LOCKHEED MARTI

# **ES/ER/TM-96/R2**

# ENVIRONMENTAL RESTORATION PROGRAM

Toxicological Benchmarks for Screening Potential Contaminants of Concern for Effects on Aquatic Biota: 1996 Revision

This document has been approved by the K-25 Site Technical Information Office for release to the public. Date: 6-26-46

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED

MANAGED BY LOCKHEED MARTIN ENERGY SYSTEMS, INC. FOR THE UNITED STATES DEPARTMENT OF ENERGY



This report has been reproduced directly from the best available copy.

Available to DOE and DOE contractors from the Office of Scientific and Technical Information, P.O. Box 62, Oak Ridge, TN 37831; prices available from 423-576-8401 (fax 423-576-2865).

Available to the public from the National Technical Information Service, U.S. Department of Commerce, 5285 Port Royal Rd., Springfield, VA 22161.

the second s	burnet and .	and the state of the second	 Line and a line	<b>~</b>

MARTIN MARIETTA

MARTIN MARIETTA ENERGY SYSTEMS, INC.

POST OFFICE BOX 2008 OAK RIDGE, TENNESSEE 37831

June 28, 1996

Ms. T. C. Perry Program Manager Environmental Restoration Division Department of Energy Oak Ridge Operations Office P.O. Box 2001 Oak Ridge, Tennessee 37831-8541

Dear Ms. Perry:

Contract DE-AC05-84OR21400, Transmittal of Toxicological Benchmarks for Screening Potential Contaminants of Concern for Effects on Aquatic Biota: 1996 Revision (ES/ER/TM-96/R2)

Enclosed you will find a copy of the subject report. As indicated by the document number, this is a revised report; therefore, previous versions of this report should be discarded. The purpose of this document is to present revised potential screening benchmarks for protection of aquatic life from contaminants in water. This document represents a completed milestone for the Environmental Restoration Risk Assessment Program.

If you have any questions or comments regarding this document, please contact me at (423) 576-2734 or Glenn Suter at (423) 574-7306.

Sincerely, Carlon We Jun

C. Wilson McGinn Risk Assessment Manager

CWM:sk

Enclosure

cc/encl: R. K. Holmes S. B. Kerr File-ER Document Management Center----RC

cc w/o encl: S. P. Riddle, DOE-ORO

• . .

### ES/ER/TM-96/R2

# Toxicological Benchmarks for Screening Potential Contaminants of Concern for Effects on Aquatic Biota: 1996 Revision

G. W. Suter II C. L. Tsao

Date Issued-June 1996

Prepared by Risk Assessment Program Health Sciences Research Division Oak Ridge, Tennessee 37831

Prepared for the U.S. Department of Energy Office of Environmental Management under budget and reporting code EW 20

LOCKHEED MARTIN ENERGY SYSTEMS, INC. managing the Environmental Management Activities at the Oak Ridge K-25 Site Paducah Gaseous Diffusion Plant Oak Ridge Y-12 Plant Portsmouth Gaseous Diffusion Plant Oak Ridge National Laboratory under contract DE-AC05-84OR21400 for the U.S. DEPARTMENT OF ENERGY

. • • •

1

# **AUTHOR AFFILIATIONS**

G. W. Suter II is a member of the Environmental Sciences Division, Oak Ridge National Laboratory, Oak Ridge, Tennessee. C. L. Tsao is affiliated with the School of the Environment, Duke University, Durham, North Carolina.

. . • . .

1

### PREFACE

The purpose of this report is to present and analyze alternate toxicological benchmarks for screening chemicals for aquatic ecological effects. This work was performed under Work Breakdown Structure 1.4.12.2.3.04.05.04 (Activity Data Sheet 8304, "Technical Integration—Risk Assessment"). Publication of this document meets a milestone for the Environmental Restoration (ER) Risk Assessment Program. Since the prior edition of this report (Suter and Mabrey 1994), both the U.S. Environmental Protection Agency Office of Solid Waste and Emergency Response and EPA Region IV have developed sets of screening benchmarks for water. This report includes those values and updates the other benchmarks that were presented in the last edition.

. . . .

.

\$

AUTHOR AFFILIATIONS iii
PREFACEv
TABLES ix
ACRONYMS xi
EXECUTIVE SUMMARY xiii
1. INTRODUCTION
2. METHODS FOR DERIVING BENCHMARKS12.1 TYPES OF BENCHMARKS12.2 WATER QUALITY CRITERIA22.3 TIER II VALUES132.4 LOWEST CHRONIC VALUES142.5 ESTIMATED LOWEST CHRONIC VALUES142.6 TEST EC20s142.7 ESTIMATED TEST EC20s152.8 SENSITIVE SPECIES TEST EC20s152.9 POPULATION EC25s152.10 ECOTOX THRESHOLDS162.11 REGION IV SCREENING VALUES162.12 BACKGROUND CONCENTRATIONS16
3. CHEMICAL-SPECIFIC INFORMATION223.1 INORGANICS233.2 ORGANICS27
4. APPLICATION OF BENCHMARKS
5. REFERENCES
Appendix A DATA USED FOR TIER II CALCULATIONS
Appendix B METHODS FOR DERIVATION OF TIER II VALUES
Appendix C TABLE SHOWING CONCENTRATIONS ESTIMATED TO CAUSE A 20% REDUCTION IN THE RECRUIT ABUNDANCE OF LARGEMOUTH BASS, WITH UPPER AND LOWER 95% CONFIDENCE BOUNDS

# CONTENTS

• .

1

# TABLES

1	Summary of conventional benchmarks for priority contaminants in fresh water
2	Summary of alternative benchmarks for priority contaminants in fresh water based
	on levels of chronic effects
3	Summary of OSWER threshold values for aquatic life (EPA 1996)
	and Region IV screening values for freshwater surface water
A.1	Data and calculated results for derivation of Tier II values
B.1	Factors for estimation of the Tier II values
C.1	Concentrations estimated to cause a 20% reduction in the recruit abundance
	of largemouth bass, with upper and lower 95% confidence bounds C-3

- -----

# ACRONYMS

ACRs	acute chronic ratios
ARARs	applicable or relevant and appropriate requirements
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CV	Chronic Value
EC50	median effective concentration
EPA	U.S. Environmental Protection Agency
ETs	Ecotox Thresholds
FACR	Final Acute-Chronic Ratio
FAV	Final Acute Value
FCV	final chronic value
GLWQI	Great Lakes Water Quality Initiative
GMAV	genus mean acute value
LC50	median lethal concentration
LOEC	Lowest Observed Effect Co
MATC	Maximum Acceptable Toxicant Concentration
NAWQC	National Ambient Water Quality Criteria
NOEC	No Observed Effect Concentration
OSWER	Office of Solid Waste and Emergency Response
RI	Remedial Investigation
SACR	secondary acute chronic ratio
SAV	Secondary Acute Values
SCV	Secondary Chronic Value
SS	sensitive species
SVs	screening values

• , •

### **EXECUTIVE SUMMARY**

One of the initial stages in ecological risk assessment of hazardous waste sites is the screening of contaminants to determine which, if any, of them are worthy of further consideration; this process is termed contaminant screening. Screening is performed by comparing concentrations in ambient media to benchmark concentrations that are either indicative of a high likelihood of significant effects (upper screening benchmarks) or of a very low likelihood of significant effects (lower screening benchmarks). Exceedance of an upper screening benchmark indicates that the chemical in question is clearly of concern and remedial actions are likely to be needed. Exceedance of a lower screening benchmark indicates that a contaminant is of concern unless other information indicates that the data are unreliable or the comparison is inappropriate. Chemicals with concentrations below the lower benchmark are not of concern if the ambient data are judged to be adequate.

This report presents potential screening benchmarks for protection of aquatic life from contaminants in water. Because there is no guidance for screening benchmarks, a set of alternative benchmarks is presented herein. The alternative benchmarks are based on different conceptual approaches to estimating concentrations causing significant effects. For the upper screening benchmark, there are the acute National Ambient Water Quality Criteria (NAWOC) and the Secondary Acute Values (SAV). The SAV concentrations are values estimated with 80% confidence not to exceed the unknown acute NAWQC for those chemicals with no NAWQC. The alternative chronic benchmarks are the chronic NAWQC, the Secondary Chronic Value (SCV), the lowest chronic values for fish and daphnids, the lowest EC20 for fish and daphnids from chronic toxicity tests, the estimated EC20 for a sensitive species, and the concentration estimated to cause a 20% reduction in the recruit abundance of largemouth bass. It is recommended that ambient chemical concentrations be compared to all of these benchmarks. If NAWQC are exceeded, the chemicals must be contaminants of concern because the NAWQC are applicable or relevant and appropriate requirements (ARARs). If NAWQC are not exceeded, but other benchmarks are, contaminants should be selected on the basis of the number of benchmarks exceeded and the conservatism of the particular benchmark values, as discussed in the text.

To the extent that toxicity data are available, this report presents the alternative benchmarks for chemicals that have been detected on the Oak Ridge Reservation. It also presents the data used to calculate the benchmarks and the sources of the data. It compares the benchmarks and discusses their relative conservatism and utility.

This report supersedes a prior aquatic benchmarks report (Suter and Mabrey 1994). It adds two new types of benchmarks. It also updates the benchmark values where appropriate, adds some new benchmark values, replaces secondary sources with primary sources, and provides more complete documentation of the sources and derivation of all values.

ł

**ء** ا

1

.

## **1. INTRODUCTION**

An important early step in the assessment of ecological risks posed by a contaminated site is the screening of contaminants. In many cases, concentrations in water will be reported for more than 100 chemicals, most of which will be reported as undetected at some defined limit of detection. The assessor must decide which of the detected chemicals constitute an ecological hazard and which of the undetected chemicals may pose a hazard at concentrations below the reported detection limits. This screening is done by comparing the reported concentrations to toxicological benchmarks. If concentrations of a chemical exceed its benchmark for a particular medium, then it is worthy of further measurement and assessment. If not, it can be ignored (assuming that the analytical data are adequate).

In practice, a series of benchmarks of differing conservatism may be used. Exceedance of an upper screening benchmark would suggest a severe hazard and a need for urgent action. Nonexceedance of all lower screening benchmarks would suggest no hazard. Exceedance of an increasing number of benchmarks would constitute increasing evidence of the need for measurement and assessment. In addition to providing a better indication of the magnitude of the hazard, the use of multiple benchmarks provides information about the nature of the hazard which can be used in development of the conceptual model and in planning the Remedial Investigation (RI). For example, is the chemical at concentrations that are toxic to only daphnids, to daphnids and fish, to fish and aquatic plants, etc.? Are they at concentrations that have been demonstrated to be toxic or do they exceed only benchmarks that include conservative factors?

The purpose of this report is to present and analyze alternate toxicological benchmarks for screening chemicals for aquatic ecological effects. Since the prior edition of this report (Suter and Mabrey 1994), both the U.S. Environmental Protection Agency (EPA) Office of Solid Waste and Emergency Response (OSWER) and EPA Region IV have developed sets of screening benchmarks for water. This report includes those values and updates the other benchmarks that were presented in the last edition.

This compilation is limited to chemicals that have been detected on the Oak Ridge Reservation and to benchmarks derived from studies of toxic effects on fresh water organisms. The list of chemicals detected on the Oak Ridge Reservation includes 45 metals and 105 industrial chemicals. Only four pesticides occur on the list, and those are persistent and wide-spread (chlordane, DDT, heptachlor, and lindane).

## 2. METHODS FOR DERIVING BENCHMARKS

#### 2.1 TYPES OF BENCHMARKS

The simplest screening benchmarks are toxicity test endpoints. A test endpoint is a statistically derived numeric summary of the results of a toxicity test. Test endpoints can be calculated in two ways. First, a level of effect can be estimated by fitting a function such as the probit or logit to the concentration-response data to derive a concentration-response model. Then by inverse regression, a concentration can be estimated that causes a particular level of effect such as the median lethal concentration (LC50). Second, hypothesis testing statistics can be used to determine whether each

1

of the tested concentrations caused an effect that was statistically significantly different from the controls. The lowest concentration causing such an effect is termed the Lowest Observed Effect Concentration (LOEC); the highest concentration for which there were no such effects is termed the No Observed Effect Concentration (NOEC). The geometric mean of the LOEC and NOEC is termed the Chronic Value (CV) and was formerly termed the Maximum Acceptable Toxicant Concentration (MATC).

Toxicity tests are conventionally divided into acute and chronic tests. Standard acute aquatic toxicity tests are 48 or 96 hours in duration and use juvenile or adult organisms; the test endpoints are the median lethal concentration (LC50) or median effective concentration (EC50) for death or some equivalent effect (e.g., immobilization). Standard chronic tests include all or most of the lifecycle of the test organisms, and they include observations of growth, deformities, and reproductive success as well as lethality. The standard endpoint for chronic tests is the CV.

Another important distinction is between response-specific and integrative endpoints. Conventionally, NOECs and LOECs are calculated for each response parameter, and the results for the most statistically sensitive parameter are reported. Because effects on populations and ecosystems are a result of the integrated effects of the toxicant on all life stages, it is more sensible to integrate the responses in the test when calculating the test endpoint. Integrative endpoints may be simple arithmetic combinations of effects such as the proportional mortality across all tested life stages or population parameters derived from simple models such as the intrinsic rate of natural increase, r.

Benchmarks may be combinations of multiple test endpoints. An example is the chronic NAWQC, which are derived from at least eight LC50s and three CVs.

Finally, benchmarks may be derived by using mathematical models to simulate an assessment endpoint, a specific environmental characteristic that is valued and is at risk due to the contamination or disturbance that is being assessed (Suter 1989). For example, in this study we present concentrations estimated to correspond to a 20% reduction in recruit abundance for largemouth bass (*Micropterus salmoides*) because production of fish, particularly game fish, is an assessment endpoint for Oak Ridge Reservation ecological risk assessments (Suter et al. 1992).

Conventional aquatic benchmarks, which are based on regulatory criteria or standard test endpoints used to derive criteria, are listed in Table 1. Unconventional aquatic benchmarks, which are based on levels of effects on integrative endpoints, are listed in Table 2.

#### 2.2 WATER QUALITY CRITERIA

The National Ambient Water Quality Criteria (NAWQC) are applicable or relevant and appropriate requirements (ARARs); therefore, they provide the basis for the screening benchmarks for contaminants in water. The acute NAWQC are calculated by the EPA as half the Final Acute Value (FAV), which is the fifth percentile of the distribution of 48- to 96-hour LC50 values or equivalent median effective concentration (EC50) values for each criterion chemical (Stephan et al. 1985). The acute NAWQC are intended to correspond to concentrations that would cause less than 50% mortality in 5% of exposed populations in a brief exposure. They may be used as a reasonable upper screening benchmark because waste site assessments are concerned with sublethal effects and largely with continuous exposures, rather than the lethal effects and episodic exposures to which the acute NAWQC are applied. The chronic NAWQC are the FAVs divided by the Final Acute-Chronic Ratio (FACR), which is the geometric mean of quotients of at least three LC50/CV

Chemical	NAWQ Criteria		Tier II Values		Lowest Chronic Value for:				
	Acute	Chronic	Secondary Acute Value	Secondary Chronic Value	Fish	Daphnids	Non- Daphnid Inverte- brates	Aquatic Plants	All Organ- isms
Aluminum	750	87			3,288	1,900		460	460
Ammonia	pH and te deper	mperature 1dent			1.7	630		2,400	1.7
Antimony			180 <sup>i</sup>	30 <sup>1</sup>	1,600	5,400		610	610
Arsenic III	360	190			2,962	914.1		2,320	914.1
Arsenic V		•	66	3.1	892	*450		48	48
Barium			110	4.0					
Beryllium .			35	0.66	*57	5.3		100,000	5.3
Boron			30	1.6		8,830			8,830
Cadmium	3.9+	1.1+			1.7	0.15		2	0.15
Calcium						116,000			116,000
Chromium III	1,700+	210+			68.63	<44		397	<44
Chromium VI	16	11			73.18	6.132		2	_ 2
Cobalt			1500	23	290	5.1			5.1
Copper	18+	12+	,		3.8	0.23	6.066	1	0.23
Cyanide	22	5.2			7.8		18.33	30	7.8
Iron		1,000			1,300	158			158
Lead	82+	3.2+			18.88	12.26	25.46	500	12.26
Lithium			260	14					
Magnesium						82,000			82,000
Manganese			2,300	120	1780	<1,100			<1,100
Mercury, inorganic or total	2.4			1.30°	<0.23	0.96		5	<0.23
Mercury, methyl			0.099	0.0028	0.52	<0.04		0.8-4.0	<0.04
Molybdenum			16,000	370		880			880

. .

Table 1. Summary of conventional benchmarks for priority contaminants in fresh water (all values in micrograms per liter)

1 --

ω

Chamical	NAWQ	NAWQ Criteria		Tier II Values		Lowest Chronic Value for:			
	Acute	Chronic	Secondary Acute Value	Secondary Chronic Value	Fish	Daphnids	Non- Daphnid Inverte- brates	Aquatic Plants	All Organ- isms
Nickel	1,400+	160+			<35	<5	128.4	5	<5
Potassium						53,000			53,000
Selenium	20	5			88.32	91.65		100	88.32
Silver	4.1+			0.36	0.12	2.6		30	0.12
Sodium						680,000			680,000
Strontium			15,000	1,500		42,000			42,000
Thallium			110	12	57	130		100	57
Tin			2,700	73		350			350
Uranium			46	2.6	*142				*142
Vanadium			280	20	80	1,900			80
Zinc	120+	110+			36.41	46.73	>5,243	30	30
Zirconium			310	17	*548				*548
				Organics					
Acenaphthene	80°	23°			74	*6,646	227	520	74
Acetone			28,000	1,500	*507,640	1,560			*507,640
Anthracene			13	0.73	*0.09	<2.1			*0.09
Benzene			2,300	130		>98,000		525,000	525,000
Benzidene			70	3.9	*134				*134
Benzo(a)anthracene			0.49	0.027		*0.65			*0.65
Benzo(a)pyrene			0.24	0.014		*0.30			*0.30
Benzoic acid			740	42	*12,976				*12,976
Benzyl alcohol			150	8.6	*589				*589

4

Table 1. (continued)

Chamical	NAWQ	Criteria	Tier II	Values		Lowest Chronic Value for:				
	Acute	Chronic	Secondary Acute Value	Secondary Chronic Value	Fish	Daphnids	Non- Daphnid Inverte- brates	Aquatic Plants	All Organ- isms	
BHC (lindane)	2	0.08			14.6	14.5	3.3	500	3.3	
BHC (other)			39	2.2		*95			*95	
Biphenyl				14 <sup>r</sup>						
Bis(2-ethylhexyl)phthalate			27	3.0		912			912	
4-Bromophenyl phenyl ether				1.5 <sup>r</sup>						
Butylbenzyl phthalate				19 <sup>r</sup>						
2-Butanone			240,000	14,000	*282,170	*1,394,927			*282,170	
Carbon disulfide			17	0.92	*9,538	*244			*244	
Carbon tetrachloride			180	9.8	1,970	*5,580			1,970	
Chlordane	2.4	0.17ª			1.6	16	1.09		1.09	
Chlorobenzene			1,100	64	*1,203	*15,042		224,000	*1203	
Chloroform			490	28	1,240	*4,483			1,240	
DDD p,p'			0.19	0.011	*1.69				*1.69	
DDT	1.1			0.013 <sup>bf</sup>	0.73°	*0.016		0.3	0.3	
Decane			880	49		*7,874			*7,874	
Di-n-butyl phthalate			190	35	717 <sup>4</sup>	697			697	
Diazinon			0.17 <sup>8</sup>	0.043 <sup>8</sup>						
Dibenzofuran			66	3.7		*1,003			*1,003	
1,2-Dichlorobenzene			260 <sup>r</sup>	14 <sup>r</sup>						
1,3-Dichlorobenzene			630 <sup>r</sup>	71 <sup>r</sup>						
1,4-Dichlorobenzene			180 <sup>r</sup>	15 <sup>r</sup>						
1,1-Dichloroethane			830	47	*14,680				*14,680	
1,2-Dichloroethane			8,800	910	41,364	15,200			15,200	

Table 1. (continued)

. .

Chambrel	NAWQ	Criteria	Tier II	Values		Lowest Chronic Value for:				
	Acute	Chronic	Secondary Acute Value	Secondary Chronic Value	Fish	Daphnids	Non- Daphnid Inverte- brates	Aquatic Plants	All Organ- isms	•
1,1-Dichloroethene			450	25	>2,800	*4,720		>798,000	>2,800	
1,2-Dichloroethene			1,100	590	*9,538				*9,538	
1,3-Dichloropropene			0.99	0.055	244	*805		4,950	244	
Dieldrin	0.18"	0.062°								
Diethyl phthalate			1,800	210				85,600	85,600	
Di-n-octyl phthalate					3,822	708			708	
Endosulfan, all isomers				0.051 <sup>r</sup>						
Endrin	0.095°	0.061°								
Ethyl benzene			130	7.3	>440	*12,922		>438,000	>440	
Fluoranthene	33.6°	6.16°			30	15		54400	15	c
Fluorene			70 <sup>r</sup>	3.9 <sup>r</sup>						
Heptachlor			0.125 <sup>g,h</sup>	0.0069 <sup>5,8</sup>	1.26	*3.18		26.7	1.26	
Hexachloroethane			210°	12 <sup>r</sup>						
Hexane			10	0.58	*65,712				*65 <b>,</b> 712	
2-Hexanone			1,800	99	*32,783				*32,783	
Methoxychlor				0.019 <sup>r</sup>						
1-Methylnaphthalene			37	2.1	*526				*526	
4-Methyl-2-pentanone			2,200	170	77,400				77,400	
2-Methylphenol			230	13	*489	*1,316			*489	
Methylene chloride			26,000	2,200	108,000	*42,667			*42,667	
Naphthalene			190	12	620	*1,163		33,000	620	
4-Nitrophenol			1,200	300	*481	7,100		4190	*481	
N-Nitrosodiphenvlamine			3,800	210	*332	*1,042			*332	

Table 1. (continued)

Chemical	NAWQ	Criteria	Tier II	Tier II Values		Lowest Chronic Value for:			
Cucinica	Acute	Chronic	Secondary Acute Value	Secondary Chronic Value	Fish	Daphnids	Non- Daphnid Inverte- brates	Aquatic Plants	All Organ- isms
2-Octanone			150	8.3					
PCBs total Aroclor® 1221	2.0		5.0	0.14 <sup>6</sup> 0.28	0.2 *60	2.1	0.8	0.144	0.1 *60
Aroclor® 1232			10	0.58	*124				*124
Aroclor® 1242			1.2	0.053	9.00		4.9	300	4.9
Aroclor® 1248			1.4	0.081				_	
Aroclor® 1254			0.60	0.033		2.9		0.1	0.1
Aroclor® 1260			1,700	94	<1.3				2.3
Pentachlorobenzene	•		8.4 <sup>r</sup>	0.47 <sup>r</sup>					
1-Pentanol			2,000	110	*30,493				*30,493
Phenanthrene	30°	6.3°				200			200
Phenol	3,600 <sup>s</sup>	110*			<200	*2,005		20,000	<200
2-Propanol			130	7.5	*590				*590
1,1,2,2 Tetrachloroethane			2,100	610	2,400	9,900		136,000	2,400
Tetrachloroethene			830	98	840	750		>816,000	750
Tetrachloromethane			4,400 <sup>r</sup>	240 <sup>r</sup>					
Toluene			120	9.8	*1,269	*25,229		245,000	*1,269
Tribromomethane			2,300 <sup>r</sup>	320 <sup>r</sup>					
1,2,4-Trichlorobenzene			700 <sup>r</sup>	110 <sup>r</sup>					
1,1,1-Trichloroethane			200	11	*3,493			>669,000	*3,493
1,1,2-Trichloroethane			5,200	1,200	9,400	18,400			9,400
Trichloroethene			440	47	11,100	*7,257			*7,257
Vinyl acetate			280	16	*810				*810

Table 1. (continued)

Table	1. (	continu	ed)
-------	------	---------	-----

Chemical	NAWQ	NAWQ Criteria		Tier II Values		Lowest Chronic Value for:			
	Acute	Chronic	Secondary Acute Value	Secondary Chronic Value	Fish	Daphnids	Non- Daphnid Inverte- brates	Aquatic Plants	All Organ- isms
Xylene			230	13	*62,308				*62,308
m-Xylene			32 <sup>r</sup>	1.8 <sup>r</sup>					

Notes:

+ Hardness dependent criterion normalized to 100 mg/L

\* Numbers preceded by \* are estimates. Methods of estimation are described in the text.

\* The chronic NAWQC for chlordane (0.0043 μg/L) and mercury (0.012 μg/L), are based on the final residue values. FCVs are used as benchmarks to protect aquatic life.

<sup>b</sup> The chronic NAWQC for DDT (0.001 μg/L), total PCBs (0.014 μg/L), and heptachlor (0.0038 μg/l) are is based on the final residue values; for benchmarks to protect aquatic life, we use SCVs.

° The CV for DDT in Jarvinen et al. 1977 of 0.9 μg/l is the arithmetic mean of the NOEC and LOEC. We used the geometric mean which is 0.73.

<sup>d</sup> For fish di-n-butyl phthalate lowest CV, the geometric mean of the measured concentrations for the NOEC and LOEC rather than the nominal concentrations used by the authors (McCarthy and Whitmore 1985) was used herein.

\* These numbers are Final Acute Values and Final Chronic Values calculated by the EPA for use in the derivation of sediment quality criteria (EPA 1993b).

<sup>f</sup> Values calculated for OSWER (1996).

<sup>8</sup> Values calculated by the Great Lakes Water Quality Initiative (EPA 1993d).

<sup>h</sup> SAV was calculated by the Great Lakes Water Quality Initiative because some data used to derive FAV were questionable (EPA 1992).

<sup>1</sup> These values are draft FAV and FCV values (EPA 1988b).

	Lowest To	est EC <sub>20</sub> for:	Sensitive	Population	
Chemical –	Fish	Daphnids	Species Test EC <sub>20</sub>	EC <sub>20</sub>	
Aluminum	4,700	540	75		
Antimony	2,310	1,900		79	
Arsenic III	2,130	633	55	1,995	
Arsenic V	1,500	>932		185	
Barium					
Beryllium	*148	3.8		21	
Boron		7,000			
Cadmium	1.8	0.75	0.013ª	4.3	
Calcium					
Chromium III	89		8.44	126	
Chromium VI	51	0.5	0.266	316	
Cobalt	810	<4.4		3.98	
Copper	5	0.205	0.26	8.6	
Cyanide	5.3		1.17	11	
Fluorine	*5,336	3,706		1,080	
Iron		16			
Lead	22		0.35	71	
Magnesium					
Manganese	1,270	<1,100		112	
Mercury, inorganic	0.87	0.87	0.18	0.32	
Mercury, methyl	<0.03	0.87		0.28	
Molybdenum		360			
Nickel	62	45	11ª	. 215	
Potassium					
Selenium	40	25	2.60		
Silver	0.20	<0.56	0.14ª	0.32	
Sodium					
Strontium					
Thallium	81	64		67	

 Table 2. Summary of alternative benchmarks for priority contaminants in fresh water based on levels of chronic effects (all values in micrograms per liter)

	10
Table 2. (	(continued)

	Lowest Te	st EC <sub>20</sub> for:	Sensitive	Population	
Chemical	Fish	Daphnids	Species Test EC <sub>20</sub>	EC <sub>20</sub>	
Tin					
Uranium	*455			27	
Vanadium	41	430		32	
Zinc	47		21	80	
Zirconium	*2,396		<u></u>	251	
	Org	anics			
Acenaphthene	<197				
Acetone	*161,867			23,714	
Anthracene	*0.35	>8.2			
Benzene	21			229	
Benzidene	*158			68	
Benzo(a)anthracene					
Benzo(a)pyrene	>2.99				
Benzoic acid	*7,409			1,259	
Benzyl alcohol	*550			375	
BHC (lindane)	<1.1	11	0.11		
BHC (other)				, ,	
Bis(2-ethylhexyl)phthalate	>54	<3		50	
2-Butanone	*98,772			17,783	
Carbon disulfide	*5719			1,000	
Carbon tetrachloride	65			224	
Chlordane	<0.25	12.1	0.50	0.71	
Chlorobenzene	1,002			165	
Chloroethane					
Chloroform	8,400			562	
DDD p,p'	*3.99			0.61	
DDT	0.35		0.008		
Decane					

	Lowest Tes	Lowest Test EC <sub>20</sub> for:		Population
Chemical	Fish	Daphnids	Species Test EC <sub>20</sub>	EC <sub>20</sub>
Di-n-butyl phthalate	270	500		251
Dibenzofuran				
1,1-Dichloroethane	*8,219			1,585
1,2-Dichloroethane	29,000	<11,000		1,259
1,1-Dichloroethene				447
1,2-Dichloroethenes	*5,719			
1,3-Dichloropropene	*350			40
Diethyl phthalate				1,000
Di-n-octyl phthalate	<100	310		1,995
Ethyl benzene				398
Fluoranthene				32
Heptachlor	0.86		0.004	0.1
Hexane	*28,995			
2-Hexanone	*16,155			1,259
1-Methylnaphthalene	*500			31.62
4-Methyl-2-pentanone				1,585
2-Methylphenol	*470			74
Methylene chloride	410			1,259
Naphthalene	450	>600		1,000
4-Nitrophenols	*464	5,000		60
N-Nitrosodiphenylamine	*339			40
3-Octanone	*3571	-		
PCBs total Aroclor® 1221	0.4 *80	1.2		0.63 10
Aroclor® 1232	*148			16
Aroclor® 1242	<2.9			1.58
Aroclor® 1248	0.4	2.5		1.26
Aroclor® 1254	0.52	1.2		0.63
Aroclor® 1260	2.1			316
1-Pentanol	*15,200			3,548

11 Table 2. (continued)

•

	12
Table 2.	(continued)

	Lowest Te	st EC <sub>20</sub> for:	Sensitive	Population EC <sub>20</sub>
Chemical	Fish	Daphnids	Species Test EC <sub>20</sub>	
Phenanthrene		110		
Phenol	<230			4,467
2-Propanol	*35,381			3,162
1,1,2,2-Tetrachloroethane	1,400	<420		1,585
Tetrachloroethene	500	510		50
Toluene	<26			200
1,1,1-Trichloroethane	*2,457	1,300		251
1,1,2-Trichloroethane	14,800	13,000		15,849
Trichloroethene	5758			232
Vinyl acetate	*718			108
Xylene	2680			

Notes:

\* Numbers preceded by \* are estimates. Methods of estimation are described in the text.

\* Study LC50's were used rather than species mean LC50s so water hardness would correspond to EC20 values.

ratios from tests of different families of aquatic organisms (Stephan et al. 1985). It is intended to prevent significant toxic effects in chronic exposures and is used in this assessment as one possible lower screening benchmark. The NAWQC are listed in Table 1.

NAWQC for several metals are functions of water hardness; the criteria are lower for lower hardness levels. The criteria for 100 mg/L hardness as reported by the EPA are presented in this report. That hardness is near the lower end of the range of hardness values reported for the Oak Ridge Reservation, so it is moderately conservative. For sites with different water hardnesses, site-specific criteria should be calculated. The formulas for hardness correction are listed in the discussions of individual chemicals.

