish Concentration (pg/g)	Sediment Concentration (pg/g dry wt.)	Water Concentration (pg/L)	
			POC=0.2	POC=1.0
Low Risk				
Fish	50	60	0.6	3.1
Mammalian Wildlife	0.7	2.5	0.008	0.04
Avian Wildlife	6	21	0.07	0.35
High Risk to Sensitive Species				
Fish	80	100	1.0	5
Mammalian Wildlife	7	25	0.08	0.4
Avian Wildlife	60	210	0.7	3.5

Note: POC - Particulate organic carbon
Fish lipid of 8% and sediment organic carbon of 3% assumed where needed.
For risk to fish, BSAF of 0.3 used; for risk to wildlife, BSAF of 0.1 used.
Low risk concentrations are derived from no-effects thresholds for reproductive effects (mortality in embryos and young) in sensitive species.
High risk concentrations are derived from TCDD doses expected to cause 50 to 100% mortality in embryos and young of sensitive species.

Aquatic Organisms

Partitioning Factors: In one study, the BSAF for carp collected from a reservoir in central Wisconsin was 0.0048. In a laboratory study, log BCFs for fathead minnow, rainbow trout, and goldfish exposed to 1,2,3,4,6,7,8-HeptaCDD were 2.71, 3.15, and 4.28, respectively.

Food Chain Multipliers: No specific food chain multipliers were identified for 1,2,3,4,6,7,8-heptaCDD. Food chain multiplier information was only available for 2,3,7,8-TCDD. Biomagnification of 2,3,7,8-TCDD does not appear to be significant between fish and their prey. Limited data for the base of the Lake Ontario lake trout food chain indicated little or no biomagnification between zooplankton and forage fish. BMFs based on fish consuming invertebrate species are probably close to 1.0 because of the 2,3,7,8-TCDD biotransformation by forage fish. BMFs greater than 1.0 may exist between some zooplankton species and their prey due to the lack of 2,3,7,8-TCDD biotransformation in invertebrates [8].

Toxicity/Bioaccumulation Assessment Profile

The polychlorinated dibenzo-*p*-dioxins (PCDDs) and polychlorinated dibenzofurans (PCDFs) each consist of 75 isomers that differ in the number and position of attached chlorine atoms. The PCDDs and PCDFs are polyhalogenated aromatic compounds and exhibit several properties common to this group of compounds. These compounds tend to be highly lipophilic and the degree of lipophilicity is increased with increasing ring chlorination [6]. In general, the PCDDs and PCDFs exhibit relative inertness to acids, bases, oxidation, reduction, and heat, increasing in environmental persistence and chemical

stability with increasing chlorination [9,6]. Because of their lipophilic nature, the PCDDs and PCDFs have been detected in fish, wildlife, and human adipose tissue, milk, and serum [6].

Each isomer has its own unique chemical and toxicological properties. The most toxic of the PCDD and PCDF isomers is 2,3,7,8-TCDD, one of the 22 possible congeners of tetrachlorodibenzo-*p*-dioxin [9]. Toxicity equivalency factors (TEFs) have been developed by EPA relating the toxicities of other PCDD and PCDF isomers to that of 2,3,7,8-TCDD [10]. The biochemical mechanisms leading to the toxic response resulting from exposure to PCDDs and PCDFs are not known in detail, but experimental data suggest that an important role in the development of systemic toxicity resulting from exposure to these chemicals is played by an intracellular protein, the Ah receptor. This receptor binds halogenated polycyclic aromatic molecules, including PCDDs and PCDFs. In several mouse strains, the expression of toxicity of 2,3,7,8-TCDD-related compounds, including cleft palate formation, liver damage, effects on body weight gain, thymic involution, and chloracnegenic response, has been correlated with their binding affinity for the Ah receptor, and with their ability to induce several enzyme systems [10].

Toxicity Equivalency Factors (TEF) for PCDD and PCDF Isomers [10]

Isomer	TEF
Total TetraCDD	1
2,3,7,8-TCDD	1
Other TCDDs	0.01
Total PentaCDDs	0.5
2,3,7,8-PentaCDDs	0.5
Other PentaCDDs	0.005
Total HexaCDDs	0.04
2,3,7,8-HexaCDDs	0.04
Other HexaCDDs	0.0004
Total HeptaCDDs	0.001
2,3,7,8-HeptaCDDs	0.001
Other HeptaCDDs	0.00001
Total TetraCDFs	0.1
2,3,7,8-TetraCDF	0.1
Other TetraCDFs	0.001
Total PentaCDFs	0.1
2,3,7,8-PentaCDFs	0.1
Other PentaCDFs	0.001
Total HexaCDFs	0.01
2,3,7,8-HexaCDFs	0.01
Other HexaCDFs	0.0001
Total HeptaCDFs	0.001
2,3,7,8-HeptaCDFs	0.001
Other HeptaCDFs	0.00001

In natural systems, PCDDs and PCDFs are typically associated with sediments, biota, and the organic carbon fraction of ambient waters [8]. Congener-specific analyses have shown that the 2,3,7,8-substituted PCDDs and PCDFs were the major compounds present in most sample extracts [6]. Results from limited epidemiology studies are consistent with laboratory-derived threshold levels to 2,3,7,8-TCDD impairment of reproduction in avian wildlife. Population declines in herring gulls (*Larus argentatus*) on Lake Ontario during the early 1970s coincided with egg concentrations of 2,3,7,8-TCDD and related chemicals expected to cause reproductive failure based on laboratory experiments (2,3,7,8-TCDD concentrations in excess of 1,000 pg/g). Improvements in herring gull reproduction through the mid-1980s were correlated with declining 2,3,7,8-TCDD concentrations in eggs and lake sediments [8]. Based on limited information on isomer-specific analysis from animals at different trophic levels, it appears that at higher trophic levels, i.e., fish-eating birds and fish, there is a selection of the planar congeners with the 2,3,7,8-substituted positions [11].

PCDDs and PCDFs are accumulated by aquatic organisms through exposure routes that are determined by the habitat and physiology of each species. With log K_{ow}>5, exposure through ingestion of contaminated food becomes an important route for uptake in comparison to respiration of water [8]. The relative contributions of water, sediment, and food to uptake of 2,3,7,8-TCDD by lake trout in Lake Ontario were examined by exposing yearling lake trout to Lake Ontario smelt and sediment from Lake Ontario along with water at a 2,3,7,8-TCDD concentration simulated to be at equilibrium with the sediments. Food ingestion was found to contribute approximately 75 percent of total 2,3,7,8-TCDD [8]. There have been a number of bioconcentration studies of 2,3,7,8-TCDD using model ecosystem and single species exposure. Although there is variation in the actual BCF values, in general, the algae and plants have the lowest BCF values, on the order of a few thousand. A log BCF value of 4.38 has been reported for the snail *Physa* sp. Crustacea and insect larvae appear to have the next highest BCF values, followed by several species of fish, with the highest log BCF value of 4.79 [11].

Exposure of juvenile rainbow trout to 2,3,7,8-TCDD and -TCDF in water for 28 days resulted in adverse effects on survival, growth, and behavior at extremely low concentrations. A no-observed-effects concentration (NOEC) for 2,3,7,8-TCDD could not be determined because the exposure to the lowest dose of 0.038 ng/l resulted in significant mortality [12]. A number of biological effects have been reported in fish following exposure to 2,3,7,8-TCDD including enzyme induction, immunological effects, wasting syndrome, dermatological effects, hepatic effects, hematological effects, developmental effects, and cardiovascular effects [11].

Summary of Biological Effects Tissue Concentrations for 1,2,3,4,6,7,8-HeptaCDD

Species: Taxa	Concentration, Units in[1]: Sediment	Water	Tissue (Sample Type)	Toxicity: Effects	Ability to Accumulate[2]: Log BCF	Log BAF	BSAF	Source: Reference	Comments[3]
Fishes									
Salmonids							0.0031	[20]	F
Oncorhynchus mukiss (Salmo gairderni), Rainbow trout		Exposure water 11-55 ng/L			3.15 ± 2.35			[16]	L
Oncorhynchus mukiss (Salmo gairderni), Rainbow trout			0.000035 mg/kg (liver)[4]	Biochemical, LOED				[19]	L; significant increase in liver ethoxyresorufin O-deethylase (EROD)
Cyprinus carpio, Carp	2,190 pg/g[5]		27 pg/g[5]				0.0048	[13]	F; Petenwell Reservoir, central Wisconsin; BSAF based on 8% tissue lipid content and 3.1% sediment organic carbon

Summary of Biological Effects Tissue Concentrations for 1,2,3,4,6,7,8-HeptaCDD

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	Sediment	Water	Tissue (Sample Type)	Effects	Log BCF	Log BAF	BSAF	Reference	Comments[3]
Carassius auratus, Goldfish			1.91/2.2 ng/g[5] (whole body)		4.28			[15]	L; fish were exposed for 120 hr; exposure water contained fly ash extract; concentrations were measured in water, but data were not presented
Pimephales promelas, Fathead minnow		Exposure water 8-39 ng/L			2.71 ± 2.03			[16]	L
Platycephalus caerulopunctatus and *Platycephalus bassensis,* Flathead	0.356 pg/g, dw		558 pg/kg					[14]	F; unimpacted coastal site; surface sediment composite; most other dioxin congeners were below detection.
Sillago bassensis, School whiting	0.356 pg/g, dw		375 pg/kg						
Wildlife									
Falco peregrinus, Peregrine falcon			0.7 ng/g (eggs) (n = 6)	11.4% eggshell thinning				[17]	F; Kola Peninsula, Russia

Summary of Biological Effects Tissue Concentrations for 1,2,3,4,6,7,8-HeptaCDD

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	Sediment	Water	Tissue (Sample Type)	Effects	Log BCF	Log BAF	BSAF	Reference	Comments[3]
Mustela vison, Mink	Diet: 5 pg/g[5]		115 pg/g[5] (liver)	NOAEL		log BMF = 1.18		[18]	L; BMF = lipid-normalized concentration in the liver divided by the lipid-normalized dietary concentration
	7 pg/g[5]		330 pg/g[5] (liver)	LOAEL; reduced kit body weights followed by reduced survival		log BMF = 1.70			
	6 pg/g[5]		290 pg/g[5] (liver)	Reduced kit body weights followed by reduced survival		log BMF = 1.69			
	13 pg/g[5]		380 pg/g[5] (liver)	Significant decrease in number of live kits whelped per female		log BMF = 1.66			

[1] Concentration units based on wet weight unless otherwise noted.
[2] BCF = bioconcentration factor, BAF = bioaccumulation factor, BSAF = biota-sediment accumulation factor.
[3] L = laboratory study, spiked sediment, single chemical; F = field study, multiple chemical exposure; other unusual study conditions or observations noted.
[4] This entry was excerpted directly from the Environmental Residue-Effects Database (ERED, www.wes.army.mil/el/ered, U.S. Army Corps of Engineers and U.S. Environmental Protection Agency). The original publication was not reviewed, and the reader is strongly urged to consult the publication to confirm the information presented here.
[5] Not clear from reference if concentration is based on wet or dry weight.

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Chemical Category: POLYCHLORINATED DIBENZO-*p*-DIOXINS

Chemical Name (Common Synonyms): **CASRN:** 39227-28-6
1,2,3,4,7,8-HEXACHLORODIBENZO-*p*-DIOXIN

Chemical Characteristics

Solubility in Water: No data [1],
8.25 x 10^{-6} mg/L [1,2]

Half-Life: No data [2,3]

Log K_{ow}: No data [4], 7.70 [2]

Log K_{oc}: 7.57 L/kg organic carbon

Human Health

Oral RfD: No data [5]

Confidence: —

Critical Effect: —

Oral Slope Factor (Reference): No data [5]

Carcinogenic Classification: —

Wildlife

Partitioning Factors: Partitioning factors for 1,2,3,4,7,8-hexaCDD in wildlife were not found in the studies reviewed.

Food Chain Multipliers: Limited information was found reporting on specific biomagnification factors of PCDDs and PCDFs through terrestrial wildlife. Due to the toxicity, high K_{ow} values, and highly persistent nature of the PCDDs and PCDFs, they possess a high potential to bioaccumulate and biomagnify through the food web. PCDDs and PCDFs have been identified in fish and wildlife throughout the global aquatic and marine environments [6]. Studies conducted in Lake Ontario indicated that biomagnification of 2,3,7,8-tetrachlorodibenzo-*p*-dioxin (2,3,7,8-TCDD) appears to be significant between fish and fish-eating birds but not between fish and their food. When calculated for older predaceous fish such as lake-trout-eating young smelt, the biomagnification factor (BMF) can equal 3. The BMF from alewife to herring gulls in Lake Ontario was 32 for 2,3,7,8-TCDD [7]. A log BMF of 0.97 was reported for mink exposed to 1,2,3,4,7,8-hexaCDD in the diet. [14].

EPA has developed risk-based concentrations of 2,3,7,8-TCDD in different media that present low and high risk to fish, mammalian, and avian wildlife. These concentrations were developed based on toxic effects of 2,3,7,8-TCDD and its propensity to bioaccumulate in fish, mammals, and birds.

Environmental Concentrations Associated With 2,3,7,8-TCDD Risk to Aquatic Life and Associated Wildlife [8]

Organism	Fish Concentration (pg/g)	Sediment Concentration (pg/g dry wt.)	Water Concentration (pg/L)	
			POC=0.2	POC=1.0
Low Risk				
Fish	50	60	0.6	3.1
Mammalian Wildlife	0.7	2.5	0.008	0.04
Avian Wildlife	6	21	0.07	0.35
High Risk to Sensitive Species				
Fish	80	100	1.0	5
Mammalian Wildlife	7	25	0.08	0.4
Avian Wildlife	60	210	0.7	3.5

Note: POC - Particulate organic carbon
Fish lipid of 8% and sediment organic carbon of 3% assumed where needed.
For risk to fish, BSAF of 0.3 used; for risk to wildlife, BSAF of 0.1 used.
Low risk concentrations are derived from no-effects thresholds for reproductive effects (mortality in embryos and young) in sensitive species.
High risk concentrations are derived from TCDD doses expected to cause 50 to 100% mortality in embryos and young of sensitive species.

Aquatic Organisms

Partitioning Factors: In a laboratory study, log BCFs for rainbow trout and fathead minnow exposed to 1,2,3,4,7,8-HexaCDD were 3.73 and 4.00, respectively.

Food Chain Multipliers: No specific food chain multipliers were identified for 1,2,3,4,7,8-hexaCDD. Food chain multiplier information was only available for 2,3,7,8-TCDD. Biomagnification of 2,3,7,8-TCDD does not appear to be significant between fish and their prey. Limited data for the base of the Lake Ontario lake trout food chain indicated little or no biomagnification between zooplankton and forage fish. BMFs based on fish consuming invertebrate species are probably close to 1.0 because of the 2,3,7,8-TCDD biotransformation by forage fish. BMFs greater than 1.0 may exist between some zooplankton species and their prey due to the lack of 2,3,7,8-TCDD biotransformation in invertebrates [8].

Toxicity/Bioaccumulation Assessment Profile

The polychlorinated dibenzo-*p*-dioxins (PCDDs) and polychlorinated dibenzofurans (PCDFs) each consist of 75 isomers that differ in the number and position of attached chlorine atoms. The PCDDs and PCDFs are polyhalogenated aromatic compounds and exhibit several properties common to this group of compounds. These compounds tend to be highly lipophilic and the degree of lipophilicity is increased with increasing ring chlorination [6]. In general, the PCDDs and PCDFs exhibit relative inertness to acids, bases, oxidation, reduction, and heat, increasing in environmental persistence and chemical

stability with increasing chlorination [9,6]. Because of their lipophilic nature, the PCDDs and PCDFs have been detected in fish, wildlife, and human adipose tissue, milk, and serum [6].

Each isomer has its own unique chemical and toxicological properties. The most toxic of the PCDD and PCDF isomers is 2,3,7,8-TCDD, one of the 22 possible congeners of tetrachlorodibenzo-*p*-dioxin [10]. Toxicity equivalency factors (TEFs) have been developed by EPA relating the toxicities of other PCDD and PCDF isomers to that of 2,3,7,8-TCDD [9]. The biochemical mechanisms leading to the toxic response resulting from exposure to PCDDs and PCDFs are not known in detail, but experimental data suggest that an important role in the development of systemic toxicity resulting from exposure to these chemicals is played by an intracellular protein, the Ah receptor. This receptor binds halogenated polycyclic aromatic molecules, including PCDDs and PCDFs. In several mouse strains, the expression of toxicity of 2,3,7,8-TCDD-related compounds, including cleft palate formation, liver damage, effects on body weight gain, thymic involution, and chloracnegenic response, has been correlated with their binding affinity for the Ah receptor, and with their ability to induce several enzyme systems [10].

Toxicity Equivalency Factors (TEF) for PCDD and PCDF Isomers [10]

Isomer	TEF
Total TetraCDD	1
2,3,7,8-TCDD	1
Other TCDDs	0.01
Total PentaCDDs	0.5
2,3,7,8-PentaCDDs	0.5
Other PentaCDDs	0.005
Total HexaCDDs	0.04
2,3,7,8-HexaCDDs	0.04
Other HexaCDDs	0.0004
Total HeptaCDDs	0.001
2,3,7,8-HeptaCDDs	0.001
Other HeptaCDDs	0.00001
Total TetraCDFs	0.1
2,3,7,8-TetraCDF	0.1
Other TetraCDFs	0.001
Total PentaCDFs	0.1
2,3,7,8-PentaCDFs	0.1
Other PentaCDFs	0.001
Total HexaCDFs	0.01
2,3,7,8-HexaCDFs	0.01
Other HexaCDFs	0.0001
Total HeptaCDFs	0.001
2,3,7,8-HeptaCDFs	0.001
Other HeptaCDFs	0.00001

In natural systems, PCDDs and PCDFs are typically associated with sediments, biota, and the organic carbon fraction of ambient waters [7]. Congener-specific analyses have shown that the 2,3,7,8-substituted PCDDs and PCDFs were the major compounds present in most sample extracts [6]. Results from limited epidemiology studies are consistent with laboratory-derived threshold levels to 2,3,7,8-TCDD impairment of reproduction in avian wildlife. Population declines in herring gulls (*Larus argentatus*) on Lake Ontario during the early 1970s coincided with egg concentrations of 2,3,7,8-TCDD and related chemicals expected to cause reproductive failure based on laboratory experiments (2,3,7,8-TCDD concentrations in excess of 1,000 pg/g). Improvements in herring gull reproduction through the mid-1980s were correlated with declining 2,3,7,8-TCDD concentrations in eggs and lake sediments [8]. Based on limited information on isomer-specific analysis from animals at different trophic levels, it appears that at higher trophic levels, i.e., fish-eating birds and fish, there is a selection of the planar congeners with the 2,3,7,8-substituted positions [11].

PCDDs and PCDFs are accumulated by aquatic organisms through exposure routes that are determined by the habitat and physiology of each species. With log K_{ow}>5, exposure through ingestion of contaminated food becomes an important route for uptake in comparison to respiration of water [8]. The relative contributions of water, sediment, and food to uptake of 2,3,7,8-TCDD by lake trout in Lake Ontario were examined by exposing yearling lake trout to Lake Ontario smelt and sediment from Lake Ontario along with water at a 2,3,7,8-TCDD concentration simulated to be at equilibrium with the sediments. Food ingestion was found to contribute approximately 75 percent of total 2,3,7,8-TCDD [8]. There have been a number of bioconcentration studies of 2,3,7,8-TCDD using model ecosystem and single species exposure. Although there is variation in the actual BCF values, in general, the algae and plants have the lowest BCF values, on the order of a few thousand. A log BCF value of 4.38 has been reported for the snail *Physa* sp. Crustacea and insect larvae appear to have the next highest BCF values, followed by several species of fish, with the highest log BCF value of 4.79 [11].

Exposure of juvenile rainbow trout to 2,3,7,8-TCDD and -TCDF in water for 28 days resulted in adverse effects on survival, growth, and behavior at extremely low concentrations. A no-observed-effects concentration (NOEC) for 2,3,7,8-TCDD could not be determined because the exposure to the lowest dose of 0.038 ng/l resulted in significant mortality [12]. A number of biological effects have been reported in fish following exposure to 2,3,7,8-TCDD including enzyme induction, immunological effects, wasting syndrome, dermatological effects, hepatic effects, hematological effects, developmental effects, and cardiovascular effects [11].

Summary of Biological Effects Tissue Concentrations for 1,2,3,4,7,8-HexaCDD

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	**Sediment**	**Water**	**Tissue (Sample Type)**	**Effects**	**Log BCF**	**Log BAF**	**BSAF**	**Reference**	**Comments[3]**
Fishes									
Oncorhynchus mukiss (Salmo gairderni), Rainbow trout		Exposure water 10-47 ng/L			3.73			[11]	L
Oncorhynchus mukiss, Rainbow trout			0.0000395 mg/kg (liver)[4]	Biochemical, LOED				[15]	L; significant increase in liver ethoxyresorufin O-deethylase (EROD)
Pimephales promelas, Fathead minnow		Exposure water 10-47 ng/L			4.00			[11]	L
Wildlife									
Falco peregrinus, Peregrine falcon			3.3 ng/g (eggs) (n = 6)	11.4% eggshell thinning				[13]	F; Kola Peninsula, Russia

Summary of Biological Effects Tissue Concentrations for 1,2,3,4,7,8-HexaCDD

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	Sediment	Water	Tissue (Sample Type)	Effects	Log BCF	Log BAF	BSAF	Reference	Comments[3]
Mustela vison, Mink	Diet: 2 pg/g[5]		6 pg/g[5] (liver)	LOAEL; reduced kit body weights followed by reduced survival		No BMF reported		[14]	L; BMF = biomagnification factor = v_l/v_d v_l = lipid-normalized tissue concentration, v_d = lipid-normalized dietary concentration.
	1 pg/g[5]		77 pg/g[5] (liver)	Reduced kit body weights followed by reduced survival		No BMF reported			
	3 pg/g[5]		15 pg/g[5] (liver)	Significant decrease in number of live kits whelped per female		Log BMF = 0.97			

[1] Concentration units based on wet weight unless otherwise noted.
[2] BCF = bioconcentration factor, BAF = bioaccumulation factor, BSAF = biota-sediment accumulation factor.
[3] L = laboratory study, spiked sediment, single chemical; F = field study, multiple chemical exposure; other unusual study conditions or observations noted.
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Chemical Category: POLYCHLORINATED DIBENZO-*p*-DIOXINS

Chemical Name (Common Synonyms): **CASRN:** 57653-85-7
1,2,3,6,7,8-HEXACHLORODIBENZO-*p*-DIOXIN

Chemical Characteristics

Solubility in Water: No data [1,2]

Half-Life: No data [2,3]

Log K_{ow}: No data [2,4]

Log K_{oc}: —

Human Health

Oral RfD: No data [5]

Confidence: —

Critical Effect: Hepatic tumors in mice and rats

Oral Slope Factor: 6.2 x 10^{+3} per (mg/kg)/day [5]

Carcinogenic Classification: B2 [5]

Wildlife

Partitioning Factors: Partitioning factors for 1,2,3,6,7,8-hexaCDD in wildlife were not found in the studies reviewed.

Food Chain Multipliers: Limited information was found reporting on specific biomagnification factors of PCDDs and PCDFs through terrestrial wildlife. Due to the toxicity, high K_{ow} values, and highly persistent nature of the PCDDs and PCDFs, they possess a high potential to bioaccumulate and biomagnify through the food web. PCDDs and PCDFs have been identified in fish and wildlife throughout the global aquatic and marine environments [6]. Studies conducted in Lake Ontario indicated that biomagnification of 2,3,7,8-tetrachlorodibenzo-*p*-dioxin (2,3,7,8-TCDD) appears to be significant between fish and fish-eating birds but not between fish and their food. When calculated for older predaceous fish such as lake-trout-eating young smelt, the biomagnification factor (BMF) can equal 3. The BMF from alewife to herring gulls in Lake Ontario was 32 for 2,3,7,8-TCDD [7]. Log BMFs of 1.42 and 1.43 were reported for mink exposed to 1,2,3,6,7,8-hexaCDD in the diet [18].

EPA has developed risk-based concentrations of 2,3,7,8-TCDD in different media that present low and high risk to fish, mammalian, and avian wildlife. These concentrations were developed based on toxic effects of 2,3,7,8-TCDD and its propensity to bioaccumulate in fish, mammals, and birds.

Environmental Concentrations Associated With 2,3,7,8-TCDD Risk to Aquatic Life and Associated Wildlife [8]

Organism	Fish Concentration (pg/g)	Sediment Concentration (pg/g dry wt.)	Water Concentration (pg/L)	
			POC=0.2	POC=1.0
Low Risk				
Fish	50	60	0.6	3.1
Mammalian Wildlife	0.7	2.5	0.008	0.04
Avian Wildlife	6	21	0.07	0.35
High Risk to Sensitive Species				
Fish	80	100	1.0	5
Mammalian Wildlife	7	25	0.08	0.4
Avian Wildlife	60	210	0.7	3.5

Note: POC - Particulate organic carbon
Fish lipid of 8% and sediment organic carbon of 3% assumed where needed.
For risk to fish, BSAF of 0.3 used; for risk to wildlife, BSAF of 0.1 used.
Low risk concentrations are derived from no-effects thresholds for reproductive effects (mortality in embryos and young) in sensitive species.
High risk concentrations are derived from TCDD doses expected to cause 50 to 100% mortality in embryos and young of sensitive species.

Aquatic Organisms

Partitioning Factors: In one study, the BSAF for carp collected from a reservoir in central Wisconsin was 0.035. The log BCF for goldfish during a laboratory exposure for 120 hours was 4.61.

Food Chain Multipliers: No specific food chain multipliers were identified for 1,2,3,6,7,8-hexaCDD. Food chain multiplier information was only available for 2,3,7,8-TCDD. Biomagnification of 2,3,7,8-TCDD does not appear to be significant between fish and their prey. Limited data for the base of the Lake Ontario lake trout food chain indicated little or no biomagnification between zooplankton and forage fish. BMFs based on fish consuming invertebrate species are probably close to 1.0 because of the 2,3,7,8-TCDD biotansformation by forage fish. BMFs greater than 1.0 may exist between some zooplankton species and their prey due to the lack of 2,3,7,8-TCDD biotransformation in invertebrates[8].

Toxicity/Bioaccumulation Assessment Profile

The polychlorinated dibenzo-*p*-dioxins (PCDDs) and polychlorinated dibenzofurans (PCDFs) each consist of 75 isomers that differ in the number and position of attached chlorine atoms. The PCDDs and PCDFs are polyhalogenated aromatic compounds and exhibit several properties common to this group of compounds. These compounds tend to be highly lipophilic and the degree of lipophilicity is increased with increasing ring chlorination [6]. In general, the PCDDs and PCDFs exhibit relative inertness to acids, bases, oxidation, reduction, and heat, increasing in environmental persistence and chemical

stability with increasing chlorination [9,6]. Because of their lipophilic nature, the PCDDs and PCDFs have been detected in fish, wildlife, and human adipose tissue, milk, and serum [6].

Each isomer has its own unique chemical and toxicological properties. The most toxic of the PCDD and PCDF isomers is 2,3,7,8 TCDD, one of the 22 possible congeners of tetrachlorodibenzo-*p*-dioxin [9]. Toxicity equivalency factors (TEFs) have been developed by EPA relating the toxicities of other PCDD and PCDF isomers to that of 2,3,7,8-TCDD [10]. The biochemical mechanisms leading to the toxic response resulting from exposure to PCDDs and PCDFs are not known in detail, but experimental data suggest that an important role in the development of systemic toxicity resulting from exposure to these chemicals is played by an intracellular protein, the Ah receptor. This receptor binds halogenated polycyclic aromatic molecules, including PCDDs and PCDFs. In several mouse strains, the expression of toxicity of 2,3,7,8-TCDD-related compounds, including cleft palate formation, liver damage, effects on body weight gain, thymic involution, and chloracnegenic response, has been correlated with their binding affinity for the Ah receptor, and with their ability to induce several enzyme systems [10].

Toxicity Equivalency Factors (TEF) for PCDD and PCDF Isomers [10]

Isomer	TEF
Total TetraCDD	1
2,3,7,8-TCDD	1
Other TCDDs	0.01
Total PentaCDDs	0.5
2,3,7,8-PentaCDDs	0.5
Other PentaCDDs	0.005
Total HexaCDDs	0.04
2,3,7,8-HexaCDDs	0.04
Other HexaCDDs	0.0004
Total HeptaCDDs	0.001
2,3,7,8-HeptaCDDs	0.001
Other HeptaCDDs	0.00001
Total TetraCDFs	0.1
2,3,7,8-TetraCDF	0.1
Other TetraCDFs	0.001
Total PentaCDFs	0.1
2,3,7,8-PentaCDFs	0.1
Other PentaCDFs	0.001
Total HexaCDFs	0.01
2,3,7,8-HexaCDFs	0.01
Other HexaCDFs	0.0001
Total HeptaCDFs	0.001
2,3,7,8-HeptaCDFs	0.001
Other HeptaCDFs	0.00001

In natural systems, PCDDs and PCDFs are typically associated with sediments, biota, and the organic carbon fraction of ambient waters [7]. Congener-specific analyses have shown that the 2,3,7,8-substituted PCDDs and PCDFs were the major compounds present in most sample extracts [6]. Results from limited epidemiology studies are consistent with laboratory-derived threshold levels to 2,3,7,8-TCDD impairment of reproduction in avian wildlife. Population declines in herring gulls (*Larus argentatus*) on Lake Ontario during the early 1970s coincided with egg concentrations of 2,3,7,8-TCDD and related chemicals expected to cause reproductive failure based on laboratory experiments (2,3,7,8-TCDD concentrations in excess of 1,000 pg/g). Improvements in herring gull reproduction through the mid-1980s were correlated with declining 2,3,7,8-TCDD concentrations in eggs and lake sediments [8]. Based on limited information on isomer-specific analysis from animals at different trophic levels, it appears that at higher trophic levels, i.e., fish-eating birds and fish, there is a selection of the planar congeners with the 2,3,7,8-substituted positions [11].

PCDDs and PCDFs are accumulated by aquatic organisms through exposure routes that are determined by the habitat and physiology of each species. With log K_{ow}>5, exposure through ingestion of contaminated food becomes an important route for uptake in comparison to respiration of water [8]. The relative contributions of water, sediment, and food to uptake of 2,3,7,8-TCDD by lake trout in Lake Ontario were examined by exposing yearling lake trout to Lake Ontario smelt and sediment from Lake Ontario along with water at a 2,3,7,8-TCDD concentration simulated to be at equilibrium with the sediments. Food ingestion was found to contribute approximately 75 percent of total 2,3,7,8-TCDD [8]. There have been a number of bioconcentration studies of 2,3,7,8-TCDD using model ecosystem and single species exposure. Although there is variation in the actual BCF values, in general, the algae and plants have the lowest BCF values, on the order of a few thousand. A log value of 4.38 has been reported for the snail *Physa* sp. Crustacea and insect larvae appear to have the next highest BCF values, followed by several species of fish, with the highest log BCF value of 4.79 [11].

Exposure of juvenile rainbow trout to 2,3,7,8-TCDD and -TCDF in water for 28 days resulted in adverse effects on survival, growth, and behavior at extremely low concentrations. A no-observed-effects concentration (NOEC) for 2,3,7,8-TCDD could not be determined because the exposure to the lowest dose of 0.038 ng/l resulted in significant mortality [12]. A number of biological effects have been reported in fish following exposure to 2,3,7,8-TCDD including enzyme induction, immunological effects, wasting syndrome, dermatological effects, hepatic effects, hematological effects, developmental effects, and cardiovascular effects [11].

Summary of Biological Effects Tissue Concentrations for 1,2,3,6,7,8-HexaCDD

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	**Sediment**	**Water**	**Tissue (Sample Type)**	**Effects**	**Log BCF**	**Log BAF**	**BSAF**	**Reference**	**Comments[3]**
Fishes									
Carassius auratus, Goldfish			0.79 ng/g[4] (whole body)		4.61			[14]	L; fish were exposed for 120 hr; exposure water contained fly ash extract; concentrations were measured in water, but data were not presented
Cyprinus carpio, Carp	180 pg/g[4]		16 pg/g[4]				0.035	[13]	F; Petenwell Reservoir, central Wisconsin; BSAF based on 8% tissue lipid content and 3.1% sediment organic carbon
Salmonids							0.0073	[19]	F

Summary of Biological Effects Tissue Concentrations for 1,2,3,6,7,8-HexaCDD

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	Sediment	Water	Tissue (Sample Type)	Effects	Log BCF	Log BAF	BSAF	Reference	Comments[3]
Wildlife									
Falco peregrinus, Peregrine falcon			7.2 ng/g (eggs) (n = 6)	11.4% eggshell thinning				[17]	F; Kola Peninsula, Russia
Haliaeetus leucocephalus, Bald eagle chicks			Powell River site: ~9,000 ng/kg lipid weight basis (yolk sac) Reference site: ~500 ng/kg lipid weight basis (yolk sac)	A hepatic cytochrome P4501A cross-reactive protein (CYP1A) was induced nearly 6-fold in chicks from Powell River site compared to the reference ($p < 0.05$). No significant concentration-related effects were found for morphological, physiological, or histological parameters.				[15]	F; southern coast of British Columbia; eggs were collected from nests and hatched in the lab; ~ indicates value was taken from a figure

Summary of Biological Effects Tissue Concentrations for 1,2,3,6,7,8-HexaCDD

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	Sediment	Water	Tissue (Sample Type)	Effects	Log BCF	Log BAF	BSAF	Reference	Comments[3]
Ardea herodias, Great blue heron chicks			Nicomekl site: 10±3.4 ng/kg (egg) (n=11)					[16]	L; eggs were collected from three British Columbia colonies with different levels of contamination and incubated in the laboratory
			Vancouver site: 89±45.4 ng/kg (egg) (n=12)	Depression of growth compared to Nicomekl site. Presence of edema.					
			Crofton site: 430±105.9 ng/kg (egg) (n=6)	Depression of growth compared to Nicomekl site. Presence of edema.					

Summary of Biological Effects Tissue Concentrations for 1,2,3,6,7,8-HexaCDD

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	**Sediment**	**Water**	**Tissue (Sample Type)**	**Effects**	**Log BCF**	**Log BAF**	**BSAF**	**Reference**	**Comments[3]**
Mustela vison, Mink	Diet: 1 pg/g[4]		54 pg/g[4] (liver)	LOAEL; reduced kit body weights followed by reduced survival		No BMF reported		[18]	L; BMF = biomagnification factor = v_l/v_d, v_l = lipid-normalized tissue concentration, v_d = lipid-normalized dietary concentration.
	3 pg/g[4]		77 pg/g[4] (liver)	Reduced kit body weights followed by reduced survival		log BMF = 1.42			
	6 pg/g[4]		130 pg/g[4] (liver)	Significant decrease in number of live kits whelped per female		log BMF = 1.53			

[1] Concentration units based on wet weight unless otherwise noted.
[2] BCF = bioconcentration factor, BAF = bioaccumulation factor, BSAF = biota-sediment accumulation factor.
[3] L = laboratory study, spiked sediment, single chemical; F = field study, multiple chemical exposure; other unusual study conditions or observations noted.
[4] Not clear from reference if concentration is based on wet or dry weight.

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18. Tillitt, D.E., R.W. Gale, J.C. Meadows, J.L. Zajicek, P.H. Peterman, S.N. Heaton, P.D. Jones, S.J. Bursian, T.J. Kubiak, J.P. Giesy, and R.J. Aulerich. 1996. Dietary exposure of mink to carp from Saginaw Bay. 3. Characterization of dietary exposure to planar halogenated hydrocarbons, dioxin equivalents, and biomagnification. *Environ. Sci. Technol*. 30:283-291.

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Chemical Category: POLYCHLORINATED DIBENZO-*p*-DIOXINS

Chemical Name (Common Synonyms): **CASRN:** 40321-76-4
1,2,3,7,8-PENTACHLORODIBENOZ-*p*-DIOXIN

Chemical Characteristics

Solubility in Water: No data [1,3] **Half-Life:** No data [2,3]

Log K_{ow}: No data [3,4] **Log K_{oc}:** —

Human Health

Oral RfD: No data [5] **Confidence:** —

Critical Effect: —

Oral Slope Factor: No data [5] **Carcinogenic Classification:** —

Wildlife

Partitioning Factors: Partitioning factors for 1,2,3,7,8-pentaCDD in wildlife were not found in the studies reviewed.

Food Chain Multipliers: Limited information was found reporting on specific biomagnification factors of PCDDs and PCDFs through terrestrial wildlife; no information was available for 1,2,3,7,8-pentaCDD, specifically. Due to the toxicity, high K_{ow} values, and highly persistent nature of the PCDDs and PCDFs, they possess a high potential to bioaccumulate and biomagnify through the food web. PCDDs and PCDFs have been identified in fish and wildlife throughout the global aquatic and marine environments [6]. Studies conducted in Lake Ontario indicated that biomagnification of 2,3,7,8-tetrachlorodibenzo-*p*-dioxin (2,3,7,8-TCDD) appears to be significant between fish and fish-eating birds but not between fish and their food. When calculated for older predaceous fish such as lake-trout-eating young smelt, the log biomagnification factor (BMF) can equal 0.48. The log BMF from alewife to herring gulls in Lake Ontario was 1.51 for 2,3,7,8-TCDD [7].

EPA has developed risk-based concentrations of 2,3,7,8-TCDD in different media that present low and high risk to fish, mammalian, and avian wildlife. These concentrations were developed based on toxic effects of 2,3,7,8-TCDD and its propensity to bioaccumulate in fish, mammals, and birds.

Environmental Concentrations Associated With 2,3,7,8-TCDD Risk to Aquatic Life and Associated Wildlife [8]

Organism	Fish Concentration (pg/g)	Sediment Concentration (pg/g dry wt.)	Water Concentration (pg/L)	
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Note: POC - Particulate organic carbon
Fish lipid of 8% and sediment organic carbon of 3% assumed where needed.
For risk to fish, BSAF of 0.3 used; for risk to wildlife, BSAF of 0.1 used.
Low risk concentrations are derived from no-effects thresholds for reproductive effects (mortality in embryos and young) in sensitive species.
High risk concentrations are derived from TCDD doses expected to cause 50 to 100% mortality in embryos and young of sensitive species.

Aquatic Organisms

Partitioning Factors: Partitioning factors for 1,2,3,7,8-pentaCDF in aquatic organisms were not found in the studies reviewed.
Food Chain Multipliers: No specific food chain multipliers were identified for 1,2,3,7,8-pentaCDD. Food chain multiplier information was only available for 2,3,7,8-TCDD. Biomagnification of 2,3,7,8-TCDD does not appear to be significant between fish and their prey. Limited data for the base of the Lake Ontario lake trout food chain indicated little or no biomagnification between zooplankton and forage fish. BMFs based on fish consuming invertebrate species are probably close to 1.0 because of the 2,3,7,8-TCDD biotransformation by forage fish. BMFs greater than 1.0 might exist between some zooplankton species and their prey due to the lack of 2,3,7,8-TCDD biotransformation in invertebrates[8].

Toxicity/Bioaccumulation Assessment Profile

The polychlorinated dibenzo-*p*-dioxins (PCDDs) and polychlorinated dibenzofurans (PCDFs) each consist of 75 isomers that differ in the number and position of attached chlorine atoms. The PCDDs and PCDFs are polyhalogenated aromatic compounds and exhibit several properties common to this group of compounds. These compounds tend to be highly lipophilic and the degree of lipophilicity is increased with increasing ring chlorination [6]. In general, the PCDDs and PCDFs exhibit relative inertness to acids, bases, oxidation, reduction, and heat, increasing in environmental persistence and chemical stability with increasing chlorination [6,9]. Because of their lipophilic nature, the PCDDs and PCDFs have been detected in fish, wildlife, and human adipose tissue, milk, and serum [6].

Each isomer has its own unique chemical and toxicological properties. The most toxic of the PCDD and PCDF isomers is 2,3,7,8-TCDD, one of the 22 possible congeners of tetrachlorodibenzo-*p*-dioxin [9]. Toxicity equivalency factors (TEFs) have been developed by the U.S. EPA relating the toxicities of other PCDD and PCDF isomers to that of 2,3,7,8-TCDD [10]. The biochemical mechanisms leading to the toxic response resulting from exposure to PCDDs and PCDFs are not known in detail, but experimental data suggest that an important role in the development of systemic toxicity resulting from exposure to these chemicals is played by an intracellular protein, the Ah receptor. This receptor binds halogenated polycyclic aromatic molecules, including PCDDs and PCDFs. In several mouse strains, the expression of toxicity of 2,3,7,8-TCDD-related compounds, including cleft palate formation, liver damage, effects on body weight gain, thymic involution, and chloracnegenic response, has been correlated with their binding affinity for the Ah receptor, and with their ability to induce several enzyme systems [10].

Toxicity Equivalency Factors (TEF) for PCDD and PCDF Isomers [10]

Isomer	TEF
Total TetraCDD	1
2,3,7,8-TCDD	1
Other TCDDs	0.01
Total PentaCDDs	0.5
2,3,7,8-PentaCDDs	0.5
Other PentaCDDs	0.005
Total HexaCDDs	0.04
2,3,7,8-HexaCDDs	0.04
Other HexaCDDs	0.0004
Total HeptaCDDs	0.001
2,3,7,8-HeptaCDDs	0.001
Other HeptaCDDs	0.00001
Total TetraCDFs	0.1
2,3,7,8-TetraCDF	0.1
Other TetraCDFs	0.001
Total PentaCDFs	0.1
2,3,7,8-PentaCDFs	0.1
Other PentaCDFs	0.001
Total HexaCDFs	0.01
2,3,7,8-HexaCDFs	0.01
Other HexaCDFs	0.0001
Total HeptaCDFs	0.001
2,3,7,8-HeptaCDFs	0.001
Other HeptaCDFs	0.00001

In natural systems, PCDDs and PCDFs are typically associated with sediments, biota, and the organic carbon fraction of ambient waters [8]. Congener-specific analyses have shown that the 2,3,7,8-substituted PCDDs and PCDFs were the major compounds present in most sample extracts [6]. Results from limited epidemiology studies are consistent with laboratory-derived threshold levels to 2,3,7,8-TCDD impairment of reproduction in avian wildlife. Population declines in herring gulls (*Larus argentatus*) on Lake Ontario during the early 1970s coincided with egg concentrations of 2,3,7,8-TCDD and related chemicals expected to cause reproductive failure based on laboratory experiments (2,3,7,8-TCDD concentrations in excess of 1,000 pg/g). Improvements in herring gull reproduction through the mid-1980s were correlated with declining 2,3,7,8-TCDD concentrations in eggs and lake sediments [8]. Based on limited information on isomer-specific analysis from animals at different trophic levels, it appears that at higher trophic levels, i.e., fish-eating birds and fish, there is a selection of the planar congeners with the 2,3,7,8-substituted positions [11].

PCDDs and PCDFs are accumulated by aquatic organisms through exposure routes that are determined by the habitat and physiology of each species. With log K_{ow}>5, exposure through ingestion of contaminated food becomes an important route for uptake in comparison to respiration of water [8]. The relative contributions of water, sediment, and food to uptake of 2,3,7,8-TCDD by lake trout in Lake Ontario were examined by exposing yearling lake trout to Lake Ontario smelt and sediment from Lake Ontario along with water at a 2,3,7,8-TCDD concentration simulated to be at equilibrium with the sediments. Food ingestion was found to contribute approximately 75 percent of total 2,3,7,8-TCDD [8]. There have been a number of bioconcentration studies of 2,3,7,8-TCDD using model ecosystem and single species exposure. Although there is variation in the actual log BCF values, in general, the algae and plants have the lowest BCF values, on the order of a few thousand. A log BCF value of 4.38 has been reported for the snail *Physa* sp. Crustacea and insect larvae appear to have the next highest BCF values, followed by several species of fish, with the highest log BCF value of 4.78 [11].

Exposure of juvenile rainbow trout to 2,3,7,8-TCDD and -TCDF in water for 28 days resulted in adverse effects on survival, growth, and behavior at extremely low concentrations. A no-observed-effects concentration (NOEC) for 2,3,7,8-TCDD could not be determined because the exposure to the lowest dose of 0.038 ng/l resulted in significant mortality [12]. A number of biological effects have been reported in fish following exposure to 2,3,7,8-TCDD including enzyme induction, immunological effects, wasting syndrome, dermatological effects, hepatic effects, hematological effects, developmental effects, and cardiovascular effects [11].

Summary of Biological Effects Tissue Concentrations for 1,2,3,7,8-PentaCDD

Species:	**Concentration, Units in[1]:**			**Toxicity:**	**Ability to Accumulate[2]:**			**Source:**	
Taxa	**Sediment**	**Water**	**Tissue (Sample Type)**	**Effects**	**Log BCF**	**Log BAF**	**BSAF**	**Reference**	**Comments[3]**
Fishes									
Carassius auratus, Goldfish			1.59/2.61 ng/g[4] (whole body)		16,982			[14]	L; fish were exposed for 120 hr; exposure water contained fly ash extract; concentrations were measured in water, but data were not presented
Cyprinus carpio, Carp	31 pg/g[4]		4.8 pg/g[4]		0.06			[13]	F; Petenwell Reservoir, central Wisconsin; BSAF based on 8% tissue lipid content and 3.1% sediment organic carbon
Salmonids							0.054	[18]	F
Wildlife									
Falco peregrinus, Peregrine falcon			11 ng/g (eggs) (n = 6)	11.4% eggshell thinning				[17]	F; Kola Peninsula, Russia

Summary of Biological Effects Tissue Concentrations for 1,2,3,7,8-PentaCDD

Species: Taxa	Concentration, Units in[1]: Sediment	Water	Tissue (Sample Type)	Toxicity: Effects	Ability to Accumulate[2]: Log BCF	Log BAF	BSAF	Source: Reference	Comments[3]
Haliaeetus leucocephalus, Bald eagle chicks			Powell River site: ~2,800 ng/kg lipid weight basis (yolk sac) Reference site: ~500 ng/kg lipid weight basis (yolk sac)	A hepatic cytochrome P4501A cross-reactive protein (CYP1A) was induced nearly six-fold in chicks from Powell River site compared to the reference ($p < 0.05$). No significant concentration-related effects were found for morphological, physiological, or histological parameters.				[15]	F; southern coast of British Columbia; eggs were collected from nests and hatched in the lab; ~ indicates value was taken from a figure.

Summary of Biological Effects Tissue Concentrations for 1,2,3,7,8-PentaCDD

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	**Sediment**	**Water**	**Tissue (Sample Type)**	**Effects**	**Log BCF**	**Log BAF**	**BSAF**	**Reference**	**Comments[3]**
Ardea herodias, Great blue heron chicks			Nicomekl site: 6±2.2 ng/kg (egg) (n = 11)					[16]	L; eggs were collected from three British Columbia colonies with different levels of contamination and incubated in the laboratory
			Vancouver site: 57±25.8 ng/kg (egg) (n = 12)	Depression of growth compared to Nicomekl site. Presence of edema.					
			Crofton site: 263±69.9 ng/kg (egg) (n = 6)	Depression of growth compared to Nicomekl site. Presence of edema.					

[1] Concentration units based on wet weight unless otherwise noted.
[2] BCF = bioconcentration factor, BAF = bioaccumulation factor, BSAF = biota-sediment accumulation factor.
[3] L = laboratory study, spiked sediment, single chemical; F = field study, multiple chemical exposure; other unusual study conditions or observations noted.
[4] Not clear from reference if concentration is based on wet or dry weight.

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Chemical Category: POLYCHLORINATED DIBENZO-*p*-DIOXINS

Chemical Name (Common Synonyms): **CASRN:** 1746-01-6
2,3,7,8-TETRACHLORODIBENZO-*p*-DIOXIN

Chemical Characteristics

Solubility in Water: 19.3 ng/L [1]

Half-Life: 1.1.15 - 1.62 years based on soil die-away test and lake water and sediment die-away test [2]

Log K_{ow}: 6.53 [3]

Log K_{oc}: 6.42 L/kg organic carbon

Human Health

Oral RfD: No data [4]

Confidence: —

Critical Effect: —

Oral Slope Factor: 1.5 x 10^{+5} per (mg/kg)/day [4]

Carcinogenic Classification: B2 [4]

Wildlife

Partitioning Factors: Partitioning factors for 2,3,7,8-TCDD in wildlife were not found in the literature.

Food Chain Multipliers: Limited information was found reporting on specific biomagnification factors of PCDDs and PCDFs through terrestrial wildlife. Due to the toxicity, high K_{ow} values, and highly persistent nature of the PCDDs and PCDFs, they possess a high potential to bioaccumulate and biomagnify through the food web. PCDDs and PCDFs have been identified in fish and wildlife throughout the global aquatic and marine environments [5]. Studies conducted in Lake Ontario indicated that biomagnification of 2,3,7,8-tetrachlorodibenzo-*p*-dioxin (2,3,7,8-TCDD) appears to be significant between fish and fish-eating birds but not between fish and their food. When calculated for older predaceous fish such as lake-trout-eating young smelt, the biomagnification factor (BMF) can equal 3. The BMF from alewife to herring gulls in Lake Ontario was 32 for 2,3,7,8-TCDD [6].

EPA has developed risk-based concentrations of 2,3,7,8-TCDD in different media that present low and high risk to fish, mammalian, and avian wildlife. These concentrations were developed based on toxic effects of 2,3,7,8-TCDD and its propensity to bioaccumulate in fish, mammals, and birds.

Environmental Concentrations Associated With 2,3,7,8-TCDD Risk to Aquatic Life and Associated Wildlife [7]

Organism	Fish Concentration (pg/g)	Sediment Concentration (pg/g dry wt.)	Water Concentration (pg/L)	
			POC=0.2	POC=1.0
Low Risk				
Fish	50	60	0.6	3.1
Mammalian Wildlife	0.7	2.5	0.008	0.04
Avian Wildlife	6	21	0.07	0.35
High Risk to Sensitive Species				
Fish	80	100	1.0	5
Mammalian Wildlife	7	25	0.08	0.4
Avian Wildlife	60	210	0.7	3.5

Note: POC - Particulate organic carbon
Fish lipid of 8% and sediment organic carbon of 3% assumed where needed.
For risk to fish, BSAF of 0.3 used; for risk to wildlife, BSAF of 0.1 used.
Low risk concentrations are derived from no-effects thresholds for reproductive effects (mortality in embryos and young) in sensitive species.
High risk concentrations are derived from TCDD doses expected to cause 50 to 100% mortality in embryos and young of sensitive species.

Aquatic Organisms

Partitioning Factors: Steady-state BSAFs for invertebrates exposed to 2,3,7,8-TCDD in the laboratory ranged from about 0.5 to 0.9 [8]. The BSAF for carp collected from a reservoir in central Wisconsin was 0.27 [9].

Food Chain Multipliers: Biomagnification of 2,3,7,8-TCDD does not appear to be significant between fish and their prey. Limited data for the base of the Lake Ontario lake trout food chain indicated little or no biomagnification between zooplankton and forage fish. BMFs based on fish consuming invertebrate species are probably close to 1.0 because of the 2,3,7,8-TCDD biotansformation by forage fish. BMFs greater than 1.0 may exist between some zooplankton species and their prey due to the lack of 2,3,7,8-TCDD biotransformation in invertebrates [7].

Toxicity/Bioaccumulation Assessment Profile

The polychlorinated dibenzo-*p*-dioxins (PCDDs) and polychlorinated dibenzofurans (PCDFs) each consist of 75 isomers that differ in the number and position of attached chlorine atoms. The PCDDs and PCDFs are polyhalogenated aromatic compounds and exhibit several properties common to this group of compounds. These compounds tend to be highly lipophilic and the degree of lipophilicity is increased with increasing ring chlorination [5]. In general, the PCDDs and PCDFs exhibit relative inertness to acids, bases, oxidation, reduction, and heat, increasing in environmental persistence and chemical stability with increasing chlorination [10,5]. Because of their lipophilic nature, the PCDDs and PCDFs have been detected in fish, wildlife, and human adipose tissue, milk, and serum [5].

Each isomer has its own unique chemical and toxicological properties. The most toxic of the PCDD and PCDF isomers is 2,3,7,8-tetrachlorodibenzo-*p*-dioxin (2,3,7,8-TCDD), one of the 22 possible congeners of tetrachlorodibenzo-*p*-dioxin [10]. Toxicity equivalency factors (TEFs) have been developed by the EPA relating the toxicities of other PCDD and PCDF isomers to that of 2,3,7,8-TCDD [11]. The biochemical mechanisms leading to the toxic response resulting from exposure to PCDDs and PCDFs are not known in detail, but experimental data suggest that an important role in the development of systemic toxicity resulting from exposure to these chemicals is played by an intracellular protein, the Ah receptor. This receptor binds halogenated polycyclic aromatic molecules, including PCDDs and PCDFs. In several mouse strains, the expression of toxicity of 2,3,7,8-TCDD-related compounds, including cleft palate formation, liver damage, effects on body weight gain, thymic involution, and chloracnegenic response, has been correlated with their binding affinity for the Ah receptor, and with their ability to induce several enzyme systems [11].

Toxicity Equivalency Factors (TEF) for PCDD and PCDF Isomers [11]

Isomer	TEF
Total TetraCDD	1
2,3,7,8-TCDD	1
Other TCDDs	0.01
Total PentaCDDs	0.5
2,3,7,8-PentaCDDs	0.5
Other PentaCDDs	0.005
Total HexaCDDs	0.04
2,3,7,8-HexaCDDs	0.04
Other HexaCDDs	0.0004
Total HeptaCDDs	0.001
2,3,7,8-HeptaCDDs	0.001
Other HeptaCDDs	0.00001
Total TetraCDFs	0.1
2,3,7,8-TetraCDF	0.1
Other TetraCDFs	0.001
Total PentaCDFs	0.1
2,3,7,8-PentaCDFs	0.1
Other PentaCDFs	0.001
Total HexaCDFs	0.01
2,3,7,8-HexaCDFs	0.01
Other HexaCDFs	0.0001
Total HeptaCDFs	0.001
2,3,7,8-HeptaCDFs	0.001
Other HeptaCDFs	0.00001

In natural systems, PCDDs and PCDFs are typically associated with sediments, biota, and the organic carbon fraction of ambient waters [7]. Congener-specific analyses have shown that the 2,3,7,8-

substituted PCDDs and PCDFs were the major compounds present in most sample extracts [5]. Results from limited epidemiology studies are consistent with laboratory-derived threshold levels to 2,3,7,8-TCDD impairment of reproduction in avian wildlife. Population declines in herring gulls (*Larus argentatus*) on Lake Ontario during the early 1970s coincided with egg concentrations of 2,3,7,8-TCDD and related chemicals expected to cause reproductive failure based on laboratory experiments (2,3,7,8-TCDD concentrations in excess of 1,000 pg/g). Improvements in herring gull reproduction through the mid-1980s were correlated with declining 2,3,7,8-TCDD concentrations in eggs and lake sediments [7]. Based on limited information on isomer-specific analysis from animals at different trophic levels, it appears that at higher trophic levels, i.e., fish-eating birds and fish, there is a selection of the planar congeners with the 2,3,7,8-substituted positions [12].

PCDDs and PCDFs are accumulated by aquatic organisms through exposure routes that are determined by the habitat and physiology of each species. With log $K_{ow}>5$, exposure through ingestion of contaminated food becomes an important route for uptake in comparison to respiration of water [7]. The relative contributions of water, sediment, and food to uptake of 2,3,7,8-TCDD by lake trout in Lake Ontario were examined by exposing yearling lake trout to Lake Ontario smelt and sediment from Lake Ontario along with water at a 2,3,7,8-TCDD concentration simulated to be at equilibrium with the sediments. Food ingestion was found to contribute approximately 75 percent of total 2,3,7,8-TCDD [7]. There have been a number of bioconcentration studies of 2,3,7,8-TCDD using model ecosystem and single species exposure. Although there is variation in the actual BCF values, in general, the algae and plants have the lowest BCF values, on the order of a few thousand. A log BCF value of 4.38 has been reported for the snail *Physa* sp. Crustacea and insect larvae appear to have the next highest BCF values, followed by several species of fish, with the highest log BCF value of 4.79 [12].

Exposure of juvenile rainbow trout to 2,3,7,8-TCDD and -TCDF in water for 28 days resulted in adverse effects on survival, growth, and behavior at extremely low concentrations. A no-observed-effects concentration (NOEC) for 2,3,7,8-TCDD could not be determined because the exposure to the lowest dose of 0.038 ng/l resulted in significant mortality [13]. A number of biological effects have been reported in fish following exposure to 2,3,7,8-TCDD including enzyme induction, immunological effects, wasting syndrome, dermatological effects, hepatic effects, hematological effects, developmental effects, and cardiovascular effects [12].

Summary of Biological Effects Tissue Concentrations for 2,3,7,8-TCDD

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	Sediment	Water	Tissue (Sample Type)	Effects	Log BCF	Log BAF	BSAF	Reference	Comments[3]
Plants									
Oedogonium cardiacum, Green algae			1.34 mg/kg (whole body)[4]	Growth, NOED				[35]	L; no effect on growth
Lemna minor, Duckweed			0.00614 mg/kg (whole body)[4]	Growth, NOED				[35]	L; no observed effect
Invertebrates									
Nereis virens, Sandworm	656±97 pg/g dw; (n = 6)		422±103 pg/g dw (whole body)				~0.5	[8,14]	L; 180-day exposure; sediment TOC was 57 mg/kg; ~ indicates approximate value, as numbers were estimated from bar graphs.
Physa sp., Snail			0.364 mg/kg (whole body)[4]	Mortality, NOED				[35]	L; no effect on survival

Summary of Biological Effects Tissue Concentrations for 2,3,7,8-TCDD

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	**Sediment**	**Water**	**Tissue (Sample Type)**	**Effects**	**Log BCF**	**Log BAF**	**BSAF**	**Reference**	**Comments[3]**
Macoma nasuta, Clam	656±97 pg/g dw; (n = 6)		142 ± 20 pg/g dw				~0.9	[8,14]	L; 120-day exposure; sediment TOC was 57 mg/kg; ~ indicates approximate value, as numbers were estimated from bar graphs.
Daphnia magna, Cladaceran			2.08 mg/kg (whole body)[4]	Mortality, NOED				[35]	L; no effect on survival
Palaemonetes pugio, Grass shrimp	656±97 pg/g dw; (n = 6)		138 ± 20 pg/g dw				~0.7	[8,14]	L; 28-day exposure; sediment TOC was 57 mg/kg ~ indicates approximate value, as numbers were estimated from bar graphs.
Pacifastacus leniusculus, Crayfish			0.003 mg/kg (whole body)[4]	Mortality, ED25				[31]	L; 25% mortality after 40 days
			0.03 mg/kg (whole body)[4]	Mortality, ED50				[31]	L; lethargy, 50% to 66% increase in mortality

Summary of Biological Effects Tissue Concentrations for 2,3,7,8-TCDD

Species:	**Concentration, Units in[1]:**			**Toxicity:**	**Ability to Accumulate[2]:**			**Source:**	
Taxa	**Sediment**	**Water**	**Tissue (Sample Type)**	**Effects**	**Log BCF**	**Log BAF**	**BSAF**	**Reference**	**Comments[3]**
			0.003 mg/kg (whole body)[4]	Behavior, LOED				[31]	L; lack of avoidance response
			0.003 mg/kg (whole body)[4]	Physiological, LOED				[31]	L; significant induction of cytochrome P450
			0.003 mg/kg (whole body)[4]	Physiological, LOED				[31]	L; significant induction of liver enzymes (cytochrome P450)
			0.1 mg/kg (whole body)[4]	Morphology, NOED				[31]	L; no significant pathology at highest dose
			0.0003 mg/kg (whole body)[4]	Mortality, NOED				[31]	L; no effect on mortality
			0.0003 mg/kg (whole body)[4]	Physiological, NOED				[31]	L; no significant induction of liver enzymes (cytochrome P450)
Callinectes sapidus, Blue crab	32.2 ppt[5] (TOC = 3.2%) 52.8 ppt[5] (TOC = 3.9%)		8.2 ppt[5] (hepatopancreas) (% lipid = 7.6)			-0.72	0.089	[15]	F; northeastern Florida; bleach-kraft paper mill receiving stream; BAF and BSAF calculated using mean of two sediment concentrations.

Summary of Biological Effects Tissue Concentrations for 2,3,7,8-TCDD

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	**Sediment**	**Water**	**Tissue (Sample Type)**	**Effects**	**Log BCF**	**Log BAF**	**BSAF**	**Reference**	**Comments[3]**
Chironomus tentans, Midge			0.47 mg/kg (whole body)	Growth, NOED				[44]	L; concentrations are lipid
Fishes									
Oncorhynchus mykiss (Salmo gairdneri), Rainbow trout		water exposure 0.038 ng/L	1.0 µg/kg[5]	28-day LOEC (survival, growth)	4.41			[13]	L
		water exposure 0.382 ng/L	10.95 ng/g[5] (whole body)		4.46				L; 6-hour exposure period
Oncorhynchus mykiss, Rainbow trout			0.00388 mg/kg (extractable lipid)[4]	Growth, LOED				[32]	L; reduced growth, exposed fish weighed 50 g vs. 130 g for controls
			0.00371 mg/kg (liver)[4]	Growth, LOED				[32]	L; reduced growth, exposed fish weighed 50 g vs. 130 g for controls
			0.00026 mg/kg (muscle)[4]	Growth, LOED				[32]	L; reduced growth, exposed fish weighed 50 g vs. 130 g for controls

Summary of Biological Effects Tissue Concentrations for 2,3,7,8-TCDD

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	Sediment	Water	Tissue (Sample Type)	Effects	Log BCF	Log BAF	BSAF	Reference	Comments[3]
			0.00065 mg/kg (whole body)[4]	Growth, LOED				[32]	L; reduced growth, exposed fish weighed 50 g vs. 130 g for controls
			0.00388 mg/kg (etractable lipid)[4]	Morphology, LOED				[32]	L; livers enlarged to nearly twice the size of control fish livers, fin rot
			0.00371 mg/kg (liver)[4]	Morphology, LOED				[32]	L; livers enlarged to nearly twice the size of control fish livers, fin rot
			0.00026 mg/kg (muscle)[4]	Morphology, LOED				[32]	L; livers enlarged to nearly twice the size of control fish livers, fin rot
			0.00065 mg/kg (whole body)[4]	Morphology, LOED				[32]	L; livers enlarged to nearly twice the size of control fish livers, fin rot
			0.00388 mg/kg (extractable lipid)[4]	Mortality, LOED				[32]	L; lethal to 7 of 90 fish over 139 days
			0.00371 mg/kg (liver)[4]	Mortality, LOED				[32]	L; lethal to 7 of 90 fish over 139 days
			0.00026 mg/kg (muscle)[4]	Mortality, LOED				[32]	L; lethal to 7 of 90 fish over 139 days

Summary of Biological Effects Tissue Concentrations for 2,3,7,8-TCDD

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	**Sediment**	**Water**	**Tissue (Sample Type)**	**Effects**	**Log BCF**	**Log BAF**	**BSAF**	**Reference**	**Comments[3]**
			0.00065 mg/kg (whole body)[4]	Mortality, LOED				[32]	L; lethal to 7 of 90 fish over 139 days
Oncorhynchus mykiss, Rainbow trout			0.01 mg/kg (whole body)[4]	Mortality, ED50				[36]	L; 80-day LD50 for mortality
			0.001 mg/kg (whole body)[4]	Growth, LOED				[36]	L; reduction in body weight
			0.025 mg/kg (whole body)[4]	Morphology, LOED				[36]	L; fin necrosis, hyperpigmentation
Oncorhynchus mykiss, Rainbow trout			0.000315 mg/kg (carcass)[4]	Growth, NOED				[38]	L; no effect on growth
			0.000102 mg/kg (gastrointestinal tract)[4]	Growth, NOED				[38]	L; no effect on growth
			0.000244 mg/kg (gill)[4]	Growth, NOED				[38]	L; no effect on growth
			0.00007 mg/kg (heart)[4]	Growth, NOED				[38]	L; no effect on growth
			0.000092 mg/kg (kidney)[4]	Growth, NOED				[38]	L; no effect on growth
			0.000072 mg/kg (liver)[4]	Growth, NOED				[38]	L; no effect on growth
			0.000355 mg/kg (pyloric caeca)[4]	Growth, NOED				[38]	L; no effect on growth

Summary of Biological Effects Tissue Concentrations for 2,3,7,8-TCDD

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	Sediment	Water	Tissue (Sample Type)	Effects	Log BCF	Log BAF	BSAF	Reference	Comments[3]
			0.000029 mg/kg (skeletal muscle)[4]	Growth, NOED				[38]	L; no effect on growth
			0.000201 mg/kg (skin)[4]	Growth, NOED				[38]	L; no effect on growth
			0.000085 mg/kg (spleen)[4]	Growth, NOED				[38]	L; no effect on growth
			0.00327 mg/kg (visceral fat)[4]	Growth, NOED				[38]	L; no effect on growth
			0.00025 mg/kg (whole body)[4]	Growth, NOED				[38]	L; no effect on growth
			0.000315 mg/kg (carcass)[4]	Morphology, NOED				[38]	L; no effect on fin necrosis or hemorrhage
			0.000102 mg/kg (gastrointestinal tract)[4]	Morphology, NOED				[38]	L; no effect on fin necrosis or hemorrhage
			0.000244 mg/kg (gill)[4]	Morphology, NOED				[38]	L; no effect on fin necrosis or hemorrhage
			0.00007 mg/kg (heart)[4]	Morphology, NOED				[38]	L; no effect on fin necrosis or hemorrhage
			0.000092 mg/kg (kidney)[4]	Morphology, NOED				[38]	L; no effect on fin necrosis or hemorrhage

Summary of Biological Effects Tissue Concentrations for 2,3,7,8-TCDD

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	**Sediment**	**Water**	**Tissue (Sample Type)**	**Effects**	**Log BCF**	**Log BAF**	**BSAF**	**Reference**	**Comments[3]**
			0.000072 mg/kg (liver)[4]	Morphology, NOED				[38]	L; no effect on fin necrosis or hemorrhage
			0.000355 mg/kg (pyloric caeca)[4]	Morphology, NOED				[38]	L; no effect on fin necrosis or hemorrhage
			0.000029 mg/kg (skeletal muscle)[4]	Morphology, NOED				[38]	L; no effect on fin necrosis or hemorrhage
			0.000201 mg/kg (skin)[4]	Morphology, NOED				[38]	L; no effect on fin necrosis or hemorrhage
			0.000085 mg/kg (spleen)[4]	Morphology, NOED				[38]	L; no effect on fin necrosis or hemorrhage
			0.00327 mg/kg (visceral fat)[4]	Morphology, NOED				[38]	L; no effect on fin necrosis or hemorrhage
			0.00025 mg/kg (whole body)[4]	Morphology, NOED				[38]	L; no effect on fin necrosis or hemorrhage
			0.000315 mg/kg (carcass)[4]	Mortality, NOED				[38]	L; no effect on mortality
			0.000102 mg/kg (gastrointestinal tract)[4]	Mortality, NOED				[38]	L; no effect on mortality

Summary of Biological Effects Tissue Concentrations for 2,3,7,8-TCDD

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	Sediment	Water	Tissue (Sample Type)	Effects	Log BCF	Log BAF	BSAF	Reference	Comments[3]
			0.000244 mg/kg (gill)[4]	Mortality, NOED				[38]	L; no effect on mortality
			0.00007 mg/kg (heart)[4]	Mortality, NOED				[38]	L; no effect on mortality
			0.000092 mg/kg (kidney)[4]	Mortality, NOED				[38]	L; no effect on mortality
			0.000072 mg/kg (liver)[4]	Mortality, NOED				[38]	L; no effect on mortality
			0.000355 mg/kg (pyloric caeca)[4]	Mortality, NOED				[38]	L; no effect on mortality
			0.000029 mg/kg (skeletal muscle)[4]	Mortality, NOED				[38]	L; no effect on mortality
			0.000201 mg/kg (skin)[4]	Mortality, NOED				[38]	L; no effect on mortality
			0.000085 mg/kg (spleen)[4]	Mortality, NOED				[38]	L; no effect on mortality
			0.00327 mg/kg (visceral fat)[4]	Mortality, NOED				[38]	L; no effect on mortality
			0.00025 mg/kg (whole body)[4]	Mortality, NOED				[38]	L; no effect on mortality
			0.00452 mg/kg (whole body)[4]	Survival, ED50				[13]	L; exposure concentration is the mean of measured TCDD concentration

Summary of Biological Effects Tissue Concentrations for 2,3,7,8-TCDD

Species:	**Concentration, Units in[1]:**			**Toxicity:**	**Ability to Accumulate[2]:**			**Source:**	
Taxa	**Sediment**	**Water**	**Tissue (Sample Type)**	**Effects**	**Log BCF**	**Log BAF**	**BSAF**	**Reference**	**Comments[3]**
Oncorhynchus mykiss, Rainbow trout			0.0000047 mg/kg (liver)[4]	Biochemical, LOED				[40]	L; significant increase in liver ethoxyresorufin O-deethylase (EROD)
			0.000038 mg/kg (liver)[4]	Biochemical, LOED				[40]	L; significant increase in liver ethoxyresorufin O-deethylase (EROD)
			0.000016 mg/kg (liver)[4]	Biochemical, LOED				[40]	L; significant increase in liver ethoxyresorufin O-deethylase (EROD)
Oncorhynchus mykiss, Rainbow trout			0.000439 mg/kg (whole body)[4]	Mortality, ED50				[42]	L; mortality from fertilization to swim-up; exposure dose calculated from text; residue measured in egg at 5-days post exposure; dosed for 48 hours and endpoint measured after approximately 24 days

Summary of Biological Effects Tissue Concentrations for 2,3,7,8-TCDD

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	Sediment	Water	Tissue (Sample Type)	Effects	Log BCF	Log BAF	BSAF	Reference	Comments[3]
			0.000421 mg/kg (whole body)[4]	Mortality, ED50				[42]	L; mortality from fertilization to swim-up; liposome used to carry dose; 93% of dose retained in egg and assumed to be in swim-up fry, flow rate = 8-12
			0.000279 mg/kg (whole body)[4]	Mortality, LOED				[42]	L; significant increase in mortality from hatch to swim-up at lowest exposure concentration tested; exposure dose calculated from text; residue measured in egg at 5-days post exposure; dosed for 48 hours and endpoint measured after approximately 24 days

Summary of Biological Effects Tissue Concentrations for 2,3,7,8-TCDD

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	**Sediment**	**Water**	**Tissue (Sample Type)**	**Effects**	**Log BCF**	**Log BAF**	**BSAF**	**Reference**	**Comments[3]**
			0.000437 mg/kg (whole body)[4]	Mortality, LOED				[42]	L; significant increase in mortality from hatch to swim-up; liposome used to carry dose; 93% of dose retained in egg and assumed to be in swim-up fry, flow rate = 8-12
			0.000291 mg/kg (whole body)[4]	Mortality, NOED				[42]	L; no significant increase in mortality from hatch to swim-up; liposome used to carry dose; 93% of dose retained in egg and assumed to be in swim-up fry, flow rate = 8 to 12
Oncorhynchus mykiss, Rainbow trout			0.00017 mg/kg (whole body)[4]	Mortality, ED50				[43]	L; estimated LD50s for 6 strains of rainbow trout, orig_con_wet ranged from 170 to 488; used low value; exposure concentration = 170 to 488

Summary of Biological Effects Tissue Concentrations for 2,3,7,8-TCDD

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	Sediment	Water	Tissue (Sample Type)	Effects	Log BCF	Log BAF	BSAF	Reference	Comments[3]
Salmo trutta, Brown trout			5.2 pg/g[5] (fillet)			4.25-4.45		[22]	F; locations throughout Maine; a range of mean BAFs is presented; the values are means for locations throughout Maine, and the range is for BAFs calculated using river concentrations from years prior to the sampling date to account for declines in paper mill discharges
Salvelinus fontinalis, Brook trout			0.0006 mg/kg (whole body)[4]	Physiological				[33]	L; induction of hepatic EROD

Summary of Biological Effects Tissue Concentrations for 2,3,7,8-TCDD

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	**Sediment**	**Water**	**Tissue (Sample Type)**	**Effects**	**Log BCF**	**Log BAF**	**BSAF**	**Reference**	**Comments[3]**
Salvelinus fontinalis, Brook trout			0.0012 mg/kg (whole body)[4]	Growth, NOED				[41]	L; no significant growth effect at highest target body burden; TCDD-spiked diet to produce desired body burden; abstract with minimal information
			0.0012 mg/kg (whole body)[4]	Mortality, NOED				[41]	L; no significant mortality at highest target body burden; TCDD-spiked diet to produce desired body burden; abstract with minimal information
			0.0012 mg/kg (whole body)[4]	Reproduction, LOED				[41]	L; significant delay in spawning; TCDD-spiked diet to produce desired body burden; abstract with minimal information

Summary of Biological Effects Tissue Concentrations for 2,3,7,8-TCDD

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	Sediment	Water	Tissue (Sample Type)	Effects	Log BCF	Log BAF	BSAF	Reference	Comments[3]
			0.0006 mg/kg (whole body)[4]	Reproduction, NOED				[41]	L; no delay in spawning; TCDD-spiked diet to produce desired body burden; abstract with minimal information
Salvelinus fontinalis, Brook trout			0.0002 mg/kg (whole body)[4]	Mortality, ED50				[43]	L; estimated LD50
Amia calva, Bowfin			11.2 ppt[5] (liver) (n = 1)			-0.59	0.180	[15]	F; northeastern Florida; bleached-kraft paper mill receiving stream; BAF and BSAF calculated using mean of two sediment concentrations. BAF = (pg TCDD/g tissue) ÷ (pg TCDD / g sediment); BSAF = (pg TCDD/g lipid) ÷ (pg TCDD / g TOC).
			18.6 ppt[5] (liver) (n = 1)			-0.36	0.255		
			46.1 ppt[5] (ovary) (n=1)			0.03	0.281		

Summary of Biological Effects Tissue Concentrations for 2,3,7,8-TCDD

Species:	**Concentration, Units in[1]:**			**Toxicity:**	**Ability to Accumulate[2]:**			**Source:**	
Taxa	**Sediment**	**Water**	**Tissue (Sample Type)**	**Effects**	**Log BCF**	**Log BAF**	**BSAF**	**Reference**	**Comments[3]**
Oncorhynchus kisutch, Coho salmon			0.000478 mg/kg (whole body)[4]	Growth, LOED				[39]	L; reduced growth
			0.000478 mg/kg (whole body)[4]	Mortality, LOED				[39]	L; reduced survival
			0.00217 mg/kg (whole body)[4]	Growth, NA				[39]	L; reduced growth
			0.00217 mg/kg (whole body)[4]	Mortality, NA				[39]	L; reduced survival
			0.000125 mg/kg (whole body)[4]	Behavior, NOED				[39]	L; no effect on food consumption or feeding
			0.000125 mg/kg (whole body)[4]	Growth, NOED				[39]	L; no effect on growth
Carp, (scientific name unknown)		water exposure 62 pg/L	2.2 µg/kg[5]	Death (71 days)				[16]	L
Salvelinus namaycush, Lake trout, (early life stage)		water exposure 20 ng/L	0.055 µg/kg[5] (egg)	48-hour LOEC (mortality)				[21]	L

Summary of Biological Effects Tissue Concentrations for 2,3,7,8-TCDD

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	Sediment	Water	Tissue (Sample Type)	Effects	Log BCF	Log BAF	BSAF	Reference	Comments[3]
		water exposure 10 ng/L	0.034 µg/kg[5] (egg)	48-hour NOEC (mortality)				[21]	L
		water exposure 62 ng/L	0.226 µg/kg[5] (egg)	48-hour LOEC (hatchability)				[21]	L
Salvelinus namaycush, Lake trout			0.000065 mg/kg (whole body)[4]	Mortality, ED50				[15]	L; lethal to 50% of sac fry
			0.000055 mg/kg (whole body)[4]	Mortality, LOED				[15]	L; lowest statistically significant increase in mortality of sac fry
			0.000226 mg/kg (whole body)[4]	Reproduction, L				[15]	L; reduced hatchability of eggs
			0.000035 mg/kg (whole body)[4]	Mortality, NOED				[15]	L; no effect on mortality of sac fry
Salvelinus namaycush, Lake trout			0.000044 mg/kg (whole body)[4]	Mortality, ED50				[34]	L; LD50 for sac fry mortality

Summary of Biological Effects Tissue Concentrations for 2,3,7,8-TCDD

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	Sediment	Water	Tissue (Sample Type)	Effects	Log BCF	Log BAF	BSAF	Reference	Comments[3]
Salvelinus namaycush, Lake trout			0.000065 mg/kg (whole body)[4]	Mortality, ED50				[42]	L; mortality from fertilization to swim-up; exposure dose calculated from text; residue measured in egg at 5-days post exposure; dosed for 48 hours and endpoint measured after approximately 24 days
			0.000055 mg/kg (whole body)[4]	Mortality, LOED				[42]	L; significant increase in mortality from hatch to swim-up; exposure dose calculated from text; residue measured in egg at 5-days post exposure; dosed for 48 hours and endpoint measured after approximately 24 days

Summary of Biological Effects Tissue Concentrations for 2,3,7,8-TCDD

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	Sediment	Water	Tissue (Sample Type)	Effects	Log BCF	Log BAF	BSAF	Reference	Comments[3]
			0.000058 mg/kg (whole body)[4]	Mortality, LOED				[42]	L; significant increase in mortality from hatch to swim-up; high control mortality; liposome used to carry dose; 93% of dose retained in egg and assumed to be in swim-up fry, flow rate = 8-12
			0.000034 mg/kg (whole body)[4]	Mortality, NOED				[42]	L; no significant increase in mortality from hatch to swim-up; exposure dose calculated from text; residue measured in egg at 5-days post exposure; dosed for 48 hours and endpoint measured after approximately 24 days

Summary of Biological Effects Tissue Concentrations for 2,3,7,8-TCDD

Species:	**Concentration, Units in[1]:**			**Toxicity:**	**Ability to Accumulate[2]:**			**Source:**	
Taxa	**Sediment**	**Water**	**Tissue (Sample Type)**	**Effects**	**Log BCF**	**Log BAF**	**BSAF**	**Reference**	**Comments[3]**
			0.000044 mg/kg (whole body)[4]	Mortality, NOED				[42]	L; no significant increase in mortality from hatch to swim-up; high control mortality; liposome used to carry dose; 93% of dose retained in egg and assumed to be in swim-up fry, flow rate = 8 to 12
Salvelinus namaycush, Lake trout			0.000065 mg/kg (whole body)[4]	Mortality, ED50				[43]	L; estimated LD50
Carassius auratus, Goldfish			0.58-0.63 ng/g[5] (whole body)		4.39			[18]	L; fish were exposed for 120 hr; exposure water contained fly ash extract; concentrations were measured in water, but data were not presented

Summary of Biological Effects Tissue Concentrations for 2,3,7,8-TCDD

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	Sediment	Water	Tissue (Sample Type)	Effects	Log BCF	Log BAF	BSAF	Reference	Comments[3]
Cyprinus carpio, Carp	170 pg/g[5]		120 pg/g[5]				0.27	[9]	F; Petenwell Reservoir, central Wisconsin; BSAF based on 8% tissue lipid content and 3.1% sediment organic carbon
Cyprinus carpio, Carp			0.0022 mg/kg (whole body)[4]	Behavior, LOED				[15]	L; difficulty swimming
			0.0022 mg/kg (whole body) [4]	Cellular, LOED				[15]	L; edema, body wall ulcers
			0.0022 mg/kg (whole body)[4]	Morphology, LOED				[15]	L; fin erosion, hemorrhage, morphologically resembling Blue Sac Disease
Cyprinus carpio, Carp			0.003 mg/kg (whole body)[4]	Mortality, ED50				[36]	L; 80-day LD50 for mortality
Cyprinus carpio, Carp			0.0022 mg/kg (whole body)[4]	Mortality, LOED				[15]	L; increased mortality

Summary of Biological Effects Tissue Concentrations for 2,3,7,8-TCDD

Species:	**Concentration, Units in[1]:**			**Toxicity:**	**Ability to Accumulate[2]:**			**Source:**	
Taxa	**Sediment**	**Water**	**Tissue (Sample Type)**	**Effects**	**Log BCF**	**Log BAF**	**BSAF**	**Reference**	**Comments[3]**
Danio rerio, Zebrafish			2.16 ng/g (egg)	ED50 (pericardial edema)				[23]	L; newly fertilized eggs were exposed for 1 hr to water containing graded concentrations of TCDD
			2.43 ng/g (egg)	ED50 (yolk sac edema)					
			2.45 ng/g (egg)	LD50					
Bracydanio rerio, Zebrafish			8.3 µg/kg[5]	LOEC (reproduction)				[24]	L; food exposure
			8.3 µg/kg[5]	LOEC (oogenesis)				[24]	L; food exposure
Pimephales promelas, Fathead minnow			17-2,042 µg/kg[5]	LD100				[17]	L; food exposure

Summary of Biological Effects Tissue Concentrations for 2,3,7,8-TCDD

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	Sediment	Water	Tissue (Sample Type)	Effects	Log BCF	Log BAF	BSAF	Reference	Comments[3]
Catostomus commerson, White sucker			9.6 pg/g[5] (whole body)			4.89-5.03		[22]	F; locations throughout Maine; a range of mean BAFs is presented; the values are means for locations throughout Maine, and the range is for BAFs calculated using river concentrations from years prior to the sampling date to account for declines in paper mill discharges

Summary of Biological Effects Tissue Concentrations for 2,3,7,8-TCDD

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	Sediment	Water	Tissue (Sample Type)	Effects	Log BCF	Log BAF	BSAF	Reference	Comments[3]
Ictalurus nebulosus, Brown bullhead catfish	32.2 -52.8 ppt[5] (TOC = 3.2-3.9%)		1.8 ppt[5] (liver) (% lipid = 3.5)			-1.40	0.043	[15]	F; northeastern Florida; bleached-kraft paper mill receiving stream; BAF and BSAF calculated using mean of two sediment concentrations. BAF = (pg TCDD/g tissue) ÷ (pg TCDD/ g sediment); BSAF = (pg TCDD/g lipid) ÷ (pg TCDD / g TOC).
			2.6 ppt[5] (liver) (% lipid = 2.9)			-1.22	0.074		
			2.8 ppt[5] (liver) (% lipid = 3.2)			-1.15	0.073		
Ictalurus melas, Black bullhead			0.005 mg/kg (whole body)[4]	Mortality, ED50				[36]	L; 80 day LD50 for mortality
			0.025 mg/kg (whole body)[4]	Morphology, LOED				[36]	L; fin necrosis, hyperpigmentation

Summary of Biological Effects Tissue Concentrations for 2,3,7,8-TCDD

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	Sediment	Water	Tissue (Sample Type)	Effects	Log BCF	Log BAF	BSAF	Reference	Comments[3]
Ictalurus punctatus, Channel catfish			0.0044 mg/kg (whole body)[4]	Mortality, ED10				[45]	L; radiolabelled compounds in sediment, compound leached into water for exposure; all fish died between days 14 and 15; body residues from dead fish
Gambusia affinis, Mosquito fish			0.0072 mg/kg (whole body)[4]	Mortality, ED10				[45]	L; radiolabelled compounds in sediment, compound leached into water for exposure; all fish died between days 14 and 15; body residues from dead fish
Oryzias latipes, Japanese medaka		Water exposure 2.2 ng/L	0.24 µg/kg[5] (embryo)	Lesions in embryos				[19]	L

Summary of Biological Effects Tissue Concentrations for 2,3,7,8-TCDD

Species: Taxa	Concentration, Units in[1]: Sediment	Water	Tissue (Sample Type)	Toxicity: Effects	Ability to Accumulate[2]: Log BCF	Log BAF	BSAF	Source: Reference	Comments[3]
Oryzias latipes, Japanese medaka (juveniles)		water exposure 101 ± 26 pg/L (n = 23)	2,408 ±241 pg/g	Obvious signs of TCDD toxicity such as generalized edema, fin erosion, and discoloration in many of the exposed fish	4.38 non-steady state 5.71 predicted steady state			[20]	L; 12-day exposure period; lipid content 7.5%
Oryzias latipes, Japanese medaka			0.24 mg/kg (whole body)[4]	Lesions, ED50				[19]	L; ten replicates per treatment
			0.3 mg/kg (whole body)[4]	Lesions, LOED				[19]	L; 50% of embryos with lesions but no statistical significance analyzed; ten replicates per treatment
			0.1 mg/kg (whole body)[4]	Lesions, NOED				[19]	L; no significant incidence of lesions at lowest doseage tested; 10 replicates per treatment, resd_conc_wet value > 0.1

Summary of Biological Effects Tissue Concentrations for 2,3,7,8-TCDD

Species:	**Concentration, Units in[1]:**			**Toxicity:**	**Ability to Accumulate[2]:**			**Source:**	
Taxa	**Sediment**	**Water**	**Tissue (Sample Type)**	**Effects**	**Log BCF**	**Log BAF**	**BSAF**	**Reference**	**Comments[3]**
Morone americana, White perch			1.2 pg/g[5]			3.48-3.88		[22]	F; locations throughout Maine; a range of mean BAFs is presented; the values are means for locations throughout Maine, and the range is for BAFs calculated using river concentrations from years prior to the sampling date to account for declines in paper mill discharges
Lepomis macrochirus, Bluegill			0.016 mg/kg (whole body)[4]	Mortality, ED50				[36]	L; 80-day LD50 for mortality
			0.005 mg/kg (whole body)[4]	Growth, LOED				[36]	L; reduction in body weight
			0.025 mg/kg (whole body)[4]	Morphology, LOED				[36]	L; fin necrosis, hyperpigmentation

Summary of Biological Effects Tissue Concentrations for 2,3,7,8-TCDD

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	Sediment	Water	Tissue (Sample Type)	Effects	Log BCF	Log BAF	BSAF	Reference	Comments[3]
Microperus dolomieu, Smallmouth bass			3.4 pg/g[5] (fillet)			4.06-4.39		[22]	F; locations throughout Maine; a range of mean BAFs is presented; the values are means for locations throughout Maine, and the range is for BAFs calculated using river concentrations from years prior to the sampling date to account for declines in paper mill discharges

Summary of Biological Effects Tissue Concentrations for 2,3,7,8-TCDD

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	Sediment	Water	Tissue (Sample Type)	Effects	Log BCF	Log BAF	BSAF	Reference	Comments[3]
Micropterus samoides, Largemouth bass	32.2 ppt[5] (TOC=3.2%)		1.8 ppt[5] (liver) (% lipid =3.9)			-1.40	0.038	[15]	F; northeastern Florida; bleached kraft paper mill receiving stream; BAF and BSAF calculated using mean of two sediment concentrations. BAF = (pg TCDD / g tissue) ÷ (pg TCDD/ g sediment); BSAF = (pg TCDD/g lipid) ÷ (pg TCDD/ g TOC).
	52.8 ppt[5] (TOC=3.9%)		2.9 ppt[5] (liver) (% lipid =2.4)			-1.15	0.100		
			8.8 ppt[5] (ovary) (% lipid =7.6)			-0.68	0.096		
Micropterus salmoides, Largemouth bass			0.011 mg/kg (whole body)[4]	Mortality, ED50				[36]	L; 80-day LD50 For Mortality
			0.025 mg/kg (whole body)[4]	Morphology, LOED				[36]	L; Fin Necrosis, Hyperpigmentation
Perca flavescens, Yellow perch			0.003 mg/kg (whole body)[4]	Mortality, ED50				[36]	L; 80-day LD50 for mortality
			0.005 mg/kg (whole body)[4]	Growth, LOED				[36]	L; reduction in body weight

Summary of Biological Effects Tissue Concentrations for 2,3,7,8-TCDD

Species: Taxa	Concentration, Units in[1]: Sediment	Water	Tissue (Sample Type)	Toxicity: Effects	Ability to Accumulate[2]: Log BCF	Log BAF	BSAF	Source: Reference	Comments[3]
			0.025 mg/kg (whole body)[4]	Morphology, LOED				[36]	L; fin necrosis, hyperpigmentation
			0.000129 mg/kg (carcass)[4]	Growth, NOED				[37]	L; no effect on growth
			0.000148 mg/kg (gastrointestinal tract)[4]	Growth, NOED				[37]	L; no effect on growth
			0.000155 mg/kg (gill)[4]	Growth, NOED				[37]	L; no effect on growth
			0.000077 mg/kg (heart)[4]	Growth, NOED				[37]	L; no effect on growth
			0.000119 mg/kg (kidney)[4]	Growth, NOED				[37]	L; no effect on growth
			0.000466 mg/kg (liver)[4]	Growth, NOED				[37]	L; no effect on growth
			0.000143 mg/kg (pyloric caeca)[4]	Growth, NOED				[37]	L; no effect on growth
			0.000009 mg/kg (skeletal muscle)[4]	Growth, NOED				[37]	L; no effect on growth
			0.000041 mg/kg (skin)[4]	Growth, NOED				[37]	L; no effect on growth
			0.000166 mg/kg (spleen)[4]	Growth, NOED				[37]	L; no effect on growth
			0.00277 mg/kg (visceral fat)[4]	Growth, NOED				[37]	L; no effect on growth

Summary of Biological Effects Tissue Concentrations for 2,3,7,8-TCDD

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	Sediment	Water	Tissue (Sample Type)	Effects	Log BCF	Log BAF	BSAF	Reference	Comments[3]
			0.000143 mg/kg (whole body)[4]	Growth, NOED				[37]	L; no effect on growth
			0.000129 mg/kg (carcass)[4]	Morphology, NOED				[37]	L; no effect on fin necrosis or hemorrhage
			0.000148 mg/kg (gastrointestinal tract)[4]	Morphology, NOED				[37]	L; no effect on fin necrosis or hemorrhage
			0.000155 mg/kg (gill)[4]	Morphology, NOED				[37]	L; no effect on fin necrosis or hemorrhage
			0.000077 mg/kg (heart)[4]	Morphology, NOED				[37]	L; no effect on fin necrosis or hemorrhage
			0.000119 mg/kg (kidney)[4]	Morphology, NOED				[37]	L; no effect on fin necrosis or hemorrhage
			0.000466 mg/kg (liver)[4]	Morphology, NOED				[37]	L; no effect on fin necrosis or hemorrhage
			0.000143 mg/kg (pyloric caeca)[4]	Morphology, NOED				[37]	L; no effect on fin necrosis or hemorrhage
			0.000009 mg/kg (skeletal muscle)[4]	Morphology, NOED				[37]	L; no effect on fin necrosis or hemorrhage

Summary of Biological Effects Tissue Concentrations for 2,3,7,8-TCDD

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	Sediment	Water	Tissue (Sample Type)	Effects	Log BCF	Log BAF	BSAF	Reference	Comments[3]
			0.000041 mg/kg (skin)[4]	Morphology, NOED				[37]	L; no effect on fin necrosis or hemorrhage
			0.000166 mg/kg (spleen)[4]	Morphology, NOED				[37]	L; no effect on fin necrosis or hemorrhage
			0.00277 mg/kg (visceral fat)[4]	Morphology, NOED				[37]	L; no effect on fin necrosis or hemorrhage
			0.000143 mg/kg (whole body)[4]	Morphology, NOED				[37]	L; no effect on fin necrosis or hemorrhage
			0.000129 mg/kg (carcass)[4]	Mortality, NOED				[37]	L; no effect on mortality
			0.000148 mg/kg (gastrointestinal tract)[4]	Mortality, NOED				[37]	L; no effect on mortality
			0.000155 mg/kg (gill)[4]	Mortality, NOED				[37]	L; no effect on mortality
			0.000077 mg/kg (heart)[4]	Mortality, NOED				[37]	L; no effect on mortality
			0.000119 mg/kg (kidney)[4]	Mortality, NOED				[37]	L; no effect on mortality
			0.000466 mg/kg (liver)[4]	Mortality, NOED				[37]	L; no effect on mortality

Summary of Biological Effects Tissue Concentrations for 2,3,7,8-TCDD

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	Sediment	Water	Tissue (Sample Type)	Effects	Log BCF	Log BAF	BSAF	Reference	Comments[3]
			0.000143 mg/kg (pyoric ceca)[4]	Mortality, NOED				[37]	L; no effect on mortality
			0.000009 mg/kg (skeletal muscle)[4]	Mortality, NOED				[37]	L; no effect on mortality
			0.000041 mg/kg (skin)[4]	Mortality, NOED				[37]	L; no effect on mortality
			0.000166 mg/kg (spleen)[4]	Mortality, NOED				[37]	L; no effect on mortality
			0.00277 mg/kg (visceral fat)[4]	Mortality, NOED				[37]	L; no effect on mortality
			0.000143 mg/kg (whole body)[4]	Mortality, NOED				[37]	L., no effect on mortality
Salmonids							0.059	[46]	F

Summary of Biological Effects Tissue Concentrations for 2,3,7,8-TCDD

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	Sediment	Water	Tissue (Sample Type)	Effects	Log BCF	Log BAF	BSAF	Reference	Comments[3]
Wildlife									
Aix sponsa, Wood duck			pg/g (eggs): Site 1 geometric mean: 36 (1.6 to 482) Site 2 geometric mean: 14 (0.8-74) Site 3 geometric mean: 4.2 (<1 to 19) Site 4 geometric mean: 0.01 (<1 to 0.5)	% eggs hatched: 47% (9.7 SE) 62% (10.1 SE) 79% (3.8 SE) 93% (3.4 SE)				[29]	F; central Arkansas; egg TEFs and hatching success and duckling production were negatively correlated; clutch size was similar among wetland Sites 1-3 which were 9, 17, and 58 km downstream from point source of contamination. respectively, and Site 4 which was 111 km away on a separate drainage; duckling abnor-malities were also noted
Aix sponsa, Wood duck									Threshold range of reduced productivity was > 20-50 ppt TEF.

