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	0.00008		0.0001						
virginica,	0.00008		0.0002						
Eastern oyster	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,	0.001		0.216						
Baltic macoma	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 x 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:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	Sediment	Water	Tissue (Sample Type)	Effects	Log BCF	Log BAF	BSAF	Reference	Comments[3]
			4.22 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: 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]
			0.54 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			Day 30:	Mortality:				[6]	L
		0.16 mg/L	3.0 µg/g	10%					
		0.33 mg/L	3.5 µg/g	20%					
		0.64 mg/L	4.0 µg/g	40%					
		1.12 mg/L	7.0 µg/g	55%					
		2.80 mg/L	14.3 µg/g	88%					
			Day 60:						
		0.16 mg/L	2.8 µg/g	10%					
		0.33 mg/L	4.1 µg/g	22%					
		0.64 mg/L	5.0 µg/g	52%					
		1.12 mg/L	9.7 µg/g	70%					
		2.80 mg/L	–	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					[8]	L
			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						
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:	Concentration, 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									
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: Taxa	Concentration, Units in[1]: Sediment	Water	Tissue (SampleType)	Toxicity: Effects	Ability to Accumulate[2]: Log BCF	Log BAF	BSAF	Source: 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: Taxa	Concentration, Units in[1]: Sediment	Water	Tissue (SampleType)	Toxicity: Effects	Ability to Accumulate[2]: Log BCF	Log BAF	BSAF	Source: 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: Taxa	Concentration, Units in[1]: Sediment	Water	Tissue (SampleType)	Toxicity: Effects	Ability to Accumulate[2]: Log BCF	Log BAF	BSAF	Source: Reference	Comments[3]
	0.02 µg/g dw	15 ±12 ng/L[4]	0.24 µg/g† (soft tissue)	Shell thickness index = 9.00; $\bar{x}$ 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; $\bar{x}$ 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; $\bar{x}$ 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; $\bar{x}$ 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; $\bar{x}$ 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; $\bar{x}$ 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; $\bar{x}$ 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; $\bar{x}$ 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; $\bar{x}$ 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; $\bar{x}$ 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; $\bar{x}$ 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; $\bar{x}$ 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:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	**Sediment**	**Water**	**Tissue (SampleType)**	**Effects**	**Log BCF**	**Log BAF**	**BSAF**	**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: Taxa	Concentration, Units in[1]: Sediment	Water	Tissue (SampleType)	Toxicity: Effects	Ability to Accumulate[2]: Log BCF	Log BAF	BSAF	Source: 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]	Histopatho- logical 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 pseudobranch- ial 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]	Histopatho-logical 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 pseudobranch-ial 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: Taxa	Concentration, Units in[1]: Sediment	Water	Tissue (SampleType)	Toxicity: Effects	Ability to Accumulate[2]: Log BCF	Log BAF	BSAF	Source: 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: Taxa	Concentration, Units in[1]: Sediment	Water	Tissue (SampleType)	Toxicity: Effects	Ability to Accumulate[2]: Log BCF	Log BAF	BSAF	Source: 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]
[TBT] * 1.12 = [TBT Cl]
[TBT Cl * 0.36 = [Sn]
[TBT Cl] * 0.89 = [TBT]

[TBTO] * 0.97 = [TBT]
[Sn] * 2.74 = [TBT Cl]
[Sn] *2.44 = [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: 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 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:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	Sediment	Water	Tissue (Sample Type)	Effects	Log BCF	Log BAF	BSAF	Reference	Comments[3]
			1.7 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:	Concentration, Units in[1]:			Toxicity:	Ability to Accumulate[2]:			Source:	
Taxa	Sediment	Water	Tissue (Sample Type)	Effects	Log BCF	Log BAF	BSAF	Reference	Comments[3]
			0.3 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: 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]
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: 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]
			0.0181 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: 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]
			4.8 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 0.8 µg/L 2.4 µg/L	2.9 µg/g wet wt 0.9 µg/g wet wt 8.4 µg/g wet wt		3.61			[10] [10] [10]	L L 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	66 µg/g	50% survival				[14]	L
		21.2 µg/L	85 µg/g	56% survival					
		42.3 µg/L	126 µg/g	51% survival					
		185 µg/L	136 µg/g	35% survival					
		316 µg/L	167 µg/g	6% survival					
			167 µg/g	3% survival					

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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