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**Toxicological Benchmarks for Screening of Potential Contaminants of
Concern for Effects on Aquatic Biota on the Oak Ridge Reservation,
Oak Ridge, Tennessee**

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EXECUTIVE SUMMARY

One of the initial stages in ecological risk assessment of hazardous waste sites is the screening of contaminants to determine which 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). Exceeding an upper screening benchmark indicates that the chemical in question is clearly of concern and remedial actions are likely to be needed. Exceeding 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 here. The alternative benchmarks are based on different conceptual approaches to estimating concentrations causing significant effects. For the upper screening benchmark, they are the acute National Ambient Water Quality Criterion (NAWQC) and the acute pesticide advisory value (a concentration that is estimated with 95% confidence not to exceed the unknown acute NAWQC for those chemicals with no NAWQC). The alternative chronic benchmarks are the chronic NAWQC, the chronic pesticide screening value, the lowest chronic values for fish and daphnids, the lowest concentration that produces a response in 20% of fish and daphnids [effective concentration 20 (EC_{20})] as established through chronic toxicity tests, the estimated EC_{20} 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 and relevant or appropriate requirements. 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 this report.

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.

1. INTRODUCTION

An important early step in the assessment of ecological risks posed by a contaminated site is the screening of contaminants. In most cases, concentrations in water will be reported for over 100 chemicals, many 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 the need for urgent action. Nonexceedance of a lower screening benchmark would suggest that no hazard exists. Exceedance of an increasing number of benchmarks would constitute increasing evidence of the need for measurement and assessment.

The purpose of this report is to present and analyze alternate toxicological benchmarks for screening chemicals for aquatic ecological effects. Screening benchmarks have not been previously proposed, and no guidance for developing such values is available from the U.S. Environmental Protection Agency (EPA) or other regulatory agencies. In general, the National Ambient Water Quality Criteria for Protection of Aquatic Life (NAWQC) have been used for this purpose. However, they were not designed for contaminant screening. They are intended to protect most aquatic species most of the time with reasonable confidence. Because screening benchmarks are intended to provide a high degree of confidence that a chemical is not hazardous, greater conservatism may be warranted. In addition, the NAWQC do not correspond to any particular type or level of effect (Suter et al. 1987). Because screening assessments are performed as the preliminary stage of ecological risk assessments, it is appropriate to consider potential toxicological benchmarks that correspond to defined types and levels of effects.

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

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 (LC_{50}). Second, hypothesis-testing statistics can be used to determine whether each 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 h or 96 h in duration and use juvenile or adult organisms; the test endpoints are the median lethal concentration (LC_{50}) or median effective concentration (EC_{50}) for death or some equivalent effect (e.g., immobilization). Standard chronic tests include all or most of the life cycle 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 makes more sense 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 LC_{50} s 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 ORR ecological risk assessments (Suter et al. 1992).

2.2 WATER QUALITY CRITERIA

The NAWQC are ARARs (applicable or relevant and appropriate requirements); 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-h LC_{50} values or equivalent median effective concentration EC_{50} 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 is 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 LC_{50}/CV 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.

NAWQC for several metals are functions of water hardness; the criteria are lower for lower hardness levels. We used the criteria for 100 mg/L hardness that are reported by the EPA. 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 NAWQC are listed in Table 1.

Many readers will note that the EPA's compilations of NAWQC contain values for many chemicals that have no NAWQC listed here (EPA 1986). That is because the EPA reports lowest CVs for those chemicals for which there is not enough data to calculate a criterion but for which there is at least one chronic value. Lowest CVs are treated as a separate category of benchmarks in this compilation. However, if sufficient data were available to calculate a final acute value (FAV), and if some chronic values were available but not the three or more needed to calculate a chronic criterion, the chronic criterion was approximated using the FAV and the geometric mean of the available chronic values. Those approximated criteria are noted in Table 1.

For particular chemicals, the lower screening benchmark could be lower than the chronic NAWQC for any one of the following five 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 response parameters 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 life cycle of fish and invertebrates are not considered. Fourth, the NAWQC are set at a level that protects "most species most of the time." A lower screening benchmark should protect all species nearly all 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 confirmed by the recent finding that nickel concentrations on the ORR that are below chronic NAWQC nonetheless are toxic to daphnids (Kszos et al. 1992).

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

Chemical	NAWQ criteria * advisory values		Lowest chronic value for:		Lowest test EC ₅₀ value for:		SS test EC ₅₀	Population EC ₅₀
	Acute	Chronic	Fish	Daphnids	Fish	Daphnids		
Inorganics								
Aluminum	750	87	5800	1900	4700	540	75	-
Antimony	*220	*18	1600	5400	2310	1900	-	79
Arsenic III	360	190	2962	914.1	2130	633	55	1995
Arsenic V	*27	*0.77	891.6	*450	1500	>932	-	185
Barium	*4400	*109	-	*20,336	-	-	-	-
Beryllium	*55	*0.61	*57	5.3	*148	3.8	-	21
Boron	-	-	-	-	-	7	-	-
Cadmium	3.9	1.1	1.7	0.15	1.8	0.75	0.013 ^a	4.3
Calcium	-	-	-	-	-	-	-	-
Chromium III	1700	210	68.83	<44	89	-	8.44	126
Chromium VI	16	11	73.18	6.132	51	0.5	0.266	316
Cobalt	*24	*0.29	290	5.1	810	<4.4	-	3.98
Copper	18	12	3.873	0.23	5	0.205	0.26	8.6
Cyanide	22	5.2	7.8	-	5.3	-	1.17	11
Fluorine	*3700	*190	*8784	4400	*5336	3706	-	1080
Iron	-	1000	-	158	-	16	-	-
Lead	82	3.2	18.88	12.26	22	-	0.35	71
Lithium	-	-	-	-	-	-	-	-
Magnesium	*6.5	*0.16	-	-	-	-	-	-
Manganese	*330	*11	1770	<1100	1270	<1100	-	112
Mercury, inorganic	2.4	1.3 ^b	<0.23	0.96	0.87	0.87	0.18	0.32
Mercury, methyl	*0.016	*0.0003	0.52	<0.04	<0.03	0.87	-	0.28
Molybdenum	*2200	*30	-	880	-	360	-	-
Nickel	1400	160	<35	<5	62	45	11 ^a	215
Niobium	-	-	-	-	-	-	-	-
Potassium	*5.3	*0.13	-	-	-	-	-	-
Selenium	260	35	88.32	91.65	40	25	2.60	-
Silver	4.1	*0.39 ^c	0.12	2.6	0.20	<0.56	0.14 ^a	0.32
Sodium	*19,000	*480	-	*85,049	-	-	-	-
Strontium	-	-	-	-	-	-	-	-
Thallium	*28	*2.5	57	135	81	64	-	67
Thorium	-	-	-	-	-	-	-	-

Table 1 (continued)