Many readers will note that the EPA's compilations of NAWQC contain values for many chemicals that have no NAWQC listed herein (EPA 1986b); the EPA lists lowest CVs for those chemicals for which there is not enough data to calculate a criterion but for which there is at least one CV. Lowest CVs are treated as a separate category of benchmarks in this compilation.

Some chronic NAWQC are based on protection of humans or other piscivorous organisms rather than protection of aquatic organisms. Those criteria are not included herein because screening for risks to wildlife or humans is performed by other methods. However, if sufficient data were available to calculate a final chronic value (FCV) for those chemicals, then the FCV are presented in place of the chronic NAWQC in Table 1, and its derivation is noted.

For particular chemicals, the lower screening benchmark could be lower than the chronic NAWQC for any one of the following reasons. First, the chronic NAWQC are based on a threshold for statistical significance rather than biological significance. In some chronic tests, because of highly variable results, the statistical threshold corresponds to greater than 50% effect on a response

parameter (Stephan and Rogers 1985, Suter et al. 1987). Second, not all important responses are included in the subchronic toxicity tests that are used to calculate many chronic NAWQC. In particular, effects on fecundity, which is the most sensitive response parameter on average in fish toxicity tests (Suter et al. 1987), are often not included. Third, the chronic NAWQC are based on the most statistically sensitive of the measured response parameters in each chronic or subchronic test. Therefore, cumulative effects over the lifecycle of fish and invertebrates are not considered. Fourth, the NAWQC are set at a level that protects "most species most of the time." Finally, many of the NAWQC have not been revised since 1980 so they do not incorporate recent data that are included in the calculation of other benchmarks. These concerns are supported by the recent finding that nickel concentrations (on the Oak Ridge Reservation) that are below chronic NAWQC are nonetheless toxic to daphnids (Kszos et al. 1992).

#### 2.3 TIER II VALUES

If NAWQC were not available for a chemical, the Tier II method described in the EPA's *Proposed Water Quality Guidance for the Great Lakes System* was applied (EPA 1993a). Tier II values were developed so that aquatic benchmarks could be established with fewer data than are required for the NAWQC. The Tier II values are concentrations that would be expected to be higher than NAWQC in no more than 20% of cases. Tier II values calculated by the EPA are listed in Table 1, and the sources are cited. Other Tier II values are derived as described in the following text.

The Tier II values equivalent to the FAV and FCV are the Secondary Acute Values (SAVs) and Secondary Chronic Values (SCVs), respectively. The sources of data for the Tier II values are listed in Appendix A, and the procedure and factors used to calculate the SACs and SCVs are in Appendix B. The methods described herein differ from EPA's (1993a) in one respect. The Great Lakes SAVs require an LC50 for a daphnid, but that requirement would severely restrict the number of benchmarks that could be calculated. The EPA has provided factors for calculating SAVs when no daphnid LC50s are available, and these factors are used herein (Stephan 1991).

Some of the SAVs and SCVs presented in this report differ from those presented in the prior edition (Suter and Mabrey 1994) for three reasons. First, in the previous report we included all data that occurred in EPA water quality criteria documents. However, much of the data included in criteria documents issued prior to 1985 are no longer considered acceptable by the EPA. Second, some data from the EPA's AQUIRE data set were used by Suter and Mabrey (1994) that appeared to be acceptable based on the information provided in the data base and the EPA's rating of the data. It has become clear that much of that data would not be acceptable to the EPA for calculating criteria. Therefore, we obtained all original publications and independently reviewed them against the criteria in Stephan et al. (1985). Those criteria are summarized in Appendix B. Finally, some new data have been found and incorporated.

Only high quality standard data are used in this document if such values are available for a chemical. That is, if even one test that meets the criteria in Stephan et al (1985) was found, all nonconforming tests were excluded. However, when no such values are available, nonstandard or lower quality test results which were judged by the authors to be reliable were used. Values derived using data that did not meet the Stephan et al. (1985) criteria are noted.

#### 2.4 LOWEST CHRONIC VALUES

The lowest chronic values for fish and invertebrates reported in the literature are potential lower benchmarks. Chronic values are used to calculate the chronic NAWQC, but the lowest chronic value may be lower than the chronic NAWQC. Because of the short generation time of algae and the relative lack of standard chronic tests for aquatic plants, EPA guidelines are followed in using any algal test of at least 96-hour duration and any biologically meaningful response for the plant values.

#### 2.5 ESTIMATED LOWEST CHRONIC VALUES

Estimated lowest chronic values for fish and invertebrates are another set of potential lower benchmarks. Estimated chronic values were extrapolated from 96-hour LC50s using equations from Suter et al. (1987) and Suter (1993). The equations are as follows where LC50 equals the lowest species mean 96-hour LC50 for fish and 48-hour EC50 for daphnids, and CV equals the estimated chronic value for that taxon. The 95% prediction interval at the mean is  $\log CV \pm$  the PI value (95% prediction intervals contain 95% of observations versus 95% confidence intervals which contain the mean with 95% confidence).

Fish CV for a metallic contaminant:

(1)  $\log CV = 0.73 \log LC50 - 0.70$ PI = 1.2

Fish CV for a nonmetallic contaminant:

$$\log CV = 1.07 \log LC50 - 1.51$$
  
PI = 1.5

Daphnid CV for a metallic contaminant: (3)  $\log CV = 0.96 \log LC50 - 1.08$ PI = 1.56

Daphnid CV for a nonmetallic contaminant:

 $\log CV = 1.11 \log LC50 - 1.30$ PI = 1.35

**2.6 TEST EC20s** 

Another potential lower benchmark is the test EC20 for fish, which is defined as the highest tested concentration causing less than 20% reduction in (1) the weight of young fish per initial female fish in a lifecycle or partial life-cycle test or (2) the weight of young per egg in an early life-stage test. A similar potential lower benchmark is the test EC20 for daphnids, which is the highest tested concentration causing less than 20% reduction in the product of growth, fecundity, and survivorship in a chronic test with a daphnid species. (Daphnids include members of the genera Daphnia, Ceriodaphnia, and Simocephalus.) These benchmarks are intended to be indices of population production. They are equivalent to chronic values in that they are simply a summary of the results of chronic toxicity tests, and in most cases the same test supplied the lowest chronic value and the lowest test EC20. However, the test EC20s are based on a level of biological effect rather than a level of statistical significance, and they integrate all of the stages of the toxicity test rather than treating each response independently. The 20% figure was chosen as approximately the mean level of effect on

(2)

(4)

individual response parameters observed at CVs and as a minimum detectable difference in population characteristics in the field (Suter et al. 1987, 1992). These values are listed in Table 2.

#### 2.7 ESTIMATED TEST EC20s

The estimated test EC20 is another potential benchmark. The estimated values were extrapolated from 96-hour LC50 values using equations from Suter (1992). The equation for the lowest fish test EC20 is as follows where LC50 equals the lowest species mean 96-hour LC50 for fish, and the EC25 for weight of juveniles per egg is used as an estimate of the test EC20 value. (The difference between 20% and 25% effect is trivial given the uncertainties in these estimates and the steepness of the concentration-response curves.) The log-scaled 95% prediction interval at the mean is log EC25  $\pm$  the PI value:

$$\log EC25 = 0.90 \log LC50 - 0.86$$
(5)  
PI = 1.6

These values are listed in Table 2 for those chemicals that have no empirical test EC20.

#### 2.8 SENSITIVE SPECIES TEST EC20s

The sixth potential benchmark is the EC20, adjusted to approximate the fifth percentile of the species sensitivity distribution. It is calculated in the same way as the chronic NAWQC except that the test EC20s are used in place of CVs, and salt water species were not included. The FAV for each of the criterion chemicals was divided by the geometric mean of ratios of LC50s to EC20s. These benchmarks are referred to as sensitive species (SS) test EC20s, and are listed in Table 2.

#### 2.9 POPULATION EC25s

The last potential benchmark is an estimate of the continuous concentration that would cause a 20% reduction in the recruit abundance of largemouth bass. The method used was described by Barnthouse et al. (1990) and is briefly summarized herein. The recruit abundance estimates are generated by a matrix model of a reservoir largemouth bass population (Bartell 1990). The fecundity, hatching success, larval survival, and post-larval survival of the model population are each decremented by a value generated from statistical extrapolation models. For each life stage for which a concentration-response relationship could be calculated, that relationship was adjusted for the relative sensitivity of the test species and the bass. For those life stages with no concentrationresponse relationship, the relationship was estimated using life stage to life stage extrapolation models, and the taxonomic adjustment was made. However, if the authors of the study reported that life stage was unaffected, the decrement for that life stage was set to zero. If no chronic test data were available, extrapolations from LC50s to chronic responses of each life stage were performed. Uncertainties in all of these extrapolations were propagated through the models to generate estimates of uncertainty. For each chemical, each available freshwater fish chronic test was used to parameterize a model run. If no chronic test data were available, each available freshwater fish LC50 was used to parameterize a model run. The results are presented in Appendix C. The geometric mean of all population EC25 estimates for each chemical is reported in Table 2.

#### 2.10 ECOTOX THRESHOLDS

The EPA's OSWER has published Ecotox Thresholds (ETs) which are intended to be used for screening contaminants at Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) sites (OSWER 1996); these values are available for 20 metals and 47 organics in fresh water and for 10 metals and 7 organics in marine waters. The fresh water values are presented in Table 3. Their derivation is briefly explained in the following text.

In general, chronic NAWQC values are preferred as aqueous ETs. However, as with the benchmarks in Table 1, criteria that are based on fish consumption rather than aquatic toxic effects (DDT, heptachlor, and toxaphene) are not used. Tier II values are presented in their place. For diazinon, the FCV calculated by the Great Lakes Water Quality Initiative (GLWQI) was used as a criterion value (EPA 1992).

OSWER recommends the use of dissolved concentrations of metals. Therefore, the method described in Prothro (1993) is used to correct for dissolved phase concentrations, which causes some of the metals criteria values used as ETs to differ slightly from the criteria listed in Table 1 or in the Region IV values.

SCVs are used when NAWQCs are not available. Four of these SCVs are from the GLWQI (EPA 1992), 34 are from the prior edition of this document (Suter and Mabrey 1994), and 18 were calculated by OSWER (1996). Three chemicals with OSWER-derived SCVs (endosulfan, methoxyclor, and malathion) had NAWQCs, but the criteria were judged to be old and unreliable. Tier II values were not derived if no daphnia acute values were available.

#### 2.11 REGION IV SCREENING VALUES

EPA Region IV has published acute and chronic ecological screening values (SVs) for fresh surface water (Waste Management Division 1995); they are presented in Table 3. The acute SVs consist of acute NAWQCs or, for chemicals with no acute NAWQC, of lowest acute LC50 or EC50 values divided by 10. The chronic SVs consist of chronic NAWQCs or, for chemicals with no chronic NAWQC, of lowest CVs divided by 10. If there were no CVs, the acute SV is divided by 10 to obtain the chronic SV. These divisions by 10 serve the same purpose as the models used to calculate Tier II values, but without the scientific or statistical basis and without using the full available data set. For some chemicals, the SVs are based on effects on fish eaters or irrigated plants rather than aquatic life. Region IV acknowledges that other values have greater ecological relevance (Waste Management Division 1995). As explained previously, there are separate benchmarks to address effects on plants and wildlife and an entirely separate set of risk assessment methods to protect humans who eat fish. Finally, the hardness dependent criteria are adjusted to 50 mg/L which is unrealistically low for the Oak Ridge Reservation and most other sites.

#### 2.12 BACKGROUND CONCENTRATIONS

Background water concentrations should be used as a check for these benchmarks. That is, because some of these benchmarks are quite conservative and because the measured concentrations in ambient water may include forms that are not bioavailable, benchmark concentrations may be lower than background water concentrations. If the background concentrations are valid and represent an uncontaminated state and if exposed site does not contain forms of the chemicals that are more

bioavailable or toxic than the forms at background sites, then screening benchmarks lower than the background concentration should not be used.

	OSWI	OSWER Values		Region IV Values <sup>3</sup>	
Chemical	NAWQC or FCV <sup>1</sup>	Tier II²	Acute Screening Values	Chronic Screening Values	
		Metals			
Aluminum			750	87	
Antimony			1300 (2s)	160 (2s)	
Arsenic III	190		360	190	
Arsenic V		8.1 *			
Barium		3.9 *			
Beryllium		5.1 *	16 (6s)	053 (1s)	
Boron				750⁴	
Cadmium	1.0 h		1.79 h	0.66 h	
Chromium III	180 h		984.32 h	117.32 h	
Chromium VI	10		16	11	
Cobalt		3.0 *			
Copper	11 h		9.22 h	6.54 h	
Iron	1000			1000	
Lead	2.5 h		33.78	1.32	
Manganese		80 *			
Mercury			2.40	0.0123	
Mercury, inorganic	1.3				
Mercury, methyl		0.003 *			
Molybdenum		240 *			
Nickel	160 h		789.00 h	87.71 h	
Selenium	5.0		20.00	5.00	
Silver			1.23 h	0.012 (1s)	
Thallium			140.00(3s)	4.00 (2s)	

Table 3. Summary of OSWER threshold values for aquatic life (EPA 1996) and Region IV screening values for freshwater surface water (Region IV 1995) (All values are µg/L)

<b>-</b>	OSWER Values		Region IV Values <sup>3</sup>	
Chemical	NAWQC or FCV <sup>1</sup>	Tier II²	Acute Screening Values	Chronic Screening Values
Vanadium		19 *		
Zinc	100 h		65.04 h	58.91 h
	Orga	nic Compound	ls	
Acenaphthene	23 S		170 (2s)	17
Acrolein			6.8 (3s)	2.1 (1s)
Acrylonitrile			755 (4s)	75.5
Aldrin			3	0.3
Benzene		46 *	530 (7s)	53
Benzidine			250 (4s)	25
Benzo(a)pyrene		0.014 *		
a-BHC				500 <sup>6</sup>
b-BHC				5000 <sup>6</sup>
g-BHC (Lindane)	0.08		2	0.08
Biphenyl		14 #		
Bis(2-chloroethyl) ether			23800 (1s)	2380
Bis(2-ethylhexyl)phthalate		32 *	1110 (2s)	<0.3 (2s)
Bromoform			2930 (2s)	293
4-Bromophenylphenyl ether		1.5 #		
4- Bromophenylphenyl phthalate			36 (2s) <sub>.</sub>	12.2 (1s)
Butylbenzyl phthalate		19 #	330 (4s)	22 (2s)
Carbon tetrachloride			3520 (3s)	352
Chlordane			2.4	0.0043 <sup>5</sup>
Chlorobenzene		130 *	1950 (5s)	195
2-Chloroethylvinyl ether			35400 (1s)	3540
Chloroform			2890 (3s)	289
2-Chlorophenol			438 (5s)	43.8
Chloropyrifos			0.083	0.041

18 Table 3. (continued)
	OSWER Values		Region IV Values <sup>3</sup>	
Chemical	NAWQC or FCV <sup>1</sup>	Tier II <sup>2</sup>	Acute Screening Values	Chronic Screening Values
4,4'-DDT		0.013 +	1.1	0.001
4,4'-DDE			105 (1s)	10.5
4,4'-DDD			0.064 (8s)	0.0064
Demeton				0.1
Diazinon	0.043 F			
Dibenzofuran		20 *		
1,2-Dichlorobenzene		14 #	158 (4s)	15.8 (3s)
1,3-Dichlorobenzene		71 #	502 (3s)	50.2
1,4-Dichlorobenzene		15 #	112 (5s)	11.2
1,1-Dichloroethane		47 *		
1,2-Dichloroethane			11800 (3s)	2000 (1s)
1,1-Dichloroethylene			3030 (3s)	303
2,4-Dichlorophenol			202 (3s)	36.5 (1s)
1,2-Dichloropropane			5250 (3s)	525
Dichloropropylene (cis and trans)			606 (2s)	24.4 (1s)
Dieldrin	0.062 S		2.5	0.0019 <sup>s</sup>
Diethyl phthalate		220 *	5210 (2s)	521
2,4-Dimethylphenol			212 (3s)	21.2
Dimethyl phthalate			3300 (2s)	330
Di-n-butyl phthalate		33 *	94 (6s)	9.4
2,4-Dinitrophenol			62 (3s)	6.2
2,4-Dinitrotoluene			3100 (2s)	310
Dioxin (2,3,7,8-TCDD)			0.1	0.000015
1,2-Diphenylhydrazine			27 (2s)	2.7
Endosulfan, mixed isomers		0.051 #		
Endosulfan, alpha		0.051 #	0.22	0.056
Endosulfan, beta		0.051 #	0.22	0.056

	19
Table 3. (	(continued)

	OSWE	R Values	Region	IV Values <sup>3</sup>
Chemical	NAWQC or FCV <sup>'1</sup>	Tier II <sup>2</sup>	Acute Screening Values	Chronic Screening Values
Endrin	0.061 S		0.18	0.0023 <sup>5</sup>
Ethylbenzene		290 *	4530 (5s)	453
Fluoranthene	8.1 S		398 (2s)	39.8
Fluorene		3.9 #		
Guthion				0.01
Heptachlor		0.0069 +	0.52	0.0038 <sup>5</sup>
Heptachlor epoxide			0.52	0.0038 <sup>5</sup>
Hexachlorobutadiene			9 (5s)	0.93 (1s)
Hexachlorocyclopentadiene			0.7 (4s)	0.07
Hexachloroethane		12 #	98 (5s)	9.8
Isophorone			11700 (2s)	1170
Lindane (see g-BHC)		•		
Malathion		0.097		0.01
Methoxychlor		0.019 #		0.03
Methyl bromide	,		1100 (1s)	110
Methyl chloride			55000 (1s)	5500
3-Methyl-4-chlorophenol (p-Chloro-m-cresol)			3 (1s)	0.3
2-Methyl-4, 6-dinitrophenol (4,6- Dinitro-o-cresol)			23 (4s)	2.3
Methylene chloride			19300 (3s)	1930
Mirex				0.001
Naphthalene		24 *	230 (4s)	62 (1s)
Nitrobenzene			2700 (2s)	270
2-Nitrophenol				3500
4-Nitrophenol			828 (3s)	82.8
n-Nitrosodiphenylamine			585 (2s)	58.5
Parathion			0.065	0.013

20 Table 3. (continued)

······································	OSWE	R Values	Region	IV Values <sup>3</sup>
Chemical	NAWQC or FCV <sup>1</sup>	Tier II <sup>2</sup>	Acute Screening Values	Chronic Screening Values
PCB (total polychlorinated biphenyls)		0.19 *		
PCB-1242			0.2 (7s)	0.014
PCB-1254			0.2 (7s)	0.014
PCB-1221			0.2 (7s)	0.014
PCB-1232			0.2 (7s)	0.014
PCB-1248			0.2 (7s)	0.014
PCB-1260			0.2 (7s)	0.014
PCB-1016			0.2 (7s)	0.014
Pentachlorobenzene		0.47 #	250	50
Pentachlorophenol	13 pH		20 pH	13 pH
Phenol			1020 (16s)	256 (1s)
Polynuclear aromatic hydrocarbons				
Phenanthrene	6.3 S			
1,2,4,5-Tetrachlorobenzene			250	50
1,1,2,2-Tetrachloroethane		420 *	932 (3s)	240 (1s)
Tetrachloroethylene		120 *	528 (5s)	84 (1s)
Tetrachloromethane		240 #		
Toluene		130 *	1750 (5s)	175
Toxaphene		0.011 #	0.73	0.00025
1,2-Trans-Dichloroethylene,			13500 (1s)	1350
Tribromomethane		320 #		
Tributyltin .				0.026
1,2,4-Trichlorobenzene		110 #	150 (4s)	44.9 (1s)
1,1,1-Trichloroethane		62 *	5280 (2s)	528
1,1,2-Trichloroethane			3600 (3s)	940 (1s)
Trichloroethylene		350 *		

21 Table 3. (continued)

	OSWER Values		Region IV Values <sup>3</sup>	
Chemical	NAWQC or FCV <sup>1</sup>	Tier II²	Acute Screening Values	Chronic Screening Values
2,4,6-Trichlorophenol			32 (3s)	3.2
m-Xylene		1.8 #		
		Other		
Chloride			860,000	230,000
Chlorine (total residual - TRC)			19	11
Cyanide	5.2		22	5.2
pH				-2.5
Oil and Grease				0.01 (Low LC <sub>50</sub> )
Sulfide (S <sub>2</sub> -, HS-)				2

22 Table 3. (continued)

Notes:

<sup>1</sup> EPA derived NAWQC or final chronic values (FCVs).

<sup>2</sup> Values calculated using the GLWQI Tier II methodology.

<sup>3</sup> Based on EPA Region IV Water Management Division, Water Quality Standards Unit's Screening List. Those followed by (*ns*) are derived by Region IV using safety factors.

<sup>4</sup> For long-term irrigation of sensitive crops (minimum standard).

<sup>5</sup> Based on the marketability of fish. The use of other values which may have greater ecological

significance may be considered.

<sup>6</sup> Lowest plant value reported.

(ns) = number of species

- h = hardness-dependent ambient water quality criterion (100 mg/L as CaCO<sub>3</sub> used for OSWER thresholds and 50 mg/L for Region IV values).
- pH = pH-dependent ambient water quality criterion (7.8 pH used for OSWER thresholds and 6.0 for Region IV values).
- S = FCV derived for EPA Sediment Quality Criteria documents.
- F = FCV calculated using GLWQI Tier 1 methodology.
- t = value is for total of all chemical forms.
- \* = value as calculated in Suter and Mabrey (1994).
- + = Value with EPA support documents.
- # = value calculated by OSWER.

# 3. CHEMICAL-SPECIFIC INFORMATION

This section describes the sources of information and procedures that are specific to individual elements. Except where noted, the sources of data for estimating chronic values and test EC20s for fish are the same. All data used to calculate Tier II values and estimated chronic values and EC20s are presented in Appendix A.

#### **3.1 INORGANICS**

Aluminum. There are NAWQC for aluminum. The toxicity of aluminum has been shown to vary widely with water hardness and pH (Ingersoll et al., 1990a 1990b; Woodward et al., 1989; Sadler and Lynam, 1988; and Cleveland et al. 1986; and others). The benchmarks were calculated using only tests in circumneutral water. Lowest chronic and test EC20 values for fish are from 28-day embryolarval tests with *Pimephales promelas*. Kimball (n.d.) presented a CV of 5800  $\mu$ g/L, however, after further analysis of Kimball's data, the EPA (1988a) offered another value of 3288  $\mu$ g/L as the CV for aluminum. Lowest chronic and test EC20 values for daphnids are from McCauley et al. (1986). The EPA (1988a) gives a 4-day test EC50 for *Selenastrum capricornutum* which is used as the plant chronic value.

Ammonia. The test EC20 value for fish is from an embryo-larval test with fathead minnows (Thurston et al. 1986). The chronic value for fish is from an early life stage test with pink salmon, *Oncorhynchus gorbuscha* (Rice and Bailey 1980). The chronic value for daphnids is from EPA (1985a). Chronic values were determined using *Daphnia magna* in life-cycle tests. EPA (1985a) provided the chronic value for aquatic plants, in which *Chlorella vulgaris* experienced growth inhibition (EC50). The NAWQC for ammonia are functions of temperature (T) and pH. The acute NAWQC for ammonia is 0.52/FT/FPH/2, and the chronic NAWQC for ammonia is 0.80/FT/FPH/Ratio, where:

FT =	$10^{0.03(20-TCAP)};$ $10^{0.03(20-T)};$	TCAP≤T≤30 0≤T≤TCAP
FPH	$= 1; \\ \frac{1+10^{7.4\mathrm{pH}}}{25};$	8≤pH≤9 6.5≤pH≤8

Ratio = 16; 
$$7.7 \le pH \le 9$$
  
= (24)  $10^{7.7-pH}$ ;  $6.5 \le pH \le 7.7$ 

- TCAP = 20° C for acute criteria and 15° C for chronic criteria when Salmonids or other sensitive cold water species are present
  - = 25° C for acute criteria and 20° C for chronic criteria when Salmonids and other sensitive coldwater species are absent

These criteria are presented in greater detail in EPA (1985a and 1986b).

Antimony. Chronic and test EC20 values for antimony are from Kimball (n.d.). The chronic tests of *Pimephales promelas* were embryo-larval, and 28-day life-cycle tests were used for *Daphnia magna*. The EPA (1978) gives a 4-day EC50 for chlorophyll A inhibition in *Selenastrum capricornutum* which is used as the plant value. The SAV and SCV listed in this report are draft FAV and FCV values (EPA 1988b).

Arsenic III. NAWQC are listed for arsenic III. The lowest chronic values for fish and daphnids are given by Call et al. (1983) and Lima et al. (1984). Early life stage tests were used on *Pimephales promelas* and life-cycle tests were used on *Daphnia magna*. Cowell (1965) provides the lowest chronic value for the algae *Spirogyra*, *Cladophora*, and *Zygnema* which is a concentration that

produced a 100% kill in 2 weeks. The test EC20 value is derived from Lima et al. (1984) for fish and from Call et al. (1983) and Lima et al. (1984) for daphnids.

Arsenic V. The chronic and test EC20 values for fish are from an early life stage test with *Pimephales promelas* (DeFoe 1982), and the test EC20 for daphnids is from Spehar et al. (1980). The estimated chronic value for daphnids was calculated with a *Daphnia magna* LC50 from EPA (1985b) using Equation (3). Vocke (1980) provides the plant value from a 14-day EC50 test with *Scenedesmus obliquus*. The SAV and SCV listed in this report are lower than the acute and chronic LOEL values listed in the Water Quality Criteria Summary (EPA 1986b).

**Barium**. The chronic value for daphnids is from a 21-day test on *Daphnia magna* by Biesinger and Christensen (1972) which resulted in 16% reproductive impairment.

**Beryllium.** The chronic and test EC20 values for *Daphnia magna* are from a life-cycle test in Kimball (n.d.). Karlander and Krauss (1972) provide the plant value for *Chlorella vannieli*, a 10 to 20% reduction in autotrophic growth rates. The estimated chronic and test EC20 values for fish were derived using data for *Pimephales promelas* from EPA (1980f) in Equations (1) and (5). The derived SAV and SCV listed in this report are lower than the lowest CV listed in the Water Quality Criteria Summary (EPA 1986b) and the acute and chronic LOEL values listed in the Water Quality Criteria Summary (EPA 1986b).

**Boron**. The EC20 value for daphnids was based on a 21-day test on *Daphnia magna* by Gerisch (1984). A 21-day test of *Daphnia magna* by Lewis and Valentine (1981) provided the lowest daphnid chronic value.

**Cadmium.** The NAWQC for cadmium are functions of water hardness. The equations for these are  $e^{(0.7852[\ln(hardness)]-3.490}$  for the chronic value and  $e^{(1.128[\ln(hardness)]-3.828)}$  for the acute value (EPA 1986b). The lowest chronic value for fish is from Sauter et al. (1976) and Chapman et al. (n.d.) for daphnids. Early life stage tests were performed on brook trout, and life-cycle tests were performed on *Daphnia magna*. The test EC20 value is from Carlson et al. (1982) for fish and Elnabarawy et al. (1986) for daphnids. The value for aquatic plants is from Conway (1977). A relatively low cadmium concentration reduced the population growth rate of *Asterionella formosa* by an order of magnitude.

**Calcium.** The chronic value for daphnids is a concentration causing a 16% reduction in reproduction of *Daphnia magna* exposed to  $CaCl_2 \cdot 2H_2O$  (Biesinger and Christensen 1972). Because the highly conservative secondary values were below commonly occurring ambient concentrations of this macronutrient, they were judged to be inappropriate and are not presented.

**Chromium III.** The NAWQC for chromium III are functions of water hardness. The equations are  $e^{(0.8190[ln(hardness)]+1.5161)}$  for the chronic value and  $e^{(0.8190[ln(hardness)]+3.638)}$  for the acute value. The lowest chronic value for fish is from an early life stage test by Stevens and Chapman (1984) on rainbow trout. Chapman et al. (n.d.) provide a chronic value from a life-cycle test of *Daphnia magna*. The plant value for chromium III is from a 4-day chronic test in which there was a 50% inhibition of growth of *Selenastrum capricornutum* (EPA 1985c). Stevens and Chapman (1984) also provided data for the test EC20 value for fish.

**Chromium VI.** There are NAWQC for chromium VI. The chronic and test EC20 values for fish are from Sauter et al. (1976). An early life stage test produced the chronic value for rainbow trout. For daphnids, a life-cycle chronic test was run by Mount (1982) on *Daphnia magna*, and the test

EC20 is from Elnabarawy et al. (1986). *Microcystis aeruginosa*, used for the aquatic plant value, showed incipient inhibition in tests reported by the EPA (1985c).

**Cobalt**. The chronic and test EC20 values for cobalt are from Kimball (n.d.). *Daphnia magna* were used in 28-day life-cycle tests, and *Pimephales promelas* were used in embryo-larval tests.

**Copper.** The NAWQC for copper are functions of water hardness. The equations are  $e^{(0.8545[\ln(hardness)]-1.465)}$  for the chronic value and  $e^{(0.9422[\ln(hardness)]-1.464)}$  for the acute value. The chronic and test EC20 values for fish are from an early life stage test with brook trout by Sauter et al. (1976). The daphnid chronic value is from Chapman (n.d.). The test EC20 value for daphnids is derived from Dave (1984a). A 21-day test LC50 on *Daphnia magna* provided the chronic value for daphnids. Arthur and Leonard (1970) provided a chronic value through 6-week tests on the amphipod, *Gammarus pseudolimnaeus*. Steeman-Nielsen and Wium-Anderson (1970) provide a plant value based on a lag in growth of the alga, *Chlorella pyrenoidosa*.

**Cyanide**. There are NAWQC for cyanide. The chronic and test EC20 values for fish were both from a brook trout life-cycle test by Koenst et al. (1977). Oseid and Smith (1979) provide full life-cycle test on *Gammarus pseudolimnaeus*, an amphipod. The alga, *Scenedesmus quadricauda*, showed incipient inhibition in chronic tests by the EPA (1985e).

Iron. The NAWQC for iron is based on a field study at a site receiving acid mine drainage and is not consistent with the current method for deriving criteria. The lowest chronic value for daphnids (158  $\mu$ g/L) is a threshold for reproductive effects from a 21-day test of FeCl<sub>2</sub> with *Daphnia magna* (Dave 1984c). It is considerably lower than the 4380  $\mu$ g/L concentration causing 16% reproductive decrement in another test of FeCl<sub>2</sub> with *D. magna* (Biesinger and Christensen 1972). Dave (1984c) argued that his result was more applicable to a situation in which "an acidic iron-containing waste water is discharged into a lake or a river" where it is neutralized, but Biesinger and Christensen's (1972) result "is probably more close to the steady-state situation in natural freshwater without any point source of iron." The lowest chronic value for fish is a concentration that caused 100% larval mortality in an embryo-larval test with rainbow trout exposed to dissolved iron salts (Amelung 1981).

Lead. The NAWQC for lead are functions of water hardness. The equations are  $e^{(1.273[\ln(hardness)]-4.705)}$  for the chronic value and  $e^{(1.273[\ln(hardness)]-1.460)}$  for the acute value. The lowest chronic value for fish was provided by an early life stage test on rainbow trout by Davies et al. (1976). *Daphnia magna* were used in 21-day tests to determine lowest chronic toxicity by Chapman et al. (manuscript). Borgmann et al. (1978) provided a chronic value for a life-cycle test on *Lymnaea palastris*, a snail. *Chlorella vulgaris, Scenedesmus quadricauda*, and *Selenastrum capricornutum* experienced 53%, 35%, and 52% growth inhibition, respectively, at the plant chronic value (EPA 1985f). The test EC20 value for fish is from Sauter et al. (1976). The acute-EC20 ratio from which the SS test EC20 was calculated had to be obtained using a species mean acute value for *Salmo gairdneri* (EPA 1985f) since no acute value was reported by Sauter et al. (1976).