Summary of Biological Effects Tissue Concentrations for 2,3,7,8-TCDD

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	Sediment	Water	Tissue (Sample Type)	Effects	Log BCF	Log BAF	BSAF	Reference	Comments[3]
Falco peregrinus, Peregrine falcon			11 ng/g (eggs) (n= 6)	11.4% eggshell thinning				[26]	F; Kola Peninsula, Russia
Haliaeetus leucocephalus, Bald eagle chicks			Powell River site: 2,200 ng/kg lipid weight basis (yolk sac) Reference site: 300 ng/kg lipid weight basis (yolk sac)	A nearly 6-fold greater incidence of an hepatic cytochrome P4501A cross-reactive protein was induced in chicks from Powell River site as compared to the reference ($p < 0.05$). No significant concentration-related effects were found for morphological, physiological, or histological parameters.				[25]	F; southern coast of British Columbia; eggs were collected from nests and hatched in the lab; ~ indicates value was taken from a figure.

Summary of Biological Effects Tissue Concentrations for 2,3,7,8-TCDD

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	Sediment	Water	Tissue (Sample Type)	Effects	Log BCF	Log BAF	BSAF	Reference	Comments[3]
Sterna forsteri, Forster's tern			Lake Poygan site: 8.0 pg/g; (egg) (n = 6) Green Bay site: 37.3 pg/g; (egg) (n = 6)	Birds from Green Bay had increased incubation period, reduced hatchability, lower body weight, increased liver to body weight ratio, and occurrence of edema when compared to birds from Lake Poygan. There was a significantly higher incidence of congenital abnormalities in dead embryos and chicks from Green Bay.				[27]	F; Green Bay, Lake Michigan, and Lake Poygan, Wisconsin

Summary of Biological Effects Tissue Concentrations for 2,3,7,8-TCDD

Species: Taxa	Concentration, Units in[1]: Sediment	Water	Tissue (Sample Type)	Toxicity: Effects	Ability to Accumulate[2]: Log BCF	Log BAF	BSAF	Source: Reference	Comments[3]
Ardea herodias, Great blue heron chicks			Nicomekl site: 10±0.9 ng/kg; (egg) (n = 11)					[28]	L; eggs were collected from three British Columbia colonies with different levels of contamination and incubated in the laboratory
			Vancouver site: 135±49.6 ng/kg (egg) (n = 12)	Depression of growth compared to Nicomekl site. Presence of edema.					
			Crofton site: 2 11±33.7 ng/kg (egg) (n = 6)	Depression of growth compared to Nicomekl site. Presence of edema.					

Summary of Biological Effects Tissue Concentrations for 2,3,7,8-TCDD

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	**Sediment**	**Water**	**Tissue (Sample Type)**	**Effects**	**Log BCF**	**Log BAF**	**BSAF**	**Reference**	**Comments[3]**
Mustela vison, Mink	Diet: 2 pg/g[5]		21 pg/g[5] (liver)	LOAEL; reduced kit body weights followed by reduced survival		log BMF= 1.05		[30]	L; BMF = biomagnification factor = v_1/v_d, v_l = lipid-normalized concentration in tissue; v_d = lipid-normalized dietary concentration
	Diet: 3 pg/g[5]		34 pg/g[5] (liver)	Reduced kit body weights followed by reduced survival		log BMF = 1.06			
	Diet: 7 pg/g[5]		50 pg/g[5] (liver)	Significant decrease in number of live kits whelped per female		log BMF = 1.04			

[1] Concentration units based on wet weight unless otherwise noted.
[2] BCF = bioconcentration factor, BAF = bioaccumulation factor, BSAF = biota-sediment accumulation factor.
[3] L = laboratory study, spiked sediment, single chemical; F = field study, multiple chemical exposure; other unusual study conditions or observations noted.
[4] This entry was excerpted directly from the Environmental Residue-Effects Database (ERED, www.wes.army.mil/el/ered, U.S. Army Corps of Engineers and U.S. Environmental Protection Agency). The original publication was not reviewed and the reader is strongly urged to consult the publication to confirm the information presented here.
[5] Not clear from reference if concentration is based on wet or dry weight.

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Chemical Category: PESTICIDE (ORGANOCHLORINE)

Chemical Name (Common Synonyms): **CASRN:** 72-54-8
1,1′-(2,2-DICHLOROETHYLIDENE)BIS(4-CHLOROBENZENE),
p,p′-DICHLORODIPHENYLDICHLOROETHANE
4,4′-DICHLORODIPHENYLDICHLOROETHANE

Chemical Characteristics

Solubility in Water: 0.16 mg/L at 24°C [1]

Half-Life: 2.0-15.6 years based on biodegradation of DDD in aerobic soils under field conditions [2]

Log K_{ow}: 6.10 [3]

Log K_{oc}: 6.0 L/kg organic carbon

Human Health

Oral RfD: Not available [4]

Confidence: —

Critical Effect: Lung tumors in male and female mice, liver tumors in male mice, thyroid tumors in male rats

Oral Slope Factor: 2.4×10^{-1} per (mg/kg)/day [4]

Carcinogenic Classification: B2 [4]

Wildlife

Partitioning Factors: Partitioning factors for DDD in wildlife were not calculated in the studies reviewed. However, based on the data presented in one study reviewed, log BCFs for birds from the lower Detroit River ranged from 4.97 to 5.22. Concentrations of DDD in birds were 3.5 to 6.1 times higher than those in sediment.

Food Chain Multipliers: Biomagnification factors of 3.2 and 85 were determined for DDT and DDE, respectively, from alewife to herring gulls in Lake Ontario [5]. A study of arctic marine food chains measured biomagnification factors for DDE that ranged from 17.6 to 62.2 for fish to seal, 0.3 to 0.7 for seal to bear, and 10.7 for fish to bear [6].

Aquatic Organisms

Partitioning Factors: Partitioning factors for DDD in aquatic organisms were not calculated in the studies reviewed. However, the data from one study reviewed showed BCFs of 17,600 for oligochaetes and 565,000 for carp. Ratios of DDD in tissue to sediment were 0.65 for oligochaetes and 21 for carp. BSAFs for clams ranged from 0.120 to 2.745 [22,25]. BSAFs for fish ranged from 0.079 to 2.379 [21,23,24,25].

Food Chain Multipliers: Food chain multipliers (FCMs) for trophic level 3 aquatic organisms were 18.5 (all benthic food web), 1.6 (all pelagic food web), and 11.3 (benthic and pelagic food web). FCMs for trophic level 4 aquatic organisms were 37.4 (all benthic food web), 3.1 (all pelagic food web), and 17.8 (benthic and pelagic food web) [28].

Toxicity/Bioaccumulation Assessment Profile

DDT is very persistent in the environment due to its low vapor pressure, high fat solubility, and resistance to degradation and photooxidation. DDT is degraded to DDE under aerobic conditions and to DDD in anoxic systems [7]. These metabolites, DDD and DDE, are similar to DDT in both their stability and toxicity. Chronic effects of DDT and its metabolites on ecological receptors include changes in enzyme production, hormonal balance, and calcium metabolism, which may cause changes in behavior and reproduction. The high octanol-water partition coefficient of DDT indicates that it is easily accumulated in tissues of aquatic organisms. Laboratory studies have shown that these compounds are readily bioconcentrated in aquatic organisms, with reported log BCFs for DDT ranging from 3.08 to 7.65 and for DDE ranging from 4.80 to 5.26 [8].

Invertebrate species are generally more susceptible than fish species to effects associated with exposure to DDT in the water column [8]. In general, the low solubility of DDT and its metabolites in water suggests that water column exposures are likely to be lower than exposures from ingestion of food or sediment. Sediments contaminated with pesticides, including DDT, have been shown to affect benthic communities at low concentrations. Results of laboratory and field investigations suggest that chronic effects generally occur at total DDT concentrations in sediment exceeding 2 µg/kg [9]. Equilibrium partitioning methods predict that chronic effects occur at DDT concentrations in sediment of 0.6 to 1.7 µg/kg [10].

For fish, the primary route of uptake is via prey items, but both DDT and its metabolites can be accumulated through the skin or gills upon exposure to water. Short-term exposure to DDT concentrations of less than 1 µg/L have been reported to elicit toxic responses in both freshwater and marine fish [8]. DDT may also be transfered to embryos from contaminated adults. DDT concentrations of 1.1 to 2.4 mg/kg in fish embryos have been associated with fry mortality [11,12].

Eggshell thinning, embryo mortality, and decreased hatchling survival have been linked to chronic exposure to DDT and its metabolites in the diet of birds. Of the three compounds, evidence strongly indicates that DDE is responsible for most reproductive toxicity in avian species [13]. Measurements of residues in eggs of birds are a reliable indicator of adverse effects. There is a large amount of variability in sensitivity to DDT and its metabolites among bird species, with waterfowl and raptor species showing the greatest sensitivities. Studies have shown the brown pelican to be most susceptible to adverse effects, with eggshell thinning and depressed productivity occurring at 3.0 µg/g of DDE in the egg and total reproductive failure when residues exceed 3.7 µg/g [13].

Summary of Biological Effects Tissue Concentrations for *p,p′*-DDD

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	**Sediment**	**Water**	**Tissue (Sample Type)**	**Effects**	**Log BCF**	**Log BAF**	**BSAF**	**Reference**	**Comments[3]**
Invertebrates									
Tubifex sp., Oligochaetes	0.023 mg/kg n = 1	water = 0.85 ng/L n = 1	0.015 mg/kg n = 1					[14]	F; lower Detroit River
Macomona liliana, Mollusk	66.7 µg/kg OC		76.3 µg/kg lipid				1.144	[22]	F; %lipid = 2.95; %sed OC = 0.30
	1,096.0 µg/kg OC		765.2 µg/kg lipid				0.698	[22]	F; %lipid = 2.33; %sed OC = 0.73
	286.4 µg/kg OC		75.1 µg/kg lipid				0.262	[22]	F; %lipid = 2.57; %sed OC = 0.22
	20.0 µg/kg OC		54.9 µg/kg lipid				2.745	[22]	F; %lipid = 2.04; %sed OC = 0.25
	25.0 µg/kg OC		22.4 µg/kg lipid				0.894	[22]	F; %lipid = 3.13; %sed OC = 0.48
Austrovnus stutchburyi, Mollusk	66.7 µg/kg OC		42.4 µg/kg lipid				0.635	[22]	F; %lipid = 5.62; %sed OC = 0.30
	286.4 µg/kg OC		34.4 µg/kg lipid				0.120	[22]	F; %lipid = 4.85; %sed OC = 0.22
	20 µg/kg OC		27.7 µg/kg lipid				1.383	[22]	F; %lipid = 3.87; %sed OC = 0.25
	25 µg/kg OC		25.1 µg/kg lipid				1.002	[22]	F; %lipid = 4.27; %sed OC = 0.48

Summary of Biological Effects Tissue Concentrations for *p,p'*-DDD

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	**Sediment**	**Water**	**Tissue (Sample Type)**	**Effects**	**Log BCF**	**Log BAF**	**BSAF**	**Reference**	**Comments[3]**
Corbicula fluminea, Asian clam	58.8 µg/kg OC		82 µg/kg lipid				1.394	[25]	F; %lipid = 0.61; %sed OC = 1.19
	159.7 µg/kg OC		82 µg/kg lipid				0.513	[25]	F; %lipid = 0.61; %sed OC = 1.19
Fish									
Anguilla anguilla, Eel	126 µg/kg OC		10 µg/kg lipid				0.079	[26]	F; %lipid = 13; %sed OC = 32
Corogonus autumnalis, Omul (endemic whitefish)		particulate: 1.0 pg/L ± 1.0 n = 7 dissolved: 17 pg/L ±7.3 n = 7	0.0086-0.15 mg/kg lipid (whole body) n = 1						
Oncorhynchus, Salmo, Salvelinus sp., Salmonids	2,667 µg/kg OC		754.5 µg/kg lipid				0.283	[24]	F; %lipid = 11; %sed OC = 2.7
		0.000093 µg/L	83 µg/kg			5.93		[24]	F; %lipid = 11
Salvelinus fontinalis, Brook trout			4.79 mg/kg (whole body)[4]	Behavior, NOED				[18]	L; temperature selection after 24 h exposure to chemical

Summary of Biological Effects Tissue Concentrations for *p,p′*-DDD

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	**Sediment**	**Water**	**Tissue (Sample Type)**	**Effects**	**Log BCF**	**Log BAF**	**BSAF**	**Reference**	**Comments[3]**
Salvelinus namaycush, Lake trout			0.9 mg/kg (whole body)[4]	Mortality, LOED				[20]	L; survival of fry reduced
Leuciscus cephalus cabeda, Chub	478 µg/kg OC		378 µg/kg lipid				0.790	[21,27]	F; %lipid = 1.27; %sed OC = 2.76
Alburnus alburnus alborella, Bleak	478 µg/kg OC		769 µg/kg lipid				1.608	[21,27]	F; %lipid = 1.95; %sed OC = 2.76
Cyprinus carpio, Carp	0.023 mg/kg n = 1	water = 0.85 ng/L n = 1	0.48 ± 0.26 mg/kg n = 9					[14]	F; lower Detroit River; value is mean ± SD
Pimephales promelas, Fathead minnow			0.6 mg/kg (whole body)[4]	Reproduction, LOED				[17]	L; significantly different from control (p = 0.05)
Gambusia affinis, Mosquito fish			5.3 mg/kg (whole body)[4]	Mortality, NOED				[19]	L; no effect on survivorship after 3 days
Catastoma macrocheilus, Largescale sucker	530 µg/kg OC		1,261 µg/kg lipid				2.379	[23]	F; %lipid = 11.1; %sed OC = 1.0

Summary of Biological Effects Tissue Concentrations for *p,p'*-DDD

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	Sediment	Water	Tissue (Sample Type)	Effects	Log BCF	Log BAF	BSAF	Reference	Comments[3]
Cottus cognatus, Slimy sculpin	2667 µg/kg OC		587.5 µg/kg lipid				0.220	[24]	F; %lipid = 8; %sed OC = 2.7
		0.000093 µg/L	47 µg g/kg			5.70		[24]	F; %lipid = 8
Comephorus dybowskii, Pelagic sculpin		particulate: 1.0 pg/L ±1.0 n = 7 dissolved: 17 pg/L ±7.3 n = 7	0.12-0.16 mg/kg lipid (whole body) n = 1					[15]	F; Lake Baikal, Siberia
Wildlife									
Bucephala clangula, Goldeneye	0.023 mg/kg n = 1	water = 0.85 ng/L n = 1	0.080 ± 0.024 mg/kg n = 3					[14]	F; lower Detroit River; value is mean ± SD
Aythya affinis, Lesser scaup	0.023 mg/kg n = 1	water = 0.85 ng/L n = 1	0.093 ± 0.027 mg/kg n = 7					[14]	F; lower Detroit River; value is mean ± SD
Aythya marila, Greater scaup	0.023 mg/kg n = 1	water = 0.85 ng/L n = 1	0.14±0.045 mg/kg n = 3					[14]	F; lower Detroit River; value is mean ± SD

Summary of Biological Effects Tissue Concentrations for *p,p'*-DDD

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	Sediment	Water	Tissue (Sample Type)	Effects	Log BCF	Log BAF	BSAF	Reference	Comments[3]
Falco peregrinus, Peregrine falcon (eggs)			9 ng/g (eggs) n = 6	11.4% eggshell thinning				[16]	F; Kola Penninsula, Russia; n = number of clutches sampled
Phoca siberica, Baikal seal		particulate: 1.0 pg/L ± 1.0 n = 7 dissolved: 17 pg/L ± 7.3 n = 7	2.0-2.2 mg/kg[5] lipid (blubber) n = 1					[15]	F; Lake Baikal, Siberia

[1] Concentration units based on wet weight, unless otherwise noted.
[2] BCF = bioconcentration factor, BAF = bioaccumulation factor, BSAF = biota-sediment accumulation factor.
[3] L = laboratory study, spiked sediment, single chemical; F = field study, multiple chemical exposure; other unusual study conditions or observations noted.
[4] This entry was excerpted directly from the Environmental Residue-Effects Database (ERED, www.wes.army.mil/el/ered, U.S. Army Corps of Engineers and U.S. Environmental Protection Agency). The original publication was not reviewed, and the reader is strongly urged to consult the publication to confirm the information presented here.
[5] Not clear from reference if concentration is based on wet or dry weight.

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Chemical Category: PESTICIDE (ORGANOCHLORINE)

Chemical Name (Common Synonyms): **CASRN:** 72-55-9
1,1′-(DICHLOROETHYLIDENE)BIS(4-CHLOROBENZENE),
p,p′-DICHLORODIPHENYLDICHLOROETHYLENE
4,4′-DICHLORODIPHENYLDICHLOROETHYLENE

Chemical Characteristics

Solubility in Water: 0.065 mg/L at 24°C [1]

Half-Life: 2.0 - 15.6 years based on biodegradation of DDD in aerobic soils under field conditions [2]

Log K_{ow}: 6.76 [3]

Log K_{oc}: 6.65 L/kg organic carbon

Human Health

Oral RfD: No data [4]

Confidence: —

Critical Effect: Liver tumors in mice and hamsters, thyroid tumors in female rats

Oral Slope Factor: 3.4 x 10^{-1} per (mg/kg)/day [4]

Carcinogenic Classification: B2 [4]

Wildlife

Partitioning Factors: Based on the data presented in one study, log BCFs for birds collected from the lower Detroit River ranged from 5.92 to 6.36. Concentrations of DDE in birds were 40 to 108 times higher than in sediment. BSAFs were calculated for red-winged blackbird eggs and tree swallow eggs during a study in the Great Lakes area, with values ranging from 13 to 870 as reported in the attached summary table. BSAFs for tree swallow nestlings were 5 and 49.

Food Chain Multipliers: Biomagnification factors of 3.2 and 85 were determined for DDT and DDE, respectively, from alewife to herring gulls in Lake Ontario [5]. A study of arctic marine food chains measured biomagnification factors for DDE that ranged from 17.6 to 62.2 for fish to seal, 0.3 to 0.7 for seal to bear, and 10.7 for fish to bear [6].

Aquatic Organisms

Partitioning Factors: Partitioning factors for DDE in aquatic organisms were not calculated in the studies reviewed. However, the data showed ratios of DDT in tissue to sediment of 0.49 for oligochaetes and 32 for fish from the lower Detroit River. Ratios of DDT in lipid to sediment for three fish species from Rio de la Plata, Argentina ranged from 87 to 26,000. BSAFs for clams ranged from 1.2313 to

107.7 [15,41,36]. BSAFs for dover sole collected in southern California ranged from 1.7 to 3.4. BSAFs for other species ranged from 1.274 to 140.

Food Chain Multipliers: Food chain multipliers (FCMs) for trophic level 3 aquatic organisms were 23.7 (all benthic food web), 1.7 (all pelagic food web), and 14.4 (benthic and pelagic food web). FCMs for trophic level 4 aquatic organisms were 57.5 (all benthic food web), 3.7 (all pelagic food web), and 26.7 (benthic and pelagic food web) [46].

Toxicity/Bioaccumulation Assessment Profile

DDT is very persistent in the environment due to its low vapor pressure, high fat solubility, and resistance to degradation and photooxidation. DDT is degraded to DDE under aerobic conditions and to DDD in anoxic systems [7]. These metabolites, DDD and DDE, are similar to DDT in both their stability and toxicity. Chronic effects of DDT and its metabolites on ecological receptors include changes in enzyme production, hormonal balance, and calcium metabolism, which may cause changes in behavior and reproduction. The high octanol-water partition coefficient of DDT indicates that it is easily accumulated in tissues of aquatic organisms. Laboratory studies have shown that these compounds are readily bioconcentrated in aquatic organisms, with reported log BCFs for DDT ranging from 3.08 to 6.65 and for DDE ranging from 4.80 to 5.26 [8].

Invertebrate species are generally more susceptible than fish species to effects associated with exposure to DDT in the water column [8]. In general, the low solubility of DDT and its metabolites in water suggests that water column exposures are likely to be lower than exposures from ingestion of food or sediment. Sediments contaminated with pesticides, including DDT, have been shown to impact benthic communities at low concentrations. Results of laboratory and field investigations suggest that chronic effects generally occur at total DDT concentrations in sediment exceeding 2 μg/kg [9]. Equilibrium partitioning methods predict that chronic effects occur at DDT concentrations in sediment of 0.6 to 1.7 μg/kg [10].

For fish, the primary route of uptake is via prey items, but both DDT and its metabolites can be accumulated through the skin or gills upon exposure to water. Short-term exposure to DDT concentrations of less than 1 μg/L have been reported to elicit toxic responses in both freshwater and marine fish [8]. DDT may also be transferred to embryos from contaminated adults. DDT concentrations of 1.1 to 2.4 mg/kg in fish embryos have been associated with fry mortality [11,12].

Eggshell thinning, embryo mortality, and decreased hatchling survival have been linked to chronic exposure to DDT and its metabolites in the diet of birds. Of the three compounds, evidence strongly indicates that DDE is responsible for most reproductive toxicity in avian species [13]. Measurements of residues in eggs of birds are a reliable indicator of adverse effects. There is a large amount of variability in sensitivity to DDT and its metabolites among bird species, with waterfowl and raptor species showing the greatest sensitivities. Studies have shown the brown pelican to be most susceptible to adverse effects, with eggshell thinning and depressed productivity occurring at 3.0 μg/g of DDE in the egg and total reproductive failure when residues exceed 3.7 μg/g [13].

Summary of Biological Effects Tissue Concentrations for *p,p'*-DDE

Species: Taxa	Concentration, Units in[1]: Sediment	Water	Tissue (Sample Type)	Toxicity: Effects	Ability to Accumulate[2]: Log BCF	Log BAF	BSAF	Source: Reference	Comments[3]
Invertebrates									
Tubifex sp., Oligochaetes	0.012 mg/kg (n = 1)	Surface water 0.57 ng/L (n = 1)	0.0059 mg/kg (n = 1)					[14]	F; lower Detroit River; value is mean ± SD
Viviparus conectus, Gastropod mollusk	294 µg/kg OC		368 µg/kg lipid				1.2517	[36]	F; %lipid = 7.06; %sed OC = 1.02
Unio elongatulus, Bivalve mollusk	294 µg/kg OC		362 µg/kg lipid				1.2313	[36]	F; %lipid = 10.49; %sed OC = 1.02
Mollusks (unspecified)	99.67 µg/kg OC		229 µg/kg lipid				2.298	[37]	F; %lipid = 1.1; %sed OC = 2.8
Macomona liliana, Mollusk	36.67 µg/kg OC		522.20 µg/kg lipid				14.241	[38]	F; %lipid = 2.95; %sed OC = 0.30
	35.62 µg/kg OC		573.39 µg/kg lipid				16.097	[38]	F; %lipid = 2.33; %sed OC = 0.73
	36.36 µg/kg OC		278.21 µg/kg lipid				7.652	[38]	F; %lipid = 2.57; %sed OC = 0.22
	20 µg/kg OC		328.92 µg/kg lipid				16.446	[38]	F; %lipid = 2.04; %sed OC = 0.25

Summary of Biological Effects Tissue Concentrations for *p,p'*-DDE

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	Sediment	Water	Tissue (Sample Type)	Effects	Log BCF	Log BAF	BSAF	Reference	Comments[3]
	6.25 µg/kg OC		61.34 µg/kg lipid				9.814	[38]	F; %lipid = 3.13; %sed OC = 0.48
Austrovenus stutchburyi, Mollusk	36.67 µg/kg OC		141.64 µg/kg lipid				3.863	[38]	F; %lipid = 5.62; %sed OC = 0.30
	35.62 µg/kg OC		148.75 µg/kg lipid				4.176	[38]	F; %lipid = 5.21; %sed OC = 0.73
	36.36 µg/kg OC		57.94 µg/kg lipid				1.594	[38]	F; %lipid = 4.85; %sed OC = 0.22
	20 µg/kg OC		59.95 µg/kg lipid				2.998	[38]	F; %lipid = 3.87; %sed OC = 0.25
	6.25 µg/kg OC		10.54 µg/kg lipid				1.686	[38]	F; %lipid = 4.27; %sed OC = 0.48
Corbicula fluminea, Asian clam	13 µg/kg OC		1,400 µg/kg lipid				107.7	[15]	F; %lipid not reported; %sed OC = 2.3
Corbicula fluminea, Asian clam	(0-5 cm) 0.3 ng/g dw	Surface water 1.8 ng/L	1.4 µg/g lipid (whole tissue)					[15]	F; Rio de La Plata, Argentina; lipid content 2.4-3.8%
	0.6 ng/g dw		1.4 µg/g lipid (whole tissue)						
Corbicula fluminea, Asian clam	9,664 µg/kg OC		540,984 µg/kg lipid				55.979	[41]	F; %lipid = 0.61; %sed OC = 0.19
	168 µg/kg OC		4,098 µg/kg lipid				24.393	[41]	F; %lipid = 0.61; %sed OC = 0.19

Summary of Biological Effects Tissue Concentrations for *p,p′*-DDE

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	**Sediment**	**Water**	**Tissue (Sample Type)**	**Effects**	**Log BCF**	**Log BAF**	**BSAF**	**Reference**	**Comments[3]**
	210 µg/kg OC		2,131 µg/kg lipid				10.148	[41]	F; %lipid = 0.61; %sed OC = 0.19
Astacidae, Crayfish	99.67 µg/kg OC		177 µg/kg lipid				1.776	[37]	F; %lipid = 1.3; %sed OC = 2.8
Chironomus riparius, Midge			1.6 mg/kg (whole body)[4]	Behavior, NOED				[31]	L; no effect on swimming behavior
			0.27 mg/kg (whole body)[4]	Behavior, NOED				[31]	L; no effect on swimming behavior
			0.1 mg/kg (whole body)[4]	Behavior, NOED				[31]	L; no effect on swimming behavior
Chironomus riparius, Midge			7.35 mg/kg (whole body)[4]	Development, LOED				[34]	L; development time from egg to 4th instar decreased from 22-25 days to 19-21 days
			3.75 mg/kg (whole body)[4]	Development, NOED				[34]	L; no effect on developmental period of larvae
Fishes									
Anguilla anguilla, Eel	5 µg/kg OC		156 µg/kg lipid				31.200	[43]	F; %lipid = 7; %sed OC = 7

Summary of Biological Effects Tissue Concentrations for *p,p′*-DDE

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	Sediment	Water	Tissue (Sample Type)	Effects	Log BCF	Log BAF	BSAF	Reference	Comments[3]
	5 µg/kg OC		213 µg/kg lipid				42.600	[43]	F; %lipid = 7; %sed OC = 14
	32 µg/kg OC		2117 µg/kg lipid				66.156	[43]	F; %lipid = 6; %sed OC = 18
	76 µg/kg OC		849 µg/kg lipid				11.171	[43]	F; %lipid = 10; %sed OC = 12
	23 µg/kg OC		658 µg/kg lipid				28.609	[43]	F; %lipid = 10; %sed OC = 12
	72 µg/kg OC		2,176 µg/kg lipid				30.222	[43]	F; %lipid = 13; %sed OC = 32
Oncorhynchus mykiss, Rainbow trout			0.15 mg/kg (fat)[4]	Growth, ED40				[29]	L; 40% decrease in growth relative to control
			0.15 mg/kg (fat)[4]	Physiological, ED30				[29]	L; 30% decrease in hemoglobin content relative to control
			0.15 mg/kg (fat)[4]	Physiological, ED30				[29]	L; 30% increase in liver size relative to control
			0.08 mg/kg (fat)[4]	Physiological, ED35				[29]	L; 35% increase in kidney size relative to control

Summary of Biological Effects Tissue Concentrations for *p,p'*-DDE

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	Sediment	Water	Tissue (Sample Type)	Effects	Log BCF	Log BAF	BSAF	Reference	Comments[3]
Oncorhynchus, Salmo, *Salvelinus* spp., Salmonids	1,889 µg/kg OC		7,817 µg/kg lipid				4.139	[40]	F; %lipid = 11; %sed OC =2.7
		0.000076 µg/L	860 µg/kg			7.05		[40]	F; %lipid = 11
Oncorhynchus sp., Salmon	99.67 µg/kg OC		925 µg/kg lipid				9.281	[37]	F; %lipid = 13.1; %sed OC = 2.8
Prosopium williamsoni, Mountain whitefish	544.4 µg/kg OC		2,333 µg/kg lipid				4.285	[39]	F; %lipid = 12.0, %sed OC = 0.9
	3,500 µg/kg OC		4,460 µg/kg lipid (arithmetic mean of two samples)				1.274	[39]	F; %lipid = 12.25 %sed OC = 0.3
Coregonus autumnalis, Omul (endemic whitefish)		particulate: <14 pg/L n = 7 dissolved: 17±7.1 pg/L n = 7	0.31-0.50 mg/kg lipid n = 2						

Summary of Biological Effects Tissue Concentrations for *p,p′*-DDE

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	**Sediment**	**Water**	**Tissue (Sample Type)**	**Effects**	**Log BCF**	**Log BAF**	**BSAF**	**Reference**	**Comments[3]**
Salvelinus fontinalis, Brook trout			44.9 mg/kg (whole body)[4]	Behavior, LOED				[30]	L; temperature selection after 24 h exposure to chemical
Salvelinus namaycush, Lake trout			1.09 mg/kg (whole body)[4]	Mortality, LOED				[33]	L; survival of fry reduced
Alburnus alburnus alborella, Bleak fish	294 µg/kg OC		1,092 µg/kg lipid				3.7143	[36]	F; %lipid = 21.43; %sed OC = 1.02
Alburnus alburnus alborella, Bleak fish	358 µg/kg OC		2,113 µg/kg lipid				5.9022	[35, 45]	F; %lipid = 1.95; %sed OC = 2.76
Chondrostoma soetta	294 µg/kg OC		1,179 µg/kg lipid				4.0102	[36]	F; %lipid = 9.75; %sed OC = 1.02
Cyprinus carpio, Common carp	99.67 µg/kg OC		4,209 µg/kg lipid				42.229	[37]	F, %lipid = 13.9; %sed OC = 2.8
Cyprinus carpio, Common carp	174 µg/kg OC		1,905 µg/kg lipid				10.948	[42]	F, %lipid = 8.4; %sed OC = 2.13

Summary of Biological Effects Tissue Concentrations for *p,p'*-DDE

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	Sediment	Water	Tissue (Sample Type)	Effects	Log BCF	Log BAF	BSAF	Reference	Comments[3]
Cyprinus carpio, Carp	0.012 mg/kg (n = 1)	Surface water 0.57 ng/L (n = 1)	0.38 ± 0.15 mg/kg (n = 9)					[14]	F; lower Detroit River; value is mean ± SD
Scardinius erythrophalmus, Rudd	294 µg/kg OC		1,473 µg/kg lipid				6.546	[36]	F; %lipid = 11.66; %sed OC = 1.02
Leuciscus cephalus, Chub	294 µg/kg OC		1,473 µg/kg lipid				5.0102	[36]	F; %lipid = 9.98; %sed OC = 1.02
Leuciscus cephalus cabeda, Chub	358 µg/kg OC		1,953 µg/kg lipid				5.4553	[35, 45]	F; %lipid = 1.27; %sed OC = 2.76
Rutilus pigus	294 µg/kg OC		728 µg/kg lipid				2.4762	[36]	F; %lipid = 12.63; %sed OC = 1.02
Rutilus rubilio	294 µg/kg OC		1,167 µg/kg lipid				3.9694	[36]	F; %lipid = 11.05; %sed OC = 1.02
Catostomus commersoni, White sucker	208 µg/kg OC		1,519 µg/kg lipid				7.303	[42]	F; %lipid = 7.9; %sed OC = 1.44

Summary of Biological Effects Tissue Concentrations for *p,p′*-DDE

Species: Taxa	Concentration, Units in[1]: Sediment	Water	Tissue (Sample Type)	Toxicity: Effects	Ability to Accumulate[2]: Log BCF	Log BAF	BSAF	Source: Reference	Comments[3]
mixed *Catastoma* sp., Suckers	3,500 µg/kg OC		3,253 µg/kg lipid (arithmetic mean of two samples)				0.929	[39]	F; %lipid = 9.2; %sed OC = 0.3
Catastoma macrocheilus, Largescale sucker	3,010 µg/kg OC		7,477 µg/kg lipid				2.484	[39]	F; %lipid = 11.1; %sed OC = 1.0
Barbus barbus, Barbel	294 µg/kg OC		1,333 µg/kg lipid				4.5340	[36]	F; %lipid = 16.43; %sed OC = 1.02
Siluris glanis, Wels fish, juveniles	294 µg/kg OC		731 µg/kg lipid				2.4864	[36]	F; %lipid = 3.83; %sed OC = 1.02
Siluris glanis, Wels fish, adults	294 µg/kg OC		1,613 µg/kg lipid				5.4864	[36]	F; %lipid = 5.38; %sed OC = 1.02
Pimelodus albicans, Mandi	0.2 ng/g dw		0.6 µg/g lipid (n = 2) (muscle)					[15]	F; Rio de La Plata, Argentina; lipid content 4%
Pimelodus albicans, Mandi	20 µg/kg OC		600 µg/kg lipid				30.0	[15]	F; %lipid not reported; %sed OC = 1.0
Gambusia affinis, Mosquito fish			29.2 mg/kg (whole body)[4]	Mortality, NOED				[32]	L; no effect on survivorship after 3 days

Summary of Biological Effects Tissue Concentrations for *p,p'*-DDE

Species: Taxa	Concentration, Units in[1]: Sediment	Water	Tissue (Sample Type)	Toxicity: Effects	Ability to Accumulate[2]: Log BCF	Log BAF	BSAF	Source: Reference	Comments[3]
Ambloplites rupestris, Rock bass	99.67 µg/kg OC		365 µg/kg lipid				3.662	[37]	F; %lipid = 0.7; %sed OC = 2.8
Sunfish (unspecified)	99.67 µg/kg OC		254 µg/kg lipid				2.548	[37]	F; %lipid = 3.7; %sed OC = 2.8
Roccus chrysops, White bass	99.67 µg/kg OC		1,586 µg/kg lipid				15.913	[37]	F; %lipid = 1.8; %sed OC = 2.8
Micropterus salmoides, Smallmouth bass	99.67 µg/kg OC		1,352 µg/kg lipid				13.565	[37]	F; %lipid = 0.6; %sed OC = 2.8
Dorosoma cepedianum, Gizzard shad	99.67 µg/kg OC		382 µg/kg lipid				3.833	[37]	F; %lipid = 6.8; %sed OC = 2.8
Perca fluviatilis, Perch	294 µg/kg OC		3,390 µg/kg lipid				11.5306	[36]	F; %lipid = 5.84; %sed OC = 1.02
Stizostedion vitreum, Walleye	99.67 µg/kg OC		2,593 µg/kg lipid				26.016	[37]	F; %lipid = 1.2; %sed OC = 2.8

Summary of Biological Effects Tissue Concentrations for *p,p′*-DDE

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	**Sediment**	**Water**	**Tissue (Sample Type)**	**Effects**	**Log BCF**	**Log BAF**	**BSAF**	**Reference**	**Comments[3]**
Microstomus pacificus, Dover sole	27 µg/g dw (n = 5)		16.0 µg/g (n = 5) (muscle)			log MBAF -0.26	1.7	[16]	F; Southern California Bight; modified bioaccumulation factor (MBAF) = C_{org} ww/ C_{sed} dw; water content of tissue was not measured
			210 µg/g (n = 3) (liver)			0.79	2.0		
	0.09 µg/g dw (n = 10)		0.24 µg/g (n = 10) (muscle)			log MBAF 0.43	1.8		
			0.80 µg/g (n = 6) (liver)			1.79	3.4		
Oligosarcus jenynsi, Common name not available	5.7 ng/g dw		0.5 µg/g lipid (n = 7) (muscle)					[15]	F; Rio de La Plata, Argentina; lipid content 0.32%
Prochilodus platensis, Curimata	20 µg/kg OC		2,800 µg/kg lipid				140	[15]	F, %lipid not reported; %sed OC = 1.0
Prochilodus platensis, Curimata	0.2 ng/g dw		Three composite samples: 1.2 (n = 4), 5.2 (n = 4) and 2 (n = 5) µg/g lipid (muscle)					[15]	F; Rio de La Plata, Argentina; lipid content 1-12.7%

Summary of Biological Effects Tissue Concentrations for *p,p′*-DDE

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	**Sediment**	**Water**	**Tissue (Sample Type)**	**Effects**	**Log BCF**	**Log BAF**	**BSAF**	**Reference**	**Comments[3]**
Gar pike (unspecified)	99.67 µg/kg OC		11,986 µg/kg lipid				120.257	[37]	F; %lipid = 0.8; %sed OC = 2.8
Comephorus bybowskii, Pelagic sculpin,		particulate: <14 pg/L n = 7 dissolved: 17 pg/L ± 7.1 n = 7	0.74-0.76 mg/kg lipid n = 1					[17]	F; Lake Baikal, Siberia
Cottus cognatus, Slimy sculpin	1,889 µg/kg OC		2,375 µg/kg lipid				1.257	[40]	F; %lipid = 8; %sed OC = 2.7
		0.000076 µg/L	190 µg/kg			6.40		[40]	F; %lipid =8; %sed OC = 2.7
Wildlife									
Bucephala clangula, Goldeneye	0.012 mg/kg (n = 1) seston = 0.10 mg/kg	Surface water 0.57 ng/L (n = 1)	0.48 ± 0.18 mg/kg (whole body) (n = 3)					[14]	F; lower Detroit River; value is mean ± SD

Summary of Biological Effects Tissue Concentrations for *p,p′*-DDE

Species:	**Concentration, Units in[1]:**			**Toxicity:**	**Ability to Accumulate[2]:**			**Source:**	
Taxa	**Sediment**	**Water**	**Tissue (Sample Type)**	**Effects**	**Log BCF**	**Log BAF**	**BSAF**	**Reference**	**Comments[3]**
Aythya affinis, Lesser scaup	0.012 mg/kg (n = 1)	Surface water 0.57 ng/L (n = 1)	0.80 ± 0.33 mg/kg (whole body) (n = 7)					[14]	F; lower Detroit River; value is mean ± SD
Aythya marila, Greater scaup	0.012 mg/kg (n = 1)	Surface water 0.57 ng/L (n = 1)	1.3 ± 0.25 mg/kg (whole body) (n = 3)					[14]	F; lower Detroit River; value is mean ± SD
Falco peregrinus, Peregrine falcon			µg/g (egg):	Young produced per active nest:				[26]	F; Alaska; young produced not adjusted for sample egg collected
			≤15	1.8					
			15-30	2.0					
			>30	1.0					

Summary of Biological Effects Tissue Concentrations for *p,p'*-DDE

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	Sediment	Water	Tissue (Sample Type)	Effects	Log BCF	Log BAF	BSAF	Reference	Comments[3]
Aquila chrysaetos, Golden eagle			µg/g (egg):	Mean % eggshell thinning =				[24]	F; Great Britain; percentage of thinning based on thickness index [24]
			0.1	7%					
			0.1	1%					
			0.2	3%					
			0.3	4%					
			0.3	5%					
Haliaeetus leucocephalus, Bald eagle			10 µg/g (egg)	Mean percent eggshell thinning= 10%				[22]	F; Oregon and Washington
			µg/g (egg):	Young produced per active nest:				[23]	F
			<2.2	1.0					
			2.2-3.5	1.0					
			3.6-6.2	0.5					
			6.3-11.9	0.3					
			≥12	0.2					
Ardea herodias, Great blue heron				Mean percent eggshell thinning =				[18]	F; Washington
			4 µg/g (egg)	10%					
			5 µg/g (egg)	13%					

Summary of Biological Effects Tissue Concentrations for *p,p'*-DDE

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	Sediment	Water	Tissue (Sample Type)	Effects	Log BCF	Log BAF	BSAF	Reference	Comments[3]
Plegadis chihi, White-faced ibis				Mean percent eggshell thinning=				[20]	F; Nevada
			2 µg/g (egg)	12%					
			1 µg/g (egg)	8%					
				Young produced per				[21]	F; Nevada; young produced not adjusted for sample egg collected
			µg/g (egg):	active nest:					
			≤1	1.8					
			1-4	1.8					
			4-8	1.3					
			8-16	0.8					
			>16	0.6					
Egretta thula, Snowy egret				Mean percent eggshell thinning=				[20]	F; Nevada; young produced not adjusted for sample egg collected
			1 µg/g (egg)	3%					
			2 µg/g (egg)	12%					
				Young produced per					
			µg/g (egg):	active nest:					
			≤1	2.2					
			1-5	2.4					
			5-10	1.0					
			10-20	1.0					

Summary of Biological Effects Tissue Concentrations for *p,p'*-DDE

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	**Sediment**	**Water**	**Tissue (Sample Type)**	**Effects**	**Log BCF**	**Log BAF**	**BSAF**	**Reference**	**Comments[3]**
Sula bassanus, Northern gannet			µg/g (egg) 19	Mean % eggshell thinning = 17%				[19]	F; Quebec
Larus californicus, California gull			430 mg/kg (brain)[4]	Mortality, not available (NA)				[28]	L
			175 mg/kg (breast)[4]	Mortality, NA				[28]	L
			3,100 mg/kg (liver)[4]	Mortality, NA				[28]	L
			220 mg/kg (brain)[4]	NA, NA				[28]	L
			490 mg/kg (breast)[4]	NA, NA				[28]	L
			800 mg/kg (liver)[4]	NA				[28]	L
			750 mg/kg (liver)[4]	NA				[28]	L
Pelecanus occidentalis, Brown pelican			4.4 mg/kg (brain)[4]	Mortality, NA				[28]	L
			59.5 mg/kg (breast)[4]	Mortality, NA				[28]	L
			7.15 mg/kg (liver)[4]	Mortality, NA				[28]	L

Summary of Biological Effects Tissue Concentrations for *p,p'*-DDE

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	**Sediment**	**Water**	**Tissue (Sample Type)**	**Effects**	**Log BCF**	**Log BAF**	**BSAF**	**Reference**	**Comments[3]**
Agelaius phoeniceus, Red-winged blackbird (eggs)	40.5 ng/g TOC = 2.5%		3,088.1 ng/g				41.4	[25]	F; Great Lakes/St. Lawrence River basin; 12 wetlands sites; sediment concentration reported as wet weight concentration which may be a typographical error
	7.9 ng/g TOC = 21.0%		777.7 ng/g				372.7		
	373.1 ng/g TOC = 7.5%		648.7 ng/g				12.9		
	1,160.7 ng/g TOC = 12%		1,299.6 ng/g				13.2		
	10.4 ng/g TOC-18.5%		305.7 ng/g				113.3		
	65.4 ng/g TOC = 11.5%		826.2 ng/g				30.3		
	1.6 ng/g TOC = 10.5%		416.1 ng/g				582.4		
	0.8 ng/g TOC = 13.8%		145.1 ng/g				522		
	1.3 ng/g TOC = 11.1%		183.5 ng/g				326.4		
	3.0 ng/g TOC = 23.9%		117.6 ng/g				203.7		

Summary of Biological Effects Tissue Concentrations for *p,p'*-DDE

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	**Sediment**	**Water**	**Tissue (Sample Type)**	**Effects**	**Log BCF**	**Log BAF**	**BSAF**	**Reference**	**Comments[3]**
Tachycineta bicolor, Tree swallow Nestlings			(whole body minus feet, beak, wings, and feathers)					[25]	F; Great Lakes/St. Lawrence River basin; 12 wetlands sites; sediment concentration reported as wet weight concentration which may be a typographical error
	65.4 ng/g TOC = 11.5%		288.2 ng/g				548.9		
	0.8 ng/g TOC = 13.8%		22.4 ng/g						
Eggs	65.4 ng/g TOC = 11.5%		794.7 ng/g				16.2		
	0.8 ng/g TOC = 13.8%		458.2 ng/g				868.6		
			3.5 µg/g (egg) (n = 6)	11.4% eggshell thinning				[27]	F; Kola Penninsula, Russia; n = number of clutches sampled

Summary of Biological Effects Tissue Concentrations for *p,p′*-DDE

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	**Sediment**	**Water**	**Tissue (Sample Type)**	**Effects**	**Log BCF**	**Log BAF**	**BSAF**	**Reference**	**Comments[3]**
Phoca siberica, Baikal seal		particulate: <14 pg/L n = 7 dissolved: 17 pg/L ± 7.1 n = 7	43-44 mg/kg lipid n = 1					[17]	F; Lake Baikal, Siberia

[1] Concentration units based on wet weight unless otherwise noted.
[2] BCF = bioconcentration factor, BAF = bioaccumulation factor, BSAF = biota-sediment accumulation factor.
[3] L = laboratory study, spiked sediment, single chemical; F = field study, multiple chemical exposure; other unusual study conditions or observations noted.
[4] This entry was excerpted directly from The Environmental Residue-Effects Database (ERED, www.wes.army.mil/el/ered, U.S. Army Corps of Engineers and U.S. Environmental Protection Agency). The original publication was not reviewed, and the reader is strongly urged to consult the publication to confirm the information presented here.

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Chemical Category: PESTICIDE (ORGANOCHLORINE)

Chemical Name (Common Synonyms): **CASRN:** 50-29-3
1,1′-(2,2,2-TRICHLOROETHYLIDENE)BIS(4-CHLOROBENZENE),
p,p′-DICHLORODIPHENYLTRICHLOROETHANE,
4,4′-DICHLORODIPHENYLTRICHLOROETHANE

Chemical Characteristics

Solubility in Water: 0.0031 - 0.0034 mg/L at 25°C [1]

Half-Life: 2.0 - 15.6 years based on biodegradation of DDD in aerobic soils under field conditions [2]

Log K_{ow}: 6.83 [3]

Log K_{oc}: 6.71 L/kg organic carbon

Human Health

Oral RfD: 5 x 10^{-4} mg/kg/day [4]

Confidence: Medium, uncertainty factor = 100

Critical Effect: Liver lesions in rats, liver tumors in mice and rats

Oral Slope Factor: 3.4 x 10^{-1} per (mg/kg)/day [4]

Carcinogenic Classification: B2 [4]

Wildlife

Partitioning Factors: Partitioning factors for DDT in wildlife were not calculated in the studies reviewed. However, based on the data in one study, log BCFs for birds from the lower Detroit River ranged from 4.81 to 5.01. Concentrations of DDT in birds were 2.1 to 3.3 times higher than in sediment.

Food Chain Multipliers: Biomagnification factors of 3.2 and 85 were determined for DDT and DDE, respectively, from alewife to herring gulls in Lake Ontario [5]. A study of arctic marine food chains measured biomagnification factors for DDE that ranged from 17.6 to 62.2 for fish to seal, 0.3 to 0.7 for seal to bear, and 10.7 for fish to bear [6].

Aquatic Organisms

Partitioning Factors: Based on the results from one study reviewed, the log BCF for carp collected from the lower Detroit River was 4.77. Ratios of DDT in lipids to sediment were 450 in clams and 1,250 to 11,000 in fish from the Rio de la Plata, Argentina. BSAFs for clams ranged from 0.060 to 302.326 [14,33,36]. BSAFs for fish ranged from 0.120 to 88.07.

Food Chain Multipliers: Food chain multipliers (FCMs) for trophic level 3 aquatic organisms were 22.5 (all benthic food web), 1.7 (all pelagic food web), and 13.7 (benthic and pelagic food web). FCMs for trophic level 4 aquatic organisms were 52.5 (all benthic food web), 3.6 (all pelagic food web), and 24.6 (benthic and pelagic food web) [39].

Toxicity/Bioaccumulation Assessment Profile

DDT is very persistent in the environment due to its low vapor pressure, high fat solubility, and resistance to degradation and photooxidation. DDT is degraded to DDE under aerobic conditions and to DDD in anoxic systems [7]. These metabolites, DDD and DDE, are similar to DDT in both their stability and toxicity. Chronic effects of DDT and its metabolites on ecological receptors include changes in enzyme production, hormonal balance, and calcium metabolism, which may cause changes in behavior and reproduction. The high octanol-water partition coefficient of DDT indicates that it is easily accumulated in tissues of aquatic organisms. Laboratory studies have shown that these compounds are readily bioconcentrated in aquatic organisms, with reported log BCFs for DDT ranging from 3.08 to 6.65 and for DDE ranging from 4.80to 5.26 [8].

Invertebrate species are generally more susceptible than fish species to effects associated with exposure to DDT in the water column [8]. In general, the low solubility of DDT and its metabolites in water suggests that water column exposures are likely to be lower than exposures from ingestion of food or sediment. Sediments contaminated with pesticides, including DDT, have been shown to affect benthic communities at low concentrations. Results of laboratory and field investigations suggest that chronic effects generally occur at total DDT concentrations in sediment exceeding 2 µg/kg [9]. Equilibrium partitioning methods predict that chronic effects occur at DDT concentrations in sediment of 0.6 to 1.7 µg/kg [10].

For fish, the primary route of uptake is via prey items, but both DDT and its metabolites can be accumulated through the skin or gills upon exposure to water. Short-term exposure to DDT concentrations of less than 1 µg/L have been reported to elicit toxic responses in both freshwater and marine fish [8]. DDT may also be transfered to embryos from contaminated adults. DDT concentrations of 1.1 to 2.4 mg/kg in fish embryos have been associated with fry mortality [11,12].

Eggshell thinning, embryo mortality, and decreased hatchling survival have been linked to chronic exposure to DDT and its metabolites in the diet of birds. Of the three compounds, evidence strongly indicates that DDE is responsible for most reproductive toxicity in avian species [13]. Measurements of residues in eggs of birds are a reliable indicator of adverse effects. There is a large amount of variability in sensitivity to DDT and its metabolites among bird species, with waterfowl and raptor species showing the greatest sensitivities. Studies have shown the brown pelican to be most susceptible to adverse effects, with eggshell thinning and depressed productivity occurring at 3.0 µg/g of DDE in the egg and total reproductive failure when residues exceed 3.7 µg/g [13].

Summary of Biological Effects Tissue Concentrations for p,p′-DDT

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	**Sediment**	**Water**	**Tissue (Sample Type)**	**Effects**	**Log BCF**	**Log BAF**	**BSAF**	**Reference**	**Comments[3]**
Invertebrates									
Macomona liliana, Mollusk	63.33 µg/kg OC		13.22 µg/kg lipid				0.209	[33]	F; %lipid = 2.95; %sed OC = 0.30
	76.71 µg/kg OC		33.91 µg/kg lipid				0.442	[33]	F; %lipid = 2.33; %sed OC = 0.73
	127.27 µg/kg OC		24.12 µg/kg lipid				0.190	[33]	F; %lipid = 2.57; %sed OC = 0.22
	20.83 µg/kg OC		7.35 µg/kg lipid				0.353	[33]	F; %lipid = 3.13; %sed OC = 0.48
Austrovenus stutchburyi, Mollusk	63.33 µg/kg OC		8.01 µg/kg lipid				0.126	[33]	F; %lipid = 5.62; %sed OC = 0.30
	76.71 µg/kg OC		7.29 µg/kg lipid				0.095	[33]	F; %lipid = 5.21; %sed OC = 0.73
	127.71 µg/kg OC		7.63 µg/kg lipid				0.060	[33]	F; %lipid = 4.85; %sed OC = 0.22
Corbicula fluminea, Asian clam	4.3 µg/kg OC		1,300 µg/kg lipid				302.326	[14]	F; %lipid = not reported; %sed OC = 2.3
Corbicula fluminea, Asian clam	3277 µg/kg OC		108,197 µg/kg lipid				33.017	[36]	F; %lipid = 0.61; %sed OC = 1.19

Summary of Biological Effects Tissue Concentrations for p,p′-DDT

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	**Sediment**	**Water**	**Tissue (Sample Type)**	**Effects**	**Log BCF**	**Log BAF**	**BSAF**	**Reference**	**Comments[3]**
	67 µg/kg OC		508 µg/kg lipid				7.563	[36]	F; %lipid = 0.61; %sed OC = 1.19
	92 µg/kg OC		164 µg/kg lipid				1.774	[36]	F; %lipid = 0.61; %sed OC = 1.19
Corbicula fluminea, Asian clam	(0-5 cm) 2.9 ng/g dw		1.3 µg/g lipid (whole tissue)					[14]	F; Rio de La Plata, Argentina; lipid content 2.4-3.8%
Mercenaria mercenaria, Quahog clam			0.126 mg/kg (whole body)[4]	Behavior, NOED				[29]	L; No effect on feeding activity
Mya arenaria, Soft shell clam				NOED				[29]	L; no effect on feeding activity
Daphnia magna, Cladoceran			1.83 mg/kg (whole body)[4]	Mortality, NOED				[23]	L; no effect on survivorship in 3 days
Diporeia spp., Amphipod			19.7 mg/kg (whole body)[4]	Mortality, NOED				[22]	L; no increase in mortality in 96 hours

Summary of Biological Effects Tissue Concentrations for p,p′-DDT

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	Sediment	Water	Tissue (Sample Type)	Effects	Log BCF	Log BAF	BSAF	Reference	Comments[3]
Gammarus fasciatus, Amphipod			0.336 mg/kg (whole body)[4]	Mortality, NOED				[23]	L; no effect on survivorship in 3 days
Palaemonetes kadiakensis, Grass shrimp			0.1 mg/kg (whole body)[4]	Mortality, NOED				[23]	L; no effect on survivorship in 3 days
Orconectes nais, Crayfish			0.0466 mg/kg (whole body)[4]	Mortality, NOED				[23]	L; no effect on survivorship in 3 days
Ephemera danica, Mayfly			6 mg/kg (whole body)[4]	Growth, NOED				[20]	L
			6 mg/kg (whole body)[4]	Mortality, NOED					L
Hexagenia bilineata, Mayfly			0.336 mg/kg (whole body)[4]	Mortality, NOED				[23]	L; no effect on survivorship after 3 days
Siphlonurus sp., Mayfly			0.216 mg/kg (whole body)[4]	Mortality, NOED				[23]	L; no effect on survivorship after 3 days

Summary of Biological Effects Tissue Concentrations for p,p′-DDT

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	**Sediment**	**Water**	**Tissue (Sample Type)**	**Effects**	**Log BCF**	**Log BAF**	**BSAF**	**Reference**	**Comments[3]**
Libellula sp., Dragonfly			0.0144 mg/kg (whole body)[4]	Mortality, NOED				[23]	L; no effect on survivorship after 2 days
Ischnura verticalis, Damselfly			0.075 mg/kg (whole body)[4]	Mortality, NOED				[23]	L; no effect on survivorship after 2 days
Chironomus sp., Midge			0.44 mg/kg (whole body)[4]	Mortality, NOED				[23]	L; no effect on survivorship in 3 days
Chironomus riparius, Midge			0.83 mg/kg (whole body)[4]	Behavior, LOED				[24]	L; reduced swimming ability
			0.18 mg/kg (whole body)[4]	Behavior, NOED				[24]	L; no effect on swimming behavior
			0.08 mg/kg (whole body)[4]	Behavior, NOED				[24]	L; no effect on swimming behavior
Fishes									
Squalus acanthias, Spiny dogfish			0.1 mg/kg (whole body)[4]	Mortality, NOED				[32]	L; no effect on mortality in 24 hours

Summary of Biological Effects Tissue Concentrations for p,p′-DDT

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	Sediment	Water	Tissue (Sample Type)	Effects	Log BCF	Log BAF	BSAF	Reference	Comments[3]
Anguilla anguilla, Eel	23 µg/kg OC		158 µg/kg lipid				6.87	[37]	F; %lipid = 7; %sed OC = 7
	8 µg/kg OC		135 µg/kg lipid				16.88	[37]	F; %lipid = 7; %sed OC = 14
	14 µg/kg OC		1233 µg/kg lipid				88.07	[37]	F; %lipid = 6; %sed OC = 18
	25 µg/kg OC		221 µg/kg lipid				8.84	[37]	F; %lipid = 10; %sed OC = 12
	34 µg/kg OC		287 µg/kg lipid				8.44	[37]	F; %lipid = 10; %sed OC = 12
	144 µg/kg OC		1064 µg/kg lipid				7.39	[37]	F; %lipid = 13; %sed OC = 32
Oncorhynchus, Salmo, Salvelinus sp., Salmonids	667 µg/kg OC		727 µg/kg lipid				1.091	[35]	F; %lipid = 11; %sed OC = 2.7
		0.000019 µg/L	80 µg/kg lipid			6.62		[35]	F; %lipid = 11
Salmonids							1.67	[38]	F
Oncorhynchus kisutch, Coho salmon			95 mg/kg (whole body)[4]	Mortality, ED50				[27]	L; 50% mortality in 31 days

Summary of Biological Effects Tissue Concentrations for p,p′-DDT

Species:	**Concentration, Units in[1]:**			**Toxicity:**	**Ability to Accumulate[2]:**			**Source:**	
Taxa	**Sediment**	**Water**	**Tissue (Sample Type)**	**Effects**	**Log BCF**	**Log BAF**	**BSAF**	**Reference**	**Comments[3]**
Prosopium williamsoni, Mountain whitefish	244 µg/kg OC		417 µg/kg lipid				1.706	[34]	F; %lipid = 12.0; %sed OC = 0.9
	6,433 µg/kg OC		772 µg/kg lipid				0.120	[34]	F; %lipid = 12.25; %sed OC = 0.30
Corogonus autumnalis, Omul (endemic whitefish)		particulate: 5.1pg/L ± 2.3 n = 7 dissolved: 50 pg/L ± 23 n = 7	0.16-0.27 mg/kg[5] lipid (whole body) n = 2					[16]	F; Lake Baikal, Siberia
Salmo salar, Atlantic salmon			3 mg/kg (whole body)[4]	Morphology, NOED				[26]	L; no effect on metabolic rate or growth, resd_conc_wet value range 3.0-5.0
Salvelinus namaycush, Lake trout			3.9 mg/kg (whole body)[4]	Behavior, LOED				[21]	L; temperature selection after 24-hour exposure to chemical

Summary of Biological Effects Tissue Concentrations for p,p′-DDT

Species:	**Concentration, Units in[1]:**			**Toxicity:**	**Ability to Accumulate[2]:**			**Source:**	
Taxa	**Sediment**	**Water**	**Tissue (Sample Type)**	**Effects**	**Log BCF**	**Log BAF**	**BSAF**	**Reference**	**Comments[3]**
			27.8 mg/kg (whole body)[4]	Behavior, LOED				[21]	L; temperature selection after 24-hour exposure to chemical
Salvelinus namaycush, Lake trout			3.66 mg/kg (whole body)[4]	Mortality, LOED				[28]	L; survival of fry reduced
			2 mg/kg (whole body)[4]	Mortality, LOED				[28]	L; survival of fry reduced
Carassius auratus, Goldfish			5.1 mg/kg (whole body)[4]	Behavior, LOED				[31]	L; behavioral changes, loss of equilibrium, convulsions
Pimephales promelas, Fathead minnow			3.8 mg/kg (whole body)[4]	Reproduction, LOED				[19]	L; significantly different from control (p = 0.05)
			24 mg/kg (whole body)[4]	Reproduction, LOED				[19]	L; significantly different from control (p = 0.05)
Cyprinus carpio, Carp	0.012 mg/kg (n = 1)	Surface water 0.39 ng/L (n = 1)	0.023 ± 0.012 mg/kg (n = 9)					[15]	F; lower Detroit River; value is mean ± SD

Summary of Biological Effects Tissue Concentrations for p,p′-DDT

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	Sediment	Water	Tissue (Sample Type)	Effects	Log BCF	Log BAF	BSAF	Reference	Comments[3]
Mixed *Catastoma* sp., Suckers	6433 µg/kg OC		869 µg/kg lipid				0.135	[34]	F; %lipid = 9.2; %sed OC = 0.30
Catastoma macrocheilus, Largescale sucker	340 µg/kg OC		811 µg/kg lipid				2.385	[34]	F; %lipid = 11.1; %sed OC = 1.0
Pimelodus albicans, (Marine catfish)	0.4 ng/g dw		0.5 µg/g lipid (n = 7) (muscle)					[14]	F; Rio de La Plata, Argentina; lipid content 4%
Pimelodus albicans, Mandi	40.0 µg/kg OC		500 µg/kg lipid					[14]	F; %lipid = not reported; %sed OC = 1.0
Gambusia affinis, Mosquito fish			18.6 mg/kg (whole body)[4]	Mortality, NOED				[25]	L; no effect on survivorship after 3 days
Leuciscus idus, Golden ide			95 mg/kg (whole body)[4]	Mortality, NOED				[30]	L; no effect on survivorship in 3 days

Summary of Biological Effects Tissue Concentrations for p,p′-DDT

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	**Sediment**	**Water**	**Tissue (Sample Type)**	**Effects**	**Log BCF**	**Log BAF**	**BSAF**	**Reference**	**Comments[3]**
Lepomis macrochirus, Bluegill			4.2 mg/kg (whole body)[4]	Behavior, LOED				[31]	L; behavioral changes, loss of equilibrium, convulsions
Comephorus dybowskii, Pelagic sculpin		particulate: 5.1pg/L ± 2.3 n = 7 dissolved: 50 pg/L ± 23 n = 7	0.52-0.64 mg/kg lipid (whole body) n = 1					[16]	F; Lake Baikal, Siberia
Cottus cognatus, Slimy sculpin	667 µg/kg OC		362 µg/kg lipid				0.544	[35]	F; %lipid = 8; %sed OC = 2.7
		0.000019 µg/L	29 µg/kg lipid			6.18		[35]	F; %lipid = 8
Prochilodus platensis, common name not available	0.4 ng/g dw		Three composite samples (µg/g lipid): 2.4 (n = 4) (muscle) 9.3 (n = 4) (muscle) 4.3 (n = 5) (muscle)					[14]	F; Rio de La Plata, Argentina; lipid content 1-12.7%
Prochilodus platensis, Curimata	40.0 µg/kg OC		5,333.33 µg/kg lipid					[14]	F; %lipid = not reported; %sed OC = 1.0

Summary of Biological Effects Tissue Concentrations for p,p′-DDT

Species: Taxa	Concentration, Units in[1]: Sediment	Water	Tissue (Sample Type)	Toxicity: Effects	Ability to Accumulate[2]: Log BCF	Log BAF	BSAF	Source: Reference	Comments[3]
Wildlife									
Bucephala clangula, Goldeneye	0.012 mg/kg (n = 1)	water = 0.39 ng/L (n = 1)	0.040 mg/kg (whole body) (n = 3)					[15]	F; lower Detroit River; value is mean ± SD
Aythya affinis, Lesser scaup	0.012 mg/kg (n = 1)	surface water 0.39 ng/L (n = 1)	0.025 mg/kg (whole body) (n = 7)					[15]	F; lower Detroit River; value is mean ± SD
Aythya marila, Greater scaup	0.012 mg/kg (n = 1)	surface water 0.39 ng/L (n = 1)	0.040 ± 0.0094 mg/kg (whole body) (n = 3)					[15]	F; lower Detroit River; value is mean ± SD
Falco peregrinus, Peregrine falcon (eggs)			22 ng/g (eggs) (n = 6)	11.4% eggshell thinning				[17]	F; Kola Penninsula, Russia; n = number of clutches sampled
Larus californicus, California gull			440 mg/kg (brain)[4]	Mortality, NA				[18]	L
			183 mg/kg (breast)[4]	Mortality, NA				[18]	L
			3200 mg/kg (liver)[4]	Mortality, NA				[18]	L

Summary of Biological Effects Tissue Concentrations for p,p′-DDT

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	Sediment	Water	Tissue (Sample Type)	Effects	Log BCF	Log BAF	BSAF	Reference	Comments[3]
Pelecanus occidentalis, Brown pelican			4.55 mg/kg (brain)[4]	Mortality, NA				[18]	L
			66 mg/kg (breast)[4]	Mortality, NA				[18]	L
			7.8 mg/kg (liver)[4]	Mortality, NA				[18]	L
Phalacrocorax penicillatus, Brandts cormorant			230 mg/kg (brain)[4]	Mortality, NA				[18]	L
			500 mg/kg (breast)[4]	Mortality, NA				[18]	L
			840 mg/kg (liver)[4]	Mortality, NA				[18]	L
			810 mg/kg (Liver)[4]	Mortality, NA				[18]	L
Phoca siberica, Baikal seal		particulate: 5.1pg/L ± 2.3 n = 1 dissolved: 50 pg/L ± 23 n = 1	17-21 mg/kg[5] lipid (blubber) n = 1					[16]	F; Lake Baikal, Siberia

1 Concentration units based on wet weight unless otherwise noted.
2 BCF = bioconcentration factor, BAF = bioaccumulation factor, BSAF = biota-sediment accumulation factor.
3 L = laboratory study, spiked sediment, single chemical; F = field study, multiple chemical exposure; other unusual study conditions or observations noted.
4 This entry was excerpted directly from the Environmental Residue-Effects Database (ERED, www.wes.army.mil/el/ered, U.S. Army Corps of Engineers and U.S. Environmental Protection Agency). The original publication was not reviewed, and the reader is strongly urged to consult the publication to confirm the information presented here.
5 Not clear from reference if concentration is based on wet or dry weight.

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Chemical Category: PESTICIDE (ORGANOPHOSPHATE)

Chemical Name (Common Synonyms): DIAZINON **CASRN:** 333-41-5

Chemical Characteristics

Solubility in Water: 0.004% at 20°C [1]

Half-Life: No data [2]

Log K_{ow}: 3.70 [3]

Log K_{oc}: 3.64 L/kg organic carbon

Human Health

Oral RfD: 9×10^{-4} mg/kg/day [4]

Confidence: —

Critical Effect: Decreased cholinesterase activity

Oral Slope Factor: No data [4,5]

Carcinogenic Classification: No data [4,5]

Wildlife

Partitioning Factors: Partitioning factors for diazinon in wildlife were not found in the literature.

Food Chain Multipliers: Food chain multipliers for diazinon in wildlife were not found in the literature.

Aquatic Organisms

Partitioning Factors: Partitioning factors for diazinon in aquatic organisms were not found in the literature. Log BCFs ranged from 0.69 to 1.23 (invertebrates) and from 1.59 to 2.90 (fishes).

Food Chain Multipliers: Food chain multipliers for diazinon in aquatic organisms were not found in the literature.

Toxicity/Bioaccumulation Assessment Profile

Diazinon is relatively toxic to aquatic organisms. The acute toxicity for aquatic invertebrates ranged from 0.9 µg/L (48-h LC50) for *Daphnia pulex* [6] to 200µg/L (96-h LC50) for *Gammarus lacustris* [7], while chronic toxicity ranged from 0.27 µg/L (30-d LC50) for *Gammarus pseudolimneaus* to 4.6 µg/L (30-d LC50) for *Acroneuria lycorias* [8]. The maximum acceptable concentration (MATC) for diazinon based on the exposure with sheepshead minnows, was 0.47 µg/L [5], and 3.2 µg/L based on the exposure with fathead minnows [9].

The mode of toxic action of organophosphorus compounds is related to the inhibition of acetylcholinesterase in tissue of animals [10]. A representative of organophosphorus insecticides, diazinon shows species-selective toxicity in fish [11]. For example, diazinon was about 10 times more toxic to the guppy than to the zebra fish [12] and 22 times more potent to loach than killifish [10]. Both the guppy and zebra fish metabolized diazinon to 2-isopropyl-6-methyl-4-pyrimidinol (pyrimidinol). The species-specific oxidative transformation of diazinon or inhibition of acetylcholinesterase are responsible for the differences in diazinon toxicity. During the exposure of pretreated fish (guppies and zebra fish) to diazinon [13], the tissue concentration of pyrimidinol initially increased, then declined to very low levels. Keizer et al. [13] hypothesized that the toxicity of diazinon to guppy is due to its metabolism to a highly toxic metabolite, e.g., diazoxon whereas toxicity to zebra fish is related to bioaccumulation of the parent compound. Fish reached an apparent steady state after 48 hours [12] or 96 hours [14].

Diazinon was most rapidly excreted from the gallbladder followed by liver, muscle, and kidney [11]. The slow excretion rate from kidney was probably because diazinon was transported from all parts of the fish to the kidney before excretion [15]. The log BCFs for eels exposed to 56 µg/L of diazinon were 2.90 in liver, 3.20 in muscle, and 3.36 in gill tissue [16]. Diazinon elimination from the selected tissues was rapid; it was not detected in any tissue after 24-hour exposure in clean water [16]. The results of the study by Kanazawa [17] showed that the concentration of diazinon in tissue of the freshwater fish reached a maximum after 4 days and then decreased gradually. The uptake of diazinon by killifish was not influenced if the fish were exposed to the individual pesticide, or to a pesticide mixture [18].

Diazinon was identified as a major toxicant in municipal effluents [19], indicating persistence of this pesticide in the environment. According to Lee et al. [20], the toxicity of diazinon can be induced by dissolved organic materials.

Summary of Biological Effects Tissue Concentrations for Diazinon

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	Sediment	Water	Tissue (Sample Type)	Effects	Log BCF	Log BAF	BSAF	Reference	Comments[3]
Invertebrates									
Cipangopoludina malleata, Pond snail		10 µg/L			0.77			[21]	L
Procambarus clarkii, Crayfish		10 µg/L			0.69			[21]	L
Indoplanorbis exustus, Red snail		10 µg/L			1.23			[21]	L
Fishes									
Pseudorasbora parva, Topmouth gudgeon		50 µg/L	11.3 ng/g		2.32			[22]	L
Anguilla anguilla, Eel		10 µg/L	80 ng/g (liver)		2.90			[16]	L
Anguilla anguilla, Eel		10 µg/L	160 ng/g (muscle)		2.90			[16]	L
Gnathopogon caerulescens, Willow shiner					2.39			[23]	F

Summary of Biological Effects Tissue Concentrations for Diazinon

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	**Sediment**	**Water**	**Tissue (Sample Type)**	**Effects**	**Log BCF**	**Log BAF**	**BSAF**	**Reference**	**Comments[3]**
Pseudorasbora parva, Topmouth gudgeon					2.18			[23]	F
Pseudorasbora parva, Motsugo		0.7 mg/kg	211 mg/kg (4-day) 17 mg/kg (30 day)	Bleeding, abnormal swimming	1.81			[17]	L
Brachydanio rerio, Zebra fish	Ingestion		1,550 mg/kg (whole body)[4]	Mortality, ED100				[13]	L; Lethal body burden
Zacco slatypus, Pale chub					2.18			[23]	F
Plecoglossus altivelis, Ayu sweetfish					1.79			[23]	F
Cyprinodon variegatus, Sheepshead minnow		1.8 µg/L	0.26 mg/kg in 4d, 0.11 mg/kg in 7d, 0.31 mg/kg in 14d		2.17			[14]	L
		3.5 µg/L	0.38 mg/kg in 4d, 0.21 mg/kg in 7d, 0.49 mg/kg in 14d		2.17			[14]	L
		6.5 µg/L	1.3 mg/kg in 4d, 0.5 mg/kg in 7d, 1.4 mg/kg in 14d		2.33			[14]	L
Cyprinodon variegatus, Sheepshead minnow			0.3 mg/kg (whole body)[4]	Morphology, LOED				[14]	L; body darkened, lateral curvature of body

Summary of Biological Effects Tissue Concentrations for Diazinon

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	Sediment	Water	Tissue (Sample Type)	Effects	Log BCF	Log BAF	BSAF	Reference	Comments[3]
			1.4 mg/kg (whole body)[4]	Morphology, not applicable				[14]	L; body darkened, lateral curvature of body
			0.5 mg/kg (whole body)[4]	Morphology, not applicable				[14]	L; body darkened, lateral curvature of body
			0.05 mg/kg (whole body)[4]	Mortality, NOED				[14]	L; no effect on morphology or appearance
			1.4 mg/kg (whole body)[4]	Mortality, NOED				[14]	L; no effect on mortality
			0.5 mg/kg (whole body)[4]	Mortality, NOED				[14]	L; no effect on mortality
			0.3 mg/kg (whole body)[4]	Mortality, NOED				[14]	L; no effect on mortality
			0.05 mg/kg (whole body)[4]	Mortality, NOED				[14]	L; no effect on mortality
			0.05 mg/kg (whole body)[4]	Physiological, LOED				[14]	L; inhibition of acetylcholinesterase activity
			1.4 mg/kg (whole body)[4]	Physiological, NA				[14]	L; 71% inhibition of acetylcholinesterase activity
			0.5 mg/kg (whole body)[4]	Physiological, NA				[14]	L; inhibition of acetylcholinesterase activity
			0.3 mg/kg (whole body)[4]	Physiological, NA				[14]	L; inhibition of acetylcholinesterase activity
			1.4 mg/kg (whole body)[4]	Reproduction, ED50				[14]	L; 45-55% reduction in average number of eggs produced

Summary of Biological Effects Tissue Concentrations for Diazinon

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	Sediment	Water	Tissue (Sample Type)	Effects	Log BCF	Log BAF	BSAF	Reference	Comments[3]
			0.5 mg/kg (whole body)[4]	Reproduction, ED50				[14]	L; 45-55% reduction in average number of eggs produced
			0.3 mg/kg (whole body)[4]	Reproduction, ED50				[14]	L; 45-55% reduction in average number of eggs produced
			0.05 mg/kg (whole body)[4]	Reproduction, LOED				[14]	L; statistically significant reduction in number of eggs produced
Poecilia reticulata, Guppy		0.8 mg/L	25.8 µg/g in 24h, 90.3 µg/g in 48h, 167.7 µg/g in 96h, 109 mg/kg (whole body)[4]	Mortality, ED100				[13]	L; lethal body burden
Poecilia reticulata, Guppy			2,430 mg/kg (whole body)[4]	Mortality, ED100				[24]	L; lifestage: 2-3 months
			2,430 mg/kg (whole body)[4]	Mortality, ED100				[24]	L; lifestage: 2-3 months

[1] Concentration units based on wet weight unless otherwise noted.
[2] BCF = bioconcentration factor, BAF = bioaccumulation factor, BSAF = biota-sediment accumulation factor.
[3] L = laboratory study, spiked sediment, single chemical; F = field study, multiple chemical exposure; other unusual study conditions or observations noted.
[4] This entry was excerpted directly from the Environmental Residue-Effects Database (ERED, www.wes.army.mil/el/ered, U.S. Army Corps of Engineers and U.S. Environmental Protection Agency). The original publication was not reviewed, and the reader is strongly urged to consult the publication to confirm the information presented here.