Chemical	NAWQ criteria * advisory values		Lowest chronic value for:		Lowest test EC ₅₀ value for:		SS test EC ₅₀	Population EC ₅₀
	Acute	Chronic	Fish	Daphnids	Fish	Daphnids		
Tin	-	-	-	-	-	-	-	-
Titanium	-	-	-	-	-	-	-	-
Uranium	*0.28	*0.007	*142	-	*455	-	-	27
Vanadium	*44	*3.0	80	>940	41	430	-	32
Zinc	120	110	36.41	46.73	47	-	21	80
Zirconium	*8.52	*0.213	*548	-	*2396	-	-	251
<i>Organics</i>								
Acenaphthene	*29	*2.2	413	*6646	<197	-	-	-
Acetone	*31,000	*770	*507,640	*3,114,182	*161,867	-	-	23714
Anthracene	*0.00058	*0.00001	*0.09	<2.1	*0.35	>8.2	-	-
Benzene	*130	*3.2	*299	>98,000	21	-	-	229
Benzidene	*6.0	*0.15	*134	-	*158	-	-	68
Benzo(a)anthracene	*0.11	*0.0027	-	*0.65	-	-	-	-
Benzo(a)pyrene	*0.053	*0.0013	-	*0.30	>2.99	-	-	-
Benzo(b)fluoranthene	-	-	-	-	-	-	-	-
Benzo(g,h,i)perylene	-	-	-	-	-	-	-	-
Benzo(k)fluoranthene	-	-	-	-	-	-	-	-
Benzoic acid	*18	*0.45	*12,976	-	*7409	-	-	1259
Benzyl alcohol	*6.0	*0.147	*589	-	*550	-	-	375
BHC (lindane)	2.0	0.08	14.6	14.5	<1.1	11	0.11	-
BHC (other)	*9.5	*0.24	-	*95	-	-	-	-
Bis(2-ethylhexyl) phthalate	*3.2	*0.01	8.4	<3	>54	<3	-	50
Butane, 1,1-oxybis	-	-	-	-	-	-	-	-
(2,1-ethanedioxy)bis	-	-	-	-	-	-	-	-
2-Butanone	*63,000	*1600	*282,170	*1,394,927	*98,772	-	-	17783
4-chloro-4,4-difluoro-	-	-	-	-	-	-	-	-
Carbon disulfide	*36	*0.91	*9538	*244	*5719	-	-	1000
Carbon tetrachloride	*690	*63	>3400	*5580	65	-	-	224

Table 1 (continued)

Chemical	NAWQ criteria * advisory values		Lowest chronic value for:		Lowest test EC ₅₀ value for:		SS test EC ₅₀	Population EC ₅₀
	Acute	Chronic	Fish	Daphnids	Fish	Daphnids		
Chlordane	2.4	0.17 ^b	1.6	16	<0.25	12.1	0.50	0.71
Chlorobenzene	*460	*11.6	*1203	*15,042	*1002	-	-	165
Chloroethane	-	-	-	-	-	-	-	-
Chloroform	*570	*14	*3578	*4483	8400	-	-	562
Chrysene	-	-	-	-	-	-	-	-
DDD	-	-	-	-	-	-	-	-
p,p'	*0.017	*0.00042	*1.69	-	*3.99	-	-	0.61
other	-	-	-	-	-	-	-	-
DDT	1.1	*0.02 ^c	0.73 ^d	*0.016	0.35	-	0.008	-
Decane	*190	*4.8	-	*7874	-	-	-	-
Di-n-butyl phthalate	*45	*4.4	717 ^e	717 ^f	270	500	-	251
Dibenzofuran	*80	*2.0	-	*1003	-	-	-	-
Dichlorodifluoromethane	-	-	-	-	-	-	-	-
1,1-Dichloroethane	*20	*0.51	*14,680	-	*8219	-	-	1585
1,2-Dichloroethane	*2300	*144	41,364	15,200	29,000	<11,000	-	1259
1,1-Dichloroethene	*590	*15	>2800	*4720	-	-	-	447
1,2-Dichloroethenes	*14	*0.34	*9538	-	*5719	-	-	-
1,3-Dichloropropene	-	-	-	-	-	-	-	-
trans-	-	-	-	-	-	-	-	-
total	*100	*2.6	*345	*805	*350	-	-	40
Diethyl phthalate	*1100	*27	-	-	-	-	-	1000
Di-n-octyl phthalate	-	-	5700	570	<100	310	-	1995
Dimethyl naphthalene	-	-	-	-	-	-	-	-
4,6-Dinitro-ortho-cresol	-	-	-	-	-	-	-	-
Ethanyl methyl benzene	-	-	-	-	-	-	-	-
Ethyl benzene	*1100	*30	>440	*12,922	-	-	-	398
Ethyl methyl benzene	-	-	-	-	-	-	-	-
Ethyl dimethyl benzene	-	-	-	-	-	-	-	-
Fluoranthene	*69	*1.7	-	*65,795	-	-	-	32
Freon 113	-	-	-	-	-	-	-	-
Freon 123	-	-	-	-	-	-	-	-

Table 1 (continued)

Chemical	NAWQ criteria * advisory values		Lowest chronic value for:		Lowest test EC ₅₀ value for:		SS test EC ₅₀	Population EC ₅₀
	Acute	Chronic	Fish	Daphnids	Fish	Daphnids		
Heptachlor	0.52	*0.01 ^c	1.26	*3.18	0.86	-	0.004	0.1
Hexane	*82	*2.1	*65,712	-	*28,995	-	-	-
2,5-Hexanedione	-	-	-	-	-	-	-	-
2-Hexanone	*43	*1.1	*32,783	-	*16,155	-	-	1259
1-methylpentyl hydroperoxide	-	-	-	-	-	-	-	-
Indeno(1,2,3-c,d)pyrene	-	-	-	-	-	-	-	-
Methyl cyclopentane	-	-	-	-	-	-	-	-
1-Methyl naphthalene	*0.90	*0.023	*526	-	*500	-	-	31.62
2-Methyl naphthalene	-	-	-	-	-	-	-	-
4-Methyl-2-pentanone	*51	*2.3	77400	-	-	-	-	1585
2-Methyl phenol	*310	*7.7	*489	*1316	*470	-	-	74
Methyl propenyl benzene	-	-	-	-	-	-	-	-
Methylpropyl benzene	-	-	-	-	-	-	-	-
Methylene chloride	*4300	*220	108,000	*42,667	410	-	-	1259
Naphthalene	*55	*2.1	620	*1163	450	>600	-	1000
Nitrophenols	-	-	-	-	-	-	-	-
4- total	*260 230 ^b	*15 150 ^b	*481	7100	*464	5000	-	60
N-Nitroso-di-n-propylam ine	-	-	-	-	-	-	-	-
N-Nitrosodiphenylamine	*100	*2.5	*332	*1042	*339	-	-	40
Nonane	-	-	-	-	-	-	-	-
3-Octanone	*1400	*34	*5449	*110,147	*3571	-	-	-
9-Octadecenamide, (z) PCB's	-	-	-	-	-	-	-	-
Aroclor [®] 1221	*0.12	*0.0029	*60	-	*80	-	-	10
Aroclor [®] 1232	*0.23	*0.0058	*124	-	*148	-	-	16
Aroclor [®] 1242	*0.21	*0.01	9.0	-	<2.9	-	-	1.58
Aroclor [®] 1248	*0.004	*0.0002	0.2	4.3	0.4	2.5	-	1.26
Aroclor [®] 1254	*0.37	*0.02	1.0	2.1	0.52	1.2	-	0.63

Table 1 (continued)

