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TOXICITIES OF SELECTED SUBSTANCES TO FRESHWATER BIOTA

by

David W. Hohrelter

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ARGONNE NATIONAL LABORATORY, ARGONNE, ILLINOIS

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under the supervision of

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Division of Environmental Impact Studies

May 1980

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Abstract

The amount of data available concerning the toxicity of various substances to freshwater biota is so large that it is difficult to use in a practical situation, such as environmental impact assessment. In this document, summary tables are presented showing acute and/or chronic toxicity of selected substances for various groups of aquatic biota. Each entry is referenced to its original source so that details concerning experimental conditions may be consulted. In addition, general information concerning factors modifying toxicity, synergisms, evidence of bioaccumulation, and water quality standards and criteria for the selected substances is given. The final table is a general toxicity table designed to provide an easily accessible and general indication of toxicity of selected substances in aquatic systems.

INTRODUCTION

A great deal of research has been conducted to determine the response of aquatic organisms to various concentrations of toxic substances and to fluctuations in water quality parameters. In fact, the body of literature on this subject is so vast that the volume of information available is almost too great to be useful or accessible in a practical, applied situation. This document is intended to draw this information together in an easy-to-use form and to provide a useful tool for assessment of environmental impacts on aquatic organisms. It also should provide a means of access to the large body of bioassay literature.

The 41 substances (Table 1) considered in this document were selected because of their known or suspected effects on aquatic organisms and because of the availability of literature concerning those effects. The substances also were selected because they are encountered frequently in aquatic environmental impact assessment. Information on each substance is summarized in tabular form to facilitate access. There is a table for each substance. In

Table 1. Substances Considered

each table, the effects of given concentrations of the particular substance on specific organisms are summarized, and additional information is presented. Entries are keyed to the original references listed at the end of the report so that these sources can be consulted for detailed information relative to the specific effects or the conditions under which they occurred.

When a substance is known to exhibit synergisms with other materials or to be subject to bioaccumulation, such facts are noted at the end of each table. In addition, a section of each table lists standards and recommended criteria for the substance.A standard is a legal entity that applies to a particular body of water or effluent. A water quality criterion is a designated concentration that when not exceeded should protect an organism, biological community, or a desired water use with an adequate degree of safety (USEPA 1976). A standard may have a criterion as its basis, but the standard may differ from the criterion because of prevailing local conditions, such as background levels of particular substances, flow characteristics, uses of the water, characteristics of the biological community, and synergistic effects of combinations of pollutants (USEPA 1976). Criteria and standards are usually derived from bioassay data by use of a predetermined formula, such as 1/10 of the 48- or 96-hour TLm (see below) (McKee and Wolf 1971).

The final table is a general toxicity table designed to provide an easily accessible and general indication of toxicity of substances in aquatic systems. The concentrations listed in the table in general apply to commonly occurring organisms. The given concentrations were usually for acute toxicity (see below) and usually occurred in the lower part of the range of concentrations given in the original table for that substance. The concentrations given were judged by the authors to be a somewhat conservative determination of concentrations that produce toxic effects and that may be generally applied to different waters. This final table differs from sets of criteria like those presented in USEPA (1976) and McKee and Wolf (1971). Those criteria were developed from bioassay data by a predetermined formula and were designed to protect aquatic systems. In contrast, the values given in this table actually have been found to be critical for aquatic organisms. They may cause injury or death. For this reason, this table may provide a more

realistic indication of the actual toxicity of these substances in freshwater systems.

Toxicity is usually expressed in terms of acute (short-term) or chronic (long-term) effects (USEPA 1976). Acute-toxicity tests usually have death as an endpoint. Acute toxicity can be expressed as the concentration lethal for a stated percentage (usually 50%) of organisms tested, or the reciprocal--the tolerance limit of a percentage of surviving organisms (USEPA 1976). Acute toxicity is usually determined for exposures of 24 to 96 hours (USEPA 1976). The most common terms for acute toxicity are MLD, TLm, LD_{50}, or LC_{50}. MLD is minimum lethal dose or the minimum concentration required to kill one or more of the test organisms (McKee and Wolf 1971). TLm (tolerance level, median) is the concentration required to kill 50% of the test organisms (McKee and Wolf 1971). LD_{50} or LC_{50} is the lethal dose or lethal concentration for 50% of the test organisms (McKee and Wolf 1971). All of these are determined for a specified time period.

Chronic effects are expressed in a variety of ways, but usually involve a sublethal effect over an extended time period (the cutoff point between acute- and chronic-toxicity determinations is generally considered to be 96 hours [McKee and Wolf 1971]). Sublethal effects would include such things as changes in feeding, metabolism, or reproduction (McKee and Wolf 1971).

There is considerable variance in values obtained from different bioassay tests. The organisms that are used may vary in age, acclimation to various conditions, and other characteristics. The conditions of different tests also may vary. For example, the water used in each experiment may be of different temperature, hardness, or pH. The experiment could be a static or continuous-flow bioassay. These and other factors will affect the concentration at which a substance will be toxic to a given organism. Variations in these factors among different experiments account for the differences in toxicity values in the tables that follow.

References

J. E. McKee and H. W. Wolf. 1971. Water Quality Criteria. 2nd ed. California State Water Resources Control Board, Publication 3A. 548 pp.

United States Environmental Protection Agency. 1976. Quality Criteria for Water. EPA 440/9-76-023.

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TOXICITY TABLES

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Aluminum

Organism	Aluminum mg/l	Remarks	Reference
Fish (General)	0.5	Lethal.	103
"Eels"	0.27	Lethal, 50 hours.	8
"	2.7	Lethal, 3.6 hours.	8
Sticklebacks (General)	0.07	Lethal.	7
" "	0.10	Lethal, 1 week.	6
" "	0.3	Lethal, 1 day.	6
Trout (General)	5.0	Lethal, 5 minutes.	101

Ammonia

Organism		Ammonia mg/l	Remarks	Reference
Plants				
	Najas, Chara, Brasenia	20 -30	Disappeared in 2-4 weeks.	171
Algae	*(Aphanizomenon sp.)*	0.4 - 0.5	Complete disappearance.	172
Diatom	*(Navicula semilanum)*	420	"50% reduction, 5 days" hard water.	60
"	" "	320	"50% reduction, 5 days" soft water.	60
Diatom	*(Nitzschia linearis)*	420	5-day TLm, acute.	120
"	" "			
Protozoa				
	Colipidium sp.	5.0	Lethal.	173
	Paramecium sp.	2.6	Lethal.	173
	Stentor sp.	0.3	Lethal.	173
	Actinosphaerium sp.	0.08	Lethal.	173
Invertebrates				
Snail	*(Physa heterostropha)*	90	96-hour TLm, acute.	120
Fly larvae	*(Eristalsis sp.)*	220	Lethal level.	173
Midge larvae	*(Chironomus sp.)*	4.3	Lethal level.	173
Stonefly larvae	*(Perla sp.)*	9.2	Lethal level.	173
Mayfly larve	*(Ecdyonurus sp.)*	3.0	Lethal level.	173
Oligochaete worm	*(Tubifex sp.)*	2.7	Lethal level.	173
Oligochaete worm	*(Stylaria sp.)*	0.3	Lethal level.	173
Leech	*(Herpobdella octoculata)*	3.2	Lethal level.	173
Turbellaria	*(Dendrocoelum sp.)*	0.4	Lethal level.	173
Turbellaria	*(Planaria spp.)*	0.2 -0.4	Lethal level.	173
Crayfish	*(Cambarus spp.)*	40	Lethal.	171
Cladocera	*Daphnia spp.*	8.0	Lethal.	20
Fish	(General)*	0.3 -1.0	Lethal in hatchery ponds under warm temperature and low flows.	174
"	"	0.2 -2.0	Lethal to trout and carp.	14
"	"	0.27	Gill hyperplasia and pathological effects on liver and blood of various species.	175
Mosquito fish	*(Gambusia affinis)*	1.1	1000 minute TLm.	176
Fathead minnow	*(Pimephales promelas)*	8.2	96-hour TLm; hard water.	177
" "	" "	5.9	96-hour TLm; soft water.	177

Ammonia (continued)

Organism		Ammonia mg/l	Remarks	Reference
Fish (Continued)				
Goldfish	*(Carassius auratus)*	2.0 - 2.5	Lethal. 1-4 days.	152
Bluegill	*(Lepomis macrochirus)*	2.5	Toxic level. Toxicity depends on pH and extent of ionization.	48
"	" "	3.1	Lethal. 96 hour TLm, soft water.	60
"		23.7	Lethal. 96 hour TLm, hard water.	60
Trout	(General)	0.3 -0.4	Toxic to fry.	178
"	"	3.0**	Trout became hyperexcitable.	179
"	"	5.0**	Ammonia excretion by fish was inhibited.	179
"	"	8.0**	($\sim$ 1 mg/l NH_3) 50% died.	179
Rainbow trout	*(Salmo gairdneri)*	0.41	48 hour TLm.	180
" "	" "	0.86-1.96	Lethal levels, depending on amount of dissolved oxygen.	186
" "	" "			
" "	" "	0.42	500 minute TLm.	187
" "	" "	0.2	Toxic, fry.	188
Brown trout	*(Salmo trutta)*	2.10	Eggs and young - irreversible damage to heart and muscle control.	189
Chinook salmon	*(O. tshawytscha)*	.002	Fingerlings. Progressive gill hyperplasia.	190
Freshwater aquatic life (General)		0.2 -2.0	Toxic.	14
Recommended Standards or criteria				
Freshwater aquatic life		0.02		14

*General Remarks

a. Undissociated NH_3 concentration is the important factor in toxicity. 92
b. pH is the major factor affecting toxicity. 191
c. pH governs this equilibrium: 14
NH_3 (toxic) $\rightleftarrows$ NH_4^+ (non-toxic)
d. Toxicity increases with increasing pH and alkalinity. 15
e. Toxicity increases as dissolved oxygen concentration decreases. 15
f. Only unionized NH_3 is toxic to fish. 191
g. "Addition of carbon dioxide lowered pH and NH_3 toxicity." 192

**NH_3 and NH_4^+

Antimony*

Organism		Antimony mg/l	Remarks	Reference
Algae				
"Green algae"		3.5	"Hindrance of cellular division".	42
	Scenedesmus	3.5	Toxic threshold, 4 days.	59
Bacteria	*(E. coli)*	33	Toxic threshold, 4 days.	59
Protozoa		15	Hindrance of food intake.	42
Invertebrates				
	Daphnia magna	9.0	Hindrance of movement.	42
	" "	9.0	Toxic threshold, 48 hours.	59
Fish				
Fathead minnow	*(Pimephales promelas)*	20.0	96-hour TLm, soft water.	107,108
" "	" "	12.0	96-hour TLm, hard water.	107,108

*All in the form of antimony potassium tartrate.