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Chemical Category: PESTICIDE (ORGANOCHLORINE)

Chemical Name (Common Synonyms): DICOFOL **CASRN:** 115-32-2

Chemical Characteristics

Solubility in Water: 1.2 mg/L at 20° C (99% purity) [1]

Half-Life: No data [2]

Log K_{ow}: No data [3]

Log K_{oc}: —

Human Health

Oral RfD: 1 x 10^{-3} mg/kg/day [4]

Confidence: —

Critical Effect: Increase in liver to body weight ratios in rats

Oral Slope Factor: No data [5]

Carcinogenic Classification: C [6]

Wildlife

Partitioning Factors: Partitioning factors for dicofol in wildlife were not found in the literature.

Food Chain Multipliers: Food chain multipliers for dicofol in wildlife were not found in the literature.

Aquatic Organisms

Partitioning Factors: Log BCFs ranging from 4.02-4.16 were reported in a study exposing fathead minnows to dicofol [10].

Food Chain Multipliers: Food chain multipliers for dicofol in aquatic organisms were not found in the literature.

Toxicity/Bioaccumulation Assessment Profile

Dicofol is an organochlorine compound used as a miticide. The principal commercial dicofol product, Kelthane, is made from DDT [7]. Clark et al. [7] reported reduction in eggshell weight and thickness of American kestrels due to dicofol. They also observed that 10 µg/g of dicofol reduced hatchability of eggs. They suggested that dicofol concentrations above 3 µg/g in food may affect bird reproduction. The 48-h and 100-h LC50s for grass shrimp (*Crangon franciscorum*) exposed to dicofol (Kelthane) were 590 and 100 µg/L, respectively [8].

The major metabolite of dicofol is 1,1-bis(4-chlorophenol)2,2dichloroethanol (pp-DCD) [9]. Because dicofol is more lipophilic than its metabolites, it was abundant in every tissue except for liver and brain. The dicofol metabolites are less toxic than dicofol and they have less impact on the formation of normal eggshells by doves [9]. The bioconcentration of dicofol in fathead minnows was reduced by 35 percent by clay particles (65 mg/L) indicating that more than 30 percent of the dicofol sorbed onto clay and was biologically unavailable to the fish [10]. Bioconcentration factors at the two dicofol concentrations were not significantly different and steady-state concentrations occured with 40 to 60 days of exposure at 10,500 to 13,900 times water levels.

Summary of Biological Effects Tissue Concentrations for Dicofol

Species:	**Concentration, Units in[1]:**			**Toxicity:**	**Ability to Accumulate[2]:**			**Source:**	
Taxa	**Sediment**	**Water**	**Tissue (Sample Type)**	**Effects**	**Log BCF**	**Log BAF**	**BSAF**	**Reference**	**Comments[3]**
Fishes									
Pimephales promelas, Fathead minnow		12.38 µg/L			4.02-4.16			[10]	L
		1.15 µg/L			4.12-4.14			[10]	L
Wildlife									
Streptopelia risoria, Ring neck dove	32 mg/kg (diet)		116.5µg/g in fat 1.07µg/g in liver 4.55µg/g in heart 0.37µg/g in brain					[9]	L

[1] Concentration units based on wet weight unless otherwise noted.
[2] BCF = bioconcentration factor, BAF = bioaccumulation factor, BSAF = biota-sediment accumulation factor.
[3] L = laboratory study, spiked sediment, single chemical; F = field study, multiple chemical exposure; other unusual study conditions or observations noted.

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Chemical Category: PESTICIDE (ORGANOCHLORINE)

Chemical Name (Common Synonyms): DIELDRIN **CASRN:** 60-57-1

Chemical Characteristics

Solubility in Water: 186 µg/L at 25°C [1]

Half-Life: 175 days to 3 years, based on unacclimated aerobic soil grab sample data and reported half-life in soil based on field data [2]

Log K_{ow}: 5.37 [3]

Log K_{oc}: 5.28 L/kg organic carbon

Human Health

Oral RfD: 5×10^{-5} mg/kg/day [4]

Confidence: Medium, uncertainty factor = 100

Critical Effect: Liver lesions (focal proliferation and focal hyperplasia) in rats, liver carcinomas in mice

Oral Slope Factor: $1.6 \times 10^{+1}$ per (mg/kg)/day [4]

Carcinogenic Classification: B2 [4]

Wildlife

Partitioning Factors: Log BCFs for tadpole and juvenile frogs have been measured at 2.20 to 3.33, whereas log BCFs for adult frogs were 1.57 to 2.58. Dieldrin appears to bioconcentrate to a lesser extent in frogs than in fish. Mallard ducklings exposed to dieldrin-contaminated water for drinking and swimming had log BCFs ranging from 1.69 to 2.21 in liver, 0.98 to 1.97 in muscle, 2.25 to 2.84 in skin, and 2.85 to 3.30 in lipid. Mallard ducklings exposed for longer periods had log BCFs up to 9.30. BSAFs were calculated for red-winged blackbirds and tree swallow eggs during a study in the Great Lakes area, with values ranging from 7.5 to 448, as reported in the attached summary table. The BSAF for tree swallow nestings was 341.

Food Chain Multipliers: A biomagnification factor of 16 has been reported for dieldrin for herring gulls feeding on alewife in Lake Ontario [5]. A study of arctic marine food chains measured biomagnification factors for dieldrin that ranged from 2.2 to 2.4 for fish to seal, 4.9 to 5.5 for seal to bear, and 11.4 for fish to bear [6].

Aquatic Organisms

Partitioning Factors: In older studies, the following log BCFs have been reported for dieldrin: 4.51 in freshwater alga [7]; from 3.38 to 4.83 in fish [8]; and log 3.20 in a saltwater mussel [9]. A log BCF of 5.36 was found for rainbow trout [34]. BSAFs ranging from 1.120 to 7.134 were reported to bivalves [33].

Food Chain Multipliers: Food chain multipliers (FCMs) for trophic level 3 aquatic organisms were 8.6 (all benthic food web), 1.2 (all pelagic food web), and 5.5 (benthic and pelagic food web). FCMs for trophic level 4 aquatic organisms were 10.8 (all benthic food web), 1.9 (all pelagic food web), and 5.8 (benthic and pelagic food web) [36].

Toxicity/Bioaccumulation Assessment Profile

Dieldrin is the name of an insecticide that was used in the United States for locust and mosquito control until production and importation were banned. In addition to man-made production, dieldrin is derived from the oxidation of aldrin, which is also an insecticide. Aldrin is readily converted to dieldrin under normal environmental conditions [10]. In addition, aldrin is readily metabolized to dieldrin, so the effects seen in animals exposed to aldrin may be caused by dieldrin [11]. Dieldrin is one of the most persistent of the chlorinated hydrocarbons, and is highly resistant to biodegradation and abiotic degradation. In water, volatilization of dieldrin to the atmosphere is probably an important process, but transformation processes in soils and sediment are slow. Dieldrin sorbs tightly to soil and sediment, particularly if substantial amounts of organic carbon are present.

Dieldrin is toxic to aquatic organisms, birds, and mammals and is capable of producing carcinogenic, teratogenic, and reproductive effects [10]. Teratogenic effects include cleft palate, webbed foot, and skeletal anomalies. Reproductive effects include decreased fertility, increased fetal death, and effects on gestation [10].

In aquatic organisms, the acute toxicity of dieldrin ranges from 0.5 to 740 µg/L for freshwater and 0.7 to >100 µg/L for saltwater organisms [12]. Differences between dieldrin concentrations causing acute lethality and chronic toxicity in species acutely sensitive to this insecticide are small; acute-chronic ratios ranged from 2.4 to 12.8 for three species [12]. Dieldrin is generally an order of magnitude more toxic to fish than is aldrin [11]. LC50s for freshwater and saltwater aquatic invertebrates exposed to sediment spiked with dieldrin in the laboratory have been shown to range from 0.0041 to 386 µg/g dw [12]. Bioconcentration factors for dieldrin in various aquatic organisms range from 400 to 68,000 [8], indicating that dieldrin will show moderate to significant bioaccumulation in various aquatic species.

Mammals appear to be more sensitive to dieldrin poisoning than birds. Brain concentrations associated with lethality in mammals are 5 mg/kg and in birds are 10 mg/kg [11]. Concentrations as low as 1 mg/kg in the brain might trigger irreversible starvation in sensitive individuals of birds [13]. Major effects on reproduction in wildlife are not expected to occur at dieldrin concentrations of less than one half those causing mortality [11]. Dieldrin is commonly found in the brain, tissues, and eggs of fish-eating birds that also have residues of organochlorines such as DDE and PCBs. Based on a number of literature studies, the State of New York proposed a dietary fish flesh criterion of 0.12 mg/kg to protect piscivorous wildlife [14]. There are limited studies relating aldrin concentrations to toxicity because of the rapid conversion of aldrin into dieldrin.

Summary of Biological Effects Tissue Concentrations for Dieldrin

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	Sediment	Water	Tissue (Sample Type)	Effects	Log BCF	Log BAF	BSAF	Reference	Comments[3]
Invertebrates									
Crassostrea virginica, Eastern oyster			107 mg/kg (whole body)[4]	Cellular, NOED				[23]	L; no histological effects on structure of gill, gut or mantle
			11 mg/kg (whole body)[4]	Cellular, NOED				[23]	
			1.03 mg/kg (whole body)[4]	Cellular, NOED				[23]	
Crassostrea virginica, Eastern oyster			1.44 mg/kg (whole body)[4]	Behavior, LOED				[29]	L; erratic shell movements, extended shell closure indicated irritation
			18.6 mg/kg (whole body)[4]	Behavior, NA				[29]	
			1.44 mg/kg (whole body)[4]	Mortality, NOED				[29]	L; no effect on mortality within 168 hours
			18.6 mg/kg (whole body)[4]	Mortality, NOED				[29]	
Crassostrea virginica, Eastern oyster			13.9 mg/kg (whole body)[4]	Growth, NOED				[31]	L; estimated NOED - no statistical summary in text

Summary of Biological Effects Tissue Concentrations for Dieldrin

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	Sediment	Water	Tissue (Sample Type)	Effects	Log BCF	Log BAF	BSAF	Reference	Comments[3]
Macomona liliana, Mollusk	73.3 µg/kg OC		201.7 µg/kg lipid				2.752	[33]	F, %lipid = 2.95; %sed OC = 0.30
	52.1 µg/kg OC		371.7 µg/kg lipid				7.134	[33]	F, %lipid = 2.33; %sed OC = 0.73
	72.7 µg/kg OC		172.0 µg/kg lipid				2.366	[33]	F, %lipid = 2.57; %sed OC = 0.22
	60.0 µg/kg OC		76.0 µg/kg lipid				1.267	[33]	F, %lipid = 2.04; %sed OC = 0.25
	20.8 µg/kg OC		80.2 µg/kg lipid				3.856	[33]	F, %lipid = 3.13; %sed OC = 0.48
Austrovenus stutchburyi, Mollusk	73.3 µg/kg OC		102.7 µg/kg lipid				1.401	[33]	F, %lipid = 5.62; %sed OC = 0.30
	52.1 µg/kg OC		127.6 µg/kg lipid				2.449	[33]	F, %lipid = 5.21; %sed OC = 0.73
	72.7 µg/kg OC		105.2 µg/kg lipid				1.447	[33]	F, %lipid = 4.85; %sed OC = 0.22
	60.0 µg/kg OC		67.2 µg/kg lipid				1.120	[33]	F, %lipid = 3.87; %sed OC = 0.25
	20.8 µg/kg OC		58.6 µg/kg lipid				2.817	[33]	F, %lipid = 4.27; %sed OC = 0.48
Mercenaria mercenaria, Quahog clam			0.38 mg/kg (whole body)[4]	Behavior, NOED				[22]	L; no effect on feeding activity

Summary of Biological Effects Tissue Concentrations for Dieldrin

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	Sediment	Water	Tissue (Sample Type)	Effects	Log BCF	Log BAF	BSAF	Reference	Comments[3]
Mya arenaria, Soft shell clam			0.87 mg/kg (whole body)[4]	Behavior, NOED				[22]	L; no effect on feeding activity
Chlamydotheca arcuata, Ostracod			1 mg/kg (whole body)[4]	Mortality, LOED				[28]	L; immobility, mortality, resd_conc_wet value > 1.0
Palaemonetes pugio, Grass shrimp			2.1 mg/kg (whole body)[4]	Mortality, LOED				[31]	L; estimated loed - no statistical summary in text
			0.09 mg/kg (whole body)[4]	Mortality, NOED				[31]	L; estimated noed - no statistical summary in text
Penaeus duorarum, Pink shrimp			0.23 mg/kg (whole body)[4]	Mortality, ED50				[31]	L; ED50 via Spearman Karber 1.5 (msl)
			0.08 mg/kg (whole body)[4]	Mortality, LOED				[31]	L; estimated LOED - no statistical summary in text
			0.01 mg/kg (whole body)[4]	Mortality, NOED				[31]	L; estimated NOED - no statistical summary in text
Chironomus riparius, Midge			1.9 mg/kg (whole body)[4]	Mortality, ED10				[24]	L; all larvae moribund in 2 hours

Summary of Biological Effects Tissue Concentrations for Dieldrin

Species:	**Concentration, Units in[1]:**			**Toxicity:**	**Ability to Accumulate[2]:**			**Source:**	
Taxa	**Sediment**	**Water**	**Tissue (Sample Type)**	**Effects**	**Log BCF**	**Log BAF**	**BSAF**	**Reference**	**Comments[3]**
			1.1 mg/kg (whole body)[4]	Behavior, ED50				[24]	L; 50 - 75% mortality, lethargy within 2 hours
			1.1 mg/kg (whole body)[4]	Mortality, ED50				[24]	
			1.1 mg/kg (whole body)[4]	Behavior, ED50				[24]	L; 50 - 75% mortality, lethargy within 2 hours
			1.1 mg/kg (whole body)[4]	Mortality, ED50				[24]	
Fishes									
Squalus acanthias, Spiny dogfish			1 mg/kg (whole body)[4]	Mortality, NOED				[27]	L; no effect on mortality in 24 hours
Oncorhynchus mykiss, Rainbow trout			0.14 mg/kg (fat)[4]	Physiological, ED30				[32]	L; 30% decrease in hemoglobin content relative to control
			0.14 mg/kg (fat)[4]	Physiological, ED30				[32]	L; 30% increase in liver size relative to control
			0.05 mg/kg (fat)[4]	Physiological, ED35				[32]	L; 35% increase in kidney size relative to control
			0.14 mg/kg (fat)[4]	Growth, ED40				[32]	L; 40% decrease in growth relative to control

Summary of Biological Effects Tissue Concentrations for Dieldrin

Species:	**Concentration, Units in[1]:**			**Toxicity:**	**Ability to Accumulate[2]:**			**Source:**	
Taxa	**Sediment**	**Water**	**Tissue (Sample Type)**	**Effects**	**Log BCF**	**Log BAF**	**BSAF**	**Reference**	**Comments[3]**
Oncorhynchus mykiss, Rainbow trout (juveniles)					5.36			[34]	L
Salmonids							6.65	[35]	F
Carassius auratus, Goldfish			3.8 mg/kg (whole body)[4]	Behavior, LOED				[26]	L; hyperexcit-ability
Leuciscus idus, Golden ide			151 mg/kg (whole body)[4]	Mortality, NOED				[25]	L; no effect on survivorship in 3 days
Cyprinodon variegatus, Sheepshead minnow			52.9 mg/kg (whole body)[4]	Mortality, ED50				[31]	L; ED50 via Spearman Karber 1.5 (msl)
			34 mg/kg (whole body)[4]	Mortality, LOED				[31]	L; estimated NOED - no statistical summary in text
			12.8 mg/kg (whole body)[4]	Mortality, NOED				[31]	
Gambusia affinis, Mosquito fish			28 mg/kg (whole body)[4]	Mortality, NOED				[30]	L; no effect on survivorship after 3 days

Summary of Biological Effects Tissue Concentrations for Dieldrin

Species: Taxa	Concentration, Units in[1]: Sediment	Water	Tissue (Sample Type)	Toxicity: Effects	Ability to Accumulate[2]: Log BCF	Log BAF	BSAF	Source: Reference	Comments[3]
Poecilia reticulata, Guppy			10.7 mg/kg (whole body)[4]	Growth, NA				[21]	L; decreased biomass of guppy population in laboratory ecosystem
Lepomis macrochirus, Bluegill			3.7 mg/kg (whole body)[4]	Behavior, LOED				[26]	L; behavioral changes, loss of equilibrium, convulsions
Wildlife									
Xenopus laevis, African clawed frog (tadpole stage)		water exposure 2.3±0.2 µg/L	0.7 mg/kg[5] (whole body)		2.48			[15]	L; 28-day exposure; insufficient tissue for replicates; values are mean ± SE
		water exposure 1.1±0.1 µg/L	1.8±1.2 mg/kg[5] (whole body)		3.21±3.04			[15]	L; 28-day exposure
		(water exposure) µg/L	mg/kg[5] (whole body):					[15]	L; 28-day exposure; insufficient tissue for replicates for all exposures; values are mean ± SE
		2.0±0.0	0.8		2.60				
		4.2±0.1	20.0±0		2.68±0				
		9.3±0.2	3.0±0.6		2.51±0.07				
		20.5±0.4	7.0		2.53				
		µg/L (water exposure):	mg/kg[5] (whole body)					[15]	L; 24-day exposure; values are mean ± SE; effects based on mortality
		0.9±0.1	0.4±0		2.67±0				
		1.8±0.2	0.8±0.2	NOAEL	2.62±1.92				
		3.8±0.3	1.5±0.5	LOAEL	2.59±2.11				
		9.7±0.4	3.0±1.0		2.49±2.01				

Summary of Biological Effects Tissue Concentrations for Dieldrin

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	**Sediment**	**Water**	**Tissue (Sample Type)**	**Effects**	**Log BCF**	**Log BAF**	**BSAF**	**Reference**	**Comments[3]**
Xenopus laevis, African clawed frog (tadpole stage)		water exposure 5.5 µg/L	1.8 mg/kg[5] (whole body)	LC50				[15]	L; 24-day exposure; LC50 tissue dieldrin estimated by graphical extrapolation
Xenopus laevis, African clawed frog (juvenile stage)		water exposure 2.1±0.2 µg/L	4.5±0.3 mg/kg[5] (whole body)		3.33±2.38			[15]	L; 28-day exposure; values are mean ± SE
Rana pipiens, Leopard frog (tadpole stage)		water exposure 0.8±0.1 µg/L	0.6±0.2 mg/kg[5] (whole body)		2.84±2.28			[15]	L; 28-day exposure; values are mean ± SE
		water exposure 2.1±0.1 µg/L	0.8±0.1 mg/kg[5] (whole body)		2.59±1.60			[15]	L; 28-day exposure; values are mean ± SE
		water expo- sure (µg/L) 0.8±0.1 1.9±0.2 4.1±0.3 10.0±0.3	whole body[5] (mg/kg) 0.4±0.1 0.4±0 0.6±0.1 2.0±0.1	 NOAEL LOAEL	 2.64±1.18 2.32±0 2.20±1.08 2.30±0			[15]	L; 28-day exposure; values are mean ± SE; effects based on mortality
Rana pipiens, Leopard frog (tadpole stage)		water exposure 8.3 µg/L	1.7 mg/kg[5] (whole body)	LC50				[15]	L; 24-day exposure; LC50 tissue dieldrin estimated by graphical extrapolation

Summary of Biological Effects Tissue Concentrations for Dieldrin

Species:	**Concentration, Units in[1]:**			**Toxicity:**	**Ability to Accumulate[2]:**			**Source:**	
Taxa	**Sediment**	**Water**	**Tissue (Sample Type)**	**Effects**	**Log BCF**	**Log BAF**	**BSAF**	**Reference**	**Comments[3]**
Rana pipiens, Leopard frog (adult stage)		water exposure 10.7±1.3 µg/L	0.4±0.4 mg/kg[5] (skin) 0.9±0.1 mg/kg[5] (muscle) 1.5±0.5 mg/kg[5] (liver)		1.57±1.57 1.92±0.95 2.15±1.67			[15]	L; 28-day exposure; values are mean ± SE
		water exposure 56.2±4.1 µg/L	7.3±2.8 mg/kg[5] (skin) 17.8±7.8 mg/kg[5] (muscle) 21.5±3.3 mg/kg[5] (liver)		2.11±1.69 2.51±2.15 2.58±1.64			[15]	L; 28-day exposure; values are mean ± SE
		water exposure 53.4 µg/L	5.5 mg/kg[5] (skin) 10.0 mg/kg[5] (muscle) 13.0 mg/kg[5] (liver)	LC50 LC50 LC50				[15]	L; 28-day exposure; LC50 tissue dieldrin estimated by graphical extrapolation
Anas platyrhynchos, Mallard (ducklings)		0.014±1 mg/L	24.5 mg/kg (lipid) 2.3 mg/kg (liver) 1.3 mg/kg (muscle)	No mortality or effects on behavior or survival observed	3.24			[18]	L; 34-day exposure; 1-day-old birds had access to dieldrin-contaminated water for drinking and swimming
		0.052±4 mg/L	68.9 mg/kg (lipid) 3.4 mg/kg (liver) 1.15 mg/kg (muscle)	No mortality or effects on behavior or survival observed	3.12				

Summary of Biological Effects Tissue Concentrations for Dieldrin

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	**Sediment**	**Water**	**Tissue (Sample Type)**	**Effects**	**Log BCF**	**Log BAF**	**BSAF**	**Reference**	**Comments[3]**
		0.118±11 mg/L	128 mg/kg (lipid) 7.4 mg/kg (liver) 1.1 mg/kg (muscle)	No mortality or effects on behavior or survival observed	3.04				
Anas platyrhynchos, Mallard (ducklings)		0.019±2 mg/L	37.9 mg/kg (lipid) 13 mg/kg (skin) 1.9 mg/kg (liver)	No mortality or effects on behavior or survival observed	3.30			[18]	L; 24-day exposure; 1-day old birds had access to dieldrin-contaminated water for drinking and swimming
		0.075±1 mg/L	107 mg/kg (lipid) 39.5 mg/kg (skin) 4.8 mg/kg (liver)	No mortality or effects on behavior or survival observed	3.15				
		0.193±8 mg/L	217 mg/kg (lipid) 75 mg/kg (skin) 11.3 mg/kg (liver)	No mortality or effects on behavior or survival observed	3.05				
		0.177±11 mg/L	125 mg/kg (lipid) 31.5 mg/kg (skin) 8.6 mg/kg (liver) 2.3 mg/kg (brain) 0.97 mg/kg muscle) 0.97 mg/kg (blood)		2.84 2.25 1.69 1.11 0.74 0.51			[18]	L; 8-day exposure; 14-day old birds had access to dieldrin-contaminated water for drinking and swimming

Summary of Biological Effects Tissue Concentrations for Dieldrin

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	Sediment	Water	Tissue (Sample Type)	Effects	Log BCF	Log BAF	BSAF	Reference	Comments[3]
			915 mg/kg (lipid) 305 mg/kg (skin) 52 mg/kg (liver)	96-Hour LC50	0.74 0.26 −0.52			[18]	L; 24-day exposure; birds were dosed with food spiked with dieldrin at measured concentrations of 0.3 to 165 mg/kg.
			395 mg/kg (lipid) 193 mg/kg (skin) 12 mg/kg (liver) 5 mg/kg (brain) 2 mg/kg (muscle)	24-Day LC50	1.13 0.81 −0.40 −0.70 −1.00				
			180 mg/kg (lipid) 102 mg/kg (skin) 7 mg/kg (liver) 2.5 mg/kg (brain) <1 mg/kg (muscle)	24-Day LOAEL	1.05 0.81 −0.40 −0.70				
			4 mg/kg (lipid) 2 mg/kg (skin) <1 mg/kg (liver) <1 mg/kg (brain) <1 mg/kg (muscle)	24-Day NOAEL	1.12 0.83				
Falco peregrinus, Peregrine falcon (eggs)			59 ng/g (eggs) (n = 6)	11.4% eggshell thinning				[19]	F; Kola Peninsula, Russia; n = number of clutches sampled
Falco tinnunculus, European kestrel			6-30 mg/kg (liver)	mortality				[16]	F

Summary of Biological Effects Tissue Concentrations for Dieldrin

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	Sediment	Water	Tissue (Sample Type)	Effects	Log BCF	Log BAF	BSAF	Reference	Comments[3]
Agelaius phoeniceus, Red-winged blackbird (eggs)	1.2 ng/g TOC=21.0%		16.6 ng/g				7.5	[20]	F; Great Lakes/St. Lawrence River basin; 12 wetlands sites; sediment concentration reported as wet weight concentration which may be a typographical error.
	11.0 ng/g TOC=7.5%		31.0 ng/g				21		
	127.8 ng/g TOC=12%		84.6 ng/g				7.8		
	0.6 ng/g TOC=18.5%		8.9 ng/g				57.2		203.7 117.6 ng/g ww
	0.7 ng/g TOC=11.5%		9.1 ng/g				31.1		
	0.1 ng/g TOC=10.5%		20.0 ng/g				448		
Tachycineta bicolor, Tree swallow			(whole body minus feet, beak, wings, and feathers)					[20]	F; Great Lakes/ St. Lawrence River basin; 12 wetlands sites; sediment concentration reported as wet weight concentration which may be a typographical error.
(nestlings)	0.7 ng/g TOC=11.5%		211.4 ng/g				340.5		
(eggs)	0.7 ng/g TOC=11.5%		19.3 ng/g				36.9		

Summary of Biological Effects Tissue Concentrations for Dieldrin

Species:	**Concentration, Units in[1]:**			**Toxicity:**	**Ability to Accumulate[2]:**			**Source:**	
Taxa	**Sediment**	**Water**	**Tissue (Sample Type)**	**Effects**	**Log BCF**	**Log BAF**	**BSAF**	**Reference**	**Comments[3]**
Tyto alba, Barn owl			6-44 mg/kg (liver)	mortality				[17]	F

[1] Concentration units based on wet weight unless otherwise noted.
[2] BCF = bioconcentration factor, BAF = bioaccumulation factor, BSAF = biota-sediment accumulation factor.
[3] L = laboratory study, spiked sediment, single chemical; F = field study, multiple chemical exposure; other unusual study conditions or observations noted.
[4] This entry was excerpted directly from the Environmental Residue-Effects Database (ERED, www.wes.army.mil/el/ered, U.S. Army Corps of Engineers and U.S. Environmental Protection Agency). The original publication was not reviewed, and the reader is strongly urged to consult the publication to confirm the information presented here.
[5] Not clear from reference if concentration is based on wet or dry weight.

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Chemical Category: PESTICIDE (ORGANOPHOSPHATE)

Chemical Name (Common Synonyms): DISULFOTON **CASRN:** 298-04-4

Chemical Characteristics

Solubility in Water: 25 ppm at 23°C [1]

Half-Life: 3 days - 21 days based on aerobic soil field data [2]

Log K_{ow}: 3.98 [3]

Log K_{oc}: 3.91 L/kg organic carbon

Human Health

Oral RfD: 4 X 10^{-5} mg/kg/day [4]

Confidence: Medium, uncertainty factor = 1000 [4]

Critical Effect: Cholinesterase inhibition and optic nerve degeneration in dogs

Oral Slope Factor: No data [4]

Carcinogenic Classification: D [6]

Wildlife

Partitioning Factors: Partitioning factors for disulfoton in wildlife were not found in the literature.

Food Chain Multipliers: Food chain multipliers for disulfoton in wildlife were not found in the literature.

Aquatic Organisms

Partitioning Factors: Partitioning factors for disulfoton in aquatic organisms were not found in the literature.

Food Chain Multipliers: Food chain multipliers for disulfoton in aquatic organisms were not found in the literature.

Toxicity/Bioaccumulation Assessment Profile

The toxicity of insecticidally active organophosphorus compounds like disulfoton to animals is attributed to their ability to inhibit acetylcholinesterase, which is a class of enzymes that catalyzes the hydrolysis of the neurotransmitting agent acetylcholine [7].

Disulfoton is relatively toxic to aquatic organisms. The acute toxicity for aquatic invertebrates ranged from 5 µg/L (96-h LC50) for *Pteronarcys californica* [8] to 52 µg/L (96-h LC50) for *Gammarus lacustris* [9], while chronic toxicity ranged from 1.4 µg/L (30-d LC50) for *Acroneuria pacifica* to 1.9 µg/L (30-d LC50) for *Pteronarcys californica* [10]. Fish are less sensitive to disulfoton. The 96-h LC50 based on the exposure with fathead minnows was 3700 µg/L [11]. The toxicity of disulfoton and its most important degradation products were measured using *Daphnia magna* [12]. The toxicity of disulfoton (24-h LC50 of 55 µg/L) was similar to two of its degradation products (disulfoton-sulfoxide and disulfoton). The remaining degradation products were much less toxic than the parent compound.

Summary of Biological Effects Tissue Concentrations for Disulfoton

Species:	Concentration, Units in:			Toxicity:	Ability to Accumulate:			Source:	
Taxa	**Sediment**	**Pore Water**	**Tissue (Sample Type)**	**Effects**	**BCF**	**BAF**	**BSAF**	**Reference**	**Comments**
Invertebrates			**[NO DATA FOUND]**						
Fishes			**[NO DATA FOUND]**						
Wildlife			**[NO DATA FOUND]**						

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Chemical Category: POLYCHLORINATED DIBENZOFURANS

Chemical Name (Common Synonyms): **CASRN:** 70648-26-9
1,2,3,4,7,8-HEXACHLORODIBENZOFURAN

Chemical Characteristics

Solubility in Water: No data [1]

Half-Life: No data [2]

Log K_{ow}: No data [3]

Log K_{oc}: —

Human Health

Oral RfD: No data [4]

Confidence: —

Critical Effect: —

Oral Slope Factor: No data [4]

Carcinogenic Classification: —

Wildlife

Partitioning Factors: Partitioning factors for 1,2,3,4,7,8-hexaCDF in wildlife were not found in the studies reviewed.

Food Chain Multipliers: Limited information was found reporting on specific biomagnification factors of PCDDs and PCDFs through terrestrial wildlife. Due to the toxicity, high K_{ow} values, and highly persistent nature of the PCDDs and PCDFs, they possess a high potential to bioaccumulate and biomagnify through the food web. PCDDs and PCDFs have been identified in fish and wildlife throughout the global aquatic and marine environments [5]. Studies conducted in Lake Ontario indicated that biomagnification of 2,3,7,8-tetrachlorodibenzo-*p*-dioxin (2,3,7,8-TCDD) appears to be significant between fish and fish-eating birds but not between fish and their food. When calculated for older predaceous fish such as lake-trout-eating young smelt, the biomagnification factor (BMF) can equal 3. The BMF from alewife to herring gulls in Lake Ontario was 32 for 2,3,7,8-TCDD [6]. Log BMFs of 1.70 to 1.81 were reported for mink from 1,2,3,4,7,8-hexaCDF-contaminated diet exposures.

EPA has developed risk-based concentrations of 2,3,7,8-TCDD in different media that present low and high risk to fish, mammalian, and avian wildlife. These concentrations were developed based on toxic effects of 2,3,7,8-TCDD and its propensity to bioaccumulate in fish, mammals, and birds.

Environmental Concentrations Associated With 2,3,7,8-TCDD Risk to Aquatic Life and Associated Wildlife [7]

Organism	Fish Concentration (pg/g)	Sediment Concentration (pg/g dry wt.)	Water Concentration (pg/L)	
			POC=0.2	POC=1.0
Low Risk				
Fish	50	60	0.6	3.1
Mammalian Wildlife	0.7	2.5	0.008	0.04
Avian Wildlife	6	21	0.07	0.35
High Risk to Sensitive Species				
Fish	80	100	1	5
Mammalian Wildlife	7	25	0.08	0.4
Avian Wildlife	60	210	0.7	3.5

Note: POC - Particulate organic carbon
Fish lipid of 8% and sediment organic carbon of 3% assumed where needed.
For risk to fish, BSAF of 0.3 used; for risk to wildlife, BSAF of 0.1 used.
Low risk concentrations are derived from no-effects thresholds for reproductive effects (mortality in embryos and young) in sensitive species.
High risk concentrations are derived from TCDD doses expected to cause 50 to 100% mortality in embryos and young of sensitive species.

Aquatic Organisms

Partitioning Factors: Partitioning factors for 1,2,3,4,7,8-hexaCDF in aquatic organisms were not found in the studies reviewed.

Food Chain Multipliers: No specific food chain multipliers were identified for 1,2,3,7,8-hexaCDF. Food chain multiplier information was only available for 2,3,7,8-TCDD. Biomagnification of 2,3,7,8-TCDD does not appear to be significant between fish and their prey. Limited data for the base of the Lake Ontario lake trout food chain indicated little or no biomagnification between zooplankton and forage fish. BMFs based on fish consuming invertebrate species are probably close to 1.0 because of the 2,3,7,8-TCDD biotansformation by forage fish. BMFs greater than 1.0 might exist between some zooplankton species and their prey due to the lack of 2,3,7,8-TCDD biotransformation in invertebrates [7]. Log BMFs of 1.70 to 1.81 were determined for mink [13].

Toxicity/Bioaccumulation Assessment Profile

The polychlorinated dibenzo-*p*-dioxins (PCDDs) and polychlorinated dibenzofurans (PCDFs) each consist of 75 isomers that differ in the number and position of attached chlorine atoms. The PCDDs and PCDFs are polyhalogenated aromatic compounds and exhibit several properties common to this group of compounds. These compounds tend to be highly lipophilic and the degree of lipophilicity is increased with increasing ring chlorination [5]. In general, the PCDDs and PCDFs exhibit relative inertness to acids, bases, oxidation, reduction, and heat, increasing in environmental persistence and chemical stability with increasing chlorination [8,5]. Because of their lipophilic nature, the PCDDs and PCDFs have been detected in fish, wildlife, and human adipose tissue, milk, and serum [5].

Each isomer has its own unique chemical and toxicological properties. The most toxic of the PCDD and PCDF isomers is 2,3,7,8-TCDD, one of the 22 possible congeners of tetrachlorodibenzo-*p*-dioxin [9]. Toxicity equivalency factors (TEFs) have been developed by EPA relating the toxicities of other PCDD and PCDF isomers to that of 2,3,7,8-TCDD [9]. The biochemical mechanisms leading to the toxic response resulting from exposure to PCDDs and PCDFs are not known in detail, but experimental data suggest that an important role in the development of systemic toxicity resulting from exposure to these chemicals is played by an intracellular protein, the Ah receptor. This receptor binds halogenated polycyclic aromatic molecules, including PCDDs and PCDFs. In several mouse strains, the expression of toxicity of 2,3,7,8-TCDD-related compounds, including cleft palate formation, liver damage, effects on body weight gain, thymic involution, and chloracnegenic response, has been correlated with their binding affinity for the Ah receptor, and with their ability to induce several enzyme systems [9].

Toxicity Equivalency Factors (TEF) for PCDD and PCDF Isomers [9]

Isomer	TEF
Total TetraCDD	1
2,3,7,8-TCDD	1
Other TCDDs	0.01
Total PentaCDDs	0.5
2,3,7,8-PentaCDDs	0.5
Other PentaCDDs	0.005
Total HexaCDDs	0.04
2,3,7,8-HexaCDDs	0.04
Other HexaCDDs	0.0004
Total HeptaCDDs	0.001
2,3,7,8-HeptaCDDs	0.001
Other HeptaCDDs	0.00001
Total TetraCDFs	0.1
2,3,7,8-TetraCDF	0.1
Other TetraCDFs	0.001
Total PentaCDFs	0.1
2,3,7,8-PentaCDFs	0.1
Other PentaCDFs	0.001
Total HexaCDFs	0.01
2,3,7,8-HexaCDFs	0.01
Other HexaCDFs	0.0001
Total HeptaCDFs	0.001
2,3,7,8-HeptaCDFs	0.001
Other HeptaCDFs	0.00001

In natural systems, PCDDs and PCDFs are typically associated with sediments, biota, and the organic carbon fraction of ambient waters [7]. Congener-specific analyses have shown that the 2,3,7,8-substituted PCDDs and PCDFs were the major compounds present in most sample extracts [5]. Results from limited epidemiology studies are consistent with laboratory-derived threshold levels to 2,3,7,8-TCDD impairment of reproduction in avian wildlife. Population declines in herring gulls (*Larus argentatus*) on Lake Ontario during the early 1970s coincided with egg concentrations of 2,3,7,8-TCDD and related chemicals expected to cause reproductive failure based on laboratory experiments (2,3,7,8-TCDD concentrations in excess of 1,000 pg/g). Improvements in herring gull reproduction through the mid-1980s were correlated with declining 2,3,7,8-TCDD concentrations in eggs and lake sediments [7]. Based on limited information on isomer-specific analysis from animals at different trophic levels, it appears that at higher trophic levels, i.e., fish-eating birds and fish, there is a selection of the planar congeners with the 2,3,7,8-substituted positions [10].

PCDDs and PCDFs are accumulated by aquatic organisms through exposure routes that are determined by the habitat and physiology of each species. With log K_{ow}>5, exposure through ingestion of contaminated food becomes an important route for uptake in comparison to respiration of water [7]. The relative contributions of water, sediment, and food to uptake of 2,3,7,8-TCDD by lake trout in Lake Ontario was examined by exposing yearling lake trout to Lake Ontario smelt and sediment from Lake Ontario along with water at a 2,3,7,8-TCDD concentration simulated to be at equilibrium with the sediments. Food ingestion was found to contribute approximately 75 percent of total 2,3,7,8-TCDD [7]. There have been a number of bioconcentration studies of 2,3,7,8-TCDD using model ecosystem and single species exposure. Although there is variation in the actual log BCF values, in general, the algae and plants have the lowest BCF values, on the order of a few thousand. A value of 4.38 has been reported for the snail *Physa* sp. Crustacea and insect larva appear to have the next highest log BCF values, followed by several species of fish, with the highest log BCF value of 4.79 [10].

Exposure of juvenile rainbow trout to 2,3,7,8-TCDD and 2,3,7,8-TCDF in water for 28 days resulted in adverse effects on survival, growth, and behavior at extremely low concentrations. A no-observed-effects concentration (NOEC) for 2,3,7,8-TCDD could not be determined because the exposure to the lowest dose of 0.038 ng/L resulted in significant mortality [11]. A number of biological effects have been reported in fish following exposure to 2,3,7,8-TCDD including enzyme induction, immunological effects, wasting syndrome, dermatological effects, hepatic effects, hematological effects, developmental effects, and cardiovascular effects [10].

Summary of Biological Effects Tissue Concentrations for 1,2,3,4,7,8-HexaCDF

Species:	**Concentration, Units in[1]:**			**Toxicity:**	**Ability to Accumulate[2]:**			**Source:**	
Taxa	**Sediment**	**Water**	**Tissue (Sample Type)**	**Effects**	**Log BCF**	**Log BAF**	**BSAF**	**Reference**	**Comments[3]**
Fishes									
Salmonids							0.0045	[14]	F
Wildlife									
Falco peregrinus, Peregrine falcon			3.2 ng/g (eggs) (n = 6)	11.4% eggshell thinning				[12]	F; Kola Peninsula, Russia
Mustela vison, Mink	Diet: 1 pg/g[4]		33 pg/g[4] (liver)	LOAEL; reduced kit body weights followed by reduced survival		No BMF reported		[13]	L; BMF = lipid-normalized concentration in the liver divided by the lipid-normalized dietary concentration
	2 pg/g[4]		73 pg/g[4] (liver)	Reduced kit body weights followed by reduced survival		Log BMF = 1.70			
	3 pg/g[4]		130 pg/g[4] (liver)	Significant decrease in number of live kits whelped per female		Log BMF = 1.81			

[1] Concentration units based on wet weight unless otherwise noted.
[2] BCF = bioconcentration factor, BAF = bioaccumulation factor, BSAF = biota-sediment accumulation factor.
[3] L = laboratory study, spiked sediment, single chemical; F = field study, multiple chemical exposure; other unusual study conditions or observations noted.
[4] Not clear from reference if concentration is based on wet or dry weight.

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Chemical Category: POLYCHLORINATED DIBENZOFURANS

Chemical Name (Common Synonyms): **CASRN:** 57117-41-6
1,2,3,7,8-PENTACHLORODIBENZOFURAN

Chemical Characteristics

Solubility in Water: No data [1]

Half-Life: No data [2]

Log K_{ow}: No data [3]

Log K_{oc}: —

Human Health

Oral RfD: No data [4]

Confidence: —

Critical Effect: —

Oral Slope Factor: No data [4]

Carcinogenic Classification: —

Wildlife

Partitioning Factors: Partitioning factors for 1,2,3,7,8-pentaCDF in wildlife were not found in the studies reviewed.

Food Chain Multipliers: Limited information was found reporting on specific biomagnification factors of PCDDs and PCDFs through terrestrial wildlife; no information was available for 1,2,3,7,8-pentaCDF, specifically. Due to the toxicity, high K_{ow} values, and highly persistent nature of the PCDDs and PCDFs, they possess a high potential to bioaccumulate and biomagnify through the food web. PCDDs and PCDFs have been identified in fish and wildlife throughout the global aquatic and marine environments [5]. Studies conducted in Lake Ontario indicated that biomagnification of 2,3,7,8-tetrachlorodibenzo-*p*-dioxin (2,3,7,8-TCDD) appears to be significant between fish and fish-eating birds but not between fish and their food. When calculated for older predaceous fish such as lake-trout-eating young smelt, the log biomagnification factor (BMF) can equal 0.48. The log BMF from alewife to herring gulls in Lake Ontario was 1.51 for 2,3,7,8-TCDD [6].

EPA has developed risk-based concentrations of 2,3,7,8-TCDD in different media that present low and high risk to fish, mammalian, and avian wildlife. These concentrations were developed based on toxic effects of 2,3,7,8-TCDD and its propensity to bioaccumulate in fish, mammals, and birds.

Environmental Concentrations Associated With 2,3,7,8-TCDD Risk to Aquatic Life and associated Wildlife [7]

Organism	Fish Concentration (pg/g)	Sediment Concentration (pg/g dry wt.)	Water Concentration (pg/L)	
			POC=0.2	POC=1.0
Low Risk				
Fish	50	60	0.6	3.1
Mammalian Wildlife	0.7	2.5	0.008	0.04
Avian Wildlife	6	21	0.07	0.35
High Risk to Sensitive Species				
Fish	80	100	1	5
Mammalian Wildlife	7	25	0.08	0.4
Avian Wildlife	60	210	0.7	3.5

Note: POC - Particulate organic carbon
Fish lipid of 8% and sediment organic carbon of 3% assumed where needed.
For risk to fish, BSAF of 0.3 used; for risk to wildlife, BSAF of 0.1 used.
Low risk concentrations are derived from no-effects thresholds for reproductive effects (mortality in embryos and young) in sensitive species.
High risk concentrations are derived from TCDD doses expected to cause 50 to 100% mortality in embryos and young of sensitive species.

Aquatic Organisms

Partitioning Factors: Partitioning factors for 1,2,3,7,8-pentaCDF in aquatic organisms were not found in the studies reviewed.

Food Chain Multipliers: No specific food chain multipliers were identified for 1,2,3,7,8-pentaCDF. Food chain multiplier information was only available for 2,3,7,8-TCDD. Biomagnification of 2,3,7,8-TCDD does not appear to be significant between fish and their prey. Limited data for the base of the Lake Ontario lake trout food chain indicated little or no biomagnification between zooplankton and forage fish. BMFs based on fish consuming invertebrate species are probably close to 1.0 because of the 2,3,7,8-TCDD biotransformation by forage fish. BMFs greater than 1.0 might exist between some zooplankton species and their prey due to the lack of 2,3,7,8-TCDD biotransformation in invertebrates [7].

Toxicity/Bioaccumulation Assessment Profile

The polychlorinated dibenzo-*p*-dioxins (PCDDs) and polychlorinated dibenzofurans (PCDFs) each consist of 75 isomers that differ in the number and position of attached chlorine atoms. The PCDDs and PCDFs are polyhalogenated aromatic compounds and exhibit several properties common to this group of compounds. These compounds tend to be highly lipophilic and the degree of lipophilicity is increased with increasing ring chlorination [5]. In general, the PCDDs and PCDFs exhibit relative inertness to acids, bases, oxidation, reduction, and heat, increasing in environmental persistence and chemical stability with increasing chlorination [8,5]. Because of their lipophilic nature, the PCDDs and PCDFs have been detected in fish, wildlife, and human adipose tissue, milk, and serum [5].

Each isomer has its own unique chemical and toxicological properties. The most toxic of the PCDD and PCDF isomers is 2,3,7,8-TCDD, one of the 22 possible congeners of tetrachlorodibenzo-*p*-dioxin [8]. Toxicity equivalency factors (TEFs) have been developed by the U.S. EPA relating the toxicities of other PCDD and PCDF isomers to that of 2,3,7,8-TCDD [9]. The biochemical mechanisms leading to the toxic response resulting from exposure to PCDDs and PCDFs are not known in detail, but experimental data suggest that an important role in the development of systemic toxicity resulting from exposure to these chemicals is played by an intracellular protein, the Ah receptor. This receptor binds halogenated polycyclic aromatic molecules, including PCDDs and PCDFs. In several mouse strains, the expression of toxicity of 2,3,7,8-TCDD-related compounds, including cleft palate formation, liver damage, effects on body weight gain, thymic involution, and chloracnegenic response has been correlated with their binding affinity for the Ah receptor, and with their ability to induce several enzyme systems [9].

Toxicity Equivalency Factors (TEF) for PCDD and PCDF Isomers [9]

Isomer	TEF
Total TetraCDD	1
2,3,7,8-TCDD	1
Other TCDDs	0.01
Total PentaCDDs	0.5
2,3,7,8-PentaCDDs	0.5
Other PentaCDDs	0.005
Total HexaCDDs	0.04
2,3,7,8-HexaCDDs	0.04
Other HexaCDDs	0.0004
Total HeptaCDDs	0.001
2,3,7,8-HeptaCDDs	0.001
Other HeptaCDDs	0.00001
Total TetraCDFs	0.1
2,3,7,8-TetraCDF	0.1
Other TetraCDFs	0.001
Total PentaCDFs	0.1
2,3,7,8-PentaCDFs	0.1
Other PentaCDFs	0.001
Total HexaCDFs	0.01
2,3,7,8-HexaCDFs	0.01
Other HexaCDFs	0.0001
Total HeptaCDFs	0.001
2,3,7,8-HeptaCDFs	0.001
Other HeptaCDFs	0.00001

In natural systems, PCDDs and PCDFs are typically associated with sediments, biota, and the organic carbon fraction of ambient waters [7]. Congener-specific analyses have shown that the 2,3,7,8-substituted PCDDs and PCDFs were the major compounds present in most sample extracts [5]. Results from limited epidemiology studies are consistent with laboratory-derived threshold levels to 2,3,7,8-TCDD impairment of reproduction in avian wildlife. Population declines in herring gulls (*Larus argentatus*) on Lake Ontario during the early 1970s coincided with egg concentrations of 2,3,7,8-TCDD and related chemicals expected to cause reproductive failure based on laboratory experiments (2,3,7,8-TCDD concentrations in excess of 1,000 pg/g). Improvements in herring gull reproduction through the mid-1980s were correlated with declining 2,3,7,8-TCDD concentrations in eggs and lake sediments [7]. Based on limited information on isomer-specific analysis from animals at different trophic levels, it appears that at higher trophic levels, i.e., fish-eating birds and fish, there is a selection of the planar congeners with the 2,3,7,8-substituted positions [10].

PCDDs and PCDFs are accumulated by aquatic organisms through exposure routes that are determined by the habitat and physiology of each species. With log K_{ow}>5, exposure through ingestion of contaminated food becomes an important route for uptake in comparison to respiration of water [7]. The relative contributions of water, sediment, and food to uptake of 2,3,7,8-TCDD by lake trout in Lake Ontario was examined by exposing yearling lake trout to Lake Ontario smelt and sediment from Lake Ontario along with water at a 2,3,7,8-TCDD concentration simulated to be at equilibrium with the sediments. Food ingestion was found to contribute approximately 75 percent of total 2,3,7,8-TCDD [7]. There have been a number of bioconcentration studies of 2,3,7,8-TCDD using model ecosystem and single species exposure. Although there is variation in the actual log BCF values, in general, the algae and plants have the lowest BCF values, on the order of a few thousand. A value of 4.38 has been reported for the snail *Physa* sp. Crustacea and insect larva appear to have the next highest BCF values, followed by several species of fish, with the highest log BCF value of 4.78 [10].

Exposure of juvenile rainbow trout to 2,3,7,8-TCDD and -TCDF in water for 28 days resulted in adverse effects on survival, growth, and behavior at extremely low concentrations. A no-observed-effects concentration (NOEC) for 2,3,7,8-TCDD could not be determined because the exposure to the lowest dose of 0.038 ng/l resulted in significant mortality [11]. A number of biological effects have been reported in fish following exposure to 2,3,7,8-TCDD including enzyme induction, immunological effects, wasting syndrome, dermatological effects, hepatic effects, hematological effects, developmental effects, and cardiovascular effects [10].

Summary of Biological Effects Tissue Concentrations for 1,2,3,7,8-PentaCDF

Species: Taxa	Concentration, Units in[1]: Sediment	Water	Tissue (Sample Type)	Toxicity: Effects	Ability to Accumulate[2]: Log BCF	Log BAF	BSAF	Source: Reference	Comments[3]
Fishes									
Salmonids							0.013	[15]	F
Wildlife									
Falco peregrinus, Peregrine falcon			4.0 ng/g (eggs) (n = 6)	11.4% eggshell thinning				[13]	F; Kola Peninsula, Russia
Haliaeetus leucocephalus, Bald eagle chicks			Powell River site: ~160 ng/kg lipid weight basis (yolk sac) Reference site: ~30 ng/kg lipid weight basis (yolk sac)	A hepatic cytochrome P4501A crossreactive protein (CYP1A) was induced nearly six-fold in chicks from Powell River site compared to the reference (p<0.05). No significant concentration-related effects were found for morphological, physiological, or histological parameters.				[12]	F; southern coast of British Columbia; eggs were collected from nests and hatched in the lab; ~ indicates value was taken from a figure.

Summary of Biological Effects Tissue Concentrations for 1,2,3,7,8-PentaCDF

Species: Taxa	Concentration, Units in[1]: Sediment	Water	Tissue (Sample Type)	Toxicity: Effects	Ability to Accumulate[2]: Log BCF	Log BAF	BSAF	Source: Reference	Comments[3]
Mustela vison, Mink	Diet:							[14]	L
	1 pg/g[4]		1 pg/g[4] (liver)	LOAEL; reduced kit body weights followed by reduced survival					
	2 pg/g[4]		2 pg/g[4] (liver)	Reduced kit body weights followed by reduced survival					
	4 pg/g[4]		2 pg/g[4] (liver)	Significant decrease in number of live kits whelped per female					

[1] Concentration units based on wet weight unless otherwise noted.
[2] BCF = bioconcentration factor, BAF = bioaccumulation factor, BSAF = biota-sediment accumulation factor.
[3] L = laboratory study, spiked sediment, single chemical; F = field study, multiple chemical exposure; other unusual study conditions or observations noted.
[4] Not clear from reference if concentration is based on wet or dry weight.

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Chemical Category: POLYCHLORINATED DIBENZOFURANS

Chemical Name (Common Synonyms): **CASRN:** 57117-31-4
2,3,4,7,8-PENTACHLORODIBENZOFURAN

Chemical Characteristics

Solubility in Water: 0.24 µg/L [1]

Half-Life: No data [2,3]

Log K_{ow}: No data [4], 6.92 [2]

Log K_{oc}: 6.80 L/kg organic carbon

Human Health

Oral RfD: No data [5]

Confidence: —

Critical Effect: —

Oral Slope Factor: No data [5]

Carcinogenic Classification: —

Wildlife

Partitioning Factors: Partitioning factors for 2,3,4,7,8-pentaCDF in wildlife were not found in the studies reviewed.

Food Chain Multipliers: Limited information was found reporting on specific biomagnification factors of PCDDs and PCDFs through terrestrial wildlife; no information was available for 2,3,4,7,8-pentaCDF, specifically. Due to the toxicity, high K_{ow} values, and highly persistent nature of the PCDDs and PCDFs, they possess a high potential to bioaccumulate and biomagnify through the food web. PCDDs and PCDFs have been identified in fish and wildlife throughout the global aquatic and marine environments [6]. Studies conducted in Lake Ontario indicated that biomagnification of 2,3,7,8-tetrachlorodibenzo-*p*-dioxin (2,3,7,8-TCDD) appears to be significant between fish and fish-eating birds but not between fish and their food. When calculated for older predaceous fish such as lake-trout-eating young smelt, the biomagnification factor (BMF) can equal 3. The BMF from alewife to herring gulls in Lake Ontario was 32 for 2,3,7,8-TCDD [7]. Log BMFs of 1.73 to 1.74 were determined for mink [18].

EPA has developed risk-based concentrations of 2,3,7,8-TCDD in different media that present low and high risk to fish, mammalian, and avian wildlife. These concentrations were developed based on toxic effects of 2,3,7,8-TCDD and its propensity to bioaccumulate in fish, mammals, and birds.

Environmental Concentrations Associated With 2,3,7,8-TCDD Risk to Aquatic Life and Associated Wildlife [8]

Organism	Fish Concentration (pg/g)	Sediment Concentration	Water Concentration (pg/L)	
			POC=0.2	POC=1.0
Low Risk				
Fish	50	60	0.6	3.1
Mammalian Wildlife	0.7	2.5	0.008	0.04
Avian Wildlife	6	21	0.07	0.35
High Risk to Sensitive Species				
Fish	80	100	1	5
Mammalian Wildlife	7	25	0.08	0.4
Avian Wildlife	60	210	0.7	3.5

Note: POC - Particulate organic carbon
Fish lipid of 8% and sediment organic carbon of 3% assumed where needed.
For risk to fish, BSAF of 0.3 used; for risk to wildlife, BSAF of 0.1 used.
Low risk concentrations are derived from no-effects thresholds for reproductive effects (mortality in embryos and young) in sensitive species.
High risk concentrations are derived from TCDD doses expected to cause 50 to 100% mortality in embryos and young of sensitive species.

Aquatic Organisms

Partitioning Factors: In one study, the BSAF for carp collected from a reservoir in central Wisconsin was 0.28. The log BCF for goldfish measured during a laboratory exposure of 120 hours was 4.48

Food Chain Multipliers: No specific food chain multipliers were identified for 2,3,4,7,8-pentaCDF. Food chain multiplier information was only available for 2,3,7,8-TCDD. Biomagnification of 2,3,7,8-TCDD does not appear to be significant between fish and their prey. Limited data for the base of the Lake Ontario lake trout food chain indicated little or no biomagnification between zooplankton and forage fish. BMFs based on fish consuming invertebrate species are probably close to 1.0 because of the 2,3,7,8-TCDD biotransformation by forage fish. BMFs greater than 1.0 might exist between some zooplankton species and their prey due to the lack of 2,3,7,8-TCDD biotransformation in invertebrates [8].

Toxicity/Bioaccumulation Assessment Profile

The polychlorinated dibenzo-*p*-dioxins (PCDDs) and polychlorinated dibenzofurans (PCDFs) each consist of 75 isomers that differ in the number and position of attached chlorine atoms. The PCDDs and PCDFs are polyhalogenated aromatic compounds and exhibit several properties common to this group of compounds. These compounds tend to be highly lipophilic and the degree of lipophilicity is increased with increasing ring chlorination [6]. In general, the PCDDs and PCDFs exhibit relative inertness to acids, bases, oxidation, reduction, and heat, increasing in environmental persistence and chemical stability with increasing chlorination [6,9]. Because of their lipophilic nature, the PCDDs and PCDFs have been detected in fish, wildlife, and human adipose tissue, milk, and serum [6].

Each isomer has its own unique chemical and toxicological properties. The most toxic of the PCDD and PCDF isomers is 2,3,7,8-TCDD, one of the 22 possible congeners of tetrachlorodibenzo-*p*-dioxin [8]. Toxicity equivalency factors (TEFs) have been developed by the EPA relating the toxicities of other PCDD and PCDF isomers to that of 2,3,7,8-TCDD [10]. The biochemical mechanisms leading to the toxic response resulting from exposure to PCDDs and PCDFs are not known in detail, but experimental data suggest that an important role in the development of systemic toxicity resulting from exposure to these chemicals is played by an intracellular protein, the Ah receptor. This receptor binds halogenated polycyclic aromatic molecules, including PCDDs and PCDFs. In several mouse strains, the expression of toxicity of 2,3,7,8-TCDD-related compounds, including cleft palate formation, liver damage, effects on body weight gain, thymic involution, and chloracnegenic response, has been correlated with their binding affinity for the Ah receptor, and with their ability to induce several enzyme systems [10].

Toxicity Equivalency Factors (TEF) for PCDD and PCDF Isomers [10]

Isomer	TEF
Total TetraCDD	1
2,3,7,8-TCDD	1
Other TCDDs	0.01
Total PentaCDDs	0.5
2,3,7,8-PentaCDDs	0.5
Other PentaCDDs	0.005
Total HexaCDDs	0.04
2,3,7,8-HexaCDDs	0.04
Other HexaCDDs	0.0004
Total HeptaCDDs	0.001
2,3,7,8-HeptaCDDs	0.001
Other HeptaCDDs	0.00001
Total TetraCDFs	0.1
2,3,7,8-TetraCDF	0.1
Other TetraCDFs	0.001
Total PentaCDFs	0.1
2,3,7,8-PentaCDFs	0.1
Other PentaCDFs	0.001
Total HexaCDFs	0.01
2,3,7,8-HexaCDFs	0.01
Other HexaCDFs	0.0001
Total HeptaCDFs	0.001
2,3,7,8-HeptaCDFs	0.001
Other HeptaCDFs	0.00001

In natural systems, PCDDs and PCDFs are typically associated with sediments, biota, and the organic carbon fraction of ambient waters [7]. Congener-specific analyses have shown that the 2,3,7,8-substituted PCDDs and PCDFs were the major compounds present in most sample extracts [6]. Results from limited epidemiology studies are consistent with laboratory-derived threshold levels to 2,3,7,8-TCDD impairment of reproduction in avian wildlife. Population declines in herring gulls (*Larus argentatus*) on Lake Ontario during the early 1970s coincided with egg concentrations of 2,3,7,8-TCDD and related chemicals expected to cause reproductive failure based on laboratory experiments (2,3,7,8-TCDD concentrations in excess of 1,000 pg/g). Improvements in herring gull reproduction through the mid-1980s were correlated with declining 2,3,7,8-TCDD concentrations in eggs and lake sediments [8]. Based on limited information on isomer-specific analysis from animals at different trophic levels, it appears that at higher trophic levels, i.e., fish-eating birds and fish, there is a selection of the planar congeners with the 2,3,7,8-substituted positions [11].

PCDDs and PCDFs are accumulated by aquatic organisms through exposure routes that are determined by the habitat and physiology of each species. With log K_{ow}>5, exposure through ingestion of contaminated food becomes an important route for uptake in comparison to respiration of water [8]. The relative contributions of water, sediment, and food to uptake of 2,3,7,8-TCDD by lake trout in Lake Ontario was examined by exposing yearling lake trout to Lake Ontario smelt and sediment from Lake Ontario along with water at a 2,3,7,8-TCDD concentration simulated to be at equilibrium with the sediments. Food ingestion was found to contribute approximately 75 percent of total 2,3,7,8-TCDD [8]. There have been a number of bioconcentration studies of 2,3,7,8-TCDD using model ecosystem and single species exposure. Although there is variation in the actual log BCF values, in general, the algae and plants have the lowest BCF values, on the order of a few thousand. A value of 4.38 has been reported for the snail *Physa* sp. Crustacea and insect larva appear to have the next highest BCF values, followed by several species of fish, with the highest log BCF value of 4.79 [11].

Exposure of juvenile rainbow trout to 2,3,7,8-TCDD and -TCDF in water for 28 days resulted in adverse effects on survival, growth, and behavior at extremely low concentrations. A no-observed-effects concentration (NOEC) for 2,3,7,8-TCDD could not be determined because the exposure to the lowest dose of 0.038 ng/L resulted in significant mortality [12]. A number of biological effects have been reported in fish following exposure to 2,3,7,8-TCDD including enzyme induction, immunological effects, wasting syndrome, dermatological effects, hepatic effects, hematological effects, developmental effects, and cardiovascular effects [11].

Summary of Biological Effects Tissue Concentrations for 2,3,4,7,8-PentaCDF

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	Sediment	Water	Tissue (Sample Type)	Effects	Log BCF	Log BAF	BSAF	Reference	Comments[3]
Fishes									
Carassius auratus, Goldfish			2.69/2.5 ng/g[4] (whole body)		4.48			[14]	L; fish were exposed for 120 hr; exposure water contained fly ash extract; concentrations were measured in water, but data were not presented
Cyprinus carpio, Carp	8 pg/g[4]		4.4 pg/g[4]				0.28	[13]	F; Petenwell Reservoir, central Wisconsin; BSAF based on 8% tissue lipid content and 3.1% sediment organic carbon
Salmonids							0.095	[19]	F
Wildlife									
Falco peregrinus, Peregrine falcon			27 ng/g (eggs) (n = 6)	11.4% eggshell thinning				[17]	F; Kola Peninsula, Russia

Summary of Biological Effects Tissue Concentrations for 2,3,4,7,8-PentaCDF

Species: Taxa	Concentration, Units in[1]: Sediment	Water	Tissue (Sample Type)	Toxicity: Effects	Ability to Accumulate[2]: Log BCF	Log BAF	BSAF	Source: Reference	Comments[3]
Haliaeetus leucocephalus, Bald eagle chicks			Powell River site: ~800 ng/kg lipid weight basis (yolk sac) Reference site: ~100 ng/kg lipid weight basis (yolk sac)	A nearly 6-fold increase in hepatic cytochrome P4501A cross-reactive protein (CYP1A) was induced in chicks from Powell River site compared to the reference ($p<0.05$). No significant concentration-related effects were found for morphological, physiological, or histological parameters.				[15]	F; southern coast of British Columbia; eggs were collected from nests and hatched in the lab; ~ indicates value was taken from a figure.

Summary of Biological Effects Tissue Concentrations for 2,3,4,7,8-PentaCDF

Species: Taxa	Concentration, Units in[1]: Sediment	Water	Tissue (Sample Type)	Toxicity: Effects	Ability to Accumulate[2]: Log BCF	Log BAF	BSAF	Source: Reference	Comments[3]
Ardea herodias, Great blue heron chicks			Nicomekl site: <2 ng/kg (egg) (n = 11)					[16]	L; eggs were collected from three British Columbia colonies with different levels of contamination and incubated in the laboratory
			Vancouver site: 33±18.5 ng/kg (egg) (n = 12)	Depression of growth compared to Nicomekl site. Presence of edema.					
			Crofton site: 33±7.6 ng/kg (egg) (n = 6)	Depression of growth compared to Nicomekl site. Presence of edema.					

Summary of Biological Effects Tissue Concentrations for 2,3,4,7,8-PentaCDF

Species: Taxa	Concentration, Units in[1]: Sediment	Water	Tissue (Sample Type)	Toxicity: Effects	Ability to Accumulate[2]: Log BCF	Log BAF	BSAF	Source: Reference	Comments[3]
Mustela vison, Mink	Diet: 4 pg/g[4]		170 pg/g[4] (liver)	LOAEL; reduced kit body weights followed by reduced survival		No BMF reported		[18]	L; BMF = lipid-normalized concentration in the liver divided by the lipid-normalized dietary concentration
	6 pg/g[4]		320 pg/g[4] (liver)	Reduced kit body weights followed by reduced survival		Log BMF = 1.74			
	14 pg/g[4]		490 pg/g[4] (liver)	Significant decrease in number of live kits whelped per female		Log BMF = 1.73			

[1] Concentration units based on wet weight unless otherwise noted.
[2] BCF = bioconcentration factor, BAF = bioaccumulation factor, BSAF = biota-sediment accumulation factor.
[3] L = laboratory study, spiked sediment, single chemical; F = field study, multiple chemical exposure; other unusual study conditions or observations noted.
[4] Not clear from reference if concentration is based on wet or dry weight.

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Chemical Category: POLYCHLORINATED DIBENZOFURANS

Chemical Name (Common Synonyms): **CASRN:** 51207-31-9
2,3,7,8-TETRACHLORODIBENZOFURAN

Chemical Characteristics

Solubility in Water: No data [1], 0.42 µg/L [2]

Half-Life: No data [3]

Log K_{ow}: No data [4], 6.53 [2]

Log K_{oc}: —

Human Health

Oral RfD: No data [5]

Confidence: —

Critical Effect: —

Oral Slope Factor: No data [5]

Carcinogenic Classification: —

Wildlife

Partitioning Factors: Partitioning factors for 2,3,7,8-TCDF in wildlife were not found in the studies reviewed.

Food Chain Multipliers: Limited information was found reporting on specific biomagnification factors of PCDDs and PCDFs through terrestrial wildlife; no information was available for 2,3,7,8-TCDF, specifically. Due to the toxicity, high K_{ow} values, and highly persistent nature of the PCDDs and PCDFs, they possess a high potential to bioaccumulate and biomagnify through the food web. PCDDs and PCDFs have been identified in fish and wildlife throughout the global aquatic and marine environments [6]. Studies conducted in Lake Ontario indicated that biomagnification of 2,3,7,8-tetrachlorodibenzo-*p*-dioxin (2,3,7,8-TCDD) appears to be significant between fish and fish-eating birds but not between fish and their food. When calculated for older predaceous fish such as lake-trout-eating young smelt, the biomagnification factor (BMF) can equal 3. The BMF from alewife to herring gulls in Lake Ontario was 32 for 2,3,7,8-TCDD [7]. A log BMF of -0.40 was determined for mink [2].

EPA has developed risk-based concentrations of 2,3,7,8-TCDD in different media that present low and high risk to fish, mammalian, and avian wildlife. These concentrations were developed based on toxic effects of 2,3,7,8-TCDD and its propensity to bioaccumulate in fish, mammals, and birds.

Environmental Concentrations Associated With 2,3,7,8-TCDD Risk to Aquatic Life and Associated Wildlife [8]

Organism	Fish Concentration (pg/g)	Sediment Concentration (pg/g dry wt.)	Water Concentration (pg/L)	
			POC=0.2	POC=1.0
Low Risk				
Fish	50	60	0.6	3.1
Mammalian Wildlife	0.7	2.5	0.008	0.04
Avian Wildlife	6	21	0.07	0.35
High Risk to Sensitive Species				
Fish	80	100	1	5
Mammalian Wildlife	7	25	0.08	0.4
Avian Wildlife	60	210	0.7	3.5

Note: POC - Particulate organic carbon
Fish lipid of 8% and sediment organic carbon of 3% assumed where needed.
For risk to fish, BSAF of 0.3 used; for risk to wildlife, BSAF of 0.1 used.
Low risk concentrations are derived from no-effects thresholds for reproductive effects (mortality in embryos and young) in sensitive species.
High risk concentrations are derived from TCDD doses expected to cause 50 to 100% mortality in embryos and young of sensitive species.

Aquatic Organisms

Partitioning Factors: In one study, steady-state BSAFs for invertebrates exposed to 2,3,7,8-TCDF in the laboratory ranged from about 0.3 to 0.7. The BSAF for carp collected from a reservoir in central Wisconsin was 0.06.

Food Chain Multipliers: No specific food chain multipliers were identified for 2,3,7,8-TCDF. Food chain multiplier information was only available for 2,3,7,8-TCDD. Biomagnification of 2,3,7,8-TCDD does not appear to be significant between fish and their prey. Limited data for the base of the Lake Ontario lake trout food chain indicated little or no biomagnification between zooplankton and forage fish. BMFs based on fish consuming invertebrate species are probably close to 1.0 because of the 2,3,7,8-TCDD biotansformation by forage fish. BMFs greater than 1.0 might exist between some zooplankton species and their prey due to the lack of 2,3,7,8-TCDD biotransformation in invertebrates [8].

Toxicity/Bioaccumulation Assessment Profile

The polychlorinated dibenzo-*p*-dioxins (PCDDs) and polychlorinated dibenzofurans (PCDFs) each consist of 75 isomers that differ in the number and position of attached chlorine atoms. The PCDDs and PCDFs are polyhalogenated aromatic compounds and exhibit several properties common to this group of compounds. These compounds tend to be highly lipophilic and the degree of lipophilicity is increased with increasing ring chlorination [6]. In general, the PCDDs and PCDFs exhibit relative inertness to acids, bases, oxidation, reduction, and heat, increasing in environmental persistence and chemical stability with increasing chlorination [9,6]. Because of their lipophilic nature, the PCDDs and PCDFs have been detected in fish, wildlife, and human adipose tissue, milk, and serum [6].

Each isomer has its own unique chemical and toxicological properties. The most toxic of the PCDD and PCDF isomers is one of the 22 possible congeners of tetrachlorodibenzo-*p*-dioxin [9]. Toxicity equivalency factors (TEFs) have been developed by EPA relating the toxicities of other PCDD and PCDF isomers to that of 2,3,7,8-TCDD [10]. The biochemical mechanisms leading to the toxic response resulting from exposure to PCDDs and PCDFs are not known in detail, but experimental data suggest that an important role in the development of systemic toxicity resulting from exposure to these chemicals is played by an intracellular protein, the Ah receptor. This receptor binds halogenated polycyclic aromatic molecules, including PCDDs and PCDFs. In several mouse strains, the expression of toxicity of 2,3,7,8-TCDD-related compounds, including cleft palate formation, liver damage, effects on body weight gain, thymic involution, and chloracnegenic response, has been correlated with their binding affinity for the Ah receptor, and with their ability to induce several enzyme systems [10].

Toxicity Equivalency Factors (TEF) for PCDD and PCDF Isomers [10]

Isomer	TEF
Total TetraCDD	1
2,3,7,8-TCDD	1
Other TCDDs	0.01
Total PentaCDDs	0.5
2,3,7,8-PentaCDDs	0.5
Other PentaCDDs	0.005
Total HexaCDDs	0.04
2,3,7,8-HexaCDDs	0.04
Other HexaCDDs	0.0004
Total HeptaCDDs	0.001
2,3,7,8-HeptaCDDs	0.001
Other HeptaCDDs	0.00001
Total TetraCDFs	0.1
2,3,7,8-TetraCDF	0.1
Other TetraCDFs	0.001
Total PentaCDFs	0.1
2,3,7,8-PentaCDFs	0.1
Other PentaCDFs	0.001
Total HexaCDFs	0.01
2,3,7,8-HexaCDFs	0.01
Other HexaCDFs	0.0001
Total HeptaCDFs	0.001
2,3,7,8-HeptaCDFs	0.001
Other HeptaCDFs	0.00001

In natural systems, PCDDs and PCDFs are typically associated with sediments, biota, and the organic carbon fraction of ambient waters [7]. Congener-specific analyses have shown that the 2,3,7,8-substituted PCDDs and PCDFs were the major compounds present in most sample extracts [6]. Results from limited epidemiology studies are consistent with laboratory-derived threshold levels to 2,3,7,8-TCDD impairment of reproduction in avian wildlife. Population declines in herring gulls (*Larus argentatus*) on Lake Ontario during the early 1970s coincided with egg concentrations of 2,3,7,8-TCDD and related chemicals expected to cause reproductive failure based on laboratory experiments (2,3,7,8-TCDD concentrations in excess of 1,000 pg/g). Improvements in herring gull reproduction through the mid-1980s were correlated with declining 2,3,7,8-TCDD concentrations in eggs and lake sediments [8]. Based on limited information on isomer-specific analysis from animals at different trophic levels, it appears that at higher trophic levels, i.e., fish-eating birds and fish, there is a selection of the planar congeners with the 2,3,7,8-substituted positions [11].

PCDDs and PCDFs are accumulated by aquatic organisms through exposure routes that are determined by the habitat and physiology of each species. With log $K_{ow}>5$, exposure through ingestion of contaminated food becomes an important route for uptake in comparison to respiration of water [8]. The relative contributions of water, sediment, and food to uptake of 2,3,7,8-TCDD by lake trout in Lake Ontario was examined by exposing yearling lake trout to Lake Ontario smelt and sediment from Lake Ontario along with water at a 2,3,7,8-TCDD concentration simulated to be at equilibrium with the sediments. Food ingestion was found to contribute approximately 75 percent of total 2,3,7,8-TCDD [8]. There have been a number of bioconcentration studies of 2,3,7,8-TCDD using model ecosystem and single species exposure. Although there is variation in the actual log BCF values, in general, the algae and plants have the lowest BCF values, on the order of a few thousand. A value of 4.38 has been reported for the snail *Physa* sp. Crustacea and insect larva appear to have the next highest BCF values, followed by several species of fish, with the highest log BCF value of 4.79 [11].

Exposure of juvenile rainbow trout to 2,3,7,8-TCDD and -TCDF in water for 28 days resulted in adverse effects on survival, growth, and behavior at extremely low concentrations. A no-observed-effects concentration (NOEC) for 2,3,7,8-TCDD could not be determined because the exposure to the lowest dose of 0.038 ng/L resulted in significant mortality [12]. A number of biological effects have been reported in fish following exposure to 2,3,7,8-TCDD including enzyme induction, immunological effects, wasting syndrome, dermatological effects, hepatic effects, hematological effects, developmental effects, and cardiovascular effects [11].

Summary of Biological Effects Tissue Concentrations for 2,3,7,8-TCDF

Species: Taxa	Concentration, Units in[1]: Sediment	Water	Tissue (Sample Type)	Toxicity: Effects	Ability to Accumulate[2]: Log BCF	Log BAF	BSAF	Source: Reference	Comments[3]
Invertebrates									
Nereis virens, Sandworm	334±6 pg/g dw n = 6		112±51 pg/g dw (whole body)				~0.25	[13,14]	L; 180-day exposure; sediment TOC was 57 mg/kg; ~ indicates approximate value, as numbers were estimated from bar graphs
Macoma nasuta, Clam	334±6 pg/g dw n = 6		51.4±6.8 pg/g dw				~0.7	[13,14]	L; 120-day exposure; sediment TOC was 57 mg/kg; ~ indicates approximate value, as numbers were estimated from bar graphs
Palaemonetes pugio, Grass shrimp	334±6 pg/g dw n = 6		58.8±7.7 pg/g dw				~0.6	[13,14]	L; 28-day exposure; sediment TOC was 57 mg/kg; ~ indicates approximate value, as numbers were estimated from bar graphs

Summary of Biological Effects Tissue Concentrations for 2,3,7,8-TCDF

Species: Taxa	Concentration, Units in[1]: Sediment	Water	Tissue (Sample Type)	Toxicity: Effects	Ability to Accumulate[2]: Log BCF	Log BAF	BSAF	Source: Reference	Comments[3]
Fishes									
Oncorhynchus mykiss (*Salmo gairdneri*), Rainbow trout		Water exposure 0.41 ng/L	2.5 µg/kg[4]	28-Day NOEC (growth)				[15]	L
		Water exposure 1.79 ng/L	7.6 µg/kg[4]	28-Day NOEC (survival)				[15]	
Oncorhynchus mykiss, Rainbow trout			0.00009 mg/kg (whole body)[4]	Growth, NOED				[15]	L
Salmonids							0.047	[22]	F
Cyprinus carpio, Carp	182 pg/g[4]		28 pg/g[4]				0.06	[16]	F; Petenwell Reservoir, central Wisconsin; BSAF based on 8% tissue lipid content and 3.1% sediment organic carbon

Summary of Biological Effects Tissue Concentrations for 2,3,7,8-TCDF

Species: Taxa	Concentration, Units in[1]: Sediment	Water	Tissue (Sample Type)	Toxicity: Effects	Ability to Accumulate[2]: Log BCF	Log BAF	BSAF	Source: Reference	Comments[3]
Wildlife									
Falco peregrinus, Peregrine falcon			30 ng/g (eggs) (n=6)	11.4% eggshell thinning				[19]	F; Kola Peninsula, Russia
Haliaeetus leucocephalus, Bald eagle chicks			Powell River site: 8,000 ng/kg lipid weight basis (yolk sac) Reference site: 500 ng/kg lipid weight basis (yolk sac)	A hepatic cytochrome P4501A cross-reactive protein (CYP1A) was induced nearly 6-fold in chicks from Powell River site compared to the reference ($p<0.05$). No significant concentration-related effects were found for morphological, physiological, or histological parameters.				[17]	F; southern coast of British Columbia; eggs were collected from nests and hatched in the laboratory.

Summary of Biological Effects Tissue Concentrations for 2,3,7,8-TCDF

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	Sediment	Water	Tissue (Sample Type)	Effects	Log BCF	Log BAF	BSAF	Reference	Comments[3]
Ardea herodias, Great blue heron chicks			Nicomekl site: <1 ng/kg (egg) n = 11					[18]	L; eggs were collected from three British Columbia colonies with different levels of contamination and incubated in the laboratory
			Vancouver site: 11±4.3 ng/kg (egg) n = 12	Depression of growth compared to Nicomekl site. Presence of edema.					
			Crofton site: 8±2.3 ng/kg (egg) n = 6	Depression of growth compared to Nicomekl site. Presence of edema.					

Summary of Biological Effects Tissue Concentrations for 2,3,7,8-TCDF

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	Sediment	Water	Tissue (Sample Type)	Effects	Log BCF	Log BAF	BSAF	Reference	Comments[3]
Aix sponsa, Wood duck			pg/g (eggs):	% eggs hatched:				[20]	F; central Arkansas; egg TEFs, hatching success, and duckling production were negatively correlated; clutch size was similar among wetland Sites 1-3, 9, 17, and 58 km downstream from point source of contamination, respectively, and Site 4, which was 111 km away on a separate drainage; duckling abnormalities were also noted; threshold range of reduced productivity was >20-50 ppt TEF
			Site 1 geometric mean: 26 (2.4-244)	47 (9.7 SE)					
			Site 2 geometric mean: 11 (1.4-60)	62 (10.1 SE)					
			Site 3 geometric mean: 5.4 (<1-22)	79 (3.8 SE)					
			Site 4 geometric mean: 0.3 (<1-3.2)	93 (3.4 SE)					

Summary of Biological Effects Tissue Concentrations for 2,3,7,8-TCDF

Species: Taxa	Concentration, Units in[1]: Sediment	Water	Tissue (Sample Type)	Toxicity: Effects	Ability to Accumulate[2]: Log BCF	Log BAF	BSAF	Source: Reference	Comments[3]
Mustela vison, Mink	Diet: 2 pg/g[5]		2 pg/g[5] (liver)	LOAEL; reduced kit body weights followed by reduced survival		No BMF reported		[21]	L; BMF= lipid-normalized concentration in the liver divided by the lipid-normalized dietary concentration
	4 pg/g[5]		2 pg/g[5] (liver)	Reduced kit body weights followed by reduced survival		Log BMF= -0.4			
	12 pg/g[5]		3 pg/g[5] (liver)	Significant decrease in number of live kits whelped per female		Log BMF= -0.4			

1 Concentration units based on wet weight, unless otherwise noted.
2 BCF = bioconcentration factor, BAF = bioaccumulation factor, BSAF = biota-sediment accumulation factor.
3 L = laboratory study, spiked sediment, single chemical; F = field study, multiple chemical exposure; other unusual study conditions or observations. noted.
4 This entry was excerpted directly from the Environmental Residue-Effects Database (ERED, www.wes.army.mil/el/ered, U.S. Army Corps of Engineers and U.S. Environmental Protection Agency). The original publication was not reviewed, and the reader is strongly urged to consult the publication to confirm the information presented here.
5 Not clear from reference if concentration is based on wet or dry weight.

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Chemical Category: POLYNUCLEAR AROMATIC HYDROCARBON (high molecular weight)

Chemical Name (Common Synonyms): FLUORANTHENE **CASRN:** 206-44-0

Chemical Characteristics

Solubility in Water: 0.20-0.26 mg/L [1]

Half-Life: 140-440 days, aerobic soil die-away test [2]

Log K_{ow}: 5.12 [3]

Log K_{oc}: 5.03 L/kg organic carbon

Human Health

Oral RfD: 4 x 10^{-2} mg/kg-day [4]

Confidence: Low, uncertainty factor = 3000

Critical Effect: Nephropathy, increased liver weights, hematological alterations, and clinical effects

Oral Slope Factor: No data [4]

Carcinogenic Classification: D [4]

Wildlife

Partitioning Factors: Partitioning factors for fluoranthene in wildlife were not found in the literature.

Food Chain Multipliers: Food chain multipliers for fluoranthene in wildlife were not found in the literature.

Aquatic Organisms

Partitioning Factors: The water quality criterion tissue level (WQCTL) for fluoranthene, which is calculated by multiplying the water quality chronic value (16 µg/L) by the BCF (1741.8), is 27,869 µg/kg [5]. Salinity and particle size of the sediment had no or very little effect on survival of three amphipod species during exposure to fluoranthene [6]. Log BCFs ranged from -0.92 for *Lumbriculues variegatus* [16] to 0.63 for *Hyallela azteca* [9]. Log BAFs of 0.36 to 0.56 were calculated for the midges *Chironomus tentans* [24].

Food Chain Multipliers: Food chain multipliers for fluoranthene in aquatic organisms were not found in the literature.

Toxicity/Bioaccumulation Assessment Profile

Polynuclear aromatic hydrocarbons, (PAHs) are readily metabolized and excreted by fish and invertebrates [7], affecting bioaccumulation kinetics and equilibrium tissue residues. According to McCarty et al. [8], the toxic body residue of individual PAHs in tissues ranged from 513 to 4,248 mg/kg.

The concentration of 382 ppb produced biological effects in environmental samples (Puget Sound). The LC50 values for fluoranthene using freshwater amphipods ranged from 11.7 to 150.3 nmol/g dry weight [9].