Chemical	NAWQ criteria * advisory values		Lowest chronic value for:		Lowest test EC ₅₀ value for:		SS test EC ₅₀	Population EC ₅₀
	Acute	Chronic	Fish	Daphnids	Fish	Daphnids		
Aroclor ^a 1260	*4.5	*0.11	2.3	-	2.1	-	-	316
1-Pentanol	*240	*5.9	*30,493	-	*15,200	-	-	3548
Phenanthrene	*8.4	*0.43	-	200	-	110	-	-
Phenol	*450	*21	1369	*2005	<230	-	-	4467
2-Propanol	*100	*2.6	*83,257	-	*35,381	-	-	3162
Pyrene	-	-	-	-	-	-	-	-
1,1,2,2-Tetrachloroethane	*400	*31	2400	9900	1400	<420	-	1585
Tetrachloroethene	*170	*8.8	840	750	500	510	-	50
Toluene	*420	*10.4	*1269	*25,229	<26	-	-	200
1,1,1-Trichloroethane	*24	*1.4	*3493	1770	*2457	1300	-	251
1,1,2-Trichloroethane	*1400	*92	9400	18,400	14,800	13,000	-	15849
Trichloroethene	*880	*55	11,060	*7257	5758	-	-	232
Trichlorofluoromethane	-	-	-	-	-	-	-	-
Trimethyl benzene	-	-	-	-	-	-	-	-
Vinyl acetate	*32	*0.8	*810	-	*718	-	-	108
Vinyl chloride	*38	*0.95	*28,879	-	*14,520	-	-	-
Xylene	*60	*1.46	*62,308	-	2680	-	-	-

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

^aStudy LC₅₀'s were used rather than species mean LC₅₀'s so water hardness would correspond to EC₅₀ values.

^bThe chronic NAWQC for inorganic mercury (0.012 µg/L) and for chlordane (0.0043 µg/L) are based on the final residue values. For consistency we use criteria derived from the final chronic values.

^cThe NAWQC for DDT (0.001 µg/L) and for Heptachlor (0.0038 µg/L) are based on the final residue values; for consistency we calculated approximated criteria for aquatic life.

^dThe MATC 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.

^eFor fish di-n-butyl phthalate lowest chronic value, we used 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)

^fFor *Daphnia magna* di-n-butyl phthalate lowest chronic value, we used the mean of the geometric means of the NOEC and LOEC concentrations measured in fresh solutions and 1-4-old solutions. (McCarthy and Whitmore 1985)

^gIn lieu of a chronic NAWQC for silver, the EPA (1986) reports a lowest chronic value. For consistency we calculated an approximate chronic criterion for aquatic life.

^hIn lieu of acute and chronic NAWQC, the EPA (1986) reports a lowest observed effect level for a species of algae. Those values are presented here because it was not judged to be appropriate to calculate estimated chronic values or advisory values to total nitrophenols.

2.3 ADVISORY VALUES

NAWQC were not available for most chemicals. If NAWQC were not available for a chemical and could not be approximated, the method of Stephan and Erickson (n.d.) for calculating pesticide advisory values was applied. Advisory values are concentrations that would be expected to be higher than NAWQC in no more than 5% of cases. The advisory values are derived in a manner analogous to the criteria in that a number equivalent to the FAV, termed the "pesticide acute value" (PAV), is derived from acute toxicity data; it is multiplied by a number equivalent to the final acute-chronic ratio, termed the "pesticide acute-chronic ratio" (PACR), to obtain the chronic advisory values. PAVs are calculated by multiplying the lowest available LC_{50} by a factor derived from the distributions of lowest LC_{50} values from subsets of data to the PAVs derived from full data sets. The PACRs are calculated using all available and acceptable pairs of measured acute and chronic values, and factors of 40 are used for missing chronic values (40 is a conservative default value supplied by Stephan and Erickson). The sources of data for the advisory values, the PAVs, and the PACRs are listed in Appendix A, and the factors used to calculate the PAVs are in Appendix B.

Knowledgeable readers may be aware of an EPA procedure for calculating advisory concentrations (OWRS & ORD 1987). Advisory concentrations have the same purpose as the pesticide advisory values, but the statistical methods employed are not as defensible as those for the pesticide advisory values. The pesticide advisory values are not peculiarly applicable to pesticides, and in fact their statistical procedures were derived using all criteria chemicals. Therefore, in the remainder of this document they will be referred to simply as advisory values.

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.

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-h LC_{50} s using equations from Suter et al. (1987) and Suter (1992). The equations are as follows where LC_{50} equals the lowest species mean 96-h LC_{50} for fish and 48-h EC_{50} 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:

$$\begin{aligned}\log CV &= 0.73 \log LC_{50} - 0.70 \\ PI &= 1.2\end{aligned}$$

Fish CV for a nonmetallic contaminant:

$$\begin{aligned}\log CV &= 1.07 \log LC_{50} - 1.51 \\ PI &= 1.5\end{aligned}$$

Daphnid CV for a metallic contaminant:

$$\begin{aligned}\log CV &= 0.96 \log LC_{50} - 1.08 \\ PI &= 1.56\end{aligned}$$

Daphnid CV for a nonmetallic contaminant:

$$\begin{aligned}\log CV &= 1.11 \log LC_{50} - 1.30 \\ PI &= 1.35\end{aligned}$$

2.6 TEST EC_{20} s

Another potential lower benchmark is the test EC_{20} 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 life cycle 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 EC_{20} 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 EC_{20} . However, the test EC_{20} s 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 observed at CVs and as a minimum detectable difference in population characteristics in the field (Suter et al. 1987, 1992).

2.7 ESTIMATED TEST EC_{20} s

The estimated test EC_{20} is another potential benchmark. The estimated values were extrapolated from 96-h LC_{50} values using equations from Suter (1992). The equation for the lowest fish test EC_{20} is as follows where LC_{50} equals the lowest species mean 96-h LC_{50} for fish and the EC_{25} for weight of juveniles per egg is used as an estimate of the test EC_{20} 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 $\log EC_{25} \pm$ the PI value:

$$\log EC_{25} = 0.90 \log LC_{50} - 0.86$$

$$PI = 1.6$$

2.8 SENSITIVE SPECIES TEST $EC_{20}s$

The sixth potential benchmark is $EC_{20}s$, adjusted to approximate the fifth percentile of the species sensitivity distribution. It is calculated in the same way as the chronic NAWQC except that test $EC_{20}s$ 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 $LC_{50}s$ to $EC_{20}s$. They are referred to as sensitive species (SS) test $EC_{20}s$.

2.9 POPULATION $EC_{20}s$

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 here. 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 postlarval 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 concentration-response 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 $LC_{50}s$ 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 LC_{50} was used to parameterize a model run. The results are presented in Table 2. The geometric mean of all population EC_{20} estimates for each chemical is reported in Table 1.

2.10 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 the background sites support normal biotic communities, then screening benchmarks lower than the background concentration should not be used.