Arsenic

Organism		Arsenic mg/l	Remarks	Reference
Invertebrates	*Daphnia magna*	7.4	48-hour TLm, acute.	3
	" "	2.85	3-week TLm, chronic.	3
	" "	1.40	50% reproductive loss, 3 weeks.	3
	" "	0.52	16% reproductive loss, 3 weeks.	3
	" "	4.3 -7.5	"Immobility".	16,17
Planaria	*(Polycelis nigra)*	40.	48 hour TLm.	18
Fish	(General)	1.1	Toxic.	5,26
Pike perch	*(Lucioperca* sp)	1.1 -2.2	Toxic, 2 days.	20
Bleak	*(Alburnus alburnus)*	2.2	Toxic, 3 days.	20
Carp	*(Cyprinus carpio)*	3.1	Toxic, 4-6 days.	20
Bass	(General)	7.6	Toxic, 10 days.	21
Minnows	"	11.6	Toxic, 36 hours.	22
Crappies, Bluegills		15	Toxic.	23
Minnows	(General)	17.8	Toxic.	24
Minnows	"	60	Toxic 16 hours.	22
Minnows	"	234	Toxic.	24
Pink salmon	*(Oncorhynchus gorbuscha)*	5.0	Lethal, 10 days.	15
Chum salmon	*(Oncorhynchus keta)*	8.4	LC_{50}, 48 hours.	15
Minnows	(General)	29	LC_{50}, 48 hours.	15
Aquatic Organisms	(General)	1.1 -4.5	Lethal, arsenite.	25
Recommended Standards or criteria				
Fish		1.0		15
Domestic		0.05		14,15
Irrigation		1.0		15
Stock watering		1.0		15
Irrigation		0.1		14
Fish		1.5 -3.8	When applied to control aquatic vegetation, i.e. concentration will control vegetation and is still safe for fish.	19
			General Remarks - Arsenic may be concentrated in the food chain - bioaccumulation.	15

Barium

Organism		Barium mg/l	Remarks	Reference
Invertebrates				
	Daphnia magna	14.5	LC_{50}, 48 hours.	3
	" "	13.5	LC_{50}, 3 weeks.	3
	" "	8.9	LC_{50}, 50% reproductive impairment.	3
	" "	5.8	LC_{50}, reproductive impairment.	3
Fish				
Stickleback	*(Gasterosteus aculeatus)*	400	Lethal concentration limit.	5,7
			General Remarks	
			In natural waters, barium readily forms precipitates. Thus, it is usually removed from solution before lethal concentrations are reached.	14,15

Beryllium

Organism	Beryllium mg/l	Remarks	Reference
Fish			
Fathead minnow *(Pimephales promelas)*	0.15	96 hour TLm, beryllium chloride, soft water.	107,108
" " " "	15.0	96 hour TLm, beryllium chloride, hard water.	107,108
" " " "	0.2	96 hour TLm, beryllium sulfate, soft water.	107,108
" " " "	11.0	96 hour TLm, beryllium sulfate, hard water.	107,108
" " " "	0.15	96 hour TLm, beryllium nitrate, soft water.	107,108
" " " "	20.0	96 hour TLm, beryllium nitrate, hard water.	107,108
Guppy *(Poecilia reticulata)*	0.19	96 hour LC_{50}, soft water.	216
" " "	20.3	96 hour LC_{50}, hard water.	216
" " "	0.16-20.0	96 hour LC_{50} over range of hardness 22-400 mg/l $CaCO_3$ respectively. Beryllium sulfate.	217
Bluegill *(Lepomis macrochirus)*	1.3	96 hour TLm, soft water.	107,108
" " "	12.0	96 hour TLm, hard water.	107,108
Amphibians			
Salamander *(Ambystoma spp.)*	4.7	Larvae. 96 hour LC_{50}, soft water.	218
" " "	26.5	Larvae. 96 hour LC_{50}, hard water.	218
Recommended standards or criteria			
Aquatic life - freshwater	0.011	Soft water.	14
Aquatic life - freshwater	1.1	Hard water.	14
Irrigation	0.1		14
		General Remarks	
		Beryllium is more toxic to fish in soft water than in hard water.	14, 15
		Its toxicity may increase 100-fold soft water over hard water.	14

Boron

Organism	Boron mg/l	Remarks	Reference
Bacteria			
"synthetic sewage"	480	50% reduction of 5-day BOD, boric acid, buffered water.	208
"sewage organisms"	1000	50% inhibition, 5-day BOD, boric acid.	209
Invertebrates			
Daphnia magna	120	Immobilization threshold, sodium borate.	210
" "	5.2	"Near immobilization threshold," 48 hours, sodium perborate.	17
Fish (General)	1600- 1700	Minimum lethal dose, distilled water, sodium borate.	209
" "	3700- 4000	Minimum lethal dose, hard water, sodium borate	209
" "	18000-19000	Minimum lethal dose, distilled water, boric acid.	209
" "	19000-19500	Minimum lethal dose, hard water, boric acid.	209
Mosquito fish *(Gambusia affinis)*	5600	96-hour TLm, boric acid.	193
" " " "	3600	96-hour TLm, sodium borate.	193
Roach *(Hesperoleucas sp.)*	6250	Lethal, 46 hours, boric acid.	211
Rudd *(Scardinius erythrophthalmus)*	6250	Lethal, 18 hours, boric.	211
Bluegill *(Lepomis macrochirus)*	15000	24-hour TLm, boron trifluoride.	71
Rainbow trout *(Salmo gairdneri)*	1800	48-hour TLm, sodium borate.	212
" " " "	5000	Slight darkening of skin, boric acid.	211
" " " "	20000	Distressed, became immobile, boric acid.	211
Recommended standards or criteria			
Irrigation	0.75		14

Cadmium

Organism		Cadmium mg/l		Remarks	Reference
Invertebrates					
Water Snail		0.05	-0.10	Distress syndromes.	27
Midge	(*Tanytarsus dissimilis*)	.0034		10 day LC_{50}.	28
"	" "	.0031		Retarded growth.	28
Mayfly	(*Ephemerella subvaria*)	2.0		LC_{50}, 96 hours.	30
Cladoceran	*Daphnia magna*	0.05		LC_{50}, 3 weeks.	3
"	" "	0.017		LC_{50}, 3 weeks, 16% reproductive impairment.	3
Fish					
Fathead minnow	(*Pimephales promelas*)	.029		LC_{50}, 30 days.	31
	" "	.057		Decreased survival of developing embryos.	31
Mosquito fish	(*Gambusia affinis*)	.0081		Reduction in number of eggs produced per female.	32
Goldfish	(*Carassius auratus*)	2.34		LC_{50}, 96 hours (fry).	33
Guppy	(*Poecilia reticulata*)	1.27		LC_{50}, 96 hours (fry).	33
Bluegill	(*Lepomis macrochirus*)	.08		LC_{50}, 11 months (adults).	34
	" "	1.94		LC_{50}, 96 hours (fry).	31
Green Sunfish	(*Lepomis cyanellus*)	2.84		LC_{50}, 96 hours (fry).	33
Catfish	(*Ictalurus punctatus*)	.017		Growth and survival of fry was reduced significantly.	35
Brook Trout	(*Salvelinus fontinalis*)	.0034		Second generation fish were smaller at 3 months than normal fish. First and second generation fish experienced extensive mortality during spawning.	36 36
" "	" "	.00092		LC_{50}, 96 hours.	35
Chinook salmon	(*O. tshawytscha*)	.002		LC_{50}, 96 hours.	35
Salmonids and others		.012		Reduction of standing crop of brown trout, lake trout, coho salmon, northern pike, white suckers, and smallmouth bass.	35
Fish (General)		.029	-73.5	LC_{50}, 96 hours.	37
Recommended Standards or criteria					
Domestic		.01	- 0.01	0.1--USSR std. 0.01--U.S. std. (ref. 14,40).	38,39,14
Cladocerans and Salmonids		.0004		Soft water.	14
		.0012		Hard water.	14
Other less sensitive aquatic species		.0040		Soft water.	14
		.0120		Hard water.	14
				General Remarks	
				Cadmium exhibits a synergism with zinc and with cyanide in its toxicity to aquatic biota.	15
				For example: 0.03 mg/l cadmium + 0.15 mg/l zinc leads to mortality of salmon fry.	15

Chlorine

Organism		Chlorine mg/l	Remarks	Reference
Viruses	(General)	2.0 -2.2	Killed in 1-10 minutes.	139
Bacteria	(General)	0.03-0.06	100% killed in 20 minutes.	140
	Salmonella and *Shigella*	2.5	Killed, 1 minute exposure.	139
Algae	(General)	0.25-3.0	"Controlled".	141,146,142
	Chlorella pyrenoidosa	0.18	22% reduction in cells, 4 days.	143
	Chlorella sorokiniana	0.2 -1.0	Algicidal.	144
"phytoplankton"	(General)	0.32	50% reduction in respiration and photo synthesis.	145
Protozoa	(General)	0.1	Lethal.	146
Invertebrates				
Nematode	*(Cheilobus quadrilobiatus)*	95 -100	10-20% survival, 15 minute exposure	139
Oligochaete	*(Nais spp.)*	1.0	95% killed after 35 min, hard water.	147
Amphipod	*(Gammarus pseudolimnaeus)*	0.22	LC_{50}, 96 hours.	148
		0.05	Reduced survival.	148
		0.0034	Reduced reproduction.	148
Snails	(General)	0.78	TL_{50}, 7 days.	149
Midge larvae	*(Chironomus sp.)*	0.65	80% killed, 24 hours.	150
Copepod	*(Cyclops sp.)*	2.0	Lethal.	151
Cladoceran	*Daphnia magna*	0.5	Lethal in 72 hours, soft water.	152
"	" "	0.014	Lethal.	149
Crayfish	(General)	0.78	TL_{50}, 7 days.	149
"Crustacea, rotifers, and diatoms"		0.15-0.2	Lethal.	154

Organism		Chlorine mg/l	Remarks	Reference
Fish				
Carp	*(Cyprinus carpio)*	0.15 -0.2	25% killed 12-16 days.	153,154
Goldfish	*(Carassius auratus)*	0.3	Lethal, 24 hours.	155
Fathead minnow	*(Pimephales promelas)*	0.007	Lethal 120 hours.	156
" "	" "	0.04 -0.09	Sublethal stress.	157
" "	" "	.082- .115	7-day TLm, acute.	158
" "	" "	0.05 -0.16	96-hour TL_{50}.	149
Golden shiner	*(Notemigonus crysoleucas)*	0.5	Lethal, 3 hours.	159
" "	" "	0.19	LC_{50}, 96 hours.	160
Mosquito fish	*(Gambusia affinis)*	2.0	Some killed on second day.	161
White sucker	*(Catostomus commersoni)*	0.132	7-day TLm, acute.	158
Black bullhead	*(Ictalurus melas)*	.099	96-hour TLm, acute.	158
Brown bullhead	*(I. nebulosus)*	0.5	Survived 10 minute exposures, but died 24 hours later.	159
Largemouth bass	*(Micropterus salmoides)*	0.261	7-day TLm.	158
" "	" "	0.1	Absent in streams.	162
Pumpkinseed	*(Lepomis gibbosus)*	1.0	All killed in less than 10 minutes.	159
Walleye	*(Stizostedion vitreum)*	0.15	7-day TLm, acute.	158
Yellow perch	*(Perca flavescens)*	0.205	7-day TLm, acute.	158
" "	" "	3.0	Eggs. 75% survival, 10 minute exposure.	159
Mummichog	*(Fundulus heteroclitus)*	2.0	Lethal, 10 minutes.	159
Pickerel	*Esox sp.*	1.0	Lethal, 30 hours.	153,154
Trout	(General)	.006	Fry, lethal, 2 days.	163
"	"	0.2 -0.3	"Somewhat toxic".	164
Brown trout	*(Salmo trutta)*	0.01	Lethal. TLm = 43.5 hours.	165
" "	" "	0.015	Absent in streams.	162
" "	" "	0.02	Lethal.	149
Brook trout	*(Salvelinus fontinalis)*	0.005	Depressant response.	166
" "	" "	0.015	Absent in streams.	162
" "	" "	0.02	Lethal.	149
" "	" "	0.04	Mean survival time = 48 hours.	166
" "	" "	0.083	7-day TLm, acute.	158

Chlorine (continued)

Organism		Chlorine mg/l	Remarks	Reference
Rainbow trout	*(Salmo gairdneri)*	0.001	Avoidance response, soft water.	167
" "	" "	0.01	Lethal in 12 days.	167
" "	" "	0.14 -0.29	96 hour TLm acute.	168
Salmon' "	(General)	0.05	Young, critical level.	169
Atlantic salmon	*(Salmo salar)*	1.0	All killed in less than 10 min.	159
Coho salmon	*(O. Kisutch)*	.083	7 day TLm, acute.	158
Salmonids	(General)	0.01	Killed adult salmonids in several days in freshwater.	14
"	"	0.006	Killed fry of these species.	14
Fish	(General)	0.11-0.13	Lethal.	170
"	"	.01	50% reduction in "species diversity".	162
"	"	0.09-0.3	96 hour LC_{50} range for walleye, black bullhead, white sucker, yellow perch, largemouth bass, fathead minnow.	158
"	"	1.0	"Coarse fish" killed.	
Amphibian		3.0		
Frog	*(Rana catesbiena)*		Survived 10 minute exposure, but died in 24 hours. Tadpoles.	159
Recommended standards or criteria				
Salmonids		.002		14
Other freshwater organisms		.01		14
General Remarks			Chlorine exhibits synergistic effects with copper in the control of *Chironomus*.	150