Magnesium. The chronic value for daphnids is a concentration causing a 16% reduction in reproduction of *Daphnia magna* exposed to  $MgCl_2 \cdot 6H_2O$  (Biesinger and Christensen 1972). Because the highly conservative secondary values were below commonly occurring ambient concentrations of this nutrient element, they were judged to be inappropriate and are not presented.

Manganese. All chronic and test EC20 values for manganese are from Kimball (n.d.). The fish chronic value is from a 28-day early life-stage test with *Pimephales promelas*.

Mercury, inorganic, or total. Mercury has NAWQC. However, the chronic criterion for mercury is based on the final residue value derived from a methyl mercury bioconcentration factor. To protect aquatic life, the secondary values were derived from the EPA's (1985f) final acute and chronic values. The chronic and test EC20 values for fish are from Call et al. (1983), and those for daphnids are from Biesinger et al. (1982). The chronic tests for fish were run on *Pimephales promeles* throughout their embryo-larval stage. *Daphnia magna* were used in flow through life-cycle tests. The plant value is for incipient inhibition of *Microcystis aeruginosa* in an 8-day test (EPA 1985f). The acute-EC20 ratio used to calculate the SS test  $EC_{20}$  value had to be derived using a species mean acute value (EPA 1985g) since no acute value was reported in Biesinger et al. (1982).

Mercury, methyl. The chronic and test EC20 values for fish are from McKim et al. (1976). Brook trout were used in three generation life-cycle tests. The test EC20 value for daphnids is from Biesinger et al. (1982). The alga, *Chlorella vulgaris*, was used in 15-day EC50 (growth) tests by Rai et al. (1981) to determine chronic toxicity values for aquatic plants.

Molybdenum. The chronic and test EC20 values for daphnids are from Kimball (n.d.). *Daphnia magna* were used in a 28-day life-cycle test to determine the chronic value.

Nickel. The NAWQC for nickel are functions of water hardness. The equation for these are  $e^{(0.8460[\ln(hardness)]+1.1645)}$  for the chronic value and  $e^{(0.8460[\ln(hardness)]+3.3612)}$  for the acute value. However, nickel concentrations of 10 µg/L in Oak Ridge Reservation stream water (considerably below the chronic NAWQC for nickel but similar to the lowest of the alternate benchmarks) reduced 7-day *Ceriodaphnia dubia* survivorship to 60% (Kszos et al. 1992). The chronic and test EC20 values for fish are from Nebeker et al. (1985). The chronic value for fish was determined through an early life stage test on rainbow trout. For daphnids, the chronic value was from Lazareva (1985) and the test EC20 was from Münzinger (1990). *Daphnia magna* were used in a life-cycle test to determine the chronic value. The caddisfly, *Clistoronia magnifica*, was used in life-cycle tests by Nebeker et al. (1984) to determine the chronic value. The plant chronic toxicity values were provided by the EPA (1986a) for *Microcystis aeruginosa*, which showed incipient inhibition.

**Potassium.** The chronic value for daphnids is a concentration causing a 16% reduction in reproduction of *Daphnia magna* exposed to KCl (Biesinger and Christensen 1972). Because the highly conservative secondary values were below commonly occurring ambient concentrations of this macronutrient, they were judged to be inappropriate and are not presented.

Selenium. NAWQC are listed for selenium. The chronic and test EC20 values for fish are from Goettl and Davies (1976). Their tests were during the early life stage of rainbow trout. The chronic value for daphnids is from Kimball (n.d.), and the test EC20 is from Johnston (1987). These tests were run for 28 days on *Daphnia magna*. The green alga, *Scenedesmus obliquus*, exhibited reduced growth in the 14-day chronic toxicity tests (Vocke et al. 1980). The acute-EC20 ratio used in calculation of the SS EC20 value had to be derived using a species mean acute value for *Daphnia magna* (EPA 1987a) because no acute value was reported by Johnston.

Silver. The acute NAWQC for silver, which is a function of water hardness, is given by the equation  $e^{(1.72[\ln(hardness)]-6.52)}$ . The SCV was estimated from the FAV and acute-chronic ratios for three species. Although questions about two of these ratios prompted the EPA to refrain from calculating a final chronic value, we judged them to be better than the default value. The lowest chronic value for fish is based on an early life stage test on rainbow trout by Davies et al. (1978). The lowest chronic value for daphnids and the test EC20 for fish are from Nebeker et al. (1983). The daphnid

CV is from a test with *Daphnia magna*. The test EC20 for daphnids is from Elnabarawy et al. (1986). The plant value is for growth inhibition in *Chlorella vulgaris* (EPA 1980y).

**Sodium.** The chronic value for daphnids is a concentration causing a 16% reduction in reproduction of *Daphnia magna* exposed to NaCl (Biesinger and Christensen 1972). Because the highly conservative secondary values were below commonly occurring ambient concentrations of this macronutrient, they were judged to be inappropriate and are not presented.

Strontium. The chronic value for daphnids is from 21-day tests on *Daphnia magna* by Biesinger and Christensen (1972) which resulted in 16% reproductive impairment.

Thallium. Chronic and test EC20 values are from Kimball (n.d.). Embryo-larval tests were run on *Pimephales promelas*, and 28-day chronic tests were run on *Daphnia magna*. The aquatic plant value is a 4-day EC50 which reduced the cell numbers of the alga, *Selenastrum capricornutum* (EPA 1978).

Tin. The chronic value is from Biesinger and Christensen (1972). It caused 16% reproductive impairment in *Daphnia magna* in 21 days.

Uranium. The chronic value for fish is an estimate based on a fathead minnow LC50 from Cushman et al. (1977) used in Equation (1). The test EC20 is an estimate based on the same data; however, Equation (5) was used.

**Vanadium.** The lowest chronic and test EC20 values for fish are from Holdway and Sprague (1979) and for daphnids from Kimball (n.d.).

**Zinc.** The NAWQC for zinc are functions of water hardness. The equations are  $e^{(0.8473[\ln(hardness)]+0.7614)}$  for the chronic value and  $e^{(0.8473[\ln(hardness)]+0.8604)}$  for the acute value. The chronic and test EC20 values for fish are from Spehar (1976), and the chronic value for daphnids is from Chapman et al. (n.d.). Life-cycle tests were run on *Jordanella floridae* and *Daphnia magna*. Nebeker et al. (1984) provided chronic values from life-cycle tests on the caddisfly, *Clistoronia magnifica*. Bartlett et al. (1974) ran 7-day tests on *Selenastrum capricornutum*. These aquatic plants showed incipient inhibition of growth.

**Zirconium**. The chronic and test EC20 values for fish are estimates based on an LC50 for *Pimephales promelas* from Cushman et al. (1977). These values were calculated using Equations (1) and (5).

#### 3.2 ORGANICS

Acenaphthene. Although the full data requirements are not met for acenaphthene, the EPA has presented final acute and chronic values for derivation of sediment quality criteria which are presented in the criteria columns (EPA 1993b). The fish chronic value is from an early life-stage test with *Pimephales promelas*, and the non-daphnid chronic value is from a life-cycle test with a midge *Paratanytarsus sp.* (EPA 1993b). The plant value is from EPA (1978). *Selenastrum capricornutum* were used in 96-hour EC50 (50% reduction in cell numbers).

Acetone. The test EC20 value for fish is an estimate based on an LC50 for rainbow trout. The chronic value for Daphnia magna is a 28-day life-cycle test from LeBlanc and Surprenant (1983).

Anthracene. The chronic value for daphnids (*Daphnia magna*) was estimated using an EC50 from Holst and Giesy (1989). The chronic and test EC20 values for fish are an estimate based on an LC50 for bluegill from Oris and Giesy (1985). Calculations were performed using Equations (2), (4), and (5).

Benzene. The lowest chronic value for daphnids is given by EPA (1978). Daphnia magna were used in life-cycle tests. The lowest chronic value for aquatic plants is given by Kauss and Hutchinson (1975), which was a 48-hour test EC50 on Chlorella vulgaris. The chronic value for fish is an estimate based on data for the rainbow trout from EPA (1980d) and Equation (2). The test EC20 value for fish is derived from Black and Birge (1982). The reader should note that Black and Birge conducted a series of screening tests for a large number of chemicals on several freshwater organisms. Larval fish survival was recorded to only 4 days post-hatch, and LOECs and NOECs were not determined. These tests, then, did not generate standard chronic values and are not equivalent to the other chronic tests cited in this report. The test EC20 values based on tests by Black and Birge may be high relative to those from conventional chronic tests.

Benzidene. The chronic and EC20 value for fish are an estimate based on data for red shiner from EPA (1980c). Calculations were performed using Equations (2) and (5).

Benzo(a)anthracene. The chronic value for daphnids is an estimate based on data for *Daphnia* magna from Trucco et al. (1983) used in Equation (4).

Benzo(a)pyrene. The test EC20 for fish is derived from Hannah et al. (1982). The chronic value for daphnids is an estimate based on data for *Daphnia magna* from Trucco et al. (1985) used in Equation (4).

Benzoic Acid. The chronic value for fish is an estimate based on data for the mosquitofish from AQUIRE used in Equation (2). The estimated test EC20 for fish is based on the same data, but Equation (5) was used.

**Benzyl Alcohol.** The chronic and test EC20 values for fish are estimates based on data for bluegill from Dawson et al. (1977). The calculations were performed using Equations (2) and (5).

BHC (lindane). There are NAWQC for lindane. The chronic values for daphnids, fish, and nondaphnid invertebrates are all from Macek et al. (1976a). The test EC20 values for daphnids and fish are also from Macek et al. (1976a). The chronic values were derived from life-cycle tests run on *Pimephales promelas*, *Daphnia magna*, and the midge *Chironimus tentans*. The chronic value for aquatic plants is from Krishnakumari (1977); *Scenedesmus acutus* exhibited 20% growth inhibition in 5 days. The acute-EC20 ratio from which the SS EC20 was calculated was derived using a species mean acute value for *Salvelinus fontinalis* (EPA 1980s) since no acute data were reported by Macek et al. (1976a).

**BHC (other).** The chronic value for daphnids was estimated using a *Daphnia magna* EC50 from AQUIRE in Equation (4).

**Bis(2-ethylhexyl)phthalate.** The chronic and test EC20 values for fish are from a rainbow trout early life-stage test (Mehrle and Mayer 1976). A much lower value was reported in the previous edition of this report, but the results of that study are now believed to be incorrect (Knowles et al. 1987). The new value is supported by a CV of 912  $\mu$ g/L from Adams and Heidolph (1985). That study is used in the derivation of the SCV because, unlike the Knowles et al. (1987) study, it has

an accompanying acute value (48-hr EC50). No test EC20 for daphnids was calculated because insufficient detail was presented by Adams and Heidolph (1985) and Knowles et al. (1987).

**2-Butanone.** The chronic values for fish and daphnids are estimates based on data from Veith et al. (1983) and Randall and Knopp (1980), respectively. Equation (4) was applied to the data for *Daphnia magna*, and Equation (2) was applied to the data for *Pimephales promelas*. The test EC20 value for fish is also an estimate using Equation (5) and an LC50 from Veith et al. (1983).

**Carbon disulfide.** The chronic and test EC20 values for fish are estimates based on data for mosquitofish from AQUIRE using equations (2) and (5). The chronic value for daphnids is an estimate for *Daphnia magna* using data from Van Leeuwen (1985) in Equation (4).

**Carbon tetrachloride**. The chronic value for fish is a rainbow trout embryo-larval LC50 (Black and Birge 1982); therefore, it may be too high. However, it is lower than values presented by Kimball et al. (n.d.) and EPA (1980h) for fathead minnows. The same test was used to derive the test EC20 for fish (see the comments on benzene). The chronic value for daphnids is from a 7-day reproduction test with *Daphnia magna* (Kimball et al. n.d.). None of the subchronic tests could be used in the calculation of the SCV.

Chlordane. The chronic NAWQC for chlordane is based on the final residue value. For a criterion to protect aquatic life rather than its use, the FCV is reported. The lowest chronic and test EC20 values are derived from *Daphnia magna*, bluegill, and *Chironomus tentans* life-cycle tests (Cardwell et al. 1977).

**Chlorobenzene.** The chronic values for fish and daphnids are estimates based on data for bluegill and *Daphnia magna* from EPA (1980j). The values were calculated using Equations (2) and (4). The plant value is a 96-hour EC50 for cell number with *Selenastrum capricornutum* (EPA 1980j).

**Chloroform.** The test EC20 value for fish is from Black and Birge (1982). (Refer to the section on benzene). The chronic value is a 27-day LC50 for rainbow trout (embryo-larval) from EPA (1980). The EPA (1986b) gives this value as a lowest observed effect value in lieu of a NAWQC. The chronic value for daphnids is an estimate based on data for *Daphnia magna* from EPA (1980l) and calculated from Equation (4).

**DDD.** The chronic and EC20 values for fish are estimates based on data for largemouth bass from Mayer and Ellersieck (1986) and are calculated using Equations (2) and (5).

**DDT.** The acute NAWQC for DDT is used. The chronic NAWQC, however, is not used because it is based on the final residue value. To protect aquatic life, an SCV is presented. The test EC20 value for fish is derived from Jarvinen et al. (1977). The fish chronic value is from a *Pimephales promelas* life-cycle test (EPA 1980m). The chronic value for daphnids is an estimate based on data for *Daphnia pulex* from EPA (1980m) and calculated with Equation (4). The aquatic plant chronic value is from Sodergreen (1968). *Chlorella vulgaris* was affected in growth and morphology.

**Decane.** The chronic value for daphnids is an estimate based on data for *Daphnia magna* from LeBlanc (1980) used in Equation (4).

Di-n-butyl phthalate. All chronic and test EC20 values are from McCarthy and Whitmore (1985). The chronic value for daphnids is based on the geometric means of the observed

concentration of fresh solutions and aged solutions. *Daphnia magna* were used in life-cycle tests, and *Pimephales promelas* were used in early life stage tests.

**Dibenzofuran.** The chronic value for daphnids is an estimate based on data for *Daphnia magna* from LeBlanc (1980) and used in Equation (4).

**1,1-Dichloroethane.** The chronic and test EC20 values for fish are estimates based on an LC50 for guppy from Koneman (1981) and calculated using Equations (2) and (5).

**1,2-Dichloroethane.** The chronic value for fish is from Ahmad et al. (1984). Early life stage tests were conducted on *Pimephales promelas*. The test EC20 value for fish is from Benoit et al. (1982). The chronic and test EC20 values for daphnids are from *Daphnia magna* 28-day life-cycle tests (Richter et al. 1983).

1,1-Dichloroethene. The chronic values for fish and aquatic plants are from EPA (1978). *Pimephales promelas* were used in embryo-larval tests. The alga, *Selenastrum capricornutum*, was used in a 96-hour EC50 where it exhibited loss of chlorophyll A and cell numbers. The chronic value for daphnids is an estimate based on data for *Daphnia magna* from EPA (1980n) used in Equation (4).

**1,2-Dichloroethene.** The chronic and test EC20 values for fish are estimates based on data for bluegill from EPA (1980n). These values were derived using Equations (2) and (5).

**1,3-Dichloropropene.** The test EC20 for fish was estimated using an LC50 for bluegill from EPA (1980o) in Equation (5). The chronic values for fish and aquatic plants are from EPA (1978). *Pimephales promelas* were used in an embryo-larval test, and *Selenastrum capricornutum* were used in a 96-hour EC50. The alga showed chlorophyll A and cell loss. The chronic value for daphnids was estimated using an EC50 for *Daphnia magna* from EPA (1980o) in Equation (4).

Diethyl phthalate. The plant value is a 96-hour EC50 for Selenastrum capricornutum (EPA 1978).

**Di-n-octyl phthalate.** All chronic and test EC20 values are from McCarthy and Whitmore (1985). Chronic values were based on *Pimephales promelas* in early life stage tests and *Daphnia magna* in life-cycle tests. There are no Tier II values for di-n-octyl phthalate because LC50s were not available.

Ethyl benzene. The chronic value for aquatic plants is from EPA (1978). Selenastrum capricornutum displayed chlorophyll A inhibition in 96-hour EC50. The chronic value for daphnids was estimated using an EC50 for *Daphnia magna* from EPA (1980p) in Equation (4).

**Fluoranthene.** Although the full data requirements are not met for fluoranthene, the EPA (1993c) has derived an FAV and FCV as a part of the derivation of sediment quality criteria which are presented in Table 1. The fish CV is from an early life-stage test with *Pimephales promelas*, and the daphnid CV is from a life-cycle test with *Daphnia magna* EPA (1993c).

Heptachlor. The acute NAWQC for heptachlor is used. Because the chronic NAWQC is based on the final residue value, an SCV is reported herein. The chronic and test EC20 values for fish are from Macek et al. (1976b). *Pimephales promelas* were used in life-cycle tests to determine the chronic value for fish. The SS test EC20 value was calculated using an acute-EC20 ratio that was derived from a species mean acute value for *Pimephales promelas* (EPA 1980r) because no acute data are available from Macek et al. (1976b). The chronic value for aquatic plants is from EPA (1980r). Growth inhibition was exhibited by *Selenastrum capricornutum* in 96-hour EC50. The chronic value for daphnids is an estimate based on data for *Daphnia pulex* from EPA (1980r) using Equation (4).

Hexane. The chronic value and test EC20 value for fish are estimates based on LC50s for golden orfe from AQUIRE and calculated using Equations (2) and (5).

2-Hexanone. The chronic value and test EC20 value are estimates based on an LC50 for *Pimephales promelas* from Geiger et al. (1986) and calculated using Equations (2) and (5).

1-Methylnaphthalene. The chronic and test EC20 values for fish are estimates based on data for *Pimephales promelas* from Mattson (1976). The values were calculated with Equations (2) and (5).

4-Methyl-2-pentanone. The chronic value for fish is from Call et al. (1985). *Pimephales promelas* embryos, larva, and juveniles were exposed for 31 to 33 days.

2-Methylphenol. The chronic value for daphnids is an estimate based on data for *Daphnia* magna from Adema (1978) and Canton and Adema (1978). The value was calculated using Equation (4). The chronic and test EC20 values for fish were estimated using an LC50 for rainbow trout from DeGraeve et al. (1980) in Equations (2) and (5).

Methylene chloride. The chronic value for fish is from Dill et al. (1987). *Pimephales promelas* were used in 32-day embryo-larval tests. The chronic value for daphnids is an estimate based on data for *Daphnia magna* from LeBlanc (1980) used in Equation (4). The test EC20 value for fish is from Black and Birge (1982). (Refer to the section on benzene concerning data from this source.)

Naphthalene. The chronic and test EC20 values for fish are from DeGraeve et al. (1982), and the test EC20 value for daphnids is from Geiger and Buikema (1982). *Pimphales promelas* were used in embryo-larval tests to determine chronic toxicity. The chronic value for aquatic plants is from EPA (1980t). The alga, *Chlorella vulgaris*, exhibited inhibited cell numbers in 48-hour EC50. The chronic value for daphnids is an estimate based on data for *Daphnia magna* from EPA (1980t) used in Equation (4).

4-Nitrophenol. The chronic and test EC20 values for daphnids are from Francis et al. (1986). The chronic and test EC20 values for fish are estimates based on data for bluegill from Buccafusco et al. (1981) and used with Equations (2) and (5). The EPA (1978) is the source for the chronic value for aquatic plants. *Selenastrum capricornutum* exhibited chlorophyll A reduction in 96-hour EC50.

**N-nitrosodiphenylamine.** The source for the estimated fish and daphnid chronic values are Buccafusco et al. (1981) and LeBlanc (1980), respectively. Equation (2) was used to calculate the estimated fish (bluegill) value, and Equation (4) was used for the estimated daphnid (*Daphnia magna*) value. The test EC20 value for fish is also an estimate. Buccafusco et al. (1981) provided the LC50 for bluegill used with Equation (5) to estimate the EC20.

**PCBs:** Total. There are NAWQC for PCBs, but the chronic criterion is based on the final residue value. Since that value is intended to protect the use of aquatic life, an SCV is calculated to protect the aquatic life itself. The fish lowest chronic value and test EC20 are from a full life-cycle test of fathead minnows by DeFoe (1978). The lowest chronic value and test EC20 for daphnids are

from a 2-week continuous flow test with *Daphnia magna* (Nebeker and Puglisi 1974). The lowest chronic value for non-daphnid invertebrates is from a 3-week LC50 for *Tanytarsis dissimilis* by Nedeker and Puglisi (1974). The lowest plant value is for reduction in carbon fixation by *Scenedesmus quadricaudata* in a 24-hour test (Laird 1973).

**PCBs:** Aroclor<sup>®</sup> 1221. The chronic and test EC20 fish values are estimates based on data for cutthroat trout by Stalling and Mayer (1972). Equations (2) and (5) were used to determine the EC20 value for fish. The chronic value for aquatic plants is a 48-hour LC50 for *Euglena gracilis* (Ewald et al. 1976).

**PCBs:** Aroclor<sup>®</sup> 1232. The chronic and test EC20 fish values are estimates based on data for cutthroat trout by Stalling and Mayer (1972) and AQUIRE. The geometric mean was derived from these two values and then placed into Equations (2) and (5).

**PCBs:** Aroclor<sup>®</sup> 1242. The chronic and test EC20 values for fish are from Nebeker et al. (1974). *Pimephales promelas* were used in full life-cycle tests. The chronic values for non-daphnid invertebrates are from Nebeker and Puglisi (1974). *Gammarus pseudolimnaeus* were exposed to PCBs for 2 months in a continuous-flow system. The chronic value for aquatic plants is a 24-hour test in which *Scenedesmus obtusiusculus* showed growth inhibition (Larsson and Tillberg 1975).

**PCBs:** Aroclor<sup>®</sup> 1248. The chronic and test EC20 values for fish are from DeFoe et al. (1978), and the chronic and test EC20 values for daphnids are from Nebeker and Puglisi (1974). The chronic values for fish were full life-cycle tests carried out on *Pimephales promelas*. The chronic value for daphnids was determined through 3-week exposures that created a 16% reproductive impairment in *Daphnia magna*. The chronic value for a non-daphnid invertebrate is from Nebeker and Puglisi (1974). Gammarus pseudolimnaeus was exposed for 2 months.

**PCBs:** Aroclor<sup>®</sup> 1254. The chronic value for fish is from a brook trout life-cycle test (Mauck et al. 1978), and the test EC20 value is from a fathead minnow life-cycle test (Nebeker et al. 1974). The chronic and test EC20 values for daphnids are from Nebeker and Puglisi (1974). *Daphnia magna* were exposed for 2 weeks in a continuous-flow environment. The lowest chronic value for nondaphnid invertebrates is from a 3-week LC50 for *Tanytarsis dissimilis* by Nedeker and Puglisi (1974). The lowest plant value is for reduction in carbon fixation by *Scenedesmus quadricaudata* in a 24-hour test (Laird 1973).

**PCBs:** Aroclor<sup>®</sup> 1260. The chronic and test EC20 values for fish are from DeFoe et al. (1978). The chronic value is ambiguous because significant effects occurred at the lowest concentration tested in a 30-day fathead minnow larval test at the lowest concentrations tested (1.3  $\mu$ g/L) but not in a 240-day lifecycle at the highest concentration tested (2.1  $\mu$ g/L).

1-Pentanol. The chronic and test EC20 values for fish are estimates based on data for rainbow trout from AQUIRE and calculated using Equations (2) and (5).

**Phenanthrene.** The chronic and test EC20 values for daphnids are from Geiger and Buikema (1982). The chronic value was determined using *Daphnia pulex* in full life-cycle tests.

**Phenol.** The chronic and test EC20 values for fish are from fathead minnow embryo-larval tests (DeGraeve et al. 1980). The chronic value for daphnids is an estimate based on data for *Daphnia longispina* from EPA (1980v) and calculated using Equation (4). The chronic value for aquatic plants

is from Reynolds (1975). *Selenastrum capricornutum* exhibited 60% reduction in cell numbers and 12% growth inhibition.

2-Propanol. The chronic and test EC20 values for fish are estimates based on data for *Pimephales promelas* from AQUIRE and Veith et al. (1983). The geometric mean of these LC50s was used in Equations (2) and (4).

1,1,2,2-Tetrachloroethane. The chronic and test EC20 values for fish are from Ahmad et al. (1984), and the values for daphnids are from Richter et al. (1983). The chronic values for fish were derived from embryo-larval tests on *Pimephales promelas*. The chronic values for daphnids were derived from 28-day tests run on *Daphnia magna*. The chronic value for aquatic plants is from EPA (1978). Selenastrum capricornutum exhibited chlorophyll A inhibition in 96-hour EC50.

Tetrachloroethene. The chronic value for fish is an embryo-larval test on fathead minnows (EPA 1980aa). The test EC20 value for fish is from Ahmad et al. (1984). The chronic and test EC20 values for daphnids are from Richter et al. (1983). These were 28-day tests on *Daphnia magna*. The plant value is from EPA (1978). *Selenastrum capricornutum* decreased in cell number and chlorophyll A during the 96-hour EC50.

Toluene. The chronic value is an estimate based on data for *Daphnia magna* from EPA (1980cc) and calculated using Equation (4). The chronic value from *Pimephales promelas* is from Devlin et al. (1982). The test EC20 value for fish is from Black and Birge (1982). (Refer to the section on benzene.) *Chlorella vulgaris* was used in 10-day tests by Kauss and Hutchinson (1975) to determine the chronic value for aquatic plants.

1,1,1-Trichloroethane. The chronic value and test EC20 value for daphnids are from Thompson and Carmichael (1989). *Daphnia magna* were used in 17-day chronic tests. The chronic value and test EC20 for fish were estimated based on data for *Pimephales promelas* from Alexander et al. (1978) and calculated using Equation (2). The chronic value for aquatic plants is from EPA (1978). *Selenastrum capricornutum* decreased in chlorophyll A and cell numbers in the 96-hour EC50.

1,1,2-Trichloroethane. The chronic value and test EC20 values for fish are from Ahmad et al. (1984) and the chronic and test EC20 values for daphnids are from Richter et al. (1983). The chronic value for fish is based on 32-day embryo-larval tests on *Pimephales promelas*, while the chronic value for daphnids is based on 28-day tests on *Daphnia magna*.

Trichloroethene. The chronic and test EC20 values for fish are from Smith et al. (1991). *Jordanella floridae*, the flagfish, was used in 28-day embryo-larval tests. The chronic value for daphnids is an estimate based on data for *Daphnia pulex* from EPA (1980dd) and calculated using Equation (4).

Vinyl acetate. The chronic and test EC20 values for fish are estimates based on an LC50 for *Pimephales promelas* from AQUIRE calculated using Equations (2) and (5).

**Xylene.** The chronic value for fish is an estimate based on an LC50 for common carp from AQUIRE and calculated using Equation (2). The test EC20 value for fish is from Black and Birge (1982). (Refer to the section on benzene.)

## 4. APPLICATION OF BENCHMARKS

Use of these aquatic screening benchmarks requires that the assessor choose which benchmarks to employ and which water concentrations to apply them to. The choice of benchmarks depends on the interpretation of the benchmarks, their regulatory standing, and their degree of conservatism.

Each of the alternative benchmarks has a different interpretation. Exceedances of NAWQC create a regulatory imperative for action under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) because they are ARARS. Exceedance of a Tier II value implies a greater than 20% chance that the NAWQC, if their value were known, would be exceeded. Exceedance of a CV indicates that the field concentration is greater than a concentration dividing statistically insignificant from significant effects in a chronic toxicity test. Exceedance of a test EC20 indicates that biologically significant effects levels were exceeded in a chronic toxicity test. Exceedance of the SS test EC20 indicates that a biologically significant effect level may be exceeded in a sensitive species. Exceedance of a population EC20 indicates that a significant reduction in a largemouth bass population could occur. Therefore, exceedance of either the acute or chronic NAWQC indicates a need for action. Exceedance of an SCV implies a low risk. Exceedance of any of the other benchmarks indicates a risk of real effects that should lead to additional data collection and assessment. However, these inferences all depend on comparison of the benchmarks to appropriate water concentrations.

Contaminant screening is not a regulatory process, but managers at some sites prefer to use only values that have regulatory standing. The NAWQC are clearly regulatory values in that they are ARARS and have been adopted by Tennessee and most other states as water quality standards. Lowest chronic values (the last column in Table 1) have been presented by the EPA in place of NAWQC (EPA 1986b), but they are not criteria. They merely indicate that the EPA believes toxic effects may occur at that concentration. The Tier II values (SAV and SCV) are proposed by the EPA as values that could be used for regulatory enforcement in the Great Lakes (EPA 1993a). They are more conceptually consistent with the NAWQC than lowest chronic values and may come to have the same standing as NAWQC, but currently they are only proposed by the EPA.

OSWER's Ecotox Thresholds and Region IV's screening values (or values proposed by other regions) are alternative benchmark sets derived by the EPA. Both are based on NAWQC values; however, Region IV uses values adjusted to 50 ppm hardness which is unrealistically conservative for most sites, while OSWER adjusts to dissolved-phase concentrations which are not available for most screening assessments. In addition, Region IV uses NAWQCs based on fish marketability which is not relevant to protecting aquatic life. Therefore, the standard EPA Office of Water NAWQC values and FCVs in Table 1 will be more useful in most cases. When NAWQCs are not available, the ETs correspond to SCVs, but some of the SCVs have been superseded by values presented in Table 1 of this document. When NAWQCs are not available, the SVs are based on divisions of lowest toxic values by 10 or 100 which is equivalent to derivation of SAVs and SCVs but is not as scientifically defensible. Therefore, for the Oak Ridge Reservation and many other sites, the NAWQCs and Tier II values listed in Table 1 are generally preferable to either the ETs or SVs.

As discussed in the introduction, the chronic benchmarks are to be used as lower screening benchmarks. The acute NAWQC and SAVs are to be used as upper screening benchmarks. However, because of their conservatism, exceedance of the SAV cannot be taken to indicate that severe effects are likely to be occurring. If an SAV is exceeded, the assessor should examine the acute values used to generate the Tier II values (Appendix A) and judge whether in fact severe effects are likely.

All of these benchmarks are based on toxicity tests conducted in the laboratory. Therefore, they should be compared to water concentrations that are as equivalent as possible to concentrations in test water which is nearly all dissolved. The EPA Office of Water has decided that for metals the appropriate comparison is to concentrations in 0.1 to 0.45  $\mu$ m filtered ambient water (HECD 1992, Prothro 1993). Acid soluble or even total recoverable concentrations, rather than dissolved concentrations, are often reported because they are required for human health risk assessments. In addition, Region IV and most other EPA regional offices require use of acid soluble concentrations in ecological risk assessments for the sake of conservatism. However, acid soluble concentrations of metals typically include 30 to 95% particle bound material (HECD 1992). Therefore, acid soluble concentrations should be used for aquatic ecological risk assessments to satisfy the regional regulators, but dissolved concentrations should also be used if possible for a realistic screening of the chemicals and to make realistic estimates of risk.

The NAWQC for hardness dependent metals are based on a hardness of 100 mg/L, which is appropriately conservative for ambient waters on the Oak Ridge Reservation. If these benchmarks are applied to a site with hard or soft water, the NAWQC for those metals should be recalculated as recommended by the EPA.