Table 2. Concentrations estimated to cause a 20% reduction in the recruit abundance of largemouth bass, with upper and lower 95% confidence bounds. All units are ug/L

Chemical	Test species	Test type	Lower 95% CL	Median	Upper 95% CL	Source
<i>Inorganics</i>						
Ammonia	Fathead minnow	Chronic	3.98	100	1585	Mayes et al. 1986
	Fathead minnow	Chronic	3.98	32	200	Thurston et al. 1986
Antimony	Fathead minnow	Acute	5.01	79	501	EPA 1980a
Arsenic III	Fathead minnow	Chronic	100	1995	31623	Call et al. 1983
Arsenic V	Fathead minnow	Acute	20	159	1000	EPA 1985a
	Rainbow trout	Acute	10	100	501	EPA 1985a
	Mosquitofish	Acute	32	398	2512	EPA 1985a
Beryllium	Fathead minnow	Acute	0.35	7.08	40	EPA 1980e
	Bluegill	Acute	2.00	32	126	EPA 1980e
	Flagfish	Acute	1.00	32	126	EPA 1980e
	Guppy	Acute	1.58	25	126	EPA 1980e
Cadmium	Fathead minnow	Chronic	1	10	79	Pickering and Gast 1972
	Bluegill	Chronic	1.99	13	50	Eaton 1974
	Brook trout	Chronic	0.13	1.26	6.31	Benoit et al. 1976
	Brook trout	Chronic	0.32	3.16	25	Sauter et al. 1976
	Flagfish	Chronic	0.63	3.98	50	Carlson et al. 1982
	Flagfish	Chronic	0.79	3.16	7.94	Spehar 1976
Chromium III	Rainbow trout	Chronic	13	126	1000	Stevens and Chapman 1984
			0.79	3.16	7.94	
Chromium VI	Fathead minnow	Chronic	25	158	1260	Pickering 1980
	Rainbow trout	Chronic	100	631	5010	Sauter et al. 1976
Cobalt	Fathead minnow	Acute	0.16	3.98	32	Lind et al. 1978

Table 2 (continued)

Chemical	Test species	Test type	Lower 95% CL	Median	Upper 95% CL	Source
Copper	Fathead minnow	Chronic	0.40	3.98	40	Mount 1968
	Fathead minnow	Chronic	0.32	3.16	16	Mount and Stephan 1969
	Bluegill	Chronic	1.995	13	50	Benoit 1975
	Brook trout	Chronic	1	3.98	16	McKim and Benoit 1971
	Brook trout	Chronic	1	5.01	40	Sauter et al. 1976
	Coho salmon	Chronic	3.16	32	316	Hazel and Meith 1970
	Rainbow trout	Chronic	3.98	32	200	Seim et al. 1984
	Fathead minnow	Chronic	0.20	2.51	16	Smith et al. 1979
Cyanide	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
	Fathead minnow	Acute	56	1000	6310	Smith et al. 1985
Fluoride ion	Rainbow trout	Acute	126	1259	10000	Smith et al. 1985
	Brown trout	Acute	79	1000	6310	AQUIRE*
	Brook trout	Chronic	13	50	316	Holcombe et al. 1976
Lead	Rainbow trout	Chronic	13	100	631	Sauter et al. 1976
	Fathead minnow	Acute	11	112	794	Kimball n.d.
Manganese	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, inorganic	Rainbow trout	Acute	0.004	0.16	1.26	EPA 1985c
	Brook trout	Acute	0.02	0.50	3.98	EPA 1985c
Mercury, methyl	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

Table 2 (continued)

Chemical	Test species	Test type	Lower 95% CL	Median	Upper 95% CL	Source
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 1980x
	Bluegill	Acute	73	1000	6310	EPA 1980x
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
			10	100	501	1979
Zinc	Fathead minnow	Chronic	3.98	40	316	Benoit and Holcombe
	Fathead minnow	Chronic	10	100	501	1978
	Coho salmon	Chronic	3.16	40	316	Brungs 1969
	Flagfish	Chronic	16	126	794	Finlayson and Verrue
	Rainbow trout	Chronic	16	126	794	1980
			6.31	32	126	Spehar 1976
			40	501	5010	Sinley et al. 1974
Zirconium	Fathead minnow	Acute	3.16	50	316	Cushman et al. 1977
	Fathead minnow	Acute	3.16	50	398	Cushman et al. 1977
	Fathead minnow	Acute	32	398	3160	Cushman et al. 1977
	Fathead minnow	Acute	63	794	6310	Cushman et al. 1977
	Bluegill	Acute	10	126	501	Cushman et al. 1977
	Bluegill	Acute	200	2510	15800	Cushman et al. 1977

Table 2 (continued)

Chemical	Test species	Test type	Lower 95% CL	Median	Upper 95% CL	Source
<i>Organics</i>						
AC 222,705	Fathead minnow	Chronic	0.0006	0.01	0.063	Spehar et al. 1983
Acetone	Fathead minnow	Acute	1780	19900	25100	AQUIRE*
	Bluegill	Acute	3160	50100	501000	AQUIRE*
	Rainbow trout	Acute	1260	31600	316000	AQUIRE*
	Mosquitofish	Acute	631	10000	100000	AQUIRE*
AG thiosulfate complex	Fathead minnow	Chronic	1000	10000	79400	LeBlanc et al. 1984
Aldicarb	Fathead minnow	Chronic	3.16	50	631	Pickering and Giliam 1982
			631	10000	100000	
Atrazine	Brook trout	Chronic	100	1000	12600	Macek et al. 1976b
Benzene	Fathead minnow	Acute	10	100	794	EPA 1980c
	Bluegill	Acute	13	158	1000	EPA 1980c
	Rainbow trout	Acute	3.16	40	316	EPA 1980c
	Mosquitofish	Acute	200	3160	25100	EPA 1980c
	Guppy	Acute	32	316	1580	EPA 1980c
Benzidine	Rainbow trout	Acute	5.01	63	398	EPA 1980b
	Lake trout	Acute	3.16	40	251	EPA 1980b
	Flagfish	Acute	10	126	794	EPA 1980b
Benzoic acid	Mosquitofish	Acute	126	1260	10000	AQUIRE*
Benzyl alcohol	Fathead minnow	Acute	16	1780	12600	AQUIRE*
	Bluegill	Acute	6.31	79	398	AQUIRE*

Table 2 (continued)

Chemical	Test species	Test type	Lower 95% CL	Median	Upper 95% CL	Source
Bis(2-ethylhexyl) phthalate	Rainbow trout	Acute	100	1000	7940	AQUIRE*
	Largemouth bass	Acute	25	316	1580	AQUIRE*
	Channel catfish	Acute	0.006	0.40	6.31	AQUIRE*
2-Butanone	Fathead minnow	Acute	501	10000	100000	AQUIRE*
	Mosquitofish	Acute	1990	31600	398000	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	Acute	11	126	1260	EPA 1980f
	Bluegill	Acute	40	398	3160	EPA 1980f
Chloramine	Fathead minnow	Chronic	0.32	3.16	13	Arthur and Eaton 1971
Chlordane	Bluegill	Chronic	0.13	0.40	2.51	Cardwell et al. 1977
	Brook trout	Chronic	0.20	1.26	7.94	Cardwell et al. 1977
Chlorobenzene	Fathead minnow	Acute	11	112	794	EPA 1980g
	Bluegill	Acute	10	126	1000	EPA 1980g
	Guppy	Acute	32	316	2510	EPA 1980g
Chloroform	Bluegill	Acute	79	794	5010	EPA 1980i
	Rainbow trout	Acute	40	398	3160	EPA 1980i

Table 2 (continued)