Chromium

Organism		Chromium mg/l	Remarks	References
Algae				
	Chlorella variegatus	6.4-16.0	Completely inhibits growth for 56 days in culture.	40
	Chlorococcum humicola	3.2-6.4	Completely inhibits growth for 56 days in culture.	40
	Scenedesmus obliquus	3.2-6.4	Completely inhibits growth for 56 days in culture.	40
	Lepocinclis steinii	0.32-1.6	Completely inhibits growth for 56 days in culture.	40
	"algae" (General)	1.39	Drastic decrease in production.	41
	" "	0.139	Slight (significant) decrease in production.	41
	Scenedesmus	5.0	Toxicity threshold.	42
Bacteria (General)		117	Cr^{+3} lowered 5-day BOD by 50%.	44
" "		62.5	Cr^{+3} lowered 5-day BOD by 50%.	50
" "		100	Cr^{+6} lowered 5-day BOD by 50%.	50
" "	"Sewage"	10	Cr^{+6}, 10% reduction BOD in 1 day.	50
" "	"	100	Cr^{+6}, 50-90% reduction BOD in 1 day.	50
Protozoa	*(Microregma)*	37	Toxicity threshold.	42
Invertebrates	*Daphnia magna*	1.2	Cr^{+3} toxicity threshold.	43
	" "	.33	16% reproductive impairment, 3 weeks.	3
	" "	.60	50% reproductive impairment, 3 weeks.	3
	" "	2.0	3-week TLm, chronic.	3
Stonefly	*(Acroneuria lycorlus)*	32	LC_{50}, 7 days.	30
Caddisfly	*(Hydropsyche betteri)*	32	LC_{50}, 7 days.	30
Mayfly	*(Ephemerella subvaria)*	16	LC_{50}, 96 hours.	30
Nymphs	*(Hexagenia)*	8.6	Mortality, 96 hours.	52
Planaria flatworm	*(Polycelis nigra)*	75	48-hour TLm.	18
Fish				
Fathead minnow	*(Pimephales promelas)*	64.7	Cr^{+3}, LC_{50}, 96 hours.	33
" "	" "	2.0	Reproductive impairment, 10 months.	33
" "	" "	27	Cr^{+3} LC_{50}, 96 hours, hard water.	45
" "	" "	33	Cr^{+6} LC_{50}, 96 hours, hard water.	45
" "	" "	17.6	Cr^{+6} LC_{50}, 96 hours, soft water.	33
" "	" "	27.3	Cr^{+6} LC_{50}, 96 hours, hard water.	33

Chromium (continued)

Organism		Chromium mg/l	Remarks	References
Goldfish	*(Carassius auratus)*	37.5	LC_{50}, 96 hours.	33
Guppy	*(Poecilia reticulata)*	30.0	LC_{50}, 96 hours. $+3$	33
Bluegill	*(Lepomis macrochirus)*	71.9	LC_{50} 96 hours, Cr	33
"	" "	110.	TL_m 96 hours, acute, soft water. (Alkalinity and hardness reduced toxicity.)	46
"	" "	170	Chromate, 96 hour TLm, acute, soft water.	46
"	" "	113.0	96-hour, TLm (dichromate).	47
"	" "	176.8	96-hour, 100% kill (dichromate).	47
"	" "	0.2	96-hour, TLm, continuous exposure.	48
"	" "	118	LC_{50}, Cr^{+6}, 96 hours, soft water.	33
"	" "	133	LC_{50}, Cr^{+6}, 96 hours, hard water.	33
Stickleback	*(Gasterosteus aculeatus)*	1.0	"Toxic limit", acute	49
"	" "	1.2	Lethal limit.	6, 7
"	" "	1.3	Survived only 1 week.	6
"	" "	2.0	Survived only 2 days.	6
"	" "	2.4	Lethal limit.	43
"	" "	5.0	Survived only 1 day.	6
Largemouth bass	*(Micropterus salmoides)*	195	TLm, 48 hours.	53
" "	" "	94	TLm, 80 hours.	53
Rainbow trout	*(Salmo gairdneri)*	69.0	TLm, 96 hours.	54
	" "	69.0	LC_{50}, 96 hours, soft water.	55
"	" "	0.40	Reproductive impairment, 2 years.	54
"	" "	5.0	40% killed, 15 days (chromate).	56
"	" "	10.0-12.5	80% killed, 15 days.	56
Brook trout	*(Salvelinus fontinalis)*	50.0	TLm, 96 hours.	54
"	" "	59.0	LC_{50}, 96 hours.	55
"	" "	0.40	Reproductive impairment, 2 years.	54
Chinook salmon	*(O. tschawytscha)*	0.2	Aleyins and juveniles, survival significantly reduced.	57
Coho salmon	*(O. kisutch)*	17.8	Cr^{+6}, toxic.	58
"Young salmon"		<10.0	Minimum lethal concentration.	58
Recommended standards or criteria				
Domestic		0.05		14,15
Stock watering		5.0		15
Fish and aquatic life		0.1		14
Fish		1.0		15
Aquatic life besides fish		0.05		15

Chromium (continued)

Organism		Chromium mg/l	Compound	Remarks	References
Algae					
	Scenedesmus	0.7	$K_2Cr_2O_7$	Threshold effect.	59
Diatom	*(Navicula)*	0.21	$K_2Cr_2O_7$	Soft water TLm.	60
"	"	0.25	$K_2Cr_2O_7$	Hard water TLm.	60
Protozoa	*(Microregma)*	0.21	$K_2Cr_2O_7$	Threshold effect.	42
Invertebrates	*Daphnia*	0.7	$K_2Cr_2O_7$	Threshold effect.	59
	Daphnia magna	0.016	$Na_2Cr_2O_7$	Toxic threshold.	5
	" "	0.05	-	Lethal in 6 days.	61
	" "	<< 0.10	$Na_2Cr_2O_7$	Toxic threshold.	16
	" "	<< 0.10	Na_2CrO_4	Toxic threshold.	16
	" "	0.51	Na_2CrO_4	Toxic threshold.	62
Amphipod	*(Gammarus pulex)*	1.4	Na_2CrO_4	Total mortality.	63
Snail (General)		17.3	$K_2Cr_2O_7$	Soft water TLm.	60
" "		40.6	$K_2Cr_2O_7$	Hard water TLm.	60
Planaria	*(Polycelis nigra)*	148	CrO_4	Toxic threshold.	64
Fish					
Goldfish	*(Carassius auratus)*	52	CrO_3	Toxic in 30 min.	65
"	" "	104	CrO_3	Toxic in 6 to 84 hours.	5,69
"	" "	177	$K_2Cr_2O_7$	Toxic in 3 days.	65
Bluegill	*(Lepomis macrochirus)*	50	-	Toxic limit for 30 day exposure.	66
"	" "	70	-	Toxic limit for 1 week's exposure.	66
"	" "	75	$K_2Cr_2O_7$	Died within 4 days.	8
"	" "	103	$K_2Cr_2O_7$	96-hour TLm.	68,71
"	" "	145	$Na_2Cr_2O_7$	24-hour TLm.	70
"	" "	148	$Na_2Cr_2O_7$	Toxic limit.	5
"	" "	213	$Na_2Cr_2O_7$	48-hour TLm.	71
"	" "	300	Na_2CrO_4	24-hour TLm.	70
"Sunfish" (General)		110	$K_2Cr_2O_7$	96-hour TLm.	46,72
" "		113	$K_2Cr_2O_7$	96-hour TLm.	60
" "		135	$K_2Cr_2O_7$	96-hour TLm, hard water.	60
" "		170	K_2CrO_4	96-hour TLm.	46,72

Organism		Chromium mg/l	Compound	Remarks	References
Fish (Continued)					
Rainbow trout	*(Salmo gairdneri)*	20	$K_2Cr_2O_7$, K_2CrO_4	Toxic.	22,69,73
Brown trout	*(Salmo trutta)*	5.2	$K_2Cr_2O_7$	Toxic.	74
Trout (General)		50	$K_2Cr_2O_7$	Lethal in 33 hours.	8
" "		100	K_2CrO_4	24-hour TLm.	75
" "		100	$K_2Cr_2O_7$	Lethal after 6 hours.	8
Fish (General)		5	-	Toxic.	
				General Remarks	
				Toxicity of chromium and its compounds to aquatic biota depends on the valence of chromium and on the hardness of the water.	15

Copper

Organism	Copper mg/l	Remarks	Reference
Algae (General)	0.15 -0.70	Minimum lethal concentrations for various Chlorophyta: *Stigeoclonium tenue, Cladophora glomerata, Oedogonium spp., Ulothrix spp., Microspora spp., Mougeotia spp., Spyrogyra spp.*	59,76
" "	0.1 -0.3	Reduced phytosynthesis, 12 hours, soft water.	77
" "	2.0	Halted growth of 6 spp. of green algae and 6 spp. of diatoms.	78
" "	.001	Algal growth delayed 24 hours.	79
Bacteria (General)	.01	Interfered with BOD determination and self-purification process of streams.	80,81
" "	.08	Toxicity threshold, *E. coli*.	59
Protozoa *(Microregma)*	.05	Toxicity threshold, 28 hours	42
Invertebrates *Daphnia magna*	.0098	48-hour TLm with no food.	3
" "	.035	LC_{50}, 50% reproductive loss, 3 weeks.	3
" "	.027	Threshold immobilization in 64 hours.	43
" "	.022	LC_{50}, 16% reproductive impairment, 3 weeks.	3
Snails (General)	.039 -1.7	96-hour TLm, acute, soft water.	82
Crayfish *(Oronectes rusticus)*	.06	Acute toxicity threshold (young).	83
Invertebrates (General)	2.2	Most normally common invertebrates (in Michigan waters) were absent.	84
Fish			
Minnows (General)	0.29 -0.33	96-hour, LC_{50} for Bluntnose minnow *(Pimephales notatus)*, Stoneroller *(Campostoma anomalum)*, Creek chub *(Semotilus atromaculatus)*, Blacknose dace *(Rhinichthys atratulus)*, and Rainbow darter *(Etheostoma caeruleum)*.	85
Goldfish and Guppy *(Carassius auratus)* *(Poecilia reticulata)*	.036	LC_{50}, 96 hours.	33

Organism	Copper mg/l	Remarks	Reference
Fish (Continued)			
Fathead minnow *(Pimephales promelas)*	.018	96-hour TLm.	78
Carp *(Cyprinus carpio)*	0.2	Toxicity threshold.	86
" " "	0.81	96-hour TLm, acute.	87
Striped bass *(Morone saxatilus)*	.05	48-hour TLm, acute.	88
White perch *(Morone americanus)*	6.2	96-hour TLm, acute.	87
Banded killifish *(Fundulus diaphanus)*	0.86	96-hour TLm.	87
Stickleback *(Gasterosteus aculeatus)*	0.02	"Toxic limit".	49
Bluegill *(Lepomis macrochirus)*	0.66	LC_{50}, 96 hours.	48
" " "	0.46	30-day TLm, soft water.	
Chinook salmon *(O. tshawytscha)*	0.02	Increased mortality and inhibited growth of fry.	89
Atlantic salmon *(Salmo salar)*	.0023	Avoidance threshold.	90
" " " "	.05	Incipient lethal level.	91
Rainbow trout *(Salmo gairdneri)*	0.4 -0.5	48-hour, TLm, acute, depending on hardness & DO.	92
" " " "	.06	Toxic soft water.	93
" " " "	.6	Toxic, hard water.	93
" " " "	.037	Reduced egg and fry survival.	94
Brook trout *(Salvalinus fontinalis)*	.03	Fry mortality, 96 hours, 43% survival of adults, 8 months.	95
" " " "	.0174	"Adverse effect on survival and growth of alevins and juveniles".	96
Lake trout *(Salvelinus namaycush)*	.111	Reduced egg and fry survival.	94
Brown trout *(Salmo trutta)*	.037	Reduced egg and fry survival.	94
Brown bullhead *(Ictalurus nebulosus)*	.18	LC_{50}, 96 hours.	97
Amphibians			
Toads *(Bufo valliceps)*	0.1	Lethal to tadpoles.	98
Recommended standards or criteria			
Domestic	1.0		14,15
Irrigation	0.1		15
Fish and FW aquatic life	0.02		15