### 5. REFERENCES

- Adams, W. J. and B. B. Heidolph. 1985. Short-cut chronic toxicity estimates using *Daphnia magna*. pp. 87–102. in R. D. Cardwell, R. Purdy, and R. C. Bahner (eds.), *Aquatic Toxicity and Hazard Assessment*, Seventh Symposium. ASTM, Philadelphia, PA.
- Adams, W. J., G. R. Biddinger, K. A. Robillard. 1995. A summary of the acute toxicity of 14 phthalate esters to representative aquatic organisms. *Environ. Toxicol. Chem.* 14:1569–1574.
- Adelman, I. R., L. L. Smith, and G. D. Siesennop. 1976. Chronic toxicity of Guthion to the fathead minnow (*Pimephales promelas* Rafinesque). Bull. Environ. Contam. Toxicol. 15:726–733.
- Adema, D. M. M. 1978. *Daphnia magna* as a test animal in acute and chronic toxicity tests. *Hydrobiologia*. 59:125-134.
- Adema, D. M. M. and I. G. J. Vink. 1981. A comparative study of the toxicity of 1,1,2-trichloroethane, dieldrin, pentachlorophenol and 3,4 dichloroaniline for marine and fresh water organisms. *Chemosphere*. 10:533-554.
- Adema, D. M. M., J. H. Canton, W. Slooff, and A. O. Hanstveit. 1981. Research for a useful combination of test methods to determine the aquatic toxicity of environmentally dangerous chemicals. Rep. No. CL81/100, Natl. Inst. Public Health Environ. Hyg., the Netherlands.
- Ahmad, N. et al. 1984. Aquatic toxicity tests to characterize the hazard of volatile organic chemicals in water: A toxicity data summary—Parts I and II. EPA-600/3-84-009. U.S. Environmental Protection Agency, Duluth, Minn.
- Alexander, H. C., W. M. McCarthy, and E. A. Bartlett. 1978. Toxicity of perchloroethylene, trichloroethylene, 1,1,1-trichloroethane, and methylene chloride to fathead minnows. *Bull. Environ. Contam. Toxicol.* 20:344–352.

- Allison, D. T. and R. O. Hermanutz. 1977. *Toxicity of diazinon to brook trout and fathead minnows*. EPA-600/3-77-060. U.S. Environmental Protection Agency, Duluth, Minn.
- Amelung, M. 1981. Auswirkungen gelöster Eisenverbindungen auf die Ei- und Larvalentwicklung von Salmo gairdneri (Richardson). Arch. Fisch Wiss. 32:77-87.
- Anderson, D. R. and E. B. Lusty. 1980. Acute toxicity and bioaccumulation of chloroform to four species of freshwater fish. PNL-3046. NUREG/CR-0893. Report No. CR-0893, U.S. Nuclear Reg. Comm., Washington, D. C.
- Arthur, J. W. and E. N. Leonard. 1970. Effects of copper on Gammarus pseudolimnaeus, Physa integra, and Campeloma decisum in soft water. J. Fish. Res. Bd. Canada. 27:1277-1283.
- Arthur, J. W. and J. G. Eaton. 1970. Effects of copper on *Gammarus pseudolimnaeus* and the fathead minnow (*Pimephales promelas*). J. Fish. Res. Board Canada. 28:1841-1845.
- Bailey, H. C., D. H. W. Liu, and H. A. Javitz. 1985. Time/toxicity relationships in short-term static, dynamic, and plug-flow bioassays. in R. C. Bahner and D. J. Hansen (eds.), *Aquatic Toxicology* and Hazard Assessment, Eighth Symposium, ASTM STP 891, Philadelphia, PA.
- Barnthouse, L. W., G. W. Suter II, and A. E. Rosen. 1990. Risks of toxic contaminants to exploited fish populations: influence of life history, data uncertainty and exploitation intensity. *Environ. Toxicol. Chem.* 9:297–311.
- Bartell, S. M. 1990. Ecosystem context for estimating stress-induced reductions in fish populations, pp. 167–182, in *American Fisheries Society Special Symposium 8*. Bethesda, MD.
- Bartlett, L. and F. W. Rabe. 1974. Effects of copper, zinc, and cadmium on Selenastrum capricornutum. Water Res. 8:179-185.
- Benoit, D. A. 1975. Chronic effects of copper on survival, growth, and reproduction of the bluegill (Lepomis macrochirus). Trans. Am. Fish. Soc. 104:353-358.
- Benoit, D. A., and G. W. Holcombe. 1978. Toxic effects of zinc on fathead minnows *Pimephales* promelas in soft water. J. Fish Biol. 13:701-708.
- Benoit, D. A., F. A. Puglisi, and D. L. Olson. 1982. A fathead minnow *Pimephales promelas* early life stage toxicity test method evaluation and exposure to four organic chemicals. *Environ. Pollut. Ser. A Ecol. Biol.* 28:189–197.
- Biesinger, K. E., L. E. Anderson, and J. G. Eaton. 1982. Chronic effects of inorganic and organic mercury on *Daphnia magna*: toxicity, accumulation, and loss. *Arch. Environm. Contam. Toxicol.* 11:769–774.
- Biesinger, K. E. and G. M. Christensen. 1972. Effects of various metals on survival, growth, reproduction, and metabolism of *Daphnia magna*. J. Fish. Res. Bd. Canada. 29:1691–1700.
- Birge, W. J., J. A. Black, and A. G. Westerman. 1978. *Effects of polychlorinated biphenyl compounds* and proposed PCB-replacement products on embryo-larval stages of fish and amphibians. Res. Rep. No. 118, University of Kentucky, Water Resour. Res. Inst., Lexington, KY.

- Black, J. A. and W. J. Birge. 1982. The aquatic toxicity of organic compounds to embryo-larval stages of fish and amphibians. University of Kentucky, Water Resources Research Institute, Lexington, Kentucky.
- Bluzat, R., O. Junot, G. Lespinasse, and J. Seuge. 1979. Chronic toxicity of acetone in the fresh water snail *Lymnea stagnalis*. *Toxicology*. 14:179–190.
- Borgmann, U., O. Kramar, and C. Loveridge. 1978. Rates of mortality, growth, and biomass production of *Lymnaia palustris* during chronic exposure to lead. J. Fish. Res. Board Can. 35:1109–1115.
- Brooke, L. T., D. J. Call, D. L. Geiger, and C. E. Northcott. 1984. Acute toxicities of organic chemicals to fathead minnows (Pimephales promelas), Vol. 1. Center for Lake Superior Environmental Studies, University of Wisconsin, Superior, WI.
- Brungs, W. A. 1969. Chronic toxicity of zinc to the fathead minnow Pimephales promelas Rafinesque. Trans. Am. Fish. Soc. 98:272-279.
- Buccafusco, R. J., S. J. Ells, and G. A. LeBlanc. 1981. Acute toxicity of priority pollutants to bluegill (*Lepomis macrochirus*). *Bull. environ. Contam. Toxicol.* 26:446–452.
- Buhl, K. J. and S. J. Hamilton. 1990. Comparative toxicity of inorganic contaminants released by placer mining to early life stages of Salmonids. *Ecotoxicol. Environ. Saf.* 20:325–342.
- Buikema, A. L. Jr., J. Cairns, Jr., and G. W. Sullivan. 1974. Evaluation of *Philodina acuticornis* (Rotifera) as bioassay organisms for heavy metals. Water Resour. Bull. Am. Water Res. Assoc. 10:648–661.
- Cairns, J. Jr and A. Scheier. 1968. A comparison of the toxicity of some common industrial waste components tested individually and combined. *Prog. Fish-Cult.* 30:3-8
- Call, D. J., L. T. Brook, N. Ahmad, and J. E. Richter. 1983. Toxicity and metabolism studies with EPA priority pollutants and related chemicals in freshwater organisms. EPA-600/3-83-095. U.S. Environmental Protection Agency, Duluth, Minn.
- Call, D. J., L. T. Brook, M.L. Knuth, S. H. Poirer, and M.D. Hoglund. 1985. Fish subchronic toxicity prediction model for industrial organic chemicals that produce narcosis. *Environ. Toxic. and Chem.* 4:335–341.
- Call, D. J., L. T. Brooke, S. L. Harting, S. H. Poirier and D. J. McCauley. 1986. Toxicity of phenanthrene to several freshwater species. Report to Battelle Memorial Research Institute, Columbus, OH, Subcontract No. F-4114 (8834)-411, Work Assignment No. 45. Center for Lake Superior Environmental Studies, University of Wisconsin-Superior, Superior, WI.
- Canton, J. H. and D. M. M. Adema. 1978. Reproducibility of short-term and reproduction toxicity experiments with *Daphnia magna* and comparison of the sensitivity of *Daphnia magna* with *Daphnia pulex* and *Daphnia cucullata* in short-term experiments. *Hydrobiologia* 59:135–140.

- Canton, J. H., P. A. Greve, W. Slooff, and G. J. Van Esch. 1975. Toxicity, accumulation and elimination studies of alpha-hexachlorocyclohexane (alpha-HCH) with freshwater organisms of different trophic levels. *Water Res.* 9:1163–1169.
- Cardwell, R. D., D. G. Foreman, T. R. Payne, and D. J. Wilbur. 1976. Acute toxicity of selected toxicants to six species of fish. EPA-600/3-76-008, U.S. EPA, Duluth, MN.
- Cardwell, R. D., D. G. Foreman, T. R. Payne, and D. J. Wilbur. 1977. Acute and chronic toxicity of chlordane to fish and invertebrates, EPA-600/3-77-019. U.S. Environmental Protection Agency, Duluth, Minn.
- Carlson, A. R. and P. A. Kosian. 1987. Toxicity of chlorinated benzenes to fathead minnows (*Pimephales promelas*). Arch. Environ. Contam. Toxicol. 16:129–135.
- Carlson, A. R. et al. 1982. Cadmium and endrin toxicity to fish in waters containing mineral fibers, EPA-600/3-82-053. U.S. Environmental Protection Agency, Duluth, Minn.
- Chandler, J. H. Jr., and L. L. Marking. 1979. Toxicity of fishery chemicals to the Asiatic clam, Corbicula manilensis. Prog. Fish-Cult. 41:148--151.
- Chapman, G. A., S. Ota, and F. Recht. n.d. *Effects of water hardness on the toxicity of metals to Daphnia magna*. U.S. Environmental Protection Agency, Corvallis, Oregon.
- Cleveland, L., E. E. Little, S. J. Hamilton, D. R. Buckler, and J. B. Hunn. 1986. Interactive toxicity of aluminum and acidity to early life stages of brook trout. *Trans. Amer. Fish. Soc.* 115:610–620.
- Conway, H. L. 1977. Sorption of arsenic and cadmium and their effects on growth, micronutrient utilization, and photosynthetic pigment composition of *Asterionella formosa*. J. Fish. Res. Board Can. 35:26-294.
- Couture, P., C. Blaise, D. Cluis, and C. Bastien. 1989. Zirconium toxicity assessment using bacteria, algae and fish assays. *Water Air Soil Pollut*. 47:87–100.
- Cowell, B. C. 1965. The effects of sodium arsenite and silex on the plankton populations in farm ponds. *Trans. Am. Fish. Soc.* 94:371–377.
- Cowgill, U. M., I. T. Takahashi, and S. L. Applegath. 1985. A comparison of the effect of four benchmark chemicals on *Daphnia magna* and *Ceriodaphnia dubia affinis* tested at two different temperatures. *Environ. Toxicol. Chem.* 4:415–422.
- Cowgill, U. M. and D. P. Milazzo. 1991. The sensitivity of *Ceriodaphnia dubia* and *Daphnia magna* to seven chemicals utilizing the three-bood test. *Arch. Environ. Contam. Toxicol.* 20:211–217.
- Cushman, R. M., S. G. Hildebrand, R. H. Strand, and R. M. Anderson. 1977. The toxicity of 35 trace elements in coal to freshwater biota: a data base with automated retrieval capabilities. ORNL/TM-5793. Oak Ridge National Laboratory.
- Dave, G. 1984a. Effects of copper on growth, reproduction, survival and haemoglobin in *Daphnia* magna. Comp. Biochem. Physiol. 78C:439-443.

- Dave, G. 1984b. Effects of fluoride on growth, reproduction, and survival in *Daphnia magna*. *Comp. Biochem. Physiol.* 78C:425-431.
- Dave, G. 1984c. Effects of waterborne iron on growth, reproduction, survival and haemoglobin in *Daphnia magna. Comp. Biochem. Physiol.* 78C:433-438.
- Davies, P. H., J. P. Goettl, Jr., and J. R. Sinley. 1978. Toxicity of silver to rainbow trout (Salmo gairdneri). Water Res. 12:113–117.
- Davies, P. H., J. P. Goettl, Jr., J. R. Sinley, and Smith. 1976. Acute and chronic toxicity of lead to rainbow trout *Salmo gairdneri*, in hard and soft water. *Water Res.* 10:199-206.
- Dawson, G. W., A. L. Jennings, D. Drozdowski, and E. Rider. 1977. The Acute toxicity of 47 Indistrial chemicals to fresh and saltwater fishes. *J. Hazard. Mater.* 1:303–318.
- DeFoe, D. L., G. D. Veith, and R. L. Carlson. 1978. Effects of Aroclor 1248 and 1260 on the fathead minnow (*Pimephales promelas*). J. Fish. Res. Board Can. 7:997-1002.
- DeFoe, D. L. 1982. Arsenic (V) Test Results. U.S. EPA, Duluth, MN (Memo to R. L. Spehar, U.S. EPA, Duluth, MN).
- DeGraeve, G. M., D. L. Geiger, J. S. Meyer, and H. L. Bergman. 1980. Acute and embryo-larval toxicity of phenolic compounds to aquatic biota. *Arch. Environ. Contam. Toxicol.* 9:557-568.
- DeGraeve, G. M., R. G.Elder, D. C.Woods, and H.L.Bergman. 1982. Effects of naphthalene and benzene on fathead minnows and rainbow trout. Arch. Environ. Contam. Toxicol. 11:487-490.
- Devlin, E. W., J. D. Brammer, and R. L. Puyear. 1982. Acute toxicity of toluene to three age groups of fathead minnows (*Pimephales promelas*). Bull. Environ. Contam. Toxicol. 29:12–17.
- Dill, D. C., W. M. McCarthy, H. C. Alexander, and E. A. Bartlett. 1980. Toxicity of 1,1-Dichloroethylene (Vinylidene chloride) to aquatic organisms. Ecol. Res. Ser., EPA-600/3-80-057, Environ. Res. Lab., U.S. EPA, Duluth, MN.
- Dill, D. C., P. G. Murphy, and M. A. Mayes. 1987. Toxicity of methylene chloride to life stages of the fathead minnow, *Pimephales promelas* Rafinesque. *Bull. Environ. Contam. Toxicol.* 39:869–876.
- Ding, S. R. 1980. Acute Toxicities of vanadium, nickel, and cobalt to several species of aquatic organisms. *Environ. Qual.* 1:17-21.
- Dominguez, S. E. and G. A. Chapman. 1984. Effect of pentachlorophenol on the growth and mortality of embryonic and juvenile steelhead trout. *Arch. Environ. Contam. Toxicol.* 13:739–743.
- Dwyer, W. P., F. L. Mayer, J. L. Allen, and D. R. Buckler. 1978. Chronic and simulated use-pattern exposures of brook trout (*Salvelinus fontinalis*) to 3-trifluoromethyl-4-nitrophenol (TFM). *Investigations in Fish Control*. 84:1–6.
- Eaton, J. G. 1974. Chronic cadmium toxicity to the bluegill (Lepomis macrochirus Rafinesque). Trans. Am. Fish. Soc. 103:729-735.

- Elnabarawy, M. T., A. N. Welter, and R. R. Robideau. 1986. Relative sensitivity of three daphnid species to selected organic and inorganic chemicals. *Environ. Toxicol. Chem.* 5:393-398.
- EPA. (n.d.). AQUIRE: Aquatic Information Retrieval Toxicity Data Base. National Technical Information Service, Springfield, Va.
- EPA. 1978. In-depth studies on health and environmental impacts of selected water pollutants. Contract No. 68-01-4646, U. S. EPA, Duluth, MN (also known as C. E. Stephan's Table of Data).
- EPA. 1980a. Ambient water quality criteria for acenaphthene. EPA 440/5-80-015. U.S. Environmental Protection Agency, Washington, D.C.
- EPA. 1980b. Ambient water quality criteria for antimony. EPA 440/5-80-020. U.S. Environmental Protection Agency, Washington, D.C.
- EPA. 1980c. Ambient water quality criteria for benzidene. EPA 440/5-80-023. U.S. Environmental Protection Agency, Washington, D.C.
- EPA. 1980d. Ambient water quality criteria for benzene. EPA 440/5-80-018. U.S. Environmental Protection Agency, Washington, D.C.
- EPA. 1980e. Ambient water quality criteria for benzidene. EPA 440/5-80-023. U.S. Environmental Protection Agency, Washington, D.C.
- EPA. 1980f. Ambient water quality criteria for beryllium. EPA 440/5-80-024. U.S. Environmental Protection Agency, Washington, D.C.
- EPA. 1980g. *Ambient water quality criteria for cadmium*. EPA 440/5-80-025. U.S. Environmental Protection Agency, Washington, D.C.
- EPA. 1980h. Ambient water quality criteria for carbon tetrachloride. EPA 440/5-80-026. U.S. Environmental Protection Agency, Washington, D.C.
- EPA. 1980i. *Ambient water quality criteria for chlordane*. EPA 440/5-80-027. U.S. Environmental Protection Agency, Washington, D.C.
- EPA. 1980j. Ambient water quality criteria for chlorinated benzenes. EPA 440/5-80-028. U.S. Environmental Protection Agency, Washington, D.C.
- EPA. 1980k. Ambient water quality criteria for chlorinated ethanes. EPA 440/5-80-029. U.S. Environmental Protection Agency, Washington, D.C.
- EPA. 1980l. Ambient water quality criteria for chloroform. EPA 440/5-80-033. U.S. Environmental Protection Agency, Washington, D.C.
- EPA. 1980m. Ambient water quality criteria for DDT. EPA 440/5-80-038. U.S. Environmental Protection Agency, Washington, D.C.
- EPA. 1980n. Ambient water quality criteria for dichloroethylenes. EPA 440/5-80-041. U.S. Environmental Protection Agency, Washington, D.C.

- EPA. 19800. Ambient water quality criteria for dichloropropane and dichloropropene. EPA 440/5-80-043. U.S. Environmental Protection Agency, Washington, D.C.
- EPA. 1980p. Ambient water quality criteria for ethylbenzene. EPA 440/5-80-048. U.S. Environmental Protection Agency, Washington, D.C.
- EPA. 1980q. Ambient water quality criteria for fluoranthene. EPA 440/5-80-049. U.S. Environmental Protection Agency, Washington, D.C.
- EPA. 1980r. *Ambient water quality criteria for heptachlor*. EPA 440/5-80-052. U.S. Environmental Protection Agency, Washington, D.C.
- EPA. 1980s. Ambient water quality criteria for hexachlorocyclohexane. EPA 440/5-80-054. U.S. Environmental Protection Agency, Washington, D.C.
- EPA. 1980t. Ambient water quality criteria for naphthalene. EPA 440/5-80-059. U.S. Environmental Protection Agency, Washington, D.C.
- EPA. 1980u. Ambient water quality criteria for nitrophenols. EPA 440/5-80-063. U.S. Environmental Protection Agency, Washington, D.C.
- EPA. 1980v. *Ambient water quality criteria for phenol*. EPA 440/5-80-066. U.S. Environmental Protection Agency, Washington, D.C.
- EPA. 1980w. Ambient water quality criteria for phthalate esters. EPA 440/5-80-067. U.S. Environmental Protection Agency, Washington, D.C.
- EPA. 1980x. Ambient water quality criteria for polychlorinated biphenyls. EPA 440/5-80-068. U.S. Environmental Protection Agency, Washington, D.C.
- EPA. 1980y. Ambient water quality criteria for silver. EPA 440/5-80-071. U.S. Environmental Protection Agency, Washington, D.C.
- EPA. 1980z. Ambient water quality criteria for beryllium. NTIS, Springfield, Virginia.
- EPA. 1980aa. Ambient water quality criteria for tetrachloroethylene. EPA 440/5-80-073. U.S. Environmental Protection Agency, Washington, D.C.
- EPA. 1980bb. *Ambient water quality criteria for thallium*. EPA 440/5-80-074. U.S. Environmental Protection Agency, Washington, D.C.
- EPA. 1980cc. *Ambient water quality criteria for toluene*. EPA 440/5-80-075. U.S. Environmental Protection Agency, Washington, D.C.
- EPA. 1980dd. Ambient water quality criteria for trichloroethylene. EPA 440/5-80-077. U.S. Environmental Protection Agency, Washington, D.C.
- EPA. 1980ee. Ambient water quality criteria for nitrosamines. EPA 440/5-80-064. U.S. Environmental Protection Agency, Washington, D.C.

- EPA. 1984a. Ambient water quality criteria for cadmium 1984. EPA 440/5-84-032. U.S. Environmental Protection Agency, Washington, D. C.
- EPA. 1985a. Ambient water quality criteria for ammonia 1984. EPA 440/5-85-001. U.S. Environmental Protection Agency, Washington, D.C.
- EPA. 1985b. Ambient water quality criteria for arsenic 1984. EPA 440/5-84-033. U.S. Environmental Protection Agency, Washington, D.C.
- EPA. 1985c. Ambient water quality criteria for chromium 1984. EPA 440/5-84-029. U.S. Environmental Protection Agency, Washington, D.C.
- EPA. 1985d. Ambient water quality criteria for copper 1984. EPA 440/5-84-031. U.S. Environmental Protection Agency, Washington, D.C.
- EPA. 1985e. Ambient water quality criteria for cyanide 1984. EPA 440/5-84-030. U.S. Environmental Protection Agency, Washington, D.C.
- EPA. 1985f. Ambient water quality criteria for lead 1984. EPA 440/5-84-027. U.S. Environmental Protection Agency, Washington, D.C.
- EPA. 1985g. Ambient water quality criteria for mercury 1984. EPA 440/5-84-026. U.S. Environmental Protection Agency, Washington, D.C.
- EPA. 1986a. Ambient water quality criteria for nickel 1986. EPA 440/5-86-004. U.S. Environmental Protection Agency, Washington, D.C.
- EPA. 1986b. *Quality criteria for water*. EPA 440/5-86-001. U.S. Environmental Protection Agency, Washington, D.C.
- EPA. 1987a. Ambient water quality criteria for selenium, 1987. EPA 440/5-87-006. U.S. Environmental Protection Agency, Washington, D.C.
- EPA. 1987b. Ambient water quality criteria for zinc, 1987. EPA 440/5-87-003. U.S. Environmental Protection Agency, Washington, D.C.
- EPA. 1988a. Ambient water quality criteria for aluminum 1988. EPA 440/5-86-008. U.S. Environmental Protection Agency, Washington, D.C.
- EPA. 1988b. Ambient water quality criteria for antimony(III). Draft. August 30th, 1988. U.S. Environmental Protection Agency, Washington, D.C.
- EPA. 1992. Great Lakes Water Quality Initiative Tier II water quality values for protection of aquatic life in ambient water. Support documents. November 23, 1992.
- EPA. 1993a. Water quality guidance for the Great Lakes System and correction; Proposed rules. *Federal Register*. 58(72):20802-21047.
- EPA. 1993b. Sediment quality criteria for the protection of benthic organisms acenaphthene. EPA-822-R-93-013. U.S. Environmental Protection Agency, Washington, D.C.

- EPA. 1993c. Sediment quality criteria for the protection of benthic organisms fluoranthene. EPA-822-R-93-012. U.S. Environmental Protection Agency, Washington, D.C.
- EPA. 1993d. Great Lakes Water Quality Initiative Criteria documents for the protection of aquatic life in ambient water (February 1993 Draft). PB93-154656. National Technical Information Service. Springfield, VA.
- Erben, R. and Z. Pisl. 1993. Acute toxicity for some evaporating aromatic hydrocarbons for freshwater snails and crustacenas. *Int. Rev. Gesamten Hydrobiol.* 78:161–167.
- Ernst, W. R. and E. T. Garside. 1987. Lethal effects of vanadium to two life stages of brook trout *Salvelinus fontinalis. Can. J. Zool.* 65:628–634.
- Ewald, W. G., J. E. French, and M. A. Champ. 1976. Toxicity of Polychlorinated Biphenyls (PCBs) to *Euglena gracilis*: Cell Population Growth, Carbon Fixation, Chlorophyll Level, Oxygen Consumption, and Protein and Nucleic Acid Synthesis. *Bull. Environ. Contam. Toxicol.* 16:71-80.
- Ewell, W. S., J. W. Gorsuch, R. O. kringle, K. A. Robillard, and R. C. Spiegel. 1986. Simultaneous evaluation of the acute effects of chemicals on seven aquatic speices. *Environ. Toxicol. Chem.* 5:831-840.
- Fargasova, A. 1994. Toxicity of metals on *Daphnia magna* and *Tubifex tubifex. Ecotoxicol. Environ.* Saf. 27:210–213.
- Finlayson, B. J., and K. M. Verrue. 1985. Toxicities of butoxyethanol ester and propylene glycol butyl ether ester formulations of 2,4-dichlorophenoxy acetic acid (2,4-D) to juvenile salmonids. Arch. Environ. Contam. Toxicol. 14:153–160.
- Francis, P. C., D. W. Grothe, and J. C. Scheuring. 1986. Chronic toxicity of 4-nitrophenol to Daphnia magna Straus under static-renewal and flow-through conditions. Bull. Environ. Contam. Toxicol. 36:730-737.
- Geiger, J. G. and A. I. Buikema, Jr. 1982. Hydrocarbons depress growth and reproduction of *Daphnia* pulex (Cladocera). Can. J. Fish. Aquati. Sci. 39:830-836.
- Geiger, D. L., C. E. Northcott, D. J. Call, and L. T. Brooke. 1985. Acute toxicities of organic chemicals to fathead minnows (Pimephales promelas), Vol. 2. Center for Lake Superior Environmental Studies, University of Wisconsin, Superior, WI.
- Geiger, D. L., D. J. Call, and L. T. Brooke. 1988. Acute toxicities of organic chemicals to fathead minnows (Pimephales promelas), Vol. 4. Center for Lake Superior Environmental Studies, University of Wisconsin, Superior, WI.
- Geiger, D. L., L. T. Brooke, and D. J. Call. 1990. Acute toxicities of organic chemicals to fathead minnows (Pimephales promelas), Vol. 5. Center for Lake Superior Environmental Studies, University of Wisconsin, Superior, WI.

- Geiger, D. L., S. H. Poirier, L. T. Brooke, and D. J. Call. 1986. Acute toxicities of organic chemicals to fathead minnows (Pimephales promelas), Vol. 3. Center for Lake Superior Environmental Studies, University of Wisconsin, Superior, WI.
- Gersich, F. M. 1984. Evaluation of a static renewal chronic toxicity test method for *Daphnia magna* straus using boric acid. *Environ. Toxicol. Chem.* 3:89–94.
- Glassi, S., M. Mingazzini, L. Vigano, D. Cesareo, and M. L. Tosato. 1988. Approaches to modeling toxic responses of aquatic organisms to aromatic hydrocarbond. *Ecotoxicol. Environn. Saf.* 16:158–169.
- Goettl, J. P., Jr. and P. H. Davies. 1976. Water pollution studies. Federal Aid Project F-33-R-11. Department of Natural Resources, Colorado Division of Wildlife.
- Hamelink, J. L., D. R. Buckler, f. L. Mayer, D. U. Palawski, and H. O. Sanders. 1986. Toxicity of fluoridone to aquatic invertebrates and fish. *Environ. Toxicol. Chem.* 5:97-94.
- Hamilton, S. J. 1995. Hazard assessment of inorganics to three endangered fish in the Green River, Utah. Ecotoxicol. Environ. Saf. 30:134–142.
- Hamilton. S. J. and K. J. Buhl. 1990. Safety assessment of selected inorganic elements to fry of chinook salmon (Oncorhynchus tshawytscha). Ecotoxicol. Environ. Saf. 20:307–324.
- Hannah, J. B., J. E. Hose, M. L. Landolt, B. S. Miller, S. P. Felton, and W. T. Iwaoko. 1982. Benzo(a)pyrene-induced morphologic and developmental abnormalities in rainbow trout. Arch. Environ. Contam. Toxicol. 11:727–734.
- Hazel, C. R. and S. J. Meith. 1970. Bioassay of king salmon eggs and sac fry in copper solutions. *Calif. Fish Game.* 2:121-124.
- HECD (Health and Criteria Division). 1992. Interim guidance on interpretation and implementation of aquatic life criteria for metals. U.S. Environmental Protection Agency, Washington, D.C.
- Hermanutz, R. O., R. H. Mueller, and K. D. Kempfer. 1973. Captan toxicity to fathead minnows (*Pimephales promelas*), bluegills (*Lepomis macrochirus*), and brook trout (*Salvelinus fontinalis*). J. Fish. Res. Board Can. 30:1811–1817.
- Hodson, P. V., R. Parisella, B. Blunt, B. Gray, K. L. E. Kaiser. 1991. Quantitative structure-activity relationships for chronic toxicity of phneol, p-chlorophenol, 2,4-dichlorophenol, pentachlorophenol, p-nitrophenol, and 1,2,4-trichlorobenzene to early life stages of rainbow trout (Oncorhynchus mykiss). Can. Tech. Rep. Fish. Aquat. Sci. 1784.
- Hodson, P. V., D. G. Dixon, and K. L. E. Kaiser. 1984. Measurement of median lethal dose as a rapid indication of contaminant toxicity to fish. *Environ. Toxicol. Chem.* 3:243-254.
- Holcombe, G. W., D. A. Benoit, E. N. Leonard, and J. M. McKim. 1976. Long term effects of lead exposure on three generations of brook trout (*Salvelinus fontinalis*). J. Fish. Res. Board Can. 33:1731–1741.