Chemical	Test species	Test type	Lower 95% CL	Median	Upper 95% CL	Source
p,p'DDD	Fathead minnow	Acute	0.79	13	100	AQUIRE*
	Bluegill	Acute	0.002	0.1	1	AQUIRE*
	Rainbow trout	Acute	0.02	0.40	3.16	AQUIRE*
	Largemouth bass	Acute	0.003	0.13	1	AQUIRE*
	Channel catfish	Acute	0.025	1.26	16	AQUIRE*
2,4-D Butoxyethanol ester	Coho salmon	Chronic	10	100	1260	Finlayson and Verrue 1985
			0.025	50	16	
Diazinon	Fathead minnow Flagfish	Chronic	0.32	3.16	25	Allison and Hermanutz 1977
		Chronic	0.025	3980	16	
Di-n-butyl phthalate	Fathead minnow		10	50	316	Allison and Hermanutz 1977
			10	50	316	
		Chronic	13	251	3980	McCarthy and Whitmore 1985
			10	3980	316	
2,6-Dichlorobenzamide	Rainbow trout	Chronic	1260	12600	50100	Van Leeuwen and Maas 1985
1,3-Dichlorobenzene	Fathead minnow	Chronic	316	1585	15849	Ahmed et al. 1984
1,4-Dichlorobenzene	Fathead minnow	Chronic	32	398	6310	Ahmed 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 1980h EPA 1980h
1,1-Dichloroethene	Fathead minnow Bluegill	Acute Acute	40 50	398 501	3160 3980	EPA 1980k EPA 1980k
2,4-Dichlorophenol	Fathead minnow	Chronic	32	200	1580	Holcombe et al. 1982

Table 2 (continued)

Chemical	Test species	Test type	Lower 95% CL	Median	Upper 95% CL	Source
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 1980f
Diethyl phthalate	Bluegill	Acute	79	1000	6310	AQUIRE*
2,4-Dimethylphenol	Fathead minnow	Chronic	100	1260	19900	Holcombe et al. 1982
Dimethyl phthalate	Rainbow trout	Chronic	0.004	0.04	0.40	Ward and Boeri 1991b
1,3-Dinitrobenzene	Rainbow trout	Chronic	100	1000	7940	Van Der Schalie 1983
	Rainbow trout	Chronic	63	794	6310	Van Der Schalie 1983
Dinoseb	Fathead minnow	Chronic	0.13	3.16	40	Call et al. 1983
Di-n-octyl phthalate	Fathead minnow	Chronic	200	1990	39800	McCarthy and Whitmore
			63	794	316	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
Enolsufan	Fathead minnow	Chronic	0.002	0.016	0.13	Macek et al. 1976b
Ethyl benzene	Fathead minnow	Acute	10	158	1000	EPA 1980m
	Bluegill	Acute	50	501	3980	EPA 1980m
	Guppy	Acute	79	794	5010	EPA 1980m
Fenitrothion	Fathead minnow	Chronic	0.1	126	1990	Kleiner et al. 1984

Table 2 (continued)

Chemical	Test species	Test type	Lower 95% CL	Median	Upper 95% CL	Source
Fluoranthene	Bluegill	Acute	2.00	32	126	EPA 1980n
Fluridone	Fathead minnow	Chronic	32	398	10000	Hamelink et al. 1986
Fonofos	Fathead minnow	Chronic	3.16 79	20 79	158 6310	Pickering and Giliam 1982
Guthion	Fathead minnow	Chronic	0.013	0.13	3.98	Adelman et al. 1976
Heptachlor	Fathead minnow	Chronic	0.01	0.1	0.63	Macek et al. 1976b
Hexachlorobutadiene	Fathead minnow	Chronic	0.32	3.98	63	Benoit et al. 1982
Hexachlorocyclohexane(lindane)	Bluegill	Chronic	0.16	1	6.31	Macek et al. 1976a
Hexachloroethane	Fathead minnow	Chronic	3.98	100	1580	Ahmed 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 79	316 79	1580 6310	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*

Table 2 (continued)

Chemical	Test species	Test type	Lower 95% CL	Median	Upper 95% CL	Source
2-Methylphenol	Fathead minnow	Acute	3.98	40	398	AQUIRE*
	Bluegill	Acute	13	126	1000	AQUIRE*
	Rainbow trout	Acute	6.31	79	398	AQUIRE*
Methylene chloride	Fathead minnow	Acute	63.10	1000	10000	AQUIRE*
	Bluegill	Acute	158	1580	12600	AQUIRE*
Naphthalene	Fathead minnow	Chronic	73	1000	12600	Degraeve et al. 1982
4-Nitrophenol	Fathead minnow	Acute	13	159	1260	AQUIRE*
	Bluegill	Acute	3.98	50	316	AQUIRE*
	Rainbow trout	Acute	6.31	79	398	AQUIRE*
	Channel catfish	Acute	0.79	20	200	AQUIRE*
N-nitrosodiphenylamine	Bluegill	Acute	3.16	40	251	AQUIRE*
PCB's: Aroclor 1221	Cutthroat trout	Acute	0.63	10	50	AQUIRE*
PCB's: Aroclor 1232	Cutthroat trout	Acute	1.26	16	126	AQUIRE*
PCB's: Aroclor 1242	Fathead minnow	Chronic	0.13	1.58	40	Nebeker et al. 1974
PCB's: Aroclor 1248	Flagfish	Chronic	0.13	1.26	7.94	Nebeker et al. 1974
PCB's: Aroclor 1254	Fathead minnow	Chronic	0.1	0.63	7.94	Nebeker et al. 1974
PCB's: Aroclor 1260	Cutthroat trout	Acute	32	316	2510	AQUIRE*
Pentachloroethane	Fathead minnow	Chronic	100	1260	19900	Ahmed et al. 1984

Table 2 (continued)

Chemical	Test species	Test type	Lower 95% CL	Median	Upper 95% CL	Source
Pentachlorophenol	Fathead minnow	Chronic	1.58	32	501	Holcombe et al. 1982
	Fathead minnow	Chronic	0.32	1.99	20	Spehar et al. 1985
	Fathead minnow	Chronic	0.63	6.31	63	Spehar et al. 1985
	Fathead minnow	Chronic	1.26	13	126	Spehar et al. 1985
	Fathead minnow	Chronic	1.99	16	158	Spehar et al. 1985
	Rainbow trout	Chronic	1.58	10	50	Dominguez and Chapman 1984
1-Pentanol	Bluegill	Acute	398	5010	39800	AQUIRE*
	Rainbow trout	Acute	200	2510	19900	AQUIRE*
Permethrin	Fathead minnow	Chronic	0.02	0.40	5.01	Spehar et al. 1983
Phenol	Fathead minnow	Chronic	1000	12600	199000	Degraeve et al. 1980
	Rainbow trout	Chronic	126	1580	15800	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
1,1,2,2-Tetrachloroethane	Fathead minnow	Chronic	251	1580	50100	Ahmed et al. 1984
Tetrachloroethene	Fathead minnow	Acute	3.16	50	398	EPA 1980w
	Bluegill	Acute	10	100	501	EPA 1980w
	Rainbow trout	Acute	3.16	40	316	EPA 1980w
Tetrachloroethylene	Fathead minnow	Chronic	40	1000	12600	Ahmed et al. 1984

Table 2 (continued)

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

*EPA (n.d.)

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 EC_{20} s are the same as those used to calculate advisory values (Appendix).