Fluoranthene is relatively toxic to aquatic species (10-day EC50 = 2.3 to 7.4 µg/L for *H. azteca*, 10-day EC50 = 3.0 to 8.7 µg/L *C. tentans*). Its toxicity increased 6- to 17-fold under UV light [10]. *H. azteca* accumulated up to 1,131 µg/g of fluoranthene during 10 days of exposure to the LC50 concentration. Below the toxic level, the concentration of fluoranthene in amphipod tissue reached 200 to 400 µg/g within the first 48 hours and then dropped to 100 µg/g [9]. During 30-day bioaccumulation exposures, fed *H. azteca* accumulated significantly more fluoranthene than unfed organisms [11]. Furthermore, in exposures in which food was added, organisms gained weight and reproduced, even when sediment was dosed with concentrations approximately 20 to 90 times the 10-day LC50 value, with sediment containing levels of organic carbon comparable to the Suedel et al. [12] experiments. These data suggest that animals in fed exposures preferentially consumed the food, given the relatively high accumulation of compound in animal tissue. Mortality due to narcosis, the mechanism thought to be responsible for PAH toxicity, ranged from 2 to 8 µmol/g for acute responses and 0.2 to 0.8 µmol/g for chronic exposures in fish [13]. In the study by Harkey et al. [11], animals accumulated up to 1.4 µmol/g after 30 days in the highest (1,004 nmol/g) sediment concentration. Previous water-only exposures [14] predicted that a body burden of 5.6 µmol/g in *H. azteca* needs to be attained to produce 50 percent mortality. The body burden of fluoranthene associated with 50 percent mortality of *Leptocheirus plumulosus* was 0.69 µmol/g wet wt, which is lower than the predicted critical body residue for nonpolar narcotic compounds [15].

Summary of Biological Effects Tissue Concentrations for Fluoranthene

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	Sediment	Water	Tissue (Sample Type)	Effects	Log BCF	Log BAF	BSAF	Reference	Comments[3]
Invertebrates									
Lumbriculus variegatus, Oligochaete worm					-0.92			[16]	F
Nereis succinea, Polychaete worm	0.218 µg/g OC 0.436 µg/g OC 0.48 µg/g OC 1.4 µg/g OC 4.55 µg/g OC 10.2 µg/g OC 19.5 µg/g OC 30.1 µg/g OC		9.20 µg/g lipid – 2.55 µg/g lipid 35.6 µg/g lipid 4.80 µg/g lipid 3.79 µg/g lipid 14.1 µg/g lipid 24.0 µg/g lipid					[17]	F
Nereis virens, Sand worm					-0.096 or -0.10 -0.02 0.52			[18]	F
Modiolus demissus, Northern horse mussel					0.36			[19]	F
Mytilus edulis, Blue mussel					-0.44			[19]	F

Summary of Biological Effects Tissue Concentrations for Fluoranthene

Species:	**Concentration, Units in[1]:**			**Toxicity:**	**Ability to Accumulate[2]:**			**Source:**	
Taxa	**Sediment**	**Water**	**Tissue (Sample Type)**	**Effects**	**Log BCF**	**Log BAF**	**BSAF**	**Reference**	**Comments[3]**
Mytilus edulis, Mussel			627 mg/kg (whole body)[4]	Physiological, ED50				[27]	L; 50% reduction in feeding rate
			1.9 mg/kg (whole body)[4]	Physiological, ED50				[28]	L; 50% reduction in feeding, clearance rate and tolerance to aerial exposure
			0.112 mg/kg (whole body)	Physiological, LOED				[28]	L; elevated activity of superoxide dimutase (SOD)
			1.5 mg/kg (whole body)[4]	Physiological, LOED				[28]	L; inhibition of superoxide dimutase (SOD) and catalase activity
			1.5 mg/kg (whole body)[4]	Reproduction, LOED				[28]	L; reduced gametogenesis, reproductive success rate
Crassostrea virginica, Eastern oyster			62 mg/kg (whole body)[4]	Morphology, LOED				[30]	L; thickness of digestive epithelium
Crassostrea virginica, Eastern oyster					-0.15 -0.28			[19]	F

Summary of Biological Effects Tissue Concentrations for Fluoranthene

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	Sediment	Water	Tissue (Sample Type)	Effects	Log BCF	Log BAF	BSAF	Reference	Comments[3]
Macoma balthica, Baltic macoma	0.218 µg/g OC 0.436 µg/g OC 0.48 µg/g OC 1.4 µg/g OC 4.55 µg/g OC 10.2 µg/g OC 19.5 µg/g OC 30.1 µg/g OC		7.62 µg/g lipid 5.12 µg/g lipid – 96.2 µg/g lipid 7.48 µg/g lipid 5.73 µg/g lipid 17.2 µg/g lipid –					[17]	F
Macoma nasuta, Clam					0.58 0.39 -0.26			[18]	F
Mercenaria mercenaria, Northern quahog					-0.05			[19]	F
Mya arenaria, Softshell					-0.08			[19]	F
Daphnia magna, Cladoceran		9 µg/L	77 nM/g		0.51			[20]	L

Summary of Biological Effects Tissue Concentrations for Fluoranthene

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	Sediment	Water	Tissue (Sample Type)	Effects	Log BCF	Log BAF	BSAF	Reference	Comments[3]
Hyalella azteca, Amphipod		14.2 µg/L	25.6 µg/g		0.51			[9]	L
			44.0 µg/g		0.54				
			44.8 µg/g		0.54				
			65.7 µg/g		0.56				
			78.4 µg/g		0.57				
Hyalella azteca, Amphipod		56.7 µg/L	169 µg/g		0.59			[9]	L
			320 µg/g		0.55				
			458 µg/g		0.57				
			751 µg/g		0.54				
		86.2 µg/L	350 µg/g		0.60			[9]	L
			531 µg/g		0.59				
			714 µg/g		0.58				
			800 µg/g		0.62				
			1,192 µg/g		0.61				
		100.8 µg/L	644 µg/g		0.61				
			898 µg/g		0.59				
			1,074 µg/g		0.60				
			1,199 µg/g		0.56				
			1,248 µg/g		0.58				
		41.5 µg/L	307 µg/g		0.58				
			363 µg/g		0.59				
			515 µg/g		0.60				
			517 µg/g		0.63				
			763 µg/g		0.63				
			815 µg/g		0.60				
			852 µg/g		0.61				
		98.3 µg/L	566 µg/g		0.61				
			825 µg/g		0.61				
			829 µg/g		0.61				
			1,035 µg/g		0.63				
			1,171 µg/g		0.60				
			1,213 µg/g		0.61				
			1,310 µg/g		0.58				

Summary of Biological Effects Tissue Concentrations for Fluoranthene

Species:	**Concentration, Units in[1]:**			**Toxicity:**	**Ability to Accumulate[2]:**			**Source:**	
Taxa	**Sediment**	**Water**	**Tissue (Sample Type)**	**Effects**	**Log BCF**	**Log BAF**	**BSAF**	**Reference**	**Comments[3]**
Hyalella azteca, Amphipod		168.0 µg/L	855 µg/g		0.61				
			884 µg/g		0.59				
			971 µg/g		0.60				
			988 µg/g		0.58				
			1,265 µg/g		0.59				
			1,375 µg/g		0.60				
		184.7 µg/L	746 µg/g		0.57				
			896 µg/g		0.58				
			1,208 µg/g		0.57				
			1,302 µg/g		0.59				
			1,382 µg/g		0.59				
			1,445 µg/g		0.58				
			1,581 µg/g		0.57				
	158 nmol/g		Day 1: 160 nmol/g	no mortality				[11]	L
			Day 2: 140 nmol/g	no mortality					
			Day 3: 60 nmol/g	no mortality					
			Day 10: 90 nmol/g	no mortality					
			Day 17: 110 nmol/g	no mortality					
			Day 30: 120 nmol/g	no mortality					
	634 nmol/g		Day 1: 900 nmol/g	no mortality					
			Day 2: 1,050 nmol/g	no mortality					
			Day 3: 850 nmol/g	no mortality					
			Day 10: 700 nmol/g	no mortality					
			Day 17: 700 nmol/g	40% mortality					
			Day 30:800 nmol/g	40% mortality					
Hyalella azteca, Amphipod	1267 nmol/g		Day 1: 1,000 nmol/g	no mortality					
			Day 2: 850 nmol/g	no mortality					
			Day 3: 950 nmol/g	no mortality					
			Day 10: 700 nmol/g	no mortality					
			Day 17: 800 nmol/g	35% mortality					
			Day 30: 1,100 nmol/g	65% mortality					

Summary of Biological Effects Tissue Concentrations for Fluoranthene

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	**Sediment**	**Water**	**Tissue (Sample Type)**	**Effects**	**Log BCF**	**Log BAF**	**BSAF**	**Reference**	**Comments[3]**
Leptocheirus plumulosus, Amphipod		38 µg/L or 187 nmol/L	0.68 µmol/g	50% mortality				[15]	L; critical body residue
		36 nmol/L							
		77 nmol/L	78 nmol/g	100% survival					
		143 nmol/L	226 nmol/g	100% survival					
		285 nmol/L	369 nmol/g	93% survival					
			721 nmol/g	46% survival					
Pontoporeia hoyi, Amphipod	60 ng/g	5 ng/mL	2,000 ng/g					[21]	L
	270 ng/g	4 ng/mL	2,000 ng/g						
	1000 ng/g	4 ng/mL	1,000 ng/g						
	21.3 nmol/g		7-12 nmol/g			1.04-1.36		[14]	L
	41.1 nmol/g		28-57 nmol/g						
	119.5 nmol/g		68-149 nmol/g						
	327.0 nmol/g		71-614 nmol/g						
Rhepoxynius abronius, Amphipod	12.09 mg/kg	14.3 µg/L		23% mortality				[22]	L
	14.50 mg/kg			52% mortality					
	25.11 mg/kg			92% mortality					
Chironomus riparius, Midge	4,040 µg/kg		181,000 µg/kg					[23]	L
Chironomus tentans Midge	377 $\mu g/g_{oc}$	4 µg/L	9,593 ng/g (larvae)			0.36		[24]	L
			22 ng/g (adult)			0.36			
	1,220 $\mu g/g_{oc}$	12 µg/L	33,455 ng/g (larvae)			0.41			
			257 ng/g (adult)			0.41			
	1,853 ug/g_{oc}	19 µg/L	72,790 ng/g (larvae)			0.56			
			9,810 ng/g (adult)			0.56			

Summary of Biological Effects Tissue Concentrations for Fluoranthene

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	Sediment	Water	Tissue (Sample Type)	Effects	Log BCF	Log BAF	BSAF	Reference	Comments[3]
Fishes									
Oncorhynchus mykiss, Rainbow trout			379 µg/g, liver					[25]	F
Cyprinus carpio, Common carp			183 mg/kg (liver)	Physiological, NOED				[29]	L; no significant increase in erod enzyme and P450 1a protein content
Lepomis macrochirus, Bluegill	4,040 µg/kg		600 µg/kg					[23]	L
Pleuronectes vetulus, English sole	320-25,000 ng/g		<6.6 ng/g liver <2.6 ng/g muscle					[26]	F

[1] Concentration units based on wet weight unless otherwise noted.
[2] BCF = bioconcentration factor, BAF = bioaccumulation factor, BSAF = biota-sediment accumulation factor.
[3] L = laboratory study, spiked sediment, single chemical; F = field study, multiple chemical exposure; other unusual study conditions or observations noted.
[4] This entry was excerpted directly from the Environmental Residue-Effects Database (ERED, www.wes.army.mil/el/ered, U.S. Army Corps of Engineers and U.S. Environmental Protection Agency). The original publication was not reviewed, and the reader is strongly urged to consult the publication to confirm the information presented here.

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Chemical Category: PESTICIDE (ORGANOCHLORINE)

Chemical Name (Common Synonyms): HEPTACHLOR **CASRN:** 76-44-8

Chemical Characteristics

Solubility in Water: 0.03 mg/L [1]

Half-Life: No data [2]

Log K_{ow}: 6.26 [3]

Log K_{oc}: 6.15 L/kg organic carbon

Human Health

Oral RfD: 5×10^{-4} mg/kg/day [4]

Confidence: Low, uncertainty factor = 300 [4]

Critical Effect: Liver weight increases in rats; benign and malignant liver tumors in mice

Oral Slope Factor: $4.5 \times 10^{+0}$ per (mg/kg)/day [4]

Carcinogenic Classification: B2 [4]

Wildlife

Partitioning Factors: Partitioning factors for heptachlor in wildlife were not found in the literature.

Food Chain Multipliers: Food chain multipliers for heptachlor in wildlife were not found in the literature.

Aquatic Organisms

Partitioning Factors: Log BCFs ranged from 5.30 to 11.70 for invertebrates and log BCFs for fishes ranged from 3.87 to 19.34.

Food Chain Multipliers: Food chain multipliers (FCMs) for trophic level 3 aquatic organisms were 20.8 (all benthic food web), 1.6 (all pelagic food web), and 12.7 (benthic and pelagic food web). FCMs for trophic level 4 aquatic organisms were 45.8 (all benthic food web), 3.4 (all pelagic food web), and 21.7 (benthic and pelagic food web) [18].

Toxicity/Bioaccumulation Assessment Profile

Hepatchlor is the most widely used insecticide in the organochlorine class [5]. Heptachlor is resistent to degradation and, therefore, persistent in the environment. Heptachlor acute toxic effects in animals are principally due to hyperexcitation in the nervous system and death is frequently ascribed to respiratory failure [5].

Heptachlor is relatively toxic to aquatic invertebrates. The acute toxicity of heptachlor ranged from 0.11 µg/L (96-h LC50) for *Penaeus duorarum* to 1.5 µg/L (96-h LC50) for *Crassostrea virginica* [6]. Fish are also relatively sensitive to heptachlor. The 96-h LC50 values based on the exposure of sheepshead minnows, pinfish, and spot were 3.68, 3.77, and 0.85µg/L, respectively [6].

Laboratory bioaccumulation exposures with spot showed that heptachlor was metabolized to heptachlor epoxide at all concentrations tested [7]. After 3 days of exposure, heptachlor concentrations averaged 52 percent of total residues. At the end of depuration the relative amount of heptachlor decreased to 10 percent, while heptachlor epoxide increased to 44 percent. Cooking (baking, charbroiling, canning, pan frying and deep frying) reduced the heptachlor contents by an average 40 percent in chinook salmon fillets [8].

Heptachlor was among chemicals responsible for the widespread decline of peregrine falcon populations [9]. Heptachlor concentrations above 4 mg/kg in brain is critical and could be associated with falcon mortality, while a concentration above 1.5 mg/kg in eggs was associated with lower reproductive success of falcons [9]. Birds whose life cycle depends on the aquatic environment contained higher residues of heptachlor in their tissue than the seed eaters [10]. The tissues of red-winged blackbirds and tree swallows demonstrated geographically distinct levels of chlorinated hydrocarbons including heptachlor [11]. The spatial variation of heptachlor concentration in eggs correlated significantly with those found in sediments. Higher concentrations of heptachlor in chick tissue rather than in eggs pointed to a local source of uptake through their diet [11].

Summary of Biological Effects Tissue Concentrations for Heptachlor

Species:	**Concentration, Units in[1]:**			**Toxicity:**	**Ability to Accumulate[2]:**			**Source:**	
Taxa	**Sediment**	**Water**	**Tissue (Sample Type)**	**Effects**	**Log BCF**	**Log BAF**	**BSAF**	**Reference**	**Comments[3]**
Invertebrates									
Crassostrea virginica, Eastern oyster		0.08 µg/L	0.43 µg/g	30% shell reduction	7.59			[6]	L
		0.4 µg/L	3.1 µg/g	28% shell reduction				[6]	L
		0.91 µg/L	7.7 µg/g	33% shell reduction				[6]	L
		4 µg/L	18 µg/g	78% shell reduction				[6]	L
		14 µg/L	55 µg/g	98% shell reduction				[6]	L
Crassostrea virginica, Eastern oyster			0.021 mg/kg (whole body)[4]	Growth, ED18				[6]	L; exposure media 65% heptachlor (technical grade)
			0.016 mg/kg (whole body)[4]	Growth, NOED				[6]	L; exposure media 65% heptachlor (technical grade)
Mercenaria mercenaria, Quahog clam			0.11 mg/kg (whole body)[4]	Behavior, NOED				[15]	L; no effect on feeding activity
Mya arenaria, Soft shell clam			1.3 mg/kg (whole body)[4]	Behavior, NOED				[15]	L; no effect on feeding activity
Penaeus duorarum, Pink shrimp		0.04 µg/L	0.01 µg/g	5% mortality	5.30			[6]	L
		0.2 µg/L	0.033 µg/g	82% mortality				[6]	L

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Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	**Sediment**	**Water**	**Tissue (Sample Type)**	**Effects**	**Log BCF**	**Log BAF**	**BSAF**	**Reference**	**Comments[3]**
Palaemonetes vulgaris, Grass shrimp		0.13 µg/L	0.062 ug/g	6% mortality	11.70			[6]	L
		0.44 µg/L	0.2 µg/g	13% mortality				[6]	L
		2 µg/L	0.97 µg/g	70% mortality				[6]	L
		5 µg/L	3.6 µg/g	95% mortality				[6]	L
Fishes									
Oncorhynchus tshawytscha, Chinook salmon			27.9 µg/kg in eggs	Rearing mortality				[12]	F
Cyprinodon variegatus, Sheepshead minnow		2.7 µg/L	20 µg/g	15% mortality	3.87			[6]	L
		3.3 µg/L	33 µg/g	50% mortality				[6]	L
		3.6 µg/L	34 µg/g	50% mortality				[6]	L
		4.0 µg/L	85 µg/g	60% mortality				[6]	L
Cyprinodon variegatus, Sheepshead minnow		8.8 µg/L	133 µg/g	85% mortality	4.33			[6]	L
Cyprinodon variegatus, Sheepshead minnow			4.5 mg/kg (whole body)[4]	Behavior, LOED				[16]	L; decreased swimming activity
			4.8 mg/kg (whole body)[4]	Behavior, LOED				[16]	L; hyperkinetic behavior
			10.4 mg/kg (whole body)[4]	Behavior, NA				[16]	L; hyperkinetic behavior

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Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	**Sediment**	**Water**	**Tissue (Sample Type)**	**Effects**	**Log BCF**	**Log BAF**	**BSAF**	**Reference**	**Comments[3]**
			10.4 mg/kg (whole body)[4]	Mortality, NA				[16]	L; 39% decline in survivorship
			4.5 mg/kg (whole body)[4]	Cellular, NOED				[16]	L; no effect on liver, kidney, pancreas, digestive tract histopathology
			4.8 mg/kg (whole body)[4]	Cellular, NOED				[16]	L; no effect on liver, kidney, pancreas, digestive tract histopathology
			10.4 mg/kg (whole body)[4]	Cellular, NOED				[16]	L; no effect on liver, kidney, pancreas, digestive tract histopathology
			4.5 mg/kg (whole body)[4]	Mortality, NOED				[16]	L; no significant effect on mortality
			4.8 mg/kg (whole body)[4]	Mortality, NOED				[16]	L; no significant effect on mortality
			16 mg/kg (whole body)[4]	Mortality, LOED				[17]	L; increase in fry mortality
			26 mg/kg (whole body)[4]	Reproduction, LOED				[17]	L; decreased egg production of adults
			211 mg/kg (whole body)[4]	Reproduction, LOED				[17]	L; decreased fertility of eggs produced by adults
			0.022 mg/kg (whole body)[4]	Mortality, ED5				[6]	L; exposure media 65% heptachlor (technical grade)
Leiostomus xanthurus, Spot		0.14 µg/L	0.34 µg/g		19.34			[7]	L
		0.26 µg/L	0.64 µg/g	25% mortality				[7]	L
		0.58 µg/L	1.73 µg/g	35% mortality				[7]	L
		1.03 µg/L	3.70 µg/g					[7]	L
		0.5 µg/L	1.5 µg/g					[7]	L
		0.65 µg/L	2.3 µg/g					[7]	L

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Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	Sediment	Water	Tissue (Sample Type)	Effects	Log BCF	Log BAF	BSAF	Reference	Comments[3]
Leiostomus xanthurus, Spot			2.6 mg/kg (whole body)[4]	Mortality, ED40				[6]	L; exposure media 65% heptachlor (technical grade)
			0.01 mg/kg (whole body)[4]	Mortality, NOED				[6]	L; exposure media 65% heptachlor (technical grade)
			0.01 mg/kg (whole body)[4]	Mortality, NOED				[6]	L; exposure media 65% heptachlor (technical grade)
Lagodon rhomboides, Pinfish			5.7 mg/kg (whole body)[4]	Mortality, NOED				[6]	L; exposure media 65% heptachlor (technical grade)
Wildlife									
Falco peregrinus anatum, American peregrine			0.018-2.070 mg/kg in eggs (1965-1986)					[9]	F
Falco peregrinus pealei, Peale's peregrine			0.015-0.049 mg/kg in eggs (1965-1986)					[9]	F
Falco peregrinus tundrius, Arctic peregrine			0.087-2.710 mg/kg in eggs (1965-1987)					[9]	F

Summary of Biological Effects Tissue Concentrations for Heptachlor

Species: Taxa	Concentration, Units in[1]: Sediment	Water	Tissue (Sample Type)	Toxicity: Effects	Ability to Accumulate[2]: Log BCF	Log BAF	BSAF	Source: Reference	Comments[3]
Martes americana, Marten			0.3 - 4.5 µg/kg in muscle; 9.1 - 12.7 µg/kg in liver					[14]	F
Martes pennanti, Fishers			1 - 5.7 µg/kg in muscle 5.8 -17µg/kg in liver					[14]	F
Quail			0.86 - 1.15 mg/kg					[13]	F
Woodcock			0.86 - 1.29 mg/kg					[13]	F
Agelaius phoeniceus, Red-winged blackbird	0.2 ng/g		4.1 ng/g in eggs		1.05			[11]	F
	0.2 ng/g		3.7 ng/g in eggs		2.34			[11]	F
	0.2 ng/g		4.3 ng/g in eggs		1.71			[11]	F

1 Concentration units based on wet weight unless otherwise noted.
2 BCF = bioconcentration factor, BAF = bioaccumulation factor, BSAF = biota-sediment accumulation factor.
3 L = laboratory study, spiked sediment, single chemical; F = field study, multiple chemical exposure; other unusual study conditions or observations noted.
4 This entry was excerpted directly from the Environmental Residue-Effects Database (ERED, www.wes.army.mil/el/ered, U.S. Army Corps of Engineers and U.S. Environmental Protection Agency). The original publication was not reviewed, and the reader is strongly urged to consult the publication to confirm the information presented here.

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Chemical Category: METAL

Chemical Name (Common Synonyms): LEAD **CASRN:** 7439-92-1

Chemical Characteristics

Solubility in Water: Insoluble [1] **Half-Life:** Not applicable, stable [1]

Log K_{ow}: – **Log K_{oc}:** –

Human Health

Oral RfD: Not available [2] **Confidence:** –

Critical Effect: Changes in levels of certain blood enzymes, altered neurobehavioral development of children. (These changes may occur at blood lead levels so low as to be essentially without a threshold; therefore, the RfD workgroup determined that it was inappropriate to develop an RfD for inorganic lead.)

Oral Slope Factor: Not available [2] **Carcinogenic Classification:** B2 [2]

Wildlife

Partitioning Factors: Partitioning factors for lead in wildlife were not found in the literature.

Food Chain Multipliers: Food chain multipliers for lead in wildlife were not found in the literature.

Aquatic Organisms

Partitioning Factors: Lead is most soluble in water and is bioavailable at low pH, low organic content, and low concentrations of calcium, iron, manganese, zinc, and cadmium. Lead is capable of forming insoluble metal sulfides and can easily complex with humic acid. The common forms of dissolved lead are lead sulfate, lead chloride, lead hydroxide, and lead carbonate, but the distribution of salts is highly dependent on the pH of the water. Most lead entering surface waters is precipitated in the sediment as carbonates or hydroxides [8]. Log BCFs of 5.15 (cladoceran) [12] and 3.56 (midge) [9] were reported in the literature.

Food Chain Multipliers: Although methylated lead is rapidly taken out from the water, e.g., by rainbow trout, there is no evidence of biomagnification in the aquatic environment [6 and 7].

Toxicity/Bioaccumulation Assessment Profile

The amount of bioavailable lead in sediment is controlled, in large part, by the concentration of acid volatile sulfides (AVS) and organic mater [3,4,5]. Lead is accumulated by aquatic organisms equally from water and through dietary exposure [6]. In the sediments, a portion of lead can be transformed to trimethyllead and tetraalkyllead compounds through chemical and microbial processes. The organolead compounds are much more toxic to aquatic organisms than are the inorganic lead compounds [7]. Bioaccumulation of organolead compounds is rapid and high; these compounds concentrate in the fatty tissues of aquatic organisms. Babukutty and Chacko [8] and others reported a strong correlation between soft tissue concentration of lead in worms and that in the exchangeable fraction of the sediment.

In vertebrates, lead is known to modify the structure and function of the kidney, bone, central nervous system, and the hematopoietic system. It produces adverse biochemical, histopathological, neuropsychological, ferotoxic, teratogenic, and reproductive effects. Inhibition of blood delta aminolevulnic acid dehydratase (ALAD), an enzyme critical in heme formation, has been observed as a result of exposure to lead in a variety of fish, invertebrates, and birds. At sufficiently high concentrations, lead effects are manifested in aquatic organisms as reduced growth, fecundity, and survivorship [9].

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Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	Sediment	Water	Tissue (Sample Type)	Effects	Log BCF	Log BAF	BSAF	Reference	Comments[3]
Eichhornia crassipes, Water hyacinth			4.4 mg/kg (leaf)	Growth, NOED				[20]	L; no effect on growth
			4.6 mg/kg (leaf)	Growth, NOED				[20]	L; no effect on growth
			135 mg/kg (root)	Growth, NOED				[20]	L; no effect on growth
			259 mg/kg (root)	Growth, NOED				[20]	L; no effect on growth
			598 mg/kg (root)	Growth, NOED				[20]	L; no effect on growth
			1030 mg/kg (root)	Growth, NOED				[20]	L; no effect on growth
			6 mg/kg (stem)	Growth, NOED				[20]	L; no effect on growth
			16.6 mg/kg (stem)	Growth, NOED				[20]	L; no effect on growth
			48.8 mg/kg (stem)	Growth, NOED				[20]	L; no effect on growth
			70.6 mg/kg (stem)	Growth, NOED				[20]	L; no effect on growth
			4.4 mg/kg (leaf)	Morphology, NOED				[20]	L; no effect on plant appearance
			4.6 mg/kg (leaf)	Morphology, NOED				[20]	L; no effect on plant appearance
			135 mg/kg (root)	Morphology, NOED				[20]	L; no effect on plant appearance
			259 mg/kg (root)	Morphology, NOED				[20]	L; no effect on plant appearance
			598 mg/kg (root)	Morphology, NOED				[20]	L; no effect on plant appearance
			1,030 mg/kg (root)	Morphology, NOED				[20]	L; no effect on plant appearance
			6 mg/kg (stem)	Morphology, NOED				[20]	L; no effect on plant appearance
			16.6 mg/kg (stem)	Morphology, NOED				[20]	L; no effect on plant appearance
			48.8 mg/kg (stem)	Morphology, NOED				[20]	L; no effect on plant appearance
			70.6 mg/kg (stem)	Morphology, NOED				[20]	L; no effect on plant appearance

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Species: Taxa	Concentration, Units in[1]: Sediment	Water	Tissue (Sample Type)	Toxicity: Effects	Ability to Accumulate[2]: Log BCF	Log BAF	BSAF	Source: Reference	Comments[3]
Invertebrates									
Invertebrates, field-collected	Total µg/g / SEM µg/g	Filt µg/L / Nonfilt µg/L	Body					[15]	F
	679 / 569	<0.2 / 276	67 µg/g						
	113 / 62	1.2 / 120	11 µg/g						
	99 / 55	0.2 / 38	10 µg/g						
	86 / 50	0.3 / 35	32 µg/g						
	38 / 19	<0.2 / 9	4 µg/g						
	14 / 4	0.4 / 24	0.5 µg/g						
Tubificidae, Oligochaete worms	365 µg/g		16.5 mg/g					[14]	F
	138 µg/g		3.7 mg/g						
	375 µg/g		23.5 mg/g						
	297 µg/g		35.8 mg/g						
	283 µg/g		22.6 mg/g						
Nereis diversicolor, Polychaete worm	44 µg/g		5.9 µg/g					[10]	F
	154 µg/g		4.4 µg/g						
	35 µg/g		3.4 µg/g						
	21 µg/g		0.7 µg/g						
	299 µg/g		5.8 µg/g						
	287 µg/g		4.9 µg/g						
	359 µg/g		3.5 µg/g						
Dreissena polymorpha, Zebra mussel			200 mg/kg (whole body)[6]	Physiological, ED100				[21]	L; mussels stopped filtering
			200 mg/kg (whole body)[6]	Mortality, LOED				[21]	L; increased mortality
			30 mg/kg (whole body)[6]	Physiological, LOED				[21]	L; reduced filtration rate
			2 mg/kg (whole body)[6]	Mortality, NOED				[21]	L; no effect on mortality

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Species: Taxa	Concentration, Units in[1]: Sediment	Water	Tissue (Sample Type)	Toxicity: Effects	Ability to Accumulate[2]: Log BCF	Log BAF	BSAF	Source: Reference	Comments[3]
			4 mg/kg (whole body)[6]	Mortality, NOED				[21]	L; no effect on mortality
			6 mg/kg (whole body)[6]	Mortality, NOED				[21]	L; no effect on mortality
			30 mg/kg (whole body)[6]	Mortality, NOED				[21]	L; no effect on mortality
			2 mg/kg (whole body)[6]	Physiological, NOED				[21]	L; no effect on filtration rate
			4 mg/kg (whole body)[6]	Physiological, NOED				[21]	L; no effect on filtration rate
			6 mg/kg (whole body)[6]	Physiological, NOED				[21]	L; no effect on filtration rate
Elliptio complanata, Freshwater mussel	<0.9-28.8 µg/g		ND[4] (foot) ND (muscle) 5.8 µg/g (visceral) 13.0 µg/g (hepatopancreas) 18.8 µg/g (gills) 13.9 µg/g (mantle)					[16]	F
	<0.9-97.5 µg/g		5.5 µg/g (foot) 3.8 µg/g (muscle) 6.9 µg/g (visceral) 14.3 µg/g (hepatopancreas) 36.0 µg/g (gills) 33.3 µg/g (mantle)						

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Species: Taxa	Concentration, Units in[1]: Sediment	Water	Tissue (Sample Type)	Toxicity: Effects	Ability to Accumulate[2]: Log BCF	Log BAF	BSAF	Source: Reference	Comments[3]
	<0.9-100.0 µg/g		ND (foot) ND (muscle) 6.0 µg/g (visceral) 15.3 µg/g (hepatopancreas) 35.4 µg/g (gills) 35.6 µg/g (mantle)						
Balanus crenatus, Barnacle			90 mg/kg (whole body)[6]	Behavior, NOED				[23]	L; regulation of metals endpoint - summer experiment
Daphnia magna, Cladoceran			1,880 mg/kg (whole body)[6]	Reproduction, ED10				[12]	L; 10% reduction in number of offspring
			5,040 mg/kg (whole body)[6]	Mortality, ED50				[12]	L; lethal body burden after 21-day exposure
Hyallela azteca, Amphipod		3.3 µg/L 2.6 µg/L 11.6 µg/L 8.8 µg/L 12.6 µg/L 24.0 µg/L	5.8 µg/g 7.1 µg/g 15.8 µg/g 19.2 µg/g 30.0 µg/g 20.9 µg/g	60% survival 65% survival 48% survival 31% survival 11% survival 4% survival				[11]	L
	Total SEM µg/g µg/g 679 569 113 62 99 55 86 50 38 19 14 4	Filt Nonfilt µg/L µg/L <0.2 276 1.2 120 0.2 38 0.3 35 <0.2 9 0.4 24	Body 7 µg/g 7 µg/g 6 µg/g 2 µg/g 6 µg/g 0.4 µg/g					[15]	F

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Hyalella azteca, Freshwater amphipod			70 mg/kg (whole body)[6]	Mortality, ED50				[22]	L; lethal body burden
			160 mg/kg (whole body)[6]	Mortality, ED50				[22]	L; lethal body burden
			90 mg/kg (whole body)[6]	Mortality, ED50				[22]	L; lethal body burden
			115 mg/kg (whole body)[6]	Mortality, ED50				[22]	L; lethal body burden
Pontoporeia affiniss, Amphipod			4 mg/kg (whole body)[6]	Mortality, NOED				[24]	L; body burden estimated from graph
			4 mg/kg (whole body)[6]	Mortality, NOED				[24]	L; body burden estimated from graph
	Total SEM µg/g µg/g	Filt Nonfilt µg/L µg/L	Body					[15]	F
	679 569	<0.2 276	7 µg/g						
	113 62	1.2 120	7 µg/g						
	99 55	0.2 38	6 µg/g						
	86 50	0.3 35	2 µg/g						
	38 19	<0.2 9	6 µg/g						
	14 4	0.4 24	0.4 µg/g						
Chironomus riparius, Midge		0.728 mg/L	2650 µg/g		3.56			[9]	L
Chironomus gr. thummi, Midge	13.99 mg/kg		12.80 mg/kg 16.22 mg/kg	normal larvae deformed larvae				[13]	F

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Taxa	**Sediment**	**Water**	**Tissue (Sample Type)**	**Effects**	**Log BCF**	**Log BAF**	**BSAF**	**Reference**	**Comments[3]**
Chironomus gr. thummi, Midge			2.56 mg/kg (whole body)[6]	Morphology, NOED				[13]	L, 4th instar larvae
Fishes									
Salvelinus fontinalis, Brook trout			24 mg/kg (gill)	Behavior, LOED				[19]	L; hyperactivity, erratic swimming, loss of equilibrium
			30 mg/kg (kidney)	Behavior, LOED				[19]	L; hyperactivity, erratic swimming, loss of equilibrium
			20 mg/kg (liver)	Behavior, LOED				[19]	L; hyperactivity, erratic swimming, loss of equilibrium
			3.2 mg/kg (red blood cells)	Behavior, LOED				[19]	L; hyperactivity, erratic swimming, loss of equilibrium
			70 mg/kg (gill)	Development, LOED				[19]	L; spinal deformities
			30 mg/kg (kidney)	Development, LOED				[19]	L; spinal deformities
			25 mg/kg (liver)	Development, LOED				[19]	L; spinal deformities
			4.02 mg/kg (whole body)[6]	Development, LOED				[19]	L; reduced embryo hatchability
			4.02 mg/kg (whole body)[6]	Growth, LOED				[19]	L; reduced weight gain
			70 mg/kg (gill)	Morphology, LOED				[19]	L; darkening of caudal peduncle
			30 mg/kg (kidney)	Morphology, LOED				[19]	L; darkening of caudal peduncle

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Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	Sediment	Water	Tissue (Sample Type)	Effects	Log BCF	Log BAF	BSAF	Reference	Comments[3]
			25 mg/kg (liver)	Morphology, LOED				[19]	L; darkening of caudal peduncle
			4.02 mg/kg (whole body)[6]	Morphology, LOED				[19]	L; deformed vertebral column
			2.55 mg/kg (whole body)[6]	Development, NOED				[19]	L; no effect on embryo hatchability
			1.6 mg/kg (whole body)[6]	Development, NOED				[19]	L; no effect on embryo hatchability
			38 mg/kg (gill)	Growth, NOED				[19]	L; no effect on length or weight
			70 mg/kg (gill)	Growth, NOED				[19]	L; no effect on growth
			60 mg/kg (gill)	Growth, NOED				[19]	L; no effect on length or weight of first generation fish
			20 mg/kg (gill)	Growth, NOED				[19]	L; no effect on length or weight of first generation fish
			6 mg/kg (gill)	Growth, NOED				[19]	L; no effect on length or weight of first generation fish
			3.2 mg/kg (gonad)	Growth, NOED				[19]	L; no effect on length or weight
			43 mg/kg (kidney)	Growth, NOED				[19]	L; no effect on length or weight
			30 mg/kg (kidney)	Growth, NOED				[19]	L; no effect on growth
			100 mg/kg (kidney)	Growth, NOED				[19]	L; no effect on length or weight of first generation fish
			40 mg/kg (kidney)	Growth, NOED				[19]	L; no effect on length or weight of first generation fish

Summary of Biological Effects Tissue Concentrations for Lead

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	Sediment	Water	Tissue (Sample Type)	Effects	Log BCF	Log BAF	BSAF	Reference	Comments[3]
			8 mg/kg (kidney)	Growth, NOED				[19]	L; no effect on length or weight of first generation fish
			13.6 mg/kg (liver)	Growth, NOED				[19]	L; no effect on length or weight
			25 mg/kg (liver)	Growth, NOED				[19]	L; no effect on growth
			18 mg/kg (liver)	Growth, NOED				[19]	L; no effect on length or weight of first generation fish
			16 mg/kg (liver)	Growth, NOED				[19]	L; no effect on length or weight of first generation fish
			4 mg/kg (liver)	Growth, NOED				[19]	L; no effect on length or weight of first generation fish
			0.6 mg/kg (muscle)	Growth, NOED				[19]	L; no effect on length or weight
			1.5 mg/kg (red blood cells)	Growth, NOED				[19]	L; no effect on length or weight
			4 mg/kg (red blood cells)	Growth, NOED				[19]	L; no effect on length or weight of first generation fish
			0.5 mg/kg (red blood cells)	Growth, NOED				[19]	L; no effect on length or weight of first generation fish
			0.2 mg/kg (red blood cells)	Growth, NOED				[19]	L; no effect on length or weight of first generation fish
			6 mg/kg (spleen)	Growth, NOED				[19]	L; no effect on length or weight
			2.55 mg/kg (whole body)[6]	Growth, NOED				[19]	L; no effect on weight gain

Summary of Biological Effects Tissue Concentrations for Lead

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	Sediment	Water	Tissue (Sample Type)	Effects	Log BCF	Log BAF	BSAF	Reference	Comments[3]
			1.6 mg/kg (whole body)[6]	Growth, NOED				[19]	L; no effect on weight gain
			2.55 mg/kg (whole body)[6]	Morphology, NOED				[19]	L; no effect on skeletal deformities
			1.6 mg/kg (whole body)[6]	Morphology, NOED				[19]	L; no effect on skeletal deformities
			38 mg/kg (gill)	Mortality, NOED				[19]	L; no effect on mortality
			70 mg/kg (gill)	Mortality, NOED				[19]	L; no effect on mortality
			60 mg/kg (gill)	Mortality, NOED				[19]	L; no effect on survival of first generation fish
			20 mg/kg (gill)	Mortality, NOED				[19]	L; no effect on survival of first generation fish
			6 mg/kg (gill)	Mortality, NOED				[19]	L; no effect on survival of first generation fish
			3.2 mg/kg (gonad)	Mortality, NOED				[19]	L; no effect on mortality
			43 mg/kg (kidney)	Mortality, NOED				[19]	L; no effect on mortality
			30 mg/kg (kidney)	Mortality, NOED				[19]	L; no effect on mortality
			100 mg/kg (kidney)	Mortality, NOED				[19]	L; no effect on survival of first generation fish
			40 mg/kg (kidney)	Mortality, NOED				[19]	L; no effect on survival of first generation fish
			8 mg/kg (kidney)	Mortality, NOED				[19]	L; no effect on survival of first generation fish
			13.6 mg/kg (liver)	Mortality, NOED				[19]	L; no effect on mortality
			25 mg/kg (liver)	Mortality, NOED				[19]	L; no effect on mortality
			18 mg/kg (liver)	Mortality, NOED				[19]	L; no effect on survival of first generation fish
			16 mg/kg (liver)	Mortality, NOED				[19]	L; no effect on survival of first generation fish
			4 mg/kg (liver)	Mortality, NOED				[19]	L; no effect on survival of first generation fish

Summary of Biological Effects Tissue Concentrations for Lead

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	Sediment	Water	Tissue (Sample Type)	Effects	Log BCF	Log BAF	BSAF	Reference	Comments[3]
			0.6 mg/kg (muscle)	Mortality, NOED				[19]	L; no effect on mortality
			1.5 mg/kg (red blood cells)	Mortality, NOED				[19]	L; no effect on mortality
			4 mg/kg (red blood cells)	Mortality, NOED				[19]	L; no effect on survival of first generation fish
			0.5 mg/kg (red blood cells)	Mortality, NOED				[19]	L; no effect on survival of first generation fish
			0.2 mg/kg (red blood cells)	Mortality, NOED				[19]	L; no effect on survival of first generation fish
			6 mg/kg (spleen)	Mortality, NOED				[19]	L; no effect on mortality
			4.02 mg/kg (whole body)[6]	Mortality, NOED				[19]	L; no effect on mortality
			2.55 mg/kg (whole body)[6]	Mortality, NOED				[19]	L; no effect on mortality
			1.6 mg/kg (whole body)[6]	Mortality, NOED				[19]	L; no effect on mortality
			38 mg/kg (gill)	Reproduction, NOED				[19]	L; no effect on number of viable eggs produced
			70 mg/kg (gill)	Reproduction, NOED				[19]	L; no effect on number of viable eggs produced by second generation fish
			60 mg/kg (gill)	Reproduction, NOED				[19]	L; no effect on number of viable eggs produced
			20 mg/kg (gill)	Reproduction, NOED				[19]	L; no effect on number of viable eggs produced
			6 mg/kg (gill)	Reproduction, NOED				[19]	L; no effect on number of viable eggs produced
			3.2 mg/kg (gonad)	Reproduction, NOED				[19]	L; no effect on number of viable eggs produced
			43 mg/kg (kidney)	Reproduction, NOED				[19]	L; no effect on number of viable eggs produced

Summary of Biological Effects Tissue Concentrations for Lead

Species: Taxa	Concentration, Units in[1]: Sediment	Water	Tissue (Sample Type)	Toxicity: Effects	Ability to Accumulate[2]: Log BCF	Log BAF	BSAF	Source: Reference	Comments[3]
			30 mg/kg (kidney)	Reproduction, NOED				[19]	L; no effect on number of viable eggs produced by second generation fish
			100 mg/kg (kidney)	Reproduction, NOED				[19]	L; no effect on number of viable eggs produced
			40 mg/kg (kidney)	Reproduction, NOED				[19]	L; no effect on number of viable eggs produced
			8 mg/kg (kidney)	Reproduction, NOED				[19]	L; no effect on number of viable eggs produced
			13.6 mg/kg (liver)	Reproduction, NOED				[19]	L; no effect on number of viable eggs produced
			25 mg/kg (liver)	Reproduction, NOED				[19]	L; no effect on number of viable eggs produced by second generation fish
			18 mg/kg (liver)	Reproduction, NOED				[19]	L; no effect on number of viable eggs produced
			16 mg/kg (liver)	Reproduction, NOED				[19]	L; no effect on number of viable eggs produced
			4 mg/kg (liver)	Reproduction, NOED				[19]	L; no effect on number of viable eggs produced
			0.6 mg/kg (muscle)	Reproduction, NOED				[19]	L; no effect on number of viable eggs produced
			1.5 mg/kg (red blood cells)	Reproduction, NOED				[19]	L; no effect on number of viable eggs produced
			4 mg/kg (red blood cells)	Reproduction, NOED				[19]	L; no effect on number of viable eggs produced
			0.5 mg/kg (red blood cells)	Reproduction, NOED				[19]	L; no effect on number of viable eggs produced
			0.2 mg/kg (red blood cells)	Reproduction, NOED				[19]	L; no effect on number of viable eggs produced
			6 mg/kg (spleen)	Reproduction, NOED				[19]	L; no effect on number of viable eggs produced

Summary of Biological Effects Tissue Concentrations for Lead

Species: Taxa	Concentration, Units in[1]: Sediment	Water	Tissue (Sample Type)	Toxicity: Effects	Ability to Accumulate[2]: Log BCF	Log BAF	BSAF	Source: Reference	Comments[3]
Pimephales promelas, Fathead minnow	107 µg/g 365 µg/g 138 µg/g 241 µg/g 375 µg/g		10.5 mg/g 5.7 mg/g 0.8 mg/g 0.9 mg/g 20.0 mg/g					[17]	F
Pimephales promelas, Fathead minnow	508 µg/g 297 µg/g 377 µg/g 283 µg/g 286 µg/g		13.6 mg/g 11.9 mg/g 19.5 mg/g 15.1 mg/g 9.3 mg/g					[17]	F
Pimephales promelas, Fathead minnow			0.816 mg/kg (brain)	Behavior, LOED				[25]	L; significant reduction in feeding rate and number of ineffective feeding behaviors with 1-day-old *Daphnia*
			0.451 mg/kg (brain)	Behavior, LOED				[25]	L; significant reduction in number of ineffective feeding behaviors in lowest test concentration with 2-day-old *Daphnia*
			0.451 mg/kg (brain)	Behavior, LOED				[25]	L; significant reduction in feeding rate and number of ineffective feeding behaviors in lowest test concentration with 7-day-old *Daphnia*
			44.2 mg/kg (whole body)[6]	Behavior, LOED				[25]	L; significant reduction in feeding rate and number of ineffective feeding behaviors with 1-day-old *Daphnia*

Summary of Biological Effects Tissue Concentrations for Lead

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	Sediment	Water	Tissue (Sample Type)	Effects	Log BCF	Log BAF	BSAF	Reference	Comments[3]
			26.2 mg/kg (whole body)[6]	Behavior, LOED				[25]	L; significant reduction in number of ineffective feeding behaviors in lowest test concentration with 2-day-old *Daphnia*
			26.2 mg/kg (whole body)[6]	Behavior, LOED				[25]	L; significant reduction in feeding rate and number of ineffective feeding behaviors in lowest test concentration with 7-day-old *Daphnia*
			0.816 mg/kg (brain)	Physiological, LOED				[25]	L; significant reduction norepinephrine and serotonin levels in brain
			44.2 mg/kg (whole body)[6]	Physiological, LOED				[25]	L; significant reduction norepinephrine and serotonin levels in brain
			0.451 mg/kg (brain)	Behavior, NOED				[25]	L; no significant reduction in feeding rate and number of ineffective feeding behaviors with 1-day-old *Daphnia*
			0.816 mg/kg (brain)	Behavior, NOED				[25]	L; no significant reduction in number of ineffective feeding behaviors with 2-day-old *Daphnia*
			26.2 mg/kg (whole body)[6]	Behavior, NOED				[25]	L; no significant reduction in feeding rate and number of ineffective feeding behaviors with 1-day-old *Daphnia*

Summary of Biological Effects Tissue Concentrations for Lead

Species: Taxa	Concentration, Units in[1]: Sediment	Water	Tissue (Sample Type)	Toxicity: Effects	Ability to Accumulate[2]: Log BCF	Log BAF	BSAF	Source: Reference	Comments[3]
			44.2 mg/kg (whole body)[6]	Behavior, NOED				[25]	L; no significant reduction in number of ineffective feeding behaviors with 2-day-old *Daphnia*
			0.451 mg/kg (brain)	Physiological, NOED				[25]	L; no significant reduction norepinephrine and serotonin levels in brain
			26.2 mg/kg (whole body)[6]	Physiological, NOED				[25]	L; No significant reduction norepinephrine and serotonin levels in brain
Wildlife									
Sterna hirundo, Common tern			247-389 ng/g (eggs) 912-1559 ng/g (feathers)					[18]	F
Sterna forsteri, Forster tern			174 ng/g (eggs) 1527 ng/g (feathers)					[18]	F
Sterna dougallii, Roseate tern			318 ng/g (eggs) 2213 ng/g (feathers)					[18]	F
Rynchops niger, Black skimmer			402-664 ng/g (eggs) 832-4091 ng/g (feathers)					[18]	F
Larus argentatus, Herring gull			1720-6743 ng/g (eggs) 1818-2101 ng/g (feathers)					[18]	F

Summary of Biological Effects Tissue Concentrations for Lead

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	Sediment	Water	Tissue (Sample Type)	Effects	Log BCF	Log BAF	BSAF	Reference	Comments[3]
Zenaida macroura, Mourning dove			58.35-214.7 mg/kg dry wt (liver alive) 267.3 mg/kg dry wt (liver dead) 346-1,297.6 mg/kg dry wt (kidney alive) 1,901 mg/kg dry wt (kidney dead)	Cellular abnormalities increased with increasing tissue concentrations				[26]	L; dosage was ingested lead shot pellets

1 Concentration units based on wet weight unless otherwise noted.
2 BCF = bioconcentration factor, BAF = bioaccumulation factor, BSAF = biota-sediment accumulation factor.
3 L = laboratory study, spiked sediment, single chemical; F = field study, multiple chemical exposure; other unusual study conditions or observations noted.
4 ND = not detected.
5 CBR = critical body residue.
6 This entry was excerpted directly from the Environmental Residue-Effects Database (ERED, www.wes.army.mil/el/ered, U.S. Army Corps of Engineers and U.S. Environmental Protection Agency). The original publication was not reviewed, and the reader is strongly urged to consult the publication to confirm the information presented here.

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Chemical Category: METAL

Chemical Name: METHYLMERCURY **CASRN:** 22967-92-6

Chemical Characteristics

Solubility in Water: No data [1]

Half-Life: No data [2]

Log K_{ow}: –

Log K_{oc}: –

Human Health

Oral RfD: 1 x 10^{-4} mg/kg-day [3]

Confidence: Medium, uncertainty factor = 10

Critical Effect: Developmental neurologic abnormalities in infants

On May 1, 1995, IRIS was updated to include an oral RfD of 1 x 10^{-4} mg/kg/d based on developmental neurological effects in human infants. An oral RfD of 3 x 10^{-4} mg/kg/d for chronic systemic effects of methylmercury among the general adult population was available in IRIS until May 1, 1995; however, it was not listed in the IRIS update on that date. For the purposes of calculating an SV for methylmercury that is protective of developing fetuses and nursing infants, EPA's Office of Water has chosen to continue to use the general adult population RfD of 3 x 10^{-4} mg/kg/d for chronic systemic effects of methylmercury until a value is relisted in IRIS, and to reduce this value by a factor of 5 to derive an RfD of 6 x 10^{-5} mg/kg/d for developmental effects among fetuses and nursing infants. The protective factor of 5 is based on experimental results that suggest a possible 5-fold increase in fetal sensitivity to methylmercury exposure. This more protective approach recommended by the Office of Water was deemed to be most prudent at this time. This approach should be considered interim until such time as the Agency has reviewed new studies on the chronic and developmental effects of methylmercury.

Oral Slope Factor: –

Carcinogenic Classification: C [3]

Wildlife

Partitioning Factors: Over 90 percent of methylmercury is absorbed from the gastrointestinal tract in animals, and following such absorption most accumulates in erythrocytes, giving red cell to plasma ratios of up to 300 to 1 [4]. This allows for efficient transport through the body and results in a generally uniform pattern of distribution in tissues and organs—blood, kidney, and brain concentrations are within a range of one to three by ratio [5]. There is an exceptional ability of methylmercury to pass the blood-brain barrier, and injury to the central nervous system then arises by strong binding of methylmercury to sulfhydryl residues and subsequent release of mercuric ions to binding sites in the central nervous system. The slow elimination of methylmercury from the body is a result of the high erythrocyte-plasma ratio [4]. Mercury will accumulate in both cerebellum and also cerebral cortex, where it will be tightly bound by sulfhydryl groups. Inside the cell, methylmercury will inhibit protein synthesis and RNA synthesis [6,7]. The effects are particularly important in the developing fetal and young brain of most animals. The ability of methylmercury to penetrate the placental barrier leads to accumulation in the fetus. The rate of transport across the placental barrier is 10-fold higher than for inorganic mercury. It appears that fetal tissue has a greater binding ability for methylmercury than does the pregnant mother. Exposure via milk is also important for feeding babies. It does appear that pregnant animals may detoxify themselves by transferences to their fetuses [8].

Food Chain Multipliers: In birds, there is a tendency for mercury concentrations to be highest in species feeding on fish (or on other seabirds) [9]. However, when one compares mercury levels among predominantly fish-eating species, levels apparently do not show clear patterns or any evident association with diet composition [10]. Particularly high concentrations have been found in some species of procellariiforms [11]. There is an inverse relationship between total mercury and percent methylmercury in tissues of various avian species [12,13]. Overall, the form of mercury in seabirds is predominantly inorganic, suggesting that biotransformation of ingested methylmercury is an important mechanism by which long-lived and slow-moulting seabirds avoid the toxic effects of accumulating large quantities of methylmercury [14,15]. Among furbearers, mecury burdens are higher in fish-eating species than in herbivorous ones [16]. Mink and river otter accumulate about 10 times more mercury than predatory fishes from the same areas [17]. Nonmarine mammals with mercury concentrations in the liver and kidney in excess of approximately 30 mg/kg of wet weight were likely to suffer mercury intoxification. The results of laboratory studies support this value and indicate that a dietary methylmercury concentration of aproximately 2 to 6 mg/kg of wet weight produced mercury poisoning in feeding experiments using a range of mammalian species [18].

Aquatic Organisms

Partitioning Factors: Concentrations of total mercury in water are usually low, typically on the order of a few nanograms per liter. Elemental mercury adsorbs to sediments, where methylmercury can be produced and destroyed by microbial processes. This complex process is affected by environmental factors [1]. A significant fraction of the total mercury in water is found in the form of methylmercury, the species predominantly accumulated by aquatic organisms [19]. In the Onondaga Lake food web, the percent of total mercury occurring as methylmercury was determined as follows [20]:

Lake water 5%
Interstitial water 37%
Phytoplankton 24%
Zooplankton 40%
Benthic macroinvertebrates 26%
Fishes 96%

Bioconcentration factors (BCFs) for methylmercury are highly variable. Log BCFs for methylmercury in brook trout range from 4.84 to 5.80, depending on the tissue analyzed. Methylmercury concentrations and bioaccumulation factors (BAFs) increased with higher trophic levels in both the pelagic and benthic components of aquatic food webs [20].

Food Chain Multipliers: Fish bioconcentrate methylmercury directly from water by uptake across the gills [21,22,23] and piscivores, such as walleye, readily accumulate mercury from dietary sources [24,25]. Methylmercury accumulation from either source may be substantial, but the relative contribution of each pathway may vary with fish species [26,27,28,29]. In addition, invertebrates generally have a lower percentage of methylmercury in their tissues than fish or marine mammals [30]. The percentage of methylmercury increases with age in both fish and invertebrates [30].

Mercury is accumulated by all trophic levels with biomagnification occurring up the food web. While sediment is usually the primary source of methylmercury in most aquatic systems, the food web is the main pathway for accumulation [24,25]. High concentrations of organic substances and reduced sulfur can complex free mercury ions in the sediment and reduce the availability to organisms [31,32]. Methylmercury can be accumulated directly from the water by uptake across the gills [21,22,23]. High-trophic-level species tend to accumulate the most methylmercury, with concentrations highest in fish-eating predators. Methylmercury concentrations in higher trophic species often do not correlate with concentrations in environmental media. Correlations have been made between sediment and lower trophic species that typically have a high percentage of inorganic mercury, and between mercury concentrations in higher trophic species and their prey items. The best measure of bioavailability of mercury in any system can be obtained through analysis of mercury concentrations in the biota at the specific site.

The transfer efficiency of mercury through the food web is affected by the form of mercury. Although inorganic mercury is the dominant form in the environment and easily accumulated, it is also depurated quickly. Methylmercury accumulates quickly, depurates very slowly, and therefore has a greater potential to biomagnify in higher-trophic-level species. Pharmacologic half-lives of total mercury in tissues of aquatic organisms have been estimated at approximately 2 months to 1 year in saltwater mussels, 1 to more than 3 years in fishes, and 1.4 to 2.7 years in pinnipeds and dolphins [33]. As the concentration of methylmercury increases in prey items, the transfer efficiency also increases [34]. Methylmercury accumulation from either the water column or food sources might be substantial, but the relative contribution of each pathway varies from species to species [26,27,28,29]. Invertebrates generally have a lower percentage of methylmercury in their tissues than fish or marine mammals, but the percentage can vary greatly, from 1 percent in deposit-feeding polychaetes to almost 100 percent in crabs.

The amount of methylmercury in animal tissues increases proportionately with the age of the organism, with the exception of marine mammals. Because marine mammals feed primarily on fish, they have the greatest potential for the highest tissue concentrations of methylmercury compared to other marine organisms. Contrary to other species or groups of animals, the tissue concentrations of methylmercury are higher in juvenile marine mammals than in adults because the adults can mineralize methylmercury into inorganic mercury [33].

Toxicity/Bioaccumulation Assessment Profile

Methylmercury is the most hazardous mercury species due to its high stability, its lipid solubility, and its ionic properties that lead to a high ability to penetrate the membranes of living organisms [35]. Because methylmercury is lipid-soluble, it can rapidly penetrate the blood-brain barrier [36,37,38,39,40]. Injury to the central nervous system arises by accumulation in the cerebellum and cerebral cortex, where methylmercury binds tightly to sulfhydryl groups, resulting in pathological changes [41]. Inside the cell, methylmercury inhibits protein synthesis and RNA synthesis [6,7].

The early developmental stages of organisms are the most sensitive to the toxic effects of mercury, with methylmercury being more toxic than inorganic mercury. Mercury adversely affects reproduction, growth, behavior, osmoregulation, and oxygen exchange in aquatic organisms. In birds and mammals, comparatively low concentrations of mercury have adverse effects on growth and development, behavior, motor coordination, vision, hearing, histology, and metabolism [33].

Toxicity of methylmercury is dependent on temperature [42], oxygen conditions [43], salinity [44], and the presence of other metals such as zinc and lead [45]. The complex behavior of methylmercury in sediments makes it difficult to predict toxicity from bulk sediment chemistry. Toxicity of mercury has been linked with bioaccumulation, but the situation is complicated by the fact that some animals exposed to low concentrations of mercury can build up a tolerance to this contaminant, as well as detoxify the free metal within their cells via the production of metallothioneins and other metal-binding proteins. Brown et al. [46] propose that toxic effects occur as the binding capacity of these metal-binding proteins becomes saturated.

Summary of Biological Effects Tissue Concentrations for Methylmercury

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	Sediment	Water	Tissue (Sample Type)	Effects	Log BCF	Log BAF	BSAF	Reference	Comments[3]
Invertebrates									
Phytoplankton		Interstitial water: 0.003 µg/L Lake water: 0.0003 µg/L	32 µg/kg			5.00		[20]	F; estimated from chart; chart reported log BAF values
Crepidula fornicata, Slipper limpet			9.00045013427734 mg/kg (whole body)[5]	Growth, ED25				[62]	L; approximate 25% reduction in growth at lowest test concentration; algal food contained mercury at approximatley 2.9 µg/L in addition to water concentration
			15.0007495880126 mg/kg (whole body)[5]	Reproduction, LOED				[62]	L; significant effect on fecundity (number of gametes); exposure includes mercury in food at approximately 9.5 µg/L

Summary of Biological Effects Tissue Concentrations for Methylmercury

Species:	**Concentration, Units in[1]:**			**Toxicity:**	**Ability to Accumulate[2]:**			**Source:**	
Taxa	**Sediment**	**Water**	**Tissue (Sample Type)**	**Effects**	**Log BCF**	**Log BAF**	**BSAF**	**Reference**	**Comments[3]**
			30.0014991760253 mg/kg (whole body)[5]	Development, NOED				[62]	L; no significant effect on number of live spat at peak settlement; exposure includes mercury in food at approximately 31 µg/L
			30.0014991760253 mg/kg (whole body)[5]	Reproduction, NOED				[62]	L; no significant effect on ability to produce gametes; exposure includes mercury in food at approximately 31 µg/L
			9.00045013427734 mg/kg (whole body)[5]	Reproduction, NOED				[62]	L; no significant effect on fecundity (number of gametes); exposure includes mercury in food at approximately 2.9 µg/L

Summary of Biological Effects Tissue Concentrations for Methylmercury

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	Sediment	Water	Tissue (Sample Type)	Effects	Log BCF	Log BAF	BSAF	Reference	Comments[3]
Elliptio complanata, Freshwater mussel			43 µg/kg	Relative to least contaminated station (17.9 mg/kg, dry total Hg in sediment vs. 0.07 mg/kg, dry), whole animal ww was reduced by 97 percent				[48]	F; 42 and 84 days exposure; probable effects at tissue concentrations >34 µg/kg, ww
Rangia cuneata, Marsh clam			12 mg/kg (whole body)[5]	Mortality, ED50				[54]	L; lethal to 50% of clams in 7 days
			28 mg/kg (whole body)[5]	Mortality, ED50				[54]	L; lethal to 50% of clams in 7 days
			73.1399993896484 mg/kg (whole body)[5]	Mortality, LOED				[54]	L; lethal body burden
			6 mg/kg (whole body)[5]	Mortality, NOED				[54]	L; no effect on mortality
Zooplankton, Cladocerans		Interstitial water: 0.003 µg/L Lake water: 0.0003 µg/L	260 µg/kg			5.94		[20]	F; estimated from chart; chart reported log BAF values

Summary of Biological Effects Tissue Concentrations for Methylmercury

Species:	**Concentration, Units in[1]:**			**Toxicity:**	**Ability to Accumulate[2]:**			**Source:**	
Taxa	**Sediment**	**Water**	**Tissue (Sample Type)**	**Effects**	**Log BCF**	**Log BAF**	**BSAF**	**Reference**	**Comments[3]**
Diaptomus oregonensis		Unfiltered water: total Hg = 0.43-4.79 ng/L MeHg = 0.04-2.20 ng/L	22-66 µg/kg (dw)		7.10			[47]	F; results were summarized for zooplankton and water samples taken from 12 lakes - ranges are given
Diaptomus minutus, Zooplankton		Filtered water: total Hg = 0.27-4.50 ng/L MeHg = 0.03-1.95 ng/L			4.04			[47]	F; results were summarized for zooplankton and water samples taken from 12 lakes - ranges are given
Holopedium gibberum, Zooplankton		Unfiltered water: total Hg = 0.43-4.79 ng/L MeHg = 0.04-2.20 ng/L Filtered water: total Hg = 0.27-4.50 ng/L MeHg = 0.03-1.95 ng/L	40-419 µg/kg (dw)					[47]	F; results were summarized for biota and water samples taken from 12 lakes - ranges are given

Summary of Biological Effects Tissue Concentrations for Methylmercury

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	Sediment	Water	Tissue (Sample Type)	Effects	Log BCF	Log BAF	BSAF	Reference	Comments[3]
Bosmina longirostris, Cladoceran		Unfiltered water: total Hg = 0.43-4.79 ng/L MeHg = 0.04-2.20 ng/L Filtered water: total Hg = 0.27-4.50 ng/L MeHg = 0.03-1.95 ng/L	479 µg/kg (dw)					[47]	F; results were summarized for biota and water samples taken from 12 lakes - ranges are given
Daphnia pulex *Daphnia galeatra mendotae* *Daphnia ambigua*, Cladocerans		Unfiltered water: total Hg = 0.43-4.79 ng/L MeHg[4] = 0.04-2.20 ng/L Filtered water: total Hg = 0.27-4.50 ng/L MeHg = 0.03-1.95 ng/L	1-211 µg/kg (dw)					[47]	F; results were summarized for biota and water samples taken from 12 lakes - ranges are given
Daphnia magna, Cladoceran			18.3999996185302 mg/kg (whole body)[5]	Mortality, ED25				[51]	L; 25% reduction in survival compared to controls in 21 days

Summary of Biological Effects Tissue Concentrations for Methylmercury

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	Sediment	Water	Tissue (Sample Type)	Effects	Log BCF	Log BAF	BSAF	Reference	Comments[3]
			2.32800006866455 mg/kg (whole body)[5]	Reproduction, NA				[51]	L; 32% reduction in number of neonates produced in 21 days
			1.63999998569488 mg/kg (whole body)[5]	Reproduction, NA				[51]	L; 35% reduction in number of neonates produced in 21 days
			4.67000007629394 mg/kg (whole body)[5]	Reproduction, NA				[51]	L; 62% reduction in number of neonates produced in 21 days
			7.57000017166137 mg/kg (whole body)[5]	Reproduction, NA				[51]	L; 63% reduction in number of neonates produced in 21 days
			18.3999996185302 mg/kg (whole body)[5]	Reproduction, NA				[51]	L; 99% reduction in number of neonates produced in 21 days
			0.859000027179718 mg/kg (whole body)[5]	Mortality, NOED				[51]	L; no effect on mortality
			1.52600002288818 mg/kg (whole body)[5]	Mortality, NOED				[51]	L; no effect on mortality
			2.32800006866455 mg/kg (whole body)[5]	Mortality, NOED				[51]	L; no effect on mortality
			1.63999998569488 mg/kg (whole body)[5]	Mortality, NOED				[51]	L; no effect on mortality
			4.67000007629394 mg/kg (whole body)[5]	Mortality, NOED				[51]	L; no effect on mortality

Summary of Biological Effects Tissue Concentrations for Methylmercury

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	Sediment	Water	Tissue (Sample Type)	Effects	Log BCF	Log BAF	BSAF	Reference	Comments[3]
			7.57000017166137 mg/kg (whole body)[5]	Mortality, NOED				[51]	L; no effect on mortality
			0.859000027179718 mg/kg (whole body)[5]	Reproduction, NOED				[51]	L; no significant reproductive impairment
			1.52600002288818 mg/kg (whole body)[5]	Reproduction, NOED				[51]	L; no significant reproductive impairment
Daphnia magna, Cladoceran			0.790000021457672 mg/kg (whole body)[5]	Reproduction, ED10				[55]	L; 10% reduction in number of offspring
			91.3000030517578 mg/kg (whole body)[5]	Mortality, ED50				[55]	L; lethal body burden after 21 day exposure
Benthic invertebrates *Scientific names not given* (amphipods and chironomids)		Interstitial water: 0.003 µg/L Lake water: 0.0003 µg/L	25 µg/kg			$8.3x10^4$		[20]	F
Palaemonetes pugio, Grass shrimp			1.09399998188018 mg/kg (whole body)[5]	Behavior, LOED				[50]	L; decreased sensitivity to physical disturbance

Summary of Biological Effects Tissue Concentrations for Methylmercury

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	Sediment	Water	Tissue (Sample Type)	Effects	Log BCF	Log BAF	BSAF	Reference	Comments[3]
			2.12299990653991 mg/kg (whole body)[5]	Mortality, NOED				[50]	L; no statistically significant increase in mortality
Uca pugnax, Fiddler crab			12.329999923706 mg/kg (whole body)[5]	Development, LOED				[53]	L; inhibition of limb regeneration and molting in male crabs
			19.4200000762939 mg/kg (whole body)[5]	Development, LOED				[53]	L; inhibition of limb regeneration and molting in female crabs
Fishes									
Squalus acanthias, Spiny dogfish			0.0930000022053719 mg/kg (whole body)[5]	Mortality, NOED				[57]	L; no effect on mortality in 24 hours

Summary of Biological Effects Tissue Concentrations for Methylmercury

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	Sediment	Water	Tissue (Sample Type)	Effects	Log BCF	Log BAF	BSAF	Reference	Comments[3]
Oncorhynchus mykiss, Rainbow trout		Exposure concentrations (CH_3HgCl): 4 µg/L	kidney = 74±30 (16-116 mg/kg) liver = 76±19 (32-114 mg/kg) spleen = 89±38 (32-118 mg/kg) brain = 19±8 (7-32 mg/kg) muscle = 31±12 (9-52 mg/kg) gill = 66±15 (42-93 mg/kg)	58.2 d±21.4				[49]	L; d = mean days to death ± SD; n = 20 fish per treatment.
		Exposure concentrations (CH_3HgCl): 9 µg/L	whole fish =11.2±6.1 (4.0-27.3 mg/kg)	24.2 d±5.6				[49]	
		Exposure concentrations (CH_3HgCl): 10 µg/L	kidney = 64±20 (40-116 mg/kg) liver = 47±10 (27-65 mg/kg) spleen = 72±22 (37-112 mg/kg) brain = 13±3 (7-19 mg/kg) muscle = 18±5 (9-27 mg/kg) gill = 51±12 (34-85 mg/kg)	21.7 d±6.0				[49]	L; n = 20 per treatment; d = days to death; n = 20 per treatment.

Summary of Biological Effects Tissue Concentrations for Methylmercury

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	**Sediment**	**Water**	**Tissue (Sample Type)**	**Effects**	**Log BCF**	**Log BAF**	**BSAF**	**Reference**	**Comments[3]**
		Exposure concentrations (CH_3HgCl): 13 µg/L	kidney = 39±21 (19-91 mg/kg) liver = 42±27 (16-129 mg/kg) spleen = 51±38 (19-194 mg/kg) brain = 7.7±5.6 (2.3-22 mg/kg) muscle = 6.2±7.7 (1.2-26 mg/kg) gill = 64±15 (36-98 mg/kg)	7.6 d±5.1				[49]	L; n = 20 per treatment; d = days to death; n = 20 per treatment.
		Exposure concentrations (CH_3HgCl): 34 µg/L	kidney = 6.2±2.7 (2.3-10 mg/kg) liver = 7.2±2.8 (3.0-12 mg/kg) spleen = 6.4±3.2 (2.7-14 mg/kg) brain = 1.1±0.3 (0.6-1.5 mg/kg) muscle = 0.7±0.3 (2.7-14 mg/kg) gill = 56±12 (29-73 mg/kg)	1.0 d				[49]	L; d = mean days to death (no SD reported)
Oncorhynchus mykiss, Rainbow trout			1.60000002384185 mg/kg (blood)[5]	Growth, NOED				[52]	L; no effect on growth
			0.100000001490116 mg/kg (blood)[5]	Growth, NOED				[52]	L; no effect on growth

Summary of Biological Effects Tissue Concentrations for Methylmercury

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	Sediment	Water	Tissue (Sample Type)	Effects	Log BCF	Log BAF	BSAF	Reference	Comments[3]
			0.5 mg/kg (brain)[5]	Growth, NOED				[52]	L; no effect on growth
			0.100000001490116 mg/kg (brain)[5]	Growth, NOED				[52]	L; no effect on growth
			0.400000005960464 mg/kg (gill)[5]	Growth, NOED				[52]	L; no effect on growth
			0.100000001490116 mg/kg (gill)[5]	Growth, NOED				[52]	L; no effect on growth
			1.60000002384185 mg/kg (kidney)[5]	Growth, NOED				[52]	L; no effect on growth
			0.200000002980232 mg/kg (kidney)[5]	Growth, NOED				[52]	L; no effect on growth
			1 mg/kg (liver)[5]	Growth, NOED				[52]	L; no effect on growth
			0.100000001490116 mg/kg (liver)[5]	Growth, NOED				[52]	L; no effect on growth
			0.5 mg/kg (muscle)[5]	Growth, NOED				[52]	L; no effect on growth
			0.100000001490116 mg/kg (muscle)[5]	Growth, NOED				[52]	L; no effect on growth
			1.60000002384185 mg/kg (posterior intestine)[5]	Growth, NOED				[52]	L; no effect on growth

Summary of Biological Effects Tissue Concentrations for Methylmercury

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	Sediment	Water	Tissue (Sample Type)	Effects	Log BCF	Log BAF	BSAF	Reference	Comments[3]
			6 mg/kg (posterior intestine)[5]	Growth, NOED				[52]	L; no effect on growth
			1.29999995231628 mg/kg (spleen)[5]	Growth, NOED				[52]	L; no effect on growth
			0.300000011920929 mg/kg (spleen)[5]	Growth, NOED				[52]	L; no effect on growth
			0.140000000596046 mg/kg (whole body)[5]	Growth, NOED				[52]	L; no effect on growth
			0.469999998807907 mg/kg (whole body)[5]	Growth, NOED				[52]	L; no effect on growth
			1.60000002384185 mg/kg (blood)[5]	Mortality, NOED				[52]	L; no effect on mortality
			0.100000001490116 mg/kg (blood)[5]	Mortality, NOED				[52]	L; no effect on mortality
			0.5 mg/kg (brain)[5]	Mortality, NOED				[52]	L; no effect on mortality
			0.100000001490116 mg/kg (brain)[5]	Mortality, NOED				[52]	L; no effect on mortality
			0.400000005960464 mg/kg (gill)[5]	Mortality, NOED				[52]	L; no effect on mortality
			0.100000001490116 mg/kg (gill)[5]	Mortality, NOED				[52]	L; no effect on mortality
			1.60000002384185 mg/kg (kidney)[5]	Mortality, NOED				[52]	L; no effect on mortality

Summary of Biological Effects Tissue Concentrations for Methylmercury

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	Sediment	Water	Tissue (Sample Type)	Effects	Log BCF	Log BAF	BSAF	Reference	Comments[3]
			0.200000002980232 mg/kg (kidney)[5]	Mortality, NOED				[52]	L; no effect on mortality
			1 mg/kg (liver)[5]	Mortality, NOED				[52]	L; no effect on mortality
			0.100000001490116 mg/kg (liver)[5]	Mortality, NOED				[52]	L; no effect on mortality
			0.5 mg/kg (muscle)[5]	Mortality, NOED				[52]	L; no effect on mortality
			0.100000001490116 mg/kg (muscle)[5]	Mortality, NOED				[52]	L; no effect on mortality
			1.60000002384185 mg/kg (posterior intestine)[5]	Mortality, NOED				[52]	L; no effect on mortality
			6 mg/kg (posterior intestine)[5]	Mortality, NOED				[52]	L; no effect on mortality
			1.29999995231628 mg/kg (spleen)[5]	Mortality, NOED				[52]	L; no effect on mortality
			0.300000011920929 mg/kg (spleen)[5]	Mortality, NOED				[52]	L; no effect on mortality
			0.140000000596046 mg/kg (whole body)[5]	Mortality, NOED				[52]	L; no effect on survival
			0.469999998807907 mg/kg (whole body)[5]	Mortality, NOED				[52]	L; no effect on survival

Summary of Biological Effects Tissue Concentrations for Methylmercury

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	Sediment	Water	Tissue (Sample Type)	Effects	Log BCF	Log BAF	BSAF	Reference	Comments[3]
Oncorhynchus mykiss, Rainbow trout			15 mg/kg (whole body)[5]	Mortality, ED100				[58]	L; 100% mortality in 15 days
			20 mg/kg (whole body)[5]	Mortality, ED100				[58]	L; 100% mortality in 15 days
			6 mg/kg (whole body)[5]	Mortality, ED50				[58]	L; 50% mortality in 15 days
			4.76000022888183 mg/kg (whole body)[5]	Mortality, ED50				[58]	L; 30 day ED50 for brain
			5.69999980926513 mg/kg (whole body)[5]	Mortality, ED50				[58]	L; 15 day ED50 for single intraperitoneal injection
			3.91000008583068 mg/kg (whole body)[5]	Mortality, ED50				[58]	L; 30 day ED50 for muscle
			2.02999997138977 mg/kg (whole body)[5]	Mortality, ED50				[58]	L; 30 day ED50 for eye
			10 mg/kg (whole body)[5]	Mortality, LOED				[58]	L; 83% mortality in 15 days
			2 mg/kg (whole body)[5]	Mortality, LOED				[58]	L; 33% mortality in 15 days
			5 mg/kg (whole body)[5]	Mortality, LOED				[58]	L; 83% mortality in 15 days
			8 mg/kg (whole body)[5]	Mortality, LOED				[58]	L; 67% mortality in 15 days

Summary of Biological Effects Tissue Concentrations for Methylmercury

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	**Sediment**	**Water**	**Tissue (Sample Type)**	**Effects**	**Log BCF**	**Log BAF**	**BSAF**	**Reference**	**Comments[3]**
			4 mg/kg (whole body)[5]	Mortality, LOED				[58]	L; 13% mortality in 15 days
			2 mg/kg (whole body)[5]	Mortality, NOED				[58]	L; no mortality in 15 days
Salvelinus fontinalis, Brook trout			46.2000007629394 mg/kg (blood cells)[5]	Development, LOED				[38]	L; affected embryo development
			16.8999996185302 mg/kg (brain)[5]	Development, LOED				[38]	L; affected embryo development
			4.40000009536743 mg/kg (carcass)[5]	Development, LOED				[38]	L; affected embryo development
			22.2000007629394 mg/kg (gill)[5]	Development, LOED				[38]	L; affected embryo development
Salvelinus fontinalis, Brook trout			12.3000001907348 mg/kg (gonad)[5]	Development, LOED				[38]	L; affected embryo development
			26.8999996185302 mg/kg (kidney)[5]	Development, LOED				[38]	L; affected embryo development
			24.3999996185302 mg/kg (liver)[5]	Development, LOED				[38]	L; affected embryo development
			10.1999998092651 mg/kg (muscle)[5]	Development, LOED				[38]	L; affected embryo development
			38.7000007629394 mg/kg (spleen)[5]	Development, LOED				[38]	L; affected embryo development
			46.2000007629394 mg/kg (blood cells)[5]	Growth, LOED				[38]	L; decreased weight

Summary of Biological Effects Tissue Concentrations for Methylmercury

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	Sediment	Water	Tissue (Sample Type)	Effects	Log BCF	Log BAF	BSAF	Reference	Comments[3]
			16.8999996185302 mg/kg (brain)[5]	Growth, LOED				[38]	L; decreased weight
			4.40000009536743 mg/kg (carcass)[5]	Growth, LOED				[38]	L; decreased weight
			22.2000007629394 mg/kg (gill)[5]	Growth, LOED				[38]	L; decreased weight
			12.3000001907348 mg/kg (gonad)[5]	Growth, LOED				[38]	L; decreased weight
			26.8999996185302 mg/kg (kidney)[5]	Growth, LOED				[38]	L; decreased weight
			24.3999996185302 mg/kg (liver)[5]	Growth, LOED				[38]	L; decreased weight
Salvelinus fontinalis, Brook trout			10.1999998092651 mg/kg (muscle)[5]	Growth, LOED				[38]	L; decreased weight
			38.7000007629394 mg/kg (spleen)[5]	Growth, LOED				[38]	L; decreased weight
			9.39999961853027 mg/kg (whole body)[5]	Mortality, LOED				[38]	L; mortality of offspring
			46.2000007629394 mg/kg (blood cells)[5]	Reproduction, LOED				[38]	L; reduced reproduction
			16.8999996185302 mg/kg (brain)[5]	Reproduction, LOED				[38]	L; reduced reproduction
			4.40000009536743 mg/kg (carcass)[5]	Reproduction, LOED				[38]	L; reduced reproduction

Summary of Biological Effects Tissue Concentrations for Methylmercury

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	Sediment	Water	Tissue (Sample Type)	Effects	Log BCF	Log BAF	BSAF	Reference	Comments[3]
			22.2000007629394 mg/kg (gill)[5]	Reproduction, LOED				[38]	L; reduced reproduction
			12.3000001907348 mg/kg (gonad)[5]	Reproduction, LOED				[38]	L; reduced reproduction
			26.8999996185302 mg/kg (kidney)[5]	Reproduction, LOED				[38]	L; reduced reproduction
			24.3999996185302 mg/kg (liver)[5]	Reproduction, LOED				[38]	L; reduced reproduction
			10.1999998092651 mg/kg (muscle)[5]	Reproduction, LOED				[38]	L; reduced reproduction
			38.7000007629394 mg/kg (spleen)[5]	Reproduction, LOED				[38]	L; reduced reproduction
			3.40000009536743 mg/kg (whole body)[5]	Reproduction, LOED				[38]	L; reduction in reproduction
			2.70000004768371 mg/kg (whole body)[5]	Development, NOED				[38]	L; no physical abnormalities
Salvelinus fontinalis, Brook trout			21.3999996185302 mg/kg (blood cells)[5]	Growth, NOED				[38]	L; decreased weight
			5.19999980926513 mg/kg (blood cells)[5]	Growth, NOED				[38]	L; decreased weight
			2.29999995231628 mg/kg (blood cells)[5]	Growth, NOED				[38]	L; decreased weight
			5.30000019073486 mg/kg (brain)[5]	Growth, NOED				[38]	L; decreased weight

Summary of Biological Effects Tissue Concentrations for Methylmercury

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	Sediment	Water	Tissue (Sample Type)	Effects	Log BCF	Log BAF	BSAF	Reference	Comments[3]
			1.70000004768371 mg/kg (brain)[5]	Growth, NOED				[38]	L; decreased weight
			0.800000011920928 mg/kg (brain)[5]	Growth, NOED				[38]	L; decreased weight
			1.60000002384185 mg/kg (carcass)[5]	Growth, NOED				[38]	L; decreased weight
			0.589999973773956 mg/kg (carcass)[5]	Growth, NOED				[38]	L; decreased weight
			0.400000005960464 mg/kg (carcass)[5]	Growth, NOED				[38]	L; decreased weight
			6.19999980926513 mg/kg (gill)[5]	Growth, NOED				[38]	L; decreased weight
			1.60000002384185 mg/kg (gill)[5]	Growth, NOED				[38]	L; decreased weight
			0.699999988079071 mg/kg (gill)[5]	Growth, NOED				[38]	L; decreased weight
			2.90000009536743 mg/kg (gonad)[5]	Growth, NOED				[38]	L; decreased weight
			0.899999976158142 mg/kg (gonad)[5]	Growth, NOED				[38]	L; decreased weight
Salvelinus fontinalis, Brook trout			0.200000002980232 mg/kg (gonad)[5]	Growth, NOED				[38]	L; decreased weight
			8.89999961853027 mg/kg (kidney)[5]	Growth, NOED				[38]	L; decreased weight

Summary of Biological Effects Tissue Concentrations for Methylmercury

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	**Sediment**	**Water**	**Tissue (Sample Type)**	**Effects**	**Log BCF**	**Log BAF**	**BSAF**	**Reference**	**Comments[3]**
			2.5 mg/kg (kidney)[5]	Growth, NOED				[38]	L; decreased weight
			1.20000004768371 mg/kg (kidney)[5]	Growth, NOED				[38]	L; decreased weight
			8.30000019073486 mg/kg (liver)[5]	Growth, NOED				[38]	L; decreased weight
			2.20000004768371 mg/kg (liver)[5]	Growth, NOED				[38]	L; decreased weight
			0.699999988079071 mg/kg (liver)[5]	Growth, NOED				[38]	L; decreased weight
			4.90000009536743 mg/kg (muscle)[5]	Growth, NOED				[38]	L; decreased weight
			1.89999997615814 mg/kg (muscle)[5]	Growth, NOED				[38]	L; decreased weight
			1 mg/kg (muscle)[5]	Growth, NOED				[38]	L; decreased weight
			11.8000001907348 mg/kg (spleen)[5]	Growth, NOED				[38]	L; decreased weight
			3.20000004768371 mg/kg (spleen)[5]	Growth, NOED				[38]	L; decreased weight
			1.20000004768371 mg/kg (spleen)[5]	Growth, NOED				[38]	L; decreased weight
			2.70000004768371 mg/kg (whole body)[5]	Mortality, NOED				[38]	L; no effect on mortality
Salvelinus fontinalis, Brook trout			21.3999996185302 mg/kg (blood cells)[5]	Reproduction, NOED				[38]	L; reduced reproduction

Summary of Biological Effects Tissue Concentrations for Methylmercury

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	Sediment	Water	Tissue (Sample Type)	Effects	Log BCF	Log BAF	BSAF	Reference	Comments[3]
			5.19999980926513 mg/kg (blood cells)[5]	Reproduction, NOED				[38]	L; reduced reproduction
			2.29999995231628 mg/kg (blood cells)[5]	Reproduction, NOED				[38]	L; reduced reproduction
			5.30000019073486 mg/kg (brain)[5]	Reproduction, NOED				[38]	L; reduced reproduction
			1.70000004768371 mg/kg (brain)[5]	Reproduction, NOED				[38]	L; reduced reproduction
			0.800000011920928 mg/kg (brain)[5]	Reproduction, NOED				[38]	L; reduced reproduction
			1.60000002384185 mg/kg (carcass)[5]	Reproduction, NOED				[38]	L; reduced reproduction
			0.589999973773956 mg/kg (carcass)[5]	Reproduction, NOED				[38]	L; reduced reproduction
			0.400000005960464 mg/kg (carcass)[5]	Reproduction, NOED				[38]	L; reduced reproduction
			6.19999980926513 mg/kg (gill)[5]	Reproduction, NOED				[38]	L; reduced reproduction
			1.60000002384185 mg/kg (gill)[5]	Reproduction, NOED				[38]	L; reduced reproduction
			0.699999988079071 mg/kg (gill)[5]	Reproduction, NOED				[38]	L; reduced reproduction
			2.90000009536743 mg/kg (gonad)[5]	Reproduction, NOED				[38]	L; reduced reproduction

Summary of Biological Effects Tissue Concentrations for Methylmercury

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	Sediment	Water	Tissue (Sample Type)	Effects	Log BCF	Log BAF	BSAF	Reference	Comments[3]
			0.899999976158142 mg/kg (gonad)[5]	Reproduction, NOED				[38]	L; reduced reproduction
Salvelinus fontinalis, Brook trout			0.200000002980232 mg/kg (gonad)[5]	Reproduction, NOED				[38]	L; reduced reproduction
			8.89999961853027 mg/kg (kidney)[5]	Reproduction, NOED				[38]	L; reduced reproduction
			2.5 mg/kg (kidney)[5]	Reproduction, NOED				[38]	L; reduced reproduction
			1.20000004768371 mg/kg (kidney)[5]	Reproduction, NOED				[38]	L; reduced reproduction
			8.30000019073486 mg/kg (liver)[5]	Reproduction, NOED				[38]	L; reduced reproduction
			2.20000004768371 mg/kg (liver)[5]	Reproduction, NOED				[38]	L; reduced reproduction
			0.699999988079071 mg/kg (liver)[5]	Reproduction, NOED				[38]	L; reduced reproduction
			4.90000009536743 mg/kg (muscle)[5]	Reproduction, NOED				[38]	L; reduced reproduction
			1.89999997615814 mg/kg (muscle)[5]	Reproduction, NOED				[38]	L; reduced reproduction
			1 mg/kg (muscle)[5]	Reproduction, NOED				[38]	L; reduced reproduction
			11.8000001907348 mg/kg (spleen)[5]	Reproduction, NOED				[38]	L; reduced reproduction

Summary of Biological Effects Tissue Concentrations for Methylmercury

Species:	**Concentration, Units in[1]:**			**Toxicity:**	**Ability to Accumulate[2]:**			**Source:**	
Taxa	**Sediment**	**Water**	**Tissue (Sample Type)**	**Effects**	**Log BCF**	**Log BAF**	**BSAF**	**Reference**	**Comments[3]**
			3.20000004768371 mg/kg (spleen)[5]	Reproduction, NOED				[38]	L; reduced reproduction
			1.20000004768371 mg/kg (spleen)[5]	Reproduction, NOED				[38]	L; reduced reproduction
Esox lucius, Northern pike			7 mg/kg (whole body)[5]	Physiological, LOED				[60]	F; lowered blood alkaline phosphatase, serum cortisol, emaciation
Planktivores: *Dorosoma cepedianum*, Gizzard shad		Interstitial water: 0.003 µg/L Lake water: 0.0003µg/L	680 µg/kg			6.40		[20]	F; mean methylmercury concentrations in whole bodies of fish were slightly lower than concentrations in fillets for 4 species evaluated (white perch, smallmouth bass, bluegill, and gizzard shad); differences were significant ($P \leq 0.05$, t-test) for bluegill only; BAF value estimated from chart as log BAF

Summary of Biological Effects Tissue Concentrations for Methylmercury

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	Sediment	Water	Tissue (Sample Type)	Effects	Log BCF	Log BAF	BSAF	Reference	Comments[3]
Benthivores: *Cyprinus carpio*; Carp; *Ictalurus punctatus*, Channel catfish; and *Lepomis macrochirus*, Bluegill		Interstitial water: 0.003 µg/L Lake water: 0.0003 µg/L	480 µg/kg			6.20		[20]	F; mean methylmercury concentrations in whole bodies of fish were slightly lower than concentrations in fillets for 4 species evaluated (white perch, smallmouth bass, bluegill, and gizzard shad); differences were significant (P≤0.05, t-test) for bluegill only; BAF value estimated from chart as log BAF
Oryzias latipes, Japanese medaka			54 mg/kg (whole body)[5]	Development, ED100				[59]	L; complete failure of eggs to hatch
			56 mg/kg (whole body)[5]	Development, ED100				[59]	L; complete failure of eggs to hatch
			54 mg/kg (whole body)[5]	Morphology, ED100				[59]	L; subcutaneous hemorrhage, deformed vertebrae
			56 mg/kg (whole body)[5]	Morphology, ED100				[59]	

Summary of Biological Effects Tissue Concentrations for Methylmercury

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	Sediment	Water	Tissue (Sample Type)	Effects	Log BCF	Log BAF	BSAF	Reference	Comments[3]
			29 mg/kg (whole body)[5]	Behavior, LOED				[59]	L; hatchlings unable to control fin movement, loss of equilibrium
			29 mg/kg (whole body)[5]	Development, LOED				[59]	L; over 50% reduction in number of eggs which hatched
			29 mg/kg (whole body)[5]	Morphology, LOED				[59]	L; subcutaneous hemorrhage, deformed vertebrae
			16 mg/kg (whole body)[5]	Development, NOED				[59]	L; no effect on hatchability of eggs compared to controls
			16 mg/kg (whole body)[5]	Morphology, NOED				[59]	L; no observations of subcutaneous hemorrhage or deformed vertebrae

Summary of Biological Effects Tissue Concentrations for Methylmercury

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	Sediment	Water	Tissue (Sample Type)	Effects	Log BCF	Log BAF	BSAF	Reference	Comments[3]
Morone americana, White perch		Interstitial water: 0.003 µg/L Lake water: 0.0003 µg/L	680 µg/kg			6.40		[20]	F; mean methylmercury concentrations in whole bodies of fish were slightly lower than concentrations in fillets for 4 species evaluated (white perch, smallmouth bass, bluegill, and gizzard shad); differences were significant (P≤0.05, t-test) for bluegill only; BAF value estimated from chart as log BAF
Perca flavescens, Yellow perch			0.135000005364418 mg/kg (whole body)[5]	Growth, NOED				[63]	F, controlled field study; two years but only 1-year-old fish analyzed; basin treated by reducing pH from about 6 to 5.6

Summary of Biological Effects Tissue Concentrations for Methylmercury

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	Sediment	Water	Tissue (Sample Type)	Effects	Log BCF	Log BAF	BSAF	Reference	Comments[3]
Piscivores: *Micropterus dolomieui*, Smallmouth bass; and *Stizostedion vitreum*, Walleye		Interstitial water: 0.003 µg/L Lake water: 0.0003 µg/L	1,100 µg/kg			$3.7x10^6$		[20]	F; mean methylmercury concentrations in whole bodies of fish were slightly lower than concentrations in fillets for 4 species evaluated (white perch, smallmouth bass, bluegill, and gizzard shad); differences were significant (P≤0.05, t-test) for bluegill only; BAF value estimated from chart as log BAF
Stizostedion vitreum, Walleye			0.25 mg/kg (whole body)[5]	Cellular, LOED				[56]	L; multifocal cell atrophy, testicular atrophy
			2.36999988555908 mg/kg (whole body)[5]	Cellular, LOED				[56]	
			0.25 mg/kg (whole body)[5]	Development, LOED				[56]	L; decreased testicular development, lowered gonadosomatic index
			2.36999988555908 mg/kg (whole body)[5]	Development, LOED				[56]	

Summary of Biological Effects Tissue Concentrations for Methylmercury

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	Sediment	Water	Tissue (Sample Type)	Effects	Log BCF	Log BAF	BSAF	Reference	Comments[3]
			2.36999988555908 mg/kg (whole body)[5]	Growth, LOED				[56]	L; significant reduction in length and weight of males, but not females
			0.25 mg/kg (whole body)[5]	Physiological, LOED				[56]	L; reduced cortisol levels
			0.25 mg/kg (whole body)[5]	Growth, NOED				[56]	L; no effect on length or weight
			0.25 mg/kg (whole body)[5]	Mortality, NOED				[56]	L; no statistically significant increase in mortality
			2.36999988555908 mg/kg (whole body)[5]	Mortality, NOED				[56]	
			2.36999988555908 mg/kg (whole body)[5]	Physiological, NOED				[56]	L; no effect on cortisol levels
Pseudopleuronectes americanus, Winter flounder			5 mg/kg (whole body)[5]	Mortality, LOED				[61]	L; increased mortality
			2 mg/kg (whole body)[5]	Physiological, LOED				[61]	L; increased ornithine decarboxylase activity

Summary of Biological Effects Tissue Concentrations for Methylmercury

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	Sediment	Water	Tissue (Sample Type)	Effects	Log BCF	Log BAF	BSAF	Reference	Comments[3]
Wildlife									
Larus californicus, California gull			0.404000014066696 mg/kg (brain)[5]	Mortality, NA				[64]	L
			0.828999996185302 mg/kg (breast)[5]	Mortality, NA				[64]	L
			1.08000004291534 mg/kg (liver)[5]	Mortality, NA				[64]	L
Pelecanus occidentalis, Brown pelican			0.202999994158745 mg/kg (brain)[5]	Mortality, NA				[64]	L
			0.347499996423721 mg/kg (breast)[5]	Mortality, NA				[64]	L
			0.806500017642974 mg/kg (liver)[5]	Mortality, NA				[64]	L
Phalacrocorax penicillatus, Brandts cormorant			0.648999989032745 mg/kg (brain)[5]	Mortality, NA				[64]	L
			0.986000001430511 mg/kg (breast)[5]	Mortality, NA				[64]	L
			2.94000005722045 mg/kg (liver)[5]	Mortality, NA				[64]	L
			3.06999993324279 mg/kg (liver)[5]	Mortality, NA				[64]	L

[1] Concentration units based on wet weight unless otherwise noted.
[2] BCF = bioconcentration factor, BAF = bioaccumulation factor, BSAF = biota-sediment accumulation factor.
[3] L = laboratory study, spiked sediment, single chemical; F = field study, multiple chemical exposure; other unusual study conditions or observations noted.
[4] MeHg = methylmercury.
[5] This entry was excerpted directly from the Environmental Residue-Effects Database (ERED, www.wes.army.mil/el/ered, U.S. Army Corps of Engineers and U.S. Environmental Protection Agency). The original publication was not reviewed, and the reader is strongly urged to consult the publication to confirm the information presented here.