Copper (continued)

Organism	Copper mg/l	General Remarks	Reference
		a. Copper-zinc; copper-cadmium; sulfates of these are synergistic in toxicity to fish.	5,67,181
		b. Copper-cadmium, copper-mercury show synergistic effects in their toxicity to aquatic biota.	15
		c. Magnesium salts affect copper toxicity to aquatic biota.	183
		d. Copper-chlorine synergism in control of *Chironomus* larvae.	150
		e. Copper-mercury synergism in toxicity to aquatic biota.	182
		f. Copper toxicity is affected by temperature and CO_2 content of water.	15
		g. Alkalinity affects toxicity - complexes, pH, etc.	15
		h. Copper is more toxic to aquatic biota at lower alkalinity.	14
		i. The copper ion is complexed by anions - reduced toxicity.	14
		j. It is more toxic in soft water than in hard water - in hard water, many copper salts will precipitate (e.g. copper carbonate).	15
		k. Copper is concentrated from the surrounding waters by plankton, mostly through surface adsorption.	15
		l. However, copper toxicity is not cumulative. Copper is excreted by organisms. Therefore, bioaccumulation in the food chain would not appear to be a problem.	15

Cyanide

Organism		Cyanide mg/l	Remarks	Reference
Protozoa				
	Microregma	.04	Toxic threshold.	44
Algae				
	Microcystis	20.0	Lethal. 90% killed.	312
Invertebrates				
	Daphnia magna	.04	96-hour TLm.	200
	" "	3.4	Toxic, 48 hours	20
Mayfly	*(Stenonema)*	0.5	48-hour TLm.	313
Caddisfly	*(Hydropsyche)*	2.0	48-hour TLm.	313
Snail	*(Lymnacea)*	130.0	96-hour TLm. Eggs.	200
Snail	*(Physa heteroclita)*	0.432	96-hour TLm. Acute.	120
Fish				
Fathead minnow	*(Pimephales promelas)*	0.18	Minimum lethal concentration (threshold). Acute.	318
" "	" "	0.12	Minimum lethal concentration (threshold). Acute.	315
" "	" "	0.24	48-hour TLm. Acute.	316
Blacknose dace	*(Rhinichthys atratulus)*	0.22	24-hour TLm.	317
Bluegill	*(Lepomis macrochirus)*	0.15	Minimum lethal concentration (threshold). Acute.	314
"	" "	0.12-0.18	96-hour TLm. Hard and soft water.	319
Smallmouth bass	*(Micropterus dolomieui)*	0.104	Minimum lethal concentration (threshold). Acute.	320
Brook trout	*(Salvelinus fontinalis)*	0.05	Minimum lethal concentration (threshold). Acute.	321
" "	" "	0.057	Minimum lethal concentration (threshold). Acute. Continuous flow bioassay. 10°C.	315
" "	" "	0.01	Reduced endurance and swimming ability.	322
Brown trout	*(Salmo trutta)*	0.07	Minimum lethal concentration (threshold). Acute	320
Rainbow trout	*(Salmo gairdneri)*	0.07	Minimum lethal concentration (threshold). Acute.	323
Coho salmon	*(Oncorhynchus kisutch)*	0.02	Reduced growth or food conversion efficiency.	324
Fish (General)		0.05-0.20	Acutely toxic.	14
Recommended standards or criteria				
Freshwater and marine aquatic life		0.005		14

Fluoride

Organism	Fluoride mg/l	Remarks	Reference
Bacteria			
E. coli	45	Toxic threshold, 4 days.	59
Protozoa			
Microregma heterostoma	226	Toxic threshold, 28 hours.	42
Invertebrates			
Daphnia magna	270	Toxic threshold, 48 hours.	59
Fish			
Mosquito fish *(Gambusia affinis)*	925	48 and 96 hour TLm, acute.	193
Tench *(Tinca vulgaris)*	678	Lethal.	194
Goldfish *(Carassius auratus)*	1000	Lethal 60-102 hours, hard water.	152
" " "	1000	Lethal 12-29 hours, soft water.	152
" " "	120	Lethal 4 days.	195
Carp *(Cyprinus carpio)*	75- 91	20-day TLm, varies with temperature.	196
Trout (General)	2.3-7.5	TLm, varies with temperature.	196,197,198
Rainbow trout *(Salmo gairdneri)*	2.7-7.3	10-day TLm.	197,198
" " " "	113	Lethal 21 days, soft water.	199
" " " "	250	Lethal 21 days, hard water.	199
Recommended standards or criteria			
Industrial	1.0		15
Irrigation	10.0		15
Stock watering	1.0		15
Aquatic life	1.5		15

Iron

Organism		Iron mg/l	Remarks	Reference
Invertebrates				
	Daphnia magna	5.9	LC_{50} 3 weeks.	3
	" "	5.2	Reproductive impairment, 3 weeks.	3
	" "	4.4	16% reproductive impairment, 3 weeks.	3
Gammarids		3.0	reproductive impairment, 4 months.	99
Caddisflies		25.0	Reduced emergence, 2 months.	99
Stonefly	*(Acroneuria lycurias)*	16.0	LC_{50}, 9 days.	30
Mayfly	*(Ephemerella subvaria)*	0.32	LC_{50}, 96 hours.	30
Caddisfly	*(Hydropsyche betteri)*	16.0	LC_{50}, 9 days.	30
Fish				
Carp	*(Cyprinus carpio)*	0.9	Lethal if pH < 5.5.	100
Fathead minnow	*(Pimephales promelas)*	50.0	Mortality, 5 months.	99
Rainbow trout	*(Salmo gairdneri)*	10.0	Serious injury or death in 5 min.	101
Brook trout	*(Salvelinus fontinalis)*	12.0	Reduced growth, 37 weeks.	99
Fish	(General)	0.2	Threshold concentration for lethality to 3 types of fish.	102
"	"	1.0-2.0	Death of pike, tench, and trout at pH 5.0-6.7.	8,103
"	"	1.0	No trout found until (Fe) was less than 1.0 mg/l, even though other conditions were suitable for trout.	104
Recommended standards or criteria				
Domestic		0.3		14,15
Industrial		0.1		15
Freshwater life		1.0*		14
			*Lab data suggest greater iron toxicity than field data. 1.0 mg/l, although it causes harmful effects in the lab, appears to be safe from field studies.	14
			General Remarks	
			Iron forms precipitates, especially in well-aerated (i.e. oxidizing) waters, that will aggregate, flocculate, and settle out. These precipitates and flocs can coat the gills of fish, suffocating the fish. They can also smother fish eggs and benthic organisms. Those effects do not appear in concentration data.	14,15

Lead

Organism		Lead mg/l	Remarks	Reference
Bacteria	*(Aerobic)*	1.0	Toxic.	20,80,105,106
	(General)	0.1 -0.5	Bacterial decomposition of organic matter inhibited.	20,80,105,106
Protozoa				
Flagellates and infusoria		0.5	Toxic.	20,80,105,106
Invertebrates	*(Daphnia magna)*	.03	16% reproductive impairment, 3 weeks.	3
"	" "	0.1 -0.3	LC_{50}, 3 weeks.	3
Stonefly	*(Acroneuria lycurias)*	64.0	LC_{50}, 14 days.	30
Mayfly	*(Ephemerella subvaria)*	16.0	LC_{50}, 7 days.	30
Caddisfly	*(Hydropsyche betteri)*	32.0	LC_{50}, 7 days.	30
Fish				
Fathead minnow	*(Pimephales promelas)*	2.4	96-hour TLm, soft water.	107,108
" "	" "	75.0	96-hour TLm, hard water.	107,108
" "	" "	0.97	96-hour TLm $PbCl_2$.	109
Carp	*(Cyprinus carpio)*	1.0	Long term toxicity.	86
Goldfish	*(Carassius auratus)*	5.5	Toxic.	65
"	" "	0.07	Behavior affected.	110
Guppy	*(Poecilia reticulata)*	0.21	Toxic.	111
Sticklebacks	(General)	0.1	96-hour TLm.	49
Bluegill	*(Lepomis macrochirus)*	1.4	48-hour TLm.	71
Catfish	*(Ictalurus punctatus)*	27.0	Toxic, 16-183 days.	8
Coho salmon	*(O. kisutch)*	0.34	48-hour TLm.	112
" "	" "	0.52	96-hour TLm, $PbCl_2$.	113
" "	" "	0.3	Fry mortality, 96 hours.	95
Chinook salmon	*(O. tshawytscha)*	1.0	Fry mortality, 96 hours.	95
Brook trout	*(Salvelinus fontinalis)*	4.5	96-hour TLm, $Pb(NO_3)_2$.	114
" "	" "	0.5	Fry mortality, 3 weeks.	94
Rainbow trout	*(Salmo gairdneri)*	1.38	96-hour TLm, $Pb(NO_3)_2$.	115
" "	" "	1.0	96-hour LC_{50}.	92
" "	" "	0.6	Fry mortality, 96 hours.	95
Rainbow and Brook trout		0.1	Detrimental effects, 2-3 months, soft water.	45

Organism		Lead mg/l	Remarks	Reference
Fish	(General)	0.33	Toxic to minnows, brown trout (*Salmo trutta*), and sticklebacks.	5,65,93,116
"	"	0.1	Toxic.	5,51,117
Recommended standards or criteria				
Fish		0.1		15
Domestic		0.05		14,15
			General Remarks	
			Lead is less toxic in hard water. Lead toxicity increases with decreasing dissolved oxygen.	15
			Lead toxicity to aquatic biota is affected by hardness, alkalinity, and pH (i.e. formation of precipitates).	14

Lithium

Organism	Lithium mg/l	Remarks	Reference
Protozoa *(Microregma)*	66	Food intake inhibited, lithium chloride.	42
Invertebrates			
"fly larvae"	848	Prevents emergence of offspring and retards development of larvae and pupae, lithium chloride.	221
Daphnia magna	7.2	Immobilization, lithium chloride.	43
" "	16.0	Threshold of toxicity, 48 hours, lithium chloride.	59
Fish (General)	2600	Lethal to mature small freshwater fish - lithium chloride.	65
" "	100	Toxic to fish, lithium chloride.	20
Goldfish *(Carassius auratus)*	3750	Lethal in 22-27 hours, lithium chloride.	65
Recommended standards or criteria			
Domestic	5.0		15

Magnesium

Organism	Magnesium mg/l	Remarks	Reference
Invertebrates			
Planaria flatworm *(Polycelis nigra)*	400	Toxic, $MgCl_2$.	5
Fish (General)	100-400	Toxic in distilled H_2O, as $MgCl_2$, $Mg(NO_3)_2$.	8
Stickleback *(Gasterosteus aculeatus)*	300	Toxic.	5,7

Manganese

Organism	Manganese mg/l	Remarks	Reference
Invertebrates *(Daphnia magna)*	5.2	Reproductive impairment, 3 weeks	54
" "	5.7	LC_{50}, 3 weeks.	54
" "	4.1	10% reproductive impairment, 3 weeks.	54
Fish			
Stickleback *(Gasterosteus aculeatus)*	40.0	Lethal.	7
Fish (General)	2.2-4.1	Lethal, 8-18 hours, permanganates*	118,119
Recommended standards or criteria			
Domestic	0.05		14,15
Industrial	0.05		15
Irrigation	0.5		15
Stock watering	10.0		15
Fish and aquatic life	1.0		15
		General Remarks	
		Manganese is antagonistic to nickel toxicity.	15
		*Permanganates are more toxic than manganese salts, but are not persistent.	15