3.1 INORGANICS

Ammonia. The test EC_{20} value for fish is from Thurston et al. (1986).

Aluminum. The toxicity of aluminum has been shown to vary widely with water hardness and pH (among others are Ingersoll et al., 1990a 1990b; Sadler and Lynam, 1988; and Cleveland et al., 1986). The benchmarks were calculated using only tests in circumneutral water. Lowest chronic values for fish are from Kimball (n.d.), and for daphnids from McCauley et al. (1986). Lowest test EC_{20} values are from Kimball (n.d.).

Antimony. Chronic and test EC_{20} values for antimony are from Kimball (n.d.).

Arsenic III. Official 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). The test EC_{20} values are from Lima et al. (1984) for fish and by Call et al. (1983) and Lima et al. (1984) for daphnids.

Arsenic V. The chronic and test EC_{20} values for fish are from Defoe (1982), and the test EC_{20} for daphnids is from Spehar et al. (1980). The EPA (1986) gives a lowest observed effect level value in lieu of a NAWQC. This value is the lowest observed effect level for adverse effects on freshwater aquatic plants, and therefore does not correspond to our lowest chronic value.

Beryllium. The chronic and test EC_{20} values for daphnids are from Kimball (n.d.).

Boron. The test EC_{20} value for daphnids is from Gerisch (1984).

Cadmium. There are official NAWQC listed for cadmium. The lowest chronic value is from Sauter et al. (1976) for fish and Chapman et al. (n.d.) for daphnids. The test EC_{20} values are from Carlson et al. (1982) for fish and Elnabarawy et al. (1986) for daphnids.

Chromium III. Official NAWQC are listed for chromium III. The lowest chronic value is from Stevens and Chapman (1984) for fish and by Chapman et al. (n.d.) for daphnids. Stevens and Chapman (1984) also provided data for the test EC_{20} value for fish.

Chromium VI. There are official NAWQC for chromium VI. The chronic and test EC_{20} values for fish are from Sauter et al. (1976). For daphnids, the chronic value is from Mount (1982) and the test EC_{20} from Elnabarawy et al. (1986).

Cobalt. The chronic and test EC_{20} values for cobalt are from Kimball (n.d.).

Copper Official NAWQC are listed for copper. The chronic and test EC_{20} values for fish are from Sauter et al. (1976). The chronic and test EC_{20} values for daphnids are from Dave (1984a).

Cyanide. There are official NAWQC for cyanide. The chronic and test EC_{20} values for fish were both from Koenst et al. (1977).

Fluoride ion. Chronic and test EC_{20} values for daphnids are from Dave (1984b).

Iron. The data for the effects of iron on daphnids was from Dave (1984c).

Lead. There are official NAWQC listed for lead. The lowest chronic value for fish is from Davies et al. (1976) and for daphnids from Chapman et al. (n.d.). The test EC_{20} value for fish is from Sauter et al. (1976). The acute- EC_{20} ratio from which the SS test EC_{20} was calculated had to be obtained using a species mean acute value for *Salmo gairdneri* (EPA 1985b) since no acute value was reported by Sauter et al.

Manganese. All chronic and test EC_{20} values for manganese are from Kimball (n.d.).

Mercury, inorganic Mercury has official NAWQC. However, the chronic criterion for mercury is based on the final residue value derived from a methyl mercury bioconcentration factor. For consistency, the criterion used was derived from the final acute and chronic values. The chronic and test EC_{20} values for fish are from Call et al. (1983), and those for daphnids are from Beisinger et al. (1982). The acute- EC_{20} ratio used to calculate the daphnid value had to be derived using a species mean acute value (EPA 1985c) as no acute value was reported in Beisinger et al.

Mercury, methyl. The chronic and test EC_{20} values for fish are from McKim et al. (1976). The chronic and test EC_{20} values for daphnids are from Beisinger et al. (1982).

Molybdenum. The chronic and test EC_{20} values for daphnids are from Kimball (n.d.).

Nickel. There are official NAWQC for nickel. However, nickel concentrations of 10 $\mu\text{g/L}$ in ORR stream water reduced 7 d *Ceriodaphnia dubia* survivorship to 60% (Kszos et al. 1992). This concentration is considerably below the chronic NAWQC for nickel but similar to the lowest of the alternate benchmarks (Table 1). The chronic and test EC_{20} values for fish are from Nebeker et al. (1985). For daphnids, the chronic value was from Lazareva (1985) and the test EC_{20} was from Münzinger (1990).

Selenium. Official NAWQC are listed for selenium. The chronic and test EC_{20} values for fish are from Goettl and Davies (1976). The chronic value for daphnids is from Kimball (n.d.), and the test EC_{20} is from Johnston (1987). The acute- EC_{20} ratio from which the latter value was calculated had to be derived using a species mean acute value for *Daphnia magna* (EPA 1987) because no acute value was reported by Johnston.

Silver. There is an official acute NAWQC for silver. The chronic NAWQC was estimated from the FAV and two measured chronic values (Davies et al. 1978, Nebeker et al. 1983). The chronic value for fish is from Davies et al. (1978). The chronic value for daphnids and

the test EC_{20} for fish are from Nebeker et al. (1983). The test EC_{20} for daphnids is from Elnabarawy et al. (1986).

Thallium. All chronic and test EC_{20} values are from Kimball (n.d.). The EPA (1986) gives a lowest observed effect level value in lieu of a NAWQC. This value is from a document that is unavailable. To be consistent, we derived an advisory value.

Vanadium. The chronic and test EC_{20} values for fish are from Holdway and Sprague (1979), and for daphnids from Kimball (n.d.).

Zinc. There are official NAWQC for zinc. The chronic and test EC_{20} values are from Spehar (1976), and the chronic value for daphnids is from Chapman et al. (n.d.).

3.2 ORGANICS

Acenaphthene. The chronic and test EC_{20} values for fish are from Cairns and Nebeker (1982).

Anthracene. The chronic and test EC_{20} values for daphnids are from Holst and Giesy (1989).

Benzene. The lowest chronic value for daphnids is given by EPA (1978) and the test EC_{20} value for fish is from Black and Birge (1982). This latter report requires comment: Black and Birge conducted a series of screening tests for a large number of chemicals on several freshwater organisms. Larval fish survival was recorded only to 4 d posthatch, and LOECs and NOECs were not determined. These tests, then, did not generate chronic values and are not equivalent to the other chronic tests cited in this report. The test EC_{20} values based on tests by Black and Birge are likely to be high relative to those from conventional chronic tests.

Benzo(a)pyrene. The test EC_{20} for fish is derived from Hannah et al. (1982).

BHC (lindane). There are official NAWQC listed for lindane. All chronic and test EC_{20} values are from Macek et al. (1976a). The acute- EC_{20} ratio from which the SS EC_{20} was calculated was derived using a species mean acute value for *Salvelinus fontinalis* (EPA 1980p) since no acute data was reported by Macek et al.

Bis(2-ethylhexyl)phthalate. The chronic and test EC_{20} values for fish are from Mehrle and Mayer (1976). The chronic and test EC_{20} values for daphnids are from Mayer and Sanders (1973).

Carbon tetrachloride. The chronic value for fish is from EPA (1978), and the test EC_{20} value is from Black and Birge (1982). See the note for benzene.