- Holcombe, G. W., G. L. Phipps, and J. T. Fiandt. 1982. Effects of phenol, 2,4-dimethylphenol,2,4dichlorophenol, and pentachlorophenol on embryo, larval, and early-juvenile fathead minnows (*Pimephales promelas*). Arch. Environ. Contam. Toxicol. 11(1):73–78.
- Holcombe, G. W., G. L. Phipps, and J. T. Fiandt. 1983. Toxicity of selected priority pollutants to various aquatic organisms. *Ecotoxicol. Environ. Saf.* 7400–7409.
- Holcombe, G. W., G. L. Phipps, M. L. Knuth, and T. Felhaber. 1984. The acute toxicity of selected substituted phenols, benzenes and benzoic acid esters to fathead minnows *Pimephales promelas*. *Environ. Pollut. Ser. A Ecol. Biol.* 35:367–381.
- Holdway, D. A. and J. B. Sprague. 1979. Chronic toxicity of vanadium to flagfish. *Water Res.* 13:905-910.
- Holman, W. F., and K. J. Macek. 1980. An aquatic safety assessment of linear alkylbenzsulfonate (LAS): chronic effects on fathead minnows. *Trans. Am. Fish. Soc.* 109:122–131.
- Holst, L. L. and J. P. Giesy. 1989. Chronic effects of the photoenhanced toxicity of anthracene on Daphnia magna reproduction. Environ. Toxicol. Chem. 8:933-942.
- Howe, G. E., L. L. marking, T. D. Bills, J. J. Rach, and F. L. Mayer, Jr. 1994. Effects of water temperature and pH on toxicity of terbufos, trichlorfon, 4-nitrophenol and 2,4-dinitrophenol to the amphipod *Gammarus pseudolimnaeus* and rainbow trout (*Onchorhynchus mykiss*). *Environ. Toxicol. Chem.* 13:51–56.
- Ingersoll, C. G. et al. 1990a. Aluminum and acid toxicity to two strains of brook trout (Salvelinus fontinalis). Can. J. Fish. Aquat. Sci. 47:1641–1648.
- Ingersoll, C. G. et al. 1990b. Effects of pH, aluminum, and calcium on survival and growth of eggs and fry of brook trout (*Salvelinus fontinalis*). *Can. J. Fish. Aquat. Sci.* 47:1580–1592.
- Jarvinen, A. W., M. J. Hoffman, and T. W. Thorslund. 1977. Long-term toxic effects of DDT food and water exposure on fathead minnows (*Pimephales promelas*). J. Fish. Res. Board Can. 34:2089–2103.
- Jarvinen, A. W., B. R. Nordling, and M. E. Henry. 1983. Chronic toxicity of dursban (chlorpyrifos) to the fathead minnow (*Pimephales promelas*) and the resultant acetylcholinesterase inhibition. *Ecotoxicol. Environ. Safety*. 7:423–434.
- Johnson, W. W. and M. T. Finley. 1980. Handbook of acute toxicity of chemicals to fish and aquatic invertebrates. Resour. Publ. 137, Fish Wildl. Serv., U.S. D.I., Washington, D.C.
- Johnston, P. A. 1987. Acute toxicity of inorganic selenium to *Daphnia magna* (Straus) and the effect of sub-acute exposure upon growth and reproduction. *Aquat. Toxicol.* 10:335–352.
- Karlander, E. P. and R. W. Krauss. 1972. Absorption and toxicity of beryllium and lithium in *Chlorella vannielii* Shihira and Krauss. *Chesapeake Science*. 13:245–253.
- Kauss, P. B. and T. C. Hutchinson. 1975. The effects of water-soluble petroleum components on the growth of *Chlorella vulgaris* Beijerinck. *Environ. Pollut.* 9:157–174.

- Keen, R., and C. R. Baillod. 1985. Toxicity to *Daphnia* of the end products of wet oxidation of phenol and substituted phenol. *Water Res.* 19:767–772.
- Khangarot, B. S. 1991. Toxicity of metals to a freshwater tubificid worm, *Tubifex tubifex. Bull.* Environ. Contam. Toxicol. 46:906-912.
- Khangarot, B. S., A. Sehgal, and M. K. Bhasin. 1985. Man and biosphere--Studies on the Sikkim Himalayas. Part 5: Acute toxicity of selected heavy metals on the tadpoles of *Rana hexadactyla*. *Acta Hydrochim. Hydrobiol.* 13:259–263.
- Kimball, G. n.d. The effects of lesser known metals and one organic to fathead minnows [*Pimephales promelas*] and *Daphnia magna*. U.S. Environmental Protection Agency, Duluth, MN.
- Kleiner, C. F., R. L. Anderson, and D. K. Tanner. 1984. Toxicity of fenitrothion to fathead minnows (*Pimephales promelas*) and alternate exposure duration studies with fenitrothion and endosulfan. *Arch. Environ. Contam. Toxicol.* 13:573–578.
- Koenst, W. M., L. L. Smith, Jr., and S. J. Broderius. 1977. Effect of chronic exposure of brook trout to sublethal concentrations of hydrogen cyanide. *Environmental Science and Technology* 11:883–886.
- Könemann, H. 1981. Quantitative structure-activity relationships in fish toxicity studies. Part 1: Relationship for 50 industrial pollutants. *Toxicology*. 19:209–221.
- Kouyoumjian, H. H. and R. F. Uglow. 1974. Some aspects of the toxicity of p,p'-DDT, p,p'-DDE and p,p'-DDD to the freshwater planarian *Polycelis felina* (Tricladida). *Environ. Pollut.* 7:103–109.
- Krishnakumari, M. K. 1977. Sensitivity of the alga Scenedesmus acutus to some pesticides. Life Sciences. 20:1525-1532.
- Kszos, L. A., A. J. Stewart, and P. A. Taylor. 1992. An evaluation of nickel toxicity to *Ceriodaphnia dubia* and *Daphnia magna* in a contaminated stream and in laboratory tests. *Environ. Toxicol. Chem.* 11:1001–1012.
- Kühn, R., M. Pattard, K. Pernak, and A. winter. 1989. Results of the harmful effects of selected water pollutants (anilines, phenol, aliphatic compounds) to *Daphnia magna*. *Water Res.* 23:495–499.
- Kühn, R., M. Pattard, K. Pernak, and A. Winter. 1989. Results of the harmful effects of water pollutants to *Daphnia magna* in the 21 day reproduction test. *Water Res.* 23:501–510.
- Larsson, L. and J. Tillberg. 1975. Effects of the Commercial Polychlorinated Biphenyl Mixture Aroclor 1242 on Growth, Viability, Phosphate Uptake, Respiration and Oxygen Evolution in *Scenedesmus. Physiol. Plant* 33:256–260.
- Lazareva, L. P. 1985. Changes in biological characteristics of *Daphnia magna* from chronic action of copper and nickel at low concentrations. *Hydrobiol. J.* 21(5):59–62.
- LeBlanc, G. A. 1980. Acute toxicity of priority pollutants to water flea (*Daphnia magna*). Bull. Environ. Contam. Toxicol. 24:684–691.

- LeBlanc, G. A. and D. C. Surprenant. 1983. The acute and chronic toxicity of acetone, dimethyl formamide, and triethylene glycol to *Daphnia magna* (Straus). *Arch. Environ. Contam. Toxicol.* 12:305–310.
- LeBlanc, G. A., J. D. Mastone, A. P. Paradice, B. F. Wilson, H. B. Lockhart, Jr., and K. A. Robillard. 1984. The influence of speciation on the toxicity of silver to fathead minnow (*Pimephales promelas*). *Environ. Toxicol. Chem.* 3:37–46.
- Leduc, G. 1978. Deleterious effects of cyanide on early life stages of atlantic salmon (*Salmo salar*). J. Fish. Res. Board Can. 35:166–174.
- Lewis, M. A. and L. C. Valentine. 1981. Acute and chronic toxicities of boric acid to *Daphnia magna* Straus. *Bull. Environ. Contam. Toxicol.* 27:309–315.
- Lima, A. R. et al. 1984. Acute and chronic toxicities of arsenic (III) to fathead minnows, flagfish, daphnids, and an amphipod. Arch. Environ. Contam. Toxicol. 13:595-601.
- Lind, D., K. Alto, and S. Chatterton. 1978. *Regional copper-nickel study; aquatic toxicology study*. Minnesota Environmental Quality Board.
- Lock, R. A. C. and A. P. van Overbeeke. 1981. Effects of mercuric chloride and methylmercuric chloride on mucus secretion in rainbow trout, *Salmo gairdneri* Richardson. *Comp. Biochem. Physiol.* 69C:67–74.
- Luard, E. J. 1973. Sensitivity of *Dunaliella* and *Scenedesmus* (*Chlorphyceae*) to Chlorinated hydrocarbons. *Phycologia* 12:29-33.
- Macek, K. J., K. S. Buxton, S. K. Derr, J. W. Dean, and S. Sauter. 1976a. Chronic toxicity of lindane to selected aquatic invertebrates and fish. EPA-600/3-76-046. U.S. Environmental Protection Agency, Duluth, Minn.
- Macek, K. J., M. A. Lindberg, S. Sauter, K. Buxton, and P. A. Costa. 1976b. Toxicity of four pesticides to water fleas and fathead minnows. EPA-600/3-76-099. U.S. Environmental Protection Agency, Duluth, Minn.
- McCarthy, J. F. and D. K. Whitmore. 1985. Chronic toxicity of di-n-butyl and di-n-octyl phthalate to *Daphnia magna* and the fathead minnow. *Environ. Toxicol. Chem.* 4:167–179.
- McCauley, D. J., L. T. Brooke, D. J. Call, and C. A. Lindberg. 1986. Acute and chronic toxicity of aluminum to <u>Ceriodaphnia dubia</u> at various pH's. Center for Lake Superior Environmental Studies, University of Wisconsin-Superior, Superior, Wis.
- McKim, J. M., and D. A. Benoit. 1971. Effects of long-term exposures to copper on survival, growth, and reproduction of brook trout (*Salvelinus fontinalis*). J. Fish. Res. Board Can. 28:655-662.
- McKim, J. M., G. F. Olson, G. W. Holcombe, and E. P. Hunt. 1976. Long-term effects of methylmercuric chloride on three generations of brook trout (*Salvelinus fontinalis*): toxicity, accumulation, distribution, and elimination. J. Fish. Res. Board Can. 33:2726–2739.

- Martin, T. R. and D. M. Holdich. 1986. The Acute lethal toxicity of heavy metals to peracarid crustaceans (with particular reference to fresh-water Asellids and Gammarids). *Water Res.* 20:1137–1147.
- Mattson, V. R., J. W. Arthur, and C. T. Walbridge. 1976. Acute toxicity of selected organic compounds to fathead minnows. Ecol. Res. Ser. EPA-600/3-76-097, Environ. Res. Lab., U.S. EPA, Duluth, MN.
- Mauck, W. L., P. M. Mehrle, and F. L. Mayer. 1978. Effects of the polychlorinated biphenyl Aroclor<sup>®</sup> 1254 on growth, survival, and bone development in brook trout (*Salvelinus fontinalis*). J. Fish. Res. Board Can. 35:1084–1088.
- Mayer, F. L., Jr., P. M. Mehrle, Jr., and W. P. Dwyer. 1975. *Toxaphene effects on reproduction, growth and mortality of brook trout.* EPA-600/3-75-013. U. S. Environmental Protection Agency, Duluth, Minn.
- Mayer, F. L., Jr., P. M. Mehrle, H. O. Sanders. 1977. Residue dynamics and biological effects of polychlorinated biphenyls in aquatic organisms. *Arch. Environ. Contam. Toxicol.* 5:501-511.
- Mayer, F. L., Jr., and H. O. Sanders. 1973. Toxicology of phthalic acid esters in aquatic organisms. *Environmental Health Perspectives* 5:153–157.
- Mayer, F. L., Jr. and M. R. Ellersieck. 1986. *Manual of acute toxicity: interpretation and data base* for 410 chemicals and 66 species of freshwater organisms. Resource Publication 160. U.S. Fish and Wildlife Service, Washington, D.C.
- Mayes, M. A., H. C. Alexander, D. L. Hopkins, P. B. Latvaitis. 1986. Acute and chronic toxicity of ammonia to freshwater fish: a site-specific study. *Environ. Toxicol. Chem.* 5:437-442.
- Mehrle, P. M., and F. L. Mayer. 1976. Di-2-ethylhexyl phthalate: residue dynamics and biological effects in rainbow trout and fathead minnows. *Trace Subst. Env. Health* 10:519–524.
- Millemann, R. E., W. J. birge, J. A. Black, R. M. Cushman, K. L. Daniels, P. J. Franco, J. M. Giddings, J. F. McCarthy, and A. J. Stewart. 1984. Comparative acute toxicity to aquatic organisms of components of coal-derived synthetic fuels. *Trans. Am. Fish. Soc.* 113:74–85.
- Moles, A., S. D. Rice, and S. Korn. 1979. Sensitivity of Alaskan freshwater and anadromous fishes to Prudhoe Bay crude oil and benzene. *Trans. Am. Fish. Soc.* 108:408-414.
- Mount, D. I. 1968. Chronic toxicity of copper to fathead minnows (*Pimephales promelas* Rafinesque). *Water Res.* 2:215–223.
- Mount, D. I. 1982. Memorandum to Charles E. Spehar. U.S. Environmental Protection Agency, Duluth, Minn. June 7.
- Mount, D. I., and C. E. Stephan. 1969. Chronic toxicity of copper to the fathead minnow (*Pimephales promelas*) in soft water. J. Fish. Res. Board Can. 26:2449–2457.

- Munoz, M. J. and J. V. Tarazona. 1993. Synergistic effect of two- and four-component combinations of the polycyclic aromatic hydrocarbons: Phenanthrene, anthracene, naphthalene and acenapthene on *Daphnia magna*. Bull. Enviorn. Contam. Toxicol. 50:363–368.
- Münzinger, A. 1990. Effects of nickel on *Daphnia magna* during chronic exposure and alterations in the toxicity to generations pre-exposed to nickel. *Wat. Res.* 24:845-852.
- Nebeker, A. V., C. K. McAuliffe, R. Mshar, and D. G. Stevens. 1983. Toxicity of silver to steelhead and rainbow trout, fathead minnows, and *Daphnia magna*. *Environ. Toxicol. Chem.* 2:95–104.
- Nebeker, A. V., C. Savonen, R. J. Baker, J. K. McCrady. 1984. Effects of copper, nickel, and zinc on the life cycle of the caddisfly *Clistoronia magnifica* (Limnephilidae). *Environ. Toxicol. Chem.* 3:645–649.
- Nebeker, A. V., C. Savonen, and D. G. Stevens. 1985. Sensitivity of rainbow trout early life stages to nickel chloride. *Environ. Toxicol. Chem.* 4:233-239.
- Nebeker, A. V., and F. A. Puglisi. 1974. Effect of polychlorinated biphenyls (PCBs) on survival and reproduction of *Daphnia*, *Gammarus*, and *Tanytarsus*. *Trans. Am. Fish. Soc.* 103:722-728.
- Nebeker, A. V., F. A. Puglisi, and D. L. DeFoe. 1974. Effect of polychlorinated biphenyl compounds on survival and reproduction of the fathead minnow and flagfish. *Trans. Am. Fish. Soc.* 103:562-568.
- Oris, J. T., J. P. Giesy Jr. 1985. The photoenhanced toxicity of anthracene to juvenile sunfish (Lepomis sp.). Aquat. Toxicol. 6:133-146.
- Oseid, D. M., L. L. Smith Jr. 1979. The effects of hydrogen cyanide on *Asellus communis* and *Gammarus pseudolimnaeus* and changes in their competitive response when exposed simultaneously. *Bull. Environ. Contam. Toxicol.* 21:439–447.
- OSWER (Office of Solid Waste and Emergency Response). 1996. Ecotox thresholds. *ECO Update* 3 (2):1–12.
- Palawski, D., J. B. Hunn, and F. J. Dwyer. 1985. Sensitivity of young striped bass to organic and inorganic contaminants in fresh and saline waters. *Trans. Am. Fish. Soc.* 114:748-753.
- Parkhurst, B. R., R. G. Elder, J. S. Meyer, D. A. Sanchez, R. W. Pennak, and W. T. Waller. 1984. An environmental hazard evaluation of uranium in a Rocky Mountain stream. *Environ. Toxicol. Chem.* 3:113–124.
- Passino, D. R. M. and A. J. Novak. 1984. Toxicity of Arsenate and DDT to the Cladoceran Bosmina logirostris. Bull. Environ. contam. Toxicol. 33:325–329.
- Passino, D. R. M. and J. M. Kramer. 1980. Toxicity of arsenic and PCBs to fry of deepwater ciscoes (Coregonus). Bull. Environ. Contam. Toxicol. 24:527–534.
- Passino, D. R. M and S. B. Smith. 1987. Acute bioassays and hazard evaluation of representative contaminants detected in Great Lakes fish. *Enviorn. Toxicol. Chem.* 6:901–907.

- Phipps, G. L., G. W. Holcombe, and J. T. Fiandt. 1981. Acute toxicity of phenol and substituted phenols to the fathead minnow. *Bull. Environ. Contam. Toxicol.* 26:585-593.
- Pickering, Q. H. 1974. Chronic toxicity of nickel to the fathead minnow and flagfish. *Trans. Am. Fish.* Soc. 103:562–568.
- Pickering, Q. H. 1980. Chronic toxicity of hexavalent chromium to the fathead minnow (*Pimephales promelas*). Arch. Environ. Contam. Toxicol. 9:405–413.
- Pickering, Q. H. and C. Henderson. 1966. Acute toxicity of some important petrochemicals to fish. J. Water Pollut. Control Fed. 38:1419–1429.
- Pickering, Q. H. and M. H. Gast. 1972. Acute and chronic toxicity of cadmium to the fathead minnow (*Pimephales promelas*). J. Fish. Res. Board Can. 29:1099-1106.
- Pickering, Q. H. and W. T. Gilliam. 1982. Toxicity of aldicarb and fonofos to the early life-stage of the fathead minnow. *Arch. Environ. Contam. Toxicol.* 11:699–702.
- Pickering, Q. H., and T. O. Thatcher. 1970. The chronic toxicity of linear allcylate sulfonate (LAS) to *Pimephales promelas*, Rafinesque. J. Water Pollut. Control Fed. 42:243–254.
- Prothro, M. G. 1993. Office of Water Policy and Technical Guidance on Interpretation and Implementation of Aquatic Life Metals Criteria. Memorandum to Water Management Division Directors and Environmental Services Division Directors, Regions I-X, October 1, 1993.
- Rai, L. C., J. P. Gaur, H. D. Kumar. 1981. Protective effects of certain environmental factors on the toxicity of zinc, mercury, and methylmercury to *Chlorella vulgaris*. *Environ. Res.* 25:250–259.
- Randall, T. L. and P. V. Knopp. 1980. Detoxification of specific organic substances by wet oxidation. J. Water Pollut. Control Fed. 52:2117–2130.
- Region IV. 1995. Ecological screening values. Ecological Risk Assessment Bulletin No. 2. Waste Management Division, U.S. Environmental Protection Agency Region IV, Atlanta, GA.
- Reynolds, J. H., E. J. Middlebrooks, D. B. Porcella, W. J. Grenney. 1975. Effects of temperature on oil refinery waste toxicity. J. Water Poll. Control Fed. 47:2674–2693.
- Rhodes, J. E, W. J. Adams, G. R. Biddinger. 1995. Chronic toxicity of 14 phthalate esters to Daphnia magna and rainbow trout (Oncorhynchus mykiss). Environ. Toxicol. Chem. 14:1967–1976.
- Richter, J. E., S. F. Peterson, and C. F. Kleiner. 1983. Acute and chronic toxicity of some chlorinated benzenes, chlorinated ethanes, and tetrachloroethylene to *Daphnia magna*. Arch. Environ. Contam. Toxicol. 12:679–684.
- Roghair, C. J., A. Buijze, E. S. E. Yedema, and J. L. M. hermens. 1994. A QSAR for base-line toxicity to the midge *Chironomus riparius*. *Chemosphere* 28:989–997.
- Sanders, H. O., 1970. Pesticide toxicities to tadpoles of the western chorus frog *Peseudacris triseriata* and flowler's toad *Bufo woodhousii fowleri*. *Copeia* 2:246–251.

- Sanders, H. O. 1969. Toxicity of pesticides to the crustacean Gammarus lacustris. Tech. Paper No. 25, Bur. Sports Fish. Wildl., Fish Wildl. Serv., U.S.D.I.
- Sanders, H. O. 1972. Toxicity of some insecticides to four species of malacostracan crustaceans. Tech. Paper No. 66, Bur. Sports Fish. Wildl., Fish Wildl. Serv., U.S.D.I.
- Sanders, H. O., F. L. Mayer, Jr., and D. F. Walsh. 1973. Toxicity, residue dynamics, and reproductive effects of phthalate esters in aquatic invertebrates. *Environ. Res.* 6:84–90.
- Sanders, H. O. and O. B. Cope. 1968. The relative toxicities of several pesticides to naiads of three species of stoneflies. *Limnol. Oceanogr.* 13:112–117.
- Sadler, K. and S. Lynam. 1988. The influence of calcium on aluminum-induced changes in the growth rate and mortality of brown trout, *Salmo trutta L. J. Fish Biol.* 33:171–179.
- Sauter, S., K. S. Buxton, K. J. Macek, and S. R. Petrocelli. 1976. Effects exposure to heavy metals on selected freshwater fish. EPA-600/3-76-105. U.S. Environmental Protection Agency, Duluth, Minn.
- Seim, W. K., L. R. Curtis, S. W. Blenn, and G. A. Chapman. 1984. Growth and survival of developing steelhead trout (Salmo gairdneri) continuously or intermittently exposed to copper. Can. J. Fish. Aquat. Sci. 41:433–438.
- Shubat, P. J., S. H. Poirier, M. L. knuth, and L. T. Brooke. 1982. Acute toxicity of tetrachloroethylene and tetrachloroethylene with dimethylformamide to rainbow trout (*Salmo gairdneri*). Bull. Environ. Contam. Toxicol. 28:7–10.
- Sinley, J. R., J. P. Goettl, Jr., and P. H. Davies. 1974. The effects of zinc on rainbow trout (Salmo gairdneri) in hard and soft water. Bull. Environ. Contam. Toxicol. 12:193-201.
- Sloff, W. 1983. Benthic macroinvertebrates and water quality assessment: Some toxicological considerations. *Aquat. Toxicol.* 4:73-82.
- Slonim, A. R. and E. E. Ray. 1975. Acute toxicity of beryllium sulfate to salamander larvae (*Ambystoma* sp.). Bull. Enviorn. Contam. Toxicol. 13:307-312.
- Slonim, C. B. and A. R. Slonim. 1973. Effect of water hardness on the tolerance of the guppy to beryllium sulfate. *Bull. Environ. Contam. Toxicol.* 10:295–301.
- Smith, A. D., A. Bharath, C. Mallard, D. Orr, K. Smith, J. A. Sutton, J. Vukmanich, L. S. McCarthy, and G. W. Ozburn. 1991. The acute and chronic toxicity of ten chlorinated organic compounds to the American flagfish (*Jordanella floridae*). Arch. Environ. Contam. Toxicol. 20:94–102.
- Smith, L. L., S. J. Broderius, D. M. Oseid, G. L. Kimball, W. M. Koenst, and D. T. Lind. 1979. Acute and chronic toxicity of HCN to fish and invertebrates. EPA-600/3-79-009. U.S. Environmental Protection Agency.
- Smith, L. R., T. M. Holsen, N. C. Ibay, R. M. Block, and A. B. de Leon. 1985. Studies on the acute toxicity of fluoride ion to stickleback, fathead minnow, and rainbow trout. *Chemosphere* 14(9):1383–1389.

- Smith, S. B., J. F. Savino, and M. A. Blouin. 1988. Acute toxicity to *Daphnia pulex* of six classes of chemical compounds potentially hazardous to Great Lakes aquatic biota. J. Great Lakes Res. 14:394–404.
- Snarski, V. M., and G. F. Olson, 1982. Chronic toxicity and bioaccumulation of mercuric chloride in the fathead minnow (*Pimephales promelas*). Aquat. Toxicol. 2:143–156.
- Spehar, R. L. 1976. Cadmium and zinc toxicity to flagfish, Jordanella floridae. J. Fish. Res. Board Can. 33:1939–1945.
- Spehar, R. L., J. T. Fiandt, R. L. Anderson, and D. L. DeFoe. 1980. Comparative toxicity of arsenic compounds and their accumulation in invertebrates and fish. Arch. Environ. Contam. Toxicol. 9:53-63.
- Spehar, R. L., D. K. Tanner, and B. R. Nordling. 1983. Toxicity of the synthetic pyrethroids, permethrin, and AC 222,705 and their accumulation in early life stages of fathead minnows and snails. *Aquat. Toxicol.* 3:171–182.
- Stalling, D. L. and F. L. Mayer, Jr. 1972. Toxicities of PCBs to fish and environmental residues. *Environ. Health Perspect.* 1:159–164.
- Steeman-Nielsen, E. and S. Wium-Andersen. 1970. Copper ions as poison in the sea and freshwater. *Marine Biology*. 6:93–97.
- Stephan, C. E. 1991. Letter to Mr. Jim Grant. Michigan Department of Natural Resources.
- Stephan, C. E., D. I. Mount, D. J. Hansen, J. H. Gentile, G. A. Chapman, and W. A. Brungs. 1985. Guidelines for deriving numerical national water quality criteria for the protection of aquatic organisms and their uses. PB85-227049. National Technical Information Service, Springfield, Va.
- Stephan, C. E., and J. R. Rogers. 1985. Advantages of using regression analysis to calculate results of chronic toxicity tests, pp. 328-339 in Aquatic Toxicology and Hazard Assessment: Eighth Symposium, R. C. Bahner and D. J. Hansen (eds.), American Society for Testing and Materials, Philadelphia.
- Stephan, E. E. and R. J. Erickson. n.d. Guidelines for deriving an aquatic life pesticide concentration. U.S. Environmental Protection Agency, Environmental Research Laboratory, Duluth, MN, unpublished document.
- Stevens, D. G. and G. A. Chapman. 1984. Toxicity of trivalent chromium to early life stages of steelhead trout. *Environ. Toxicol. Chem.* 3:125-133.
- Streufert, J. M., J. R. Jones, and H. O. Sanders. 1980. Toxicity and biological effects of phthalate esters on midges (*Chironomus plumosus*). *Trans. Mo. Acad. Sci.* 14:33-40.
- Suter, G. W. II. 1989. Ecological endpoints, pp. 2-1–2-28, in *Ecological Assessment of Hazardous Waste Sites: A Field and Laboratory Reference Document*. EPA 600/3-89/013. W. Warren-Hicks, B. R. Parkhurst, and S. S. Baker, Jr. (eds.). Corvallis Environmental Research Laboratory, Oregon.

- Suter, G. W., II, M. A. Futrell, G. A. Kerchner. 1992. Toxicological benchmarks for screening of potential contaminants of concern for effects on aquatic biota on the Oak Ridge Reservation, Oak Ridge, Tennessee. ORNL/ER-139. Oak Ridge National Laboratory.
- Suter, G. W., II, A. E. Rosen, E. Linder, and D. F. Parkhurst. 1987. End points for responses of fish to chronic toxic exposures. *Environ. Toxicol. Chem.* 6:793-809.
- Suter, G. W., II. 1992. Ecological Risk Assessment. Lewis Publishers, Chelsea, MI.
- Suter, G. W., II, A. Redfearn, R. K. White, and R. A. Shaw. 1992. Approach and strategy for performing ecological risk assessments for the Department of Energy Oak Ridge Field Office Environmental Restoration Program. ES/ER/TM-33. Environmental Restoration Division, Oak Ridge National Laboratory, Oak Ridge, TN.
- Thompson, R. S., and N. G. Carmichael. 1989. 1,1,1-Trichloroethane: medium-term toxicity to carp, daphnids, and higher plants. *Ecotox. Environ. Safety* 17:172–182.
- Thurston, R.V., R. C. Russo, E. L. Meyn, and R. K. Zajdel. 1986. Chronic toxicity of ammonia to fathead minnows. *Trans. Amer. Fish. Soc.* 115:196–207.
- Trucco, R. G., F. R. Engelhardt, and B. Stacey. 1983. Toxicity, accumulation and clearance of aromatic hydrocarbons in *Daphnia pulex. Environ. Pollut. Ser. A. Ecol. Biol.* 31:191–202.
- van den Dikkenberg, R. P., H. H. Canton, L. A. M. Mathijssen-Spiekman, and C. J. Roghair. 1989. *The usefulness of gasterosteus aculeatus-the three-spined stickleback-as a test organism in routine toxicity testing.* Rep. No. 718625003, Natl. Inst. Public Health Environ. Protection, Bilthoven, the Netherlands.
- Van der Schalie, W. H. 1983. The acute and chronic toxicity of 3,5-dinitroaniline, 1,3-dinitrobenzene, and 1,3,5-trinitrobenzene to freshwater aquatic organisms. Technical Report 8305. U.S. Army Medical Bioengineering Research and Development Laboratory, Fort Detrick, Frederick, MD.
- Van Leeuwen, C. J. and H. Maas. 1985. The aquatic toxicity of 2,6-dichlorobenzamide (BAM), a degradation product of the herbicide dichlobenil. *Environ. Pollut. Ser. A.* 37:105–115.
- Van Leeuwen, C. J., J. L. Maas-Diepeveen, G. Niebeek, W. H A. Vergouw, P. S. Griffioen, and M. W. Luijken. 1985. Aquatic toxicological aspects of dithiocarbamates and related compounds. I. Short-term toxicity tests. Aquat. Toxicol. 7:145–164.
- Vareille-Morel, C. and J. Debord. 1990. Sensibilité du Mollusque prosobranche *Potamopyrgus jenkinsi* Smith à l'action de chlorures métalliques (ZnCl<sub>2</sub>, BaCl<sub>2</sub>, CuCl<sub>2</sub>)et d'un molluscicide de synthèse, la N-tributyl-morpholine. *Ann Rech. Vét.* 21:111-118.
- Veith, G. D., D. J. Call, L. T. Brooke. 1983. Estimating the acute toxicity of narcotic industrial chemicals to fathead minnows, pp. 90-97, in *Aquatic Toxicol. and Hazard Assessment: Sixth Symposium.* W. E. Bishop, R. D. Cardwell, and B. B. Heidolph (eds.), ASTM STP 802, Philadelphia.
- Veith, G. D., D. J. Call, and L. T. Brooke. 1983. Structure-toxicity relationships for the fathead minnow, *Pimephales promelas*: narcotic industrial chemicals. *Can. J. Fish. Aquat. Sci.* 40:743-748.