Mercury

Organism		Mercury mg/l	Remarks	Reference
Algae	*Macrocystis pyrifera*	50	50% reduction in photosynthesis, 4 days.	1
Diatom	*(Nitzschia delicatissma)*	0.1	Reduced growth and photosynthesis.	1
Phytoplankton	(General)	100	Complete inactiviation, 4 days.	1
Phytoplankton	(General)	0.9 -60.0	Minimum lethal concentration.	2
Invertebrates	*Daphnia magna*	.13	LC_{50}, 3 weeks.	3
	" "	6.7	50% reproductive impairment, 3 weeks.	3
	" "	3.4	10% reproductive impairment, 3 weeks.	3
	" "	5.0	LC_{50}, 48 hours.	3
	Daphnia magna	.0027	As mercuric chloride, significant reproductive impairment.	4
	Daphnia magna	.00004	As methyl mercuric chloride, significant reproductive impairment.	4
Fish				
Stickleback		.008	Lethal.	5,6,7
Minnows		.01	Killed after 90-92 days.	8
Fathead minnow	*(Pimephales promelas)*	.00023	92% dead after 3 months - methymercuric chloride.	9
" "	" "	.0004 - .0008	All dead after 3 months . " "	9
" "	" "	.00012	Spawning completely inhibited " "	9
" "	" "	.00007	No effect " "	9
Brook trout	*(Salvelinus fontinalis)*	.0029	6 months, gross toxic symptoms.	10
" "	" "	.00093	Reduced growth of offspring, behavioral symptoms (i.e. no spawning), 94% mortality after 24 months' exposure.	10
Rainbow trout	*(Salmo gairdneri)*	.0085	LC_{50}, phenylmercuric acetate.	11
" "	" "	.030	LC_{50}, methyl mercuric chloride.	11
" "	" "	.310	LC_{50}, mercuric chloride.	11
" "	" "	.024	LC_{50}, 96 hr., newly-hatched sac fry.	12
" "	" "	.042	LC_{50}, 96 hr., fingerlings.	12
Fish (Freshwater)		.004 - .020	Harmful.	13
Fish (General)		.05 - .01	Killed fish, 6-12 days.	8
Recommended Standards or criteria				
Domestic		.002		14
F.W. aquatic life		.00005		14

Organism	Mercury mg/l	Remarks	Reference
		General Remarks	
		Mercury is accumulated and concentrated by plants and plankton - adsorption.	14
		It is subject to bioaccumulation in the food chain.	14
		Fish - can concentrate mercury 10,000 times the concentration in the surrounding water.	184
		Synergism - toxicity to fish is accentuated by copper.	182
		Microorganisms can convert mercuric ions (which are retained electrostatically in the sediments) to methyl mercuric compounds (which are *not* retained in the sediments. are much more toxic to aquatic biota than mercuric ions, and which accumulate in fatty tissues of organisms).	185

Molybdenum

Organism	Molybdenum mg/l	Remarks	Reference
Algae *(Scenedesmus)*	54	Threshold concentration for deleterious effect.	59
Fish			
Fathead minnow *(Pimephales promelas)*	70	96-hour TLm, MoO_3, soft water.	107
" " " "	370	96-hour TLm, MoO_3, hard water.	107

Nickel

Organism		Nickel mg/l	Remarks	Reference
Invertebrates				
	Daphnia magna	.03	16% reproductive impairment, 3 weeks.	3
	" "	.095	50% reproductive impairment, 3 weeks.	3
	" "	.13	LC_{50}, 3 weeks, soft water.	3
Stonefly	*(Acroneuria lycurias)*	33.5	LC_{50}, 96 hours.	30
Mayfly	*(Ephemerella subvaria)*	4.0	LC_{50}, 96 hours.	30
Caddisfly	*(Hydropsyche betteri)*	64.0	LC_{50}, >14 days.	30
Fish (General)		4.6 - 9.8	LC_{50}, 96 hours, soft water.	33
" "		39.2 -42.4	LC_{50}, 96 hours, hard water.	33
Fathead minnow	*(Pimephales promelas)*	4.58	LC_{50}, 96 hours.	33
" "	" "	.73	Significant reduction in # eggs per spawning and hatchability of eggs.	214
Goldfish	*(Carassius auratus)*	9.82	LC_{50}, 96 hours.	33
Guppy	*(Poecilia reticulata)*	4.45	LC_{50}, 96 hours.	33
Sticklebacks (General)		0.8	Lethal limit.	7
Rainbow trout	*(Salmo gairdneri)*	32.0	LC_{50}, 48 hours.	213

General Remarks

a. Nickel toxicity to aquatic biota is affected by water hardness. Increased hardness leads to decreased toxicity. — 14

b. Nickel forms a complex with cyanide (CN^-) which is stable in alkaline waters, but if the pH goes down, the complex dissociates releasing nickel and cyanide into solution. — 15

Nitrate

Organism		Nitrate mg/l	Remarks	Reference
Invertebrates				
Planaria	*(Polycelis nigra)*	1000	48 hour TLm.	18
Cladocera	*Daphnia magna*	5000	Immobilized in 48 hours.	16
"	" "	665	96 hour TLm, acute.	200
Snail	*Biomphalaria alexandrina*	6000	Lethal, 24 hours, acute.	201
"	*Bulinus truncatus*	3100	Lethal, 24 hours, acute.	201
"	*Lymnaea sp.*	3251	96 hour TLm, acute.	200
Fish				
Mosquito fish	*(Gambusia affinis)*	6650	96 hour TLm, acute.	193
Goldfish	*(Carassius auratus)*	1282	Lethal in 14 hours.	202
Bluegill	*(Lepomis macrochirus)*	9400	96 hour TLm, small fish.	68
"	" "	10,000	96 hour TLm, medium fish.	68
"	" "	9000	96 hour TLm, large fish.	68
"	" "	2000	LC_{50}, 96 hours, sodium nitrate.	203
"	" "	420	LC_{50}, 96 hours, potassium nitrate.	203
Rainbow trout	*(Salmo gairdneri)*	1060	LC_{50}, 7 days, fingerlings.	204
Chinook salmon	*(Oncorhynchus tshawytscha)*	1080	LC_{50}, 7 days.	204
Recommended Standards or criteria				
Domestic		10*		14

General Remarks

a. Nitrate is converted to nitrite (which is 10 times more toxic than nitrate) by bacteria in nature. — 14,185

b. Nitrate, under proper conditions, can serve as a precursor in the microbial formation of nitrosamines in natural waters. (Nitrosamines are known carcinogens, mutagens, teratogens, and acute toxicants). — 185

* c. Standard for drinking water is 10 mg/l. At 20 mg/l, methemoglobinemia (blue baby disease) is common in infants. Standard employs a very narrow safety factor of 2, and perhaps a lower standard should be considered for waters that will be used for drinking. — 185

Phosphate

Organism		Phosphate mg/l	Remarks	Reference
Algae				
	Scenedesmus	250	Toxic, diethyl phosphate.	20
	"	12.5	Toxic, 4 days. Dimethyl phosphate.	20
Protozoa	*(Microregma)*	100	Toxic, 24 hours, diethyl phosphate.	20
	"	500	Toxic, 24 hours, dimethyl phosphate.	20
Invertebrates				
	(Daphnia magna)	25	Toxic, 48 hours, diethyl phosphate.	20
	" "	125	Toxic, 48 hours, dimethyl phosphate.	20
Fish				
Bluegill	*(Lepomis macrochirus)*	15	Toxic.	219,220
Rainbow trout	*(Salmo gairdneri)*	1090	Death of all fish, 24 hours, fingerlings.	15
			General Remarks	
			In themselves, phosphates seldom exhibit toxic effects upon fish and other aquatic life. They may be beneficial to fish culture by increasing algae and zooplankton. However, they may result in an overabundance of algae "with concomitant odors and detriment to fish", (i.e. eutrophication).	15

Selenium

Organism		Selenium mg/l	Remarks	Reference
Algae	*(Scenedesmus)*	2.5	Threshold toxicity, 4 days.	59
Bacteria	*(E. coli)*	90	Threshold toxicity.	59
Protozoa	*(Microregma)*	183	Threshold toxicity.	59
Invertebrate	*(Daphnia magna)*	2.5	Threshold toxicity, 48 hours.	59
Fish				
Goldfish	*(Carassius auratus)*	2.0	Toxic, 8 days.	5
"	" "	20	Lethal, 18-46 days.	5
Fathead minnow	*(Pimephales promelas)*	2.9	LC_{50}, 96 hours, fry.	215
Bluegill	*(Lepomis macrochirus)*	40.0	LC_{50}, 96 hours, juveniles.	215
Recommended standards or criteria				
Domestic		.01		14
			General Remarks	
			a. Selenium is subject to bioaccumulation in the food chain.	(a) 15
			b. There is evidence that selenium is converted microbiologically into different forms with varying toxicities.	(b)185

Sulfate

Organism		Sulfate mg/l	Remarks	Reference
Algae				
	Nitzschia linearis	3200	96-hour TLm	120
Diatom	*(Navicula seminulum)*	3200	50% reduction in growth rate	60
Invertebrates				
	Daphnia magna	203	100-hour TLm, acute.	200
	" "	152	"Threshold immobilization", adult.*	205
	" "	106	"Threshold immobilization", young.*	205
Copepod	*(Dioptomus oregonensis)*	13	"Threshold immobilization".*	205
Snail	*(Biomphalaria alexandrina)*	800	Lethal concentration, 24 hours.	201
Snail	*(Bulina truncatus)*	300	Lethal concentration, 24 hours.	201
Fish				
Mosquito fish	*(Gambusia affinis)*	240	24 to 96-hour TLm, acute.	193
Goldfish	*(Carassius auratus)*	100	Lethal, 72 hours.	152
Bluegill	*(Lepomis macrochirus)*	2980	96-hour TLm, acute.	120
Orangespotted sunfish	*(Lepomis humilis)*	420-500	Lethal in 1 hour.	206
Rainbow trout	*(Salmo gairdneri)*	10000	Survive for 24 hours, 25% kill in 18 days.	207
" "	" "	6820	"Survive 3 weeks".	207
" "	" "	3163	"Safe for 4 weeks".	207
" "	" "	1000	LE = 29.9 minutes, tap water.**	22
" "	" "	1000	LE = 847 minutes, distilled water.**	22
Recommended standards or criteria				
Domestic		500		15
Irrigation		200		15
Stock watering		500		15
			*Lower dissolved oxygen reduces the threshold values.	62
			**LE = avg. time to loss of equilibrium.	22

Sulfite - Hydrogen Sulfide

Organism		Sulfide mg/l	Remarks	Reference
Invertebrates				
	Daphnia magna	1.0	Minimum lethal concentration.	65,325,326
Mayfly larvae		1.0	Minimum lethal concentration.	325
Chironomid larvae		750.0	Minimum lethal concentration.	325
Fish				
Northern pike	*(Esox lucius)*	0.025	Hatchability of eggs reduced.	327
" "	" "	.017-.032	96-hour LC_{50}. Fry.	327
" "	" "	.009	96-hour TLm. Fry. 2 ppm. O_2.	327
" "	" "	.026	96-hour TLm. Fry. 6 ppm. O_2.	327
" "	" "	.030	96-hour TLm. Eggs. 2 ppm. O_2.	327
" "	" "	.032	96-hour TLm. Eggs. 6 ppm. O_2.	327
Fathead minnow	*(Pimephalos promelas)*	1.38	48-hour TLm.	316
Goldfish	*(Carassius auratus)*	4.3	Toxic, 24 hours.	21,328
Carp	*(Cyprinus carpio)*	3.3	Toxic, 24 hours.	328
White sucker	*(Catostomus commersoni)*	3.8	Toxic, 24 hours.	21,328
" "	" "	.013-.026	96-hour TLm. Fry. 6 ppm. O_2	329
Walleye	*(Stizostedion vitreum)*	.066-.083	48-hour TLm. Eggs. 6 ppm. O_2	329
"	" "	.007	96-hour TLm. Fry. 6 ppm. O_2	329
"	" "	.05	72-hour TLm. Fry.	330
Rainbow Trout	*(Salmo gairdneri)*	.049	96-hour TLm. Eggs.	330
" "	" "	.020	72-hour TLm. Fry.	330
Cutthroat trout	*(Salmo clarki)*	1.0	Minimum lethal concentration, 5 days.	331
Coho salmon	*(Oncorhynchus kisutch)*	1.2	Minimum lethal concentration, 5 days.	331
Chinook salmon	*(Oncorhynchus tshawytscha)*	1.0	Minimum lethal concentration, 5 days.	331
Trout		.86	Toxic, 24 hours.	21,328
Recommended standards or criteria				
Freshwater aquatic life		.002	As undissociated hydrogen sulfide (H_2S).	14