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Chemical Category: METAL

Chemical Name (Common Synonyms): NICKEL **ASRN:** 7440-02-0

Chemical Characteristics

Solubility in Water: Insoluble [1]

Half-Life: Not applicable, stable [1]

Log K_{ow}: –

Log K_{oc}: –

Human Health

Oral RfD: 2 x 10^{-2} mg/kg/day [2]

Confidence: Medium uncertainty factor = 300

Critical Effect: Decreased body and organ weights

Oral Slope Factor: Not available [2]

Carcinogenic Classification: A [2]

Wildlife

Partitioning Factors: Partitioning factors for nickel in wildlife were not found in the literature.

Food Chain Multipliers: Food chain multipliers for nickel in wildlife were not found in the literature.

Aquatic Organisms

Partitioning Factors: Nickel in the aquatic environment can partition to dissolved and particulate organic carbon. Also, the bioavailability of nickel can be influenced to some extent by the concentrations of calcium and magnesium in water. The bioavailability of nickel in sediments is controlled by the concentration of acid-volatile sulfides (AVS) [8].

Food Chain Multipliers: Little evidence exists to support the general occurrence of biomagnification of nickel in the aquatic environment [9 and 10].

Toxicity/Bioaccumulation Assessment Profile

Bioaccumulation of nickel is most pronounced in sediments when the ratio of simultaneously extracted metals to acid-volatile sulfide (SEM/AVS) is greater than 1. Although nickel concentrations in animals from sediments with SEM/AVS ratios >1 were approximately 2- to 10-fold greater than nickel concentrations in benthic organisms from sediments with SEM/AVS ratio <1, nickel uptake (tissue concentration) was proportional to the concentration in sediment. Ankley et al. [3] have shown that bioaccumulation of nickel from the sediment by *Lumbriculus variegatus* was not predictable based on total sediment metal concentration, but was related to the sediment SEM/AVS ratio.

Summary of Biological Effects Tissue Concentrations for Nickel

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	**Sediment**	**Water**	**Tissue (Sample Type)**	**Effects**	**Log BCF**	**Log BAF**	**BSAF**	**Reference**	**Comments[3]**
Invertebrates									
Lumbriculus		0.58 µmol/L	0.10 µmol/g					[3]	F
variegatus,		16.44 µmol/L	5.00 µmol/g						
Oligochaete worm		38.24 µmol/L	3.32 µmol/g						
		31.40 µmol/L	0.87 µmol/g						
		4.53 µmol/L	0.07 µmol/g						
		32.77 µmol/L	0.33 µmol/g						
		8.58 µmol/L	1.88 µmol/g						
		14.43 µmol/L	0.97 µmol/g						
		3.72 µmol/L	3.59 µmol/g						
		17.96 µmol/L	2.77 µmol/g						
		0.52 µmol/L	0.10 µmol/g						
		2.75 µmol/L	0.29 µmol/g						
		0.50 µmol/L	1.41 µmol/g						
		3.51 µmol/L	1.91 µmol/g						
		16.67 µmol/L	7.79 µmol/g						
		17.20 µmol/L	0.95 µmol/g						
Tubificidae	51 µg/g		7.20 mg/g					[6]	L
	50 µg/g		3.19 mg/g						
	93 µg/g		6.96 mg/g						
	76 µg/g		12.04 mg/g						
	75 µg/g		9.45 mg/g						

Summary of Biological Effects Tissue Concentrations for Nickel

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	Sediment	Water	Tissue (Sample Type)	Effects	Log BCF	Log BAF	BSAF	Reference	Comments[3]
Neanthes arenaceodentata, Polychaete worm		<0.28 µmol/L	<0.002 µmol/g	3% mortality				[4]	F
		0.42 µmol/L	0.01 µmol/g	13% mortality					
		2.62 µmol/L	0.01 µmol/g	0% mortality					
		0.16 µmol/L	<0.002 µmol/g	3% mortality					
		<0.74 µmol/L	<0.001 µmol/g	7% mortality					
		3.72 µmol/L	0.01 µmol/g	13% mortality					
		0.37 µmol/L	0.02 µmol/g	0% mortality					
		0.80 µmol/L	<0.006 µmol/g	0% mortality					
		54.30 µmol/L	0.12 µmol/g	20% mortality					
		1.28 µmol/L	<0.002 µmol/g	7% mortality					
		64.8 µmol/L	0.05 µmol/g	10% mortality					
		67.4 µmol/L	0.06 µmol/g	0% mortality					
		36.4 µmol/L	0.12 µmol/g	3% mortality					
		0.86 µmol/L	0.02 µmol/g	0% mortality					
		73.1 µmol/L	0.10 µmol/g	0% mortality				[5]	F
		52.4 µmol/L	0.21 µmol/g	0% mortality					
		449 µmol/L	1.69 µmol/g	3% mortality					
Cerastoderma edule, Clam			56.6 mg/kg (whole body)[4]	Mortality, ED50				[12]	L; estimated body residue by regression from other data values, number of replicates is 2 to 5

Summary of Biological Effects Tissue Concentrations for Nickel

Species: Taxa	Concentration, Units in[1]: Sediment	Water	Tissue (Sample Type)	Toxicity: Effects	Ability to Accumulate[2]: Log BCF	Log BAF	BSAF	Source: Reference	Comments[3]
			128 mg/kg (adductor muscle)[4]	Physiological, NOED				[12]	L; no significant effect on respiration rate at 100 µg/L (highest test concentration at which body residues were measured), number of replicates is 2 to 5
			140 mg/kg (foot)[4]	Physiological, NOED				[12]	
			209 mg/kg (gill)[4]	Physiological, NOED				[12]	
			274 mg/kg (mantle)[4]	Physiological, NOED				[12]	
			138 mg/kg (visceral tissue)[4]	Physiological, NOED				[12]	
			167 mg/kg (whole body)[4]	Physiological,NOED				[12]	
Mytilus galloprovincialis, Mussel			1.1-1.4 mg/kg				0.22	[11]	F
Lamellidans marginalis, Freshwater mussel	110 mg/L		Day 4: 1456.1 µg/g (ctenidium) 432.7 µg/g (mantle) 468.3 µg/g (hepatopancreas) 328.4 µg/g (foot) 373.9 µg/g (adductor muscle)					[5]	L

Summary of Biological Effects Tissue Concentrations for Nickel

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	**Sediment**	**Water**	**Tissue (Sample Type)**	**Effects**	**Log BCF**	**Log BAF**	**BSAF**	**Reference**	**Comments[3]**
Lamellidans marginalis, Freshwater mussel	22 mg/L		Day 15: 569.8 µg/g (ctenidium) 277.1 µg/g (mantle) 327.1 µg/g (hepatopancreas) 218.6 µg/g (foot) 186.7 µg/g (adductor muscle)					[5]	L
Daphnia magna, Cladoceran			223 mg/kg (whole body)[4]	Mortality, ED50				[6]	L; lethal body burden after 21-day exposure
Fishes									
Cyprinus carpio, Carp		40 mg/L	Day 4: 202.8 mg/L (gill) 226.3 mg/L (kidney) 82.2 mg/L (liver) 97.1 mg/L (brain) 118.1 mg/L (white muscle)					[5]	L
		8 mg/L	Day 15: 103.0 mg/L (gill) 80.3 mg/L (kidney) 97.1 mg/L (liver) 40.6 mg/L (brain) 58.0 mg/L (white) muscle)						

Summary of Biological Effects Tissue Concentrations for Nickel

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	Sediment	Water	Tissue (Sample Type)	Effects	Log BCF	Log BAF	BSAF	Reference	Comments[3]
Pimephales promelas, Fathead minnow	31 µg/g		8.69 mg/g					[7]	F
	51 µg/g		8.19 mg/g						
	50 µg/g		5.66 mg/g						
	57 µg/g		4.02 mg/g						
	93 µg/g		10.72 mg/g						
	73 µg/g		10.10 mg/g						
	76 µg/g		11.51 mg/g						
	60 µg/g		13.32 mg/g						
	75 µg/g		11.75 mg/g						
	53 µg/g		10.90 mg/g						

[1] Concentration units based on wet weight unless otherwise noted.
[2] BCF = bioconcentration factor, BAF = bioaccumulation factor, BSAF = biota-sediment accumulation factor.
[3] L = laboratory study, spiked sediment, single chemical; F = field study, multiple chemical exposure; other unusual study conditions or observations noted.
[4] This entry was excerpted directly from the Environmental Residue-Effects Database (ERED, www.wes.army.mil/el/ered, U.S. Army Corps of Engineers and U.S. Environmental Protection Agency). The original publication was not reviewed, and the reader is strongly urged to consult the publication to confirm the information presented here.

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Chemical Category: PESTICIDE (CHLOROPHENOXY)

Chemical Name (Common Synonyms): OXYFLUORFEN **CASRN:** 42874-03-3

Chemical Characteristics

Solubility in Water: No data [1]

Half-Life: No data [2]

Log K_{ow}: No data [3]

Log K_{oc}: —

Human Health

Oral RfD: 3 x 10^{-3} mg/kg/day [4]

Confidence: High, uncertainty factor = 100

Critical Effect: Increased absolute liver weight and nonneoplastic lesions in mice

Oral Slope Factor: 1.3 x 10^{-1} per (mg/kg)/day [5]

Carcinogenic Classification: C [5]

Wildlife

Partitioning Factors: Partitioning factors for in wildlife were not found in the literature.

Food Chain Multipliers: Food chain multipliers for oxyfluorfen in wildlife were not found in the literature.

Aquatic Organisms

Partitioning Factors: Partitioning factors for oxyfluorfen in aquatic organisms were not found in the literature.

Food Chain Multipliers: Food chain multipliers for oxyfluorfen in aquatic organisms were not found in the literature.

Toxicity/Bioaccumulation Assessment Profile

A light activated herbicide, oxyfluorfen at 10^{-2} mM increased cell membrane permeability in *Lemna minor* [6]. The screening tissue value for fish for oxyfluorfen presented by the Chesapeake Bay Program is 800 ng/g [7].

Summary of Biological Effects Tissue Concentrations for Oxyfluorfen

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	**Sediment**	**Water**	**Tissue (Sample Type)**	**Effects**	**Log BCF**	**Log BAF**	**BSAF**	**Reference**	**Comments[3]**
Invertebrates			**[NO DATA]**						
Fishes			**[NO DATA]**						
Wildlife			**[NO DATA]**						

[1] Concentration units based on wet weight unless otherwise noted.
[2] BCF = bioconcentration factor, BAF = bioaccumulation factor, BSAF = biota-sediment accumulation factor.
[3] L = laboratory study, spiked sediment, single chemical; F = field study, multiple chemical exposure; other unusual study conditions or observations noted.

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Chemical Category: BIPHENYLS

Chemical Name (Common Synonyms): 2,4,4′-TRICHLOROBIPHENYL **CASRN:** 7012-37-5

Chemical Characteristics

Solubility in Water: No data [1], 160 µg/L [2]

Half-Life: No data [3,4]

Log K_{ow}: 5.60 [2]

Log K_{oc}: 5.51 L/kg organic carbon

Human Health

Oral RfD: No data [5]

Confidence: —

Critical Effect: —

Oral Slope Factor: No data [5]

Carcinogenic Classification: No data [5]

Wildlife

Partitioning Factors: No partitioning factors were identified for wildlife.

Food Chain Multipliers: For PCBs as a class the most toxic congeners have been shown to be selectively accumulated from organisms at one trophic level to the next [6]. At least three studies have concluded that PCBs have the potential to biomagnify in food webs based on aquatic organisms and predators that feed primarily on aquatic organisms [7,8,9]. The results from Biddinger and Gloss [7] and USACE [9] generally agreed that highly water-insoluble compounds (including PCBs) have the potential to biomagnify in these types of food webs. Thomann's [10] model also indicated that highly water-insoluble compounds (log K_{ow} values 5 to 7) showed the greatest potential to biomagnify. Log biomagnification factors of 1.07 and 1.97 were determined for total PCBs from alewife to herring gull eggs and from alewife to whole body herring gull, respectively [11]. No specific food chain multipliers were identified for PCB 28.

Aquatic Organisms

Partitioning Factors: Biota-sediment accumulation factors (BSAFs) range from 1.5 to 18.2 for aquatic invertebrate species. The highest BSAF was provided for marine crustaceans.

Food Chain Multipliers: Polychlorinated biphenyls as a class have been demonstrated to biomagnify through the food web. Oliver and Niimi [12], studying accumulation of PCBs in various organisms in the Lake Ontario food web, reported concentrations of total PCBs in phytoplankton, zooplankton, and several species of fish. Their data indicated a progressive increase in tissue PCB concentrations moving from organisms lower in the food web to top aquatic predators. In a study of PCB accumulation in lake trout (*Salvelinus namaycush*) of Lake Ontario, Rasmussen et al. [13] reported that each trophic level contributed about a 3.5-fold biomagnification factor to the PCB concentrations in the trout. No specific food chain multipliers were identified for PCB 28 or other trichlorobiphenyls.

Toxicity/Bioaccumulation Assessment Profile

PCBs are a group (209 congeners/isomers) of organic chemicals, based on various substitutions of chlorine atoms on a basic biphenyl molecule. These manufactured chemicals have been widely used in various processes and products because of the extreme stability of many isomers, particularly those with five or more chlorines [14]. A common use of PCBs was as dielectric fluids in capacitors and transformers. In the United States, Aroclor is the most familiar registered trademark of commercial PCB formulations. Generally, the first two digits in the Aroclor designation indicate that the mixture contains biphenyls, and the last two digits give the weight percent of chlorine in the mixture

As a result of their stability and their general hydrophobic nature, PCBs released to the environment have dispersed widely throughout the ecosystem [14]. PCBs are among the most stable organic compounds known, and chemical degradation rates in the environment are thought to be slow. As a result of their highly lipophilic nature and low water solubility, PCBs are generally found at low concentrations in water and at relatively high concentrations in sediment [15]. Individual PCB congeners have different physical and chemical properties based on the degree of chlorination and position of chlorine substitution, although differences with degree of chlorination are more significant [15]. Solubilities and octanol-water partition coefficients for PCB congeners range over several orders of magnitude [16]. Octanol-water partition coefficients, which are often used as estimators of the potential for bioconcentration, are highest for the most chlorinated PCB congeners.

Dispersion of PCBs in the aquatic environment is a function of their solubility [15], whereas PCB mobility within and sorption to sediment are a function of chlorine substitution pattern and degree of chlorination [17]. The concentration of PCBs in sediments is a function of the physical characteristics of the sediment, such as grain size [18,19] and total organic carbon content [18,19,20,21]. Fine sediments typically contain higher concentrations of PCBs than coarser sediments because of more surface area [15]. Mobility of PCBs in sediment is generally quite low for the higher chlorinated biphenyls [17]. Therefore, it is common for the lower chlorinated PCBs to have a greater dispersion from the original point source [15]. Limited mobility and high rates of sedimentation could prevent some PCB congeners in the sediment from reaching the overlying water via diffusion [17].

The persistence of PCBs in the environment is a result of their general resistance to degradation [16]. The rate of degradation of PCB congeners by bacteria decreases with increasing degree of chlorination [22]; other structural characteristics of the individual PCBs can affect susceptibility to microbial degradation to a lesser extent [16]. Photochemical degradation, via reductive dechlorination, is also known to occur in aquatic environments; the higher chlorinated PCBs appear to be most susceptible to this process [21].

Toxicity of PCB congeners is dependent on the degree of chlorination as well as the position of chlorine substitution. Lesser chlorinated congeners are more readily absorbed, but are metabolized more rapidly than higher chlorinated congeners [23]. PCB congeners with no chlorine substituted in the ortho (2 and 2′) positions but with four or more chlorine atoms at the meta (3 and 3′) and para (4 and 4′) positions can assume a planar conformation that can interact with the same receptor as the highly toxic 2,3,7,8-tetrachlorodibenzo-*p*-dioxin (TCDD) [24]. Examples of these more toxic, coplanar congeners are

3,3′,4,4′-trachlorobiphenyl (PCB 77), 3,3′,4,4′,5-pentachlorobiphenyl (PCB 126), and 3,3′,4,4′,5,5′-hexachlorobiphenyl (PCB 169). A method that has been proposed to estimate the relative toxicity of mixtures is to use toxic equivalency factors (TEFs) [25]. With this method, relative potencies for individual congeners are calculated by expressing their potency in relation to 2,3,7,8-TCDD. The following TEFs have been recommended [25,26]:

Congener Class	Recommended TEF
3,3′,4,4′,5-PentaCB	0.1
3,3′,4,4′,5,5′-HexaCB	0.05
3,3′4,4′-TetraCB	0.01
Monoortho coplanar PCBs	0.001
Diortho coplanar PCBs	0.00002

Due to the toxicity, high Kow values, and highly persistent nature of many PCBs, they possess a high potential to bioaccumulate and exert reproductive effects in higher-trophic-level organisms. Aquatic organisms have a strong tendency to accumulate PCBs from water and food sources. The log bioconcentration factor for fish is approximately 4.70 [27]. This factor represents the ratio of concentration in tissue to the ambient water concentration. Aquatic organisms living in association with PCB-contaminated sediments generally have tissue concentrations equal to or greater than the concentration of PCB in the sediment [27]. Once taken up by an organism, partition primarily into lipid compartments [15]. Thus, differences in PCB concentration between species and between different tissues within the same species may reflect differences in lipid content [15]. PCB concentrations in polychaetes and fish have been strongly correlated to their lipid content [28]. Elimination of PCBs from organisms is related to the characteristics of the specific PCB congeners present. It has been shown that uptake and depuration rates in mussels are high for lower-chlorinated PCBs and much lower for higher-chlorinated congeners [29, 30]. In some species, tissue concentrations of in females can be reduced during gametogenesis because of PCB transfer to the more lipophilic eggs. Therefore, the transferred are eliminated from the female during spawning [31,32]. Fish and other aquatic organisms biotransform PCBs more slowly than other species, and they appear less able to metabolize, or excrete, the higher chlorinated PCB congeners [31]. Consequently, fish and other aquatic organisms may accumulate more of the higher chlorinated PCB congeners than is found in the environment [16].

The acute toxicity of PCBs appears to be relatively low, but results from chronic toxicity tests indicate that PCB toxicity is directly related to the duration of exposure [33]. Toxic responses have been noted to occur at concentrations of 0.03 and 0.014 µg/L in marine and freshwater environments, respectively [33]. The LC50 for grass shrimp exposed to PCBs in marine waters for 4 days was 6.1 to 7.8 µg/L [33]. Chronic toxicity of PCBs presents a serious environmental concern because of their resistance to degradation [34], although the acute toxicity of PCBs is relatively low compared to that of other chlorinated hydrocarbons. Sediment contaminated with PCBs has been shown to elicit toxic responses at relatively low concentrations. Sediment bioassays and benthic community studies suggest that chronic effects generally occur in sediment at total PCB concentrations exceeding 370 [35].

A number of field and laboratory studies provide evidence of chronic sublethal effects on aquatic organisms at low tissue concentrations [16]. Field and Dexter [16] suggest that a number of marine and freshwater fish species have experienced chronic toxicity at PCB tissue concentrations of less than 1.0 mg/kg and as low as 0.1 mg/kg. Spies et al. [36] reported an inverse relationship between PCB concentrations in starry flounder eggs in San Francisco Bay and reproductive success, with an effective PCB concentration in the ovaries of less than 0.2 mg/kg. Monod [37] also reported a significant correlation between PCB concentrations in eggs and total egg mortality in Lake Geneva char. PCBs have also been shown to cause induction of the mixed function oxidase (MFO) system in aquatic animals, with MFO induction by PCBs at tissue concentrations within the range of environmental exposures [16].

Summary of Biological Effects Tissue Concentrations for PCB 28

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	Sediment	Water	Tissue (Sample Type)	Effects	Log BCF	Log BAF	BSAF	Reference	Comments[3]
Invertebrates									
Microcystis aeruginosa, *Daphnia longispina*, Plankton	1.35 ± 0.9 ng/g dw (n = 11) (0-20 cm)		0.23 ± 0.22 ng/g (n=14)				3.3	[38]	F; Amsterdam; value is mean ± SD; mean sediment TOC = 9.7%; mean lipid = 0.65%
Plankton, Species not reported	1.949[4] (mean) SD = 0.7309 (n = 9) µg/kg dw	0.008[4] (mean) SD = 0.0031 (n = 3) ng/L	0.350[4] (mean) SD = 0.2353 (n = 5) µg/kg					[39]	F; collected in western Lake Erie (offshore Middle Sister Island); sediment TOC = 7.4% (SD = 1.78), lipid = 1.2% (mean) SD = 0.24
Dreissena polymorpha, Zebra mussel	1.949[4] (mean) SD = 0.7309 (n = 9) µg/kg dw	0.008[4] (mean) SD = 0.0031 (n = 3) ng/L	0.431[4] (mean) SD = 0.4642 (n = 20) µg/kg						lipid = 1.3% (mean) SD = 0.34
Dreissena polymorpha, Zebra mussel	1.35 ± 0.9 ng/g dw (n = 11) (0-20 cm)		0.52 ± 0.36 ng/g (n = 5)				2.8	[38]	F; Amsterdam; value is mean ± SD; mean sediment TOC = 9.7%; mean lipid = 1.74%
Corbicula fluminea, Bivalve	Station B6: 0.4[4] ng/g dw	1.1[4] ng/L	0.33[4] µg/g[5] of lipid (whole animal)					[40]	F; samples collected from the Rio de la Plata. Sediment depth samples was 0-5 cm. Water sample was filtered.
	Station C10: 0.03[4] ng/g dw	<DL[4]	0.3 µg/g[5] of lipid						

Summary of Biological Effects Tissue Concentrations for PCB 28

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	Sediment	Water	Tissue (Sample Type)	Effects	Log BCF	Log BAF	BSAF	Reference	Comments[3]
Crustaceans *Gammarus tigrinus, Assellus aquaticus, Orchestra carimana*	1.35 ± 0.9 ng/g dw (n = 11) (0-20 cm)		2.93 ± 1.41 ng/g (n = 7)				18.2	[38]	F; Amsterdam; value is mean ± SD; mean sediment TOC = 9.7%; mean lipid = 0.86%
Gammarus fasciatus, Amphipod	1.949[4] (mean) SD = 0.7309 (n = 9) µg/kg dw	0.008[4] (mean) SD = 0.0031 (n = 3) ng/L	0.666[4] (mean) SD = 0.2768 (n = 4) µg/kg						lipid = 2.1% (mean) SD = 1.04
Orconectes propinquus, Crayfish	1.949[4] (mean) SD = 0.7309 (n = 9) µg/kg dw	0.008[4] (mean) SD = 0.0031 (n = 3) ng/L	0.392[4] (mean) SD = 0.2407 (n = 5) µg/kg						lipid = 1.7% (mean) SD = 0.11
Hydropsyche alterans, Caddisfly larva	1.949[4] (mean) SD = 0.7309 (n = 9) µg/kg dw	0.008[4] (mean) SD = 0.0031 (n = 3) ng/L	0.369[4] (n = 1) µg/kg						lipid = 1.7% (mean)
Fishes									
Prochilodus platensis, Fish	Station F17: 0.08[4] ng/g dw	<DL[4]	0.9[4]µg/g[5] of lipid					[40]	F; samples collected from the Rio de la Plata.
Oligosarcus jenynsi, Fish	Station A1: 6[4] ng/g dw	0.7[4] ng/L	0.3[4] µg/g[5] of lipid					[40]	F; samples collected from the Rio Santiago.

Summary of Biological Effects Tissue Concentrations for PCB 28

Species:	**Concentration, Units in[1]:**			**Toxicity:**	**Ability to Accumulate[2]:**			**Source:**	
Taxa	**Sediment**	**Water**	**Tissue (Sample Type)**	**Effects**	**Log BCF**	**Log BAF**	**BSAF**	**Reference**	**Comments[3]**
Anguilla anguilla, Eel	1.35 ± 0.9 ng/g dw (n = 11) (0-20 cm)		3.98 ± 3.42 ng/g (n = 6)				1.5	[38]	F; Amsterdam; value is mean ± SD; mean sediment TOC = 9.7%; mean lipid = 14.9%

[1] Concentration units based on wet weight unless otherwise noted.
[2] BCF = bioconcentration factor, BAF = bioaccumulation factor, BSAF = biota-sediment accumulation factor.
[3] L = laboratory study, spiked sediment, single chemical; F = field study, multiple chemical exposure; other unusual study conditions or observations noted.
[4] Reported concentrations reflect both congeners 28 and 31.
[5] Not clear from reference if concentration is based on wet or dry weight.

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Chemical Category: POLYCHLORINATED BIPHENYLS

Chemical Name (Common Synonyms): 3,3′,4,4′-TETRACHLOROBIPHENYL **CASRN:** 32598-13-3

Chemical Characteristics

Solubility in Water: 0.18 mg/L [1]

Half-Life: No data [2,3]

Log K_{ow}: No data [4], 6.1 [5]

Log K_{oc}: —

Human Health

Oral RfD: No data [6]

Confidence: —

Critical Effect: —

Oral Slope Factor: No data [6]

Carcinogenic Classification: No data [6]

Wildlife

Partitioning Factors: Bioaccumulation factors (BAFs) were determined for mink. The mink had less PCB-77 in their tissues than was measured in their diet. BAF values ranged from 0.1 to 0.2.

Food Chain Multipliers: For PCBs as a class the most toxic congeners have been shown to be selectively accumulated from organisms at one trophic level to the next [7]. At least three studies have concluded that PCBs have the potential to biomagnify in food webs based on aquatic organisms and predators that feed primarily on aquatic organisms [8,9,10]. The results from Biddinger and Gloss [8] and USACE [10] generally agreed that highly water-insoluble compounds (including PCBs) have the potential to biomagnify in these types of food webs. Thomann's [11] model also indicated that highly water-insoluble compounds (log K_{ow} values 5 to 7) showed the greatest potential to biomagnify. Log biomagnification factors (BMFs) for tetrachlorobiphenyls from alewife to herring gulls ranged from 1.52 to 1.83, but were not measured specifically for PCB 77 [12]. A study of arctic marine food chains measured log biomagnification factors for tetrachlorobiphenyls that ranged from 0.08 to 0.40 for fish to seal, <-0.40 for seal to bear, and <-0.30 for fish to bear [13]. Log BMFs calculated for mink fed PCB 77-contaminated feed ranged from -1.00 to -0.70 [40].

Aquatic Organisms

Partitioning Factors: Log bioconcentration factors (BCFs) for blue mussels deployed in New Bedford Harbor, MA, were approximately 6.40 and 6.60 during two years of the study, as reported in the attached summary table [42].

Food Chain Multipliers: Polychlorinated biphenyls as a class have been demonstrated to biomagnify through the food web. Oliver and Niimi [14], studying accumulation of PCBs in various organisms in the Lake Ontario food web, reported concentrations of total PCBs in phytoplankton, zooplankton, and several species of fish. Their data indicated a progressive increase in tissue PCB concentrations moving from organisms lower in the food web to top aquatic predators. In a study of PCB accumulation in lake trout (*Salvelinus namaycush*) of Lake Ontario, Rasmussen et al. [15] reported that each trophic level contributed about a 3.5-fold biomagnification factor to the PCB concentrations in the trout. No specific food chain multipliers were identified for PCB 77 or other tetrachlorobiphenyls.

Toxicity/Bioaccumulation Assessment Profile

PCBs are a group (209 congeners/isomers) of organic chemicals, based on various substitutions of chlorine atoms on a basic biphenyl molecule. These manufactured chemicals have been widely used in various processes and products because of the extreme stability of many isomers, particularly those with five or more chlorines [16]. A common use of PCBs was as dielectric fluids in capacitors and transformers. In the United States, Aroclor is the most familiar registered trademark of commercial PCB formulations. Generally, the first two digits in the Aroclor designation indicate that the mixture contains biphenyls, and the last two digits give the weight percent of chlorine in the mixture.

As a result of their stability and their general hydrophobic nature, PCBs released to the environment have dispersed widely throughout the ecosystem [16]. PCBs are among the most stable organic compounds known, and chemical degradation rates in the environment are thought to be slow. As a result of their highly lipophilic nature and low water solubility, PCBs are generally found at low concentrations in water and at relatively high concentrations in sediment [17]. Individual PCB congeners have different physical and chemical properties based on the degree of chlorination and position of chlorine substitution, although differences with degree of chlorination are more significant [17]. Solubilities and octanol-water partition coefficients for PCB congeners range over several orders of magnitude [18]. Octanol-water partition coefficients, which are often used as estimators of the potential for bioconcentration, are highest for the most chlorinated PCB congeners.

Dispersion of PCBs in the aquatic environment is a function of their solubility [17] , whereas PCB mobility within and sorption to sediment are a function of chlorine substitution pattern and degree of chlorination [19]. The concentration of PCBs in sediments is a function of the physical characteristics of the sediment, such as grain size [20,21] and total organic carbon content [20,21,22,23]. Fine sediments typically contain higher concentrations of PCBs than coarser sediments because of more surface area [17]. Mobility of PCBs in sediment is generally quite low for the higher chlorinated biphenyls [19]. Therefore, it is common for the lower chlorinated PCBs to have a greater dispersion from the original point source [17]. Limited mobility and high rates of sedimentation could prevent some PCB congeners in the sediment from reaching the overlying water via diffusion [19].

The persistence of PCBs in the environment is a result of their general resistance to degradation [18]. The rate of degradation of PCB congeners by bacteria decreases with increasing degree of chlorination [24]; other structural characteristics of the individual PCBs can affect susceptibility to microbial degradation to a lesser extent [18]. Photochemical degradation, via reductive dechlorination, is also known to occur in aquatic environments; the higher chlorinated PCBs appear to be most susceptible to this process [23].

Toxicity of PCB congeners is dependent on the degree of chlorination as well as the position of chlorine substitution. Lesser chlorinated congeners are more readily absorbed, but are metabolized more rapidly than higher chlorinated congeners [25]. PCB congeners with no chlorine substituted in the ortho (2 and 2′) positions but with four or more chlorine atoms at the meta (3 and 3′) and para (4 and 4′) positions can assume a planar conformation that can interact with the same receptor as the highly toxic 2,3,7,8-tetrachlorodibenzo-*p*-dioxin (TCDD) [26]. Examples of these more toxic, coplanar congeners are 3,3′,4,4′-tetrachlorobiphenyl (PCB 77), 3,3′,4,4′,5-pentachlorobiphenyl (PCB 126), and 3,3′,4,4′,5,5′-hexachlorobiphenyl (PCB 169). A method that has been proposed to estimate the relative toxicity of mixtures is to use toxic equivalency factors (TEFs) [27]. With this method, relative potencies for individual congeners are calculated by expressing their potency in relation to 2,3,7,8-TCDD. The following TEFs have been recommended [27,28]:

Congener Class	Recommended TEF
3,3′,4,4′,5-PentaCB	0.1
3,3′,4,4′,5,5′-HexaCB	0.05
3,3′4,4′-TetraCB	0.01
Monoortho coplanar PCBs	0.001
Diortho coplanar PCBs	0.00002

Due to the toxicity, high K_{ow} values, and highly persistent nature of many PCBs, they possess a high potential to bioaccumulate and exert reproductive effects in higher-trophic-level organisms. Aquatic organisms have a strong tendency to accumulate PCBs from water and food sources. The log bioconcentration factor for fish is approximately 4.70 [29]. This factor represents the ratio of concentration in tissue to the ambient water concentration. Aquatic organisms living in association with PCB-contaminated sediments generally have tissue concentrations equal to or greater than the concentration of PCB in the sediment [29]. Once taken up by an organism, PCBs partition primarily into lipid compartments [17]. Thus, differences in PCB concentration between species and between different tissues within the same species may reflect differences in lipid content [17]. PCB concentrations in polychaetes and fish have been strongly correlated to their lipid content [30]. Elimination of PCBs from organisms is related to the characteristics of the specific PCB congeners present. It has been shown that uptake and depuration rates in mussels are high for lower-chlorinated PCBs and much lower for higher-chlorinated congeners [31,32]. In some species, tissue concentrations of PCBs in females can be reduced during gametogenesis because of PCB transfer to the more lipophilic eggs. Therefore, the transferred PCBs are eliminated from the female during spawning [33,34]. Fish and other aquatic organisms biotransform PCBs more slowly than other species, and they appear less able to metabolize, or excrete, the higher chlorinated PCB congeners [33]. Consequently, fish and other aquatic organisms may accumulate more of the higher chlorinated PCB congeners than is found in the environment [18].

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Summary of Biological Effects Tissue Concentrations for PCB 77

Species: Taxa	Concentration, Units in[1]: Sediment	Water	Tissue (Sample Type)	Toxicity: Effects	Ability to Accumulate[2]: Log BCF	Log BAF	BSAF	Source: Reference	Comments[3]
Invertebrates									
Mytilus edulis, Blue mussel		1993: Particulate 1.7 µg/L ±0.5 n = 9 Dissolved 1.0 µg/L ±0.1 n = 9			~6.60			[42]	F; New Bedford Harbor, MA; deployment study; tissue concentrations were only presented for 1994 samples; BCF and tissue concentrations are approximations (~) as data were taken from figure
Mytilus edulis, Blue mussel		1994: Particulate 2.3 µg/L ±0.9 n = 3 Dissolved 0.9 µg/L ±0.1 n = 3	-360 ng/g dw (whole body)		~6.40			[42]	Presented for 1994 samples; BCF and tissue concentrations are approximations (~) as data were taken from figure

Summary of Biological Effects Tissue Concentrations for PCB 77

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	Sediment	Water	Tissue (Sample Type)	Effects	Log BCF	Log BAF	BSAF	Reference	Comments[3]
Daphnia magna, Freshwater cladoceran		exposure water 0.1 µg/L	~6.5 ng/mg dw (n = 3)	No significant effect on survival or reproduction; increased biomass				[40]	L; 21-day static renewal tests; tissue concentrations are approximations (~), as data were taken from figures
		1.0 µg/L	~55 ng/mg dw (n = 3)	No significant effect on survival or reproduction; decreased biomass					
Mysis relicta, Epibenthic freshwater shrimp	118.47 µg/kg dw (TOC = 22.8%)		Screened mysids: 0.72 µg/kg					[41]	L; mysids exposed to field contaminated sediments from Lake Champlain, NY; 24-day exposure; screened mysids were screened from direct contact with sediments (% lipid = 5.94 ± 0.27) whole body;
			Unscreened mysids: 8.74 µg/kg						unscreened mysids were allowed to burrow into sediment.(% lipid = 5.80 ± 0.18) whole body

Summary of Biological Effects Tissue Concentrations for PCB 77

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	Sediment	Water	Tissue (Sample Type)	Effects	Log BCF	Log BAF	BSAF	Reference	Comments[3]
Strongylocentrotus droebachiensis, Sea urchin	0.050 ng/g		0.087 ng/g					[43]	F; sediment and biota collected near or in Hamlet in Cambridge Bay, NW Territories, Canada.
Fishes									
Myoxocephalus quadricornis, Fourhorn sculpin	0.050 ng/g dw		0.056 ng/g (liver) 0.11ng/g (whole body)					[43]	F; sediment and biota collected near or in Hamlet in Cambridge Bay, NW Territories, Canada.
Salmonids							0.29	[47]	F
Wildlife									
Falco peregrinus, Peregrine falcon			1.5 ng/g (eggs) (n = 6)	11.4% eggshell thinning				[46]	F; Kola Peninsula, Russia
White leghorn chicken (embryo)			2.6 µg/kg (egg) 8.6 µg/kg (egg)	LD50 LD50				[44]	L; PCBs were injected into the air cell of eggs

Summary of Biological Effects Tissue Concentrations for PCB 77

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	**Sediment**	**Water**	**Tissue (Sample Type)**	**Effects**	**Log BCF**	**Log BAF**	**BSAF**	**Reference**	**Comments[3]**
Mustela vison, Mink	Diet: 11 pg/g[4]		50 pg/g[4] (liver)	NOAEL		No BMF reported		[45]	L; BMF = lipid-normalized concentration in the liver divided by the lipid-normalized dietary concentration
	300 pg/g[4]		45 pg/g[4] (liver)	LOAEL; reduced kit body weights followed by reduced survival		Log BMF = −0.70			
	600 pg/g[4]		50 pg/g[4] (liver)	Reduced kit body weights followed by reduced survival		Log BMF = −1.00			
	1,100 pg/g[4]		90 pg/g[4] (liver)	Significant decrease in number of live kits whelped per female		Log BMF = −1.00			

[1] Concentration units expressed in wet weight unless otherwise noted.
[2] BCF = bioconcentration factor, BAF = bioaccumulation factor, BSAF = biota-sediment accumulation factor.
[3] L = laboratory study, spiked sediment, single chemical; F = field study, multiple chemical exposure; other unusual study conditions or observations noted.
[4] Not clear whether units are in dry or wet weight.

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Chemical Category: POLYCHLORINATED BIPHENYLS

Chemical Name (Common Synonyms): 3,4,4′,5-TETRACHLOROBIPHENYL **CASRN:** 70362-50-4

Chemical Characteristics

Solubility in Water: No data [1,2]

Half-Life: No data [2,3]

Log K_{ow}: No data [2,4]

Log K_{oc}: —

Human Health

Oral RfD: No data [5]

Confidence: —

Critical Effect: —

Oral Slope Factor: No data [5]

Carcinogenic Classification: No data [5]

Wildlife

Partitioning Factors: Bioaccumulation factors were determined for mink. At PCB 81 concentration ≥ 66 pg/g, the mink had less PCB 81 in their tissues (liver) than was measured in their diet. At low PCB 81 concentrations (e.g., 27 pg/g), there was an increase in the tissue burden. Log BAF values ranged from −0.10 to 0.23.

Food Chain Multipliers: For PCBs as a class the most toxic congeners have been shown to be selectively accumulated from organisms at one trophic level to the next [6]. At least three studies have concluded that PCBs have the potential to biomagnify in food webs based on aquatic organisms and predators that feed primarily on aquatic organisms [7,8,9]. The results from Biddinger and Gloss [7] and USACE [9] generally agreed that highly water-insoluble compounds (including PCBs) have the potential to biomagnify in these types of food webs. Thomann's [10] model also indicated that highly water-insoluble compounds (log K_{ow} values 5 to 7) showed the greatest potential to biomagnify. Log biomagnification factors for tetrachlorobiphenyls from alewife to herring gulls ranged from 1.52 to 1.83, but were not measured specifically for PCB 81 [11]. A study of arctic marine food chains measured log biomagnification factors for tetrachlorobiphenyls that ranged from 0.08 to 0.40 for fish to seal, <−0.4 for seal to bear, and <−0.3 for fish to bear [12]. No specific food chain multipliers were identified for PCB 81.

Aquatic Organisms

Partitioning Factors: No partitioning factors were identified for aquatic organisms.

Food Chain Multipliers: Polychlorinated biphenyls as a class have been demonstrated to biomagnify through the food web. Oliver and Niimi [13], studying accumulation of PCBs in various organisms in the Lake Ontario food web, reported concentrations of total PCBs in phytoplankton, zooplankton, and several species of fish. Their data indicated a progressive increase in tissue PCB concentrations moving from organisms lower in the food web to top aquatic predators. In a study of PCB accumulation in lake trout (*Salvelinus namaycush*) of Lake Ontario, Rasmussen et al. [14] reported that each trophic level contributed about a 3.5-fold biomagnification factor to the PCB concentrations in the trout. No specific food chain multipliers were identified for PCB 81.

Toxicity/Bioaccumulation Assessment Profile

PCBs are a group (209 congeners/isomers) of organic chemicals, based on various substitutions of chlorine atoms on a basic biphenyl molecule. These manufactured chemicals have been widely used in various processes and products because of the extreme stability of many isomers, particularly those with five or more chlorines [15]. A common use of PCBs was as dielectric fluids in capacitors and transformers. In the United States, Aroclor is the most familiar registered trademark of commercial PCB formulations. Generally, the first two digits in the Aroclor designation indicate that the mixture contains biphenyls, and the last two digits give the weight percent of chlorine in the mixture.

As a result of their stability and their general hydrophobic nature, PCBs released to the environment have dispersed widely throughout the ecosystem [15]. PCBs are among the most stable organic compounds known, and chemical degradation rates in the environment are thought to be slow. As a result of their highly lipophilic nature and low water solubility, PCBs are generally found at low concentrations in water and at relatively high concentrations in sediment [16]. Individual PCB congeners have different physical and chemical properties based on the degree of chlorination and position of chlorine substitution, although differences with degree of chlorination are more significant [16]. Solubilities and octanol-water partition coefficients for PCB congeners range over several orders of magnitude [17]. Octanol-water partition coefficients, which are often used as estimators of the potential for bioconcentration, are highest for the most chlorinated PCB congeners.

Dispersion of PCBs in the aquatic environment is a function of their solubility [16], whereas PCB mobility within and sorption to sediment are a function of chlorine substitution pattern and degree of chlorination [18]. The concentration of PCBs in sediments is a function of the physical characteristics of the sediment, such as grain size [19,20] and total organic carbon content [19,20,21,22]. Fine sediments typically contain higher concentrations of PCBs than coarser sediments because of more surface area [16]. Mobility of PCBs in sediment is generally quite low for the higher chlorinated biphenyls [18]. Therefore, it is common for the lower chlorinated PCBs to have a greater dispersion from the original point source [16]. Limited mobility and high rates of sedimentation could prevent some PCB congeners in the sediment from reaching the overlying water via diffusion [18].

The persistence of PCBs in the environment is a result of their general resistance to degradation [17]. The rate of degradation of PCB congeners by bacteria decreases with increasing degree of chlorination [23]; other structural characteristics of the individual PCBs can affect susceptibility to microbial degradation to a lesser extent [17]. Photochemical degradation, via reductive dechlorination, is also known to occur in aquatic environments; the higher chlorinated PCBs appear to be most susceptible to this process [22].

Toxicity of PCB congeners is dependent on the degree of chlorination as well as the position of chlorine substitution. Lesser chlorinated congeners are more readily absorbed, but are metabolized more rapidly than higher chlorinated congeners [24]. PCB congeners with no chlorine substituted in the ortho (2 and

2′) positions but with four or more chlorine atoms at the meta (3 and 3′) and para (4 and 4′) positions can assume a planar conformation that can interact with the same receptor as the highly toxic 2,3,7,8-tetrachlorodibenzo-*p*-dioxin (TCDD) [25]. Examples of these more toxic, coplanar congeners are 3,3′,4,4′-tetrachlorobiphenyl (PCB 77), 3,3′,4,4′,5-pentachlorobiphenyl (PCB 126), and 3,3′,4,4′5,5′-hexachlorobiphenyl (PCB 169). A method that has been proposed to estimate the relative toxicity of mixtures is to use toxic equivalency factors (TEFs) [26]. With this method, relative potencies for individual congeners are calculated by expressing their potency in relation to 2,3,7,8-TCDD. The following TEFs have been recommended [26,27]:

Congener Class	Recommended TEF
3,3′,4,4′,5-PentaCB	0.1
3,3′,4,4′,5,5′-HexaCB	0.05
3,3′4,4′-TetraCB	0.01
Monoortho coplanar PCBs	0.001
Diortho coplanar PCBs	0.00002

Due to the toxicity, high K_{ow} values, and highly persistent nature of many PCBs, they possess a high potential to bioaccumulate and exert reproductive effects in higher-trophic-level organisms. Aquatic organisms have a strong tendency to accumulate PCBs from water and food sources. The log bioconcentration factor for fish is approximately 4.70 [28]. This factor represents the ratio of concentration in tissue to the ambient water concentration. Aquatic organisms living in association with PCB-contaminated sediments generally have tissue concentrations equal to or greater than the concentration of PCB in the sediment [28]. Once taken up by an organism, PCBs partition primarily into lipid compartments [16]. Thus, differences in PCB concentration between species and between different tissues within the same species may reflect differences in lipid content [16]. PCB concentrations in polychaetes and fish have been strongly correlated to their lipid content [29]. Elimination of PCBs from organisms is related to the characteristics of the specific PCB congeners present. It has been shown that uptake and depuration rates in mussels are high for lower-chlorinated PCBs and much lower for higher-chlorinated congeners [30, 31]. In some species, tissue concentrations of PCBs in females can be reduced during gametogenesis because of PCB transfer to the more lipophilic eggs. Therefore, the transferred PCBs are eliminated from the female during spawning [32,33]. Fish and other aquatic organisms biotransform PCBs more slowly than other species, and they appear less able to metabolize, or excrete, the higher chlorinated PCB congeners [32]. Consequently, fish and other aquatic organisms may accumulate more of the higher chlorinated PCB congeners than is found in the environment [17].

The acute toxicity of PCBs appears to be relatively low, but results from chronic toxicity tests indicate that PCB toxicity is directly related to the duration of exposure [34]. Toxic responses have been noted to occur at concentrations of 0.03 and 0.014 µg/L in marine and freshwater environments, respectively [34]. The LC50 for grass shrimp exposed to PCBs in marine waters for 4 days was 6.1 to 7.8 µg/L [34]. Chronic toxicity of PCBs presents a serious environmental concern because of their resistance to degradation [35], although the acute toxicity of PCBs is relatively low compared to that of other chlorinated hydrocarbons. Sediment contaminated with PCBs has been shown to elicit toxic responses at relatively low concentrations. Sediment bioassays and benthic community studies suggest that chronic effects generally occur in sediment at total PCB concentrations exceeding 370 µg/kg [36].

A number of field and laboratory studies provide evidence of chronic sublethal effects on aquatic organisms at low tissue concentrations [17]. Field and Dexter [17] suggest that a number of marine and freshwater fish species have experienced chronic toxicity at PCB tissue concentrations of less than 1.0 mg/kg and as low as 0.1 mg/kg. Spies et al. [37] reported an inverse relationship between PCB concentrations in starry flounder eggs in San Francisco Bay and reproductive success, with an effective PCB concentration in the ovaries of less than 0.2 mg/kg. Monod [38] also reported a significant correlation between PCB concentrations in eggs and total egg mortality in Lake Geneva char. PCBs have also been shown to cause induction of the mixed function oxidase (MFO) system in aquatic animals, with MFO induction by PCBs at tissue concentrations within the range of environmental exposures [17].

Summary of Biological Effects Tissue Concentrations for PCB 81

Species:	**Concentration, Units in[1]:**			**Toxicity:**	**Ability to Accumulate[2]:**			**Source:**	
Taxa	**Sediment**	**Water**	**Tissue (Sample Type)**	**Effects**	**Log BCF**	**Log BAF**	**BSAF**	**Reference**	**Comments[3]**
Invertebrates									
Tubifex sp, Oligochaetes .	0.0006 mg/kg (n = 1)		0.0003 mg/kg (one composite)					[39]	F; lower Detroit River
Fishes									
Cyprinus carpio, Carp	0.0006 mg/kg (n = 1)		0.021±0.012 mg/kg (n = 9)					[39]	F; lower Detroit River
Salmonids							0.67	[42]	F
Wildlife									
Bucephala clangula, Goldeneye	0.0006 mg/kg (n = 1)		0.017±0.0002 mg/kg (n = 3)					[39]	F; lower Detroit River
Aythya affinis, Lesser scaup	0.0006 mg/kg (n = 1)		0.31±0.017 mg/kg (n = 7)					[39]	F; lower Detroit River
Aythya marila, Greater scaup	0.0006 mg/kg (n = 1)		0.046±0.016 mg/kg (n = 3)					[39]	F; lower Detroit River
Falco peregrinus, Peregrine falcon			0.14 ng/g (eggs) (n = 6)	11.4% eggshell thinning				[40]	F; Kola Peninsula, Russia

Summary of Biological Effects Tissue Concentrations for PCB 81

Species:	**Concentration, Units in[1]:**			**Toxicity:**	**Ability to Accumulate[2]:**			**Source:**	
Taxa	**Sediment**	**Water**	**Tissue (Sample Type)**	**Effects**	**Log BCF**	**Log BAF**	**BSAF**	**Reference**	**Comments[3]**
Mustela vison, Mink	Diet: 2 pg/g[4]		50 pg/g[4] (liver)	NOAEL		No BMF reported		[41]	L; BMF = lipid-normalized concentration in the liver divided by the lipid-normalized dietary concentration
	27 pg/g[4]		45 pg/g[4] (liver)	LOAEL; reduced kit body weights followed by reduced survival		Log BMF = 0.23			
	66 pg/g[4]		50 pg/g[4] (liver)						
	150 pg/g[4]					Log BMF = −0.10			
			100 pg/g[4] (liver)	Reduced kit body weights followed by reduced survival		Log BMF = 0.00			
				Significant decrease in number of live kits whelped per female					

[1] Concentration units in wet weight unless otherwise noted.
[2] BCF = bioconcentration factor, BAF = bioaccumulation factor, BSAF = biota-sediment accumulation factor.
[3] L = laboratory study, spiked sediment, single chemical; F = field study, multiple chemical exposure; other unusual study conditions or observations noted.
[4] Not clear whether units are in dry or wet weight.

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Chemical Category: POLYCHLORINATED BIPHENYLS

Chemical Name (Common Synonyms): **CASRN:** 32598-14-4
2,3,3′,4,4′-PENTACHLOROBIPHENYL

Chemical Characteristics

Solubility in Water: No data [1], 0.0008 - 0.17 mg/L [2]

Half-Life: No data [2,3]

Log K_{ow}: 5.6 - 6.5 [2], No data [4]

Log K_{oc}: 5.51 - 6.39 L/kg organic carbon

Human Health

Oral RfD: No data [5]

Confidence: —

Critical Effect: —

Oral Slope Factor: No data [5]

Carcinogenic Classification: No data [5]

Wildlife

Partitioning Factors: One study reported biomagnification factors (BMFs) for mink exposed to PCB-contaminated food. The lipid-normalized BMFs ranged from 3.8 to 6.8 indicating an accumulation of this PCB congener in the liver.

Food Chain Multipliers: For PCBs as a class the most toxic congeners have been shown to be selectively accumulated from organisms at one trophic level to the next [6]. At least three studies have concluded that PCBs have the potential to biomagnify in food webs based on aquatic organisms and predators that feed primarily on aquatic organisms [7,8,9]. The results from Biddinger and Gloss [7] and USACE [9] generally agreed that highly water-insoluble compounds (including PCBs) have the potential to biomagnify in these types of food webs. Thomann's [10] model also indicated that highly water-insoluble compounds (log K_{ow} values 5 to 7) showed the greatest potential to biomagnify. The log biomagnification factor for PCB 105 from alewife to herring gulls in Lake Ontario was 2.01 [11]. A study of arctic marine food chains measured log biomagnification factors for pentachlorobiphenyls that ranged from 0.71 to 1.05 for fish to seal, 0.28 to 0.49 for seal to bear, and 1.14 for fish to bear [12].

Aquatic Organisms

Partitioning Factors: Two studies were found that reported laboratory-measured data to calculate non-normalized log bioaccumulation factors (BAFs) and biota-sediment accumulation factors (BSAFs). In the first study the log BAFs determined for marine clams ranged from 0.86 to 1.35 [41]. The BSAFs ranged from 1.63 to 3.85, with the highest BSAF value associated with the lowest BAF. In the second study, only BSAF for marine clams were reported. These values ranged from 0.22 to 0.68 [42]. A BSAF of 4.49 was determined for salmonids [46].

Food Chain Multipliers: Polychlorinated biphenyls as a class have been demonstrated to biomagnify through the food web. Oliver and Niimi [13], studying accumulation of PCBs in various organisms in the Lake Ontario food web, reported concentrations of total PCBs in phytoplankton, zooplankton, and several species of fish. Their data indicated a progressive increase in tissue PCB concentrations moving from organisms lower in the food web to top aquatic predators. In a study of PCB accumulation in lake trout (*Salvelinus namaycush*) of Lake Ontario, Rasmussen et al. [14] reported that each trophic level contributed about a 3.5-fold biomagnification factor to the PCB concentrations in the trout. No specific food chain multipliers were identified for PCB 105 or other pentachlorobiphenyls.

Toxicity/Bioaccumulation Assessment Profile

PCBs are a group (209 congeners/isomers) of organic chemicals, based on various substitutions of chlorine atoms on a basic biphenyl molecule. These manufactured chemicals have been widely used in various processes and products because of the extreme stability of many isomers, particularly those with five or more chlorines [15]. A common use of PCBs was as dielectric fluids in capacitors and transformers. In the United States, Aroclor is the most familiar registered trademark of commercial PCB formulations. Generally, the first two digits in the Aroclor designation indicate that the mixture contains biphenyls, and the last two digits give the weight percent of chlorine in the mixture.

As a result of their stability and their general hydrophobic nature, PCBs released to the environment have dispersed widely throughout the ecosystem [15]. PCBs are among the most stable organic compounds known, and chemical degradation rates in the environment are thought to be slow. As a result of their highly lipophilic nature and low water solubility, PCBs are generally found at low concentrations in water and at relatively high concentrations in sediment [16]. Individual PCB congeners have different physical and chemical properties based on the degree of chlorination and position of chlorine substitution, although differences with degree of chlorination are more significant [16]. Solubilities and octanol-water partition coefficients for PCB congeners range over several orders of magnitude [17]. Octanol-water partition coefficients, which are often used as estimators of the potential for bioconcentration, are highest for the most chlorinated PCB congeners.

Dispersion of PCBs in the aquatic environment is a function of their solubility [16], whereas PCB mobility within and sorption to sediment are a function of chlorine substitution pattern and degree of chlorination [18]. The concentration of PCBs in sediments is a function of the physical characteristics of the sediment, such as grain size [19,20] and total organic carbon content [19,20,21,22]. Fine sediments typically contain higher concentrations of PCBs than coarser sediments because of more surface area [16]. Mobility of PCBs in sediment is generally quite low for the higher chlorinated biphenyls [18]. Therefore, it is common for the lower chlorinated PCBs to have a greater dispersion from the original point source [16]. Limited mobility and high rates of sedimentation could prevent some PCB congeners in the sediment from reaching the overlying water via diffusion [18].

The persistence of PCBs in the environment is a result of their general resistance to degradation [17]. The rate of degradation of PCB congeners by bacteria decreases with increasing degree of chlorination [23]; other structural characteristics of the individual PCBs can affect susceptibility to microbial degradation to a lesser extent [17]. Photochemical degradation, via reductive dechlorination, is also known to occur in aquatic environments; the higher chlorinated PCBs appear to be most susceptible to this process [22].

Toxicity of PCB congeners is dependent on the degree of chlorination as well as the position of chlorine substitution. Lesser chlorinated congeners are more readily absorbed, but are metabolized more rapidly than higher chlorinated congeners [24]. PCB congeners with no chlorine substituted in the ortho (2 and 2′) positions but with four or more chlorine atoms at the meta (3 and 3′) and para (4 and 4′) positions can assume a planar conformation that can interact with the same receptor as the highly toxic 2,3,7,8-tetrachlorodibenzo-*p*-dioxin (TCDD) [25]. Examples of these more toxic, coplanar congeners are 3,3′,4,4′-tetrachlorobiphenyl (PCB 77), 3,3′,4,4′,5-pentachlorobiphenyl (PCB 126), and 3,3′,4,4′,5,5′-hexachlorobiphenyl (PCB 169). A method that has been proposed to estimate the relative toxicity of mixtures is to use toxic equivalency factors (TEFs) [26]. With this method, relative potencies for individual congeners are calculated by expressing their potency in relation to 2,3,7,8-TCDD. The following TEFs have been recommended [26,27]:

Congener Class	Recommended TEF
3,3′,4,4′,5-PentaCB	0.1
3,3′,4,4′,5,5′-HexaCB	0.05
3,3′4,4′-TetraCB	0.01
Monoortho coplanar PCBs	0.001
Diortho coplanar PCBs	0.00002

Due to the toxicity, high K_{ow} values, and highly persistent nature of many PCBs, they possess a high potential to bioaccumulate and exert reproductive effects in higher-trophic-level organisms. Aquatic organisms have a strong tendency to accumulate PCBs from water and food sources. The log bioconcentration factor for fish is approximately 4.70 [28]. This factor represents the ratio of concentration in tissue to the ambient water concentration. Aquatic organisms living in association with PCB-contaminated sediments generally have tissue concentrations equal to or greater than the concentration of PCB in the sediment [28]. Once taken up by an organism, PCBs partition primarily into lipid compartments [16]. Thus, differences in PCB concentration between species and between different tissues within the same species may reflect differences in lipid content [16]. PCB concentrations in polychaetes and fish have been strongly correlated to their lipid content [29]. Elimination of PCBs from organisms is related to the characteristics of the specific PCB congeners present. It has been shown that uptake and depuration rates in mussels are high for lower-chlorinated PCBs and much lower for higher-chlorinated congeners [30,31]. In some species, tissue concentrations of PCBs in females can be reduced during gametogenesis because of PCB transfer to the more lipophilic eggs. Therefore, the transferred PCBs are eliminated from the female during spawning [32,33]. Fish and other aquatic organisms biotransform PCBs more slowly than other species, and they appear less able to metabolize, or excrete, the higher chlorinated PCB congeners [32]. Consequently, fish and other aquatic organisms may accumulate more of the higher chlorinated PCB congeners than is found in the environment [17].

The acute toxicity of PCBs appears to be relatively low, but results from chronic toxicity tests indicate that PCB toxicity is directly related to the duration of exposure [34]. Toxic responses have been noted to occur at concentrations of 0.03 and 0.014 µg/L in marine and freshwater environments, respectively [34]. The LC50 for grass shrimp exposed to PCBs in marine waters for 4 days was 6.1 to 7.8 µg/L [34].

Chronic toxicity of PCBs presents a serious environmental concern because of their resistance to degradation [35], although the acute toxicity of PCBs is relatively low compared to that of other chlorinated hydrocarbons. Sediment contaminated with PCBs has been shown to elicit toxic responses at relatively low concentrations. Sediment bioassays and benthic community studies suggest that chronic effects generally occur in sediment at total PCB concentrations exceeding 370 µg/kg [36].

A number of field and laboratory studies provide evidence of chronic sublethal effects on aquatic organisms at low tissue concentrations [17]. Field and Dexter [17] suggest that a number of marine and freshwater fish species have experienced chronic toxicity at PCB tissue concentrations of less than 1.0 mg/kg and as low as 0.1 mg/kg. Spies et al. [37] reported an inverse relationship between PCB concentrations in starry flounder eggs in San Francisco Bay and reproductive success, with an effective PCB concentration in the ovaries of less than 0.2 mg/kg. Monod [38] also reported a significant correlation between PCB concentrations in eggs and total egg mortality in Lake Geneva char. PCBs have also been shown to cause induction of the mixed function oxidase (MFO) system in aquatic animals, with MFO induction by PCBs at tissue concentrations within the range of environmental exposures [17].

Summary of Biological Effects Tissue Concentrations for PCB 105

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	Sediment	Water	Tissue (Sample Type)	Effects	Log BCF	Log BAF	BSAF	Reference	Comments[3]
Invertebrates									
Plankton, Species not given	2.703 (mean) SD = 1.0659 (n = 9) fg/kg dw	Surface water: 0.003 (mean) SD = 0.0020 (n = 3) ng/L	0.666 (mean) SD = 0.1881 (n = 5) fg/kg					[39]	F; collected in western Lake Erie (offshore Middle Sister Island). Sediment TOC = 7.4% (SD-1.78); lipid = 1.2% (mean) SD-0.24
Plankton (a mixture of primarily phytoplankton and some zooplankton)	14 ± 5.1 ng/g dw (0-3 cm) (n = 38)	10 ± 8.4 pg/L (surface water) (n = 7)	0.8 ± 0.2 ng/g (n = 3)					[13]	F; Lake Ontario; value is mean ± SD; lipid content = 0.5%
Mainly *Tubifex tubifex* and *Limnodrilus hoffmeisteri,* Oligochaete	14 ± 5.1 ng/g dw (0-3 cm) (n = 38)	10 ± 8.4 pg/L (surface water) (n = 7)	2.6 ± 1.4 ng/g (n = 6)					[13]	F; Lake Ontario; value is mean ± SD; lipid content = 1%
Dreissena polymorpha, Zebra mussel	2.703 (mean) SD = 1.0659 (n = 9) fg/kg dw	0.003 (mean) SD = 0.0020 (n = 3) ng/L	1.627 (mean) SD = 1.6470 (n = 20) fg/kg						lipid = 1.3% (mean) SD = 0.34

Summary of Biological Effects Tissue Concentrations for PCB 105

Species: Taxa	Concentration, Units in[1]: Sediment	Water	Tissue (Sample Type)	Toxicity: Effects	Ability to Accumulate[2]: Log BCF	Log BAF	BSAF	Source: Reference	Comments[3]
Macoma nasuta, Bent-nose clam	52.6 ng/g dw (grain size < 1 mm)		1,046 ng/g dw (n = 30)			22.2 (dw)	1.63	[41]	L; steady state BAFs were calculated with average tissue residues and sediment concentrations from exposure days 42-119
	43.2 ng/g dw (grain size < 0.25 mm)		575 ng/g dw (n = 30)			14.5 (dw)	2.87		
	48.8 ng/g dw (grain size < 0.125 mm)		297 ng/g dw (n = 30)			7.3 (dw)	3.85		
Macoma nasuta, Bent-nose clam	ng/g dw:		ng/g dw:					[42]	L; value given is mean ± SE; sediment TOC ranged from 0.84% to 7.4%
	1.51 ±0.032		6.6±0.83				0.68		
	1.26		1.8±0.67				0.22		
	8.6±0.37		8.2±0.75				0.64		
	20±3.7		11.9±0.84				0.56		
	70±7.6		20.3±2.83				0.39		
Mysis relicta, Mysid	89.97 µg/kg dw (TOC = 22.8%)		Screened mysids: 1.46 µg/kg (whole body) Unscreened mysids: 9.85 µg/kg (whole body)					[40]	L; mysids exposed to field contaminated sediments from Lake Champlain, NY; 24 day exposure; screened mysids were screened from direct contact with sediments (% lipid = 5.94±0.27); unscreened mysids were allowed to burrow into sediment.(% lipid = 5.80±0.18)

Summary of Biological Effects Tissue Concentrations for PCB 105

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	Sediment	Water	Tissue (Sample Type)	Effects	Log BCF	Log BAF	BSAF	Reference	Comments[3]
Mysis relicta, Mysid	14 ± 5.1 ng/g dw (0-3 cm) (n = 38)	10 ±8.4 pg/L surface water (n = 7)	8.5 ± 3.5 ng/g (n = 2)					[13]	F; Lake Ontario; value is mean ± SD; lipid content = 3%
Gammarus fasciatus, Amphipod	2.703 (mean) SD = 1.0659 (n = 9) fg/kg dw	0.003 (mean) SD = 0.0020 (n = 3) ng/L	1.611 (mean) SD = 0.7505 (n = 4) fg/kg						lipid = 2.1% (mean) SD = 1.04
Pontoporeia affinis, Amphipod	14 ± 5.1 ng/g dw (0-3 cm) (n = 38)	10 ± 8.4 pg/L (surface water) (n = 7)	12 ± 8 ng/g (n = 6)					[13]	F; Lake Ontario; value is mean ± SD; lipid content = 3%
Orconectes propinquus, Crayfish	2.703 (mean) SD = 1.0659 (n = 9) fg/kg dw	0.003 (mean) SD = 0.0020 (n = 3) ng/L	0.606 (mean) 0.1101 (n = 5) fg/kg						lipid = 1.7% (mean) SD = 0.11
Hydropsyche alterans, Caddisfly larva	2.703 (mean) SD = 1.0659 (n = 9) fg/kg dw	0.003 (mean) SD = 0.0020 (n = 3) ng/L	1.109 (n = 1) fg/kg						lipid = 1.7% (mean)
Fishes									
Alosa pseudoharengus, Alewife	14 ± 5.1 ng/g dw (0-3 cm) (n = 38)	10 ±8.4 pg/L surface water (n = 7)	27 ng/g (one composite)					[13]	F; Lake Ontario; value is mean ± SD; lipid content = 7%

Summary of Biological Effects Tissue Concentrations for PCB 105

Species:	**Concentration, Units in[1]:**			**Toxicity:**	**Ability to Accumulate[2]:**			**Source:**	
Taxa	**Sediment**	**Water**	**Tissue (Sample Type)**	**Effects**	**Log BCF**	**Log BAF**	**BSAF**	**Reference**	**Comments[3]**
Cottus cognatus, Sculpin	14 ± 5.1 ng/g dw (0-3 cm) (n = 38)	10 ±8.4 pg/L surface water (n = 7)	39 ng/g (one composite)					[13]	F; Lake Ontario; value is mean ± SD; lipid content = 8%
Osmerus mordax, Small rainbow smelt	14 ± 5.1 ng/g dw (0-3 cm) (n = 38)	10 ±8.4 pg/L surface water (n = 7)	15 ± 2.0 ng/g (n = 4)					[13]	F; Lake Ontario; value is mean ± SD; lipid content = 4%
Osmerus mordax, Large rainbow smelt	14 ± 5.1 ng/g dw (0-3 cm) (n = 38)	10 ± 8.4 pg/L (surface water) (n = 7)	38 ng/g (one composite)					[13]	F; Lake Ontario; value is mean ± SD; lipid content = 4%
Salmonids: *Oncorhynchus kisutch,* Coho salmon; *Oncorhynchus mykiss (Salmo gairdner),* Rainbow trout; *Salvelinus namaycush,* Lake trout; *Salmo trutta,* Brown trout	10 ± 8.4 ng/g dw (0-3 cm) (n = 38)	14 ±5.1 pg/L surface water (n = 7)	110 ± 82 ng/g (n = 60)					[13]	F; Lake Ontario; value is mean ± SD; lipid content = 11%; wild fish.
							4.49	[46]	
Wildlife									
Falco peregrinus, Peregrine falcon			72 ng/g (eggs) (n = 6)	11.4% eggshell thinning				[44]	F; Kola Peninsula, Russia
White leghorn chicken embryo			2,200 µg/kg (egg)	LD50				[43]	L; PCBs were injected into the air cell of eggs

Summary of Biological Effects Tissue Concentrations for PCB 105

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	Sediment	Water	Tissue (Sample Type)	Effects	Log BCF	Log BAF	BSAF	Reference	Comments[3]
Mustela vison, Mink	Diet: 510 pg/g[4]		2,900 pg/g[4] (liver)	NOAEL		Log BMF = 0.58		[45]	L; BMF = lipid-normalized concentration in the liver divided by the lipid-normalized dietary concentration
	12,000 pg/g[4]		54,000 pg/g[4] (liver)	LOAEL; reduced kit body weights followed by reduced survival		Log BMF = 0.68			
	23,000 pg/g[4]		105,000 pg/g[4] (liver)	Reduced kit body weights followed by reduced survival		Log BMF = 0.66			
	41,000 pg/g[4]		181,000 pg/g[4] (liver)	Significant decrease in number of live kits whelped per female		Log BMF = 0.83			

[1] Concentration units given in wet weight unless otherwise indicated.
[2] BCF = bioconcentration factor, BAF = bioaccumulation factor, BSAF = biota-sediment accumulation factor.
[3] L = laboratory study, spiked sediment, single chemical; F = field study, multiple chemical exposure; other unusual study conditions or observations noted.
[4] Not clear whether units are in dry or wet weight.

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Chemical Category: POLYCHLORINATED BIPHENYLS

Chemical Name (Common Synonyms): 2,3′,4,4′,5-PENTACHLOROBIPHENYL

CASRN: 31508-00-6

Chemical Characteristics

Solubility in Water: No data [1]

Half-Life: No data [2,3]

Log K_{ow}: —

Log K_{oc}: 5.51 - 6.39 L/kg organic carbon

Human Health

Oral RfD: No data [5]

Confidence: —

Critical Effect: —

Oral Slope Factor: No data [5]

Carcinogenic Classification: No data [5]

Wildlife

Partitioning Factors: In a laboratory study with mink, the lipid-normalized ratios of PCB 118 in liver to food ranged from 3.4 to 5.9 (log BMF = 0.53 to 0.77) [49]. The ratio of PCB 118 in three species of duck to sediment in the lower Detroit River ranged from 21 to 35 [40].

Food Chain Multipliers: For PCBs as a class, the most toxic congeners have been shown to be selectively accumulated from organisms at one trophic level to the next [6]. At least three studies have concluded that PCBs have the potential to biomagnify in food webs based on aquatic organisms and predators that feed primarily on aquatic organisms [7,8,9]. The results from Biddinger and Gloss [7] and USACE [9] generally agreed that highly water-insoluble compounds (including PCBs) have the potential to biomagnify in these types of food webs. Thomann's [10] model also indicated that highly water-insoluble compounds (log K_{ow} values 5 to 7) showed the greatest potential to biomagnify. The biomagnification factor for PCB 118 from alewife to herring gulls in Lake Ontario was 80 [11]. A study of arctic marine food chains measured log biomagnification factors for pentachlorobiphenyls that ranged from 0.71 to 1.05 for fish to seal, 0.28 to 0.49 for seal to bear, and 1.14 for fish to bear [12].

Aquatic Organisms

Partitioning Factors: Steady-state BSAFs for the bent-nose clam ranged from 0.59 to 4.7 in two laboratory studies. The ratio of PCB 118 in carp tissue to sediment from the lower Detroit River was 25.

Food Chain Multipliers: Polychlorinated biphenyls as a class have been demonstrated to biomagnify through the food web. Oliver and Niimi [13], studying accumulation of PCBs in various organisms in the Lake Ontario food web, reported concentrations of total PCBs in phytoplankton, zooplankton, and several species of fish. Their data indicated a progressive increase in tissue PCB concentrations moving

from organisms lower in the food web to top aquatic predators. In a study of PCB accumulation in lake trout (*Salvelinus namaycush*) of Lake Ontario, Rasmussen et al. [14] reported that each trophic level contributed about a 3.5-fold biomagnification factor to the PCB concentrations in the trout. No specific food chain multipliers were identified for PCB 118 or other pentachlorobiphenyls.

Toxicity/Bioaccumulation Assessment Profile

PCBs are a group (209 congeners/isomers) of organic chemicals, based on various substitutions of chlorine atoms on a basic biphenyl molecule. These manufactured chemicals have been widely used in various processes and products because of the extreme stability of many isomers, particularly those with five or more chlorines [15]. A common use of PCBs was as dielectric fluids in capacitors and transformers. In the United States, Aroclor is the most familiar registered trademark of commercial PCB formulations. Generally, the first two digits in the Aroclor designation indicate that the mixture contains biphenyls, and the last two digits give the weight percent of chlorine in the mixture.

As a result of their stability and their general hydrophobic nature, PCBs released to the environment have dispersed widely throughout the ecosystem [15]. PCBs are among the most stable organic compounds known, and chemical degradation rates in the environment are thought to be slow. As a result of their highly lipophilic nature and low water solubility, PCBs are generally found at low concentrations in water and at relatively high concentrations in sediment [16]. Individual PCB congeners have different physical and chemical properties based on the degree of chlorination and position of chlorine substitution, although differences with degree of chlorination are more significant [16]. Solubilities and octanol-water partition coefficients for PCB congeners range over several orders of magnitude [17]. Octanol-water partition coefficients, which are often used as estimators of the potential for bioconcentration, are highest for the most chlorinated PCB congeners.

Dispersion of PCBs in the aquatic environment is a function of their solubility [16], whereas PCB mobility within and sorption to sediment are a function of chlorine substitution pattern and degree of chlorination [18]. The concentration of PCBs in sediments is a function of the physical characteristics of the sediment, such as grain size [19,20] and total organic carbon content [19,20,21,22]. Fine sediments typically contain higher concentrations of PCBs than coarser sediments because of more surface area [16]. Mobility of PCBs in sediment is generally quite low for the higher chlorinated biphenyls [18]. Therefore, it is common for the lower chlorinated PCBs to have a greater dispersion from the original point source [16]. Limited mobility and high rates of sedimentation could prevent some PCB congeners in the sediment from reaching the overlying water via diffusion [18].