- Villar, D., M. H. Li, and D. J. Schaeffer. 1993. Toxicity of organophosphorus pesticides to *Dugesia* dorotocephala. Bull. Environ. Contam. Toxicol. 51:80-87.
- Vincent, M., J. Debord, and B. Penicaut. 1986. Comparative studies on the toxicity of metal chlorides and of a synthetic organic molluscicide, N-trityl-Morpholine, upon two aquatic amphipods: Gammarus pulex and Echinogammarus berilloni. Ann. Rech. Vét. 17:441-446.
- Vocke, R. W., K. L. Sears, J. J. O'Toole, R. B. Wildham. 1980. Growth responses of selected freshwater algae to trace elements and scrubber ash slurry generated by coal-fired power plants. *Water Res.* 14:141–150.
- Walbridge, C. T., J. T. Fiandt, G. L. Phipps, and G. W. Holcombe. 1983. Acute toxicity of ten chlorinated aliphatic hydrocarbons to the fathead minnow (*Pimephales promelas*). Arch. Environ. Contam. Toxicol. 12:661–666.
- Wallen, I. E., W. C. Greer, and R. Lasater. 1957. Toxicity to *Gambusia affinis* of certain pure chemicals in trubid waters. *Sewage Ind. Wastes* 29:695-711.
- Ward, T. J., and R. L. Boeri. 1991a. Early Life Stage Toxicity of Di-n-Butyl Phthalate (DnBP) to the rainbow Trout (<u>Oncorhynchus mykiss</u>) Under Flow-Through Conditions. 9102-CMA. Chemical Manufacturers Association, Washington, D.C.
- Waste Management Division. 1995. Ecological screening values, Ecological Risk Assessment Bulletin No. 2. U.S. Environmental Protection Agency Region IV. Atlanta, Georgia.
- Williams, P.L. and D.B.Dusenbery. 1990. Aquatic toxicity testing using the nematode, Caenorhabditis elegans. Environ. Toxicol. Chem. 9:1285–1290
- Woodward, D. F., A. M. Farag, M. E. Mueller, E. E. Little, F. A. Vertucci. 1989. Sensitivity of endemic Snake River cutthroat trout to acidity and elevated aluminum. Trans. Amer. Fish. Soc. 118:630–643.
- Ziegenfuss, P. S., W. J. Renaudette, and W. J. Adams. 1986. Methodology for assessing the acute toxicity of chemicals sorbed to sediments: Testing the equilibrium partitioning theory. in T. M. Poston and R. Purdy (eds.), *Aquatic Toxicology and Environmental Fate, Ninth Volume.* ASTM, Philadelphia, PA.
Appendix A

DATA USED FOR TIER II CALCULATIONS



Compound	Genus/species	Requirement*	Endpoint	Concentration	GMAV <sup>b</sup>	A-C Ratio <sup>c</sup>	Reference
Arsenic V			INORGANICS				
	Bosmina longirostris	4	EC50	850	850		Passino and Novak, 1984
	Daphnia pulex	4	LC50	3,600	3,600		Jurewicz and Buikema, 1980
	Gambusia affinis	2,3	LC50	49,000	49,000		Jurewicz and Buikema, 1980
	Morone saxatilis	2,3	LC50	40,500			Palawski et al., 1985
	Morone saxatilis	2,3	LC50	30,500	35,150		Palawski et al., 1985
	Oncorhynchus kisutch	1	LC50	43,600			Buhl and Hamilton, 1990
	Oncorhynchus kisutch	1	LC50	58,500			Buhl and Hamilton, 1990
	Oncorhynchus mykiss	1	LC50	28,000			Palawski et al., 1985
	Oncorhynchus mykiss	1	LC50	67,500	46,860		Buhl and Hamilton, 1990
	Pimephales promelas	2,3	LC50	42,000			Palawski et al., 1985
	Pimephales promelas	2,3	LC50	25,600	32,790		DeFoe, 1982
	Pimephales promelas		cv	892		28.7	DeFoe, 1982
	Thymallus arcticus	1	LC50	5,020			Buhl and Hamilton, 1990
	Thymallus arcticus	1	LC50	5,500	5,255		Buhl and Hamilton, 1990
	Tubifex tubifex	7,8	LC50	127,360	127,360		Fargasova, 1994

Table A.1. Data and calculated results for derivation of Tier II values (all values in µg/l). Requirements are listed in App. B.2; other terms are defined in the text

Tier II Values Tier II Parameters 12.9 FAVF SAV 65.89 SACR 20.95 SCV 3.1

.

. .

The eight acute data requirements.
Genus Mean Acute Value.
Acute-Chronic Ratio.

1

Compound	Genus/species	Requirement	Endpoint	Concentration	GMAV A-C Ratio	Reference
Barium	Daphnia magna	4	LC50	410,000	410,000.	LeBlanc, 1980
	Daphnia magna		EC16	5,800	70.69*	Biesinger and Christensen, 1972
	Echinogammarus berilloni	5	LC50	122,000	122,000	Vincent et al., 1986
	Gammarus pulex	5	LC50	238,000	238,000	Vincent et al., 1986
	Potamopyrgus jenkinsi	7,8	LC50	1,700		Vareille-Morel, 1990
	Potamopyrgus jenkinsi	7,8	LC50	930		Vareille-Morel, 1990
	Potamopyrgus jenkinsi	7,8	LC50	1,800		Vareille-Morel, 1990
	Potamopyrgus jenkinst	7,8	LC50	1,400		Vareille-Morel, 1990
	Potamopyrgus jenkinsi	7,8	LC50	· 1,100		Vareille-Morel, 1990
	Potamopyrgus jenkinsi	7,8	LC50	440		Varcille-Morel, 1990
	Potamopyrgus jenkinst	7,8	LC50	330		Vareille-Morel, 1990
	Potamopyrgus jenkinsi	7,8	LC50	1,300	976.6	Vareille-Morel, 1990
					Tier II Parameters	Tier II Values
					FAVF	8.6
					SAV	113.6
					SACR	28.29
					SCV	4.0

Table A.1. (continued)

\* In the absence of any experimental value, EC16 is used to calculate an A-C ratio.

.

•

٠

Compound	Genus/species	Requirement	Endpoint	Concentration	GMAV	A-C Ratio	Reference
Beryllium	Asellus intermedius	5	LC50	10,000	10,000		Ewell et al., 1986
	Dugesia tigrina	7,8	LC50	10,000	10,000		Ewell et al., 1986
	Gammarus fasciatus	5	LC50	700	700		Ewell et al., 1986
•	Helisoma trivolvis	7,8	LC50	10,000	10,000		Ewell et al., 1986
	Lumbriculus variegatus	7,8	LC50	10,000	10,000	~	Ewell et al., 1986
	Pimephales promelas	2,3	LC50	10,000	10,000		Ewell et al., 1986
	Ambystoma maculatum	2,3	LC50	3,150			Slonim and Ray, 1975
	Ambystoma maculatum	2,3	LC50	18,200			Slonim and Ray, 1975
	Ambystoma maculatum	2,3	LC50	8,020			Slonim and Ray, 1975
	Ambystoma maculatum	2,3	LC50	8,320			Slonim and Ray, 1975
	Ambystoma opacum	2,3	LC50	3,150	4,977		Slonim and Ray, 1975
	Caenorhabditis elegans	7,8	LC50	140	140		Williams and Dunsenbery, 1990
	Carassius auratus	2,3	LC50	55,900	55,900		Cardwell et al., 1976
	Daphnia magna	4	EC50	2,410			Kimball n.d.
	Daphnia magna	4	EC50	2,450	2,430		Kimball n.d.
	Daphnia magna		CV	5,267		461.4	Kimball n.d.
	Jordanella floridae	2,3	LC50	46,300			Cardwell et al., 1976
	Jordanella floridae	2,3	LC50	41,100			Cardwell et al., 1976
	Jordanella floridae	2,3	LC50	41,100	42,760		Cardwell et al., 1976
	Pimephales promelas	2,3	LC50	37,900			Cardwell et al., 1976
	Pimephales promelas	2,3	LC50	17,900			Kimball n.d.
	Pimephales promelas	2,3	LC50	17,500	22,810		Kimball n.d.
	Poecilia reticulata	2,3	LC50	1,330			Slonim and Slonim, 1973
	Poecilia reticulata	2,3	LC50	160			Slonim and Slonim, 1973
	Poecilia reticulata	2,3	LC50	190			Slonim and Slonim, 1973

Table A.1. (continued)

Compound	Genus/species	Requirement	Endpoint	Concentration	GMAV A-C Ratio	Reference
	Poecilia reticulata	2,3	LC50	1,330	343.2	Slonim and Slonim, 1973
	Tubifex tubifex	7,8	EC50	10,250	10,250	Khangarot, 1991
					Tier II Parameters	Tier II Values
					FAVF	4.0
					SAV	35
					SACR	52.88
					SCV	0.66

.

### Table A.1. (continued)

٠

Compound	Genus/species	Requirement	Endpoint	Concentration	GMAV A-C Ratio	Reference
Boron	Daphnia magna	4	LC50	133,000		Gersich, 1984
	Daphnia magna		CV	9,330		Gersich, 1984
	Daphnia magna	4	LC50	226,000	173,400	Lewis and Valentine, 1981
	Daphnia magna		CV	8,832	19.10*	Lewis and Valentine, 1981
	Ptychocheilus lucius	2,3	LC50	279		Hamilton, 1995
	Ptychocheilus lucius	2,3	LC50	>100		Hamilton, 1995
	Ptychocheilus lucius	2,3	LC50	527	383.4	Hamilton, 1995
	Xyrauchen texanus	2,3	LC50	>100		Hamilton, 1995
	Xyrauchen texanus	2,3	LC50	233		Hamilton, 1995
	Xyrauchen texanus	2,3	LC50	279	255.0	Hamilton, 1995
	Gila elegans	2,3	LC50	>100		Hamilton, 1995
	Gila elegans	2,3	LC50	280		Hamilton, 1995
	Gila elegans	2,3	LC50	552	393.1	Hamilton, 1995
					Tier II Parameters	Tier II Values
					FAVF	8.6
					SAV	29.65
					SACR	18.29
					SCV	1.6

Table A.1. (continued)

• The A-C Ratio for D. magna is the geometric mean of A-C Ratios from Gersich, 1987 and Lewis and Valentine, 1981.

1

Compound	Genus/species	Requirement	Endpoint	Concentration	GMAV	A-C Ratio	Reference
Cobait <sup>*</sup>	Asellus intermedius	5	LC50	>100,000			Eweil et al., 1986
	Carassius auratus	2,3	LC50	66,800	66,800		Ding, 1980
	Cyprinus carpio	2,3	LC50	82,700	82,700		Ding, 1980
	Daphnia magna	4	EC50	6,830			Kimball, 1978
	Daphnia magna	4	EC50	5,150	5,931		Kimbali, 1978
	Daphnia magna		cv	5.103		1,162	Kimball, 1978
	Dugesia tigrina	7,8	LC50	25,000	25,000 .		Ewell et al., 1986
	Gammarus fasciatus	5	LC50	. >100,000			Ewell et al., 1986
	Helisoma trivolvis	7,8	LC50	>100,000			Ewell et al., 1986
	Lumbriculus variegatus	7,8	LC50	>100,000			Ewell et al., 1986
	Philodina acuticornis	7,8	EC50	59,000	59,000		Buikema et al., 1974
	Pimephales promelas	2,3	LC50	22,000			Ewell et al., 1986
	Pimephales promelas	2,3	LC50	3,750			Kimball, 1978
	Pimephales promelas	2,3	LC50	3,460	6,584		Kimball, 1978
	Pimephales promelas		cv	286.2		12.59	Kimball, 1978
	Rana hexadactyla	3	LC50	17,590	17,590		Khangarot et al., 1985
	Tubifex tubifex	7,8	EC50	139,320	139,320		Khangarot, 1991
•							
					Tier II P	arameters	Tier II Values
						FAVF	4.0
						SAV	1,483
						SACR	63.98

scv

23

Table A.1. (continued)

• All data are for cobalt II.

.

Compound	Genus/species	Requirement	Endpoint	Concentration	GMAV A-C Ratio	Reference
Lithium	Ptychocheilus lucius	2,3	LC50	28,000		Hamilton, 1995
	Ptychocheilus lucius	2,3	LC50	41,000	33,880	Hamilton, 1995
	Xyrauchen texanus	2,3	LC50	53,000		Hamilton, 1995
	Xyrauchen texanus	2,3	LC50	186,000	99,290	Hamilton, 1995
	Gila elegans	2,3	LC50	62,000		Hamilton, 1995
	Gila elegans	2,3	LC50	65,000	63,480	Hamilton, 1995
	Tubifex tufifex	7,8	EC50	9,340	9,340	Khangarto, 1991

Tier II Parameters	Tier II Values	
FAVF	36.2	
SAV	258.0	
SACR	17.9	
SCV	14	

Compound	Genus/species	Requirement	Endpoint	Concentration	GMAV A-C Ratio	Reference
Manganese*	Asellus aquaticus	5	EC50	333,000	333,000	Martin and Holdich, 1986
	Crangonyx pseudogracilis	5	EC50	694,000	694,000	Martin and Holdich, 1986
	Daphnia magna	. 4	EC50	19,500		Kimball'n.d.
	Daphnia magna	4	EC50	19,200	19,350	Kimball n.d.
	Pimephales promelas	2,3	LC50	30,600		Kimball n.d.
	Pimephales promelas	2,3	LC50	36,900	33,600	Kimball n.d.
	Pimephales promelas		cv	1,775	18.93	Kimball n.d.
					Tier II Parameters	Tier II Values
					FAVF	8.6
					SAV	2,250
					SACR	. 18.24
					scv	120

Table A.1. (continued)

.

\* All data are for manganese II.

A-10

.

Compound	Genus/species	Requirement	Endpoint	Concentration	GMAV A-C Ratio	Reference
Mercury, methyl	Oncorhynchus mykiss	. 1	LC50	24	24	Lock and van Overbeeke, 1981
	Salvelinus fontinalis	1	LC50	65		McKim et al., 1976
	Salvelinus fontinalis	1	LC50	84	74	McKim et al., 1976
	Salvelinus fontinalis		CV	0.5193	142.3	McKim et al., 1976
					Tier II Parameters	Tier II Values
					FAVF	242
					SAV	0.09917
					SACR	35.72
					SCV	0.0028

1

Compound	Genus/species	Requirement	Endpoint	Concentration	GMAV	A-C Ratio	Reference	
Molybdenum	Daphnia magna	4	LC50	203,200			Kimball n.d.	
	Daphnia magna	4	LC50	210,300	206,700		Kimball n.d.	
	Daphnia magna		CV	877.8		235.5	Kimball n.d.	
	Pimephales promelas	2,3	LC50	628,000	628,000		Kimball n.d.	
					Tier II F	arameters	Tier II Values	
					<del></del>	FAVF	13.2	
						SAV	15,660	
						SACR	42.26	
						SCV	370	

Table A.1. (continued)

\* All tests are for molybdenum VI.

•

Compound	Genus/species	Requirement	Endpoint	Concentration	GMAV	A-C Ratio	Reference
Strontium	Daphnia magna	4	LC50	125,000	125,000		Biesinger and Christensen, 1972
	Daphnia magna		EC16	42,000		2.98	Biesinger and Christensen, 1972
	Tubifex tubifex	7,8	EC50	240,800	240,800		Khangarot, 1991
	Caenorhabditis elegans	7,8	LC50	465,000	465,000		Williams and Dusenbery, 1990
					Tier II	Parameters	Tier II Values
						FAVF	8.6
						SAV	14,530
						SACR	9.85
						scv	1,500

•

\*In the absence of any experimental chronic values, EC16 is used to calculate an A-C Ratio.

Compound	Genus/species	Requirement	Endpoint	Concentration	GMAV	A-C Ratio	Reference
Thallium*	Daphnia magna	4	EC50	880			Kimball, n.d.
	Daphnia magna	4	·EC50	930	905.0		Kimball, n.d.
	Daphnia magna		cv	134.5		6.724	Kimball, n.d.
	Cyprinodon variegatus		LC50	20,900 <sup>6</sup>			EPA, 1978
	Cyprinodon variegatus		CV	6,010		3.478	EPA, 1978
	Lepomis macrochirus	2,3	LC50	120,000			Buccafusco et al., 1981
	Lepomis macrochirus	2,3	LC50	132,000	125,900		Dawson et al., 1977
	Pimephales promelas	2,3	LC50	1,810			Kimball, n.d.
	Pimephales promelas	2,3	LC50	1,780	1,795		Kimball, n.d.
	Pimephales promelas		CV	56.92		31.53	Kimball, n.d.

Table A.1. (continued)

.

Tier II Parameters Tier II Values FAVF 8.6 SAV 105.2 SACR 9.034 SCV 12

<sup>4</sup> All data are for thallium I. <sup>b</sup> Acute value of *C. variegatus*, a saltwater species, is used for SACR calculation only.

Compound	Genus/species	Requirement	Endpoint	Concentration	GMAV A-C Ratio	Reference
Tin <sup>*</sup>	Daphnia magna	4	LC50	55,000	55,000	Biesinger and Christensen, 1972
	Daphnia magna		EC16 <sup>b</sup>	350	157.1	Biesinger and Christensen, 1972
					Tier II Parameters FAVF	Tier II Values 20.5
					SAV	2,683
					SACR	36.93
					304	15

.

#### Table A.1. (continued)

1

\* All data are for tin II. \* In the absence of any experimental chronic values, EC16 is used to calculate an A-C Ratio.

•

. .

.

Compound	Genus/species	Requirement	Endpoint	Concentration	GMAV	A-C Ratio	Reference	
Uranium	Salvelinus fontinalis	1	LC50	5,500			Parkhurst et al., 1984	
	Salvelinus fontinalis	1	LC50	23,000	11,250		Parkhurst et al., 1984	
					Tier II I	Parameters	Tier II Values	
						FAVF	242	
						SAV	46.48	
						SACR	17.9	
						SCV	2.6	

Compound	Genus/species	Requirement	Endpoint	Concentration	GMAV	A-C Ratio	Reference
Vanadium <sup>*</sup>	Daphnia magna	4	EC50	1,580			Kimball, n.d.
	Daphnia magna	4	EC50	1,460			Kimball, n.d.
	Daphnia magna	4	EC50	3,800			Bensen &Neven, 1987
	Daphnia magna	4	EC50	2,900			Bensen &Neven, 1987
	Daphnia magna	4	EC50	3,900			Bensen &Neven, 1987
	• Daphnia magna	4	EC50	3,600			Bensen &Neven, 1987
	Daphnia magna	4	EC50	3,300	2,746		Bensen &Neven, 1987
	Daphnia magna		CV	1900		2 <sup>b</sup>	Bensen &Neven, 1987
	Gala elegans	2,3	LC50	8,800			Hamilton, 1995
	Gala elegans	2,3	LC50	4,000			Hamilton, 1995
	Gala elegans	2,3	LC50	3,000	4,727		Hamilton, 1995
	Jordanella floridae	2,3	LC50	11,200	11,200		Holdway and Sprague, 1979
	Jordanella floridae		CV	83.49		134.1	Holdway and Sprague, 1979
	Oncorhynchus tshawytscha	1	LC50	16,500	16,500		Hamilton and Buhl, 1990
	Pimephales prometas	2,3	LC50	1,800			Kimball, n.d.
	Pimephales promelas	2,3	LC50	1,900	1,850		Kimball, n.d.
	Pimephales promelas		CV	169.7		10.90	Kimball, n.d.
	Ptychocheilus lucius	2,3	LC50	7,800			Hamilton, 1995
	Ptychocheilus lucius	2,3	LC50	3,800			Hamilton, 1995
	Ptychocheilus lucius	2,3	LC50	4,300	5,032		Hamilton, 1995
	Salvelinus fontinalis	1	LC50	7,000			Ernst and Garside, 1987
	Salvelinus fontinalis	1	LC50	15,000	10,250		Ernst and Garside, 1987
	Xyrauchen texanus	2,3	LC50	5,300			Hamilton, 1995

Table A.1. (continued)

•

Compound	Genus/species	Requirement	Endpoint	Concentration	GMAV A-C Ratio	Reference	
	Xyrauchen texanus	2,3	LC50	2,200		Hamilton, 1995	
	Xyrauchen texanus	2,3	LC50	4,600	3,770	Hamilton, 1995	
					Tier II Parameters	Ticr II Values	
					FAVF	6.5	-
					SAV	284.6	
					SACR	14.29	
					SCV	20	

\* All data are for vanadium V.

.

<sup>b</sup> Since the experimental A-C Ratio is less than 2, the A-C Ratio of D. magna is et to 2 (Stephan et al., 1985).

A-18

Compound	Genus/species	Requirement	Fudpoint	Concentration	GMAV A-C Ratio	Reference
	Genusiapeeres	Requirement	Chopolint	Concentration		Reference
Zirconium	Oncorhynchus mykiss	1	LC50	20,000	20,000	Couture et al., 1989
	Tubifex tubifex .	7,8	EC50	221,180	221,180	Khangarot, 1991
					Tier II Parameters	Tier II Values
					FAVF	64.8
					SAV	308.6
					SACR	17.9
					SCV	17

Compound	Genus/species	Requirement	Endpoint	Concentration	GMAV	A-C Ratio	Reference
Acetone			ORGANICS				
	Asellus intermedius	5	LC50	>100,000	>100,000		Ewell et al., 1986
	Ceriodaphnia dubia	4	LC50	8,098,000	8,098,000		Cowgill and Milazzo, 1991
	Chironomus tentans	6	LC50	46,900,000	46,900,000		Ziegenfuss et al., 1986
	Corbicula manilensis	7,8	LC50	20,000,000	20,000,000	•	Chandler and Marking, 1979
	Daphnia magna	4	EC50	13,500,000	13,500,000		Randall and Knopp, 1980
	Daphnia magna	4	LC50	30,640			LeBlanc and Surprenant, 1983
	Daphnia magna		CV	1,556		19.69	LeBlanc and Surprenant, 1983
	Dugesia Ilgrina	7,8	LC50	>100,000	>100,000		Ewell et al., 1986
	Gammarus fasciatus	5	LC50	>100,000	>100,000		Ewell et al., 1986
	Helisoma trivolvis	7,8	LC50	>100,000	>100,000		Ewell et al., 1986
	Lepomis macrochirus	2,3	LC50	8,300,000	8,300,000		Cairns and Scheier, 1968
	Lumbriculus variegatus	7,8	LC50	>100,000	>100,000		Ewell et al., 1986
	Oncorhynchus mykiss	1	LC50	5,540,000	5,540,000		Johnson and Finley, 1980
	Pimephales promelas	2,3	EC50	7,280,000			Brooke et al., 1984
	Pimephales promelas	2,3	EC50	8,120,000			Brooke et al., 1984
	Pimephales promelas	2,3	EC50	6,210,000	7,160,000		Brooke et al., 1984
					Tier II Parameters	Tier II V	alues
					FAVE		36

Table A.1. (continued)

\*Since the acute test was part of the same study as the chronic test, the acute value was used to derive an ACR for D. magna. The LC50 value was not used as part of GMAV because EC50 for immobilization is available.

SAV

SACR

SCV

27,780

18.48

1500

Compound	Genus/species	Requirement	Endpoint	Concentration	GMAV A-C Ratio	Reference
Anthracene	Daphnia magna	4	EC50	95		Munoz and Tarazona, 1993
	Daphnia pulex	4	EC50	754	267.6	Smith et al., 1988
					Tier II Parameters	Tier II Values
					FAVF	20.5
					SAV	13.06
					SACR	17.0
					SACK	17.2
					SCV	0.73

Compound	Genus/species	Requirement	Endpoint	Concentration	GMAV A-C Ratio	Reference
Benzene	Asellus aquaticus	5	LC50	254,000	254,000	Erben and Pisl, 1993
	Carassius auratus	2,3	LC50	34,420	34,420	Pickering and Henderson, 1966
	Chironomus thummi	6	LC50	100,000	100,000	Sloff, 1983
	Cottus cognatus	2,3	LC50	13,500	13,500	Moles et al., 1979
	Daphnia magna	4	LC50	200,000		LeBlanc, 1980
·	Daphnia magna	4	LC50	400,000		Canton and Adema, 1978
	Daphnia magna	4	LC50	620,000		Canton and Adema, 1978
	Daphnia magna	4	LC50	412,000		Canton and Adema, 1978
	Daphnia magna	4	LC50	356,000		Canton and Adema, 1978
	Daphnia magna	4	LC50	412,000		Canton and Adema, 1978
	Daphnia magna	4	LC50	356,000	376,200	Canton and Adema, 1978
	Daphnia pulex	4	LC50	345,000		Canton and Adema, 1978
	Daphnia pulex	4	LC50	265,000	302,400	Canton and Adema, 1978
	Gasterosteus aculeatus	2,3	LC50	21,800	21,800	Moles et al., 1979
	Ictalurus punctatus	2,3	LC50	425,000	425,000	Johnson and Finley, 1980
	Lepomis macrochirus	2,3	LC50	22,490	22,490	Pickering and Henderson, 1966
	Oncorhynchus gorbuscha	1	LC50	4,630		Moles et al., 1979
	Oncorhynchus kisutch	1	LC50	12,350		Moles et al., 1979
•	Oncorhynchus mykiss	2,3	LC50	5,300		DeGraeve et al., 1982
	Oncorhynchus mykiss	1	LC50	21,600	•	Hodson et al., 1984
	Oncorhynchus nerka	1	LC50	9,430		Moles et al., 1979
	Oncorhynchus tshawytscha	1	LC50	10,280	9,008	Moles et al., 1979
	Pimephales promelas	2,3	LC50	24,600		Geiger et al, 1990

Compound	Genus/species	Requirement	Endpoint	Concentration	GMAV A-C Ratio	Reference
	Pimephales promelas	2,3	LC50	12,600	17,600	Geiger et al, 1990
	Poecilia reticulata	2,3	LC50	36,600		Pickering and Henderson, 1966
	Poecilia reticulata	2,3	LC50	28,600	32,350	Galassi et al., 1988
	Salvelinus malma	2,3	LC50	10,430		Moles et al., 1979
	Salvelinus malma	2,3	LC50	10,480	10,450	Moles et al., 1979
	Thymallus arcticus	2,3	LC50	12,890	12,890	Moles et al., 1979

Tier II Parameters	Tier II Values	
FAVF	4.0	
SAV	2,252	
SACR	17.9	
SCV	130	

A-23

. .

· •

Commound	Convolonation	Desulusus	Paulastat	0	01411	
Dessiding	Genus/species	Requirement	Enapoint	Concentration	GMAV A-C Ratio	Reference
Benzidine	Daphnia magna	4	EC50	600	600	Kuhn et al., 1989
	Oncorhynchus mykiss	1	LC50	7,400	7,400*	EPA, 1980c
	Salmo trutta lacustris	1	LC50	4,350	4,350°	EPA, 1980c
	Notropis lutrensis	2,3	LC50	2,500	2,500*	EPA, 1980c
					Tier II Parameters	Tier II Values
					FAVF	8.6
					SAV	69.77
					SACR	17.9
	,				SCV	, 3.9

Table A.1. (continued)

\* The EPA criteria document was cited because the data come from an EPA internal investigation, which was not available.

Compound	Genus/species	Requirement	Endpoint	Concentration	GMAV A-C Ratio	Reference	
Benzo(a)anthracene							
	Daphnia pulex	4	LC50 MOR	10*	10	Trucco et al., 1983	
					Tier II Parameters	Tier II Values	
					FAVF	20,5	
					0437	0.4070	
					SAV	0.4878	
					SACR	17.9	
					601	0.027	
					307	0.027	
					SCV	0.027	

\* The test was based on a non-standard, but conservative, exposure of 96 hours. The standard exposure is 48 hr for daphnids. The length of the Daphnid is 1.9-2.1 mm; the age of the Daphnid species is not available.

ł

.

,

.

Compound	Genus/species	Requirement	Endpoint	Concentration	GMAV A-C Ratio	Reference
Benzo(a)pyrene	Daphnia pulex	4	LC50 MOR	5*	5	Trucco et al., 1983
					Tier II Parameters	Tier II Values
					FAVF	20.5
					SAV	0.2439
					SACR	17.9
					SCV	0.014

.

### Table A.1. (continued)

\*The test was based on a non-standard, but conservative, exposure of 96 hours. The standard exposure is 48 hr for daphnids. The length of the Daphnid is 1.9-2.1 mm; the age of the Daphnid species is not available.

Compound	Genus/species	Requirement	Endpoint	Concentration	GMAV	A-C Ratio	Reference	
Benzoic acid	Gambusia affinis	2,3	LC50	180,000*	180,000		Wallen et al., 1957	
					Tier II	Parameters	Tier II Values	
						SAV	743.8	
						SACR	17.9	
						SCV	42	

\* Done in turbid water.

Compound	Genus/species	Requirement	Endpoint	Concentration	GMAV	A-C Ratio Reference
Benzyl alcohol	Lepomis macrochirus	2,3	LC50	10,000	10,000	Dawson et al., 1977
	Pimephales promelas	2,3	LC50	460,000	460,000	Mattson et al., 1976
					Tier II Parameters	Tier II Values
					FAVF	64.8
					SAV	154.3
					SACR	17.9
					SCV	8.6

Compound	Genus/species	Requirement	Endpoint	Concentration	GMAV A-C Ratio	Reference	
BHC (other than Linda	ane)						
	Daphnia magna	4	EC50	800	800	Canton et al., 1975	
					Tier II Perameters	Tier II Volues	
						Tiel II Values	
					FAVF	20.5	
					SAV	39.02	
					on t	57.02	
					SACR	17.9	
					601		
					30.4	2.2	
					SAV SACR SCV	39.02 17.9 2.2	

Compound	Genus/species	Requirement	Endpoint	Concentration	GMAV A-C Ratio	Reference .
Bis(2-ethylhexyl) phtha	late Chironomus plumosus	6	EC50	>18,000		Streufert et al., 1980
	Daphnia pulex	4	EC50	133	133	LeBlanc, 1980
	Daphnia magna	4	LC50	2,000*		Adams & Heidolph, 1985
	Daphnia magna		cv	912	2.193	Adams & Heidolph, 1985
	Gammarus pseudolimnaeus	4	LC50	>32,000		Sanders et al., 1973
	Gasterosteus aculeatus	2,3	LC50	>300		van den Dikkenberg et al., 1989
	Ictalurus punctatus	2,3	LC50	>100,000		Johnson and Finley, 1980
	Jordanella floridae	2,3	LC50	>320		Adema et al., 1981
	Lepomis macrochirus	2,3	LC50	>770,000		Buccafusco et al., 1981
	Lepomis macrochirus	2,3	LC50	>100,000		Johnson and Finley, 1980
	Oncorhynchus kisutch	1	LC50	>100,000		Johnson and Finley, 1980
	Oncorhynchus mykiss	1	LC50	> 320		Adams et al., 1995
	Pimephales promelas	2,3	LC50	>670		Adams et al., 1995
	Pimephales promelas	2,3	LC50	>160		Adams et al., 1995
	Rana pipiens	3	LC50	4,440	4,440	Birge et al., 1978
					Tier II Parameters	Tier II Values
					FAVF	5.0
					SAV	26.60
					SACR	8.890
					scv	3.0

Table A.1. (continued)

\* This LC50 was used to calculate the A-C ratio, but not the GMAV because an EC50 was available.

Compound	Genus/species	Requirement	Endpoint	Concentration	GMAV	A-C Ratio Reference
2-Butanone	Daphnia magna	4	EC50	5,091,000	5,091,000	Randall and Knopp, 1980
	Pimephales promelas	2,3	LC50	3,200,000	3,200,000	Veith et al, 1983
					Tier II Parameters	Tier II Values
					FAVF	13.2
					SAV	242,400
					SACR	17.9
					SCV	14,000

~
ď
Ð,
,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,
Ħ
E:
0
ల.
_
_
-
-
<b>\.1</b> .
A.1.
e A.1.
ble A.1.
able A.1. (
lable A.1.
Table A.1.

Reference	Van Leeuwen et al., 1985	Tier II Values	242	16.53	17.9	0.92
A-C Ratio		Parameters	FAVF	SAV	SACR	scv
GMAV	4,000	Tier II				
Concentration	4,000					
Endpoint	LC50 MOR					
Reguirement	2,3					
Genus/snecies	Poecilia reticulata					
Compound	Carbon disfulfide					

\* Although carbon disfulide is a volatile compound, static test was used because flow-through, measured tests are not available.

Compound	Genus/species	Requirement	Endpoint	Concentration	GMAV A-C R	ntio Reference
Carbon tetrachloride*						<u></u>
	Pimephales promelas	2,3	LC50	41,400		Geiger et al., 1990
	Pimephales promelas	2,3	LC50	43,300		Kimball, n.d.
	Pimephales promelas	2,3	LC50	42,900	42,530	Kimball, n.d.
					Tier II Parameter	s Tier II Values
					FAVF	242
					SAV	175.7
					SACR	17.9
					SCV ·	9.8

\* Because carbon tetrachloride is a volatile compound, only flow-through, measured tests were used.

.

.

. .

.

.