Chlordane. The official chronic NAWQC for chlordane is based on the final residue value. For consistency, we report an estimated criterion derived from the FAV and final acute/chronic ratio. The lowest chronic and test EC_{20} values are from Cardwell et al. (1977).

Chloroform. The test EC_{20} value for fish is from Black and Birge (1982). See the note for benzene. The EPA (1986) gives a lowest observed effect value in lieu of a NAWQC. This value is a 27-d LC_{50} value, and therefore does not correspond to our lowest chronic value.

DDT. The official chronic NAWQC is based on the final residue value. For consistency, we report an estimated criterion calculated using the FAV and an acute chronic ration derived from the single available chronic value. The chronic and test EC_{20} values for fish are from Jarvinen et al. (1977). The estimated fish chronic value is from EPA (1980j).

Di-n-butyl phthalate. All chronic and test EC_{20} values are from McCarthy and Whitmore (1985).

1,2-Dichloroethane. The chronic value for fish is from Ahmed et al. (1984), and the test EC_{20} value for fish is from Benoit et al. (1982). The chronic and test EC_{20} values for daphnids are from Richter et al. (1983).

1,1-Dichloroethene. The chronic value for fish is from EPA (1978).

Di-n-octyl phthalate. All chronic and test EC_{20} values are from McCarthy and Whitmore (1985).

Ethyl benzene. The chronic value for fish is from EPA (1978).

Heptachlor. The chronic NAWQC is based on the final residue value. For consistency, we report an estimated chronic criterion calculated using the FAV and the single available chronic value. The chronic and test EC_{20} values for fish are from Macek et al. (1976b). The SS test EC_{20} value was calculated using an acute- EC_{20} ratio that was derived from a species mean acute value for *Pimephales promelas* (EPA 1980o) because no acute data is available from Macek et al. (1976b).

4-Methyl-2-pentanone. The chronic value for fish is from Call et al. (1985).

Methylene chloride. The chronic value for fish is from Dill et al. (1987), and the test EC_{20} value is from Black and Birge (1982). See the note for benzene.

Naphthalene. The chronic and test EC_{20} values for fish are from DeGraeve et al. (1982), and the test EC_{20} value for daphnids is from Geiger and Buikema (1982).

4-Nitrophenol. The chronic and test EC_{20} values for daphnids are from Francis et al. (1986). The EPA (1980r) is the source for the estimated fish chronic value and test EC_{20} .

Nitrophenols (total). In lieu of a NAWQC, EPA (1986) gives an acute value which is the lowest observed effect level and a chronic value which is the lowest observed effect level for a species of algae.

N-nitrosodiphenylamine. The source for the estimated fish and daphnid chronic values and the test EC_{20} is EPA (1980aa).

PCBs: Aroclor® 1242. The chronic and test EC_{20} values for fish are from Nebeker et al.

(1974).

PCBs: Aroclor® 1248. The chronic and test EC_{20} values for fish are from DeFoe et al. (1978), and the chronic and test EC_{20} values for daphnids are from Nebeker and Puglisi (1974).

PCBs: Aroclor® 1254. The chronic value for fish is from Mauck et al. (1978), and the test EC_{20} value is from Nebeker et al. (1974). The chronic and test EC_{20} values for daphnids are from Nebeker and Puglisi (1974).

PCBs: Aroclor® 1260. The chronic and test EC_{20} values for fish are from DeFoe et al. (1978).

Phenanthrene. The chronic and test EC_{20} values for daphnids are from Geiger and Buikema (1982).

Phenol. The chronic and test EC_{20} values for fish are from DeGraeve et al. (1980).

1,1,2,2-Tetrachloroethane. The chronic and test EC_{20} values for fish are from Ahmed et al. (1984), and the values for daphnids are from Richter et al. (1983).

Tetrachloroethene. The chronic and test EC_{20} values for fish are from Ahmed et al. (1984). The chronic and test EC_{20} values for daphnids are from Richter et al. (1983).

Toluene. The test EC_{20} value for fish is from Black and Birge (1982). See the note for benzene.

1,1,1-Trichloroethane. The chronic and test EC_{20} values for daphnids are from Thompson and Carmichael (1989). EPA 1980h is the source for the estimated fish chronic value and test EC_{20} .

1,1,2-Trichloroethane. The chronic and test EC_{20} values for fish are from Ahmed et al. (1984), and the chronic and test EC_{20} values for daphnids are from Richter et al. (1983).

Trichloroethene. The chronic and test EC_{20} values for fish are from Smith et al. (1991).

Xylene. The test EC_{20} value for fish is from Black and Birge (1982). See the note for benzene.

4. COMPARISON OF BENCHMARKS

The chronic NAWQC are the lowest benchmark for only 5.5% of the chemicals for which they have been promulgated (Table 3). This result was expected given the characteristics of the criteria discussed above. At the other extreme, the advisory values using the method of Stephan and Erickson were lowest in every case for which they were calculated (i.e., chemicals with some standard data but no NAWQC). This conservatism was not surprising given the goal of the method of ensuring with 95% confidence that these values would not exceed the NAWQC. To determine how conservative the advisory values are in practice, we calculated advisory values for the chemicals with official criteria. Because most of the advisory values were calculated using only four or fewer LC_{50} values (Table 4), we randomly selected one, two, three, and four LC_{50} s from the lists of eight or more LC_{50} s available for each criterion chemical in Table 1 and calculated advisory values for each data set (Table 5). These results demonstrate that the degree of conservatism required to achieve 95% confidence is quite large when data are sparse. To indicate the relative conservatism of the advisory values, the number of acute and chronic test data that were used to calculate each value is listed in Table 4.

Table 3. Comparisons of alternative screening benchmarks for aquatic life on the basis of the number of chemicals for which each could be calculated (n), the percentage of those chemicals for which it was the lowest benchmark, and the median, minimum, and maximum ratio of each benchmark to the chronic NAWQC for the criterion chemicals

	n	Percent lowest	Ratio to chronic NAWQC		
			Median	Minimum	Maximum
Chronic NAWQC	18	5.5	–		
Advisory value	73	100	–		
Fish chronic value					
Measured	44	4.5	2.52	0.18	182.50
Estimated	34	0			
Daphnid chronic value					
Measured	38	5.3	0.74	0.02	181.25
Estimated	29	0			
Fish test EC_{20}					
Measured	47	2.1	1.14	0.39	54.02
Estimated	30	0			
Daphnid test EC_{20}	37	8.1	0.69	0.02	137.50
SS test EC_{20}	17	71	0.14	0.01	2.94
Population EC_{20}	68	0	1.70	0.20	28.7

Table 4. Amount of data available and used to calculate advisory values

(Advisory values based on more data are less conservative.)