The persistence of PCBs in the environment is a result of their general resistance to degradation [17]. The rate of degradation of PCB congeners by bacteria decreases with increasing degree of chlorination [23]; other structural characteristics of the individual PCBs can affect susceptibility to microbial degradation to a lesser extent [17]. Photochemical degradation, via reductive dechlorination, is also known to occur in aquatic environments; the higher chlorinated PCBs appear to be most susceptible to this process [22]. Toxicity of PCB congeners is dependent on the degree of chlorination as well as the position of chlorine substitution. Lesser chlorinated congeners are more readily absorbed, but are metabolized more rapidly than higher chlorinated congeners [24]. PCB congeners with no chlorine substituted in the ortho (2 and 2′) positions but with four or more chlorine atoms at the meta (3 and 3′) and para (4 and 4′) positions can assume a planar conformation that can interact with the same receptor as the highly toxic 2,3,7,8-

tetrachlorodibenzo-*p*-dioxin (TCDD) [25]. Examples of these more toxic, coplanar congeners are 3,3′,4,4′-tetrachlorobiphenyl (PCB 77), 3,3′,4,4′,5-pentachlorobiphenyl (PCB 126), and 3,3′,4,4',5,5'-hexachlorobiphenyl (PCB 169). A method that has been proposed to estimate the relative toxicity of mixtures is to use toxic equivalency factors (TEFs) [26]. With this method, relative potencies for individual congeners are calculated by expressing their potency in relation to 2,3,7,8-TCDD. The following TEFs have been recommended [26,27]:

Congener Class	Recommended TEF
3,3′,4,4′,5-PentaCB	0.1
3,3′,4,4′,5,5′-HexaCB	0.05
3,3′4,4′TetraCB	0.01
Monoortho coplanar PCBs	0.001
Diortho coplanar PCBs	0.00002

Due to the toxicity, high K_{ow} values, and highly persistent nature of many PCBs, they possess a high potential to bioaccumulate and exert reproductive effects in higher-trophic-level organisms. Aquatic organisms have a strong tendency to accumulate PCBs from water and food sources. The log bioconcentration factor for fish is approximately 4.70 [28]. This factor represents the ratio of concentration in tissue to the ambient water concentration. Aquatic organisms living in association with PCB-contaminated sediments generally have tissue concentrations equal to or greater than the concentration of PCB in the sediment [28]. Once taken up by an organism, PCBs partition primarily into lipid compartments [16]. Thus, differences in PCB concentration between species and between different tissues within the same species may reflect differences in lipid content [16]. PCB concentrations in polychaetes and fish have been strongly correlated to their lipid content [29]. Elimination of PCBs from organisms is related to the characteristics of the specific PCB congeners present. It has been shown that uptake and depuration rates in mussels are high for lower-chlorinated PCBs and much lower for higher-chlorinated congeners [30,31]. In some species, tissue concentrations of PCBs in females can be reduced during gametogenesis because of PCB transfer to the more lipophilic eggs. Therefore, the transferred PCBs are eliminated from the female during spawning [32,33]. Fish and other aquatic organisms biotransform PCBs more slowly than other species, and they appear less able to metabolize, or excrete, the higher chlorinated PCB congeners [32]. Consequently, fish and other aquatic organisms may accumulate more of the higher chlorinated PCB congeners than is found in the environment [17].

The acute toxicity of PCBs appears to be relatively low, but results from chronic toxicity tests indicate that PCB toxicity is directly related to the duration of exposure [34]. Toxic responses have been noted to occur at concentrations of 0.03 and 0.014 µg/L in marine and freshwater environments, respectively [34]. The LC50 for grass shrimp exposed to PCBs in marine waters for 4 days was 6.1 to 7.8 µg/L [34]. Chronic toxicity of PCBs presents a serious environmental concern because of their resistance to degradation [35], although the acute toxicity of PCBs is relatively low compared to that of other chlorinated hydrocarbons. Sediment contaminated with PCBs has been shown to elicit toxic responses at relatively low concentrations. Sediment bioassays and benthic community studies suggest that chronic effects generally occur in sediment at total PCB concentrations exceeding 370 µg/kg [36].

A number of field and laboratory studies provide evidence of chronic sublethal effects on aquatic organisms at low tissue concentrations [17]. Field and Dexter [17] suggest that a number of marine and freshwater fish species have experienced chronic toxicity at PCB tissue concentrations of less than 1.0 mg/kg and as low as 0.1 mg/kg. Spies et al. [37] reported an inverse relationship between PCB concentrations in starry flounder eggs in San Francisco Bay and reproductive success, with an effective PCB concentration in the ovaries of less than 0.2 mg/kg. Monod [38] also reported a significant correlation between PCB concentrations in eggs and total egg mortality in Lake Geneva char. PCBs have also been shown to cause induction of the mixed function oxidase (MFO) system in aquatic animals, with MFO induction by PCBs at tissue concentrations within the range of environmental exposures [17].

Summary of Biological Effects Tissue Concentrations for PCB 118

:Species Taxa	Concentration, Units in[1]: Sediment	Water	Tissue (Sample Type)	Toxicity: Effects	Ability to Accumulate[2]: Log BCF	Log BAF	BSAF	Source: Reference	Comments[3]
Invertebrates									
Plankton	4.514 (mean) SD = 1.8449 (n = 9) µg/kg dw	0.007 (mean) SD = 0.0044 (n = 3) ng/L	0.750 (mean) SD = 0.4919 (n = 5) fg/kg					[42]	F; collected in western Lake Erie (offshore Middle Sister Island); sediment TOC = 7.4%; SD = 1.78 lipid = 1.2% (mean) SD = 0.24
Tubifex sp., Oligochaetes	0.017 mg/kg		0.0069 mg/kg					[40]	F; lower Detroit River
Macoma nasuta, Bent-nose clam	ng/g dw: 2.93 ± 0.067 2.5 16.5 ± 1.42 45 ± 9.2 162 ± 16.5		ng/g dw: 20 ± 3.0 12.0 ± 1.89 28.9 ± 2.60 40.3 ± 2.64 66 ± 8.9				 1.08 0.73 1.17 0.82 0.54	[43]	L; value given is mean ± SE; sediment TOC ranged from 0.84% to 7.4%
Macoma nasuta, Bent-nose clam	44.2 ng/g dw (grain size < 1 mm)		1,049 ng/g dw (n = 30)			30.3 (dw)	2.02	[41]	L; steady state BAFs were calculated with average tissue residues and sediment concentrations from exposure days 42-119.
	36.2 ng/g (grain size < 0.25 mm)		550 ng/g dw (n = 30)			18.5 (dw)	3.28		
	41.6 ng/g dw (grain size < 0.125 mm)		296 ng/g dw (n = 30)			8.4 (dw)	4.74		

Summary of Biological Effects Tissue Concentrations for PCB 118

:Species	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
					Log	Log			
Taxa	**Sediment**	**Water**	**Tissue (Sample Type)**	**Effects**	**BCF**	**BAF**	**BSAF**	**Reference**	**Comments[3]**
Dreissena polymorpha, Zebra mussel	4.514 (mean) SD = 1.8449 (n = 9) µg/kg dw	0.007 (mean) SD = 0.0044 (n = 3) ng/L	2.156 (mean) SD = 0.8847 (n = 20) µg/kg						Lipid = 1.3% (mean) SD = 0.34
Mytilus edulis, Blue mussel		Water column: ~16.0 ng/L ~4.0 ng/L ~0.8 ng/L	Whole body: ~1,780 ng/g dw ~1,000 ng/g dw ~130 ng/g dw					[45]	F; New Bedford Harbor, MA; deployment study; ~ -read all values off figures
Daphnia magna, Freshwater cladoceran		0.1 fg/L	~3.5 ng/mg dw (n = 3)	No significant effect on survival, reproduction, or biomass				[39]	L; 21-day static renewal tests; tissue concentrations are approximations (~), as data were taken from figures
		1.0 fg/L	~130 ng/mg dw (n = 3)	No significant effect on survival, reproduction, or biomass					
Gammarus fasciatus, Amphipod	4.514 (mean) SD = 1.8449 (n = 9) µg/kg dw	0.007 (mean) SD = 0.0044 (n = 3) ng/L	3.113 (mean) SD = 1.7881 (n = 4) µg/kg						Lipid = 2.1% (mean) SD = 1.04

Summary of Biological Effects Tissue Concentrations for PCB 118

:Species	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
					Log	Log			
Taxa	Sediment	Water	Tissue (Sample Type)	Effects	BCF	BAF	BSAF	Reference	Comments[3]
Orconectes propinquus, Crayfish	4.514 (mean) SD = 1.8449 (n = 9) µg/kg dw	0.007 (mean) SD = 0.0044 (n = 3) ng/L	2.242 (mean) SD = 0.3628 (n = 5) µg/kg						Lipid = 1.7% (mean) SD = 0.11
Hydropsyche alterans, Caddisfly larva	4.514 (mean) SD = 1.8449 (n = 9) µg/kg dw	0.007 (mean) SD = 0.0044 (n = 3) ng/L	4.780 (n = 1) µg/kg						Lipid = 1.7% (mean)
Mysis relicta, Mysid	135.73 µg/kg dw (TOC = 22.8%)		Screened mysids: 2.39 µg/kg (whole body) Unscreened mysids: 15.67 µg/kg (whole body)					[44]	L; mysids exposed to field contaminated sediments from Lake Champlain, NY; 24-day exposure screened mysids were screened from direct contact with sedi-ments (% lipid = 5.94 ± 0.27); unscreened mysids were allowed to burrow into sediment.(% lipid = 5.80 ± 0.18)

Summary of Biological Effects Tissue Concentrations for PCB 118

:Species	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	Sediment	Water	Tissue (Sample Type)	Effects	Log BCF	Log BAF	BSAF	Reference	Comments[3]
Fishes									
Salvelinus namaycush namaycush, Lake trout	0.87 ng/g ± 0.11 n = 4	0.20 ng/L ± 0.29 n = 11	290 ng/g lipid					[46, 47]	F; Siskiwit Lake, Isle Royale, Lake Superior; tissue concentrations are means of concentrations measured in several size classes; organic carbon content of sediment was not presented.
Coregonus culpeaformis neohantoniensus, Whitefish	0.87 ng/g ± 0.11 n = 4	0.20 ng/L ± 0.29 n = 11	280 ng/g lipid						
Salmonids						8.15	4.09	[13]	F; %lipid = 11; %sed OC = 2.7
							1.72	[50]	F
Cyprinus carpio, Carp	0.017 mg/kg (n = 1)		0.42 ± 0.26 mg/kg (n = 9)					[40]	F; lower Detroit River
Wildlife									
Bucephala clangula, Goldeneye	0.017 mg/kg (n = 1)		0.36 ± 0.041 mg/kg (n = 3)					[40]	F; lower Detroit River

Summary of Biological Effects Tissue Concentrations for PCB 118

:Species	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
					Log	Log			
Taxa	Sediment	Water	Tissue (Sample Type)	Effects	BCF	BAF	BSAF	Reference	Comments[3]
Aythya affinis, Lesser scaup	0.017 mg/kg (n = 1)		0.52 ± 0.26 mg/kg (n = 7)					[40]	F; lower Detroit River
Aythya marila, Greater scaup	0.017 mg/kg (n = 1)		0.59 ± 0.10 mg/kg (n = 3)					[40]	F; lower Detroit River
Falco peregrinus, Peregrine falcon			450 ng/g (eggs) (n = 6)	11.4% eggshell thinning				[48]	F; Kola Peninsula, Russia
Mustela vison, Mink	Diet: 1,660 pg/g[4]		8,500 pg/g[4] (liver)	NOAEL		log BMF = 0.53		[49]	L; BMF = lipid-normalized concentration in the liver divided by the lipid-normalized dietary concentra-tion
	35,000 pg/g[4]		20,000 pg/g[4] (liver)	LOAEL; reduced kit body weights followed by reduced survival		log BMF = 0.56			
	68,000 pg/g[4]		284,000 pg/g[4] (liver)	Reduced kit body weights followed by reduced survival		log BMF = 0.63			
	125,000 pg/g[4]		478,000 pg/g[4] (liver)	Significant decrease in number of live kits whelped per female		log BMF = 0.77			

[1] Concentration units expressed in wet weight unless otherwise noted.
[2] BCF = bioconcentration factor, BAF = bioaccumulation factor, SAF = biota-sediment accumulation factor.
[3] L = laboratory study, spiked sediment, single chemical; F = field study, multiple chemical exposure; other unusual study conditions or observations noted.
[4] Not clear whether units are in dry or wet weight.

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Chemical Category: POLYCHLORINATED BIPHENYLS

Chemical Name (Common Synonyms): 3,3′,4,4′,5-PENTACHLOROBIPHENYL

CASRN: 57465-28-8

Chemical Characteristics

Solubility in Water: No data [1]
0.004 - 0.099 mg/L [2]

Half-Life: No data [2,3]

Log K_{ow}: 6.2 - 6.85 [2], No data [4]

Log K_{oc}: 6.09 - 6.73 L/kg organic carbon

Human Health

Oral RfD: No data [5]

Confidence: No data [5]

Critical Effect: —

Oral Slope Factor: No data [5]

Carcinogenic Classification: No data [5]

Wildlife

Partitioning Factors: Partitioning factors for PCB 126 in wildlife were not found.

Food Chain Multipliers: For PCBs as a class the most toxic congeners have been shown to be selectively accumulated from organisms at one trophic level to the next [6]. At least three studies have concluded that PCBs have the potential to biomagnify in food webs based on aquatic organisms and predators that feed primarily on aquatic organisms [7,8,9]. The results from Biddinger and Gloss [7] and USACE [9] generally agreed that highly water-insoluble compounds (including PCBs) have the potential to biomagnify in these types of food webs. Thomann's [10] model also indicated that highly water-insoluble compounds (log K_{ow} values 5 to 7) showed the greatest potential to biomagnify. The log biomagnification factor for pentachlorobiphenyls from alewife to herring gulls in Lake Ontario ranged from 1.18 to 2.00 [11]. A study of arctic marine food chains measured biomagnification factors for pentachlorobiphenyls that ranged from 0.71 to 1.05 for fish to seal, 0.28 to 0.49 for seal to bear, and 1.14 for fish to bear [12]. No specific food chain multipliers were identified for PCB 126.

Aquatic Organisms

Partitioning Factors: In an 83-day laboratory study with three-spined stickleback, the lipid-normalized ratio of PCB 126 in food to fish tissue ranged from 3.8 to 6.1. A log bioconcentration factor (BCF) for deployed mussels in New Bedford Harbor, MA, was approximately 6.90, as reported in the attached table.

Food Chain Multipliers: Polychlorinated biphenyls as a class have been demonstrated to biomagnify through the food web. Oliver and Niimi [13], studying accumulation of PCBs in various organisms in the Lake Ontario food web, reported concentrations of total PCBs in phytoplankton, zooplankton, and several species of fish. Their data indicated a progressive increase in tissue PCB concentrations moving from organisms lower in the food web to top aquatic predators. In a study of PCB accumulation in lake trout (*Salvelinus namaycush*) of Lake Ontario, Rasmussen et al. [14] reported that each trophic level contributed about a 3.5-fold biomagnification factor to the PCB concentrations in the trout. No specific food chain multipliers were identified for PCB 126 or other pentachlorobiphenyls.

Toxicity/Bioaccumulation Assessment Profile

PCBs are a group (209 congeners/isomers) of organic chemicals, based on various substitutions of chlorine atoms on a basic biphenyl molecule. These manufactured chemicals have been widely used in various processes and products because of the extreme stability of many isomers, particularly those with five or more chlorines [15]. A common use of PCBs was as dielectric fluids in capacitors and transformers. In the United States, Aroclor is the most familiar registered trademark of commercial PCB formulations. Generally, the first two digits in the Aroclor designation indicate that the mixture contains biphenyls, and the last two digits give the weight percent of chlorine in the mixture.

As a result of their stability and their general hydrophobic nature, PCBs released to the environment have dispersed widely throughout the ecosystem [15]. PCBs are among the most stable organic compounds known, and chemical degradation rates in the environment are thought to be slow. As a result of their highly lipophilic nature and low water solubility, PCBs are generally found at low concentrations in water and at relatively high concentrations in sediment [16]. Individual PCB congeners have different physical and chemical properties based on the degree of chlorination and position of chlorine substitution, although differences with degree of chlorination are more significant [16]. Solubilities and octanol-water partition coefficients for PCB congeners range over several orders of magnitude [17]. Octanol-water partition coefficients, which are often used as estimators of the potential for bioconcentration, are highest for the most chlorinated PCB congeners.

Dispersion of PCBs in the aquatic environment is a function of their solubility [16], whereas PCB mobility within and sorption to sediment are a function of chlorine substitution pattern and degree of chlorination [18]. The concentration of PCBs in sediments is a function of the physical characteristics of the sediment, such as grain size [19,20] and total organic carbon content [19,20,21,22]. Fine sediments typically contain higher concentrations of PCBs than coarser sediments because of more surface area [16]. Mobility of PCBs in sediment is generally quite low for the higher chlorinated biphenyls [18]. Therefore, it is common for the lower chlorinated PCBs to have a greater dispersion from the original point source [16]. Limited mobility and high rates of sedimentation could prevent some PCB congeners in the sediment from reaching the overlying water via diffusion [18].

The persistence of PCBs in the environment is a result of their general resistance to degradation [17]. The rate of degradation of PCB congeners by bacteria decreases with increasing degree of chlorination [23]; other structural characteristics of the individual PCBs can affect susceptibility to microbial degradation to a lesser extent [17]. Photochemical degradation, via reductive dechlorination, is also known to occur in aquatic environments; the higher chlorinated PCBs appear to be most susceptible to this process [22].

Toxicity of PCB congeners is dependent on the degree of chlorination as well as the position of chlorine substitution. Lesser chlorinated congeners are more readily absorbed, but are metabolized more rapidly than higher chlorinated congeners [24]. PCB congeners with no chlorine substituted in the ortho (2 and 2′) positions but with four or more chlorine atoms at the meta (3 and 3′) and para (4 and 4′) positions can assume a planar conformation that can interact with the same receptor as the highly toxic 2,3,7,8-tetrachlorodibenzo-*p*-dioxin (TCDD) [25]. Examples of these more toxic, coplanar congeners are 3,3′,4,4′-tetrachlorobiphenyl (PCB 77), 3,3′,4,4′,5-pentachlorobiphenyl (PCB 126), and 3,3′,4,4′,5,5′-hexachlorobiphenyl (PCB 169). A method that has been proposed to estimate the relative toxicity of mixtures is to use toxic equivalency factors (TEFs) [26]. With this method, relative potencies for individual congeners are calculated by expressing their potency in relation to 2,3,7,8-TCDD. The following TEFs have been recommended [26,27]:

Congener Class	Recommended TEF
3,3′,4,4′,5-PentaCB	0.1
3,3′,4,4′,5,5′-HexaCB	0.05
3,3′4,4′-TetraCB	0.01
Monoortho coplanar PCBs	0.001
Diortho coplanar PCBs	0.00002

Due to the toxicity, high K_{ow} values, and highly persistent nature of many PCBs, they possess a high potential to bioaccumulate and exert reproductive effects in higher-trophic-level organisms. Aquatic organisms have a strong tendency to accumulate PCBs from water and food sources. The log bioconcentration factor for fish is approximately 4.70 [28]. This factor represents the ratio of concentration in tissue to the ambient water concentration. Aquatic organisms living in association with PCB-contaminated sediments generally have tissue concentrations equal to or greater than the concentration of PCB in the sediment [28]. Once taken up by an organism, PCBs partition primarily into lipid compartments [16]. Thus, differences in PCB concentration between species and between different tissues within the same species may reflect differences in lipid content [16]. PCB concentrations in polychaetes and fish have been strongly correlated to their lipid content [29]. Elimination of PCBs from organisms is related to the characteristics of the specific PCB congeners present. It has been shown that uptake and depuration rates in mussels are high for lower-chlorinated PCBs and much lower for higher-chlorinated congeners [30,31]. In some species, tissue concentrations of PCBs in females can be reduced during gametogenesis because of PCB transfer to the more lipophilic eggs. Therefore, the transferred PCBs are eliminated from the female during spawning [32,33]. Fish and other aquatic organisms biotransform PCBs more slowly than other species, and they appear less able to metabolize, or excrete, the higher chlorinated PCB congeners [32]. Consequently, fish and other aquatic organisms may accumulate more of the higher chlorinated PCB congeners than is found in the environment [17].

The acute toxicity of PCBs appears to be relatively low, but results from chronic toxicity tests indicate that PCB toxicity is directly related to the duration of exposure [34]. Toxic responses have been noted to occur at concentrations of 0.03 and 0.014 µg/L in marine and freshwater environments, respectively [34]. The LC50 for grass shrimp exposed to PCBs in marine waters for 4 days was 6.1 to 7.8 µg/L [34]. Chronic toxicity of PCBs presents a serious environmental concern because of their resistance to degradation [35], although the acute toxicity of PCBs is relatively low compared to that of other chlorinated hydrocarbons. Sediment contaminated with PCBs has been shown to elicit toxic responses at relatively low concentrations. Sediment bioassays and benthic community studies suggest that chronic effects generally occur in sediment at total PCB concentrations exceeding 370 µg/kg [36].

A number of field and laboratory studies provide evidence of chronic sublethal effects on aquatic organisms at low tissue concentrations [17]. Field and Dexter [17] suggest that a number of marine and freshwater fish species have experienced chronic toxicity at PCB tissue concentrations of less than 1.0 mg/kg and as low as 0.1 mg/kg. Spies et al. [37] reported an inverse relationship between PCB concentrations in starry flounder eggs in San Francisco Bay and reproductive success, with an effective PCB concentration in the ovaries of less than 0.2 mg/kg. Monod [38] also reported a significant correlation between PCB concentrations in eggs and total egg mortality in Lake Geneva char. PCBs have also been shown to cause induction of the mixed function oxidase (MFO) system in aquatic animals, with MFO induction by PCBs at tissue concentrations within the range of environmental exposures [17].

Summary of Biological Effects Tissue Concentrations for PCB 126

Species: Taxa	Concentration, Units in[1]: Sediment	Water	Tissue (Sample Type)	Toxicity: Effects	Ability to Accumulate[2]: Log BAF	Log BAF	BSAF	Source: Reference	Comments[3]
Invertebrates									
Mytilus edulis, Blue mussel		1993: particulate 0.2 µg/L ±0.1 n = 9 dissolved 0.02 µg/L ±0.01 n = 9 1994: particulate 0.2 µg/L ±0.1 n = 3 dissolved 0.03 µg/L ±0.01 n = 3	~20 ng/g dw (whole body)		6.90			[39]	F; New Bedford Harbor, MA; deployment study; tissue concentrations were only presented for 1994 samples; BCF and tissue concentrations read from figures (~)
Fishes									
Gasterosteus aculeatus, Three-spined stickleback						0.78 (male) 0.58 (female)		[41]	L; 83-day dosing study; BAF = lipid-normalized concent-ration in fish divided by the lipid-normalized concentration in food
Myoxocephalus quadricornis, Four-horn sculpin	0.013 ng/g dw		0.035 ng/g (liver) 0.068 ng/g (whole body)					[40]	F; collected in or near Hamlet in Cambridge Bay, NW Territories, Canada
Salmonids							3.21	[45]	F

Summary of Biological Effects Tissue Concentrations for PCB 126

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	Sediment	Water	Tissue (Sample Type)	Effects	Log BAF	Log BAF	BSAF	Reference	Comments[3]
Wildlife									
Sterna hirundo, Common tern (embryo)			45 µg/kg[4] (egg)	35% embryo mortality (through hatching)				[42]	L; PCBs were injected into the air cell of eggs
Falco peregrinus, Peregrine falcon			1.3 ng/g (eggs) (n = 6)	11.4% eggshell thinning				[44]	F; Kola Peninsula, Russia
Falco sparverius, American kestrel (embryo)			65 µg/kg[4] (egg)	LD50 (through hatching)				[42]	L; PCBs were injected into the air cell of eggs
Falco sparverius, American kestrel (nestling)			156 µg/kg[4] (liver)	Histopathology of liver, thyroid, and spleen				[42]	L
Colinus virginianus, Bobwhite (embryo)			24 µg/kg[4] (egg)	LD50 (through hatching)				[42]	L; PCBs were injected into the air cell of eggs
White leghorn chicken (embryo)			0.4 µg/kg (egg)	LD50				[42]	L; PCBs were injected into the air cell of eggs from day 4 of incubation through hatching
White leghorn chicken (embryo)			3.1 µg/kg (egg)	LD50				[43]	L; PCBs were injected into the air cell of eggs from day 7 through day 10 of incubation

[1] Concentration units expressed in wet weight unless otherwise indicated.
[2] BCF = bioconcentration factor, BAF = bioaccumulation factor, BSAF = biota-sediment accumulation factor.
[2] L = laboratory study, spiked sediment, single chemical; F = field study, multiple chemical exposure; other unusual study conditions or observations noted.
[4] Not clear from reference if concentration is based on wet or dry weight.

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Chemical Category: POLYCHLORINATED BIPHENYLS

Chemical Name (Common Synonyms): **CASRN:** 38380-08-4
2,3,3′,4,4′,5-HEXACHLOROBIPHENYL

Chemical Characteristics

Solubility in Water: No data [1], 0.004 - 0.038 mg/L [2] **Half-Life:** No data [2,3]

Log K_{ow}: 6.7 - 7.3 [2] **Log K_{oc}:** 6.59 - 7.18 L/kg organic carbon

Human Health

Oral RfD: No data [5] **Confidence:** —

Critical Effect: —

Oral Slope Factor: No data [5] **Carcinogenic Classification:** No data [5]

Wildlife

Partitioning Factors: In a laboratory study with mink, the lipid-normalized ratios of PCB 156 in liver to food ranged from 5.5 to 11.6. The ratio of PCB 156 in tissues of three species of duck to sediment in the lower Detroit River ranged from 27 to 41.

Food Chain Multipliers: For PCBs as a class the most toxic congeners have been shown to be selectively accumulated from organisms at one trophic level to the next [6]. At least three studies have concluded that PCBs have the potential to biomagnify in food webs based on aquatic organisms and predators that feed primarily on aquatic organisms [7,8,9]. The results from Biddinger and Gloss [7] and USACE [9] generally agreed that highly water-insoluble compounds (including PCBs) have the potential to biomagnify in these types of food webs. Thomann's [10] model also indicated that highly water-insoluble compounds (log K_{ow} values 5 to 7) showed the greatest potential to biomagnify. The log biomagnification factors for hexachlorobiphenyls from alewife to herring gulls in Lake Ontario ranged from 1.30 to 2.14 [11]. A study of arctic marine food chains measured log biomagnification factors for hexachlorobiphenyls that ranged from 0.99 to 1.36 for fish to seal, 0.97 to 1.26 for seal to bear, and 2.23 for fish to bear [12]. No specific food chain multipliers were identified for PCB 156.

Aquatic Organisms

Partitioning Factors: In Lake Ontario, ratios of PCB-156 in tissue (wet weight) to sediment (dry weight) for plankton, oligochaetes, mysids, and amphipods were 0.10, 0.14, 0.57, and 1.9 respectively; ratios in sculpin, alewife, rainbow smelt, and salmonids were 6.7, 3.0, 2.9, and 16, respectively. In carp from the lower Detroit River the tissue to sediment ratio (wet weight) was 25. BSAFs for clam in a laboratory study ranged from 0.16 to 0.67.

Food Chain Multipliers: Polychlorinated biphenyls as a class have been demonstrated to biomagnify through the food web. Oliver and Niimi [13], studying accumulation of PCBs in various organisms in the Lake Ontario food web, reported concentrations of total PCBs in phytoplankton, zooplankton, and several species of fish. Their data indicated a progressive increase in tissue PCB concentrations moving from organisms lower in the food web to top aquatic predators. In a study of PCB accumulation in lake trout (*Salvelinus namaycush*) of Lake Ontario, Rasmussen et al. [14] reported that each trophic level contributed about a 3.5-fold biomagnification factor to the PCB concentrations in the trout. No specific food chain multipliers were identified for PCB 156 or other hexachlorobiphenyls.

Toxicity/Bioaccumulation Assessment Profile

PCBs are a group (209 congeners/isomers) of organic chemicals, based on various substitutions of chlorine atoms on a basic biphenyl molecule. These manufactured chemicals have been widely used in various processes and products because of the extreme stability of many isomers, particularly those with five or more chlorines [15]. A common use of PCBs was as dielectric fluids in capacitors and transformers. In the United States, Aroclor is the most familiar registered trademark of commercial PCB formulations. Generally, the first two digits in the Aroclor designation indicate that the mixture contains biphenyls, and the last two digits give the weight percent of chlorine in the mixture.

As a result of their stability and their general hydrophobic nature, PCBs released to the environment have dispersed widely throughout the ecosystem [15]. PCBs are among the most stable organic compounds known, and chemical degradation rates in the environment are thought to be slow. As a result of their highly lipophilic nature and low water solubility, PCBs are generally found at low concentrations in water and at relatively high concentrations in sediment [16]. Individual PCB congeners have different physical and chemical properties based on the degree of chlorination and position of chlorine substitution, although differences with degree of chlorination are more significant [16]. Solubilities and octanol-water partition coefficients for PCB congeners range over several orders of magnitude [17]. Octanol-water partition coefficients, which are often used as estimators of the potential for bioconcentration, are highest for the most chlorinated PCB congeners.

Dispersion of PCBs in the aquatic environment is a function of their solubility [16], whereas PCB mobility within and sorption to sediment are a function of chlorine substitution pattern and degree of chlorination [18]. The concentration of PCBs in sediments is a function of the physical characteristics of the sediment, such as grain size [19,20] and total organic carbon content [19,21,22]. Fine sediments typically contain higher concentrations of PCBs than coarser sediments because of more surface area [16]. Mobility of PCBs in sediment is generally quite low for the higher chlorinated biphenyls [18]. Therefore, it is common for the lower chlorinated PCBs to have a greater dispersion from the original point source [16]. Limited mobility and high rates of sedimentation could prevent some PCB congeners in the sediment from reaching the overlying water via diffusion [18].

The persistence of PCBs in the environment is a result of their general resistance to degradation [17]. The rate of degradation of PCB congeners by bacteria decreases with increasing degree of chlorination [23]; other structural characteristics of the individual PCBs can affect susceptibility to microbial degradation to a lesser extent [17]. Photochemical degradation, via reductive dechlorination, is also known to occur in aquatic environments; the higher chlorinated PCBs appear to be most susceptible to this process [22].

Toxicity of PCB congeners is dependent on the degree of chlorination as well as the position of chlorine substitution. Lesser chlorinated congeners are more readily absorbed, but are metabolized more rapidly than higher chlorinated congeners [24]. PCB congeners with no chlorine substituted in the ortho (2 and 2′) positions but with four or more chlorine atoms at the meta (3 and 3′) and para (4 and 4′) positions can assume a planar conformation that can interact with the same receptor as the highly toxic 2,3,7,8-tetrachlorodibenzo-*p*-dioxin (TCDD) [25]. Examples of these more toxic, coplanar congeners are 3,3′,4,4′-tetrachlorobiphenyl (PCB 77), 3,3′,4,4′,5-pentachlorobiphenyl (PCB 126), and 3,3′,4,4′,5,5′-hexachlorobiphenyl (PCB 169). A method that has been proposed to estimate the relative toxicity of mixtures is to use toxic equivalency factors (TEFs) [26]. With this method, relative potencies for individual congeners are calculated by expressing their potency in relation to 2,3,7,8-TCDD. The following TEFs have been recommended [26,27]:

Congener Class	Recommended TEF
3,3′,4,4′,5-PentaCB	0.1
3,3′,4,4′,5,5′-HexaCB	0.05
3,3′4,4′-TetraCB	0.01
Monoortho coplanar PCBs	0.001
Diortho coplanar PCBs	0.00002

Due to the toxicity, high K_{ow} values, and highly persistent nature of many PCBs, they possess a high potential to bioaccumulate and exert reproductive effects in higher-trophic-level organisms. Aquatic organisms have a strong tendency to accumulate PCBs from water and food sources. The log bioconcentration factor for fish is approximately 4.70 [28]. This factor represents the ratio of concentration in tissue to the ambient water concentration. Aquatic organisms living in association with PCB-contaminated sediments generally have tissue concentrations equal to or greater than the concentration of PCB in the sediment [28]. Once taken up by an organism, PCBs partition primarily into lipid compartments [16]. Thus, differences in PCB concentration between species and between different tissues within the same species may reflect differences in lipid content [16]. PCB concentrations in polychaetes and fish have been strongly correlated to their lipid content [29]. Elimination of PCBs from organisms is related to the characteristics of the specific PCB congeners present. It has been shown that uptake and depuration rates in mussels are high for lower-chlorinated PCBs and much lower for higher-chlorinated congeners [30,31]. In some species, tissue concentrations of PCBs in females can be reduced during gametogenesis because of PCB transfer to the more lipophilic eggs. Therefore, the transferred PCBs are eliminated from the female during spawning [32,33]. Fish and other aquatic organisms biotransform PCBs more slowly than other species, and they appear less able to metabolize, or excrete, the higher chlorinated PCB congeners [32]. Consequently, fish and other aquatic organisms may accumulate more of the higher chlorinated PCB congeners than is found in the environment [17].

The acute toxicity of PCBs appears to be relatively low, but results from chronic toxicity tests indicate that PCB toxicity is directly related to the duration of exposure [34]. Toxic responses have been noted to occur at concentrations of 0.03 and 0.014 µg/L in marine and freshwater environments, respectively [34]. The LC50 for grass shrimp exposed to PCBs in marine waters for 4 days was 6.1 to 7.8 µg/L [34]. Chronic toxicity of PCBs presents a serious environmental concern because of their resistance to degradation [35], although the acute toxicity of PCBs is relatively low compared to that of other chlorinated hydrocarbons. Sediment contaminated with PCBs has been shown to elicit toxic responses at relatively low concentrations. Sediment bioassays and benthic community studies suggest that chronic effects generally occur in sediment at total PCB concentrations exceeding 370 µg/kg [36].

A number of field and laboratory studies provide evidence of chronic sublethal effects on aquatic organisms at low tissue concentrations [17]. Field and Dexter [17] suggest that a number of marine and freshwater fish species have experienced chronic toxicity at PCB tissue concentrations of less than 1.0 mg/kg and as low as 0.1 mg/kg. Spies et al. [37] reported an inverse relationship between PCB concentrations in starry flounder eggs in San Francisco Bay and reproductive success, with an effective PCB concentration in the ovaries of less than 0.2 mg/kg. Monod [38] also reported a significant correlation between PCB concentrations in eggs and total egg mortality in Lake Geneva char. PCBs have also been shown to cause induction of the mixed function oxidase (MFO) system in aquatic animals, with MFO induction by PCBs at tissue concentrations within the range of environmental exposures [17].

Summary of Biological Effects Tissue Concentrations for PCB 156

Species: Taxa	Concentration, Units in[1]: Sediment	Water	Tissue (Sample Type)	Toxicity: Effects	Ability to Accumulate[2]: Log BCF	Log BAF	BSAF	Source: Reference	Comments[3]
Invertebrates									
Plankton (a mixture of primarily phytoplankton and some zooplankton)	2.1 ± 1.4 ng/g dw (0-3 cm) (n = 38)	Not detected in surface water (n = 7)	0.2 ± 0.1 ng/g (n = 3)					[13]	F; Lake Ontario; value is mean ± SD; lipid content = 0.5%
Mainly *Tubifex tubifex* and *Limnodrilus hoffmeisteri,* Oligochaete	2.1 ± 1.4 ng/g dw (0-3 cm) (n = 38)	Not detected in surface water (n = 7)	0.3 ± 0.4 ng/g (n = 6)					[13]	F; Lake Ontario; value is mean ± SD; lipid content = 1%
Tubifex sp, Oligochaetes	0.0024 mg/kg (n = 1)		0.0016 mg/kg (n = 1)					[39]	F; lower Detroit River
Macoma nasuta, Bent-nose clam	ng/g dw: 0.60 ± 0.019 0.48 NA 11.6 ± 2.29 34 ± 5.3		ng/g dw: 2.6 ± 0.59 1.93 ± 0.284 2.61 ± 0.192 2.89 ± 0.215 4.1 ± 0.77				 0.67 0.61 0.51 0.23 0.16	[40]	L; values given are mean ± SE; sediment TOC ranged from 0.84% to 7.4%. *Macoma* were exposed to 5 sediments containing different PCB concentrations; NA means number was not legible.
Pontoporeia affinis, Amphipods	2.1 ± 1.4 ng/g dw (0-3 cm) (n = 38)	Not detected in surface water (n = 7)	3.9 ± 2.3 ng/g (n = 6)					[13]	F; Lake Ontario; value is mean ± SD; lipid content = 3%

Summary of Biological Effects Tissue Concentrations for PCB 156

Species: Taxa	Concentration, Units in[1]: Sediment	Water	Tissue (Sample Type)	Toxicity: Effects	Ability to Accumulate[2]: Log BCF	Log BAF	BSAF	Source: Reference	Comments[3]
Mysis relicta, Mysids	2.1 ± 1.4 ng/g dw (0-3 cm) (n = 38)	Not detected in surface water (n = 7)	1.2 ± 0.1 ng/g (n = 2)					[13]	F; Lake Ontario; value is mean ± SD; lipid content = 3%
Fishes									
Salmonids: *Oncorhynchus velinus namaycush,* Coho salmon; *Oncorhynchus mykiss* (*Salmo gairdneri*), Rainbow trout; *Salvelinus namaycush,* Lake trout; *Salmo trutta,* Brown trout	2.1 ± 1.4 ng/g dw (0-3 cm) (n = 38)	Not detected in surface water (n = 7)	34 ± 27 ng/g (n = 60)				3.97	[13]	F; Lake Ontario; value is mean ± SD; lipid content = 11%
Cyprinus carpio, Carp	0.0024 mg/kg (n = 1)		0.061±0.024 mg/kg (n = 9)					[39]	F; lower Detroit River
Cottus cognatus, Sculpin	2.1 ± 1.4 ng/g dw (0-3 cm) (n = 38)	Not detected in surface water (n = 7)	14 ng/g (one composite)					[13]	F; Lake Ontario; value is mean ± SD; lipid content = 8%
Alewife	2.1 ± 1.4 ng/g dw (0-3 cm) (n = 38)	Not detected in surface water (n = 7)	6.3 ng/g (one composite)					[13]	F; Lake Ontario; value is mean ± SD; lipid content = 7%
Osmerus mordax, Small rainbow smelt	2.1 ± 1.4 ng/g dw (0-3 cm) (n = 38)	Not detected in surface water (n = 7)	2.7 ± 1.9 ng/g (n = 4)					[13]	F; Lake Ontario; value is mean ± SD; lipid content = 4%

Summary of Biological Effects Tissue Concentrations for PCB 156

Species: Taxa	Concentration, Units in[1]: Sediment	Water	Tissue (Sample Type)	Toxicity: Effects	Ability to Accumulate[2]: Log BCF	Log BAF	BSAF	Source: Reference	Comments[3]
Osmerus mordax, Large rainbow smelt	2.1 ± 1.4 ng/g dw (0-3 cm) (n = 38)	Not detected in surface water (n = 7)	6.1 ng/g (one composite)					[13]	F; Lake Ontario; value is mean ± SD; lipid content = 4%
Wildlife									
Bucephala clangula, Goldeneye	0.0024 mg/kg (n = 1)		0.064±0.018 mg/kg (n = 3)					[39]	F; lower Detroit River
Aythya affinis, Lesser scaup	0.0024 mg/kg (n = 1)		0.090±0.044 mg/kg (n = 7)					[39]	F; lower Detroit River
Aythya marila, Greater scaup	0.0024 mg/kg (n = 1)		0.098±0.0091 mg/kg (n = 3)					[39]	F; lower Detroit River
Falco peregrinus, Peregrine falcon			82 ng/g (eggs) (n = 6)	11.4% eggshell thinning				[41]	F; Kola Peninsula, Russia

Summary of Biological Effects Tissue Concentrations for PCB 156

Species: Taxa	Concentration, Units in[1]: Sediment	Water	Tissue (Sample Type)	Toxicity: Effects	Ability to Accumulate[2]: Log BCF	Log BAF	BSAF	Source: Reference	Comments[3]
Mustela vison, Mink	Diet: 110 pg/g[4]		920 pg/g[4] (liver)	NOAEL		Log BMF = 0.74		[42]	L; BMF = lipid-normalized concentration in the liver divided by the lipid-normalized dietary concentra-tion
	1,300 pg/g[4]		12,000 pg/g[4] (liver)	LOAEL; reduced kit body weights followed by reduced survival		Log BMF = 0.96			
	2,800 pg/g[4]		23,000 pg/g[4] (liver)	reduced kit body weights followed by reduced survival		Log BMF = 0.91			
	5,000 pg/g[4]		37,100 pg/g[4] (liver)	Significant decrease in number of live kits whelped per female		Log BMF = 1.06			

[1] Concentration units expressed in wet weight unless otherwise noted.

2 BCF = bioconcentration factor, BAF = bioaccumulation factor, BSAF = biota-sediment accumulation factor.

[3] L = laboratory study, spiked sediment, single chemical; F = field study, multiple chemical exposure; other unusual study conditions or observations noted.

[4] Not clear whether units are in dry or wet weight.

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Chemical Category: POLYCHLORINATED BIPHENYLS

Chemical Name (Common Synonyms): **CASRN:** 32774-16-6
3,3′,4,4′,5,5′-HEXACHLOROBIPHENYL

Chemical Characteristics

Solubility in Water: No data [1], 0.5 mg/L [2]

Half-Life: No data [2,3]

Log K_{ow}: 7.4 [5]

Log K_{oc}: 7.27 L/kg organic carbon

Human Health

Oral RfD: No data [5]

Confidence: —

Critical Effect: —

Oral Slope Factor: No data [5]

Carcinogenic Classification: No data [5]

Wildlife

Partitioning Factors: In a laboratory study with mink, the lipid-normalized ratios of PCB 169 in liver to food ranged from 12.4 to 21.4.

Food Chain Multipliers: For PCBs as a class the most toxic congeners have been shown to be selectively accumulated from organisms at one trophic level to the next [6]. At least three studies have concluded that PCBs have the potential to biomagnify in food webs based on aquatic organisms and predators that feed primarily on aquatic organisms [7,8,9]. The results from Biddinger and Gloss [7] and USACE [9] generally agreed that highly water-insoluble compounds (including PCBs) have the potential to biomagnify in these types of food webs. Thomann's [10] model also indicated that highly water-insoluble compounds (log K_{ow} values 5 to 7) showed the greatest potential to biomagnify. The log biomagnification factors for hexachlorobiphenyls from alewife to herring gulls in Lake Ontario ranged from 1.30 to 2.14 [11]. A study of arctic marine food chains measured log biomagnification factors for hexachlorobiphenyls that ranged from 0.99 to 1.36 for fish to seal, 0.99 to 1.26 for seal to bear, and 2.23 for fish to bear [12]. Log BMFs ranged from 1.09 to 1.33 for mink fed PCB 169 in the diet [40].

Aquatic Organisms

Partitioning Factors: In an 83-day laboratory study with three-spined stickleback, the lipid-normalized ratio of PCB 169 in food to fish tissue (log BAF) ranged from 0.50 to 0.79.

Food Chain Multipliers: Polychlorinated biphenyls as a class have been demonstrated to biomagnify through the food web. Oliver and Niimi [13], studying accumulation of PCBs in various organisms in the Lake Ontario food web, reported concentrations of total PCBs in phytoplankton, zooplankton, and several species of fish. Their data indicated a progressive increase in tissue PCB concentrations moving from organisms lower in the food web to top aquatic predators. In a study of PCB accumulation in lake trout (*Salvelinus namaycush*) of Lake Ontario, Rasmussen et al. [14] reported that each trophic level contributed about a 3.5-fold biomagnification factor to the PCB concentrations in the trout. No specific food chain multipliers were identified for PCB 169 or other hexachlorobiphenyls.

Toxicity/Bioaccumulation Assessment Profile

PCBs are a group (209 congeners/isomers) of organic chemicals, based on various substitutions of chlorine atoms on a basic biphenyl molecule. These manufactured chemicals have been widely used in various processes and products because of the extreme stability of many isomers, particularly those with five or more chlorines [15]. A common use of PCBs was as dielectric fluids in capacitors and transformers. In the United States, Aroclor is the most familiar registered trademark of commercial PCB formulations. Generally, the first two digits in the Aroclor designation indicate that the mixture contains biphenyls, and the last two digits give the weight percent of chlorine in the mixture.

As a result of their stability and their general hydrophobic nature, PCBs released to the environment have dispersed widely throughout the ecosystem [15]. PCBs are among the most stable organic compounds known, and chemical degradation rates in the environment are thought to be slow. As a result of their highly lipophilic nature and low water solubility, PCBs are generally found at low concentrations in water and at relatively high concentrations in sediment [16]. Individual PCB congeners have different physical and chemical properties based on the degree of chlorination and position of chlorine substitution, although differences with degree of chlorination are more significant [16]. Solubilities and octanol-water partition coefficients for PCB congeners range over several orders of magnitude [17]. Octanol-water partition coefficients, which are often used as estimators of the potential for bioconcentration, are highest for the most chlorinated PCB congeners.

Dispersion of PCBs in the aquatic environment is a function of their solubility [18], whereas PCB mobility within and sorption to sediment are a function of chlorine substitution pattern and degree of chlorination [18]. The concentration of PCBs in sediments is a function of the physical characteristics of the sediment, such as grain size [19,20] and total organic carbon content [19,20,21,22]. Fine sediments typically contain higher concentrations of PCBs than coarser sediments because of more surface area [16]. Mobility of PCBs in sediment is generally quite low for the higher chlorinated biphenyls [18]. Therefore, it is common for the lower chlorinated PCBs to have a greater dispersion from the original point source [16]. Limited mobility and high rates of sedimentation could prevent some PCB congeners in the sediment from reaching the overlying water via diffusion [18].

The persistence of PCBs in the environment is a result of their general resistance to degradation [19]. The rate of degradation of PCB congeners by bacteria decreases with increasing degree of chlorination [23]; other structural characteristics of the individual PCBs can affect susceptibility to microbial degradation to a lesser extent [17]. Photochemical degradation, via reductive dechlorination, is also known to occur in aquatic environments; the higher chlorinated PCBs appear to be most susceptible to this process [22].

Toxicity of PCB congeners is dependent on the degree of chlorination as well as the position of chlorine substitution. Lesser chlorinated congeners are more readily absorbed, but are metabolized more rapidly than higher chlorinated congeners [24]. PCB congeners with no chlorine substituted in the ortho (2 and 2′) positions but with four or more chlorine atoms at the meta (3 and 3′) and para (4 and 4′) positions can assume a planar conformation that can interact with the same receptor as the highly toxic 2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD) [25]. Examples of these more toxic, coplanar congeners are 3,3′,4,4′-tetrachlorobiphenyl (PCB 77), 3,3′,4,4′,5-pentachlorobiphenyl (PCB 126), and 3,3′,4,4′,5,5′-hexachlorobiphenyl (PCB 169). A method that has been proposed to estimate the relative toxicity of mixtures is to use toxic equivalency factors (TEFs) [26]. With this method, relative potencies for individual congeners are calculated by expressing their potency in relation to 2,3,7,8-TCDD. The following TEFs have been recommended [26,27]:

Congener Class	Recommended TEF
3,3′,4,4′,5-PentaCB	0.1
3,3′,4,4′,5,5′-HexaCB	0.05
3,3′4,4′-TetraCB	0.01
Monoortho coplanar PCBs	0.001
Diortho coplanar PCBs	0.00002

Due to the toxicity, high K_{ow} values, and highly persistent nature of many PCBs, they possess a high potential to bioaccumulate and exert reproductive effects in higher-trophic-level organisms. Aquatic organisms have a strong tendency to accumulate PCBs from water and food sources. The log bioconcentration factor for fish is approximately 4.70 [28]. This factor represents the ratio of concentration in tissue to the ambient water concentration. Aquatic organisms living in association with PCB-contaminated sediments generally have tissue concentrations equal to or greater than the concentration of PCB in the sediment [28]. Once taken up by an organism, PCBs partition primarily into lipid compartments [16]. Thus, differences in PCB concentration between species and between different tissues within the same species may reflect differences in lipid content [16]. PCB concentrations in polychaetes and fish have been strongly correlated to their lipid content [29]. Elimination of PCBs from organisms is related to the characteristics of the specific PCB congeners present. It has been shown that uptake and depuration rates in mussels are high for lower-chlorinated PCBs and much lower for higher-chlorinated congeners [30,31]. In some species, tissue concentrations of PCBs in females can be reduced during gametogenesis because of PCB transfer to the more lipophilic eggs. Therefore, the transferred PCBs are eliminated from the female during spawning [32,33]. Fish and other aquatic organisms biotransform PCBs more slowly than other species, and they appear less able to metabolize, or excrete, the higher chlorinated PCB congeners [32]. Consequently, fish and other aquatic organisms may accumulate more of the higher chlorinated PCB congeners than is found in the environment [17].

The acute toxicity of PCBs appears to be relatively low, but results from chronic toxicity tests indicate that PCB toxicity is directly related to the duration of exposure [34]. Toxic responses have been noted to occur at concentrations of 0.03 and 0.014 µg/L in marine and freshwater environments, respectively [34]. The LC50 for grass shrimp exposed to PCBs in marine waters for 4 days was 6.1 to 7.8 µg/L [34]. Chronic toxicity of PCBs presents a serious environmental concern because of their resistance to degradation [35], although the acute toxicity of PCBs is relatively low compared to that of other chlorinated hydrocarbons. Sediment contaminated with PCBs has been shown to elicit toxic responses at relatively low concentrations. Sediment bioassays and benthic community studies suggest that chronic effects generally occur in sediment at total PCB concentrations exceeding 370 µg/kg [36].

A number of field and laboratory studies provide evidence of chronic sublethal effects on aquatic organisms at low tissue concentrations [17]. Field and Dexter [17] suggest that a number of marine and freshwater fish species have experienced chronic toxicity at PCB tissue concentrations of less than 1.0 mg/kg and as low as 0.1 mg/kg. Spies et al. [37] reported an inverse relationship between PCB concentrations in starry flounder eggs in San Francisco Bay and reproductive success, with an effective PCB concentration in the ovaries of less than 0.2 mg/kg. Monod [38] also reported a significant correlation between PCB concentrations in eggs and total egg mortality in Lake Geneva char. PCBs have also been shown to cause induction of the mixed function oxidase (MFO) system in aquatic animals, with MFO induction by PCBs at tissue concentrations within the range of environmental exposures [17].

Summary of Biological Effects Tissue Concentrations for PCB 169

Species: Taxa	Concentration, Units in[1]: Sediment	Water	Tissue (Sample Type)	Toxicity: Effects	Ability to Accumulate[2]: Log BCF	Log BAF	BSAF	Source: Reference	Comments[3]
Fishes									
Gasterosteus aculeatus, Three-spined stickleback						0.79 (male) 0.50 (female)		[39]	L; 83-day dosing study; BAF = lipid-normalized concentration in fish divided by the lipid-normalized concentration in food
Wildlife									
Mustela vison, Mink	Diet: 2 pg/g[4]		65 pg/g[4] (liver)	NOAEL		Log BMF = 1.33		[40]	L; BMF = lipid-normalized concentration in the liver divided by the lipid-normalized dietary concentration
	5 pg/g[4]		65 pg/g[4] (liver)	LOAEL; reduced kit body weights followed by reduced survival		Log BMF = 1.10			
	10 pg/g[4]		120 pg/g[4] (liver)	Reduced kit body weights followed by reduced survival		Log BMF = 1.09			
	20 pg/g[4]		205 pg/g[4] (liver)	Significant decrease in number of live kits whelped per female		Log BMF = 1.20			

[1] Concentration units expressed as wet weight unless otherwise noted.
[2] BCF = bioconcentration factor, BAF = bioaccumulation factor, BSAF = biota-sediment accumulation factor.
[3] L = laboratory study, spiked sediment, single chemical; F = field study, multiple chemical exposure; other unusual study conditions or observations noted.
[4] Not clear from reference if concentration is based on wet or dry weight.

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Chemical Category: SUBSTITUTED PHENOLS

Chemical Name (Common Synonyms): PENTACHLOROPHENOL (PCP) **CASRN:** 87-86-5

Chemical Characteristics

Solubility in Water: 14 mg/L at 20°C [1]

Half-Life: 23 - 178 days, sediment grab sample, estimated unacclimated aqueous aerobic biodegradation [2]

Log K_{ow}: 5.09 [3]

Log K_{oc}: 5.00 L/kg organic carbon

Human Health

Oral RfD: 3×10^{-2} mg/kg/day [4]

Confidence: Medium, uncertainty factor = 100

Critical Effect: Liver and kidney pathology

Oral Slope Factor: 1.2×10^{-1} per (mg/kg)/day [4]

Carcinogenic Classification: B2 [4]

Wildlife

Partitioning Factors: Partitioning factors for pentachlorophenol in wildlife were not found in the literature.

Food Chain Multipliers: Food chain multipliers for pentachlorophenol in wildlife were not found in the literature.

Aquatic Organisms

Partitioning Factors: Partitioning factors for pentachlorophenol in aquatic organisms were not found in the literature.

Food Chain Multipliers: Food chain multipliers for pentachlorophenol in aquatic organims were not found in the literature.

Toxicity/Bioaccumulation Assessment Profile

Technical PCP has been reported to contain chlorodiphenylethers, chlorodibenzo-*p*-dioxins, chlorodibezofurans, and hydroxychlorodiphenylethers, whereas commercial PCP contains significant quantities of tetrachlorophenol [5]. These impurities contribute to PCP toxicity, especially sublethal effects at low concentrations of PCP. PCP undergoes rapid degradation (by chemical, microbiological, or photochemical processes) in the environment.

PCP affects energy metabolism by increasing oxygen consumption and altering the activities of several glycolytic and citric acid cycle enzymes and by increasing the consumption rate of stored lipid [6]. PCP toxicity ranged from 3 to 100 µg/L for invertebrates and 1 to 68 µg/L for fish. In oral doses PCP was fatal to birds at 380 to 580 mg/kg. Adverse sublethal effects in birds were observed in a diet containing 1 mg/kg of PCP [5].

Residues above 11 mg/kg in bird tissues were associated with acute toxicity. Studies with birds showed that PCP killed various species at single oral doses of 380 to 504 mg/kg at dietary concentration of 3,850 mg/kg, fed over a 5-day period. Residues of PCP in dead birds were 11 mg/kg in brain, 20 mg/kg in kidney, and 46 mg/kg in liver [7]. Chickens fed 1 mg/kg PCP over an 8-week period accumulated substantial amounts of PCP: 2 mg/kg in muscle, 80 mg/kg in kidney, 25 mg/kg in liver [8]. Residues of PCP in dead organisms after treatment in rice fields were 8.1 mg/kg in frogs and 36.8 mg/kg in snails, and the residues ranged from 31.2 to 59.5 mg/kg in three fish species [7].

Accumulation of PCP is pH-dependent; at pH 4, PCP is completely protonated and therefore highly lipophilic. At this pH, PCP has the greatest accumulation potential. Conversely, PCP is completely ionized at pH 9. Early studies estimated the lethal body burden or critical body residue for goldfish was 0.36 mmol PCP/kg [12] and 0.75 mmol PCP/kg for brown trout [13] (these were prior to 1985 and are not included in the following table). Experiments with rainbow trout [9] showed that neither the twofold difference in body weight nor the 3-percent difference in body lipid content gave fish resistance to the toxicity of PCP. Mean lethal body residues (= critical body residue) ranged from 0.08 to 0.15 mmol/kg. The PCP accumulation by medaka (*Oryzias latipes*) acclimated in freshwater and saltwater decreased with increased salinity [10]. However, the amount of PCP accumulated by killifish acclimated to freshwater was greater than that accumulated by killifish acclimated to saltwater. The growth rate of bluegill was reduced by 75 percent during the 22-day subchronic exposure to 173 µg/L of PCP [11]. The critical body residue for chlorophenols for fathead minnows ranged from 1.1 to 1.7 mmol/kg [14].

PCP is rapidly accumulated and rapidly excreted, and it has no tendency to persist in living organisms. However, PCP tends to accumulate in mammalian tissues unless it is efficiently conjugated into a readily excretable form [15]. Humans eliminate 75 percent of all PCP in the urine. Rats (*Rattus* sp.) and mice can eliminate PCP in the urine very efficiently; however, rhesus monkeys (*Macaca mulatta*) are unable to excrete PCP efficiently.

Summary of Biological Effects Tissue Concentrations for Pentachlorophenol

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	**Sediment**	**Water**	**Tissue (Sample Type)**	**Effects**	**Log BCF**	**Log BAF**	**BSAF**	**Reference**	**Comments[3]**
Invertebrates									
Glycera dibranchiata, Polychaete			6.64 mg/kg (whole body)[4]	Cellular, LOED				[20]	L; reduced ability of amebocytes to recognize foreign material
			1.55 mg/kg (whole body)[4]	Physiological, LOED				[20]	L; reduced antibacterial activity
Neanthes virens, Polychaete - sandworm			28 mg/kg (whole body)[4]	Physiological, LOED				[23]	L; significant reduction in coelomic fluid glucose level, number of replicates is 8 to 10
			112 mg/kg (whole body)[4]	Physiological, LOED				[23]	L; decrease in tissue glycogen
			13.8 mg/kg (whole body)[4]	Mortality, ED100				[32]	L; lethal body burden
			469 mg/kg (extractable lipid)[4]	Mortality, ED50				[9]	L; median survival time with fish fed low fat diet for 11 weeks then PCP exposure
			471 mg/kg (extractable lipid)[4]	Mortality, ED50				[9]	L; median survival time with fish fed high fat diet for 11 weeks then PCP exposure

Summary of Biological Effects Tissue Concentrations for Pentachlorophenol

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	Sediment	Water	Tissue (Sample Type)	Effects	Log BCF	Log BAF	BSAF	Reference	Comments[3]
			29.8 mg/kg (whole body)[4]	Mortality, ED50				[9]	L; median survival time with fish fed low fat diet for 11 weeks then PCP exposure
			39.4 mg/kg (whole body)[4]	Mortality, ED50				[9]	L; median survival time with fish fed high fat diet for 11 weeks then PCP exposure

Summary of Biological Effects Tissue Concentrations for Pentachlorophenol

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	Sediment	Water	Tissue (Sample Type)	Effects	Log BCF	Log BAF	BSAF	Reference	Comments[3]
Eisenia fetida, Earthworm,	6.75 mmol/kg 3.75 mmol/kg 2.10 mmol/kg 1.20 mmol/kg 0.68 mmol/kg 0.38 mmol/kg 0.21 mmol/kg 0.12 mmol/kg 0.068 mmol/kg 0.038 mmol/kg		1.39-2.65 mmol/kg 0.74-1.19 mmol/kg 0.62-1.35 mmol/kg 0.56-1.16 mmol/kg 0.59-1.58 mmol/kg 0.51-0.80 mmol/kg 0.33-0.84 mmol/kg 0.79-1.16 mmol/kg 0.44-1.29 mmol/kg 0.21 mmol/kg					[19]	L
Physa sp., Snail			0.33 mg/kg (whole body)[4]	Mortality, NOED				[28]	L; no effect on survivorship in 24 hours

Summary of Biological Effects Tissue Concentrations for Pentachlorophenol

Species:	**Concentration, Units in[1]:**			**Toxicity:**	**Ability to Accumulate[2]:**			**Source:**	
Taxa	**Sediment**	**Water**	**Tissue (Sample Type)**	**Effects**	**Log BCF**	**Log BAF**	**BSAF**	**Reference**	**Comments[3]**
Anodonta anatina, Duck mussel			3.1 mg/kg (whole body)[4]	Behavior, LOED				[30]	L; behavioral changes, distended foot could not be retracted
			1.5 mg/kg (whole body)[4]	Behavior, NOED				[30]	L; no effect on behavior
			3.1 mg/kg (whole body)[4]	Mortality, NOED				[30]	L; no effect on mortality
Mytilus edulis, Blue mussel	5 µg/kg		32-244 µg/kg					[16]	F
Mytilus edulis, Mussel			2.34 mg/kg (whole body)[4]	Physiological, LOED				[34]	L; significant increase in anoxic heat dissipation (j/h/g)at test concentration
			2.34 mg/kg (whole body)[4]	Physiological, NA				[34]	L; 10% reduction in anoxia tolerance as percent of controls
			9.9 mg/kg (whole body)[4]	Physiological, NA				[34]	L; 36% reduction in anoxia tolerance as percent of controls
			29.4 mg/kg (whole body)[4]	Physiological, NA				[34]	L; 54% reduction in anoxia tolerance as percent of controls

Summary of Biological Effects Tissue Concentrations for Pentachlorophenol

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	Sediment	Water	Tissue (Sample Type)	Effects	Log BCF	Log BAF	BSAF	Reference	Comments[3]
Mercenaria mercenaria, Quahog clam			0.498 mg/kg (whole body)[4]	Physiological, LOED				[21]	L; impaired ability to clear flavobacterium
			0.498 mg/kg (whole body)[4]	Mortality, NOED				[21]	L; no effect on mortality
Daphnia magna, Cladoceran			0.45 mg/kg (whole body)[4]	Mortality, NOED				[28]	L; no effect on survivorship in 24 hours
Pontoporeia hoyi, Amphipod			48.6 mg/kg (whole body)[4]	Survival, ED50				[27]	L
		200 mmol/L	3.8 mmol/kg	lethal				[17]	L
		300 mmol/L	5.6 mmol/kg	lethal					
		430 mmol/L	7.6 mmol/kg	lethal					
			CBR = 0.33 to1.1 mmol/kg						
Chironomus riparius, Midge			1.1 mg/kg (whole body)[4]	Behavior, NOED				[29]	L; no effect on swimming behavior
			0.87 mg/kg (whole body)[4]	Behavior, NOED				[29]	L; no effect on swimming behavior
			0.38 mg/kg (whole body)[4]	Behavior, NOED				[29]	L; no effect on swimming behavior

Summary of Biological Effects Tissue Concentrations for Pentachlorophenol

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	Sediment	Water	Tissue (Sample Type)	Effects	Log BCF	Log BAF	BSAF	Reference	Comments[3]
Strongylocentrotus purpuratus, Purple sea urchin			95 mg/kg (whole body)[4]	Development, LOED				[22]	L; increase in number of abnormal embryos
			927 mg/kg (whole body)[4]	Development, LOED				[22]	L; genotoxicity, anaphase aberrations
			662 mg/kg (whole body)[4]	Reproduction, LOED				[22]	L; reduced fertilization of embryos
Fishes									
Oncorhynchus kisutch, Coho salmon		1.3 µg/L	21 µg/kg					[17]	L
Oncorhynchus mykiss, Rainbow trout		1.3 µg/L	24 µg/kg						

Summary of Biological Effects Tissue Concentrations for Pentachlorophenol

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	Sediment	Water	Tissue (Sample Type)	Effects	Log BCF	Log BAF	BSAF	Reference	Comments[3]
		1100 mmol/L	3.8 mmol/kg	lethal				[17]	L
		1150 mmol/L	4.0 mmol/kg	lethal					
		1300 mmol/L	4.3 mmol/kg	lethal					
		1400 mmol/L	4.4 mmol/kg	lethal					
		1600 mmol/L	5.2 mmol/kg	lethal					
		1700 mmol/L	6.0 mmol/kg	lethal					
		2300 mmol/L	8.0 mmol/kg	lethal					
			CBR = 0.08 to 0.15 mmol/kg						
Salmo trutta, Brown trout		0.2 mg/l	200 mg/kg (whole body)[4]	Mortality, ED50				[13]	L; lethal body burden
Salvelinus namaycush, Lake trout		1.3 µg/L	11 µg/kg					[17]	L
Carassius auratus, Goldfish			82 mg/kg (whole body)[4]	Mortality, ED100				[25]	L; lethal body burden
			97 mg/kg (whole body)[4]	Mortality, ED100				[25]	L; lethal body burden
			89 mg/kg (whole body)[4]	Mortality, ED100				[25]	L; lethal body burden

Summary of Biological Effects Tissue Concentrations for Pentachlorophenol

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	Sediment	Water	Tissue (Sample Type)	Effects	Log BCF	Log BAF	BSAF	Reference	Comments[3]
			88 mg/kg (whole body)[4]	Mortality, ED100				[25]	L; lethal body burden
			97 mg/kg (whole body)[4]	Mortality, ED100				[25]	L; lethal body burden
			99 mg/kg (whole body)[4]	Mortality, ED100				[25]	L; lethal body burden
			87 mg/kg (whole body)[4]	Mortality, ED100				[25]	L; lethal body burden
			86 mg/kg (whole body)[4]	Mortality, ED100				[25]	L; lethal body burden
			82 mg/kg (whole body)[4]	Mortality, ED100				[25]	L; lethal body burden
			107 mg/kg (whole body)[4]	Mortality, ED100				[25]	L; lethal body burden
			92 mg/kg (whole body)[4]	Mortality, ED100				[25]	L; lethal body burden
			89 mg/kg (whole body)[4]	Mortality, ED100				[25]	L; lethal body burden
			100 mg/kg (whole body)[4]	Mortality, ED100				[25]	L; lethal body burden
			82 mg/kg (whole body)[4]	Mortality, ED100				[25]	L; lethal body burden

Summary of Biological Effects Tissue Concentrations for Pentachlorophenol

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	Sediment	Water	Tissue (Sample Type)	Effects	Log BCF	Log BAF	BSAF	Reference	Comments[3]
			99 mg/kg (whole body)[4]	Mortality, ED100				[25]	L; lethal body burden
			86 mg/kg (whole body)[4]	Mortality, ED100				[25]	L; lethal body burden
			95 mg/kg (whole body)[4]	Mortality, ED50				[26]	L; mortality
Pimephales promelas, Fathead minnow			CBR = 1.1-1.7 mmol/kg	50% mortality				[14]	L
Pimephales promelas, Fathead minnow			69 mg/kg (whole body)[4]	Growth, LOED				[33]	L; pH was 8.5
			22.1 mg/kg (whole body)[4]	Growth, LOED				[33]	L; pH was 8.0
			25.1 mg/kg (whole body)[4]	Growth, LOED				[33]	L; pH was 7.5
			43.8 mg/kg (whole body)[4]	Morphology, LOED				[33]	L; pH was 8.0
			69 mg/kg (whole body)[4]	Morphology, LOED				[33]	L; pH was 8.5

Summary of Biological Effects Tissue Concentrations for Pentachlorophenol

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	Sediment	Water	Tissue (Sample Type)	Effects	Log BCF	Log BAF	BSAF	Reference	Comments[3]
			35.1 mg/kg (whole body)[4]	Mortality, LOED				[33]	L; pH was 8.5
			45.9 mg/kg (whole body)[4]	Mortality, LOED				[33]	L; pH was 6.5
			45.9 mg/kg (whole body)[4]	Mortality, LOED				[33]	L; pH was 6.5
			43.8 mg/kg (whole body)[4]	Mortality, LOED				[33]	L; pH was 8.0
			12.6 mg/kg (whole body)[4]	Growth, NOED				[33]	L; pH was 8.0
			12.3 mg/kg (whole body)[4]	Growth, NOED				[33]	L; pH was 7.5
			45.9 mg/kg (whole body)[4]	Growth, NOED				[33]	L; pH was 6.5
			35.1 mg/kg (whole body)[4]	Growth, NOED				[33]	L; pH was 8.5
			35.1 mg/kg (whole body)[4]	Morphology, NOED				[33]	L; pH was 8.5
			22.1 mg/kg (whole body)[4]	Morphology, NOED				[33]	L; pH was 8.0
			21.5 mg/kg (whole body)[4]	Morphology, NOED				[33]	L; pH was 6.5

Summary of Biological Effects Tissue Concentrations for Pentachlorophenol

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	Sediment	Water	Tissue (Sample Type)	Effects	Log BCF	Log BAF	BSAF	Reference	Comments[3]
			25.1 mg/kg (whole body)[4]	Morphology, NOED				[33]	L; pH was 7.5
			17.8 mg/kg (whole body)[4]	Mortality, NOED				[33]	L; pH was 8.5
			22.1 mg/kg (whole body)[4]	Mortality, NOED				[33]	L; pH was 8.0
			25.1 mg/kg (whole body)[4]	Mortality, NOED				[33]	L; pH was 7.5
			21.5 mg/kg (whole body)[4]	Mortality, NOED				[33]	L; pH was 6.5
			25.1 mg/kg (whole body)[4]	Reproduction, NOED				[33]	L; pH was 7.5
			45.9 mg/kg (whole body)[4]	Reproduction, NOED				[33]	L; pH was 6.5
			69 mg/kg (whole body)[4]	Reproduction, NOED				[33]	L; pH was 8.5
			43.8 mg/kg (whole body)[4]	Reproduction, NOED				[33]	L; pH was 8.0
Ictalurus nebulosus, Brown bullhead		5.7 µg/L	260 µg/kg					[18]	F

Summary of Biological Effects Tissue Concentrations for Pentachlorophenol

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	Sediment	Water	Tissue (Sample Type)	Effects	Log BCF	Log BAF	BSAF	Reference	Comments[3]
Oryzias latipes, Medaka		100 µg/L	41.02 µg/g 38.02 µg/g 37.50 µg/g					[10]	L
Gambusia affinis, Mosquito fish			0.8 mg/kg (whole body)[4]	Mortality, NOED				[28]	L; no effect on survivorship in 24 hours
Osmerus mordax, Rainbow smelt		1.3 µg/L	6 µg/kg					[17]	L
Leuciscus idus, Golden ide			13 mg/kg (whole body)[4]	Mortality, NOED				[24]	L; no effect on survivorship in 3 days
Micropterus salmoides, Largemouth bass			9.6 mg/kg (whole body)[4]	Behavior, LOED				[31]	L; reduced success rate of prey capture
			9.6 mg/kg (whole body)[4]	Growth, LOED				[31]	L; reduction in growth
			9.6 mg/kg (whole body)[4]	Physiological, LOED				[31]	L; reduced food conversion efficiency, condition factor
			10.8 mg/kg (whole body)[4]	Mortality, NOED				[31]	L; no effect on mortality

Summary of Biological Effects Tissue Concentrations for Pentachlorophenol

Species:	**Concentration, Units in[1]:**			**Toxicity:**	**Ability to Accumulate[2]:**			**Source:**	
Taxa	**Sediment**	**Water**	**Tissue (Sample Type)**	**Effects**	**Log BCF**	**Log BAF**	**BSAF**	**Reference**	**Comments[3]**
Perca flavescens, Yellow perch		5.7 µg/L	260 µg/kg					[18]	F

[1] Concentration units based on wet weight unless otherwise noted.

[2] BCF = bioconcentration factor, BAF = bioaccumulation factor, BSAF = biota-sediment accumulation factor.

[3] L = laboratory study, spiked sediment, single chemical; F = field study, multiple chemical exposure; other unusual study conditions or observations noted.

[4] This entry was excerpted directly from the Environmental Residue-Effects Database (ERED, www.wes.army.mil/el/ered, U.S. Army Corps of Engineers and U.S. Environmental Protection Agency). The original publication was not reviewed, and the reader is strongly urged to consult the publication to confirm the information presented here.

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Chemical Category: POLYNUCLEAR AROMATIC HYDROCARBON (low molecular weight)

Chemical Name (Common Synonyms): PHENANTHRENE **CASRN:** 85-01-8

Chemical Characteristics

Solubility in Water: 0.6 ± 0.1 mg/L, 22°C [1]

Half-Life: 16-200 days, aerobic soil die-away test [2]

Log K_{ow}: 4.55 [3]

Log K_{oc}: 4.47 L/kg organic carbon

Human Health

Oral RfD: No data [4]

Confidence: ___

Critical Effect: ___

Oral Slope Factor: No data [4]

Carcinogenic Classification: D [4]

Wildlife

Partitioning Factors: Partitioning factors for phenanthrene in wildlife were not found in the literature.

Food Chain Multipliers: Food chain multipliers for phenanthrene in wildlife were not found in the literature.

Aquatic Organisms

Partitioning Factors: The water quality criterion tissue level (WQCTL) for phenanthrene, which is calculated by multiplying the water quality chronic value (4.6 µg/L) by the BCF (1380.38), is 6,350 µg/kg [5]. The partitioning between interstitial water and sediment particles increases with sediment aging [6]. The increasing partitioning suggests that phenanthrene becomes more tightly bound with increased contact time. A log BCF of 2.51 was reported for *Daphnia magna* [16].

Food Chain Multipliers: Food chain multipliers for phenanthrene in aquatic organisms were not found in the literature.

Toxicity/Bioaccumulation Assessment Profile

PAHs are readily metabolized and excreted by fish and invertebrates [11], affecting bioaccumulation kinetics and equilibrium tissue residues. The bioconcentration of phenanthrene by *Hexagenia* was related to the weight of the mayflies [12]. The bioaccumulation of phenanthrene by three amphipod species was much higher (up to 24 times) for the water-only exposure than for uptake from the sediment [13].

According to Landrum et al. [7], accumulation of sediment-associated PAHs (including phenanthrene) by the amphipod *Diporeia* spp. was limited by both the desorption rate to the interstitial water and the rate of accumulation through ingestion. Because of these limitations the concentration required to produce biological effects (mortality) was approximately 20 times greater than would be predicted using an equilibrium-partitioning approach. Amphipods exposed to 0.08, 0.18, 0.45, and 0.62 µmol/g of phenanthrene accumulated up to 5.8 µmol/g. The highest concentration (0.62 µmol/g of phenanthrene) was slightly toxic to the amphipods (12% mortality in highest concentration). According to the authors the amphipods never reached 6.1 µmol/g in their tissues, the concentration that was required (according to equilibrium-partitioning) to produce toxicity. The results reported by Swartz et al. [8] suggest that phenanthrene at a concentration more than two orders of magnitude higher than the acute concentration measured in the laboratory was not toxic to amphipods. The toxic level of phenanthrene established in the laboratory for the amphipod *Rhepoxynius abronius* was 3.68 mg/kg [9] (10-day LC50 value), while exposure of amphipods to 2,000 mg/kg of phenanthrene in sediment from Eagle Harbor did not produce acute responses. According to McCarty et al. [10], the toxic (critical) body residue of individual PAHs in tissues ranged from 513 to 4,248 mg/kg.

Summary of Biological Effects Tissue Concentrations for Phenanthrene

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	Sediment µmol/g	Water µmol/L	Tissue (Sample Type) µmol/g	Effects	Log BCF	Log BAF	BSAF	Reference	Comments[3]
Invertebrates									
Nereis succinea,	0.001		0.094					[14]	F
Polychaete worm,	0.004		0.035						
	0.006		0.007						
	0.023		0.029						
	0.023		0.063						
	0.028		0.046						
	0.042		0.340						
	0.051		0.039						
Crassostrea	0.00001		0.00003					[15]	F
virginica,	0.00001		0.00013						
Eastern oyster	0.00001		0.00017						
	0.00002		0.00015						
	0.00002		0.00010						
	0.00004		0.00020						
	0.00004		0.00018						
	0.00005		0.00029						
	0.00005		0.00022						
	0.00005		0.00025						
	0.00007		0.00022						
	0.00007		0.00009						
	0.00007		0.00022						
	0.00007		0.00018						

Summary of Biological Effects Tissue Concentrations for Phenanthrene

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	Sediment µmol/g	Water µmol/L	Tissue (Sample Type) µmol/g	Effects	Log BCF	Log BAF	BSAF	Reference	Comments[3]
Crassostrea virginica, Eastern oyster	0.00008		0.0001						
	0.00008		0.0002						
	0.00008		0.0001						
	0.00008		BDL[4]						
	0.00010		0.0003						
	0.00010		0.0006						
	0.00010		0.0002						
	0.00010		0.0001						
	0.00010		0.0001						
	0.00010		0.0001						
	0.00010		0.0002						
	0.00010		0.0001						
	0.0002		0.0002						
	0.0002		0.0002						
	0.0003		0.0004						
	0.0005		0.0001						
	0.0009		0.0001						
Mytilus edulis, Mussel			30.7 mg/kg (whole body)[5]	Physiological, ED50				[22]	L; 50% reduction in feeding rate
Macoma balthica, Baltic macoma	0.001		0.216						
	0.004		0.062						
	0.006		--						
	0.023		0.026						
	0.023		0.027						
	0.028		0.110						
	0.042		0.396						
	0.051								
Daphnia magna, Cladoceran		0.225	73 nM/G		2.51			[16]	L

Summary of Biological Effects Tissue Concentrations for Phenanthrene

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	**Sediment µmol/g**	**Water µmol/L**	**Tissue (Sample Type) µmol/g**	**Effects**	**Log BCF**	**Log BAF**	**BSAF**	**Reference**	**Comments[3]**
Diporeia sp., Amphipod	0.08		Day 1: 0.2 Day 3: 0.4 Day 8: 0.2 Day 16: 0.1 Day 32: 0.1					[7]	L
	0.18		Day 1: 0.2 Day 3: 0.4 Day 8: 0.2 Day 16: 0.1 Day 32: 0.1						
	0.45		Day 1: 3.2 Day 3: 3.8 Day 8: 1.4 Day 16: 0.6 Day 32: 0.4						
Diporeia sp., Amphipod	0.62		Day 1: 2.2 Day 3: 5.8 Day 8: 2.8 Day 16: 1.2 Day 32: 0.4					[7]	L
Diporeia spp., Amphipod			71 mg/kg (whole body)[5]	Mortality, LOED				[21]	L; 12% mortality

Summary of Biological Effects Tissue Concentrations for Phenanthrene

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	**Sediment µmol/g**	**Water µmol/L**	**Tissue (Sample Type) µmol/g**	**Effects**	**Log BCF**	**Log BAF**	**BSAF**	**Reference**	**Comments[3]**
Eohaustorius estuarius, Amphipod	0.208	0.014 overlying water	0.225, lipid 5.899, total					[13]	L
		0.14 overlying water	0.719, lipid 17.191, total						
Grandidierella japonica, Amphipod	0.208	0.0140 overlying water	0.096, lipid 1.011, total					[13]	L
		0.140 overlying water	0.938, lipid 10.169, total						
Leptocheirus plumulosus, Amphipod	0.208	0.0140 overlying water	0.073, lipid 0.899, total					[13]	L
		0.140 overlying water	0.360, lipid 3.427, total						
Pontoporeia hoyi, Amphipod	0.0004 0.004	0.006 0.008	0.004 0.007					[18]	L
Fishes									

Summary of Biological Effects Tissue Concentrations for Phenanthrene

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	**Sediment µmol/g**	**Water µmol/L**	**Tissue (Sample Type) µmol/g**	**Effects**	**Log BCF**	**Log BAF**	**BSAF**	**Reference**	**Comments[3]**
Oncorhynchus mykiss, Rainbow trout			30 mg/kg (whole body)[5]	Physiological, LOED				[24]	L; induction of hepatic mixed function oxidases
Brachydanio rerio, Zebrafish	0.013	0.004	0.013 -24 hours 0.0007 - 240 hours					[20]	L
Leuciscus idus, Golden ide			88 mg/kg (whole body)[5]	Mortality, NOED				[23]	L; no effect on survivorship In 3 days
Pleuronectes vetulus, English sole	0.0009-1.07		0.0005 (liver) <0.00001 (muscle)					[19]	F

[1] Concentration units based on wet weight unless otherwise noted.
[2] BCF = bioconcentration factor, BAF = bioaccumulation factor, BSAF = biota-sediment accumulation factor.
[3] L = laboratory study, spiked sediment, single chemical; F = field study, multiple chemical exposure; other unusual study conditions or observations noted.
[4] BDL = below detection limit.
[5] This entry was excerpted directly from the Environmental Residue-Effects Database (ERED, www.wes.army.mil/el/ered, U.S. Army Corps of Engineers and U.S. Environmental Protection Agency). The original publication was not reviewed, and the reader is strongly urged to consult the publication to confirm the information presented here.

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Chemical Category: POLYNUCLEAR AROMATIC HYDROCARBON (high molecular weight)

Chemical Name (Common Synonyms): PYRENE **CASRN:** 129-00-0

Chemical Characteristics

Solubility in Water: 0.135 mg/L at 25°C [1]

Half-Life: 210 days - 5.2 yrs based on aerobic soil die-away test data at 10-30°C [2]

Log K_{ow}: 5.11 [3]

Log K_{oc}: 5.02 L/kg organic carbon

Human Health

Oral RfD: 3×10^{-2} mg/kg/day [4]

Confidence: Low, uncertainty factor = 3000

Critical Effect: Kidney effects (renal tubular pathology, decreased kidney weights)

Oral Slope Factor (Reference): No data [4]

Carcinogenic Classification: No data [4]

Wildlife

Partitioning Factors: Partitioning factors for pyrene in wildlife were not found in the literature.

Food Chain Multipliers: Food chain multipliers for pyrene in wildlife were not found in the literature.

Aquatic Organisms

Partitioning Factors: Log BCFs for pyrene ranged from 2.85 for midges [6] to 4.05 for guppies [17]. Log BAFs ranged from −0.43 for clams to 4.65 for amphipods [16].

Food Chain Multipliers: Food chain multipliers for pyrene in aquatic organisms were not found in the literature.

Toxicity/Bioaccumulation Assessment Profile

The acute toxicity of hydrocarbons, including pyrene, to both fresh and saltwater crustaceans is largely nonselective, i.e., it is not primarily influenced by molecular structure, but is rather controlled by organism-water partitioning which, for nonpolar organic chemicals, is in turn a reflection of aqueous solubility. The toxic effect is believed to occur at a relatively constant concentration within the organism [5]. Bioconcentration and depuration of pyrene and its biotransformation products display a clear pH-dependency both in rate and bioconcentration [6]. Decreasing ambient pH leads to decreasing bioconcentration rates, depuration rates, bioconcentration factors. The accumulation kinetics of pyrene suggest that uptake occurs largely via the sediment interstitial water and is controlled by desorption from sediment particles and dissolved organic matter [7].

Bioavailability of sediment-associated PAHs has been observed to decline with increased contact time [8]. The concentration of pyrene declined significantly over the course of the exposures for all aging durations. Increases in the length of contact between the sediment and pyrene reduced its bioavailability compared to 3 days of aging, but after 60 days, the bioavailability appeared to stabilize. Pyrene exhibited increased partitioning between interstitial water and sediment particles as aging increased [8]. The increasing partitioning suggests that the compounds are becoming more tightly bound with increased contact time.

The results from the laboratory experiments performed by Harkey et al. [9] indicated that accumulation of pyrene from pore-water exposures was lower than accumulation from whole sediment. The concentrations of pyrene in whole sediment and pore water were 0.14-0.87 ng/g and 0.001-0.016 mg/mL, respectively. Harkey et al. [9] concluded that aqueous extracts of whole sediment did not accurately represent the exposure observed in whole sediment. The aqueous extracts of whole sediment underexposed organisms compared to whole sediment, even after adjusting accumulation to the fraction of organic carbon contained in the test media. While the total pyrene concentration in the sediment stayed constant, total concentration decreased appreciably in pore water and elutriate over the course of the exposure, and it is likely that the bioavailability concentrations in these media also decreased. The dissolved organic material in the interstitial waters interfered with the direct uptake of PAHs, e.g., pyrene, in a manner similar to that observed with humic material [10]. Unlike the Aldrich humics that showed a very close relationship between log K_{ow} and log K_b, sorption by dissolved organic carbon from interstitial waters would not necessarily be predicted from K_{ow}. Pyrene was quickly accumulated by *Lumbriculus variegatus* and achieved apparent steady state within 48 to 168 hours [11].

The relative pyrene distribution among sediment particle size revealed 44 percent of pyrene within 43-63 µm particle size [12]. In general, most of pyrene was found in the smallest-sized particles. The narcotic effect for *Diporeia* exposed to pyrene depends on attaining a certain molar concentration in the organism [12]. Using equilibrium-partitioning theory, the BCF value, and critical body residue (LD50), Landrum et al. [12] calculated the sediment concentration that would produce 50 percent amphipod mortality. Based on these assumptions, the pyrene concentration of 14.2 µg/g in sediment should produce 50 percent mortality. The LC50 based on laboratory exposure was estimated to be between 147 and 223 µg/g pyrene. The comparison of the calculated values with the estimated LC50 value (147 to 223 µg/g) from the laboratory experiments suggested that the equilibrium-partitioning approach overestimated the toxicity of sediment-associated pyrene by a factor of 10 at minimum.