۲

Compound	Genus/species	Requirement	Endpoint	Concentration	GMAV A-C	C ratio	Reference
Chlorobenzene	Carassius auratus	2,3	LC50	51,620	51,620		Pickering and Henderson, 1966
	Ceriodaphnia dubia	4	LC50	7,900'			Cowgill et al., 1985
	Ceriodaphnia dubia	. 4	LC50	7,900'			Cowgill et al., 1985
	Ceriodaphnia dubia	4	LC50	11,400	8,927		Cowgill et al., 1985
	Daphnia magna	4	LC50	86,000			LeBlanc, 1980
	Daphnia magna	4	LC50	13,000*			Cowgill et al., 1985
	Daphnia magna	4	LC50	10,700*			Cowgill et al., 1985
	Daphnia magna	4	LC50	15,400*	116,500		Cowgill et al., 1985
	Lepomis macrochirus	2,3	LC50	7,400	7,400		Bailey et al., 1985
	Oncorhynchus mykiss	1	LC50	7,460	7,460		Hodson et al., 1984
	Pimephales promelas	2,3	LC50	16,900	16,900		Geiger et al., 1990
	Poecilia reticulata	2,3	LC50	45,530	45,530		Pickering and Henderson, 1966
					Tier II Param	eters	Tier II Values
	•				FA	VF	6.5
					SA	V	1,138
					SAC	CR	17.9
					SC	v	64

\* Author indicated both D. magna and C. dubia/affinis are less sensitive to chlorobenzene at 24°C than at 20°C; thus, tests with 20°C were used to established a conservative estimate of the effect of chlorobenzene.

Compound	Genus/species	Requirement	Endpoint	Concentration	GMAV A-CR	atio Reference
Chloroform*	Ictalurus punctatus	2,3	LC50	75,000	75,000	Anderson and Lusty, 1980
	Lepomis macrochirus	2,3	LC50	16,200		Anderson and Lusty, 1980
	Lepomis macrochirus	2,3	LC50	22,300		Anderson and Lusty, 1980
	Lepomis macrochirus	2,3	LC50	13,300		Anderson and Lusty, 1980
	Lepomis macrochirus	2,3	LC50	18,300		Anderson and Lusty, 1980
	Lepomis macrochirus	2,3	LC50	20,800	17,880	Anderson and Lusty, 1980
	Micropterus salmoides	2,3	LC50	55,800		Anderson and Lusty, 1980
	Micropterus salmoides	2,3	LC50	52,500		Anderson and Lusty, 1980
	Micropterus salmoides	2,3	LC50	45,400	51,040	Anderson and Lusty, 1980
	Oncorhynchus mykiss	1	LC50	18,200		Anderson and Lusty, 1980
	Oncorhynchus mykiss	1	LC50	18,400		Anderson and Lusty, 1980
	Oncorhynchus mykiss	1	LC50	22,100		Anderson and Lusty, 1980
	Oncorhynchus mykiss	1	LC50	15,100		Anderson and Lusty, 1980
	Oncorhynchus mykiss	1	LC50	17,100	18,040	Anderson and Lusty, 1980
	Pimephales promelas	2,3	EC50	70,700	70,700	Geiger et al., 1990

Tier II ParametersTier II ValuesFAVF36.2SAV493.9SACR17.9SCV28

•

. .

٠

,

\* Because chloroform is a volatile compound, only flow-through, measured tests were used.

----

ŧ

Į.

Compound	Genus/species	Requirement	Endpoint	Concentration	GMAV A-C Ratio	Reference
p,p'DDD	Asellus brevicaudus	5	LC50	10		Sanders, 1972
	Asellus brevicaudus	5	LC50	16	12.65	Mayer and Ellersieck, 1986
	Bufo woodhousei	3	LC50	140	140	Sanders, 1970
	Cypridopsis vidua	5	EC50	45	45	Mayer and Ellersieck, 1986
	Daphnia pulex	4	EC50	3.2	3.2	Mayer and Ellersieck, 1986
	Gammarus fasciatus	5	LC50	0.6		Sanders, 1972
	Gammarus fasciatus	5	LC50	0.86		Sanders, 1972
	Gammarus lacustris	5	LC50	0.64	0.68	Sanders, 1969
	Ictalurus punctatus	2,3	LC50	1,500	15,000	Mayer and Ellersieck, 1986
	Ischnura verticalis	6	LC50	34	34	Mayer and Ellersieck, 1986
	Micropterus salmoides	2,3	LC50	42	42	Mayer and Ellersieck, 1986
	Oncorhynchus mykiss	1	LC50	70	72	Mayer and Ellersieck, 1986
	Palaemonetes kadiakensis	5	LC50	0.68		Sanders, 1972
	Palaemonetes kadiakensis	5	LC50	2.4	1.3	Mayer and Ellersieck, 1986
	Pimephales promelas	2,3	LC50	4,400	4,400	Mayer and Ellersieck, 1986
	Polycelis felina	7,8	LC50	740	740	Kouyoumjian and Uglow, 1974
	Pseudacris triseriata	3	LC50	400	400	Sanders, 1970
	Pteronarcys californica	6	LC50	380	380	Sanders and Cope, 1968
	Simocephalus serrulatus	4	EC50	4.5	4.5	Mayer and Ellersieck, 1986
	Stizostedion vitreum	2,3	LC50	14	14	Mayer and Ellersieck, 1986
					Tier II Parameters	Tier II Values
					FAVF	3.6
					SAV	0.1889
					SACR	17.9
					SCV	0.011

Table A.1. (continued)
Reference	LcBlanc, 1980	Ticr II Values	20.5	878.0	17.9	49
A-C Ratio		Parameters	FAVF	SAV	SACR	SCV
GMAV	18,000	Tier II				
Concentration	18,000					
Endpoint	LC50					
Requirement	4					
Genus/species	Daphnia magna					
Compound	ncraic					

\* Although decane is a volatile compound, static test was used because flow-through tests were not available.

Compound	Genus/species	Requirement	Endpoint	Concentration	GMAV	A-C ratio	Reference
Di-n-butyl phthalate						· · · · · · · · · · · · · · · · · · ·	
	Chironomus plumosus	6	EC50	760	760		Streufert et al., 1980
	Daphnia magna	4	EC50	5200	5200		McCarthy and Whitmore, 1985
	Daphnia magna		cv	1004		5.179	McCarthy and Whitmore, 1985
	Gammarus pseudolimnaeus	5	LC50	2100	2100		Johnson and Finley, 1980
	Ictalurus punctatus	2,3	LC50	2900	2900		Johnson and Finley, 1980
	Lepomis macrochirus	2,3	LC50	1200			Buccafusco et al., 1981
	Lepomis macrochirus	2,3	LC50	700	916.5		Johnson and Finley, 1980
	Oncorhynchus mykiss	1	LC50	1600	1600		Adams et al., 1995
	Oncorhynchus mykiss		cv	137.8*		11.61	Rodes et al., 1995
	Orconectes nais	5	LC50	10000 <sup>6</sup>	10000		Johnson and Finley, 1980
	Pimephales promelas	2,3	LC50	1100			Geiger et al., 1985
	Pimephales promelas	2,3	LC50	850			Geiger et al., 1985
	Pimephales promelas	2,3	LC50	2020 <sup>c.4</sup>			McCarthy and Whitmore, 1985
	Pimephales promelas	2,3	LC50	920	1148		Adams et al., 1995
	Pimephales promelas	•	CV	748.3		2.699	McCarthy and Whitmore, 1985
					Tier II Pa	arameters	Tier II Values
						FAVF	4.0
						SAV	190.0
						SACR	5.455
						SCV	35

\* Length of the test is 60 d post-hatch (99 d exposure); the National Guidelines recommend 90 d post-hatch for salmonids.

<sup>b</sup> Authors note toxicity is hardness(44-272 ppm) and pH(6.5-9.0) independent; no further data are available.

,

i 4

ţ

j 1 \* Derived from range-finding test. \* ACR derived from acute test of larval fathead minnows is the only test available as part of the same study as the chronic test. The National Guidelines

Because of an accident during the experiment, length of the test is 20 d post-hatch; the National Guidelines recommend 28-32 d post-hatch for fish other than salmonids.
fish died at 1.0 mg/L, "no evidence that additional exposure time would have produced any meaningful result".

However, the authors note since a larger number of

Compound	Genus/species	Requirement	Endpoint	Concentration	GMAV A-C Ratio	Beference
Dibenzofuran	Daphnia magna	4	LC50	1,700	1,700	LeBiane, 1980
	Pimephales promelas	2,3	EC50	780		Geiger et al., 1988
	Pimephales promelas	2,3	EC50	980	874.3	Geiger et al., 1988
					Tier II Parameters	Tier II Values
					FAVF	13.2
					SAV	66.23
					SACR	17.9
		·			SCV	3.7

Table A.1. (continued)

Compound	Genus/species	Requirement	Endpoint	Concentration	GMAV	A-C Ratio	Reference	
1,1-Dichloroethane*	Poecilia reticulata	2.3	LC50	202.000	202.000		Köneman, 1981	
				,			·····, ····	
						<b>-</b> .		
					Tier II	Parameters	Tier II Values	
						FAVF	242	•
						SAV	834.7	
						SACR	17.9	
						SCV	47	

. .

• Although 1,1-dichloroethane is a volatile compound, static test was used because flow-through test is not available.

Compound	Genus/species	Requirement	Endpoint	Concentration	GMAV	A-C ratio	Reference
1,2-Dichloroethane*	Daphnia magna	4	EC50	160,000	160,000	<u></u>	Richter et al., 1983
	Pimephales promelas	2,3	LC50	116,000	116,000		Walbridge et al., 1983
	Pimephales promelas		CV	41,360		2.804	Benoit et al, 1985
	1				Tier II	Parameters	Tier II Values
						FAVF	13.2
						SAV	8,788
						SACR	9.649
					•	SCV	910

٠

# Table A.1. (continued)

\* Because 1,2-Dichloroethane is a volatile compound, only flow-through, measured tests were used (static, measured tests for Daphnids).

Compound	Genus/species	Requirement	Endpoint	Concentration	GMAV	A-C Ratio	Reference	
1,1-Dichlorolethene*	Pimephales promelas	2,3	LC50 MOR	108,000	108,000		Dill et al., 1980	
					Tier II	Parameters FAVF	Tier II Values 242	
						SAV	446.3	
						SACR	17.9	
						SCV	25	

\* Although 1,1-dichloroethene is a volatile compound, static test is used because flow-through, measured tests are not available.

Compound	Genus/species	Requirement	Endpoint	Concentration	GMAV A-C Ratio	Reference
1,2-Dichloroethene*	Lepomis macrochirus	2,3	LC50	140,000	140,000	Buccafusco, 1981
	Daphnia magna	4	LC50	220,000	220,000	LeBlanc, 1980
					,	,
					Tier II Parameters	Tier II Values
					FAVF	13.2
					C 4 3 7	10 (10
					SAV	10,010
					SACR	17.9
					SCV	590

.

\* Although 1,2-dichloroethene is a volatile compound, static tests were used because flow-through, measured tests are not available.

Compound	Genus/species	Requirement	Endpoint	Concentration	GMAV A-C Ratio	Reference
1,3-Dichloropropene*						
	Pimephales prometas	2,3	EC50	239	239	Geiger et al., 1990
					Tier II Parameters	Tier II Values
					FAVE	242
						212
					SAV	0.0876
					ψ <b>Λ</b> Υ	0.5870
					04.00	15.0
					SACK	17.9
					SCV	0.055

.

# Table A.1. (continued)

a Because 1,3-dichloropropene is a volatile compound, only flow-through measured test was used.

•

Compound	Genus/species	Requirement	Endpoint	Concentration	GMAV A-C Ratio	Beference
Diethyl phthalate	Daphnia magna	4	EC50	86,000	86,000	Adams et al., 1995
	Daphnia magna		cv	38,410	2.239	Rhodes et al., 1995
	Lepomis macrochirus	2,3	LC50	16,700	16,700	Adams et al., 1995
. 、	Pimephales promelas	2,3	LC50	31,800		Geiger et al., 1985
	Pimephales prometas	2,3	LC50	17,000	23,250	Adams et al., 1995
	Oncorhynchus mykiss	1	LC50	12,000	12,000	Adams et al., 1995
					Tier II Parameters	Tier II Values
					FAVF	6.5
	•				SAV	1,846
					SACR	8.952
					SCV	210

.

Table A.1. (continued)

	-
	ā
	=
	-
	-
- 1	-
	-
	Ξ.
	0
	Ľ۵.
1.14	_
	_
	-
	_
,	
,	Ę
	<b>٩.1.</b> (
	A.I. (
	e A.I. (
	le A.1. (
	ole A.1. (
	ble A.I. (
	able A.I. (
	Table A.I. (

				t			
Reference	Geiger et al., 1990	Galassi et al., 1988	Ticr II Values	64.8	130.4	17.9	7.3
MAV A-C Ratio	8,450	9,600	Tier II Parameters	FAVF	SAV	SACR	SCV
Concentration G	8,450	9,600		1			
Endpoint	EC50	LC50					
Requirement	2,3	2,3					
Genus/species	Pimephales promelas	Poccilia reticulata					
Compound Edual herrenot							

\* Because ethyl benzene is a volatile compound, only flow-through, measured tests were used.

Compound	Genus/species	Requirement	Endpoint	Concentration	GMAV A-C Ratio	Reference	
Hexane	Pimephales promelas	2,3	EC50	2,500	2,500	Geiger et al., 1990	·
					Tier II Parameters	Tier II Values	
					SAV	10.33	
					SACR	. 17.9	
					SCV	0.58	

Compound	Genus/species	Requirement	Endpoint	Concentration	GMAV	A-C Ratio	Reference	······
2-Hexanone	Pimephales promelas	2,3	LC50	428,000	428,000		Geiger et al., 1986	
					Tier II	Parameters FAVF	Tier II Values 242	
						SAV	1,769	
						SACR	17.9	
						scv	99	

Compound	Genus/species	Requirement	Endpoint	Concentration	GMAV A-C Ratio	Reference
1-Methylnaphthalene						
	Pimephales promelas	2,3	EC50	9,000	9,000	Mattson et al., 1976
						•
					Tier II Parameters	Tier II Values
					FAVF	242
•						
					0.417	27.10
			•		SAV	37.19
					SACR	17.9
					SCV	21
					504	2.1

•

# Table A.1. (continued)

Compound	Genus/species	Requirement	Endpoint	Concentration	GMAV	A-C Ratio	Reference	
4-Methyl-2-pentanone	Pimephales promelas	2,3	LC50	540,000			Brooke et al., 1984	
	Pimephales promelas	2,3	LC50	505,000	522,200	`	Veith et al., 1983a	
	Pimephales promelas		cv	77,360		6.750	Call et al., 1985	
					Tier II l	Parameters	Tier II Values	
						FAVF	242	
						SAV	2,158	
						SACR	12.93	
						SCV	170	

÷

# Table A.1. (continued)

Compound	Genus/species	Requirement	Endpoint	Concentration	GMAV A-C Ratio	Reference
2-Methylphenol	Carassius auratus	2,3	LC50 MOR	23,250	23,250 .	Pickering and Henderson, 1966
	Lepomis macrochirus	2,3	LC50 MOR	20,780	20,780	Pickering and Henderson, 1966
	Oncorhynchus mykiss	1	LC50 MOR	8,400	8,400	DeGraeve et al., 1980
	Pimephales promelas	2,3	LC50	14,000		Geiger et al., 1990
	Pimephales promelas	2,3	LC50	18,200	15,960	DeGraeve et al., 1980
	Poecilia reticulata	2,3	LC50	18,850	18,850	Pickering and Henderson, 1966
					Tier II Parameters	Ticr II Values
					FAVF	36.2
					SAV	232.0
			•		SACR	17.9
					SCV	13

x

Table A.1. (continued)

Compound	Genus/species	Requirement	Endpoint	Concentration	GMAV A-C Ra	tioReference
Methylene chloride	Daphnia magna	4	LC50 MOR	220,000	220,000	LeBlanc, 1980
	Lepomis macrochirus	2,3	LC50 MOR	220,000	220,000	Buccafusco et al., 1981
	Pimephales promelas	2,3	EC50	330,000	330,000	Geiger, 1986
	Pimephales promelas		LC50 MOR	502,000	•	Dill et al., 1987
	Pimephales promelas		CV	108,540	4.6	25 Dill et al., 1987
					Tier II Parameters	Tier II Values
					FAVF	8.6
					SAV	25,580
					SACR	11.40
					scv	2,200

• The LC50 value is used to calculate the ACR because it is part of the same study as the chronic test; but it is not used to determine the GMAV of *Pimephales* sp. because an EC50 is available.

1 1

,

Compound	Genus/species	Requirement	Endpoint	Concentration	GMAV	A-C ratio	Reference
Napthalene							
	Daphnia magna	4.	EC50	2,194			Munoz and Tarazona, 1993
	Daphnia pulex	4	EC50	4,663	3,199		Smith et al., 1988
		•	* 669	1 (00			
	Oncorhynchus mykiss	1	LC50	1,600	1,600		DeGraeve et al., 1982
	Piwanhalan provolan	2.2	1.050	6 140			Critere et al. 1085
	1 mephales prometas	2,5	LCJU	0,140			Geiger et al., 1965
	Pimephales prometas	2.3	LC50	7.900	6.965		DeGraeve et al., 1982
		-,-			•,• ••		
	Pimephales promelas		cv	619		12.77	DcGracve et al., 1982
							·

Table A.1. (continued)

Tier II Parameters	Tier II Values
FAVF	8.6
SAV	186.0
SACR	15.96
SCV	12

Compound	Genus/species	Requirement	Endpoint	Concentration	GMAV	A-C Ratio	Reference
4-Nitrophenol	Daphnia magna	4	EC50	7,680			Keen and Baillod, 1985
	Daphnia magna	4	EC50	4,700	6,008		Kuhn et al., 1989
	Daphnia magna		CV	7,071		2"	Kuhn et al., 1989
	Gammarus pseudolimnaeus	5	LC50	6,550	6,550		Howe et al., 1994
	Ictalurus punctatus	2,3	LC50	15,000	15,000		Holcombe et al., 1984
	Lepomis macrochirus	2,3	LC50	8,300	8,300		Buccafusco et al., 1981
	Oncorhynchus mykiss	1	LC50	7,900	7,900		Hodson et al., 1984
	Oncorhynchus mykiss		CV	989.1		7.987	Hodson et al., 1991
	Pimephales promelas	2,3	LC50	59,000			Phipps et al., 1981
	Pimephales promelas	2,3	LC50	62,000			Phipps et al., 1981
	Pimephales promelas	2,3	LC50	41,000			Holcombe et al., 1984
	Pimephales promelas	2,3	LC50	37,300			Geiger et al., 1985
	Pimephales promelas	2,3	LC50	41,000			Geiger et al., 1985
	Pimephales promelas	2,3	LC50	58,600	48,760		Geiger et al., 1985
					Tier II P	arameters	Tier II Values
						FAVF	5.0
						SAV	1,202
						SACR	3.997
						SCV	300

.

• •

### Table A.1. (continued)

\* Since the experimental A-C Ratio was less than 2, the A-C Ratio of D. magna is set to 2 (Stephan et al, 1985).

Υ.

i

i.

ued)
ontin
<u>ə</u>
•
A.1.
ible A.1.

			I			
Reference	LeBlanc, 1980	Tier II Values	20.5	3,805	9.71	210
AV A-C Ratio	800	ier II Parameters	FAVF	SAV	SACR	SCV
GM/	9,7 (	Ĩ				
Concentration	7,800					
Endpoint	LC50					
Reguirement	4					
Genus/species	ne Daplınla magna					
Compound	N-Nitrosodiphenylami					

Compound	Genus/species	Requirement	Endpoint	Concentration	GMAV A-C Ratio	Reference	
2-Octanone*	Pimephales promelas	2,3	EC50	36,000	36,000	Brooke, 1984	
					Tier II Parameters	Tier II Values	
					SAV	242	
					SACR	17.9	
					SCV	8.3	

\*Because 3-Octanone tests do not have standardard exposure, 2-Octanone tests, which have the standard exposure, were used.

. .

Table A.1.	(continued)
------------	-------------

Compound	Genus/species	Requirement	Endpoint	Concentration	GMAV	A-C Ratio	Reference
PCBs: total							
	Pimephales promelas					9.443	Nebeker et al., 1974
				Tier I Parameters	Tier I	Values	-
				FAV		2.0	EPA, 1980x
				Tier II Parameters	Tier II	Values	
				SACR		14.64	•
				SCV		0.14	
					•		
		<u> </u>	•				· · · · · · · · · · · · · · · · · · ·

		I			
Reference	Mayer et al., 1977	Tier II Values	242 4.959	17.9	0.28
GMAV A-C Batin		Tier II Parameters	SAV	SACR	SCV
Concentration	1,200				
Endnoint	LC50				
Requirement	_				
Genus/snecies	Oncorhynchus clarki				
Compound	PCBs: Aroclor <sup>®</sup> 1221				

Compound	Genus/species	Requirement	Endpoint	Concentration	GMAV A-C Ratio	Reference
PCBs: Aroclor <sup>®</sup> 1232	Oncorhynchus clarki	1	LC50	2,500		Johnson and Finley, 1980
					Tier II Parameters FAVF	Tier II Values 242
					SAV	10.33
					SACR	17.9
					SCV	0.58

Compound	Genus/species	Requirement	Endpoint	Concentration	GMAV A-C Ratio	Reference
PCBs: Aroclor® 1242	Gammarus pseudolimnaeus	5	LC50	72		Nebeker and Puglisi, 1974
	Gammarus pseudolimnaeus	5	LC50	74	72.99	Nebeker and Puglisi, 1974
	Ictalurus punctatus	2,3	LC50	>100		Johnson and Finley, 1980
	Ischnura verticalis	7,8	LC50	400	400	Mayer et al., 1977
	Oncorhynchus clarki	1	LC50	5,400	5,400	Mayer et al., 1977
	Perca flavescens	2,3	LC50	>150		Johnson and Finley, 1980
	Pimephales promelas	2,3	LC50	15	15	Nebeker et al., 1974
	Pimephales promelas		LC50	300*		Nebeker et al., 1974
	Pimephales promelas		CV	9.000	33,33	Nebeker et al., 1974
					Tier II Parameters	Tier II Values
					FAVF	12.9
					SAV	1.163
					SACR	22.02

a Because this value is more than ten times of another life stage, it is not used in the GMAV calculation. However, since the preferred life stage in deriving the A-C Ratio is juvenile, it is used in A-C Ratio derivation.

.

scv

.

0.053

Compound	Genus/species	Requirement	Endpoint	Concentration	GMAV A-C Ratio	Reference
PCBs: Aroclor <sup>®</sup> 1248	Gammarus pseudolimnaeus	5	LC50 MOR	29	29	Nebeker and Puglisi, 1974
	Ictalurus punctatus	2,3	LC50 MOR	>100		Johnson and Finley, 1980
	Lepomis macrochirus	2,3	LC50 MOR	278		Stalling and Mayer, 1972
	Lepomis macrochirus	2,3	LC50	690	438.0	Johnson and Finley, 1980
	Oncorhynchus clarki	1	LC50	5,750	5,750	Johnson and Finley, 1980
	Perca flavescens	2,3	LC50	>100		Johnson and Finley, 1980
					Tier II Parameters	Tier II Values
					FAVF	20.1
					SAV	1.443
•					SACR	17.9
					scv	0.081

Table A.1. (continued)

Compound	Genus/species	Requirement	Endpoint	Concentration	GMAV	A-C Ratio	Reference
PCBs: Aroclor <sup>®</sup> 1254	Coregonus hoyi	1	LC50	>10,000			Passino and Kramer, 1980
	Gammarus fasciatus	5	LC50	2,400	2,400		Johnson and Finley, 1980
	Ictalurus punctatus	2,3	LC50	>200			Johnson and Finley, 1980
	Ischnura verticalis	6	LC50	200	200		Mayer et al., 1977
	Lepomis macrochirus	2,3	LC50	2,740	2,740		Johnson and Finley, 1980
	Oncorhynchus clarki	1	LC50	42,500	42,500		Johnson and Finley, 1980
	Orconectes nais	5	LC50	100	100		Johnson and Finley, 1980
	Perca flavescens	2,3	LC50	>150			Johnson and Finley, 1980
	Pimephales promelas	2,3	LC50	7.7	7.7		Nebeker et al., 1974
	Pimephales promelas		CV	2.878		2.676	Nebeker et al., 1974

FAVF 12.9	FAVF 12.9 SAV 0.5969 SACR 17.9
SAV 0.5969	SAV 0.5969 SACR 17.9
0.3707	SACR 17.9
SACR 17.9	

Table A.1. (continued)

Compound	Genus/species	Requirement	Endpoint	Concentration	GMAV	A-C Ratio	Reference
PCBs: Aroclor <sup>®</sup> 1260	• • •						
	Ictaturus punctatus	2,3	LC20	>400			Johnson and Finley, 1980
	Lepomis macrochirus	2,3	LC50	>400			Johnson and Finley, 1980
	Oncorhynchus clarki	1	LC50	61,000	61,000		Mayer et al., 1977
	Perca flavescens	2,3	LC50	>200			Johnson and Finley, 1980

Tier II Values	Tier II Parameters
36.2	FAVF
1,685	SAV
17.9	SACR
94	SCV

Compound	Genus/species	Requirement	Endpoint	Concentration	GMAV	A-C ratio	Reference	
1-Pentanol*	Pimephales promelas	2,3	LC50	472,000	472,000		Geiger et al., 1986	
				·	•			
					Tier	II Parameters	Tier II Values	
						FAVF	242	
						SAV	1950	
						SACR	17.9	
						SCV	110	

\*Because 1-pentanol is a volatile compound, only flow-through, measured test was used.

Compound	Genus/species	Requirement	Endpoint	Concentration	GMAV A-C Ratio	Reference
2-Propanol	Chironomus riparius	7	LC50	12,500,000	12,500,000	Roghair et al., 1994
	Pimephales promelas	2,3	LC50	10,400		Veith et al., 1983
	Pimephales promelas	2,3	LC50	9,640		Veith et al., 1983
	Pimephales promelas	2,3	LC50	6,550	8,692	Brooke et al., 1984

Table A.1. (continued)

	Tier II Parameters	Tier II Values
	FAVF	64.8
	SAV	134.1
	SACR	17.9
· · ·	scv	7.5

Compound	Genus/species	Requirement	Endpoint	Concentration	GMAV	A-C Ratio	Reference
1,1,2,2-Tetrachloroetha	ne						
	Daphnia magna	4	EC50	23,000	23,000		Richter et al., 1983
	Daphnia magna		cv	9,829		2.34	Richter et al., 1983
	Jordanella floridae	2,3	LC50	18,480	18,480		Smith et al., 1991
	Jordanella floridae		CV	8,467		2.183	Smith et al., 1991
	Pimephales promelas	2,3	LC50	20,400			Walbridge et al., 1983
	Pimephales promelas	2,3	LC50	20,300	20,350		Geiger et al., 1985
	Pimephales promelas		CV	2,366		8,601	Ahmad et al., 1984
					Tier II F	Parameters	Tier II Values
						FAVF	8.6
						SAV	2,149
						SACR	3.529
						SCV	610

. .

\* Because 1,1,2,2-tetrachloroethane is a volatile compound, only flow-through, measured tests were used.

.

Compound	Genus/species	Requirement	Endpoint	Concentration	GMAV	A-C Ratio	Reference	
Tetrachloroethene*	Daphnia magna	4	EC50	8,500	8,500		Richter et al., 1983	
	Daphnia magna		CV	750.0		11.33	Richter et al., 1983	
	Jordanella floridae	2,3	LC50	. 8,430	8,430		Smith et al., 1991	
	Jordanella floridae		CV	3,107		2.714	Smith et al., 1991	
	Oncorhynchus mykiss	1	LC50	5,840			Shubat et al., 1982	
	Oncorhynchus mykiss	1	LC50	4,990	5,398		Shubat et al., 1982	
	Pimephales promelas	2,3	LC50	13,400			Walbridge et al., 1983	
	Pimephales promelas	2,3	LC50	20,300	16,490		Geiger et al., 1985	
	Pimephales promelas		CV	836.7		19.71	Geiger et al., 1985	
					Tier II Pa	arameters	Tier II Values	
						FAVF	6.5	
						SAV	830.5	
						SACR	8.463	
						SCV	98	

Table A.1. (continued)

\*Because tetrachloroethene is a volatile compound, only flow-through, measured tests were used.

Compound	Genus/species	Requirement	Endpoint	Concentration	GMAV A-C Ratio	Reference
Toluene	Pimephales promelas	23	LC50	31,700		Geiger et al., 1990
	Pimephales promelas	2,3	LC50	36,200		Geiger et al., 1986
	Pimephales promelas	2,3	LC50	30,000		Devlin et al., 1982
	Pimephales promelas	2,3	LC50	31,000		Devlin et al., 1982
	Pimephales promelas	2,3	LC50	26,000		Devlin et al., 1982
	Pimephales promelas	2,3	LC50	18,000	28,170	Devlin et al., 1982
	Pimephales promelas		CV	4,899	5.243	Devlin et al., 1982
					Tier II Parameters	Tier II Values
					FAVF	242
					SAV	116.4
					SACR	11.89
					SCV	9.8

\* Because toluene is a volatile compound, only flow-through, measured tests were used.

. .

-
'nď
õ
Ħ
I
÷
õ
્ચ્
$\sim$
<u> </u>
7
◄
-
Ľ
2
3
<b>F</b>
•

.

Compound	Genus/species	Reguirement	Endpoint	Concentration	GMAV A-C Ratio	Reference
1,1,1-Trichlorocthane*	Pimephales promelas	2,3	LC50	52,900		Geiger et al., 1986
	Pimephales promelas	2,3	LC50	42,300	47,300	Geiger et al., 1986
					Tier II Parameters	Tier II Values
					FAVF	242
					SAV	195.5
					SACR	17.9
				-	SCV	11

.

\* Because 1,1,1-trichloroethane is a volatile compound, only flow-through, measured tests were used.

.

,

٠

Compound	Genus/species	Requirement	Endpoint	Concentration	GMAV	A-C Ratio	Reference
1,1,2-Trichloroethane	Daphnia magna	4	EC50	81,000	81,000		Richter et al., 1983
	Daphnia magna		CV	18,385		4.406	Richter et al., 1983
	Jordanella floridae	2,3	LC50	45,117	45,117		Smith et al., 1991
	Jordanella floridae		CV	46,609		2۴	Smith et al., 1991
	Pimephales promelas	2,3	LC50	81,600	81,600		Alunad et al., 1984
	Pimephales promelas		CV	9,423		8.659	Ahmad et al., 1984
					Tier II I	arameters	Tier II Values
						FAVF	8.6
						SAV	5,246
						SACR	4.241
•							
						201	1200

.

• ,

#### Table A.1. (continued)

.

. .

\* Because 1,1,2-trichloroethane is a volatile compound, only flow-through, measured tests were used.

\* Since the experimental A-C Ratio is less than 2, the A-C Ratio of J. floridae is set to 2 (Stephan et al., 1985).