Uranium

Organism	Uranium mg/l	Remarks	Reference
Algae (*Scenedesmus*)	22	Threshold effect, uranyl nitrate.	42,59
Bacteria (*E. coli*)	1.7-2.2	Threshold effect, uranyl nitrate.	42,59
Protozoa (*Microregma*)	28	Threshold effect, uranyl nitrate.	42,59
Invertebrate (*Daphnia magna*)	13	Threshold effect, uranyl nitrate.	42,59
Fish			
Fathead minnow (*Pimephales promelas*)	2.8	96-hour TLm, uranyl sulfate, soft water.	107
" " " "	135.0	96-hour TLm, uranyl sulfate, hard water	107
" " " "	3.1	96-hour TLm, uranyl acetate.	107
Recommended standards or criteria			
Domestic	0.5-1.0		15
		General Remarks	
		Uranium is more toxic to aquatic biota in soft water than in hard water.	15

Vanadium

Organism	Vanadium mg/l	Remarks	Reference
Fish			
Fathead minnow (*Pimephales promelas*)	4.8	96-hour TLm, vanadyl sulfate, soft water.	107
" " " "	30	96-hour TLm, vanadyl sulfate, hard water.	107
" " " "	13	96-hour TLm, vanadium pentoxide, soft water.	107
" " " "	55	96-hour TLm, vanadium pentoxide, hard water.	107
Bluegill (*Lepomis macrochirus*)	6	96-hour TLm, vanadyl sulfate, soft water.	107
" " "	55	96-hour TLm, vanadyl sulfate, hard water.	107

Zinc

Organism		Zinc mg/l	Remarks	Reference
Algae (Phytoplankton)		0.1 - 0.5	Reduced phytosynthesis, soft water.	77
Chlorophyta	(General)	0.22-6.0	Minimum lethal concentrations for *Stigeoclonium tenue, Cladophora glomerata, Oedogonium spp., Ulothrix spp., Microspora spp., Mougeotia spp.*, and *Spyrogyra spp.*	76
	(Selenostrum capricornutum)	0.5	Not tolerated.	123
Diatom	*(Nitzschia linearis)*	4.3	96-hour TLm, acute.	120
Plant	*(Elodea condensus)*	11.0	Withered.	121
Bacteria				
"sewage"		.0001	"Toxic at this lowest level, BOD test".	122
"		1.0	BOD was 63% of control.	
Invertebrates				
Snail	*(Limnaea pereger)*	0.2	"Highest dose tolerated".	117
"	*(Physa heterostropha)*	0.62-0.78	96-hour TLm, soft water.	125
"	" "	2.36-6.36	96-hour TLm, hard water.	125
"	" "	.303	LC_{50}, 96 hours, soft water.	126
"	" "	.434	LC_{50}, 96 hours, hard water.	126
Snails	*(Planorbis glabratus, Balinus contortus)*	2.2-11	Lethal, 2-4 days.	121
Limpet	*(Ancylastrum fluviatile)*	0.2	Highest dose tolerated.	117
Amphipod	*(Gammarus pulex)*	0.3	Highest dose tolerated.	117
Mayfly nymph	*(Chloeon simile)*	0.2 -0.5	Highest dose tolerated.	117
Mayfly	*(Ephemerella subvaria)*	16.0	LC_{50}, 10 days.	30
Caddisfly	*(Hydropsyche betteri)*	32.0	LC_{50}, 11 days.	30
Stonefly	*(Acroneuria lycurias)*	32.0	LC_{50}, 14 days.	30
Planaria	*(Polycelis nigra)*	30.0	Highest dose tolerated.	117
Cladocera	*(Daphnia magna)*	0.07	16% reproductive loss, 3 weeks.	3
		0.1	LC_{50}, 48 hours Note: Ref. 14, 15, and 19 list numerous higher concentrations for toxicity to *Daphnia*. Those listed here are the lowest ones presented.	3,(14)

Organism		Zinc mg/l	Remarks	Reference
Fish (General)**				
Carp	*(Cyprinus carpio)*	7.8	96-hour TLm, acute.	87
"	" "	5.0	Detrimental to embryos and larvae.	127
Goldfish	*(Carassius auratus)*	6.44	96-hour TLm.	33
Guppy	*(Poecilia reticulata)*	0.04	20% killed, 100 hours.	128
Striped bass	*(Morone saxatilus)*	6.7	96-hour TL_{50}.	87
" "	" "	0.1	48 to 96-hour TLm, acute, larvae and juveniles.	88
Pumpkinseed	*(Lepomis gibbosus)*	20.0	96-hour TLm	87
Bluegill	*(Lepomis macrochirus)*	0.235	Inhibited spawning and killed new fry.	129
"	" "	1.9 - 3.6	96-hour TLm.	130
"	" "	0.9 - 2.1	50% survival, soft water.	149
"	" "	6.18 - 9.5	50% survival, hard water.	149
White perch	*(Morone americanus)*	10.1	48-hour TLm.	13
Banded killifish	*(Fundulus diaphanus)*	19.1	96-hour TLm.	87
Fathead minnow	*(Pimephales promelas)*	0.87	96-hour TL_{50}, soft water.	33
" "	" "	33.0	96-hour TL_{50}, hard water.	33
" "	" "	4.7 -39.5	96-hour TLm, varies with pH and hardness.	133
" "	" "	0.18 - 1.3	Reduction in spawning according to dose.	134
Trout (General)		0.01	Toxic to ova and young.	135
" "		0.15	Toxic.	136
Cutthroat trout	*(Salmo clarki)*	0.09	96-hour TL_{50}.	41
Rainbow trout	*(Salmo gairdneri)*	0.01	Killed 54% in 28 days, alevins.	135
" "	" "	0.09	96-hour TL_{50}.	41
Brown "	*(Salmo trutta)*	0.01	Toxic to ova and alevins, acid water.	135
Brook trout	*(Salvelinus fontinalis)*	1.38	96-hour TL_{50}.	114
Salmon (General)		0.15	Toxic, fry.	137
Atlantic salmon	*(Salmo salar)*	0.042	24-hour TLm, acute.	130
" "	" "	0.053	Avoidance threshold.	138
Chinook salmon	*(O. tschawytscha)*	0.103	96-hour TLm.	113
Coho salmon	*(O. kisutch)*	0.14	Fry mortality, 96 hours.	95
Sticklebacks (General)		0.1	"Toxic limit".	49
Mummichog	*(Fundulus heteroclitus)*	19.1	96-hour TLm, acute.	87

Zinc (continued)

Organism	Zinc mg/l	Remarks	Reference
Recommended standards or criteria			
Domestic	5.0		15
		Cu-Zn synergism	
**Fish (General)	8.0	Zn alone, tolerated, 8 hours, soft water.	15
" "	1.0	With .025 mg/l copper- most fish died in 8 hours, soft water. Other effects vary with D.O., temp. hardness.	15
		General Remarks	
		a. Zinc exhibits synergism with copper (in soft water).	(a) 8, 15
		b. Toxicity of zinc to aquatic biota is affected by water hardness, temperature, dissolved oxygen. Increased temperature and reduced D.O. result in increasd toxicity.	(b) 14
		c. Hardness is antagonistic to zinc's toxicity to aquatic biota.	(c) 15
		d. Zinc is often adsorbed on silt, where it can be ingested by organisms (e.g. bottom feeders), but this zinc will not show up in concentration data for the water column.	(d) 15
		e. Certain heavy metal salts are synergistic to zinc toxicity.	(e) 14

Aldrin (Insecticide)

Organism		Aldrin mg/l	Remarks	Reference
Invertebrates				
	Chironomus	.012	Killed 50% in 8 hours, larvae.	243
	Daphnia magna	.029	Immobilized in 50 hours.	244
Lymnaeid snails		4.8	Lethal in 24 hours.	245
Fish				
Minnows	(General)	.018	10-day TLm.	246
Goldfish	*(Carassius auratus)*	.02	50% killed, 10 days.	246
"	" "	.032	80% killed, 10 days.	246
"	" "	.028	96-hour TLm.	231
Fathead minnow	*(Pimephales promelas)*	.028	96-hour TLm.	231
Guppy	*(Poecilia reticulata)*	.033	96-hour TLm.	231
Bluegill	*(Lepomis macrochirus)*	.013	96-hour TLm.	231
Trout	(General)	.025	Toxicity threshold.	237,238
Brown trout	*(Salmo trutta)*	.025	33% killed, 48 hours.	222
" "	" "	.033	100% killed, 48 hours.	222
Recommended standards or criteria				
Freshwater aquatic life		.000003		14
			General Remarks	
			Aldrin is metabolically converted to dieldrin.	247
			Aldrin is persistent and is subject to bioaccumulation and concentration in the food chain.	14

Chlordane (Insecticide)

Organism		Chlordane mg/l	Remarks	Reference
Invertebrates				
	Daphnia magna	.028	96 hour LC_{50}.	256
Amphipod	*(Hyallela azteca)*	.097	96 hour LC_{50}.	256
Midge	*(Chironomus)*	.010	24 hour LC_{50}, larvae.	257
"	"	.015	50% killed, 8 hours, larvae.	243
Fish				
Goldfish	*(Carassius auratus)*	.082	96 hour TLm.	231
"	" "	.050	50% killed, 4 days.	222
Fathead minnow	*(Pimephales promelas)*	.052	96 hour TLm, soft water.	231
" "	" "	.069	96 hour TLm, hard water.	231
" "	" "	.037	96 hour LC_{50}.	256
Guppy	*(Poecilia reticulata)*	.019	96 hour TLm.	231
Channel catfish	*(Ictalurus punctatus)*	0.5	96 hour TLm.	258
Bluegill	*(Lepomis macrochirus)*	.022	96 hour TLm.	231
Bass	(General)	.2	Toxic, fingerlings.	235
Pike	(General)	.005	Distress, 24 hours.	257
"	"	.05	100% mortality, 24 hours.	256
Trout	(General)	.03	Toxicity threshold.	237,238
"	"	1.0	Death in 3 hours.	259
"	"	.025	20% killed, 48 hours, 4-7" trout.	255
Brook trout	*(Salvelinus fontinalis)*	.047	96 hour LC_{50}.	256
Recommended standards or criteria				
Freshwater aquatic life		.00001		14
			General Remarks	
			Chlordane is persistent and is subject to bioaccumulation in the food chain. It is also a carcinogen.	14

2,4-D (Herbicide)

Organism		2,4-D mg/l	Remarks	Reference
Plants				
Water milfoil		6.0	Controlled growth.	303
Bacteria	(Aerobic)	2.0	Inhibited growth.	304
Fish				
Carp	*(Cyprinus carpio)*	65.0	Some mortality.	222
Bream		100	Some mortality.	222
Bleak		75	Toxicity threshold.	20, (15)
Perch		75	Toxicity threshold.	20, (15)
Bass	(General)	100	Some mortality.	222
Largemouth bass	*(Micropterus salmoides)*	350	24-hour TLm.	305
Bluegill	*(Lepomis macrochirus)*	350	24-hour TLm.	305
"	" "	1.0	40% killed, fingerlings, esters and amines.*	306
"	" "	5.0	100% killed, fingerlings, esters and amines.*	306
Recommended standards or criteria				
Domestic		0.1		14
			General Remarks	
			*The esters and amines of 2,4-D are more toxic than 2,4-D itself.	15;306
			The synergisms and antagonisms affecting 2,4-D toxicity are not well-understood. The concentration of chemical that will kill weeds in one lake without harming fish may be toxic to fish in another lake.	307