Summary of Biological Effects Tissue Concentrations for Pyrene

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	Sediment µmol/g	Water µmol/L	Tissue (Sample Type) µmol/g	Effects	Log BCF	Log BAF	BSAF	Reference	Comments[3]
Invertebrates									
Nereis virens, Polychaete	0.006	0.008	0.023-0.031 in 4 days		3.33			[14]	L
Lumbriculus variegatus, Oligochate	0.003	17.327	0.004					[16]	L
		0.000001	0.0002 in 2 days, 0.0003 in 25 days, 0.0004 in 58 days,					[11]	L
		0.0003	0.0015 in 96 h, 0.0014 in 168 h,					[11]	L
		0.0007	0.0019 in 96 h, 0.0020 in 168 h,					[11]	L
		0.001	0.0019 in 96 h, 0.0020 in 168 h,					[11]	L
		0.0013	0.0023 in 96 h, 0.0016 in 168 h,					[11]	L
Dreissena polymorpha, Zebra mussel					4.65			[13]	L; not lipid normalized
Mytilus edulis, Mussel	0.006	0.008	0.022-0.031 in 4 days		3.70			[14]	L

Summary of Biological Effects Tissue Concentrations for Pyrene

Species:	**Concentration, Units in[1]:**			**Toxicity:**	**Ability to Accumulate[2]:**			**Source:**	
Taxa	**Sediment µmol/g**	**Water µmol/L**	**Tissue (Sample Type) µmol/g**	**Effects**	**Log BCF**	**Log BAF**	**BSAF**	**Reference**	**Comments[3]**
Mytilus edulis, Mussel			189 mg/kg (whole body)[4]	Physiological, ED50				[20]	L;50% reduction in feeding rate, exp_conc = >0.04
Macoma nasuta, Clam	0.00006		0.0002			−0.28		[15]	F
	0.00006		0.0002			−0.36		[15]	F
	0.0005		0.0003			−0.43		[15]	F
	0.0006		0.0004			−0.30		[15]	F
	0.0018		0.0009			−0.33		[15]	F
	0.0025		0.0008			−0.37		[15]	F
Diporeia spp., Amphipod			1270 mg/kg (whole body)[4]	Mortality, ED50				[12]	L; 50% mortality
Diporeia spp., Amphipod	0.52		6.8 in 28d, 2.8 in 14d,					[12]	L
	0.86		7.4 in 28d, 4.6 in 14d,	LD50 (critical body residue) was 6.3 and 9.4 µmol/g				[12]	L
	1.11		6.6 in 28d, 4.6 in 14d,	LC50 was between 147 and 223 µg/g (0.72-1.1 µmol/g)				[12]	L

Summary of Biological Effects Tissue Concentrations for Pyrene

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	**Sediment µmol/g**	**Water µmol/L**	**Tissue (Sample Type) µmol/g**	**Effects**	**Log BCF**	**Log BAF**	**BSAF**	**Reference**	**Comments[3]**
Pontoporeia hoyi, Amphipod	0.0006		0.005					[7]	L
	0.0002	0.02	0.007			4.65		[16]	L
Pontoporeia hoyi, Amphipod	0.0014	0.014	0.015					[16]	L
Chironomus riparius					2.85			[6]	L; at pH of 4
								[6]	L; at pH of 6
								[6]	L; at pH of 8
Crangon separenaria, Shrimp	0.006	0.008	0.010-0.011 in 4 days		2.95			[14]	L
Fishes									
Oncorhynchus mykiss, Rainbow trout			30 mg/kg (whole body)[4]	Physiological, LOED				[21]	L; increased hepatic concentration of cytochrome P450

Summary of Biological Effects Tissue Concentrations for Pyrene

Species:	**Concentration, Units in[1]:**			**Toxicity:**	**Ability to Accumulate[2]:**			**Source:**	
Taxa	**Sediment µmol/g**	**Water µmol/L**	**Tissue (Sample Type) µmol/g**	**Effects**	**Log BCF**	**Log BAF**	**BSAF**	**Reference**	**Comments[3]**
Cyprinus carpio, Common carp			28.7 mg/kg (liver)[4]	Physiological, NA				[19]	L; significant increrase in EROD enzyme and P450 1a protein content
Brachydanio rerio, Zebrafish	0.011	0.088	0.008 -24 hours 0.001 - 240 hours					[18]	L
Poecilia reticulata, Guppy		0.6	0.742		4.05			[17]	L

[1] Concentration units based on wet weight unless otherwise noted.

[2] BCF = bioconcentration factor, BAF = bioaccumulation factor, BSAF = biota-sediment accumulation factor.

[3] L = laboratory study, spiked sediment, single chemical; F = field study, multiple chemical exposure; other unusual study conditions or observations noted.

[4] This entry was excerpted directly from the Environmental Residue-Effects Database (ERED, www.wes.army.mil/el/ered, U.S. Army Corps of Engineers and U.S. Environmental Protection Agency). The original publication was not reviewed, and the reader is strongly urged to consult the publication to confirm the information presented here.

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Chemical Category: METAL

Chemical Name (Common Synonyms): SELENIUM **CASRN:** 7782-49-2

Chemical Characteristics

Solubility in Water: Insoluble [1]

Half-Life: Not applicable, stable [1]

Log K_{ow}: –

Log K_{oc}: –

Human Health

Oral RfD: 5×10^{-3} mg/kg/day [2]

Confidence: High, uncertainty factor = 3

Critical Effect: Clinical selenosis (hair or nail loss, morphological changes of the nails, skin lesions, central nervous system abnormalities including peripheral anesthesia, acroparesthesia, and pain in the extremities, and liver dysfunction indicated by prolongation of blood clotting time and reduced serum glutathione titer)

Oral Slope Factor: Inadequate data [2]

Carcinogenic Classification: D, selenium sulfide B2 [2]

Wildlife

Partitioning Factors: Partitioning factors for selenium in wildlife were not found in the literature.

Food Chain Multipliers: Food chain multipliers for selenium in wildlife were not found in the literature.

Aquatic Organisms

Partitioning Factors: Most of the selenium in sediments is bound to humic and fulvic acids. Microorganisms are closely involved with the selenium cycle and are capable of oxidizing elemental selenium to selenite [6].

Food Chain Multipliers: The results of several studies showed that selenium can biomagnify within the aquatic system [7,8].

Toxicity/Bioaccumulation Assessment Profile

Selenium is an element normally found at low levels in aquatic ecosystems. Although the literature values for acute (600 to 35,000 µg/L) or chronic (30 to 60 µg/L) toxicity via water exposure for fish are a few orders of magnitude higher than its concentration in surface waters, a dietary uptake at relatively low levels (5 to 10 µg/L) can be toxic to fish. The dietary toxicity was confirmed by Schultz and Hermanutz [1] and Woock et al. [2]. They demonstrated that fish fed with invertebrates containing high levels of selenium developed signs of selenosis and some of them died. Female fish transferred selenium to their progeny, and embryos showed an increased incidence of edema and lordosis. Monitoring concentrations of selenium in sediment and benthic fauna is essential since selenium can biomagnify sufficiently to cause acute toxicity to fishes.

Three species, *Chlorella vulgaris*, *Brachionus calyciflorus*, and *Pimephales promelas* were exposed to selenate for 25 days in a three-trophic level system [10]. Selenium as selenate reduced larval fathead minnow biomass and impared both the algal and rotifer population growth rates at 108.1 µg/L. The results of Dobbs et. al [10] supported the work of earlier researchers [7,8] who found that selenium had a negative impact on aquatic biota at concentrations above 100 µg/L.

Summary of Biological Effects Tissue Concentrations for Selenium

Species:	**Concentration, Units in[1]:**			**Toxicity:**	**Ability to Accumulate[2]:**			**Source:**	
Taxa	**Sediment**	**Water**	**Tissue (Sample Type)**	**Effects**	**Log BCF**	**Log BAF**	**BSAF**	**Reference**	**Comments[3]**
Plants									
Chlorella vulgaris, Green algae			7.4 mg/kg (whole body)[5]	Growth, LOED				[10]	L; reduced growth
Invertebrates									
Brachionus calyciflorus, Rotifer			15 mg/kg (whole body)[5]	Mortality, ED100				[10]	L; lethal body burden
			6.5 mg/kg (whole body)[5]	Growth, LOED				[10]	L; reduction in population biomass
Daphnia magna, Cladoceran			3 mg/kg (whole body)[5]	Growth, LOED				[15]	L; increased biomass over controls
			25 mg/kg (whole body)[5]	Mortality, LOED				[15]	L; mortality
			2.94 mg/kg (whole body)[5]	Growth, LOED				[16]	L; reduced growth
			10.2 mg/kg (whole body)[5]	Physiological, LOED				[16]	L; decreased whole body chloride concentration
			2.94 mg/kg (whole body)[5]	Physiological, LOED				[16]	L; increased whole body calcium content

Summary of Biological Effects Tissue Concentrations for Selenium

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	Sediment	Water	Tissue (Sample Type)	Effects	Log BCF	Log BAF	BSAF	Reference	Comments[3]
			6.34 mg/kg (whole body)[5]	Reproduction, LOED				[16]	L; delayed time to first brood, decreased intrinsic rate of natural increase
			10.2 mg/kg (whole body)[5]	Growth, NA				[16]	L; reduced growth
			6.34 mg/kg (whole body)[5]	Growth, NA				[16]	L; reduced growth
			6.34 mg/kg (whole body)[5]	Physiological, NA				[16]	L; increased whole body calcium content
			10.2 mg/kg (whole body)[5]	Reproduction, NA				[16]	L; delayed time to first brood, decreased intrinsic rate of natural increase
			4.22 mg/kg (whole body)[5]	Growth, NOED				[16]	L; no effect on growth
			0.26 mg/kg (whole body)[5]	Growth, NOED				[16]	L; no effect on growth
			10.2 mg/kg (whole body)[5]	Mortality, NOED				[16]	L; no effect on mortality
			6.34 mg/kg (whole body)[5]	Mortality, NOED				[16]	L; no effect on mortality
			2.94 mg/kg (whole body)[5]	Mortality, NOED				[16]	L; no effect on mortality

Summary of Biological Effects Tissue Concentrations for Selenium

Species: Taxa	Concentration, Units in[1]: Sediment	Water	Tissue (Sample Type)	Toxicity: Effects	Ability to Accumulate[2]: Log BCF	Log BAF	BSAF	Source: Reference	Comments[3]
			4.22 mg/kg (whole body)[5]	Mortality, NOED				[16]	L; no effect on mortality
			0.26 mg/kg (whole body)[5]	Mortality, NOED				[16]	L; no effect on mortality
			4.22 mg/kg (whole body)[5]	Physiological, NOED				[16]	L; no effect on whole body ions
			0.26 mg/kg (whole body)[5]	Physiological, NOED				[16]	L; no effect on whole body ions
			2.94 mg/kg (whole body)[5]	Reproduction, NOED				[16]	L; no effect on reproduction
			4.22 mg/kg (whole body)[5]	Reproduction, NOED				[16]	L; no effect on reproduction
			0.26 mg/kg (whole body)[5]	Reproduction, NOED				[16]	L; no effect on reproduction
Chironomus decorus, Midge			2 mg/kg (whole body)[5]	Growth, LOED				[12]	L; reduced growth, exp_conc = <1.0
			12.6 mg/kg (whole body)[5]	Mortality, ED50				[19]	L; lethal to 50% of animals in 48 hours
			17 mg/kg (whole body)[5]	Mortality, ED50				[19]	L; lethal to 50% of animals in 48 hours
			0.51 mg/kg (whole body)[5]	Growth, LOED				[20]	L; reduction in growth

Summary of Biological Effects Tissue Concentrations for Selenium

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	**Sediment**	**Water**	**Tissue (Sample Type)**	**Effects**	**Log BCF**	**Log BAF**	**BSAF**	**Reference**	**Comments[3]**
Fishes									
Oncorhynchus tshawytscha, Chinook salmon			0.68 mg/kg (whole body)[5]	Growth, LOED				[5]	L; diet exposure, reduced weight and length gain in 30 days
			0.66 mg/kg (whole body)[5]	Growth, LOED				[5]	L; diet exposure, reduced weight and length gain in 60 days
			2.88 mg/kg (whole body)[5]	Growth, LOED				[5]	L; diet exposure, reduced length after 120 days
			2.01 mg/kg (whole body)[5]	Growth, LOED				[5]	L; diet exposure, reduced weight and length gain in 60 days
			2.16 mg/kg (whole body)[5]	Growth, LOED				[5]	L; diet exposure, reduced weight and length gain in 60 days
			1.6 mg/kg (whole body)[5]	Growth, LOED				[5]	L; diet exposure, reduced weight gain after 120 days
			4.64 mg/kg (whole body)[5]	Growth, LOED				[5]	L; diet exposure, reduced weight and length gain in 120 days in salt water

Summary of Biological Effects Tissue Concentrations for Selenium

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	Sediment	Water	Tissue (Sample Type)	Effects	Log BCF	Log BAF	BSAF	Reference	Comments[3]
			5.88 mg/kg (whole body)[5]	Mortality, LOED				[5]	L; diet exposure, reduced survival in 60 days
			1.3 mg/kg (whole body)[5]	Mortality, LOED				[5]	L; diet exposure, reduced survival in 90 days
			2.08 mg/kg (whole body)[5]	Mortality, LOED				[5]	L; diet exposure, no effect on survival in 60 days
			0.52 mg/kg (whole body)[5]	Mortality, LOED				[5]	L; diet exposure, no effect on survival in 90 days
			4.68 mg/kg (whole body)[5]	Mortality, LOED				[5]	L; diet exposure, reduced survival in 60 days
			1.08 mg/kg (whole body)[5]	Mortality, LOED				[5]	L; diet exposure, reduced survival in 90 days
			1.02 mg/kg (whole body)[5]	Growth, NOED				[5]	L; diet exposure, no effect on weight or length gain in 30 days
			1.06 mg/kg (whole body)[5]	Growth, NOED				[5]	L; diet exposure, no effect on weight or length gain in 60 days

Summary of Biological Effects Tissue Concentrations for Selenium

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	Sediment	Water	Tissue (Sample Type)	Effects	Log BCF	Log BAF	BSAF	Reference	Comments[3]
			0.54 mg/kg (whole body)[5]	Growth, NOED				[5]	L; diet exposure, no effect on weight or length gain in 90 days
			1.6 mg/kg (whole body)[5]	Growth, NOED				[5]	L; diet exposure, no effect on length after 120 days
			1.08 mg/kg (whole body)[5]	Growth, NOED				[5]	L; diet exposure, no effect on weight or length gain in 90 days
			0.72 mg/kg (whole body)[5]	Growth, NOED				[5]	L; diet exposure, no effect on weight gain after 120 days
			2.52 mg/kg (whole body)[5]	Growth, NOED				[5]	L; diet exposure, no effect on lenght and weight gain in salt water
			2.66 mg/kg (whole body)[5]	Mortality, NOED				[5]	L; diet exposure, no effect on survival in 60 days
			0.8 mg/kg (whole body)[5]	Mortality, NOED				[5]	L; diet exposure, no effect on survival in 90 days
			5.76 mg/kg (whole body)[5]	Mortality, NOED				[5]	L; diet exposure, no effect on survival in 120 days

Summary of Biological Effects Tissue Concentrations for Selenium

Species: Taxa	Concentration, Units in[1]: Sediment	Water	Tissue (Sample Type)	Toxicity: Effects	Ability to Accumulate[2]: Log BCF	Log BAF	BSAF	Source: Reference	Comments[3]
			4.64 mg/kg (whole body)[5]	Mortality, NOED				[5]	L; diet exposure, no effect on survival in 120 days
Pimephales promelas, Fathead minnow			12.2 mg/kg (whole body)[5]	Growth, LOED				[16]	L; reduction in size and growth of larvae
			10.3 mg/kg (whole body)[5]	Growth, NOED				[14]	L; no effect on larval growth
			12.2 mg/kg (whole body)[5]	Mortality, NOED				[14]	L; no effect on mortality
			15.2 mg/kg (whole body)[5]	Growth, LOED				[10]	L; reduced growth of larvae
			17.8 mg/kg (whole body)[5]	Mortality, LOED				[10]	L; mortality, loss of weight
Lepomis macrochirus, Bluegill			2.4 mg/kg (whole body)[5]	Mortality, NOED				[13]	L; no effect on mortality
			15.8 mg/kg (liver)[5]	Mortality, LOED				[7]	L
			2.8 mg/kg (skeletal muscle)[5]	Mortality, LOED				[7]	L
			6.3 mg/kg (testis)[5]	Mortality, LOED				[7]	L

Summary of Biological Effects Tissue Concentrations for Selenium

Species:	**Concentration, Units in[1]:**			**Toxicity:**	**Ability to Accumulate[2]:**			**Source:**	
Taxa	**Sediment**	**Water**	**Tissue (Sample Type)**	**Effects**	**Log BCF**	**Log BAF**	**BSAF**	**Reference**	**Comments[3]**
			4.6 mg/kg (whole body)[5]	Mortality, LOED				[7]	L
			4.6 mg/kg (whole body)[5]	Growth, NA				[7]	L
			4.6 mg/kg (whole body)[5]	Reproduction, NA				[7]	L; measurable but not statistically significant reduced survival of embryos and larvae
			0.4 mg/kg (brain)[5]	Mortality, NOED				[17]	L; no effect on survivorship
			8.3 mg/kg (gill)[5]	Mortality, NOED				[17]	L; no effect on survivorship
			1.8 mg/kg (gonad)[5]	Mortality, NOED				[17]	L; no effect on survivorship
			13.7 mg/kg (heart)[5]	Mortality, NOED				[17]	L; no effect on survivorship
			2.2 mg/kg (intestine)[5]	Mortality, NOED				[17]	L; no effect on survivorship
			10.2 mg/kg (kidney)[5]	Mortality, NOED				[17]	L; no effect on survivorship
			11.4 mg/kg (liver)[5]	Mortality, NOED				[17]	L; no effect on survivorship
			2.4 mg/kg (plasma)[5]	Mortality, NOED				[17]	L; no effect on survivorship

Summary of Biological Effects Tissue Concentrations for Selenium

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	Sediment	Water	Tissue (Sample Type)	Effects	Log BCF	Log BAF	BSAF	Reference	Comments[3]
			7.2 mg/kg (red blood cells)[5]	Mortality, NOED				[17]	L; no effect on survivorship
			17.7 mg/kg (spleen)[5]	Mortality, NOED				[17]	L; no effect on survivorship
			1 mg/kg (stomach)[5]	Mortality, NOED				[17]	L; no effect on survivorship
			2.6 mg/kg (white muscle)[5]	Mortality, NOED				[17]	L; no effect on survivorship
			4.3 mg/kg (whole body)[5]	Mortality, NOED				[17]	L; no effect on survivorship
			1.6 mg/kg (whole body)[5]	Cellular, LOED				[18]	L; structural changes in gill tissue
			1.6 mg/kg (whole body)[5]	Mortality, LOED				[18]	L; 35% reduction in survival after 180 days
			1.6 mg/kg (whole body)[5]	Physiological, LOED				[18]	L; increased respiratory demands, lipid depletion
			1.6 mg/kg (whole body)[5]	Behavior, NOED				[18]	L; no effect on feeding behavior

Summary of Biological Effects Tissue Concentrations for Selenium

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	Sediment	Water	Tissue (Sample Type)	Effects	Log BCF	Log BAF	BSAF	Reference	Comments[3]
Lepomis macrochirus, Bluegill		0.16 mg/L	Day 30:	Mortality:				[6]	L
		0.33 mg/L	3.0 µg/g	10%					
		0.64 mg/L	3.5 µg/g	20%					
		1.12 mg/L	4.0 µg/g	40%					
		2.80 mg/L	7.0 µg/g	55%					
			14.3 µg/g	88%					
		0.16 mg/L	Day 60:						
		0.33 mg/L	2.8 µg/g	10%					
		0.64 mg/L	4.1 µg/g	22%					
		1.12 mg/L	5.0 µg/g	52%					
		2.80 mg/L	9.7 µg/g	70%					
			–	98%					
			Day 258:					[7]	L
		10 µg/L	9.3 µg/g (liver)						
			4.4 µg/g (ovaries)						
			3.0 µg/g (testes)						
			1.8 µg/g (muscles)						
			Day 356:						
			7.3 µg/g (liver)						
			4.5 µg/g (ovaries)						
			7.6 µg/g (testes)						
			4.2 µg/g (muscles)						

Summary of Biological Effects Tissue Concentrations for Selenium

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	Sediment	Water	Tissue (Sample Type)	Effects	Log BCF	Log BAF	BSAF	Reference	Comments[3]
Lepomis macrochirus, Bluegill			8.4 µg/L water, 0.8 µg/g diet: 3 µg/g 1 µg/g 10.5 µg/L water, 4.6 µg/g diet: 3 µg/g 10.5 µg/L water, 8.4 µg/g diet: 5 µg/g 10.1 µg/L water, 16.8 µg/g diet: 10 µg/g 11.0 µg/L water, 33.3 µg/g diet: 19 µg/g					[8]	L
Micropterus salmoides, Largemouth bass			0.4 mg/kg (brain)[5]	Mortality, NOED				[17]	L; no effect on survivorship
			6.2 mg/kg (gill)[5]	Mortality, NOED				[17]	L; no effect on survivorship
			1.7 mg/kg (gonad)[5]	Mortality, NOED				[17]	L; no effect on survivorship
			12 mg/kg (heart)[5]	Mortality, NOED				[17]	L; no effect on survivorship
			2.1 mg/kg (intestine)[5]	Mortality, NOED				[17]	L; no effect on survivorship

Summary of Biological Effects Tissue Concentrations for Selenium

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	Sediment	Water	Tissue (Sample Type)	Effects	Log BCF	Log BAF	BSAF	Reference	Comments[3]
			8.6 mg/kg (kidney)[5]	Mortality, NOED				[17]	L; no effect on survivorship
			10 mg/kg (liver)[5]	Mortality, NOED				[17]	L; no effect on survivorship
			3.2 mg/kg (plasma)[5]	Mortality, NOED				[17]	L; no effect on survivorship
			8 mg/kg (red blood cells)[5]	Mortality, NOED				[17]	L; no effect on survivorship
			16.4 mg/kg (spleen)[5]	Mortality, NOED				[17]	L; no effect on survivorship
			1.3 mg/kg (stomach)[5]	Mortality, NOED				[17]	L; no effect on survivorship
			1.4 mg/kg (white muscle)[5]	Mortality, NOED				[17]	L; no effect on survivorship
			3 mg/kg (whole body)[5]	Mortality, NOED				[17]	L; no effect on survivorship

Summary of Biological Effects Tissue Concentrations for Selenium

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	Sediment	Water	Tissue (Sample Type)	Effects	Log BCF	Log BAF	BSAF	Reference	Comments[3]
Wildlife									
Anas platyrhynochos, Mallard			0 ppm diet: 2.5 ppm (liver) 15 ppm diet: 2.0 ppm (liver) 0/100 ppm diet: 35.0 ppm (liver) 15/100 ppm diet: 53.0 ppm (liver)					[9]	L
			0 ppm diet: 0.88 ppm (liver) females 0.69 ppm, males 1.1 ppm, 3.5 ppm diet: 3.7 ppm (liver) females 3.2 ppm, males 4.3 ppm, 7.0 ppm diet: 6.2 ppm (liver) females 5.1 ppm, males 7.3 ppm					[11]	L

[1] Concentration units based on wet weight unless otherwise noted.
[2] BCF = bioconcentration factor, BAF = bioaccumulation factor, BSAF = biota-sediment accumulation factor.
[3] L = laboratory study, spiked sediment, single chemical; F = field study, multiple chemical exposure; other unusual study conditions or observations noted.
[4] BDL = below detection limit.
[5] This entry was excerpted directly from the Environmental Residue-Effects Database (ERED, www.wes.army.mil/el/ered, U.S. Army Corps of Engineers and U.S. Environmental Protection Agency). The original publication was not reviewed, and the reader is strongly urged to consult the publication to confirm the information presented here.

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Chemical Category: METAL

Chemical Name (Common Synonyms): SILVER **CASRN:** 7440-22-4

Chemical Characteristics

Solubility in Water: Insoluble [1]

Half-Life: Not applicable, stable [1]

Log K_{ow}: –

Log K_{oc}: –

Human Health

Oral RfD: 5×10^{-3} mg/kg/day [2]

Confidence: Low, uncertainty factor = 3

Critical Effect: Argyria—permanent, but benign, bluish-gray discoloration of the skin

Oral Slope Factor: No data [2]

Carcinogenic Classification: D [2]

Wildlife

Partitioning Factors: Partitioning factors for silver in wildlife were not found in the literature.

Food Chain Multipliers: Food chain mulitpliers for silver in wildlife were not found in the literature.

Aquatic Organisms

Partitioning Factors: Silver in the water column can partition to dissolved and particulate organic carbon. Important issues related to water column concentrations of silver are water hardness (i.e., calcium concentration), pH, and metal speciation, since the monovalent form of silver is believed to be responsible for observed biological effects. In addition, silver is known to form a variety of relatively insoluble (i.e., nonbioavailable) complexes, including silver sulfides formed with acid volatile sulfides, that can be important in controlling the toxicity and bioaccumulation of silver in sediments [8 and 9].

Food Chain Multipliers: Little evidence exists to support the general occurrence of biomagnification of silver within marine or freshwater food webs [3]. Silver uptake by aquatic organisms appears to be almost entirely from the dissolved form. When silver was bound to algal cell membranes, it could not be dislodged by either mechanical disruption or leaching at low pH; therefore, silver bound to algal cells is likely unassimilable by higher organisms [3].

Toxicity/Bioaccumulation Assessment Profile

Silver does not appear to be a highly mobile element under typical conditions in most aquatic habitats. Tissue residue-toxicity relationships can also vary because organisms may sequester metal in different forms that might be analytically measurable as tissue residue, but might actually be stored in unavailable forms within the organism as a form of detoxification [4]. Whole-body residues also might not be indicative of effects concentrations at the organ level because concentrations in target organs, such as the kidneys and liver, can be 20 times greater than whole body residues [5]. The application of “clean” chemical analytical and sample preparation techniques is also critical in the measurement of metal tissue residues [6]. Exposure of rainbow trout to three different silver salts revealed that silver, introduced as silver nitrate, was 15,000 and 11,000 times more toxic than silver chloride and silver thiosulfate [11]. However, all three forms of dissolved silver were taken up by rainbow trout and accumulated in the tissue. Interestingly, extremely high levels of silver were found in livers of fish exposed to silver as silver chloride and silver thiosulfate. Hogstrand et al. [11] attributed low toxicity to these two forms to production of metallothionein, a small cysteine-rich, intracellular protein that avidly binds most metals.

Summary of Biological Effects Tissue Concentrations for Silver

Species: Taxa	Concentration, Units in[1]: Sediment	Water	Tissue (Sample Type)	Toxicity: Effects	Ability to Accumulate[2]: Log BCF	Log BAF	BSAF	Source: Reference	Comments[3]
Invertebrates									
Busycotypus canaliculatum, Channeled whelk		0.1-0.5 µg/L	1.1 µg/g					[7]	F
Corbicula fluminea, Asiatic clam			1,650 mg/kg (whole body)[4]	Growth, LOED				[8]	L; reduction in growth
			800 mg/kg (whole body)[4]	Growth, NOED				[8]	L; no effect on growth
			2,510 mg/kg (whole body)[4]	Mortality, LOED				[8]	L; reduced survival
			1,650 mg/kg (whole body)[4]	Mortality, NOED				[8]	L; no effect on survival
Mytilus edulis, Mussel			3.7 mg/kg (whole body)[4]	Physiological, LOED				[12]	L; significantly increased oxygen consumption at lowest test concentration at 25 ppt salinity, number of replicates is 12 to 20
Crassostrea virginica, Eastern oyster		2 µg/L 5 µg/L 7 µg/L	2.6 µg/g 6.5 µg/g 4.8 µg/g					[9]	L

Summary of Biological Effects Tissue Concentrations for Silver

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	**Sediment**	**Water**	**Tissue (Sample Type)**	**Effects**	**Log BCF**	**Log BAF**	**BSAF**	**Reference**	**Comments[3]**
Crassostrea virginica, Oyster			38 mg/kg (gill)[4]	Physiological, LOED				[12]	L; Significantly increased oxygen consumption at lowest test concentration at 25 ppt salinity, number of replicates is 12 to 20
			12.4 mg/kg (whole body)[4]	Physiological, LOED				[12]	
Mercenaria mercenaria, Quahog clam			7.6 mg/kg (gill)[4]	Physiological, LOED				[12]	L; significantly increased oxygen consumption at lowest test concentration at 25 ppt salinity, number of replicates is 12 to 20
			0.8 mg/kg (whole body)[4]	Physiological, LOED				[12]	
Mya arenaria, Soft shell clam			10.4 mg/kg (whole body)[4]	Physiological, LOED				[12]	L; significantly increased oxygen consumption at lowest test concentration at 25 ppt salinity, number of replicates is 12 to 20

Summary of Biological Effects Tissue Concentrations for Silver

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	Sediment	Water	Tissue (Sample Type)	Effects	Log BCF	Log BAF	BSAF	Reference	Comments[3]
Homarus americanus, American lobster		0.1-0.5 µg/L	2.3 µg/g					[7]	F
Fishes									
Oncorhyncus mykiss, Rainbow trout		4.3 µg/L	16 µg/g (liver), 4 µg/g (gills)					[11]	L
		7.2 µg/L	13 µg/g (liver) 4 µg/g (gills)						
		9.3 µg/L	20 µg/g (liver) 4.8 µg/g (gills)						
Salmo trutta, Brown trout			1343 Bq/g in food, Day 7: 17.6 Bq/g 269 Bq/g in food, Day 13: 18.5 Bq/g 296 Bq/g in food, Day 20: 21.7 Bq/g						
Salmo trutta, Brown trout			289 Bq/g in food, Day 26: 26.6 Bq/g 273 Bq/g in food, Day 33: 27.4 Bq/g					[10]	L

Summary of Biological Effects Tissue Concentrations for Silver

Species:	**Concentration, Units in[1]:**			**Toxicity:**	**Ability to Accumulate[2]:**			**Source:**	
Taxa	**Sediment**	**Water**	**Tissue (Sample Type)**	**Effects**	**Log BCF**	**Log BAF**	**BSAF**	**Reference**	**Comments[3]**
			623.8 Bq/g (liver) 24.9 Bq/g (kidneys) 25.5 Bq/g (viscera) 5.5 Bq/g (gills) 23.9 Bq/g (digestive tract) 3.2 Bq/g (muscle) 4.4 Bq/g (bone) 2.9 Bq/g (head) 7.2 Bq/g (skin)					[10]	L

[1] Concentration units based on wet weight unless otherwise noted.
[2] BCF = bioconcentration factor, BAF = bioaccumulation factor, BSAF = biota-sediment accumulation factor.
[3] L = laboratory study, spiked sediment, single chemical; F = field study, multiple chemical exposure; other unusual study conditions or observations noted.
[4] This entry was excerpted directly from the Environmental Residue-Effects Database (ERED, www.wes.army.mil/el/ered, U.S. Army Corps of Engineers and U.S. Environmental Protection Agency). The original publication was not reviewed, and the reader is strongly urged to consult the publication to confirm the information presented here.

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Chemical Category: METAL

Chemical Name (Common Synonyms): TRIBUTYLTIN **CASRN:** 688-73-3

Tributyltin compounds, such as those used in antifouling paints, consist of a tin (Sn) atom covalently bonded to three butyl (C_4H_9-) moieties and an associated anion (X). A number of organotin compounds have been used as ingredients in paints, pesticides, and preservatives, including trialkyltins (e.g., bis(tributyltin) oxide (TBTO), bis(tributyltin) sulfide, tributyltin acetate, tributyltin fluoride, tributyltin naphthenate, and tributyltin resinate), triaryltins (e.g., triphenyltin hydroxide), dialkyltins (e.g., (TBTFl) dibutyltin dilaurte, dibutyltin isooctylmercaptonacetate, and dibutyltin maleate), and monooctyltins (e.g., monooctyltin tris isooctyl mercaptoacetate). In aquatic systems, the distribution of TBT species is dependent on pH and salinity. In seawater, the hydrated TBT cation, tributyltin chloride, (TBTCl) bis(tributyltin carbonate), and tributyltin hydroxide are in equilibrium. It is widely accepted that tributyltin toxicity is ascribed to the cation (TBT^{++}) and not to which anion is associated with the biocide in the neutral compound. Researchers have been inconsistent and at times ambiguous in reporting concentrations of organotins and in their use of units in the literature [1]. The following discussion is based on the tributyltin cation (TBT^{++}) and not the various species. The table summarizing biological effects contains data for the tributyltin cation, as well as for tributyltin chloride, tributyltin fluoride, tributyltin oxide, and tin. The table identifies the chemical species measured, if the information was available in the original document reviewed.

Chemical Characteristics

Solubility in Water: <1 to >200 mg/L [2]

Half-Life: Sediments: >20 months [3]

Log K_{ow}: 2.2 - 4.4 [2]

Log K_{oc}: 4.36 - 5.02 [4]

Human Health

Oral RfD: 3 x 10^{-5} mg/kg/day [5]

Confidence: Low, uncertainty factor = 1000

Critical Effect: Immunotoxicity in rats

Oral Slope Factor (Reference): No data [5]

Carcinogenic Classification: No data [5]

Wildlife

Partitioning Factors: Laboratory studies have demonstrated accumulation of TBT in mice and rats, and butyltin residues were detected recently in the blubber of a number of marine mammal species [2]. However, accurate determination of partitioning factors for TBT in wildlife is difficult because this compound is rapidly metabolized once it has been taken up by vertebrates. No partitioning factors were identified for wildlife in the studies reviewed.

Food Chain Multipliers: Biomagnification of butyltins in aquatic systems does not occur, or if it does, only to a minor extent [2].

Aquatic Organisms

Partitioning Factors: Uptake of TBT from sediment to tissues is a complex, non-linear process, and may be better approximated by a power function [6]. Uptake and elimination rates vary considerably by species [4] and the bioavailability of sediment-associated TBT is controlled by a wide range of parameters (eg., chemical speciation, pH, organic content), further moderating uptake rates [2,6]. Attempts to derive BSAFs with wide-ranging utility are also hampered by the fact that tissues burdens in aquatic animals have traditionally been correlated with TBT concentrations in the water column, rather than sediment concentrations.

Once TBT has been incorporated, it tends to partition into multiple tissue compartments. Log BCFs ranged from 2.70 in carp muscle [7] to 2.32-2.74 in whole rainbow trout [8] and 3.26 in muscle tissue, 3.66 in viscera, and 3.41 in whole body residues of sheepshead minnow [9]. Tsuda et al. [7] found that BCFs for carp were highest in kidney, followed by gall bladder, liver, and muscle, in that order. In rainbow trout, BCFs for TBT were highest for peritoneal fat, followed by kidney, liver, and gall bladder. As with wildlife, TBT can be rapidly metabolized by many aquatic organisms. The rapid metabolism of TBT possibly explains why apparent uptake rates in bivalves, whose enzyme systems metabolize butyltins at a much slower rate, are typically higher than in other organisms [2]. Seasonal variability has been reported for the eastern oyster *Crassostrea gigas*. The lowest proportion of TBT in tissues was found in the summer months and associated with either higher biodegradation rates of TBT in the water column or higher biotransformation rates in oyster tissues [10]. In the studies reviewed, Log BCF's for marine bivalves range from 4.09 to 5.10 The highest log BCF identified was for the zebra mussel (*Dreissena polymorpha*) at 5.95 Reported log BCFs for polychaete worms are approximately 3.85.

Food Chain Multipliers: Biomagnification of TBT does not appear to be significant in aquatic systems. Although TBT is accumulated or concentrated to a very high degree in lower trophic level organisms, dietary uptake in higher trophic level organisms appears to be counteracted by biotransformation in the liver [2].

Toxicity/Bioaccumulation Assessment Profile

Tri-substituted organotins (such as tributyltin) are most commonly used as pesticides in commercial and agricultural applications. Tributyltin (TBT) is widely used as a preservative for timber and wood, textiles, paper, and leather [2]. The use of marine paints containing TBT compounds as toxic additives has been found to be very effective in eliminating fouling problems [11]. TBT-based antifouling paints typically contain up to 20 percent by weight of a suitable tributyl or triphenyltin toxicant which is slowly leached into the surrounding water in the immediate vicinity of the hull. The active lifetime of these paints is usually 1-2 years, after which time the vessel must be repainted [12].

The toxicity of organotins increases with progressive introduction of organic groups at the tin atom [2]. Thus, the high toxicity of TBT led to its use as a fungicide, bactericide, and algicide. TBT-containing antifouling paints were recognized as up to 100 times more effective than copper-based antifouling paints [10]. In fact, studies have demonstrated that TBT is deleterious at concentrations far lower than those indicated for other marine pollutants [13]. Consequently TBT has been used in antifouling paints since the early 1960s and gained widespread application on all types of vessels in the 1970s and 1980s [2]. Shell thickening in oysters (*Crassostrea gigas*) has been reported in some areas of France since the outset of its introduction in that country in 1968 [14]. TBT leaching from the ship hulls into the water appeared to be the major pathway of entry into the aquatic environment [2]. Other sources of TBT in the aqueous environment include releases of fugitive paint and paint chips from vessel repair and dry-dock facilities [15]. TBT is likely to partition between suspended particles in the water column and sediments, although up to 99 percent of the TBT may reside in the sediments. TBT-contaminated sediments can represent a substantial source of organotin to aquatic receptors [16]. TBT has a significant lipid solubility and thus a high affinity for bioaccumulation [17]. Some organisms, including fishes, crustaceans, bivalves, and microorganisms, have the ability to bioconcentrate TBT to concentrations which are orders of magnitude higher than the exposure concentration [13].

Acute effects of TBT have been observed in the water column at TBT concentrations of 1 ng/L. This concentration has been associated with reduced reproduction in snails [17]. Histological alterations were observed in young European minnows exposed to an aqueous TBT concentration of 0.8 µg/L [17]. Reduced growth was noted in long-term exposures of rainbow trout yolk sac fry to 0.2 µg/L TBT, resulting in an estimated NOEC of 0.04 µg/L [17]. Immunotoxic effects were observed in the guppy at 0.32 µg/L TBT. In studies of *Acartia tonsa*, reductions in survival in acute tests were observed at 0.029 µg/L; NOECs and LOECs for survival during chronic tests were 0.024 and 0.017 µg/L, respectively [18].

As a group, molluscs are among the most sensitive to TBT. Gastropod snails exhibit anatomical abnormalities referred to as imposex, the superimposition of male characteristics onto a normal female reproductive system [19]. Growth in oyster spat is inhibited at aqueous concentrations of 0.15 µg/L and shell thickening has been reported at 0.2 µg/L. Other effects in oysters include abnormal veliger development, malformation of trocophores, larval anomalies, perturbation in food assimilation, and high mortality [20]. Some freshwater and marine bivalves are able to tolerate short-term TBT exposure due to their ability to isolate themselves from the irritating environment by closing their valves.

TBT concentrations in sediments can be from one to several thousand times higher than concentrations found in the overlying water [21]. Bivalve populations can be completely eliminated when sediment TBT concentrations exceed 0.8 µg/g [17]. No sediment criteria exist for TBT, and ER-L and ER-M ranges are unavailable. However, studies indicate that mollusks respond to sediment concentrations of TBT as low as 10 ng/g, while some copepod crustaceans, echinoderms, polychaetes, tunicates, phytoplankton, and fish respond to sediment TBT concentrations between 10 and 100 ng/g [21].

Summary of Biological Effects Tissue Concentrations for Tributyltin

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	**Sediment**	**Water**	**Tissue (SampleType)**	**Effects**	**Log BCF**	**Log BAF**	**BSAF**	**Reference**	**Comments[3]**
Invertebrates									
Nereis diversicolor, Polychaete	445 ± 83 ng/g dw (n=5)	68.2 ± 40.6 ng/L[3] (n=8)	479 ± 249 ng/g dw[†] (pooled, whole body) (n=5)		3.85			[21]	F
Neanthes arenaceodentata, Polychaete		100 ng/L[3]	6.27µg/g dw TBT[++] (whole body)	Reduced growth and reproduction				[23]	L[5]
		50 ng/L[3]	<3.0 µg/g dw TBT[++] (whole body)	No significant effect on survival, growth, or reproduction				[23]	L[5]
		500 ng/L[4]	16.81 µg/g dw TBT[++] (whole body)	Significant effect on survival				[23]	L[5]
Littorina littorea, Gastropod mollusk (Common winkle)	445±83 ng dw (n = 5)	68.2± 40.6 ng/L (n = 8)	1,009±428 ng/g dw (pooled, soft tissue) (n = 4)		4.17			[21]	F

Summary of Biological Effects Tissue Concentrations for Tributyltin

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	Sediment	Water	Tissue (SampleType)	Effects	Log BCF	Log BAF	BSAF	Reference	Comments[3]
Littorina littorea, Periwinkle			0.1 mg/kg TBTCl (whole body)[8]	Reproduction, NOED				[46]	L and F combined; imposex - intersex response (prostate length, isi); estimated wet weight
Marisa cornuarietis, Freshwater gastropod (Ramshorn snail)		50 ng Sn/L[4]	≈800 µg Sn/g dw (soft tissue)	VDS index constant at stage 1	4.23[4]			[32]	L; equilibrium reached after 3 to 4 months; females accumulate more than males
Marisa cornuarietis, Freshwater gastropod (Ramshorn snail)		200 ng Sn/L[4]	≈1600 µg Sn/g dw (soft tissue)	VDS index increased from stage 1 to stage 3	4.96[4]			[32]	L; equilibrium reached after 3 to 4 months; females accumulate more than males
Ilyanassa obsoleta, Mud snail		20 ng/L[4]	620 ng/g dw[†] (soft tissue)	100% occurrence of imposex in females				[35]	F
Nucella lapillus, Dog welk		18.7 ng/L[4]	♂: 1,475 ng Sn/g dw ♀: 1,864 ng Sn/g dw (soft tissue)	Imposex	♂: 77,900 ♀: 99,700			[36]	F

Summary of Biological Effects Tissue Concentrations for Tributyltin

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	**Sediment**	**Water**	**Tissue (SampleType)**	**Effects**	**Log BCF**	**Log BAF**	**BSAF**	**Reference**	**Comments[3]**
		107 ng/L[4]	♂: 2,436 ng Sn/g dw ♀: 3,498 ng Sn/g dw (soft tissue)	Sterilization (♀)	♂: 22,800 ♀: 32,700			[36]	F
			0.1 mg/kg (whole body)	Induction of imposex				[37]	L
			0.1 µg Sn/g dw (soft tissue)	Normal breeding occurs				[38]	L
		0.25 ng Sn/L[4]	0.025 µg Sn/g dw (soft tissue)	Stage 1 (infolding of pallian cavity floor) Imposex				[38]	L
		1-2 ng Sn/L[4]	0.238 - 0.239 µg Sn/g dw (soft tissue)	Relative Penis Size (RPS) = 48%; Vas Deferens Sequence (VDS) = Stage 4.4 (breeding not impaired)				[38]	L
		3-5 ng Sn/L[4]	0.602 - 0.569 µg Sn/g dw (soft tissue)	RPS = 96.6%; VDS = Stage 5.1 (breeding impaired)				[38]	L
		20 ng Sn/L[4]	1.464 - 1.696 µg Sn/g dw (soft tissue)	RPS = 109%; VDS = Stage 5.0 (breeding impaired)				[38]	L

Summary of Biological Effects Tissue Concentrations for Tributyltin

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	Sediment	Water	Tissue (SampleType)	Effects	Log BCF	Log BAF	BSAF	Reference	Comments[3]
Nucella lapillus, Dog welk		100 ng Sn/L[4]	2.520 - 3.164 µg Sn/g dw (soft tissue)	RPS = 90.4%; VDS = Stage 5.0 (breeding impaired)				[38]	L
		<0.5 ng Sn/L[4]	0.039 - 0.092 µg Sn/g dw (soft tissue)	RPS = 3.7%; VDS = Stage 3.2 (breeding not impaired)				[38]	F
Nucella lapillus, Dog whelk			2 mg/kg TBT ion and DBT ion (whole body)[8]	Development, NA				[36]	L and F combined; paint on shell; female penis length increased; body burden as tin not TBT or DBT
			1.97 mg/kg TBT ion and DBT ion (whole body)[8]	Development, NOED				[36]	L and F combined; paint on shell; no effect in male penis length; body burden as tin not TBT or DBT

Summary of Biological Effects Tissue Concentrations for Tributyltin

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	Sediment	Water	Tissue (SampleType)	Effects	Log BCF	Log BAF	BSAF	Reference	Comments[3]
			0.0413 mg/kg TBTCl (whole body)[8]	Development, LOED				[36]	L and F combined; relative penis size significantly decreased (female/male penis length); body burden as tin not TBT or DBT
			1.17 mg/kg TBTCl (whole body)[8]	Reproduction, LOED				[36]	L and F combined; sterility in females; body burden as tin not TBT or DBT
			0.733 mg/kg TBTCl (whole body)[8]	Reproduction, LOED				[36]	L and F combined; sterility in females; body burden as tin not TBT or DBT
			1.82 mg/kg TBTCl (whole body)[8]	Development, NA				[36]	L and F combined; paint on shell; no effect in male penis length; body burden as tin not TBT or DBT

Summary of Biological Effects Tissue Concentrations for Tributyltin

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	**Sediment**	**Water**	**Tissue (SampleType)**	**Effects**	**Log BCF**	**Log BAF**	**BSAF**	**Reference**	**Comments[3]**
			1.33 mg/kg TBTCl (whole body)[8]	Development, NA				[36]	L and F combined; paint on shell; female penis length increased; body burden as tin not TBT or DBT
			0.909 mg/kg TBTCl (whole body)[8]	Development, NOED				[36]	L and F combined; paint on shell; no effect in male penis length; body burden as tin not TBT or DBT
			0.0666 mg/kg TBTCl (whole body)[8]	Development, NOED				[36]	L and F combined; no increase in penis length; equals 0.5 ug/g TBT+DBT; body burden as tin not TBT or DBT
Thais clavigera, Whelk			0.013 mg/kg TBTCl (whole body)[8]	Reproduction, LOED				[50]	L; degradation products present
Mytilus edulis, Blue mussel			0.019 - 0.047 µg/g† (pooled, soft tissue)	Reduced growth				[24]	F; 82-day exposure

Summary of Biological Effects Tissue Concentrations for Tributyltin

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	Sediment	Water	Tissue (SampleType)	Effects	Log BCF	Log BAF	BSAF	Reference	Comments[3]
			2.0 µg/g dw† (soft tissue)	Threshold for reduced scope for growth				[25]	F; other contaminants present
			4 µg/g dw† (soft tissue)	Severe inhibition of growth, significantly reduced feeding rate, threshold concentration				[26]	L[5]
			1.5 mg/kg† (soft tissue)	Threshold for growth rate inhibition				[27]	F; 84-day exposure
			2.20 mg/kg TBTO (soft tissue)	Reduced growth in spat				[28]	L; 45-day exposure
		200 ng/L[4]	1.5 µg/g† (whole body)	Reduced growth				[29]	F[6]
	0.08 µg/g dw	15 ±8 ng/L[4]	0.64 µg/g † (soft tissue)					[30]	F
Mytilus edulis, Blue mussel	0.03 µg/g dw	33 ±27 ng/L[4]	0.75 µg/g† (soft tissue)					[30]	F
	0.02 µg/g dw	21 ±8 ng/L[4]	0.34 µg/g† (soft tissue)					[30]	F
	0.10 µg/g dw	13 ng/L[4]	0.16 µg/g† (soft tissue)					[30]	F
	0.15 µg/g dw	22 ±12 ng/L[4]	0.66 µg/g† (soft tissue)					[30]	F
	0.04 µg/g dw	17 ±12 ng/L[4]	0.44 µg/g† (soft tissue)					[30]	F

Summary of Biological Effects Tissue Concentrations for Tributyltin

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	Sediment	Water	Tissue (SampleType)	Effects	Log BCF	Log BAF	BSAF	Reference	Comments[3]
	0.08 µg/g dw	13 ng/L[4]	0.30 µg/g† (soft tissue)					[30]	F
	0.05 µg/g dw	8 ng/L[4]	0.15 µg/g† (soft tissue)					[30]	F
	0.04 µg/g dw	35 ±17 ng/L[4]	1.01 µg/g† (soft tissue)					[30]	F
	0.11 µg/g dw	17 ±9 ng/L[4]	0.61 µg/g† (soft tissue)					[30]	F
	0.07 µg/g dw	22 ±14 ng/L[4]	0.46 µg/g† (soft tissue)					[30]	F
	0.04 µg/g dw	8 ±2 ng/L[4]	0.29 µg/g† (soft tissue)					[30]	F
	0.36 µg/g dw	45 ±17 ng/L[4]	0.98 µg/g† (soft tissue)					[30]	F
	0.15 µg/g dw	31 ±18 ng/L[4]	1.04 µg/g† (soft tissue)					[30]	F
	0.31 µg/g dw	23 ±18 ng/L[4]	0.38 µg/g† (soft tissue)					[30]	F
Mytilus edulis, Blue mussel	0.10 µg/g dw	11 ±4 ng/L[4]	0.29 µg/g† (soft tissue)					[30]	F
	0.07 µg/g dw	26 ±9 ng/L[4]	0.75 µg/g† (soft tissue)					[30]	F
	0.05 µg/g dw	22 ±15 ng/L[4]	0.47 µg/g† (soft tissue)					[30]	F
	0.27 µg/g dw	13 ±5 ng/L[4]	0.27 µg/g† (soft tissue)					[30]	F
	0.07 µg/g dw	8 ng/L[4]	0.17 µg/g† (soft tissue)					[30]	F

Summary of Biological Effects Tissue Concentrations for Tributyltin

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	Sediment	Water	Tissue (SampleType)	Effects	Log BCF	Log BAF	BSAF	Reference	Comments[3]
	0.05 µg/g dw	26 ±12 ng/L[4]	0.45 µg/g† (soft tissue)					[30]	F
	0.02 µg/g dw	18 ±13 ng/L[4]	0.41 µg/g† (soft tissue)					[30]	F
	0.02 µg/g dw	15 ±12 ng/L[4]	0.19 µg/g† (soft tissue)					[30]	F
	0.04 µg/g dw	8 ±2 ng/L[4]	0.12 µg/g† (soft tissue)					[30]	F
	<0.01 µg/g dw	11 ng/L[4]	0.30 µg/g† (soft tissue)					[30]	F
	0.01 µg/g dw	23 ±23 ng/L[4]	0.35 µg/g† (soft tissue)					[30]	F
	0.02 µg/g dw	3 ±2 ng/L[4]	0.07 µg/g† (soft tissue)					[30]	F
	0.01 µg/g dw	16 ng/L[4]	0.17 µg/g† (soft tissue)					[30]	F
	0.01 µg/g dw	6 ±5 ng/L[4]	0.11 µg/g† (soft tissue)					[30]	F
Mytilus edulis, Blue mussel	0.05 µg/g dw	6 ±5 ng/L[4]	0.11 µg/g† (soft tissue)					[30]	F
	<0.01 µg/g dw	2 ng/L[4]	0.05 µg/g† (soft tissue)					[30]	F
	0.66 µg/g dw	38 ±21 ng/L[4]	1.06 µg/g† (soft tissue)					[30]	F
	0.26 µg/g dw	366 ±29 ng/L[4]	0.82 µg/g† (soft tissue)					[30]	F
	0.15 µg/g dw	76 ±43 ng/L[4]	0.32 µg/g† (soft tissue)					[30]	F

Summary of Biological Effects Tissue Concentrations for Tributyltin

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	Sediment	Water	Tissue (SampleType)	Effects	Log BCF	Log BAF	BSAF	Reference	Comments[3]
	0.53 µg/g dw	25 ng/L[4]	0.35 µg/g† (soft tissue)					[30]	F
	0.08 µg/g dw	38 ±33 ng/L[4]	0.60 µg/g† (soft tissue)					[30]	F
	0.19 µg/g dw	13 ±4 ng/L[4]	0.41 µg/g† (soft tissue)					[30]	F
	0.17 µg/g dw	13 ±5 ng/L[4]	0.20 µg/g† (soft tissue)					[30]	F
	0.07 µg/g dw	8 ±3 ng/L[4]	0.11 µg/g† (soft tissue)					[30]	F
	0.06 µg/g dw	15 ±6 ng/L[4]	0.93 µg/g† (soft tissue)					[30]	F
	0.03 µg/g dw	11 ±6 ng/L[4]	0.58 µg/g† (soft tissue)					[30]	F
	0.04 µg/g dw	5 ±2 ng/L[4]	0.10 µg/g† (soft tissue)					[30]	F
	0.05 µg/g dw	12 ±10 ng/L[4]	0.33 µg/g† (soft tissue)					[30]	F
Mytilus edulis, Blue mussel	0.02 µg/g dw	7 ±6 ng/L[4]	0.23 µg/g† (soft tissue)					[30]	F
	0.03 µg/g dw	6 ±2 ng/L[4]	0.09 µg/g† (soft tissue)					[30]	F
	0.02 µg/g dw	6 ±4 ng/L[4]	0.07 µg/g† (soft tissue)					[30]	F
	4.6 µg/g dw	93 ±45 ng/L[4]	2.57 µg/g† (soft tissue)					[30]	F
	10.8 µg/g dw	1090 ±1850 ng/L[4]	3.22 µg/g† (soft tissue)					[30]	F

Summary of Biological Effects Tissue Concentrations for Tributyltin

Species:	**Concentration, Units in[1]:**			**Toxicity:**	**Ability to Accumulate[2]:**			**Source:**	
Taxa	**Sediment**	**Water**	**Tissue (SampleType)**	**Effects**	**Log BCF**	**Log BAF**	**BSAF**	**Reference**	**Comments[3]**
	0.23 µg/g dw	25 ±7 ng/L[4]	0.81 µg/g† (soft tissue)					[30]	F
Mytilus edulis, Mussel			2.58 mg/kg TBTCl (whole body)[8]	Physiological, LOED				[53]	L; significant increase in anoxic heat dissipation (j/h/g) at test concentration
			2.58 mg/kg TBTCl (whole body)[8]	Physiological, NA				[53]	L; 35% reduction in anoxia tolerance as percent of controls

Summary of Biological Effects Tissue Concentrations for Tributyltin

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	Sediment	Water	Tissue (SampleType)	Effects	Log BCF	Log BAF	BSAF	Reference	Comments[3]
Mytilus edulis, Mussel			0.556 mg/kg TBTCl (whole body)[8]	Physiological, ED5				[26]	L; 50% increase in respiration as compared to controls calculated from formula in text; exposure concentrations variable because of rapid uptake by test organisms so not measured or reported
			1.8 mg/kg TBTCl (whole body)[8]	Physiological, ED5				[26]	L; 50%reduction in clearance rate (feeding rate) as compared to controls; exposure concentrations variable because of rapid uptake by test organisms so not measured or reported

Summary of Biological Effects Tissue Concentrations for Tributyltin

Species:	**Concentration, Units in[1]:**			**Toxicity:**	**Ability to Accumulate[2]:**			**Source:**	
Taxa	**Sediment**	**Water**	**Tissue (SampleType)**	**Effects**	**Log BCF**	**Log BAF**	**BSAF**	**Reference**	**Comments[3]**
			1.08 mg/kg TBTCl (whole body)[8]	Physiological, LOED				[26]	L; significant decrease in clearance rate (feeding); exposure concentrations variable because of rapid uptake by test organisms so not measured or reported
			1.08 mg/kg TBTCl (whole body)[8]	Physiological, LOED				[26]	L; significant decrease in scope for growth; exposure concentrations variable because of rapid uptake by test organisms so not measured or reported
			0.8 mg/kg TBTCl (whole body)[8]	Physiological, NOED				[26]	L; no significant decrease in clearance rate (feeding); exposure concentrations variable because of rapid uptake by test organisms so not measured or reported

Summary of Biological Effects Tissue Concentrations for Tributyltin

Species: Taxa	Concentration, Units in[1]: Sediment	Water	Tissue (SampleType)	Toxicity: Effects	Ability to Accumulate[2]: Log BCF	Log BAF	BSAF	Source: Reference	Comments[3]
			0.8 mg/kg TBTCl (whole body)[8]	Physiological, NOED				[26]	L; no significant decrease in scope for growth; exposure concentrations variable because of rapid uptake by test organisms so not measured or reported
			2 mg/kg TBTCl (whole body)[8]	Physiological, NOED				[26]	L; no significant change in food absorption eficiency; exposure concentrations variable because of rapid uptake by test organisms so not measured or reported
Arca zebra, Mussel			1.11 µg/g dw[†] (soft tissue)	35 % reduction in scope for growth				[25]	F

Summary of Biological Effects Tissue Concentrations for Tributyltin

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	**Sediment**	**Water**	**Tissue (SampleType)**	**Effects**	**Log BCF**	**Log BAF**	**BSAF**	**Reference**	**Comments[3]**
Dreissena polymorpha, Zebra mussel		70 ng/L[4] ($\bar{x}$; n = 2)	73.13 µg/g dw TBT cation (soft tissue) ($\bar{x}$; n = 2)	Reduction in growth after 105 days exposure and transfer to clean site	5.95			[31]	F; steady-state reached after 35 days; 105-day uptake and depuration phases
Dreissena polymorpha, Zebra mussel			12.7 mg/kg TBTCl (whole body)[8]	Growth, NOED				[31]	F; concentration of TBT in tissues and water; field study at marina with exposure to TBT and DBT likely; mean values provided; no significant impact on growth
			1.66 mg/kg TBTCl (whole body)[8]	Growth, NOED				[31]	F; concentration of DBT in tissues and TBT in water; field study at marina with exposure to TBT and DBT likely; mean values provided; no significant impact on growth

Summary of Biological Effects Tissue Concentrations for Tributyltin

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	**Sediment**	**Water**	**Tissue (SampleType)**	**Effects**	**Log BCF**	**Log BAF**	**BSAF**	**Reference**	**Comments[3]**
Crassostrea gigas, Pacific oyster			0.75 mg/kg† (whole body)	Reduction in condition factor and growth				[33]	F
			0.27 µg/g† (soft tissue)	Reduced tissue growth; shell thickening				[34]	F
			2.38 mg/kg TBTO (soft tissue)	Reduced growth in spat				[28]	L; 45-day exposure
	0.08 µg/g dw	15 ±8 ng/L[4]	1.61 µg/g† (soft tissue)	Shell thickness index = 4.39; $\bar{x}$ tissue weight = 1.29				[30]	F
	0.03 µg/g dw	33 ±27 ng/L[4]	1.64 µg/g† (soft tissue)	Shell thickness index = 4.85; $\bar{x}$ tissue weight = 0.70				[30]	F
	0.02 µg/g dw	21 ±8 ng/L[4]	0.62 µg/g† (soft tissue)	Shell thickness index = 6.85; $\bar{x}$ tissue weight = 2.59				[30]	F
	0.10 µg/g dw	13 ng/L[4]	0.36 µg/g† (soft tissue)	Shell thickness index = 9.82; $\bar{x}$ tissue weight = 5.66				[30]	F

Summary of Biological Effects Tissue Concentrations for Tributyltin

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	Sediment	Water	Tissue (SampleType)	Effects	Log BCF	Log BAF	BSAF	Reference	Comments[3]
Crassostrea gigas, Pacific oyster	0.15 µg/g dw	22 ±12 ng/L[4]	1.20 µg/g† (soft tissue)	Shell thickness index = 4.78; $\bar{x}$ tissue weight = 1.26				[30]	F
	0.04 µg/g dw	17 ±12 ng/L[4]	1.46 µg/g† (soft tissue)	Shell thickness index = 4.67; $\bar{x}$ tissue weight = 0.67				[30]	F
	0.08 µg/g dw	13 ng/L[4]	0.44 µg/g† (soft tissue)	Shell thickness index = 8.10; $\bar{x}$ tissue weight = 2.62				[30]	F
	0.05 µg/g dw	8 ng/L[4]	0.33 µg/g† (soft tissue)	Shell thickness index = 10.2; $\bar{x}$ tissue weight = 2.84				[30]	F
	0.04 µg/g dw	35 ±17 ng/L[4]	1.49 µg/g† (soft tissue)	Shell thickness index = 5.14; $\bar{x}$ tissue weight = 0.97				[30]	F
	0.11 µg/g dw	17 ±9 ng/L[4]	1.73 µg/g† (soft tissue)	Shell thickness index = 5.29; $\bar{x}$ tissue weight = 0.84				[30]	F

Summary of Biological Effects Tissue Concentrations for Tributyltin

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	**Sediment**	**Water**	**Tissue (SampleType)**	**Effects**	**Log BCF**	**Log BAF**	**BSAF**	**Reference**	**Comments[3]**
	0.07 µg/g dw	22 ±14 ng/L[4]	0.61 µg/g † (soft tissue)	Shell thickness index = 8.07; $\bar{x}$ tissue weight = 2.23				[30]	F
	0.04 µg/g dw	8 ±2 ng/L[4]	0.38 µg/g† (soft tissue)	Shell thickness index = 9.83; $\bar{x}$ tissue weight = 2.90				[30]	F
	0.36 µg/g dw	45 ±17 ng/L[4]	1.24 µg/g† (soft tissue)	Shell thickness index = 4.95; $\bar{x}$ tissue weight = 0.77				[30]	F
	0.15 µg/g dw	31 ±18 ng/L[4]	1.57 µg/g† (soft tissue)	Shell thickness index = 5.04; $\bar{x}$ tissue weight = 0.49				[30]	F
Crassostrea gigas, Pacific oyster	0.31 µg/g dw	23 ±18 ng/L[4]	0.50	e weight = 2.39				[30]	F
	0.10 µg/g dw	11 ±4 ng/L[4]	0.45 µg/g† (soft tissue)	Shell thickness index = 10.2; $\bar{x}$ tissue weight = 2.77				[30]	F

Summary of Biological Effects Tissue Concentrations for Tributyltin

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	Sediment	Water	Tissue (SampleType)	Effects	Log BCF	Log BAF	BSAF	Reference	Comments[3]
	0.07 µg/g dw	26 ±9 ng/L[4]	0.74 µg/g[†] (soft tissue)	Shell thickness index = 5.06; $\bar{x}$ tissue weight = 1.24				[30]	F
	0.05 µg/g dw	22 ±15 ng/L[4]	1.26 µg/g[†] (soft tissue)	Shell thickness index = 5.24; $\bar{x}$ tissue weight = 1.24				[30]	F
	0.27 µg/g dw	13 ±5 ng/L[4]	0.34 µg/g[†] (soft tissue)	Shell thickness index = 9.83; $\bar{x}$ tissue weight = 2.44				[30]	F
	0.07 µg/g dw	8 ng/L[4]	0.31 µg/g[†] (soft tissue)	Shell thickness index = not sampled; $\bar{x}$ tissue weight = not sampled				[30]	F
	0.05 µg/g dw	26 ±12 ng/L[4]	0.80 µg/g[†] (soft tissue)	Shell thickness index = 5.39; $\bar{x}$ tissue weight = 1.18				[30]	F
	0.02 µg/g dw	18 ±13 ng/L[4]	0.98 µg/g[†] (soft tissue)	Shell thickness index = 5.29; $\bar{x}$ tissue weight = 1.14				[30]	F

Summary of Biological Effects Tissue Concentrations for Tributyltin

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	**Sediment**	**Water**	**Tissue (SampleType)**	**Effects**	**Log BCF**	**Log BAF**	**BSAF**	**Reference**	**Comments[3]**
	0.02 µg/g dw	15 ±12 ng/L[4]	0.24 µg/g† (soft tissue)	Shell thickness index = 9.00; x̄ tissue weight = 2.50				[30]	F
Crassostrea gigas, Pacific oyster	0.04 µg/g dw	8 ±2 ng/L[4]	0.27 µg/g† (soft tissue)	Shell thickness index = 8.62; x̄ tissue weight = 5.92				[30]	F
	<0.01 µg/g dw	11 ng/L[4]	0.37 µg/g† (soft tissue)	Shell thickness index = 9.63; x̄ tissue weight = 1.39				[30]	F
	0.01 µg/g dw	23 ±23 ng/L[4]	0.56 µg/g† (soft tissue)	Shell thickness index = 6.48; x̄ tissue weight = 1.44				[30]	F
	0.02 µg/g dw	10 ± ng/L[4]	0.17 µg/g† (soft tissue)	Shell thickness index = not sampled; x̄ tissue weight = not sampled				[30]	F
	0.02 µg/g dw	3 ±2 ng/L[4]	0.11 µg/g† (soft tissue)	Shell thickness index = 19.8; x̄ tissue weight = 5.96				[30]	F

Summary of Biological Effects Tissue Concentrations for Tributyltin

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	Sediment	Water	Tissue (SampleType)	Effects	Log BCF	Log BAF	BSAF	Reference	Comments[3]
	0.01 µg/g dw	16 ng/L[4]	0.18 µg/g† (soft tissue)	Shell thickness index = 12.4; $\bar{x}$ tissue weight = 2.72				[30]	F
	0.01 µg/g dw	6 ±5 ng/L[4]	0.28 µg/g† (soft tissue)	Shell thickness index = 9.64; $\bar{x}$ tissue weight = 2.06				[30]	F
	0.05 µg/g dw	6 ±5 ng/L[4]	0.08 µg/g† (soft tissue)	Shell thickness index = 23.3; $\bar{x}$ tissue weight = 4.11				[30]	F
	<0.01 µg/g dw	2 ng/L[4]	0.08 µg/g† (soft tissue)	Shell thickness index = 21.0; $\bar{x}$ tissue weight = 9.28				[30]	F
Crassostrea gigas, Pacific oyster	0.66 µg/g dw	38 ±21 ng/L[4]	2.26 µg/g† (soft tissue)	Shell thickness index = 4.95; $\bar{x}$ tissue weight = 1.00				[30]	F
	0.26 µg/g dw	366 ±29 ng/L[4]	2.18 µg/g† (soft tissue)	Shell thickness index = 3.96; $\bar{x}$ tissue weight = 0.97				[30]	F

Summary of Biological Effects Tissue Concentrations for Tributyltin

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	Sediment	Water	Tissue (SampleType)	Effects	Log BCF	Log BAF	BSAF	Reference	Comments[3]
	0.15 µg/g dw	76 ±43 ng/L[4]	1.34 µg/g† (soft tissue)	Shell thickness index = 6.87; $\bar{x}$ tissue weight = 2.53				[30]	F
	0.53 µg/g dw	25 ng/L[4]	0.65 µg/g† (soft tissue)	Shell thickness index = 14.9; $\bar{x}$ tissue weight = 3.65				[30]	F
	0.08 µg/g dw	38 ±33 ng/L[4]	0.88 µg/g† (soft tisue)	Shell thickness index = 10.6; $\bar{x}$ tissue weight = 1.56				[30]	F
	0.19 µg/g dw	13 ±4 ng/L[4]	1.35 µg/g† (soft tisue)	Shell thickness index = 5.98; $\bar{x}$ tissue weight = 0.89				[30]	F
	0.17 µg/g dw	13 ±5 ng/L[4]	0.50 µg/g† (soft tisue)	Shell thickness index = 12.5; $\bar{x}$ tissue weight = 3.19				[30]	F
	0.07 µg/g dw	8 ±3 ng/L[4]	0.26 µg/g† (soft tissue)	Shell thickness index = 14.7; $\bar{x}$ tissue weight = 7.09				[30]	F

Summary of Biological Effects Tissue Concentrations for Tributyltin

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	Sediment	Water	Tissue (SampleType)	Effects	Log BCF	Log BAF	BSAF	Reference	Comments[3]
	0.06 µg/g dw	15 ±6 ng/L[4]	1.39 µg/ [†] (soft tissue)	Shell thickness index = 7.56; x̄ tissue weight = 1.77				[30]	F
	0.03 µg/g dw	11 ±6 ng/L[4]	1.44 µg/g[†] (soft tissue)	Shell thickness index = 5.41; x̄ tissue weight = 1.32				[30]	F
Crassostrea gigas, Pacific oyster	0.04 µg/g dw	5 ±2 ng/L[4]	0.21 µg/g[†] (soft tissue)	Shell thickness index = 13.1; x̄ tissue weight = 8.07				[30]	F
	0.05 µg/g dw	12 ±10 ng/L[4]	0.30 µg/g[†] (soft tissue)	Shell thickness index =10.6; x̄ tissue weight = 1.56				[30]	F
	0.02 µg/g dw	7 ±6 ng/L[4]	0.49 µg/g[†] (soft tissue)	Shell thickness index = 12.4; x̄ tissue weight = 1.24				[30]	F
	0.03 µg/g dw	6 ±2 ng/L[4]	0.25 µg/g[†] (soft tissue)	Shell thickness index = 25.7; x̄ tissue weight = 5.22				[30]	F

Summary of Biological Effects Tissue Concentrations for Tributyltin

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	Sediment	Water	Tissue (SampleType)	Effects	Log BCF	Log BAF	BSAF	Reference	Comments[3]
	0.02 µg/g dw	6 ±4 ng/L[4]	0.13 µg/g† (soft tissue)	Shell thickness index = 189; $\bar{x}$ tissue weight = 6.23				[30]	F
	4.6 µg/g dw	93 ±45 ng/L[4]	6.35 µg/g† (soft tissue)	Shell thickness index = 3.21; $\bar{x}$ tissue weight = 0.37				[30]	F
	10.8 µg/g dw	1,090 ±1,850 ng/L[4]	3.65 µg/g† (soft tissue)	Shell thickness index = 8.06; $\bar{x}$ tissue weight = 0.12				[30]	F
	1.1 µg/g dw	82 ±9 ng/L[4]	5.60 µg/g† (soft tissue)	Shell thickness index = 4.34; $\bar{x}$ tissue weight = 0.95				[30]	F
	0.23 µg/g dw	25 ±7 ng/L[4]	1.28 µg/g† (soft tissue)	Shell thickness index = 6.73; $\bar{x}$ tissue weight = 1.24				[30]	F
Crassostrea gigas, Oyster			22 mg/kg TBTFl (whole body)[8]	Morphology, ED100				[45]	L and F combined; malformation of shells

Summary of Biological Effects Tissue Concentrations for Tributyltin

Species: Taxa	**Concentration, Units in[1]:** Sediment	Water	Tissue (SampleType)	**Toxicity:** Effects	**Ability to Accumulate[2]:** Log BCF	Log BAF	BSAF	**Source:** Reference	Comments[3]
			5 mg/kg TBTFl (whole body)[8]	Morphology, LOED				[45]	L and F combined; malformation of shells
			22 mg/kg TBTFl (whole body)[8]	Mortality, ED100				[45]	Land F combined; 100% mortality after 170 days
			5 mg/kg TBTFl (whole body)[8]	Mortality, NA				[45]	L and F combined; 30% mortality after 110 days
Crassostrea gigas, Oyster			0.75 mg/kg TBTCl (whole body)[8]	Growth, NA				[47]	F; 44% reduction in condition factor and growth
Crassostrea gigas, Oyster			3.7 mg/kg TBTO (whole body)[8]	Growth, ED100				[52]	L; no growth (weight increase or length) in high test concentration

Summary of Biological Effects Tissue Concentrations for Tributyltin

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	Sediment	Water	Tissue (SampleType)	Effects	Log BCF	Log BAF	BSAF	Reference	Comments[3]
			4.89 mg/kg TBTO (whole body)[8]	Growth, ED100				[52]	L; no growth (length) in high test concentration (with sediment present at 30 mg/L)
			1.71 mg/kg TBTO (whole body)[8]	Growth, ED100				[52]	L; no growth (length) in low test concentration
			4.89 mg/kg TBTO (whole body)[8]	Growth, NA				[52]	L; 92% reduction in growth (weight increase) in high test concentration relative to control
			1.71 mg/kg TBTO (whole body)[8]	Growth, NA				[52]	L; 70% reduction in growth (weight increase) in low test concentration relative to control

Summary of Biological Effects Tissue Concentrations for Tributyltin

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	**Sediment**	**Water**	**Tissue (SampleType)**	**Effects**	**Log BCF**	**Log BAF**	**BSAF**	**Reference**	**Comments[3]**
			1.3 mg/kg TBTO (whole body)[8]	Growth, NA				[52]	L; 47% reduction in growth (weight increase) in low test concentration with 30 mg/L sediment present relative to control
			1.71 mg/kg TBTO (whole body)[8]	Growth, NA				[52]	L; 70% reduction in growth (length) in low test concentration with 30 mg/L sediment present relative to control
			1.71 mg/kg TBTO (whole body)[8]	Mortality, NOED				[52]	L; no mortality in low test concentration (both with and without sediment present)
			3.7 mg/kg TBTO (whole body)[8]	Physiological, NA				[52]	L; 63% reduction in condition index relative to control in high test concentration

Summary of Biological Effects Tissue Concentrations for Tributyltin

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	Sediment	Water	Tissue (SampleType)	Effects	Log BCF	Log BAF	BSAF	Reference	Comments[3]
			4.89 mg/kg TBTO(whole body)[8]	Physiological, NA				[52]	L; 42% reduction in condition index relative to control in high test concentration with 30 mg/L sediment present
			1.71 mg/kg TBTO(whole body)[8]	Physiological, NA				[52]	L; 18% reduction in condition index relative to control in low test concentration
			1.3 mg/kg TBTO (whole body)[8]	Physiological, NA				[52]	L; 11% reduction in condition index relative to control in low test concentration with 30 mg/L sediment present
Ostrea edulis, Oyster			0.53 mg/kg TBTO (soft tissue)	No effect on growth in spat				[28]	L; 45-day exposure
Ostrea edulis, Oyster			0.75 mg/kg TBTO (soft tissue)	Reduced growth in spat				[28]	L; 45-day exposure

Summary of Biological Effects Tissue Concentrations for Tributyltin

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	Sediment	Water	Tissue (SampleType)	Effects	Log BCF	Log BAF	BSAF	Reference	Comments[3]
Saccostria commercialis, Sydney rock oyster			0.012 mg/kg TBTCl (whole body)[8]	Morphology, LOED				[51]	F
			0.04 mg/kg TBTCl (whole body)[8]	Morphology, LOED				[51]	F
Saccostria commercialis, Sydney rock oyster			110 ng Sn/g^{-1} (soft tissues)	Shell deformations; shell curl				[39]	F
			107 ng Sn/g^{-1} (soft tissues)	Shell deformations; shell curl				[39]	F
			86 ng Sn/g^{-1} (soft tissues)	Shell deformations; shell curl				[39]	F
			98 ng Sn/g^{-1} (soft tissues)	Shell deformations; shell curl				[39]	F
			87 ng Sn/g^{-1} (soft tissues)	Shell deformations; shell curl				[39]	F
			350 ng Sn/g^{-1} (soft tissues)	Shell deformations; shell curl				[39]	F
Cerastoderma edule, Cockle	445 ± 83 ng/g dw (n=5)	68.2 ± 40.6 ng/L[4] (n=8)	4,128 ng/g, dw[†] (pooled, soft tissue) (n=1)		4.78			[21]	F

Summary of Biological Effects Tissue Concentrations for Tributyltin

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	**Sediment**	**Water**	**Tissue (SampleType)**	**Effects**	**Log BCF**	**Log BAF**	**BSAF**	**Reference**	**Comments[3]**
Macoma balthica, Clam	445 ± 83 ng/g dw (n=5)	68.2 ± 40.6 ng/L[4] (n=8)	4,587 ± 2,793 ng/g dw† (pooled, soft tissue) (n=4)		4.83			[21]	F
Merceneria mercenaria, Hard shell clam	445 ± 83 ng/g dw (n=5)	68.2 ± 40.6 ng/L[4] (n=8)	8,649 ng/g dw† (pooled, soft tissue) (n=1)		5.10			[21]	F
Venerupis decussata, Clam			2.64 mg/kg TBTO (soft tissue)	Reduced growth in spat				[28]	L; 45-day exposure
Venerupis semidecussata, Clam			1.48 mg/kg TBTO (soft tissue)	No effect on spat growth				[28]	L; 45-day exposure
Mya arenaria, Soft shell clam	445 ± 83 ng/g dw (n = 5)	68.2 ± 40.6 ng/L[4] (n = 8)	36,807 ± 9,800 ng/g dw† (pooled, soft tissue) (n = 4)		5.73			[21]	F
Petricola pholadiformis, American piddock	445 ± 83 ng/g dw (n = 5)	68.2 ± 40.6 ng/L[4] (n = 8)	838 ± 108 ng/g dw† (pooled, soft tissue) (n = 2)		4.09			[21]	F

Summary of Biological Effects Tissue Concentrations for Tributyltin

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	Sediment	Water	Tissue (SampleType)	Effects	Log BCF	Log BAF	BSAF	Reference	Comments[3]
Scrobicularia plana, Clam	445 ± 83 ng/g dw (n = 5)	68.2 ± 40.6 ng/L[4] (n=8)	3,375 ± 232 ng/g dw† (pooled, soft tissue) (n = 4)		4.69			[21]	F
Scorbicularia plana, Clam	0.03 µg/g dw	4.0-17.5 ng/L[4]	0.635 µg Sn/g dw (soft tissues)					[40]	F
	µg/g dw	7.0-10.8 ng/L[4]	0.263 µg Sn/g dw (soft tissues)					[40]	F
	0.03 µg/g dw (n=3)	15.2-51.6 ng/L[4]	2.04 µg Sn/g dw (soft tissues)					[40]	F
	0.039 µg/g dw (n=3)	17.2-51.3 ng/L[4]	1.12 µg Sn/g dw (soft tissues)					[40]	F
	0.22 µg/g dw (n=3)	0.6-213 ng/L[4]	2.05 µg Sn/g dw (soft tissues)					[40]	F
Scorbicularia plana, Clam	0.12 µg/g dw (n=6)	10.9-33.2 ng/L[4]	1.69 µg Sn/g dw (soft tissues)					[40]	F
	0.11 µg/g dw	7.4 ng/L[4]	1.51 µg Sn/g dw (soft tissues)					[40]	F
	0.02 µg/g dw	2.7 ng/L[4]	0.62 µg Sn/g dw (soft tissues)					[40]	F
	0.126 µg/g dw	230 ng/L[4]	5.09 µg Sn/g dw (soft tissues)					[40]	F
			2.91 mg/kg TBTO (soft tissue)	Reduced growth in spat				[28]	L; 45-day exposure

Summary of Biological Effects Tissue Concentrations for Tributyltin

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	Sediment	Water	Tissue (SampleType)	Effects	Log BCF	Log BAF	BSAF	Reference	Comments[3]
Hyalella azteca, Amphipod		4.8 nM[3]	110 nmol/g dw (whole body)	4 week LC50				[22]	L; 1 week to reach equilibrium in tissues
Fishes									
Oncorhynchus mykiss, Rainbow trout		1.41 µg Sn/L		96-hr LC50	406			[8]	L
		0.42 µg Sn/L	1.21 mg Sn/kg (liver) 0.34 mg Sn/kg (gall bladder) 2.30 mg Sn/kg (kidney) 1.38 mg Sn/kg (carcass) 5.56 mg Sn/kg (peritoneal fat) 1.04 mg Sn/kg (gill) 0.67 mg Sn/kg (blood) 0.50 mg Sn/kg (gut) 0.32 mg Sn/kg (muscle) 2.20 mg Sn/kg (brain)					[8]	L; 15-dy exposure period

Summary of Biological Effects Tissue Concentrations for Tributyltin

Species:	**Concentration, Units in[1]:**			**Toxicity:**	**Ability to Accumulate[2]:**			**Source:**	
Taxa	**Sediment**	**Water**	**Tissue (SampleType)**	**Effects**	**Log BCF**	**Log BAF**	**BSAF**	**Reference**	**Comments[3]**
Oncorhynchus mykiss, Rainbow trout			0.11 mg/kg TBTO (whole body)	Behavior, LOED				[43]	L; significantly increased swimming behavior (distances and directions of)
			0.35 mg/kg TBTO (whole body)	Growth, LOED				[43]	L; significantly lower weight increase at lowest test concentration
			0.13 mg/kg TBTO (whole body)	Growth, LOED				[43]	L; significantly increased swimming behavior (distances and directions of)
			0.27 mg/kg TBTO (whole body)	Growth, LOED				[43]	L; significantly lower weight increase at lowest test concentration; residue from

Summary of Biological Effects Tissue Concentrations for Tributyltin

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	Sediment	Water	Tissue (SampleType)	Effects	Log BCF	Log BAF	BSAF	Reference	Comments[3]
Oncorhynchus mykiss, Rainbow trout		0.6 µg TBTO/L[4]	2.5 µg TBTO/g (whole body)[7]	Histopathological effects Spleen: 20% had lymphocytic depletion; 20% increased erythrophagia; Gills: 10% had cell necrosis within primary lamellae, 30% within secondary lamellae; Pseudobranch: 30% had cell necrosis within pseudobranchial tissue				[44]	L; 28-day exposure

Summary of Biological Effects Tissue Concentrations for Tributyltin

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	Sediment	Water	Tissue (SampleType)	Effects	Log BCF	Log BAF	BSAF	Reference	Comments[3]
		1.0 µg TBTO/L[4]	2.75 µg TBTO/g (whole body)[7]	Histopathological effects Spleen: 90% had lymphocytic depletion; 50% increased erythrophagia; Gills: 20% had cell necrosis within primary lamellae, 50% within secondary lamellae; Pseudobranch: 50% had cell necrosis within pseudobranchial tissue				[44]	L; 28-day exposure

Summary of Biological Effects Tissue Concentrations for Tributyltin

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	**Sediment**	**Water**	**Tissue (SampleType)**	**Effects**	**Log BCF**	**Log BAF**	**BSAF**	**Reference**	**Comments[3]**
Oncorhynchus mykiss, Rainbow trout		2.0 µg TBTO/L	5.5 µg TBTO/g (whole body)[7]	Histopathological effects Spleen: 30% had lymphocytic depletion; 70% increased erythrophagia; Gills: 40% had cell necrosis within primary lamellae, 50% within secondary lamellae; Pseudobranch: 20% had cell necrosis within oral mucosa, 30% had cell necrosis within pseudobranchial tissue				[44]	L; 28-day exposure
Oncorhynchus mykiss, Rainbow trout			13.1 mg/kg TBTO oxide (whole body)[8]	Mortality, ED50				[49]	L; median lethal dose

Summary of Biological Effects Tissue Concentrations for Tributyltin

Species:	**Concentration, Units in[1]:**			**Toxicity:**	**Ability to Accumulate[2]:**			**Source:**	
Taxa	**Sediment**	**Water**	**Tissue (SampleType)**	**Effects**	**Log BCF**	**Log BAF**	**BSAF**	**Reference**	**Comments[3]**
Oncorhynchus mykiss, Rainbow trout		4.0 µg TBTO/L[4]	7.0 µg TBTO/g (whole body)[7]	Histopathological effects; Spleen: 100% had lymphocytic depletion; 90% increased erythrophagia; Gills: 100% had cell necrosis within primary lamellae, 80% within secondary lamellae; Pseudobranch: 60% had cell necrosis within oral mucosa, 70% had cell necrosis within pseudobranchial tissue				[44]	L; 28-day exposure

Summary of Biological Effects Tissue Concentrations for Tributyltin

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	Sediment	Water	Tissue (SampleType)	Effects	Log BCF	Log BAF	BSAF	Reference	Comments[3]
Cyprinodon variegatus, Sheepshead minnow			40,800 mg/kg TBTO (liver)[8]	Development, NOED				[9]	L; TBTO as tin; no significant response for length or weight of F1 generation fish (parental exposure)
			1,210 mg/kg TBTO (muscle)[8]	Development, NOED				[9]	L; TBTO as tin; no significant response for length or weight of F1 generation fish (parental exposure)
			2,480 mg/kg TBTO (viscera)[8]	Development, NOED				[9]	L; TBTO as tin; no significant response for length or weight of F1 generation fish (parental exposure)
			2,600 mg/kg TBTO (whole body)[8]	Development, NOED				[9]	L; TBTO as tin in whole body of F1 generation; no significant response for length or weight of F1 generation fish (parental exposure)

Summary of Biological Effects Tissue Concentrations for Tributyltin

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	Sediment	Water	Tissue (SampleType)	Effects	Log BCF	Log BAF	BSAF	Reference	Comments[3]
			40,800 mg/kg TBTO (liver)[8]	Growth, NOED				[9]	L; TBTO as tin; no significant response for length or weight
			1,210 mg/kg TBTO (muscle)[8]	Growth, NOED				[9]	L; TBTO as tin; no significant response for length or weight
			2,480 mg/kg TBTO (viscera)[8]	Growth, NOED				[9]	L; TBTO as tin; no significant response for length or weight
			2,600 mg/kg TBTO (whole body)[8]	Growth, NOED				[9]	L; TBTO as tin in whloe body of F1 generation; no significant response for length or weight in adults
			40,800 mg/kg TBTO (liver)[8]	Reproduction, NOED				[9]	L; TBTO as tin; no significant response for number of eggs spawned per day per female, or hatching success

Summary of Biological Effects Tissue Concentrations for Tributyltin

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	Sediment	Water	Tissue (SampleType)	Effects	Log BCF	Log BAF	BSAF	Reference	Comments[3]
			1,210 mg/kg TBTO (muscle)[8]	Reproduction, NOED				[9]	L; TBTO as tin; no significant response for number of eggs spawned per day per female, or hatching success
			2,480 mg/kg TBTO (viscera)[8]	Reproduction, NOED				[9]	L; TBTO as tin; no significant response for number of eggs spawned per day per female, or hatching success
			2,600 mg/kg TBTO (whole body)[8]	Reproduction, NOED				[9]	L; TBTO as tin in whloe body of F1 generation; no significant response for number of eggs spawned per day per female, or hatching success in adults
Ictalurus punctatus, Channel catfish			0.1 mg/kg (whole body tissue residue concentrations)	Significant ($P < 0.05$) suppression of humoral response				[41]	L

Summary of Biological Effects Tissue Concentrations for Tributyltin

Species:	**Concentration, Units in[1]:**			**Toxicity:**	**Ability to Accumulate[2]:**			**Source:**	
Taxa	**Sediment**	**Water**	**Tissue (SampleType)**	**Effects**	**Log BCF**	**Log BAF**	**BSAF**	**Reference**	**Comments[3]**
Poecilia reticulata, Guppy			0.7 mg/kg TBTO (whole body tissue residue concentrations)	Histopatho-logical changes				[42]	
Stenotomus chrysops, Scup			202 mg/kg TBTCl (liver)[8]	Physiological, LOED				[48]	L; statistically significant reduction of hepatic enzyme activity
			16.3 mg/kg TBTCl (whole body)[8]	Physiological, LOED				[48]	L; statistically significant reduction of hepatic enzyme activity
			8 mg/kg TBTCl (liver)[8]	Cellular, NOED				[48]	L; no effect on liver histopathology
			14.7 mg/kg TBTCl (liver)[8]	Cellular, NOED				[48]	L; no effect on liver histopathology
			202 mg/kg TBTCl (liver)[8]	Cellular, NOED				[48]	L; no effect on liver histopathology
			3.3 mg/kg TBTCl (whole body)[8]	Cellular, NOED				[48]	L; no effect on liver histopathology

Summary of Biological Effects Tissue Concentrations for Tributyltin

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	**Sediment**	**Water**	**Tissue (SampleType)**	**Effects**	**Log BCF**	**Log BAF**	**BSAF**	**Reference**	**Comments[3]**
			8.1 mg/kg TBTCl (whole body)[8]	Cellular, NOED				[48]	L; no effect on liver histopathology
			16.3 mg/kg TBTCl (whole body)[8]	Cellular, NOED				[48]	L; no effect on liver histopathology
			8 mg/kg TBTCl (liver)[8]	Physiological, NOED				[48]	L; statistically insignificant reduction of hepatic enzyme activity
			14.7 mg/kg TBTCl (liver)[8]	Physiological, NOED				[48]	L; statistically insignificant reduction of hepatic enzyme activity
			3.3 mg/kg TBTCl (whole body)[8]	Physiological, NOED				[48]	L; statistically insignificant reduction of hepatic enzyme activity
			8.1 mg/kg TBTCl (whole body)[8]	Physiological, NOED				[48]	L; statistically insignificant reduction of hepatic enzyme activity

[1] Concentration units based on wet weight unless otherwise noted.
[2] BCF = bioconcentration factor, BAF = bioaccumulation factor, BSAF = biota-sediment accumulation factor.