Compound	Genus/species	Requirement	Endpoint	Concentration	GMAV A-C Ratio	Reference
Trichloroethene*	Jordanella floridae	2,3	LC50	28,280	28,280	Smith et al., 1991
	Jordanella floridae		cv	11,057	2.558	Smith et al., 1991
	Pimephales promelas	2,3	LC50	40,700		Alexander et al., 1978
	Pimephales promelas	2,3	LC50	45,000		Walbridge et al., 1983
	Pimephales promelas	2,3	LC50	44,100	43,230	Geiger et al., 1985
					Tier II Parameters	Tier II Values
					FAVF	64.8
					SAV	436.4
					SACR	9.358
					SCV	47

Table A.1. (continued)

\* Because trichloroethene is a volatile compound, only flow-through, measured tests were used.
Compound	Genus/species	Requirement	Endpoint	Concentration	GMAV A-C Ratio	Reference
inyl acetate*	Carassius auratus	2,3	LC50	42,330	42,330	Pickering and Henderson, 1966
	Lepomis macrochirus	2,3	LC50	18,000	18,000	Pickering and Henderson, 1966
	Pimephales promelas	2,3	LC50	14,000		Pickering and Henderson, 1966
	Pimephales promelas	2,3	LC50	15,000		Pickering and Henderson, 1966
	Pimephales promelas	2,3	LC50	14,000		Pickering and Henderson, 1966
	Pimephales promelas	2,3	LC50	15,000		Pickering and Henderson, 1966
	Pimephales promelas	2,3	LC50	15,000		Pickering and Henderson, 1966
	Pimephales promelas	2,3	LC50	23,000		Pickering and Henderson, 1966
	Pimephales promelas	2,3	LC50	26,000		Pickering and Henderson, 1966
	Pimephales promelas	2,3	LC50	20,000		Pickering and Henderson, 1966
	Pimephales promelas	2,3	LC50	24,000 <sup>b</sup>		Pickering and Henderson, 1966
	Pimephales promelas	2,3	LC50	19,730	18,090	Pickering and Henderson, 1966
	Poecilia reticulata	2,3	LC50	31,080	31,080	Pickering and Henderson, 1966
					Tier II Parameters	Tier II Values
					FAVF	64.8 .
					SAV	277.8
					SACR	17.9
					SCV	16

.

Table A.1. (continued)

\* Although vinyl acetate is a volatile compound, static tests were used because flow-through, measured tests are not available. \* Auther notes hardness influences toxicity; vinyl acetate is more toxic in soft water than hard water.

.

ł 1

ł

- 1

.

. .

Table A.1. (continued)

scv

13

Compound	Genus/species	Requirement	Endpoint	Concentration	GMAV	A-C ratio	Reference	
Xylene*					•			
	Lepomis macrochirus	2,3	LC50	15,700	15,700		Bailey et al., 1985	
•	Pimephales promelas	2,3	EC50	15,300 <sup>%d</sup>			Geiger et al., 1990	
	Pimephales promelas	2,3	EC50	14,800	15,050		Geiger et al., 1990	
					Tier II	Parameters	Tier II Values	
					<b>6</b>	FAVF	64.8	
						SAV	232.3	
						SACR	17.9	

Because xylene is a volatile compound, only flow-through, measured tests were used.
 o-xylene (99+% purity) was used.
 m-xylene (99% purity) was used.
 Because analytical procedures used at waste sites do not discriminate isomers, toxicity tests on individual and mixture of isomers are considered equivalent.

Appendix B

# METHODS FOR DERIVATION OF TIER II VALUES

·

-----

,

## **METHODS FOR DERIVATION OF TIER II VALUES**

## **B.1** Method for data selection

The procedure used to select and aggregate test data was adopted from the guidelines for deriving National Ambient Water Quality Criteria (NAWQC) (Stephan et al. 1985). The selection criteria are summarized in the following text.

## **B.1.1 Chemical Considerations**

Not all forms of inorganic chemicals require unique Tier II values. Metal salts with the same oxidation state at ambient conditions (e.g.,  $BeCl_2$  and  $BeSO_4$ ) are expected to exhibit similar toxicity and are given a common Tier II value. Nonionizable, covalently bonded compounds of metals or metals of different oxidation states were considered different chemicals, for which separate Tier II values were derived.

For volatile compounds, only results of flow-through tests with measured chemical concentrations were used, if available. However, if flow-through measured tests were not available, the genus mean acute value (GMAV) was based on static and flow-through unmeasured tests.

Pesticides were screened for commercial formulations; wettable powder, emulsifiable concentrates, and formulated mixtures were eliminated. Only pesticides of technical grades or better were considered.

## **B.1.2 Dilution water considerations**

Test results were rejected if unusual dilution water was used (e.g., TOC > 5 ppm, lack of appropriate salts, low dissolved oxygen), unless toxicity has been demonstrated to be independent of these factors. Tests in which dissolved oxygen fell below 40% saturation for static or 60% saturation for flow-through were eliminated.

### **B.1.3 Biological parameters**

Tests of certain organisms were excluded from the Tier II value derivation. Single-celled organisms and brine shrimp (*Artemia* sp.) were not used. Fish were generally limited to species with wild North American populations. However, if none of the tests with North American fish were acceptable and values for other organisms were not available, non-resident fish were used.

Tests which did not refer to a standard procedure or indicate use of a control group were excluded. Acute tests in which organisms were fed were eliminated, unless feeding was demonstrated to be independent of toxicity.

For the acute tests, only daphnids and midges (*Chironomus* sp.) have a specified starting age. Daphnids must be less than 24 hours of age at the start of the test. Midges in second or third instar larvae were preferred, but midge tests starting at fourth instar were accepted. Although the starting age for all other organisms has not been specified, juvenile stages were preferred whenever they were available (unless another life stage is more sensitive to the chemical). All organisms should receive a 96-hour exposure period, except daphnids and midges, where 48 hours is the standard exposure period. The endpoint for daphnids and midges is the EC50 for immobilization. If this is not available,

LC50 is used. For fish, the preferred endpoint is the EC50 for loss of equilibrium, immobilization, and/or mortality. If those are not available, LC50 is used.

In chronic tests, the starting age, exposure duration, and endpoints may be different for daphnids and fish and for salmonids and non-salmonids. Daphnids must be less than 24 hours old at the start of the test, and the test should last at least 21 days. Endpoints are based on mortality and number of young per female.

For a given fish species, preference is given to the following types of chronic tests in the order as follows: full life cycle, partial life cycle, and early life stage. The less desirable chronic test is not included in the calculation if a more desirable type is available.

## **B.1.4 Variation of Acute Values within the same genus**

If the acute values within a species or among species in a genus differ by a factor of 10 or more, the higher values were excluded, and those that are within the factor of 10 range were used to attain a conservative estimate. If the acute concentrations of a given species differ by a factor of two or more among different life stages, the more sensitive life stage is used to protect the organisms in all life stages.

## **B.1.5 ACR Considerations**

If the acute chronic ratios (ACRs) for a chemical differ by more than a factor of 10, the tests were carefully examined to determine whether outliers should be rejected. ACRs from saltwater species should be used along with the freshwater ACRs when less than three ACRs from freshwater species are available. If the lowest GMAV is from larvae of barnacles, bivalves, lobsters, crabs, shrimp, or abalones, the secondary acute chronic ratio (SACR) is assumed to be 2. If an ACR is less than 2, acclimation may have occurred. The ACR is then set to 2.

Preference was given to acute and chronic tests done in the same study. If these are not available, an acute value with water characteristics similar to the chronic value was used. If values from similar water are not available, the GMAV of the species is used with the chronic value to derive an ACR. If multiple chronic values for a species are available but none are part of the same study as an acute test, the geometric mean of the chronic values was calculated and used with the GMAV to derive an ACR for that species.

## B.1.6 Acceptable exposure types and life stage used to derive ACR

For daphnids, renewal is required for chronic tests; while for acute tests, static exposure is acceptable. All chronic test concentrations should be measured. The life stage of daphnids has to be 24 hours or younger at the start of both acute and chronic tests.

For fish, both acute and chronic tests require flow-through measured tests. For acute fish tests, the life stage of the organism should be juvenile.

## **B.1.7 Other considerations**

Concentrations above the solubility of chemicals and "greater than" values were used only when at least one definitive concentration was available.

#### **B.2** Calculation method

Tier II values are derived if fewer than eight of the acute data requirements or three chronic data requirements presented in EPA (1993a) are met. The eight acute data requirements include:

- 1. The family Salmonidae in the class Osteichthyes
- 2. One other family (preferably a commercially, or recreationally important, warmwater species) in the class *Osteichthyes* (e.g., bluegill, channel catfish, etc.)
- 3. A third family in the phylum Chordata (e.g., fish, amphibian, etc.)
- 4. A planktonic crustacean (e.g., a cladocceran, copepod, etc.)
- 5. A benthic crustacean (e.g., ostracod, isopod, amphipod, crayfish, etc.)
- 6. An insect (e.g., mayfly, dragonfly, damselfly, stonefly, caddisfly, mosquito, midge, etc.)
- 7. A family in a phylum other than Arthropoda or Chordata (e.g., Rotifera, Annelida, Mollusca, etc.)
- 8. A family in any order of insect or any phylum not already represented

If all of these data requirements are not met, then an FAV is calculated. The FAV is a Tier I criterion, and its derivation is documented in Stephan et al. (1985) and in Appendix A of EPA (1993a). The FAV, however, is used in the derivation of the SCV if the chronic data requirements are not met.

Tier II values, as mentioned previously, are calculated when the data requirements are not met. The first calculation of the Tier II criteria is the SAV. The SAV is derived by taking the lowest genus mean acute value (GMAV) for any of the genera present and dividing it by a Final Acute Value Factor (FAVF). The FAVF is selected from Table B.1 where n is the number of the eight acute data requirements that are satisfied. FAVFs are selected from the two columns depending on whether an acute value (LC50 or EC50) for a daphnid is included in the data set.

Once the SAV is calculated, the Secondary Acute-Chronic Ratio (SACR) is derived. If three or more Acute-Chronic Ratios (ACRs) are present, then the SACR is determined by finding the geometric mean of the ACRs. There must be at least three ACRs. If there are not three chronic values from the literature, then a default value of 17.9 (EPA 1991) is used until the total number of ACRs is three. If multiple ACRs are given for the same genus, then the geometric mean of those ACRs must be calculated. This genus mean ACR can then be used in the derivation of the SACR. Therefore, several members of the same genus can only present one value towards the mandatory three. If no ACRs are given, then the SACR is 17.9.

The final calculation for Tier II values is the derivation of an SCV. The SCV is calculated by dividing the FAV or SAV by the SACR.

Number of GMAVs <sup>a</sup>	Factor for data sets that include an acute value for a daphnid <sup>b</sup>	Factors for data sets that do not include an acute value for a daphnid <sup>b</sup>
1	20.5	242
2	13.2	64.8
3	8.6	36.2
4	6.5	20.1
5	5.0	12.9
6	4.0	9.2
7	3.6	7.2

------

 Table B.1. Factors for estimation of the Tier II values (EPA 1993 and Stephan 1991)

.

<sup>a</sup> GMAV is Genus Mean Acute Value <sup>b</sup> Daphnids includes members of the genera *Daphnia, Ceriodaphnia,* and *Simocephalus*.

# Appendix C

TABLE SHOWING CONCENTRATIONS ESTIMATED TO CAUSE A 20% REDUCTION IN THE RECRUIT ABUNDANCE OF LARGEMOUTH BASS, WITH UPPER AND LOWER 95% CONFIDENCE BOUNDS • . \$ . , .

Chemical	Test Species	Test Type	Lower 95% CL	Median	Upper 95%CL	Source
Ammonia	Fathead minnow Fathead minnow	Chronic Chronic	3.98 3.98	100 32	1585 200	Mayes et al. 1986 Thurston et al. 1986
Antimony	Fathead minnow	Acute	5.01	79	501	ЕРА 1980ь
Arsenic III	Fathead minnow	Chronic	100	1995	31623	Call et al. 1983
Arsenic V	Fathead minnow Rainbow trout Mosquitofish	Acute Acute Acute	20 10 32	159 100 398	1000 501 2512	EPA 1985a EPA 1985a EPA 1985a
Beryllium	Fathead minnow Bluegill Flagfish Guppy	Acute Acute Acute Acute	0.35 2.00 2.00 1.58	7.08 32 32 25	40 126 126 126	EPA 1980f EPA 1980f EPA 1980f EPA 1980f
Cadmium	Fathead minnow Bluegill Brook trout Brook trout Flagfish Flagfish	Chronic Chronic Chronic Chronic Chronic Chronic	1 1.99 0.13 0.32 0.63 0.79	10 13 1.26 3.16 3.98 3.16	79 50 6.31 25 50 7.94	Pickering and Gast 1972 Eaton 1974 Benoit et al. 1976 Sauter et al. 1976 Carlson et al. 1982 Spehar 1976
Chromium III	Rainbow trout	Chronic	13	126	1000	Stevens and Chapman 1984
Chromium VI	Fathead minnow Rainbow trout	Chronic Chronic	25 100	158 631	1260 5010	Pickering 1980 Sauter et al. 1976
Cobalt	Fathead minnow	Acute	0.16	3.98	32	Lind et al. 1978
Copper	Fathead minnow Fathead minnow Bluegill Brook trout Brook trout	Chronic Chronic Chronic Chronic	0.40 0.32 1.995 1	3.98 3.16 13 3.98	40 16 50 16	Mount 1968 Mount and Stephan 1969 Benoit 1975 McKim and Benoit 1971 Souter et al. 1976
	Coho salmon	Chronic	3.16	32	316	Hazel and Meith 1970

Table C.1. Concentrations estimated to cause a 20% reduction in the recruit abundance of largemouth bass, with upper and lower95% confidence bounds. All units are ug/L

÷

ł

- 1

. .

င္ပ

Chemical	Test Species	Test Type	Lower 95% CL	Median	Upper 95%CL	Source
	<b></b>					
	Rainbow trout	Chronic	3.98	32	200	Seim et al. 1984
Cyanide	Fathead minnow	Chronic	0.20	2.51	16	Smith et al. 1979
•	Atlantic Salmon	Chronic	1.99	16	200	Leduc 1978
	Bluegill	Chronic	5.01	25	158	Smith et al. 1979
	Brook trout	Chronic	1.58	13	79	Smith et al. 1979
Lead	Brook trout	Chronic	13	50	316	Holcombe et al. 1976
	Rainbow trout	Chronic	13	100	631	Sauter et al. 1976
Manganese	Fathead minnow	Acute	11	112	794	Kimball n.d.
Mercury, inorganic	Fathead minnow	Chronic	0.04	0.79	13	Call et al. 1983
	Fathead minnow	Chronic	0.01	0.13	3.16	Snarski and Olson 1982
Mercury, methyl	Rainbow trout	Acute	0.004	0.16	1.26	EPA 1985e
•••••	Brook trout	Acute	0.02	0.50	3.98	EPA 1985e
Nickel	Fathead minnow	Chronic	32	126	501	Pickering 1974
	Rainbow trout	Chronic	13	63	398	Nebeker et al. 1985
	Rainbow trout	Chronic	126	1260	15800	Nebeker et al. 1985
Silver	Fathead minnow	Chronic	0.01	0.1	1	Holcombe et al. 1983
	Rainbow trout	Chronic	0.1	1	7.94	Nebeker et al. 1983
Thallium	Fathead minnow	Acute	0.25	4.47	40	EPA 1980bb
	Blucgill	Acute	73	1000	6310	EPA 1980bb
Uranium	Fathead minnow	Acute	0.398	10	50	Cushman et al. 1977
	Fathead minnow	Acute	0.501	10	50	Cushman et al. 1977
	Fathead minnow	Acute	0.631	13	79	Cushman et al. 1977
	Fathead minnow	Acute	32	398	3980	Cushman et al. 1977
Vanadium	Fathead minnow	Acute	0.28	5.01	40	Kimball n.d.
	Brook trout	Acute	5.01	63	398	Ernst and Garside 1987
	Flagfish	Acute	10	100	501	Holdway and Sprague 1979
Zinc	Fathead minnow	Chronic	3.98	40	316	Benoit and Holcombe 1978

## Table C.1. (continued)

C4

Chemical	Test Species	Test Type	Lower 95% CL	Median	Upper 95%CL	Source
	Fathead minnow Coho salmon	Chronic Chronic	3.16 16	40 126	316 794	Brungs 1969 Finlayson and Verrue
	Flagfish Rainbow trout	Chronic Chronic	6.31 40	32 501	126 5010	Spehar 1976 Sinley et al. 1974
Zirconium	Fathead minnow Fathead minnow Fathead minnow Fathead minnow Bluegill Bluegill	Acute Acute Acute Acute Acute Acute	3.16 3.16 32 63 10 200	50 50 398 794 126 2510	316 398 3160 6310 501 15800	Cushman et al. 1977 Cushman et al. 1977
Organics						
AC 222,705	Fathead minnow	Chronic	0.0006	0.01	0.063	Spehar et al. 1983
Acetone	Fathead minnow Bluegill Rainbow trout Mosquitofish	Acute Acute Acute Acute	1780 3160 1260 631	19900 50100 31600 10000	25100 501000 316000 100000	AQUIRE* AQUIRE* AQUIRE* AQUIRE*
AG thiosulfate complex	Fathcad minnow	Chronic	1000	10000	79400	LeBlanc et al. 1984
Aldicarb	Fathcad minnow	Chronic	3.16	50	631	Pickering and Giliam 1982
Atrazine	Brook trout	Chronic	100	1000	12600	Macck et al. 1976b
Benzene	Fathead minnow Bluegill Rainbow trout Mosquitofish Guppy	Acute Acute Acute Acute Acute	10 13 3.16 200 32	100 158 40 3160 316	794 1000 316 25100 1580	EPA 1980d EPA 1980d EPA 1980d EPA 1980d EPA 1980d
Benzidene	Rainbow trout Lake trout Flagfish	Acute Acute Acute	5.01 3.16 10	63 40 126	398 251 794	EPA 1980c EPA 1980c EPA 1980c
Benzoic acid	Mosquitofish	Acute	126	1260	10000	AQUIRE*
Benzyl alcohol	Fathead minnow Bluegill	Acute Acute	16 6.31	1780 79	12600 398	AQUIRE <sup>®</sup> AQUIRE <sup>®</sup>
Bis(2-ethylhexyl)phthalate Rainbow trout	Acute	100	1000	7940		AQUIRE*

.

Table C.1. (continued)

Chemical	Test Species	Test Type	Lower 95% CL	Median	Upper 95%CL	Source
2-Butanone	Largemouth bass Channel catfish Fathcad minnow Mosquitofish	Acute Acute Acute Acute	25 0.006 501 1990	316 0.40 10000 31600	1580 6.31 100000 398000	AQUIRE* AQUIRE* AQUIRE* AQUIRE*
Captan	Fathead minnow	Chronic	0.32	3.16	20	Hermanutz et al. 1973
Carbaryl	Fathead minnow	Chronic	3.16	32	1000	Carlson 1971
Carbon disulfide	Mosquitofish	Acute	100 _	1000	7940	AQUIRE*
Carbon tetrachloride	Fathead minnow Bluegill	Acute Acute	11 40	126 398	1260 3160	EPA 1980h EPA 1980h
Chloramine	Fathead minnow	Chronic	0.32	3.16	13	Arthur and Eaton 1971
Chlordane	Bluegill Brook trout	Chronic Chronic	0.13 0.20	0.40 1.26	2.51 7.94	Cardwell et al. 1977 Cardwell et al. 1977
Chlorobenzene	Fathead minnow Bluegill Guppy	Acute Acute Acute	11 10 32	112 126 316	794 1000 2510	EPA 1980j EPA 1980j EPA 1980j
Chloroform	Bluegill Rainbow trout	Acute Acute	79 40	794 398	5010 3160	EPA 19801 EPA 19801
p,p'DDD	Fathead minnow Bluegill Rainbow trout Largemouth bass Channel catfish	Acute Acute Acute Acute Acute	0.79 0.002 0.02 0.003 0.025	13 0.1 0.40 0.13 1.26	100 1 3.16 1 16	AQUIRE <sup>®</sup> AQUIRE <sup>®</sup> AQUIRE <sup>®</sup> AQUIRE <sup>®</sup>
2,4-D Butoxyethanol ester	Coho salmon	Chronic	10	100	1260	Finlayson and Verrue
Diazinon	Fathead minnow	Chronic	0.32	3.16	25	1985 Allison and Hermanutz
	Flagfish	Chronic	10	50	316	1977 Allison and Hermanutz 1977
Di-n-butyl phthalate	Fathead minnow	Chronic	13	251	3980	McCarthy and Whitmore 1985
2,6-Dichlorobenzamide	Rainbow trout	Chronic	1260	12600	50100	Van Lecuwen and Maas 1985

Table C.1. (continued)

င်

Chemical	Test Species	Test Type	Lower 95% CL	Median	Upper 95%CL	Source
1,3-Dichlorobenzene	Fathead minnow	Chronic	316	1585	15849	Ahmad et al. 1984
1,4-Dichlorobenzene	Fathead minnow	Chronic	32	398	6310	Ahmad et al. 1984
1,1-Dichloroethane	Guppy	Acute	158	1580	12600	AQUIRE*
1,2-Dichloroethane	Fathead minnow Bluegill	Acute Acute	40 316	398 3980	3160 31600	EPA 1980k EPA 1980k
1,1-Dichloroethene	Fathead minnow Bluegill	Acute Acute	40 50	398 501	3160 3980	EPA 1980n EPA 1980n
2,4-Dichlorophenol	Fathcad minnow	Chronic	32	200	1580	Holcombe et al. 1982
1,2-Dichloropropane	Fathead minnow	Chronic	398	3980	39800	Benoit et al. 1982
1,3-Dichloropropane	Fathead minnow	Chronic	501	5010	50100	Benoit et al. 1982
1,3-Dichloropropene	Bluegill	Acute	3.16	40	251	EPA 1980o
Diethyl phthalate	Bluegill	Acute	79	1000	6310	AQUIRE*
2,4-Dimethylphenol Dimethyl phthalate	Fathead minnow Rainbow trout	Chronic Chronic	100 0.004	1260 0.04	19900 0.40	Holcombe et al. 1982 Ward and Boeri 1991b
1,3-Dinitrobenzene	Rainbow trout Rainbow trout	Chronic Chronic	100 63	1000 794	7940 6310	Van Der Schalie 1983 Van Der Schalie 1983
Dinoseb	Fathcad minnow	Chronic	0.13	3.16	40	Call et al. 1983
Di-n-octyl phthalate	Fathead minnow	Chronic	200	1990	39800	McCarthy and Whitmore 1985
Diuron	Fathead minnow	Chronic	1	16	158	Call et al. 1983
Dursban	Fathead minnow	Chronic	0.002	0.032	0.20	Jarvinen et al. 1983
DNBP	Rainbow trout	Chronic	0.00004	0.0004	0.005	Ward and Boeri 1991a
Endrin	Fathead minnow	Chronic	0.005	0.13	1.58	Carlson et al. 1982
Endosulfan	Fathead minnow	Chronic	0.002	0.016	0.13	Macek et al. 1976b
Ethyl benzene	Fathead minnow Bluegill	Acute Acute	10 50	158 501	1000 3980	EPA 1980p EPA 1980p

Chemical	Test Species	Test Type	Lower 95% CL	Median	Upper 95%CL	Source
	Guppy	Acute	79	794	5010	EPA 1980p
Fenitrothion	Fathead minnow	Chronic	0.1	126	1990	Kleiner et al. 1984
Fluoranthene	Bluegill	Acute	2.00	32	126	EPA 1980q
Fluridone	Fathead minnow	Chronic	32	398	10000	Hamelink et al. 1986
Fonofos	Fathead minnow	Chronic	3.16	20	158	Pickering and Giliam 1982
Guthion Heptachlor	Fathead minnow Fathead minnow	Chronic Chronic	0.013 0.01	0.13 0.1	3.98 0.63	Adeiman et al. 1976 Macek et al. 1976b
Hexachlorobutadiene	Fathead minnow	Chronic	0.32	3.98	63	Benoit et al. 1982
Hexachlorocyclohexane (lindane)	Bluegill Macek et al. 1976a	Chronic	0.16	1	6.31	
Hexachloroethane	Fathead minnow	Chronic	3.98	100	1580	Ahmad et al. 1984
2-Hexanone	Fathead minnow	Acute	100	1260	12600	AQUIRE*
Kelthane	Fathead minnow	Chronic	0.32	7.94	100	Spehar et al. 1982
LAS 11.2	Fathead minnow	Chronic	126	1580	25100	Holman et al. 1980
LAS 11.7	Fathead minnow	Chronic	13	200	2510	Holman et al. 1980
LAS Mixture	Fathead minnow	Chronic	20	316	1580	Pickering and Thatcher 1970
Malathion	Flagfish	Chronic	3.162	20	126	Hermanutz 1978
1-Methylnaphthalene	Fathead minnow	Acute	1.78	31.62	200	AQUIRE*
4-Methyl-2-pentanone	Fathead minnow	Acute	141	1580	15800	AQUIRE*
2-Methylphenol	Fathead minnow Bluegill Rainbow trout	Acute Acute Acute	3.98 13 6.31	40 126 79	398 1000 398	AQUIRE* AQUIRE* AQUIRE*
Methylene chloride	Fathead minnow Bluegill	Acute Acute	63.10 158	1000 1580	10000 12600	AQUIRE* AQUIRE*

Table C.1. (continued)

C-8

Chemical	Test Species	Test Type	Lower 95% CL	Median	Upper 95%CL	Source
Naphthalene	Fathead minnow	Chronic	73	1000	12600	DeGraeve et al. 1982
4-Nitrophenol	Fathead minnow Bluegill Rainbow trout Channel catfish	Acute Acute Acute Acute	13 3.98 6.31 0.79	159 50 79 20	1260 316 398 200	AQUIRE" AQUIRE" AQUIRE" AQUIRE"
N-nitrosodiphenylamine	Blucgill	Acute	3.16	40	251	AQUIRE*
PCBs: Aroclor 1221	Cutthroat trout	Acute	0.63	10	50	AQUIRE*
PCBs: Aroclor 1232	Cutthroat trout	Acute	1.26	16	126	AQUIRE*
PCBs: Aroclor 1242	Fathead minnow	Chronic	0.13	1.58	40	Nebeker et al. 1974
PCBs: Aroclor 1248	Flagfish	Chronic	0.13	1.26	7.94	Nebeker et al. 1974
PCBs: Aroclor 1254	Fathead minnow	Chronic	0.1	0.63	7.94	Nebeker et al. 1974
PCBs: Aroclor 1260	Cutthroat trout	Acute	32	316	2510	AQUIRE*
Pentachloroethane	Fathead minnow	Chronic	100	1260	19900	Ahmad et al. 1984
Pentachlorophenol	Fathead minnow Fathead minnow Fathead minnow Fathead minnow Fathead minnow Rainbow trout	Chronic Chronic Chronic Chronic Chronic Chronic	1.58 0.32 0.63 1.26 1.99 1.58	32 1.99 6.31 13 16 10	501 20 63 126 158 50	Holcombe et al. 1982 Spehar et al. 1985 Spehar et al. 1985 Spehar et al. 1985 Spehar et al. 1985 Dominguezand Chapman 1984
1-Pentanol	Bluegill Rainbow trout	Acute Acute	398 200	5010 2510	39800 19900	AQUIRE <sup>®</sup> AQUIRE <sup>®</sup>
Permethrin	Fathcad minnow	Chronic	0.02	0.40	5.01	Spehar et al. 1983
Phenol	Fathead minnow Rainbow trout	Chronic Chronic	1000 126	12600 1580	199000 15800	Degraeve et al. 1980 Degraeve et al. 1980
Propanil	Fathead minnow	Chronic	0.01	0.1	0.63	Call et al. 1983
2-Propanol	Fathead minnow	Acute	200	3160	31600	AQUIRE*
Pydrin	Fathead minnow	Chronic	0.006	0.13	1.58	Spehar et al. 1982

Table C.1. (continued)

6-)

• •

Chemical	Test Species	Test Type	Lower 95% CL	Median	Upper 95%CL	Source
1,1,2,2-Tetrachloroethane	Fathcad minnow	Chronic	251	1580	50100	Ahmad et al. 1984
Tetrachloroethene	Fathcad minnow Blucgill Rainbow trout	Acute Acute Acute	3.16 10 3.16	50 100 40	398 501 316	EPA 1980aa EPA 1980aa EPA 1980aa
Tetrachloroethylene	Fathcad minnow	Chronic	40	1000	12600	Ahmad et al. 1984
Toluene	Fathead minnow Bluegill Guppy	Acute Acute Acute	10 13 50	126 126 501	1000 1000 3160	EPA 1980cc EPA 1980cc EPA 1980cc
Toxaphene	Brook trout	Chronic	0.01	0.063	0.40	Mayer et al. 1975
1,1,1-Trichloroethane	Fathead minnow Bluegill	Acute Acute	18 32	200 316	1580 1580	AQUIRE* AQUIRE*
1,1,2-Trichloroethane	Fathead minnow	Chronic	1000	15800	251000	Ahmad et al. 1984
Trichloroethene	Fathead minnow Flagfish Bluegill	Acute Acute Acute	13 20 32	158 251 316	1260 1260 . 1990	EPA 1980dd Smith et al. 1991 EPA 1980dd
2-Trifluoromethyl-4-phenol	Brook trout	Chronic	100	501	3160	Dwyer et al. 1978
Trifluralin	Fathcad minnow	Chronic	0.063	0.63	7.94	Macek et al. 1976b
1,3,5-Trinitrobenzene	Fathead minnow Rainbow trout Rainbow trout	Chronic Chronic Chronic	3.16 13 13	50 158 158	631 1580 1580	Van der Schalie 1983 Van der Schalie 1983 Van der Schalie 1983
Vinyl acetate	Fathead minnow Bluegill Guppy	Acute Acute Acute	3.16 10 25	40 126 . 251	398 794 1580	AQUIRE* AQUIRE* AQUIRE*

Table C.1. (continued)

• EPA (n.d.)

C-10

## DISTRIBUTION

L. V. Asplund
 R. R. Bonczek
 M. Clauberg
 J. Croswait
 J. R. Duncan
 R. E. Efroymson
 K. M. Golden
 R. K. Holmes
 J. Jagoe
 D. S. Jones
 11–25. S. B. Kerr
 J. M. Loar
 Z. D. M. Matteo
 C. W. McGinn
 D. B. Miller

30. J. H. Moyer

31. B. D. Nourse

32. D. M. Opresko 33. P. T. Owen 34. S. T. Purucker 35. A. S. Quist 36. B. E. Sample 37. D. M. Steinhauff 38-40. G. W. Suter 41. S. S. Talmage 42. M. F. Tardiff 43-44. C. L. Tsao 45. C. J. E. Welsh 46. D. C. White 47. M. E. Will 48. Central Research Library 49. ER Central Document Management Center 50. ORNL Laboratory Records

- 51. A. Temeshy, Bechtel National Inc., 151 Lafayette Dr., Oak Ridge, TN 37831-0350
- M. Leslie, CDM Federal Programs Corporation, 800 Oak Ridge Turnpike, Suite 500, Oak Ridge, TN 37830
- 53. D. Gonzales, Jacobs Engineering, 125 Broadway, Oak Ridge, TN 37830
- 54. G. Snyder, Jacobs, Engineering, 100 West 3rd St., Piketon, OH 45611
- 55. J. Tate, Jacobs, Engineering, 125 Broadway, Oak Ridge, TN 37830
- 56. D. Wilkes, Jacobs, Engineering, 175 Freedom Blvd., Kevil, KY 42053
- P. Carter, Science Applications International Corporation, 11197 U.S. Route 23, Suite 200, Waverly, Ohio 45690
- B. Kornaby, Science Applications International Corporation, P.O. Box 2501, 301, Laboratory Rd., Oak Ridge, TN 37831
- S. Pack, Science Applications International Corporation, P.O. Box 2501, 301, Laboratory Rd., Oak Ridge, TN 37831
- 60. B. G. Blaylock, SENES, 102 Donner Drive, Oak Ridge, TN 37831
- 61. K. Hopper, Systematic Management Services, 117 Broadway Ave., Oak Ridge, TN 37830