DDT (Insecticide)

Organism		DDT mg/l	Remarks	Reference
Invertebrates	(General)	.013 -.022*	DDD. Drastic temporary loss of fish food organisms.	222
Stonefly		0.1	96-hour TLm.	223
Caddisfly		0.1	96-hour TLm.	224
	Culex larvae	.001	Median lethal dace.	225
Midge	*(Chironomus)*	.01	"Infestation controlled".	226
	Daphnia	.001	64-hour tolerance limit.	222
	Chaoborus	0.013*	DDD. Controlled *Chaoborus*, did not eliminate fish, but did temporarily eliminate chironomid larvae, an important part of fishes' diet.	227
Crayfish	(General)	0.25 -0.50	Lethal.	228
"	*Oronectes nais*	.00024	LC_{50}, 96 hours.	229
Fish	(General)	.01 -1.0	Lethal.	228
"	(General)	0.1	Lethal. (alcohol solution).	230
Dace		.01	Lethal.	222
Fathead minnow	*(Pimephales promelas)*	.032	96-hour TLm.	231
Goldfish	*(Carassius auratus)*	.027	96-hour TLm.	231
Golden shiner	*(Notemigonus crysoleucas)*	0.5	Lethal.	232
Creek chub	*(Semotilus atromaculatus)*	0.01	Lethal (alcohol suspension).	230
Common sucker	*(Catostomus commersoni)*	.001	Lethal (alcohol suspension).	230
Channel catfish	*(Ictalurus punctatus)*	2.6*	DDD. 96-hour TLm.	233
Sculpins	*(Cottus sp.)*	0.14	Lethal, powder form.	232
Darters		0.14	Lethal, powder form.	232
"		0.12	Killed 22%.	234
Bass	(General)	.01	Lethal. Yearlings.	235
Largemouth bass	*(Micropterus salmoides)*	.002	LC_{50}, 96 hours.	236
Bluegill	*(Lepomis macrochirus)*	.01	Toxicity threshold.	237,238
"	" "	.016	96-hour TLm.	231
Crappie	(Pomoxis sp.)	0.18	Lethal.	232
Black crappie	*(Pomoxis nigromaculatus)*	.013- .022*	DDD. Lethal.	222
Guppy	*(Poecilia reticulata)*	.043	96-hour TLm.	231
"	" "	.01	Toxicity threshold.	237

DDT (continued)

Organism		DDT mg/l	Remarks	Reference
Fish (Continued)				
Mosquito fish	*(Gambusia affinis)*	.01	Median lethal dose.	225
Trout	(General)	0.14	Lethal, powder form.	232,237
Brook trout	*(Salvelinus fontinalis)*	.001	Lethal (alcohol suspension).	230
" "	" "	.06	Tolerance limit.	239
" "	" "	10.0	Tolerance limit, powder form.	239
Rainbow trout	*(Salmo gairdneri)*	.388	96-hour TLm.	240
" "	" "	.0237-.074	96-hour TLm	241
" "	" "	50.0	Critical level, powder form.	169
Salmon	(General)	.047	24-hour TLm.	242
Chinook salmon	*(Oncorhynchus tshawytscha)*	17.8	Critical level, powder form.	169
Amphibians	(General)	0.1	Tadpoles, all killed.	228
Recommended standards or criteria				15,14
Freshwater aquatic life		.000001		

General Remarks

*DDD has much the same general properties and is used similarly to DDT. Its insecticidal toxicity approximates DDT, but its mammalian toxicity is only about one-fifth that of DDT. 15

DDT is subject to bioaccumulation and concentration in the food chain. Concentrations have been found in fish that are 2 x 10^6 times the concentration in the surrounding water. 14

Diazinon (Insecticide)

Organism		Diazinon mg/l	Remarks	Reference
Invertebrates				
	Daphnia magna	.0043	Immobilization in 50 hours.	244
Fish				
Guppy	*(Poecilia reticulata)*	4.0	Abnormal behavior in one hour, death in 24-58 hours.	282

Dieldrin (Insecticide)

Organism		Dieldrin mg/l	Remarks	Reference
Invertebrates				
Daphnid	*(Simocephalus serrulatus)*	.2	Immobilization.	248
"	*(Daphnia pulex)*	.25	Immobilization.	248
"	*(Daphnia magna)*	.33	Immobilization, 50 hours.	244
Midge larvae	*(Chironomus)*	.007	50% killed.	243
Stonefly	*(Acroneuria pacifica)*	.0002	LC_{50}, 20 days.	249
Snails	(Lymnaeid)	2.5	100% killed, 24 hours.	245
Fish	(General)	.0056-.042	TLm, depending on water hardness.	250
"	"	.125	Lethal for all fish tested.	251
Goldfish	*(Carassius auratus)*	0.012	17% killed, 96 hours.	252
"	" "	.006	Approximate TLm.	222
"	" "	.037	96 hour TLm.	231
Fathead minnow	*(Pimephales promelas)*	.016	96-hour TLm.	231
Golden shiner	*(Notemigonus crysoleucas)*	.04	Approximate TLm.	222
Guppy	*(Poecilia reticulata)*	0.2	Distress in one hour, death in 12 hours.	253
Sailfin molly	*(Poecilia latipinna)*	.00075	Growth rate and reproduction adversely affected.	254
Bluegill	*(Lepomis macrochirus)*	.0079	96-hour TLm.	231
Green sunfish	*(Lepomis cyanellus)*	.0085	96-hour TLm.	231
Bass	(General)	.006	Approximate TLm.	222
Trout	(General)	.016	Toxicity threshold.	237
"	"	.025	100% killed, 48 hours.	255
Brown trout	*(Salmo trutta)*	.016	40% killed, 48 hours.	255
" "	" "	.02	Lethal in 48 hours.	237
Rainbow trout.	*(Salmo gairdneri)*	.0237-.074	96-hour TLm, fingerlings.	241
" "	" "	.0237	96-hour TLm.	240
Recommended standards or criteria				
Freshwater aquatic life		.000003		14
			General Remarks	
			Dieldrin is persistent and subject to bioaccumulation and concentration in the food chain. It is also a carcinogen.	14
			Dieldrin concentrations in fish may be 100,000 times that of the surrounding water.	14

Malathion (Insecticide)

Organism		Malathion mg/l	Remarks	Reference
Invertebrates				
Stoneflies	*(Acroneuria pacifica)*	.0056	96 hour TLm.	223
"	*(Pteronarcys californica)*	.100	96 hour TLm.	223
"	*(Claassenia sabulosa)*	.056	96 hour TLm.	223
"	*(Pteronarcella badia)*	.001	96 hour LC_{50}.	263
Caddisfly	*(Arctopsyche grandis)*	.032	96 hour TLm.	223
Daphnid	*(Daphnia magna)*	.0009	64 hour tolerance limit.	244
"	*(Daphnia magna)*	.0009	Immobilized in 50 hours.	244
"	*(Daphnia pulex)*	.0018	48 hour LC_{50}.	248
"	*(Simocephalus serrulatus)*	.0035	96 hour LC_{50}.	248
Amphipod	*(Gammarus lacustris)*	.001	96 hour LC_{50}.	278
"	" "	.00076	96 hour LC_{50}.	229
Midge	*(Chironomus)*	.002	24 hour LC_{50}, larvae.	279
Fish				
Goldfish	*(Carassius auratus)*	5.0	Lethal.	280
Fathead minnow	*(Pimephales promelas)*	12.5	96 hour TLm.	231
" "	" "	25.0	24 hour TLm.	280
Red-sided shiner	*(Richardsonius balteatus)*	8.9	96 hour TLm, soft water.	281
" "	" "	9.6	96 hour TLm, hard water.	281
Mosquito fish	*(Gambusia affinis)*	.05	40% killed.	280
Guppy	*(Poecilia reticulata)*	2.0	Death in 24 hours.	282
Yellow perch	*(Perca flavescens)*	5.0	Lethal.	280
Bluegill	*(Lepomis macrochirus)*	.11	96 hour LC_{50}.	283
Largemouth bass	*(Micropterus salmoides)*	.05	96 hour LC_{50}.	284
Sunfish	(General)	5.0	Lethal.	280
Salmonids	(General)	.12-.265	96 hour LC_{50}.	285
Salmon	(General)	.033	24 hour TLm, young salmon.	286
"	"	.1	Toxic, fingerlings.	280
Chinook salmon	*(Oncorhynchus tschawytscha)*	.023	96 hour LC_{50}.	287
Rainbow trout	*(Salmo gairdneri)*	.068	96 hour LC_{50}.	288
Recommended standards or criteria				
Freshwater aquatic life		.0001		14

Organism	Malathion mg/l	Remarks	Reference
		General Remarks	
		a) The chemical and biological conditions of the water affect the stability of malathion in that water.	(a) 289
		b) The effects of malathion exposure may be additive over time.	(b) 14

Parathion (Insecticide)

Organism		Parathion mg/l	Remarks	Reference
Invertebrates				
	Daphnia magna	.00062	96-hour LC_{50}.	290
	" "	.0008	50-hour LC_{50}.	248
	Daphnia pulex	.0006	48-hour LC_{50}.	248
Daphnid	*(Simocephalus serrulatus)*	.00037	48-hour LC_{50}.	248
Stonefly	*(Acroneuria pacifica)*	.00093	5-day LC_{50}, larvae.	291
"	" "	.00044	30 day LC_{50}.	291
"	" "	.0001	96-hour TLm.	223
"	" "	.00008	Statistically significant reproductive impairment.	291
Stonefly	*(Pteronarcys californica)*	.0022	30-day LC_{50}.	291
"	" "	.0032	96-hour TLm.	223
Caddisfly	*(Hydropsyche californica)*	.00043	96-hour LC_{50}.	292
"	(General)	.001	96-hour TLm.	223
Midge	*(Tanypus grodhausi)*	.0005	24-hour LC_{50}.	293
"	*(Chironomus tentans)*	.031	96-hour LC_{50}.	290
"	*(Chironomus)*	.008	50% killed, 8 hours, larvae.	242
Amphipod	*(Gammarus fasciatus)*	.00040	96-hour LC_{50}.	290
"	" "	.00007	43-day LC_{50}.	291
"	" "	.00004	"Significantly greater mortality".	291
Snails	*Lymnaeid snails*	.325	Lethal, 24 hours.	245
Fish				
Minnows	(General)	2.5	LC_{50}.	294
Fathead minnow	*(Pimephales promelas)*	1.4	96-hour TLm, parathion No. 1, soft water.	231
" "	" "	1.6	96-hour TLm, parathion No. 1, hard water.	231
" "	" "	2.7	96-hour TLm, parathion No. 2, soft water.	231
" "	" "	3.6	96-hour TLm, parathion No. 2, hard water.	231
" "	" "	1.6	96-hour LC_{50}.	290
" "	" "	.004	8-1/2 months, reproductive impairment and deformities.	290
Goldfish	*(Carassius auratus)*	1.5	TLm.	222
"	" "	2.0	Lethal.	222
Guppy	*(Poecilia reticulata)*	0.5	Distress in one hour, death in several days.	282
"	" "	0.1	Inhibition of spermatogenesis.	295

Organism		Parathion mg/l	Remarks	Reference
Brown bullhead	*(Ictalurus nebulosus)*	0.03	30 days, caused "tremors".	296
" "	" "	0.06	30 days, caused convulsions, deformed vertebral column.	296
Bluegill	*(Lepomis macrochirus)*	0.5	96-hour LC_{50}.	290
"	" "	0.05	LC_{50}.	294
"	" "	0.04	Heavy mortality.	222
"	" "	0.063	Lethal.	232
"	" "	.00034	23 months, caused deformities.	290
Brook trout	*(Salvelinus fontinalis)*	1.76	96-hour LC_{50}.	290
" "	" "	.032	Abnormal development, mortality of embryos.	290

General Remarks

Goldfish and Japanese killifish that were kept one month in a concentration of one thirtieth of the 48-hour TLm experienced retarded growth and consumed less food. This study concluded that the arbitrary concentration of 1/10 the 48-hour TLm that is sometimes used as a limiting value is too toxic.