[3] L = laboratory study, spiked sediment, single chemical; F = field study, multiple chemical exposure; other unusual study conditions or observations noted.
[4] Surface water or aqueous concentration; not pore water.
[5] Laboratory toxicity test, co-occurrence of multiple contaminants with listed contaminant.
[6] Outdoor microcosm or artificial stream test, co-occurrence of multiple contaminants with listed contaminant.
[7] Residue concentration estimated from graphical material.
[8] This entry was excerpted directly from the Environmental Residue-Effects Database (ERED, www.wes.army.mil/el/ered, U.S. Army Corps of Engineers and U.S. Environmental Protection Agency). The original publication was not reviewed, and the reader is strongly urged to consult the publication to confirm the information presented here.

† Type of tributyltin species not reported.

Conversion Factors:

[TBT] * 0.41 = [Sn]	[TBTO] * 0.97 = [TBT]
[TBT] * 1.12 = [TBT Cl]	[Sn] * 2.74 = [TBT Cl]
[TBT Cl * 0.36 = [Sn]	[Sn] *2.44 = [TBT]
[TBT Cl] * 0.89 = [TBT]	

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Chemical Category: PESTICIDE (ORGANOPHOSPHATE)

Chemical Name (Common Synonyms): TERBUFOS **CASRN:**13071-79-9

Chemical Characteristics

Solubility in Water: 15 ppm [1] **Half-Life:** No data [2]

Log K_{ow}: No data [3] **Log K_{oc}:** —

Human Health

Oral RfD: 1.3 x 10^{-4} mg/kg/day [4] **Confidence:** Not available, uncertainty factor = 10

Critical Effect: Inhibition of plasma cholinesterase observed in dogs

Oral Slope Factor: No data [5] **Carcinogenic Classification:** D [6]

Wildlife

Partitioning Factors: Partitioning factors for terbufos in wildlife were not found in the literature.

Food Chain Multipliers: Food chain multipliers for terbufos in wildlife were not found in the literature.

Aquatic Organisms

Partitioning Factors: Partitioning factors for terbufos in aquatic organisms were not found in the literature.

Food Chain Multipliers: Food chain multipliers for terbufos in aquatic organisms were not found in the literature.

Toxicity/Bioaccumulation Assessment Profile

Terbufos, an organophosphate pesticide, is the active ingredient of Counter [7]. The application of Counter at the rate of 1.45 kg per hectare resulted in low-level exposure sufficient to induce blood plasma cholinesterase depressions, but generally not at levels sufficient to cause increased mortality to bobwhites and cottontails [8]. Turbofos is highly toxic to mammals. The acute oral LD50 for mice (*Mus musculus*) was 3.5 mg/kg [9], whereas 63 percent of exposed deer mice [7] were killed at 2.48 mg/kg dose. The residue of terbufos in live earthworms (1.73 mg/kg) was significantly lower than the residue (18.1 mg/kg) in dead organisms after a 32-day exposure [10].

Acute toxicity, expressed as the 96-h LC50 of terbufos to aquatic species, ranged from 4.7 µg/L for *Menidia beryllina* to 390 µg/L for *Pimephales promelas* [11]. Terbufos toxicity in the aquatic environment is influenced by pH and other physicochemical factors [12]. Experiments conducted with rainbow trout and *Gammarus* showed that terbufos was least toxic at pH 7.5, and more toxic at higher and lower pH. The accumulation factor (AF) for terbufos was influenced by salinity and temperature [13]. The AF for grass shrimp ranged from 20 at 30 ppt salinity and 22ºC to 64 at 25 ppt salinity and 17ºC, while the AF for sheepshead minnows ranged from 71 at 15 ppt salinity and 22ºC to 287 at 15 ppt salinity and 17ºC.

Summary of Biological Effects Tissue Concentrations for Terbufos

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	**Sediment**	**Water**	**Tissue (Sample Type)**	**Effects**	**Log BCF**	**Log BAF**	**BSAF**	**Reference**	**Comments[3]**
Invertebrates									
Gammarus pseudolimnaeus, Amphipod			0.168 mg/kg (whole body)[4]	Mortality, ED50				[12]	L; lethal to 50% of animals in 96 hours
Palaemonetes pugio, Grass shrimp			0.07 mg/kg (whole body)[4]	Mortality, ED100				[13]	L; mortality
Fishes									
Oncorhynchus mykiss, Rainbow trout			4.08 mg/kg (whole body)[4]	Mortality, ED50				[12]	L; lethal to 50% of animals in 96 hours
Cyprinodon variegatus, Sheepshead minnow			0.11 mg/kg (whole body)[4]	Mortality, ED100				[13]	L; mortality

[1] Concentration units based on wet weight unless otherwise noted.
[2] BCF = bioconcentration factor, BAF = bioaccumulation factor, BSAF = biota-sediment accumulation factor.
[3] L = laboratory study, spiked sediment, single chemical; F = field study, multiple chemical exposure; other unusual study conditions or observations noted.
[4] This entry was excerpted directly from the Environmental Residue-Effects Database (ERED, www.wes.army.mil/el/ered, U.S. Army Corps of Engineers and U.S. Environmental Protection Agency). The original publication was not reviewed, and the reader is strongly urged to consult the publication to confirm the information presented here.

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Chemical Category: POLYCHLORINATED BIPHENYLS

Chemical Name (Common Synonyms): Total PCBs **CASRN:** 1336-36-3

Chemical Characteristics

Solubility in Water: See Aroclors and congeners [1]

Half-Life: No data [2,3], See Aroclors congeners

Log K_{ow}: —

Log K_{oc}: —

Human Health

Oral RfD: See Aroclors and congeners [4]

Confidence: —

Critical Effect: See Aroclors and congeners

Oral Slope Factor: No data [4]

Carcinogenic Classification: 2A [4]

Wildlife

Partitioning Factors: BSAFs were calculated for red-winged blackbird and tree swallow eggs during a study in the Great Lakes are; with values ranging from 4.2 to 133, as reported in the attached table. BSAFs for tree swallow nestlings were 6.7 and 9.5.

Food Chain Multipliers: The most toxic congeners have been shown to be selectively accumulated from organisms at one trophic level to the next [5]. At least three studies have concluded that PCBs have the potential to biomagnify in food webs based on aquatic organisms and predators that feed primarily on aquatic organisms [6,7,8]. The results from Biddinger and Gloss [6] and USACE [8] generally agreed that highly water-insoluble compounds (including PCBs) have the potential to biomagnify in these types of food webs. Thomann's [9] model also indicated that highly water-insoluble compounds (log k_{ow} values 5 to 7) showed the greatest potential to biomagnify. Biomagnification factors of 32 and 93 were determined for total PCBs from alewife to herring gull eggs and from alewife to whole body herring gull, respectively [10]. A study of arctic marine food chains measured total PCB biomagnification factors of 3.7 to 8.8 for fish to seal, 7.4 to 13.9 for seal to bear, and 49.2 for fish to bear [11].

Aquatic Organisms

Partitioning Factors: A log BCF of 3.62 was measured for perch in a Swedish lake [40]. In a study of several lakes in central Ontario, BSFs for zooplankton ranged from 1.0 to 9.1. Log BAFs for fish ranged from −0.22 to 0.97, as reported in the summary table, and BSFs from 0.13 to 30 were noted.

Log BAFs for crayfish ranged –0.70 to 0.89 and BSFs ranged from 2.0 to 23.7 in the Ontario lakes study [35]. Log BAFs for clams in that study ranged from –0.05 to 0.32 with BSF values from 2.1 to 10.4.

Food Chain Multipliers: Polychlorinated biphenyls have been demonstrated to biomagnify through the food web. Oliver and Niimi [12], studying accumulation of PCBs in various organisms in the Lake Ontario food web, reported concentrations of total PCBs in phytoplankton, zooplankton, and several species of fish. Their data indicated a progressive increase in tissue PCB concentrations moving from organisms lower in the food web to top aquatic predators (see following table). In a study of PCB accumulation in lake trout (*Salvelinus namaycush*) of Lake Ontario, Rasmussen et al. [13] reported that each trophic level contributed about a 3.5-fold biomagnification factor to the PCB concentrations in the trout. In a study of several lakes in Ontario, log biomagnification factors for transfer from zooplankton to fish ranged from 0.00 to 0.97, as reported in the attached summary table for total PCBs.

Observed and Relative Concentrations of PCBs in Organisms of the Lake Ontario Food Web [12]

Species	Observed Concentrations (ng/g ww)	Relative Concentration
Phytoplankton	50	1
Mysids	330	6.6
Pontoporeia affinis	790	15.8
Oligochaetes	180	3.6
Sculpin	1600	32
Alewife	1300	26
Smelt	1400	28
Salmonids	4300	86

Toxicity/Bioaccumulation Assessment Profile

PCBs are a group (209 congeners/isomers) of organic chemicals, based on various substitutions of chlorine atoms on a basic biphenyl molecule. These manufactured chemicals have been widely used in various processes and products because of the extreme stability of many isomers, particularly those with five or more chlorines [14]. A common use of PCBs was as dielectric fluids in capacitors and transformers. In the United States, Aroclor is the most familiar registered trademark of commercial PCB formulations. Generally, the first two digits in the Aroclor designation indicate that the mixture contains biphenyls, and the last two digits give the weight percent of chlorine in the mixture.

As a result of their stability and their general hydrophobic nature, PCBs released to the environment have dispersed widely throughout the ecosystem [14]. PCBs are among the most stable organic compounds known, and chemical degradation rates in the environment are thought to be slow. As a result of their highly lipophilic nature and low water solubility, PCBs are generally found at low concentrations in water and at relatively high concentrations in sediment [15]. Individual PCB congeners have different physical and chemical properties based on the degree of chlorination and position of chlorine substitution, although differences with degree of chlorination are more significant [15]. Solubilities and octanol-water partition coefficients for PCB congeners range over several orders of magnitude [16]. Octanol-water partition coefficients, which are often used as estimators of the potential for bioconcentration, are highest for the most chlorinated PCB congeners.

Dispersion of PCBs in the aquatic environment is a function of their solubility [15], whereas PCB mobility within and sorption to sediment are a function of chlorine substitution pattern and degree of chlorination [17]. The concentration of PCBs in sediments is a function of the physical characteristics of the sediment, such as grain size [18,19] and total organic carbon content [18,19,20,21]. Fine sediments typically contain higher concentrations of PCBs than coarser sediments because of more surface area [15]. Mobility of PCBs in sediment is generally quite low for the higher chlorinated biphenyls [17]. Therefore, it is common for the lower chlorinated PCBs to have a greater dispersion from the original point source [15]. Limited mobility and high rates of sedimentation could prevent some PCB congeners in the sediment from reaching the overlying water via diffusion [17].

The persistence of PCBs in the environment is a result of their general resistance to degradation [16]. The rate of degradation of PCB congeners by bacteria decreases with increasing degree of chlorination [22]; other structural characteristics of the individual PCBs can affect susceptibility to microbial degradation to a lesser extent [16]. Photochemical degradation, via reductive dechlorination, is also known to occur in aquatic environments; the higher chlorinated PCBs appear to be most susceptible to this process [21].

Due to the toxicity, high K_{ow} values, and highly persistent nature of many PCBs, they possess a high potential to bioaccumulate and exert reproductive effects in higher-trophic-level organisms. Aquatic organisms have a strong tendency to accumulate PCBs from water and food sources. The log bioconcentration factor for fish is approximately 4.70 [23]. This factor represents the ratio of concentration in tissue to the ambient water concentration. Aquatic organisms living in association with PCB-contaminated sediments generally have tissue concentrations equal to or greater than the concentration of PCB in the sediment [23]. Once taken up by an organism, PCBs partition primarily into lipid compartments [15]. Thus, differences in PCB concentration between species and between different tissues within the same species may reflect differences in lipid content [15]. PCB concentrations in polychaetes and fish have been strongly correlated to their lipid content [24]. Elimination of PCBs from organisms is related to the characteristics of the specific PCB congeners present. It has been shown that uptake and depuration rates in mussels are high for lower-chlorinated PCBs and much lower for higher-chlorinated congeners [25,26]. In some species, tissue concentrations of PCBs in females can be reduced during gametogenesis because of PCB transfer to the more lipophilic eggs. Therefore, the transferred PCBs are eliminated from the female during spawning [27,28]. Fish and other aquatic organisms biotransform PCBs more slowly than other species, and they appear less able to metabolize, or excrete, the higher chlorinated PCB congeners [27]. Consequently, fish and other aquatic organisms may accumulate more of the higher-chlorinated PCB congeners than are found in the environment [15].

The acute toxicity of PCBs appears to be relatively low, but results from chronic toxicity tests indicate that PCB toxicity is directly related to the duration of exposure [29]. Toxic responses have been noted to occur at concentrations of 0.03 and 0.014 µg/L in marine and freshwater environments, respectively [29]. The LC50 for grass shrimp exposed to PCBs in marine waters for 4 days was 6.1 to 7.8 µg/L

[29]. Chronic toxicity of PCBs presents a serious environmental concern because of their resistance to degradation [30], although the acute toxicity of PCBs is relatively low compared to that of other chlorinated hydrocarbons. Sediment contaminated with PCBs has been shown to elicit toxic responses at relatively low concentrations. Sediment bioassays and benthic community studies suggest that chronic effects generally occur in sediment at total PCB concentrations exceeding 370 µg/kg [31].

A number of field and laboratory studies provide evidence of chronic sublethal effects on aquatic organisms at low tissue concentrations [16]. Field and Dexter [16] suggest that a number of marine and freshwater fish species have experienced chronic toxicity at PCB tissue concentrations of less than 1.0 mg/kg and as low as 0.1 mg/kg. Spies et al. [32] reported an inverse relationship between PCB concentrations in starry flounder eggs in San Francisco Bay and reproductive success, with an effective PCB concentration in the ovaries of less than 0.2 mg/kg. Monod [33] also reported a significant correlation between PCB concentrations in eggs and total egg mortality in Lake Geneva char. PCBs have also been shown to cause induction of the mixed function oxidase (MFO) system in aquatic animals, with MFO induction by PCBs at tissue concentrations within the range of environmental exposures [16].

Summary of Biological Effects Tissue Concentrations for Total PCBs

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	Sediment	Water	Tissue (Sample Type)	Effects	Log BCF	Log BAF	BSAF	Reference	Comments[3]
Invertebrates									
Zooplankton, (species not named specifically)	Boshkung Lake: 27.2; 356 (TOC normalized) µg/kg (dw)	0.93 ng/L	11.6, 392 (lipid normalized) µg/kg[4]				1.6	[34,35]	F; seven lakes in central Ontario; water samples are filtered samples collected from the water column at 1 m depth; BSF values appear in the BSAF column; BSF was calculated as the concentration of total PCBs (lipid basis) divided by the concentration in surface sediment (organic carbon basis)
	Wood Lake: 15.2; 156 (TOC normalized) µg/kg (dw)	1.85 ng/L	3.56, 1030 (lipid normalized) µg/kg				6.4		
	St. Nora Lake: 12; 227 (TOC normalized) µg/kg (dw)	1.60 ng/L	4.36, 1550 (lipid normalized) µg/kg				6.7		
	Opeongo Lake: 53.9; 546 (TOC normalized) µg/kg (dw)	1.23 ng/L	6.11, 766 (lipid normalized) µg/kg				1.4		
	Skugog Lake:						9.1		
	Rice Lake:						8.5		
	Clear Lake:						1.0		

Summary of Biological Effects Tissue Concentrations for Total PCBs

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	**Sediment**	**Water**	**Tissue (Sample Type)**	**Effects**	**Log BCF**	**Log BAF**	**BSAF**	**Reference**	**Comments[3]**
Nephtys incisa, Polychaete worm	Stations: M1C = 385 µg/kg (dw) M2B = 325 µg/kg (dw) M4 = 1060 µg/kg (dw) M5 = 2.73 µg/kg (dw) M8 = 1290 µg (dw) M89B = 559 µg/kg (dw)		Stations: M1C = 314 µg/kg M2B = 143 µg/kg M4 = 349 µg/kg M5 = 279 µg/kg M8 = 872 µg/kg M89B= 153 µg/kg					[36]	F; sediment samples from the New York Bight; total PCB concentrations were quantified as a sum of Aroclor 1242 and 1254
Nereis incisa, Polychaete worm	Station: M1C = 385 µg/kg (dw)		Station: M1C = 326 µg/kg					[36]	F; sediment samples from the New York Bight; total PCB concentrations were quantified as a sum of Aroclor 1242 and 1254

Summary of Biological Effects Tissue Concentrations for Total PCBs

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	**Sediment**	**Water**	**Tissue (Sample Type)**	**Effects**	**Log BCF**	**Log BAF**	**BSAF**	**Reference**	**Comments[3]**
Nereis virens, Sandworm	Day 180: 4,310±640 µg/kg (dw)		Day 180: 522±178 µg/kg					[36]	L; sediment from Passaic River from four stations was composited for bioaccumulation study with commercial species; TOC was 5.7%. sediment and tissue (whole body) concentrations are mean and SD concentrations of three replicate tests
Ninoe nigripes, Polychaete worm	Stations: M5 = 2.73 µg/kg (dw) M89A = 13.3 µg/kg (dw) Ref = 33.1 µg/kg (dw)		Stations: M5 = 48.9 µg/kg M89A = 402 µg/kg MXRef = 176 µg/kg					[36]	F; sediment samples from the New York Bight; total PCB concentrations were quantified as a sum of Aroclor 1242 and 1254

Summary of Biological Effects Tissue Concentrations for Total PCBs

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	Sediment	Water	Tissue (Sample Type)	Effects	Log BCF	Log BAF	BSAF	Reference	Comments[3]
Pherusa affinis, Polychaete worm	Stations: M1C = 385 µg/kg (dw) M4B = 201 µg/kg (dw)		Stations: M1C = 129 µg/kg M4B = 107 µg/kg					[36]	F; sediment samples from the New York Bight; total PCB concentrations were quantified as a sum of Aroclor 1242 and 1254
Polinices duplicatus, Moon snail	Station: M5 = 2.73 µg/kg (dw)		Station: M5 = 78.1 µg/kg					[36]	F; sediment samples from the New York Bight; total PCB concentrations were quantified as a sum of Aroclor 1242 and 1254
Mytilus edulis, Mussel	0.14-45µg/kg dw	0.045-1.8 ng/L	2.7-3.2 ng/g						
Mytilus edulis, Mussel			0.6 mg/kg (whole body)[5]	Mortality, NA				[64]	L; no significant decrease in anoxic survival time (control 13 days)
			1.4 mg/kg (whole body)[5]	Mortality, NA				[64]	L; decreased anoxic survival time (control 10.7 days)

Summary of Biological Effects Tissue Concentrations for Total PCBs

Species: Taxa	Concentration, Units in[1]: Sediment	Water	Tissue (Sample Type)	Toxicity: Effects	Ability to Accumulate[2]: Log BCF	Log BAF	BSAF	Source: Reference	Comments[3]
			1.4 mg/kg (whole body)[5]	Physiological, NOED				[64]	L; no significant changes in adenylate energy charge or glycogen content
Clams (species not named specifically)	Boshkung Lake: 27.2, 356 (TOC normalized) µg/kg (dw)	0.93 ng/L	8.16, 2330 (lipid normalized) µg/kg			0.59	6.5	[34,35]	F; six lakes in central Ontario; water samples are filtered samples collected from the water column at 1 m depth; BSF values appear in the BSAF column; BSF was calculated as the concentration of total PCBs (lipid basis) divided by the concentration in surface sediment (organic carbon basis)
	Wood Lake: 15.2, 156 (TOC normalized) µg/kg (dw)	1.85 ng/L	4.63, 1670 (lipid normalized) µg/kg			0.20	10.4		
	St. Nora Lake: 12, 227 (TOC normalized) µg/kg (dw)	1.60 ng/L	3.57, 1590 (lipid normalized) µg/kg			0.00	6.9		
	Opeongo Lake: 53.9, 546 (TOC normalized) µg/kg (dw)	1.23 ng/L	6.32, 1630 (lipid normalized) µg/kg			0.32	2.1		
	Rice Lake:					-0.05	6.9		
	Clear Lake					0.46	2.7		

Summary of Biological Effects Tissue Concentrations for Total PCBs

Species:	**Concentration, Units in[1]:**			**Toxicity:**	**Ability to Accumulate[2]:**			**Source:**	
Taxa	**Sediment**	**Water**	**Tissue (Sample Type)**	**Effects**	**Log BCF**	**Log BAF**	**BSAF**	**Reference**	**Comments[3]**
Corbicula fluminea, Asian clam	2.3 ng/g dw 3.3 ng/g dw	surface water: 43.2 ng/L 6.4 ng/L	7.6 µg/g of lipid 7.2 µg/g of lipid					[38]	F; Rio Santiago and Rio de la Plata, Argentina
Spisula solidissima, Clam	Station: M5B = ND µg/kg (dw)		Station: M5B = 38.1µg/kg					[36]	F; Sediment samples from the New York Bight; total PCB concentrations were quantified as a sum of Aroclor 1242 and 1254.
Macoma nasuta, Clam	Day 180: 4310 ± 640 µg/kg (dw)		Day 120: 68.9 ±10.3µg/kg					[36]	L; sediment from Passaic River from four stations was composited for bioaccumulation study with commercial species; TOC was 5.7%; sediment and tissue whole body concentrations are mean and SD concentrations of three replicate tests
Macoma nasuta, Bent nose clam			1.7 mg/kg (whole body)[5]	Behavior, NOED				[45]	L; no effect on burrowing behavior

Summary of Biological Effects Tissue Concentrations for Total PCBs

Species: Taxa	Concentration, Units in[1]: Sediment	Water	Tissue (Sample Type)	Toxicity: Effects	Ability to Accumulate[2]: Log BCF	Log BAF	BSAF	Source: Reference	Comments[3]
			1.7 mg/kg (whole body)[5]	Mortality, NOED				[45]	L; no effect on mortality
Mercenaria mercenaria, Clam	Stations: M7 = 12.8 µg/kg (dw) MXRef = 33.1 µg/kg (dw)		Stations: M7 = 48.7µg/kg MX>Ref = 95.7µg/kg					[36]	F; sediment samples from the New York Bight; total PCB concentrations were quantified as a sum of Aroclor 1242 and 1254
Pitar morrhuana, Clam	Station: M4B = 201 µg/kg (dw)		Station: M4B = 37.2µg/kg						
Mya truncata, Bivalves:	0.14-45 µg/kg dw	surface water: 0.045-1.8 ng/L	0.89-2.2 ng/g					[37]	F; sum of 47 congeners in Cambridge Bay, Northwest Territories, Canada; sediment samples collected from 65 sites over 3 years
Orchomene sp., Amphipod	0.14-45 g/kg dw	0.045-1.8 ng/L	32-36 ng/g						

Summary of Biological Effects Tissue Concentrations for Total PCBs

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	Sediment	Water	Tissue (Sample Type)	Effects	Log BCF	Log BAF	BSAF	Reference	Comments[3]
Palaemonetes pugio, Grass shrimp	Mean of day 0 and day 180 replicates: 3,550±1,070 µg/kg (dw)		Day 28: 147 ± 42µg/kg					[36]	TOC was 5.7%; sediment and tissue whole body concentrations are mean and SD concentrations of three replicate tests; early removal of shrimp to avoid preying upon other species (28-day exposure, not yet steady state)
Mysis relicta, Opossum Shrimp			1.9 mg/kg (whole body)[5]	Behavior, NOED				[56]	L; no effect on feeding behavior

Summary of Biological Effects Tissue Concentrations for Total PCBs

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	Sediment	Water	Tissue (Sample Type)	Effects	Log BCF	Log BAF	BSAF	Reference	Comments[3]
Procambarus sp., Crayfish				Scugog Lake Rice Lake Clear Lake		0.41 -0.70 0.89	23.7 2.0 7.3	[35]	F; three lakes in central Ontario; water samples are filtered samples collected from the water column at 1 m depth; BSF values appear in the BSAF column; BSF was calculated as the concentration of total PCBs (lipid basis) divided by the concentration in surface sediment (organic carbon basis)
Callinectes sapidus, Crab	Station: M5 =2.73µg/kg (dw)		Station: M5 = 69.9 µg/kg (muscle) M5 = 1,870 µg/kg (hepatopancreas)					[36]	F; sediment samples from the New York Bight; total PCB concentrations were quantified as a sum of Aroclor 1242 and 1254
Chironomus riparius, Midge			3.3 mg/kg (whole body)[5]	Behavior, NOED				[57]	L; no effect on swimming behavior
			1.1 mg/kg (whole body)[5]	Behavior, NOED				[57]	L; no effect on swimming behavior

Summary of Biological Effects Tissue Concentrations for Total PCBs

Species: Taxa	Concentration, Units in[1]: Sediment	Water	Tissue (Sample Type)	Toxicity: Effects	Ability to Accumulate[2]: Log BCF	Log BAF	BSAF	Source: Reference	Comments[3]
			0.3 mg/kg (whole body)[5]	Behavior, NOED				[57]	L; no effect on swimming behavior
Ephemera danica, Mayfly			1.5 mg/kg (whole body)[5]	Growth, NOED				[63]	L
			1.5 mg/kg (whole body)[5]	Mortality, NOED				[63]	L
Asterias rubens, Starfish			19.2 mg/kg (gonad)[5]	Reproduction, LOED				[47]	L; concentrations are ug/g lipid gonadal indices evaluated
			0.146 mg/kg (gonad)[5]	Development, LOED				[48]	L; estimated wet weight adult males
			0.324 mg/kg (gonad)[5]	Development, LOED				[48]	L; estimated wet weight adult females
Fishes									
Oncorhynchus mykiss, Rainbow trout			50 mg/kg (whole body)[5]	Physiological, LOED				[53]	L; mixed function oxidase induction, including benzo(a)pyrene hydroxylase induction
			100 mg/kg (whole body)[5]	Physiological, NA				[53]	
			200 mg/kg (whole body)[5]	Physiological, NA				[53]	

Summary of Biological Effects Tissue Concentrations for Total PCBs

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	Sediment	Water	Tissue (Sample Type)	Effects	Log BCF	Log BAF	BSAF	Reference	Comments[3]
			0.29 mg/kg (whole body)[5]	Physiological, ED50				[54]	L; internal dose used as tissue concentration; induction of aryl hydrocarbon hydroxylase (AHH)
			0.56 mg/kg (whole body)[5]	Physiological, ED50				[54]	
Oncorhynchus mykiss, Rainbow trout			1.3 mg/kg (fat)[5]	Physiological, ED30				[61]	L; 30% decrease in hemoglobin content relative to control
			2.2 mg/kg (Fat)[5]	Physiological, ED30				[61]	L; 30% increase in liver size relative to control
			2.2 mg/kg (fat)[5]	Physiological, ED30				[61]	L; 30% decrease in hemoglobin content relative to control
			1.3 mg/kg (fat)[5]	Physiological, ED30				[61]	L; 30% increase in liver size relative to control
			1.7 mg/kg (fat)[5]	Physiological, ED35				[61]	L; 35% increase in kidney size relative to control
			1.3 mg/kg (fat)[5]	Physiological, ED35				[61]	L; 35% increase in kidney size relative to control

Summary of Biological Effects Tissue Concentrations for Total PCBs

Species:	**Concentration, Units in[1]:**			**Toxicity:**	**Ability to Accumulate[2]:**			**Source:**	
Taxa	**Sediment**	**Water**	**Tissue (Sample Type)**	**Effects**	**Log BCF**	**Log BAF**	**BSAF**	**Reference**	**Comments[3]**
			2.2 mg/kg (fat)[5]	Growth, ED40				[61]	L; 40% decrease in growth relative to control
			1.3 mg/kg (fat)[5]	Growth, ED40				[61]	L; 40% decrease in growth relative to control
Oncorhynchus kisutch, Coho salmon			645 mg/kg (whole body)[5]	Mortality, ED100				[60]	L; radiolabeled - contaminated food fed
			43 mg/kg (carcass)[5]	Morphology, LOED				[55]	L; decrease in hepatosomatic index
			43 mg/kg (carcass)[5]	Physiological, LOED				[55]	L; lipid levels in carcass decreased
			9.8 mg/kg (carcass)[5]	Morphology, NOED				[55]	L; no decrease in hepatosomatic index
			9.8 mg/kg (carcass)[5]	Physiological, NOED				[55]	L; no effect on lipid levels in carcass
Oncorhynchus tshawytscha, Chinook salmon			3.5 mg/kg (whole body)[5]	Cellular, LOED				[52]	L; structure changes in intestine cells, increased exfoliation of mucosa, mucosal cell inclusions
			3.5 mg/kg (whole body)[5]	Growth, NOED				[52]	L; no effect on weight gain

Summary of Biological Effects Tissue Concentrations for Total PCBs

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	Sediment	Water	Tissue (Sample Type)	Effects	Log BCF	Log BAF	BSAF	Reference	Comments[3]
Salmo salar, Atlantic salmon			30 mg/kg (whole body)[5]	Mortality, NOED				[46]	L; no effect on mortality
Salmonids						7.81 (log BAF)	1.85	[12]	F
Salvelinus namaycush, Lake trout			0.31 mg/kg (eggs)	Egg hatchability reduced by 57% and fry survival reduced by 19% relative to the control.				[39]	L; Total PCB was measured as Aroclor 1284; total DDT in eggs was 0.15 mg/kg which was also significantly higher than in controls
Salvelinus namaycush, Lake trout	Boshkung Lake: 27.2; 356 (TOC normalized) µg/kg (dw)	0.93 ng/L	87.6, 1,550 (lipid normalized) µg/kg			0.41	4.3	[34,35]	F; four lakes in central Ontario; water samples are filtered samples collected from the water column at 1 m depth; BSF values appear in the BSAF column; BSF was calculated as the concentration of total PCBs (lipid basis) divided by the concentration in surface sediment (organic carbon basis)
	St. Nora Lake: 12; 227 (TOC normalized) µg/kg (dw)	1.6 ng/L	17.4, 2,460 (lipid normalized) µg/kg			0.20	10.7		
	Opeongo Lake: 53.9; 546 (TOC normalized) µg/kg (dw)	1.23 ng/L	48.8, 2,100 (lipid normalized) µg/kg			0.43	3.8		

Summary of Biological Effects Tissue Concentrations for Total PCBs

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	**Sediment**	**Water**	**Tissue (Sample Type)**	**Effects**	**Log BCF**	**Log BAF**	**BSAF**	**Reference**	**Comments[3]**
	Clear Lake:					0.97	8.8		
Salvenlinus namaycush, Lake trout			2.3 mg/kg (whole body)[5]	Growth, LOED				[58]	L; PCB dosed with acetone carrier; enhanced growth (weight only; not length)
			2.4 mg/kg (whole body)[5]	Growth, LOED				[58]	L; PCB dosed with acetone carrier; enhanced growth (weight and length)
			1.8 mg/kg (whole body)[5]	Growth, LOED				[58]	L; PCB with no acetone carrier; enhanced growth (weight and length)
			0.76 mg/kg (whole body)[5]	Growth, NOED				[58]	L; PCB dosed with acetone carrier; no effect on growth (weight or length)
			2.1 mg/kg (whole body)[5]	Growth, NOED				[58]	L; PCB with no acetone carrier; no effect on growth (weight or length)
			0.76 mg/kg (whole body)[5]	Growth, NOED				[58]	L; on growth (weight or length)

Summary of Biological Effects Tissue Concentrations for Total PCBs

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	Sediment	Water	Tissue (Sample Type)	Effects	Log BCF	Log BAF	BSAF	Reference	Comments[3]
			0.76 mg/kg (whole body)[5]	Mortality, NOED				[58]	L; PCB dosed with acetone carrier; no effect on mortality
			2.3 mg/kg (whole body)[5]	Mortality, NOED				[58]	L; PCB dosed with acetone carrier; no effect on mortality
			2.4 mg/kg (whole body)[5]	Mortality, NOED				[58]	L; PCB dosed with acetone carrier; no effect on mortality
			0.76 mg/kg (whole body)[5]	Mortality, NOED				[58]	L; PCB with no acetone carrier; no effect on mortality
			2.1 mg/kg (whole body)[5]	Mortality, NOED				[58]	L; PCB with no acetone carrier; no effect on mortality
			1.8 mg/kg (whole body)[5]	Mortality, NOED				[58]	L; PCB with no acetone carrier; no effect on mortality
			1.5 mg/kg (eggs)[5]	Reproduction, LOED				[59]	L
Myoxocephalus quadricornis, Four horn sculpin	0.14-45µg/kg dw	surface water: 0.045-1.8 ng/L	7.3-230 ng/g (whole body excluding liver) 12-1,300 (liver)					[37]	F; 2-4 individuals of each species of sculpin were pooled to make a sample from each site

Summary of Biological Effects Tissue Concentrations for Total PCBs

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	Sediment	Water	Tissue (Sample Type)	Effects	Log BCF	Log BAF	BSAF	Reference	Comments[3]
Myoxocephalus scorpius, Short-horn sculpin	0.14-45µg/kg dw	0.045-1.8 ng/L	1.4-38 ng/g (whole body excluding liver) 5.5-220 (liver)						
Gados ogac, Greenland cod	0.14-45µg/kg dw	0.045-1.8 ng/L	4.4-39 ng/g (whole body excluding liver) 100-2,500 (liver)						F; analyzed as individual fish
Salvelinus alpinus, Arctic char	0.14-45µg/kg dw	0.045-1.8 ng/L	3.4-3.5 ng/g (whole body excluding liver) 5.1-7.8 (liver)						F; analyzed as individual fish
Prochilodus platensis	3 ng/g dw	13.8 ng/L	6.7, 17.8, 9.2 µg/g of lipid (muscle)					[38]	F; Rio Santiago and Rio de la Plata, Argentina
Pimelodus albicans	3 ng/g dw	13.8 ng/L	3.3 µg/g of lipid (muscle)						
Oligoscarcus jenynsi	58 ng/g dw	42.3 ng/L	4.1 µg/g of lipid (muscle)						
Carassius auratus, Goldfish			253 mg/kg (whole body)[5]	Mortality, ED50				[51]	L; lethal body burden
			271 mg/kg (whole body)[5]	Mortality, ED50				[51]	L; lethal body burden

Summary of Biological Effects Tissue Concentrations for Total PCBs

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	Sediment	Water	Tissue (Sample Type)	Effects	Log BCF	Log BAF	BSAF	Reference	Comments[3]
			293 mg/kg (whole body)[5]	Mortality, ED50				[51]	L; lethal body burden
			324 mg/kg (whole body)[5]	Mortality, ED50				[51]	L; lethal body burden
			250 mg/kg (whole body)[5]	Mortality, ED50				[51]	L; lethal body burden
			256 mg/kg (whole body)[5]	Mortality, ED50				[51]	L; lethal body burden
			250 mg/kg (whole body)[5]	Behavior, LOED				[51]	L; loss of appetite, lack of coordination
			250 mg/kg (whole body)[5]	Morphology, LOED				[51]	L; color changes
Notemigonvs crysoleucas, Golden shiner	Boshkung Lake: 27.2; 356 (TOC normalized) µg/kg (dw)	0.93 ng/L	5.44,642 (lipid normalized) µg/kg			0.04	1.8	[34,35]	F; six lakes in central Ontario; water samples are filtered samples collected from the water column at 1 m depth; BSF values appear in the BSAF column; BSF was calculated as the concentration of total PCBs (lipid basis) divided by the concentration in surface sediment (organic carbon basis)
	Wood Lake: 15.2; 156 (TOC normalized) µg/kg (dw)	1.85 ng/L	4.25,1170 (lipid normalized) µg/kg			0.04	7.3		
	St. Nora Lake: 12; 227 (TOC normalized) µg/kg (dw)	1.60 ng/L	5.20,683 (lipid normalized) µg/kg			-0.22	3.0		

Summary of Biological Effects Tissue Concentrations for Total PCBs

Species:	**Concentration, Units in[1]:**			**Toxicity:**	**Ability to Accumulate[2]:**			**Source:**	
Taxa	**Sediment**	**Water**	**Tissue (Sample Type)**	**Effects**	**Log BCF**	**Log BAF**	**BSAF**	**Reference**	**Comments[3]**
	Opeongo Lake: 53.9; 546 (TOC normalized) µg/kg (dw)	1.23 ng/L	11.9,482 (lipid normalized) µg/kg			-0.22	0.9		
	Rice Lake:					-0.40	2.9		
	Clear Lake:					-1.00	0.13		
Phoxinus phoxinus, Minnow			1.6 mg/kg (whole body)[5]	Behavior, LOED				[43]	L; changes in feeding behavior
			170 mg/kg (whole body)[5]	Growth, LOED				[43]	L; increased growth
			170 mg/kg (whole body)[5]	Mortality, LOED				[43]	L; doubling of mortality rate compared to controls after 300 days
			15 mg/kg (whole body)[5]	Reproduction, LOED				[43]	L; reduction in time to hatch, fry death
			170 mg/kg (whole body)[5]	Reproduction, NA				[43]	L; 85% reduction in hatchability of eggs

Summary of Biological Effects Tissue Concentrations for Total PCBs

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	**Sediment**	**Water**	**Tissue (Sample Type)**	**Effects**	**Log BCF**	**Log BAF**	**BSAF**	**Reference**	**Comments[3]**
Pimephales notatus, Bluntnose minnow	Boshkung Lake: 27.2; 356 (TOC normalized) µg/kg (dw)	0.93 ng/L	9.78, 1130 (lipid normalized) µg/kg			0.28	3.1	[34,35]	F; six lakes in central Ontario; water samples are filtered samples collected from the water column at 1 m depth; BSF values appear in the BSAF column; BSF was calculated as the concentration of total PCBs (lipid basis) divided by the concentration in surface sediment (organic carbon basis)
	Wood Lake: 15.2; 156 (TOC normalized) µg/kg (dw)	1.85 ng/L	6.24, 446 (lipid normalized) µg/kg			-0.40	2.8		
	St. Nora Lake: 12; 227 (TOC normalized) µg/kg (dw)	1.60 ng/L	10.4, 993 (lipid normalized) µg/kg			-0.22	4.3		
	Opeongo Lake: 53.9; 546 (TOC normalized) µg/kg (dw)	1.23 ng/L	7.96, 893 (lipid normalized) µg/kg			0.08	1.6		
	Scugog Lake:					0.23	13.2		
	Clear Lake:					1.20	13.8		
Lepomis macrochirus, Bluegill			0.6 mg/kg (muscle)[5]	Physiological, ED50				[49]	L; inhibition of Mg-ATPase activity

Summary of Biological Effects Tissue Concentrations for Total PCBs

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	**Sediment**	**Water**	**Tissue (Sample Type)**	**Effects**	**Log BCF**	**Log BAF**	**BSAF**	**Reference**	**Comments[3]**
Morone saxatilis, Striped bass			4.4 mg/kg (whole body)[5]	Growth, NOED				[65]	L; parental exposure to PCBs in field, then post yolk absorption exposure of immature to PCB contaminated brine shrimp; no significant change in growth
Micropterus dolomieu, Smallmouth bass	Boshkung Lake: 27.2; 356 (TOC normalized) µg/kg (dw)	9.3 ng/L	25.5, 2420 (lipid normalized) µg/kg			0.6	6.7	[34,35]	F; seven lakes in central Ontario; water samples are filtered samples collected from the water column at 1 m depth; BSF values appear in the BSAF column; BSF was calculated as the concentration of total PCBs (lipid basis) divided by the concentration in surface sediment (organic carbon basis)
	Wood Lake: 15.2; 156 (TOC normalized) µg/kg (dw)	1.85 ng/L	6.17, 1160 (lipid normalized)µg/kg			0,04	7.3		
	St. Nora Lake: 12; 227 (TOC normalized) µg/kg (dw)	1.60 ng/L	35.4, 2910 (lipid normalized)µg/kg			0.28	12.7		
	Opeongo Lake: 53.9; 546 (TOC normalized) µg/kg (dw)	1.23 ng/L	4.77, 2200 (lipid normalized)µg/kg			0.46	4.0		
	Scugog Lake:					-0.22	5.1		
	Rice Lake:					0.26	15.5		
	Clear Lake:					0.60	3.8		

Summary of Biological Effects Tissue Concentrations for Total PCBs

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	**Sediment**	**Water**	**Tissue (Sample Type)**	**Effects**	**Log BCF**	**Log BAF**	**BSAF**	**Reference**	**Comments[3]**
Perca flavescens, Yellow perch	Boshkung Lake: 27.2; 356 (TOC normalized) µg/kg (dw)	0.93 ng/L	11.4, 4260 (lipid normalized) µg/kg			0.86	11.8	[34,35]	F; seven lakes in central Ontario; water samples are filtered samples collected from the water column at 1 m depth; BSF values appear in the BSAF column; BSF was calculated as the concentration of total PCBs (lipid basis) divided by the concentration in surface sediment (organic carbon basis)
	Wood Lake: 15.2; 156 (TOC normalized) µg/kg (dw)	1.85 ng/L	8.76, 3440 (lipid normalized) µg/kg			0.52	26.8		
	St. Nora Lake: 12; 227 (TOC normalized) µg/kg (dw)	1.60 ng/L	8.43, 3140 (lipid normalized) µg/kg			0.30	13.7		
	Opeongo Lake: 53.9; 546 (TOC normalized) µg/kg (dw)	1.23 ng/L	4.98, 3310 (lipid normalized) µg/kg			0.63	6.0		
	Scugog Lake:					0.52	30		
	Rice Lake:					-0.30	4.4		
	Clear Lake:					0.84	6.6		

Summary of Biological Effects Tissue Concentrations for Total PCBs

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	Sediment	Water	Tissue (Sample Type)	Effects	Log BCF	Log BAF	BSAF	Reference	Comments[3]
Perca fluviatilis, Perch		Surface water: 8.6 ng/L (geometric mean) (4.2-20.8)	825 ng/g (geometric mean) (513-1,244)		3.62			[40]	F; fat % = 2.3, SD = 0.6. Fish and water were sampled in Lake Jarnsjon, Sweden. PCBs in water were measured continuously in summer and autumn (concentration reflects both dissolved and particulate). Ten fish were collected.
Fundulus heteroclitus, Mummichog			10 mg/kg (whole body)[5]	Physiological, LOED				[50]	L; induction of ethoxyresorufin O-deethylase (EROD)
			32 mg/kg (whole body)[5]	Physiological, LOED				[50]	L; induction of cytochrome P4501a
			100 mg/kg (whole body)[5]	Physiological, not applicable				[50]	L; hepatic enzyme induction (P4501 & EROD)
			0.32 mg/kg (whole body)[5]	Physiological, NOED				[50]	L; no induction of hepatic enzymes
			1 mg/kg (whole body)[5]	Physiological, NOED				[50]	L; no induction of hepatic enzymes
			3.2 mg/kg (whole body)[5]	Physiological, NOED				[50]	L; no induction of hepatic enzymes

Summary of Biological Effects Tissue Concentrations for Total PCBs

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	**Sediment**	**Water**	**Tissue (Sample Type)**	**Effects**	**Log BCF**	**Log BAF**	**BSAF**	**Reference**	**Comments[3]**
Platyichthes stellatus, Starry flounder			<0.2 mg/kg (eggs)	Reduced reproductive success				[32]	F; field-collected fish injected with carp pituitary extract to induce final stages of gametogenesand spawning; in the field, the fish were exposed to sediments contaminated with PCBs, DDT, and PAHs
Pleuronectes americanus, Winter flounder			7.1 mg/kg (whole body)[5]	Growth, LOED				[44]	L; reduced length and weight of larvae
Limanda limanda, Dab			0.0181 mg/kg (muscle)[5]	Biochemical, LOED				[62]	L; total cytochrome P450 levels significantly different from control / sum of CB 77,105,118,156)
			0.0181 mg/kg (muscle)[5]	Biochemical, LOED				[62]	L; 7-ethoxyresorutin-O-deethylase (EROD) activity significantly different from control/sum of CB congeners 77, 105, 118, 156)

Summary of Biological Effects Tissue Concentrations for Total PCBs

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	**Sediment**	**Water**	**Tissue (Sample Type)**	**Effects**	**Log BCF**	**Log BAF**	**BSAF**	**Reference**	**Comments[3]**
			0.0181 mg/kg (muscle)[5]	Biochemical, LOED				[62]	L; Cytochrome P4501a (CYPIA) levels significantly different from control/sum of CB congeners77, 105, 118, 156)
Wildlife									
Haliaeetus leucocephalus, Bald eagle			fish tissue (diet in natural system): interior fish = 0.2 mg/kg shoreline fish =2.1 mg/kg	NOAEC at 4.0 mg/kg (egg), 0.14 mg/kg (fish); egg lethality from diet of interior fish at 0.2 mg/kg, shoreline fish at 2.1 mg/kg				[10]	F

Summary of Biological Effects Tissue Concentrations for Total PCBs

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	Sediment	Water	Tissue (Sample Type)	Effects	Log BCF	Log BAF	BSAF	Reference	Comments[3]
Agelaius phoeniceus, Red-winged blackbird (eggs)	7.4 ng/g TOC=2.5%		223.5 ng/g				16.4	[41]	F; Great Lakes/St. Lawrence River basin; 12 wetlands sites; sediment concentration reported as wet weight concentration which may be a typographical error
	32.6 ng/g TOC=21.0%		50.1 ng/g				5.8		
	68.2 ng/g TOC=7.5%		54.6 ng/g				6.0		
	147.7 ng/g TOC=12%		52.7 ng/g				4.2		
	28.1 ng/g TOC-18.5%		163.5 ng/g				22.4		
	144.1 ng/g TOC=11.5%		247.8 ng/g				6.6		
	2.3 ng/g TOC-10.5%		105.9 ng/g				102.8		
	2.9 ng/g TOC=13.8%		64.9 ng/g				64.4		
	8.0 ng/g TOC=11.1%		108.3 ng/g				31.3		
	11.1 ng/g TOC-23.9%		81.8 ng/g				38.3		
Tachycineta bicolor, Tree swallow (nestlings)	144.1 ng/g TOC=11.5%		(whole body minus feet, beak, wings, and feathers)				9.5	[41]	F; Great Lakes/St. Lawrence River basin; 12 wetlands sites; sediment concentration reported as wet weight concentration which may be a typographical error
	2.9 ng/g TOC=13.8%		754.5 ng/g 11.2 ng/g				6.7		
(eggs)	144.1 ng/g TOC=11.5%		1,019.7 ng/g				15.2		
	2.9 ng/g TOC=13.8%		254.6 ng/g				133.1		

Summary of Biological Effects Tissue Concentrations for Total PCBs

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	Sediment	Water	Tissue (Sample Type)	Effects	Log BCF	Log BAF	BSAF	Reference	Comments[3]
Mustela vison, Ranch mink, (fed PCB-contaminated *Cyprinus carpio* carp)			NOAEL (control group) 0.09 µg PCBs/g liver tissue <5.00 pg TEQ/g liver tissue LOAEL (10% carp in diet group) 2.19 µg PCBs/g liver tissue 496 pg TEQ/g liver tissue	In general, carp diets caused impaired reproduction and/or reduced survival of kits; compared to controls. Kits body weight was significantly reduced in the 20 and 40% carp groups; kit body weight and survival in the 10 and 20% carp groups were significantly reduced at three and six weeks of age. Females fed 40% carp whelped the fewest number of kits, all of which were stillborn or died within 24 hours. Weight of kits and % kit survival to age 6 weeks were inversely proportional to % carp in mothers'diets; physical abnormalities and a dose-related decrease in relative organ weights were also observed in kits				[43]	L; concentration of total PCBs in carp /percent carp in diet per treatment group: 0.015 mg-PCBs/kg-diet/0% 0.72 mg-PCBs/kg-diet/10% 1.53 mg-PCBs/kg-diet/20% 2.56 mg-PCBs/kg-diet/40%; carp also contained 2,3,7,8-TCDD with resulting diet concentrations of 1.03, 19.41, 40.02, and 80.76 ng-TEQs/kg diet in the 0, 10, 20, and 40% diet exposures; mink exposed prior to and throughout reproductive period

[1] Concentration units based on wet weight unless otherwise noted.
[2] BCF = bioconcentration factor, BAF = bioaccumulation factor, BSAF = biota-sediment accumulation factor.
[3] L = laboratory study, spiked sediment, single chemical; F = field study, multiple chemical exposure; other unusual study conditions or observations noted.
[4] Wet weight calculated assuming a dry weight of 25% of the total weight in paper.
[5] This entry was excerpted directly from the Environmental Residue-Effects Database (ERED, www.wes.army.mil/el/ered, U.S. Army Corps of Engineers and U.S. Environmental Protection Agency). The original publication was not reviewed, and the reader is strongly urged to consult the publication to confirm the information presented here.

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Chemical Category: PESTICIDE (ORGANOCHLORINE)

Chemical Name (Common Synonyms): TOXAPHENE **CASRN:** 8001-35-2

Chemical Characteristics

Solubility in Water: 3.0 mg/L at room temperature [1].

Half-Life: No data [2]

Log K_{ow}: 5.50 [3]

Log K_{oc}: 5.41 L/kg organic carbon

Human Health

Oral RfD: 3.6 x 10^{-4} mg/kg/day [4]

Confidence: Not available, uncertainty factor = 100.

Critical Effect: Hepatocellular tumors in mice and thyroid tumors in rats

Oral Slope Factor: 1.1 x 10^{+0} per(mg/kg)/day [5]

Carcinogenic Classification: B2 [5]

Wildlife

Partitioning Factors: Partitioning factors for toxaphene in wildlife were not found in the literature.

Food Chain Multipliers: Food chain multipliers for toxaphene in wildlife were not found in the literature.

Aquatic Organisms

Partitioning Factors: Toxaphene is a complex mixture of more than 180 chlorinated bornanes. The composition of toxaphene which changes markedly appears to be caused by chemical transformation processes [6]. Toxaphene persistence and degradation in water and biota is modified by numerous and disparate biological and abiotic factors [7]. In lakes, toxaphene persistence was related to depth, stratification, and turnover. Toxaphene can persist in water from several months to more than nine years [8]. Log BCFs for toxaphone ranged from 3.52 for white mullet [10] to 4.72 for fathead minnow [7], as reported in the following table.

Food Chain Multipliers: Biomagnification of toxaphene was demonstrated in 16 species collected in lakes in northeastern Louisiana [9]. The highest residues (1.7 to 5.5 mg/kg ww) were measured among tertiary consumers, such as green-backed heron, spotted gar, and largemouth bass. Secondary consumers (bluegill, blacktail shiner) contained lower toxaphene residues (0.9 to 1.2 mg/kg ww), whereas primary consumers, including crayfish and shad, contained lowest levels (0.6 to 1.0 mg/kg ww).

Toxicity/Bioaccumulation Assessment Profile

Since toxaphene represents a complex mixture of nearly 200 compounds, it is difficult to relate observed toxicity to a specific complex of toxaphene compounds. Fewer than 6 percent of the total number of toxaphene components have been isolated and individually examined for toxicity [10]. Isensee et al. [11] separated toxaphene into nine fractions on a silica gel column. Only the first two fractions and last two fractions revealed reduced toxicity compared with the unfractionated toxaphene, while the middle five fractions were as toxic as or more toxic than the original pesticide. Although chlorinated hydrocarbons have low solubility in water, they are readily absorbed by oils, waxes, and fats [12]. Therefore, toxaphene is generally more toxic to aquatic organisms than are other insecticides and herbicides. Acute toxicity for freshwater fish species range from 3 to 50 µg/L [13]. A concentration as low as 5 µg/L toxaphene can reduce a population of small fish in lakes without affecting the population of large fish [14]. Freshwater fishes of the Arroyo Colorado accumulated up to 31.5 mg/kg wet weight while fish-eating birds contained only up to 3 mg/kg of toxaphene [15]. Unlike fishes, avian species readily metabolize and excrete toxaphene.

Toxaphene compounds have been found in environmental samples and tissues in the Canadian Northern Territories. The toxicity of toxaphene components present in fish and mammals from Yukon Territory is unknown [16]. Toxaphene components are present in northern animals in concert with a suite of other organic contaminants, but neither the risks to the animals bearing the residues nor the risks to people consuming the animals are known.

Summary of Biological Effects Tissue Concentrations for Toxaphene

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	**Sediment**	**Water**	**Tissue (Sample Type)**	**Effects**	**Log BCF**	**Log BAF**	**BSAF**	**Reference**	**Comments[3]**
Invertebrates									
Crassostrea virginica, Eastern oyster					4.52			[7]	F
Crassostrea virginica, Eastern oyster			85 mg/kg (whole body)[4]	Growth, ED27				[18]	L; tissue analyses on survivors
			47 mg/kg (whole body)[4]	Growth, ED34				[18]	L; tissue analyses on survivors
			199 mg/kg (whole body)[4]	Growth, ED64				[18]	L; tissue analyses on survivors
			409 mg/kg (whole body)[4]	Growth, ED96				[18]	L; tissue analyses on survivors
Palaemonetes pugio, Grass shrimp			2.7 mg/kg (whole body)[4]	Mortality, ED25				[18]	L; tissue analyses on survivors
			3.3 mg/kg (whole body)[4]	Mortality, ED53				[18]	L; tissue analyses on survivors
			9.7 mg/kg (whole body)[4]	Mortality, ED68				[18]	L; tissue analyses on survivors

Summary of Biological Effects Tissue Concentrations for Toxaphene

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	**Sediment**	**Water**	**Tissue (Sample Type)**	**Effects**	**Log BCF**	**Log BAF**	**BSAF**	**Reference**	**Comments[3]**
			4.8 mg/kg (whole body)[4]	Mortality, ED70				[18]	L; tissue analyses on survivors
			8.1 mg/kg (whole body)[4]	Mortality, ED75				[18]	L; tissue analyses on survivors
Penaeus duorarum, Pink shrimp			0.36 mg/kg (whole body)[4]	Mortality, ED15				[18]	L; tissue analyses on survivors
			0.54 mg/kg (whole body)[4]	Mortality, ED20				[18]	L; tissue analyses on survivors
			0.83 mg/kg (whole body)[4]	Mortality, ED65				[18]	L; tissue analyses on survivors
			1.7 mg/kg (whole body)[4]	Mortality, ED90				[18]	L; tissue analyses on survivors
Fishes									
Salvelinus fontinalis, Brook trout					4.00			[7]	F

Summary of Biological Effects Tissue Concentrations for Toxaphene

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	**Sediment**	**Water**	**Tissue (Sample Type)**	**Effects**	**Log BCF**	**Log BAF**	**BSAF**	**Reference**	**Comments[3]**
Salvelinus fontinalis, Brook trout			1 mg/kg (whole body)[4]	Development, LOED				[21]	L; backbone development adversely affected, collagen content decreased
			3.7 mg/kg (whole body)[4]	Development, LOED				[21]	
			0.4 mg/kg (whole body)[4]	Growth, LOED				[21]	L; reduced growth of fry
			0.6 mg/kg (whole body)[4]	Growth, LOED				[21]	
			9.2 mg/kg (whole body)[4]	Development, NA				[21]	L; backbone development adversely affected, collagen content decreased
			38 mg/kg (whole body)[4]	Development, NA				[21]	L; backbone development adversely affected, collagen content decreased
			4.5 mg/kg (whole body)[4]	Development, NA				[21]	

Summary of Biological Effects Tissue Concentrations for Toxaphene

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	Sediment	Water	Tissue (Sample Type)	Effects	Log BCF	Log BAF	BSAF	Reference	Comments[3]
			18 mg/kg (whole body)[4]	Development, NA				[21]	L; backbone development adversely affected, collagen content decreased
			2.2 mg/kg (whole body)[4]	Development, NA				[21]	
			8.3 mg/kg (whole body)[4]	Development, NA				[21]	
			1.8 mg/kg (whole body)[4]	Growth, NA				[21]	L; reduced growth of fry
			2.6 mg/kg (whole body)[4]	Growth, NA				[21]	L; reduced growth of fry
			0.9 mg/kg (whole body)[4]	Growth, NA				[21]	
			1.4 mg/kg (whole body)[4]	Growth, NA				[21]	
			0.2 mg/kg (whole body)[4]	Development, NOED				[21]	L; no effect on backbone development
			2.6 mg/kg (whole body)[4]	Development, NOED				[21]	
Pimephales promelas, Fathead minnow					52000			[7]	F

Summary of Biological Effects Tissue Concentrations for Toxaphene

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	**Sediment**	**Water**	**Tissue (Sample Type)**	**Effects**	**Log BCF**	**Log BAF**	**BSAF**	**Reference**	**Comments[3]**
Pimephales promelas, Fathead minnow			5.9 mg/kg (whole body)[4]	Development, LOED				[20]	L; significant reduction in bone development, bone collagen in 150 days
			5.9 mg/kg (whole body)[4]	Growth, LOED				[20]	L; significant reduction in growth, both length and weight
			52 mg/kg (whole body)[4]	Mortality, LOED				[20]	L; increased mortality after 150 days
			13 mg/kg (whole body)[4]	Development, NA				[20]	L; significant reduction in bone development, bone collagen in 150 days
			22 mg/kg (whole body)[4]	Development, NA				[20]	
			52 mg/kg (whole body)[4]	Development, NA				[20]	
			13 mg/kg (whole body)[4]	Growth, NA				[20]	L; significant reduction in growth, both length and weight

Summary of Biological Effects Tissue Concentrations for Toxaphene

Species:	**Concentration, Units in[1]:**			**Toxicity:**	**Ability to Accumulate[2]:**			**Source:**	
Taxa	**Sediment**	**Water**	**Tissue (Sample Type)**	**Effects**	**Log BCF**	**Log BAF**	**BSAF**	**Reference**	**Comments[3]**
			22 mg/kg (whole body)[4]	Growth, NA				[20]	L; significant reduction in growth, both length and weight
			52 mg/kg (whole body)[4]	Growth, NA				[20]	L; significant reduction in growth, both length and weight
Cyprinodon variegatus, Sheepshead minnow					4.32-4.49			[17]	L
Cyprinodon variegatus, Sheepshead minnow			4.1 mg/kg (whole body)[4]	Mortality, ED25				[18]	L; tissue analyses on survivors
			35 mg/kg (whole body)[4]	Mortality, ED85				[18]	L; tissue analyses on survivors
			2.4 mg/kg (whole body)[4]	Mortality, NOED				[18]	L; tissue analyses on survivors
Cyprinodon variegatus, Sheepshead minnow			10 mg/kg (whole body)[4]	Behavior, LOED				[22]	L; decreased swimming activity

Summary of Biological Effects Tissue Concentrations for Toxaphene

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	**Sediment**	**Water**	**Tissue (Sample Type)**	**Effects**	**Log BCF**	**Log BAF**	**BSAF**	**Reference**	**Comments[3]**
			36 mg/kg (whole body)[4]	Behavior, NA				[22]	L; decreased swimming activity
			36 mg/kg (whole body)[4]	Mortality, NA				[22]	L; 90% mortality in 28 days
			10 mg/kg (whole body)[4]	Mortality, NOED				[22]	L; no effect on mortality
Fundulus similis, Longnose killifish					4.59			[17]	L
Fundulus similis, Longnose killifish			19.3 mg/kg (whole body)[4]	Mortality, ED15				[18]	L; fish are fry (test 2)
			10 mg/kg (whole body)[4]	Mortality, ED17				[18]	L; fish are fry (test 1)
			0.9 mg/kg (whole body)[4]	Mortality, ED25				[18]	L; fish are adults
			46.6 mg/kg (whole body)[4]	Mortality, ED35				[18]	L; fish are fry (test 2)
			24.7 mg/kg (whole body)[4]	Mortality, ED35				[18]	L; fish are juveniles
			34 mg/kg (whole body)[4]	Mortality, ED53				[18]	L; fish are fry (test 1)

Summary of Biological Effects Tissue Concentrations for Toxaphene

Species:	**Concentration, Units in[1]:**			**Toxicity:**	**Ability to Accumulate[2]:**			**Source:**	
Taxa	**Sediment**	**Water**	**Tissue (Sample Type)**	**Effects**	**Log BCF**	**Log BAF**	**BSAF**	**Reference**	**Comments[3]**
			102 mg/kg (whole body)[4]	Mortality, ED95				[18]	L; fish are juveniles
			0.5 mg/kg (whole body)[4]	Mortality, NOED				[18]	L; fish are adults
			8 mg/kg (whole body)[4]	Mortality, NOED				[18]	L; fish are fry (test 1)
			8.8 mg/kg (whole body)[4]	Mortality, NOED				[18]	L; fish are fry (test 2)
Leiostomus xanthurus, Spot		0.7 µg/L	2.9 µg/g wet wt		3.61			[10]	L
		0.8 µg/L	0.9 µg/g wet wt					[10]	L
		2.4 µg/L	8.4 µg/g wet wt					[10]	L
Mugil curema, White mullet		0.7 µg/L	4.0 µg/g wet wt		3.76			[10]	L
		0.8 µg/L	2.6 µg/g wet wt		3.52			[10	L
		2.4 µg/L	10.4 µg/g wet wt		3.63			[10]	L
		4.1 µg/L	27.0 µg/g wet wt		3.82			[10]	L
Lagodon rhomboides, Pinfish			1.9 mg/kg (whole body)[4]	Mortality, ED25				[18]	L; tissue analyses on survivors

Summary of Biological Effects Tissue Concentrations for Toxaphene

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	Sediment	Water	Tissue (Sample Type)	Effects	Log BCF	Log BAF	BSAF	Reference	Comments[3]
			1.6 mg/kg (whole body)[4]	Mortality, NOED				[18]	L; tissue analyses on survivors
Ictalurus punctatus, Channel catfish			1.2 mg/kg (whole body)[4]	Cellular, LOED				[19]	L; skin and liver lesions
			1.8 mg/kg (whole body)[4]	Growth, LOED				[19]	L; reduction in growth
			1.2 mg/kg (whole body)[4]	Physiological, LOED				[19]	L; hepatic enzyme induction
			0.8 mg/kg (whole body)[4]	Cellular, NA				[19]	L; skin and liver lesions
			1.8 mg/kg (whole body)[4]	Cellular, NA				[19]	L; skin and liver lesions
			14 mg/kg (whole body)[4]	Cellular, NA				[19]	L; skin and liver lesions
			5.4 mg/kg (whole body)[4]	Cellular, NA				[19]	L; skin and liver lesions
			14 mg/kg (whole body)[4]	Growth, NA				[19]	L; reduction in growth
			5.4 mg/kg (whole body)[4]	Growth, NA				[19]	L; reduction in growth

Summary of Biological Effects Tissue Concentrations for Toxaphene

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	Sediment	Water	Tissue (Sample Type)	Effects	Log BCF	Log BAF	BSAF	Reference	Comments[3]
			0.8 mg/kg (whole body)[4]	Physiological, NA				[19]	L; hepatic enzyme induction
			1.8 mg/kg (whole body)[4]	Physiological, NA				[19]	L; hepatic enzyme induction
			14 mg/kg (whole body)[4]	Physiological, NA				[19]	L; hepatic enzyme induction
			5.4 mg/kg (whole body)[4]	Physiological, NA				[19]	L; hepatic enzyme induction
			1.2 mg/kg (whole body)[4]	Growth, NOED				[19]	L; no effect on growth
			0.8 mg/kg (whole body)[4]	Growth, NOED				[19]	L; no effect on growth

1 Concentration units based on wet weight unless otherwise noted.
2 BCF = bioconcentration factor, BAF = bioaccumulation factor, BSAF = biota-sediment accumulation factor.
3 L = laboratory study, spiked sediment, single chemical; F = field study, multiple chemical exposure; other unusual study conditions or observations noted.
4 This entry was excerpted directly from the Environmental Residue-Effects Database (ERED, www.wes.army.mil/el/ered, U.S. Army Corps of Engineers and U.S. Environmental Protection Agency). The original publication was not reviewed, and the reader is strongly urged to consult the publication to confirm the information presented here.

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Chemical Category: METAL

Chemical Name (Common Synonyms): ZINC **CASRN:** 7440-66-6

Chemical Characteristics

Solubility in Water: Insoluble [1] **Half-Life:** Not applicable, stable [1]

Log K_{ow}: — **Log K_{oc}:** —

Human Health

Oral RfD: 3×10^{-1} mg/kg/day [2] **Confidence:** Medium, uncertainty factor = 3

Critical Effect: 47 percent decrease in erythrocyte superoxide dismutase concentration, also decreased serum ferritin and hematocrit values, in adult human females after 10 weeks of zinc exposure; lowered HDL-cholesterol values in human males after several weeks of zinc exposure

Oral Slope Factor: No data [2] **Carcinogenic Classification:** D [2]

Wildlife

Partitioning Factors: Partitioning factors for zinc in wildlife were not found in the literature.

Food Chain Multipliers: Food chain multipliers for zinc in wildlife were not found in the literature.

Aquatic Organisms

Partitioning Factors: Zinc in the water column can partition to dissolved and particulate organic carbon. Water hardness (i.e., calcium concentration), pH, and metal speciation are important factors in controlling the water column concentrations of zinc since the divalent zinc ion is believed to be responsible for observed biological effects [17]. Bioavailability of zinc in sediments is controlled by the AVS concentration [18].

Food Chain Multipliers: Most studies reviewed contained data which suggest that zinc is not a highly mobile element in aquatic food webs, and there appears to be little evidence to support the general occurrence of biomagnification of zinc within marine or freshwater food webs [3]. A log biomagnification factor of 2.90 was determined for the midge *Chironomus riparius* [3].

Toxicity/Bioaccumulation Assessment Profile

Zinc does not appear to be a highly mobile element under typical conditions in most aquatic habitats. Tissue residue-toxicity relationships can also be variable because organisms sequester metals in different forms that are measurable as tissue residue but can actually be stored in unavailable forms within the organism as a form of detoxification [4,5]. Whole-body residues also might not be indicative of effects concentrations at the organ level because concentrations in target organs, such as the kidneys and liver, can be 20 times greater than whole body residues [6]. The application of "clean" chemical analytical and sample preparation techniques is also critical in the measurement of metal tissue residues. After evaluating the effects of sample preparation techniques on measured concentrations of metals in the edible tissue of fish, Schmitt and Finger [7] concluded that there was little direct value in measuring copper, zinc, iron, or manganese tissue residues in fish because they do not bioaccumulate to any appreciable extent. It has also been suggested that there is no compelling evidence to support inordinate concern about zinc as a putative toxic agent in the environment, and in fact there is considerable evidence that zinc deficiency is a serious, worldwide human health problem that outweighs the potential problems associated with accidental, self-imposed, or environmental exposure to zinc excess [8].

Summary of Biological Effects Tissue Concentrations for Zinc

Species:	**Concentration, Units in[1]:**			**Toxicity:**	**Ability to Accumulate[2]:**			**Source:**	
Taxa	**Sediment**	**Water**	**Tissue (Sample Type)**	**Effects**	**Log BCF**	**Log BAF**	**BSAF**	**Reference**	**Comments[3]**
Invertebrates									
Invertebrates, field-collected	Total SEM µg/g µg/g							[9]	F
	10,100 8,873	18900 µg/L	1665 µg/g						
	911 700	1180 µg/L	304 µg/g						
	631 408	187 µg/L	293 µg/g						
	734 562	189 µg/L	453 µg/g						
	365 294	132 µg/L	359 µg/g						
	29 <15	<70 µg/L	212 µg/g						
Tubificidae, Oligochaete worm	2,560 µg/g		203.1 mg/g					[10]	F
	1,110 µg/g		113.9 mg/g						
	3,180 µg/g		264.1 mg/g						
	3,210 µg/g		393.4 mg/g						
	2,550 µg/g		256.6 mg/g						
Nereis diversicolor, Polychaete worm	339 µg/g		199 µg/g					[11]	F
	140 µg/g		163 µg/g						
	99 µg/g		176 µg/g						
	122 µg/g		155 µg/g						
	518 µg/g		185 µg/g						
	532 µg/g		194 µg/g						
	2,237 µg/g								

Summary of Biological Effects Tissue Concentrations for Zinc

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	**Sediment**	**Water**	**Tissue (Sample Type)**	**Effects**	**Log BCF**	**Log BAF**	**BSAF**	**Reference**	**Comments[3]**
Elliptio complanata, Freshwater mussel	1.5-78.4 µg/g		127 µg/g (foot) 83 µg/g (muscle) 78 µg/g (visceral) 123 µg/g, (hepato-pancreas) 265 µg/g (gills) 173 µg/g (mantle)					[12]	F
	19.1-342 µg/g		144 µg/g (foot) 88 µg/g (muscle) 90 µg/g (visceral) 119 µg/g (hepato-pancreas) 790 µg/g (gills) 275 µg/g (mantle)					[12]	F
	16-433 µg/g		148 µg/g (foot) 119 µg/g (visceral) 208 µg/g (hepato-pancreas) 1360 µg/g (gills) 1190 µg/g (mantle)					[12]	F
Mytilus edulis, Mussel			130 mg/kg (whole body)[4]	Mortality, ED100				[21]	L; 100% mortality in 14 days
Mytilus galloprovincialis, Mussel			14 -20 mg/kg				0.145	[19]	F

Summary of Biological Effects Tissue Concentrations for Zinc

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	Sediment	Water	Tissue (Sample Type)	Effects	Log BCF	Log BAF	BSAF	Reference	Comments[3]
Dreissena polymorpha, Zebra mussel			21.6 mg/kg (whole body)[4]	Physiological, NOED				[25]	L; no effect on internal zinc regulatory process
			600 mg/kg (whole body)[4]	Mortality, LOED				[26]	L; increased mortality
			130 mg/kg (whole body)[4]	Physiological, LOED				[26]	L; reduced filtration rate
			600 mg/kg (whole body)[4]	Physiological, NA				[26]	L; reduced filtration rate
			22 mg/kg (whole body)[4]	Growth, NOED				[26]	L; no effect on weight gain of surviving mussels
			40 mg/kg (whole body)[4]	Growth, NOED				[26]	L; no effect on weight gain of surviving mussels
			46 mg/kg (whole body)[4]	Growth, NOED				[26]	L; no effect on weight gain of surviving mussels
			130 mg/kg (whole body)[4]	Growth, NOED				[26]	L; no effect on weight gain of surviving mussels
			600 mg/kg (whole body)[4]	Growth, NOED				[26]	L; no effect on weight gain of surviving mussels
			22 mg/kg (whole body)[4]	Mortality, NOED				[26]	L; no effect on mortality

Summary of Biological Effects Tissue Concentrations for Zinc

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	Sediment	Water	Tissue (Sample Type)	Effects	Log BCF	Log BAF	BSAF	Reference	Comments[3]
			40 mg/kg (whole body)[4]	Mortality, NOED				[26]	L; no effect on mortality
			46 mg/kg (whole body)[4]	Mortality, NOED				[26]	L; no effect on mortality
			130 mg/kg (whole body)[4]	Mortality, NOED				[26]	L; no effect on mortality
			22 mg/kg (whole body)[4]	Physiological, NOED				[26]	L; no effect on filtration rate
			40 mg/kg (whole body)[4]	Physiological, NOED				[26]	L; no effect on filtration rate
			46 mg/kg (whole body)[4]	Physiological, NOED				[26]	L; no effect on filtration rate
Daphnia magna, Cladoceran			1340 mg/kg (whole body)[4]	Reproduction, ED10				[13]	L; 10% reduction in number of offspring
			2690 mg/kg (whole body)[4]	Mortality, ED50				[13]	L; lethal body burden after 21-day exposure
Hyallella azteca, Amphipod		13.0 µg/L 21.2 µg/L 42.3 µg/L 185 µg/L 316 µg/L	66 µg/g 85 µg/g 126 µg/g 136 µg/g 167 µg/g 167 µg/g	50% survival 56% survival 51% survival 35% survival 6% survival 3% survival				[14]	L

Summary of Biological Effects Tissue Concentrations for Zinc

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	Sediment	Water	Tissue (Sample Type)	Effects	Log BCF	Log BAF	BSAF	Reference	Comments[3]
	Total SEM µg/g µg/g 10100 8873 911 700 631 408 734 562 365 294 29 <15	 18900 µg/L 1180 µg/L 187 µg/L 189 µg/L 132 µg/L <70 µg/L	 259 µg/g 106 µg/g 80 µg/g 79 µg/g 74 µg/g 56 µg/g					[9]	F
			71.4 mg/kg (whole body)[4]	Mortality, NA				[21]	L; 7.5% mortality in 14 days
Balanus crenatus, Barnacle			3200 mg/kg (whole body)[4]	Behavior, NOED				[28]	L; regulation of metals endpoint - winter experiment
Chironomus riparius, Midge		0.9 mg/L	710 µg/g					[3]	L
Chironomus gr. thummi, Midge			42.89 mg/kg 16.22 mg/kg	Normal larvae Deformed larvae				[15]	L
			61.6 mg/kg (whole body)[4]	Morphology, NOED				[24]	L; 4th instar larvae

Summary of Biological Effects Tissue Concentrations for Zinc

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	Sediment	Water	Tissue (Sample Type)	Effects	Log BCF	Log BAF	BSAF	Reference	Comments[3]
Fishes									
Oncorhynchus mykiss, Rainbow trout			40 mg/kg (whole body)[4]	Physiological, LOED				[20]	L; induction of metallothionein
Salvelinus fontinalis, Brook trout			22.6 mg/kg (whole body)[4]	Reproduction, LOED				[23]	L; reduction in percentage of eggs hatching in second generation trout
			30 mg/kg (gill)[4]	Growth, NOED				[23]	L; no effect on growth
			30 mg/kg (gill)[4]	Growth, NOED				[23]	L; no effect on growth
			30 mg/kg (gill)[4]	Growth, NOED				[23]	L; no effect on growth
			50 mg/kg (liver)[4]	Mortality, NOED				[23]	L; no effect on survival
			50 mg/kg (liver)[4]	Mortality, NOED				[23]	L; no effect on survival
			50 mg/kg (liver)[4]	Mortality, NOED				[23]	L; no effect on survival
			7 mg/kg (kidney)[4]	Reproduction, NOED				[23]	L; no effect on number of eggs produced

Summary of Biological Effects Tissue Concentrations for Zinc

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	Sediment	Water	Tissue (Sample Type)	Effects	Log BCF	Log BAF	BSAF	Reference	Comments[3]
			7 mg/kg (kidney)[4]	Reproduction, NOED				[23]	L; no effect on number of eggs produced
			7 mg/kg (kidney)[4]	Reproduction, NOED				[23]	L; no effect on number of eggs produced
			19.3 mg/kg (whole body)[4]	Reproduction, NOED				[23]	L; no reduction in percentage of eggs hatching in second generation trout
			15.3 mg/kg (whole body)[4]	Reproduction, NOED				[23]	L; no reduction in percentage of eggs hatching in second generation trout
			6.7 mg/kg (whole body)[4]	Reproduction, NOED				[23]	L; no reduction in percentage of eggs hatching in second generation trout
Salvelinus namaycush, Lake trout			6 cpm/g (whole) 17 cpm/g (spleen) 30 cpm/g (liver) 21 cpm/g (kidney) 9 cpm/g (brain) 32 cpm/g (gonad) 4 cpm/g (muscle) 8 cpm/g (blood) 11 cpm/g (gill) 80 cpm/g (gut)					[16]	F

Summary of Biological Effects Tissue Concentrations for Zinc

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	Sediment	Water	Tissue (Sample Type)	Effects	Log BCF	Log BAF	BSAF	Reference	Comments[3]
Salmo salar, Atlantic Salmon			60 mg/kg (whole body)[4]	Physiological, LOED				[22]	L; reduced caloric content of fish
			60 mg/kg (whole body)[4]	Growth, NOED				[22]	L; no effect on growth
			42 mg/kg (whole body)[4]	Growth, NOED				[22]	L; no effect on growth
			37 mg/kg (whole body)[4]	Growth, NOED				[22]	L; no effect on survivorship
			60 mg/kg (whole body)[4]	Mortality, NOED				[22]	L; no effect on survivorship
			42 mg/kg (whole body)[4]	Mortality, NOED				[22]	L; no effect on survivorship
			37 mg/kg (whole body)[4]	Mortality, NOED				[22]	L; no effect on survivorship
			42 mg/kg (whole body)[4]	Physiological, NOED				[22]	L; no effect on caloric content of fish
			37 mg/kg (whole body)[4]	Physiological, NOED				[22]	L; no effect on caloric content of fish

Summary of Biological Effects Tissue Concentrations for Zinc

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	**Sediment**	**Water**	**Tissue (Sample Type)**	**Effects**	**Log BCF**	**Log BAF**	**BSAF**	**Reference**	**Comments[3]**
Pimephales promelas, Fathead minnow	770 µg/g 2560 µg/g 1110 µg/g 2180 µg/g 3180 µg/g 3210 µg/g 3120 µg/g 2550 µg/g 2050 µg/g		320.0 mg/g 251.5 mg/g 300.2 mg/g 268.3 mg/g 402.0 mg/g 264.6 mg/g 378.8 mg/g 366.8 mg/g 333.0 mg/g 314.7 mg/g					[10]	F
Jordanella floridae, American flagfish			50 mg/kg (whole body)[4]	Mortality, LOED				[29]	L; body burden estimated from graph
			58 mg/kg (whole body)[4]	Growth, NOED				[29]	L; body burden estimated from graph
			50 mg/kg (whole body)[4]	Mortality, NOED				[29]	L; body burden estimated from graph
			58 mg/kg (whole body)[4]	Reproduction, NOED				[29]	L; body burden estimated from graph
			220 mg/kg (whole body)[4]	Growth, LOED				[30]	L; body burden estimated from graph, total length of females

Summary of Biological Effects Tissue Concentrations for Zinc

Species:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	**Sediment**	**Water**	**Tissue (Sample Type)**	**Effects**	**Log BCF**	**Log BAF**	**BSAF**	**Reference**	**Comments[3]**
			300 mg/kg (whole body)[4]	Growth, LOED				[30]	L; body burden estimated from graph, total length of males
			220 mg/kg (whole body)[4]	Mortality, LOED				[30]	L; body burden estimated from graph
			230 mg/kg (whole body)[4]	Growth, NOED				[30]	L; body burden estimated from graph, total length of males
			190 mg/kg (whole body)[4]	Growth, NOED				[30]	L; body burden estimated from graph, total length of females
			300 mg/kg (whole body)[4]	Mortality, NOED				[30]	L; body burden estimated from graph
			220 mg/kg (whole body)[4]	Mortality, NOED				[30]	L; body burden estimated from graph
Poecilia reticulata, Guppy			0.284 mg/kg (whole body)[4]	Mortality, NOED				[27]	L

[1] Concentration units based on wet weight unless otherwise noted.
[2] BCF = bioconcentration factor, BAF = bioaccumulation factor, BSAF = biota-sediment accumulation factor.

[3] L = laboratory study, spiked sediment, single chemical; F = field study, multiple chemical exposure; other unusual study conditions or observations noted.

[4] This entry was excerpted directly from the Environmental Residue-Effects Database (ERED, www.wes.army.mil/el/ered, U.S. Army Corps of Engineers and U.S. Environmental Protection Agency). The original publication was not reviewed, and the reader is strongly urged to consult the publication to confirm the information presented here.

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