Polychlorinated Biphenyls (PCBs)

Organism		PCB mg/l	Remarks	Reference
Invertebrates				
	Daphnia magna	.0013	3-week LC_{50}, Aroclor 1254	298
	" "	.0035	100% mortality, Aroclor 1254	298
Fish				
Fathead minnow	*(Pimephales promelas)**	.015	96 hour LC_{50}, Aroclor 1242.	299
" "	" "	.0077	96 hour LC_{50}, Aroclor 1254.	299
" "	" "	.0088	50% killed, 60 days, Aroclor 1242.	299
" "	" "	.0046	50% killed, 60 days, Aroclor 1254.	299
" "	" "	.0018	Spawning affected, Aroclor 1254.	299
" "	" "	.0100	Lethal to newly-hatched fry, Aroclor 1242.	299
" "	" "	.0047	TL_{50}, 30 days, newly-hatched, Aroclor 1248	300
" "	" "	.0033	TL_{50}, 30 days, newly-hatched, Aroclor 1260.	300
Bluegill	*(Lepomis macrochirus)*	.054	LC_{50}, 15 days, Aroclor 1242.	301
"	" "	.076	LC_{50}, 15 days, Aroclor 1248.	301
"	" "	.024	LC_{50}, 15 days, Aroclor 1254.	301
Cutthroat trout	*(Salmo clarki)*	1.17-50.0	96-hour LC_{50}, Aroclors 1221-1268.	301
Rainbow trout	*(Salmo gairdneri)*	>1500	Acute toxicity, Aroclors 1242-1260.	301

General Remarks

* a) Fathead minnows were able to reproduce at PCB concentrations that were actually lethal to the larvae. — 300

b) Freshwater invertebrates are generally more susceptible to acute toxic affects of PCB's than fish. — 301,302

c) Bioaccumulation in aquatic organisms may result in PCB concentrations in fish that are 2.3×10^5 times that of the surrounding water. — 299

2,4,5-T (Herbicide)

Organism		2,4,5 T mg/l	Remarks	Reference
Fish	(General)	10.0	25% killed, 72 hours.	169
Perch		55.0	Threshold toxicity.	20 (15)
Bleak		60.0	Threshold toxicity.	20 (15)
Recommended Standards or Criteria				
Domestic		.01		14

Toxaphene (Insecticide)

Organism		Toxaphene mg/l	Remarks	Reference
Algae	(General)	2.0	Inhibited growth of 50% of test algae, 21 days.	260
Invertebrates				
Midge	*(Chironomis)*	0.1	Lethal.	261
"	"	.03	Lethal, larvae.	262
Damselfly		.03	Lethal.	262
Dragonfly		.03	Lethal.	262
Stoneflies		.0013-.0030	96-hour LC_{50}, *Pteronarcys californica, Pteronarcella badia, Claassenia sabulosa*	263
Fish	(General)	.006	Lethal in 10 days.	264
"	"	.036	Lethal.	265,266
Minnows	"	.02	Lethal.	237
Goldfish	*(Carassius auratus)*	.005	TLm 10 days.	267
"	" "	.0056	96-hour TLm.	231
"	" "	.04	Lethal.	231
Carp	*(Cyprinus carpio)*	.1	Lethal, 72 hours.	268
Fathead minnow	*(Pimephales promelas)*	.0051	96-hour TLm, hard water.	231
" "	" "	.0075	96-hour TLm, soft water.	231
" "	" "	.000055	Significantly reduced growth.	269
Creek Chub	*(Semotilus atromaculatus)*	.02	Lethal.	237
Fallfish	*(Semotilus corporalis)*	.02	Lethal.	237
Shiners	*(Notropis sp.)*	.02	Lethal.	237
Blacknose dace	*(Rhinichthys atratulus)*	.02	Lethal.	237
Guppy	*(Poecilia reticulata)*	.005	Distress in 12 hours, death in 30 hours.	253
"	" "	.02	96-hour TLm.	231
Sculpins	*(Cottus sp.)*	.02	Lethal.	237
Catfish	(General)	1.9	96-hour TLm.	258
Black bullhead	*(Ictalurus melas)*	.0018	96-hour LC_{50}.	270
Darters	(General)	.02	Lethal.	237
Yellow perch	*(Perca flavescens)*	0.1	Lethal.	222
Bluegill	*(Lepomis macrochirus)*	.01	Toxic threshold	237
"	" "	.05	Lethal, fingerlings.	235
"	" "	.0035	96-hour TLm.	231
"	" "	.0180	96-hour LC_{50}.	236

Toxaphene (continued)

Organism		Toxaphene mg/l	Remarks	Reference
Fish (Continued)				
Bass	(General	.05	Lethal, fingerlings	235
Largemouth bass	*(Micropterus salmoides)*	0.1	Lethal.	222
" "	" "	.002	96-hour LC_{50}.	236
Trout	(General)	.005	Lethal.	271
"	"	.0135-.0165	96-hour TLm, finerlings.	241
Rainbow trout	*(Salmo gairdneri)*	.005	Toxic threshold	238
" "	" "	.125	Toxic.	272
" "	" "	.0135	96-hour TLm.	240
Brown trout	*(Salmo trutta)*	.005	Toxic threshold.	238
" "	" "	.025	Killed 70% in 24 hours.	255
" "	" "	0.1	Lethal.	222
Brook trout	*(Salvelinus fontinalis)*	.000039	Adversely affected growth of fry, greater mortality.	273
" "	" "	.0108	96-hour LC_{50}, 16 month-old trout.	273
Recommended standards or criteria				
Domestic		.005		14
Freshwater aquatic life		.000005		14

General Remarks

a) Toxaphene is persistent. Its toxicity to fish may last up to 5 years after its application. — 274,276

b) Toxaphene is concentrated by organisms and is subject to bioaccumulation in the food chain. Trout have been found with toxaphene concentrations 20,000 times that of the surrounding water. — 14

c) The breakdown of toxaphene is more rapid in highly turbid lakes. — 275

d) Hard water detoxifies toxaphene more rapidly than soft water. Stirring increases the rate of detoxification in lab studies. — 277

Total Dissolved Solids

Organism		TDS mg/l	Remarks	Reference
Fish	(General)	5,000-10,000	Limiting concentrations for freshwater fish according to species and prior acclimating.	15

General Remarks

a. Freshwater fish can become acclimitized slowly to higher salinities than they are accustomed, but cannot survive sudden low to high salinity changes. — 15

b. Dissolved solids can affect the toxicity of heavy metals and organic compounds to aquatic biota. It has an antagonistic effect on the toxicity of heavy metals like copper, chromium, and zinc. — 15

General Toxicity Table for Aquatic Biota

(all concentrations mg/L)

Element	Algae	Bacteria	Protozoa	Insects	Crustaceans	Other Invertebrates	Fish	Remarks	Reference
Hg	0.9 -60.0				5.0[a]		0.00012[b] 0.05[c]	a. *Daphnia*. B. Spawning inhibited, fathead minnow. c. Killed fish (General).	2,3,8,9
As					1.4[d]	40.[e]	1.1	d. *Daphnia*. e. Planaria (*Polycelis nigra*.	3,18,20
Cd					0.05[f]		0.029-73.5	f. *Daphnia*.	3,37
Cr	0.32- 1.6	62.5	37.	16.0[h]	0.6[g]		17.6-27.3[d] 27.[j]	g. *Daphnia*. h. Mayfly - *Ephemerella subvaria*. i. Fathead minnows depending on hardness, Cr^{+6}. j. Fathead minnow, hard water, Cr^{+3}.	3,30,33, 40,42,45, 50
Cu	0.15-0.70	0.08	0.05		0.035[k] 0.06[ℓ]	0.039-1.7[m]	0.4 -0.5[n] .06 -0.6[n]	k. *Daphnia*. ℓ. Crayfish - *Oronectes rusticus*. m. Snails. n. Rainbow trout *(Salmo gairdneri)*, depending on hardness and DO.	3,42,59, 76,82,83, 84,93
Fe				16.0[p]	5.9[o]		1.0-2.0	o. *Daphnia*. p. Caddisfly - *Hydropsyche batteri*.	3,8,30, 103
Pb		1.0[q]		16.0[s]	0.1-0.3[r]		0.33	q. Aerobic. r. *Daphnia*. s. Mayfly - *Ephemerella subvaria*.	3,5,20,30 65,80,93, 105,106
Mn					5.7[t]		2.2 -4.1	t. *Daphnia*.	54,118, 119
Zn	0.22-6.0			16.0[v]	0.1[u]	0.3[w]	0.9 -2.1[x] 6.18-9.5[y]	u. *Daphnia*. v. Mayfly - *Ephemerella submaria*. w. Amphipod - *Gammarus pulex*. x. Bluegill, soft water. y. Bluegill, hard water.	3,30,76, 117,149
Se	2.5	90.	183.		2.5[z]		2.9[aa] 40.0[bb]	z. *Daphnia*. aa. Fathead minnow. bb. Bluegill.	59,215
Mg						400.[cc]	100-400	cc. Planaria - *Polycelis nigra*.	5,8
SO_4	3200.				203.[dd]	300.[ee]	2980.[ff]	dd. *Daphnia*. ee. Snail. ff. Bluegill - *Lepomis macrochirus*.	60,120, 200,201
B		480.		120.			3700-4000[gg] 19000-19500[hh]	gg. Sodium borate, hard water, fish (general). hh. Boric acid, hard water, fish (general).	208,209, 210
F		45.	226.			270.[ii]	113.[jj] 250.[kk]	ii. *Daphnia*. jj. Rainbow trout, soft water. kk. Rainbow trout, hard water.	42,59, 199
Mo	54.						70.[ℓℓ] 370.[mm]	ℓℓ. Soft water. fathead minnow. mm. hard water, fathead minnow.	59,107
NO_3				665.		1000[nn] 3100[oo]	9000 - 10000.[pp]	nn. Planaria. oo. Snail. pp. Bluegill.	18,68,200, 201
Al							0.07[qq]	qq. Sticklebacks.	7
Ba					8.9[rr]		400.0[ss]	rr. *Daphnia*. ss. Stickleback	3;5,7
PO_4	12.5	100.			25.[tt]		15.0	tt. *Daphnia*.	20,200, 201

General Toxicity Table for Aquatic Biota (continued)

Element	Algae	Bacteria	Protozoa	Insects	Crustaceans	Other Invertebrates	Fish		Reference
Ni				4.0[vv]	0.095[uu]		4.6- 9.8[ww] 39.2-42.4[xx]	uu. *Daphnia*. vv. Mayfly - *Ephemerella subvaria*. ww. soft water. xx. hard water.	3,30,33
V							4.8[yy] 30.0[zz]	zz. Soft water Hard water } fathead minnow.	107
Be							0.2[A] 11.0[B]	A. Beryllium sulfate, soft water. B. Beryllium sulfate, hard water.	107,108
Li			66.	848.[D]	16.0[C]		2600.	C. *Daphnia*. D. Fly larvae	42,59,65,221
Sb	3.5	33.	15.		9.0[E]		12.0[F] 20.0[G]	E. *Daphnia*. F. Hard water - fathead minnow. G. Soft water - fathead minnow.	42,59,107,108
U	22.	1.7-2.2	28.		13.[H]		2.8[I] 135.0[J]	H. *Daphnia*. I. Soft water J. Hard water. } fathead minnow	42,59,107

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