Contaminants	Number of LC ₅₀ s	Number of Chronics
Antimony	2	2
Arsenic V	5	1
Barium	1	0
Beryllium	4	1
Cobalt	2	2
Fluorine	4	2
Magnesium	1	0
Manganese	2	1
Mercury, methyl	2	1
Potassium	1	0
Sodium	1	0
Thallium	3	2
Uranium	1	0
Vanadium	4	3
Zirconium	2	0
Acenaphthene	2	1
Acetone	4	0
Anthracene	1	0
Benzene	4	0
Benzidene	3	0
Benzo(a)anthracene	1	0
Benzoic acid	1	0
Benzyl alcohol	2	0
BHC (other than gamma)	1	0
Bis(2-ethylhexyl)phthalate	4	2
2-Butanone	3	0
Carbon disulfide	2	0
Carbon tetrachloride	3	1
Chlorobenzene	4	0
Chloroform	3	0
p,p'DDD	7	0
Decane	1	0
Di-n-butyl phthalate	6	2
Dibenzofuran	1	0
1,1-Dichloroethane	1	0
1,2-Dichloroethane	3	2
1,1-Dichloroethene	3	0
1,2-Dichloroethenes	1	0
1,3-Dichloropropene	2	0
Diethyl phthalate	2	0
Ethyl benzene	4	0
Fluoranthene	2	0
Hexane	1	0
2-Hexanone	1	0
1-Methyl naphthalene	1	0
4-Methyl-2-pentanone	1	1

Table 4 (continued)

Contaminants	Number of LC ₅₀ s	Number of Chronics
2-Methyl phenol	4	0
Methylene chloride	3	1
Naphthalene	4	1
4-Nitrophenol	5	1
N-nitrosodiphenylamine	2	0
3-Octanone	2	0
PCB 1221	1	0
PCB 1232	1	0
PCB 1242	3	2
PCB 1248	1	1
PCB 1254	3	1
PCB 1260	1	0
1-Pentanol	2	0
Phenanthrene	2	0
Phenol	6	2
2-Propanol	1	0
1,1,2,2-Tetrachloroethane	3	2
Tetrachloroethene	5	2
Toluene	4	0
1,1,1-Trichloroethane	2	1
1,1,2-Trichloroethane	3	2
Trichloroethene	3	1
Vinyl acetate	3	0
Vinyl chloride	1	0
Xylene	2	0

Table 5. Quotients of ratios of NAWQC/Advisory Values calculated for those chemicals for which NAWQC were available. The advisory values were calculated for each criterion chemical using one, two, three, and four LC_{50} values chosen at random from the eight or more LC_{50} s used to calculate the NAWQC for that chemical

(The quotients are a measure of the conservatism of the advisory values.)

Data used	Acute criterion	Chronic criterion
One		
LC_{50}	1681	19544
Mean	4.6	52
Minimum	7654	110,000
Maximum		
Two		
LC_{50} s	393	3617
Mean	6.8	77
Minimum	1302	18333
Maximum		
Three		
LC_{50} s	129	1554
Mean	14	22
Minimum	367	4583
Maximum		
Four		
LC_{50} s	6.95	44.69
Mean	0.04	0.42
Minimum	55	239
Maximum		

The other potential lower screening benchmarks are intermediate in their conservatism. In general, benchmarks based on effects on fish are less conservative than those based on daphnids or than the NAWQC that include daphnids. This result is consistent with other studies (Stephan and Erickson n.d., Suter 1992).

The test EC_{20} values are lower than the CVs for the same taxa in 62.5% and 82% of cases for fish and daphnids, respectively. This result is expected given that the test EC_{20} s integrate across life stages but the CVs do not.

After the advisory values, the most conservative benchmark is the SS test EC_{20} . These values are on average 14% of the NAWQC when both could be calculated. They are equivalent to the NAWQC but use integrative test endpoints.

The fact that some CVs for fish and daphnids are lower than chronic NAWQC is surprising at first because conceptually the chronic NAWQC are estimates of CVs for sensitive species. However, the CVs are not used directly but rather are used to calculate acute/chronic ratios that are used in the criteria calculation. Unless a species that is highly

sensitive in a chronic test has a high acute/chronic ratio, it will not lower the chronic NAWQC.

The relative utility of the benchmarks is determined in large part by their availability. The NAWQC and the SS test EC_{20} values are available for relatively few of the chemicals detected on the ORR because they require large data sets. The Advisory Values and the population EC_{20} are available for most of the chemicals because they each require only a single LC_{50} . For the same reason, if estimated values are included, the CVs for fish and daphnids and the test EC_{20} s for fish are available for most chemicals.

The measured test EC_{20} values differ from the other potential benchmarks in that they represent an observed and specified effect. All other benchmarks are estimates (population EC_{20} s and estimated CVs and test EC_{20} s), correspond to no particular effect (CVs and NAWQC), or both (Advisory Values).

Finally, the Advisory Values differ from the other benchmarks in that they are based on lower 5% confidence bounds rather than best estimates of a threshold for significant effects. The lower 5% confidence bound on the Population EC_{20} could be used as an equivalently conservative benchmark (Table 2). Lower 5% prediction intervals can be derived for the estimated CVs and test EC_{20} s by subtracting the PIs listed in the text from the base 10 logs of the estimates reported in Table 1. (For all three of these equations, the variance changes negligibly with deviation from mean $\bar{X}$.) These lower likelihood bounds were not used because the other benchmarks do not have the legal imperative of the NAWQC. However, to be certain of a conservative screen, lower bounds could be substituted for the population EC_{20} s and estimated CVs and test EC_{20} s listed in Table 1.

5. APPLICATION OF BENCHMARKS

Each of the alternative benchmarks has a different interpretation. Exceedances of NAWQC create a regulatory imperative for action under CERCLA because they are ARARS. Exceedance of an advisory value implies a greater than 5% chance that the NAWQC, if its 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 EC_{20} indicates that biologically significant effects levels were exceeded in a chronic toxicity test. Exceedance of the SS test EC_{20} indicates that a biologically significant effect level may be exceeded in a sensitive species. Exceedance of a population EC_{20} indicates that a significant reduction in a largemouth bass population could occur. Hence, exceedance of either the acute or chronic NAWQC indicates a need for action. Exceedance of a chronic advisory level implies a low risk. Exceedance of any of the other benchmarks indicates a risk of real effects, which should lead to additional data collection and assessment. However, these inferences all depend on comparison of the benchmarks to appropriate water concentrations.

As discussed in the introduction, the chronic benchmarks are to be used as lower screening benchmarks. The acute NAWQC and advisory values are to be used as upper screening benchmarks. However, because of their conservatism, exceedance of the acute advisory values cannot be taken to indicate that severe effects are likely to be occurring. If an acute advisory value is exceeded, the assessor should examine the acute values used to generate the advisory value (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 that is nearly all dissolved. That is, they should be compared to concentrations dissolved in ambient water [i.e., 0.1-0.45 μ m filtered before being extracted with acid or organic solvents (HECD 1992)]. Because total recoverable concentrations are required for human health risk assessments, they, rather than dissolved concentrations, are often reported. However, for metals, total recoverable concentrations typically include 30-95% particle-bound material (HECD 1992). Therefore, total recoverable concentrations should be used for aquatic ecological risk assessments only if dissolved concentrations are not available.

The NAWQC for hardness-dependent metals are based on a hardness of 100 mg/L, which is appropriate for ambient waters on the ORR. 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.

These benchmarks may also be applied to sediments if pore water concentrations can be measured or estimated. The EPA (OWRS 1989) has recommended that sediment concentrations be converted to pore water concentrations with equilibrium partitioning models so that the NAWQC can be used as sediment quality criteria. Guidance for assessment of ecological risks from sediments will be presented in a separate document.

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Appendix A

DATA USED FOR ADVISORY VALUE CALCULATIONS

Table A-1. Data used for advisory value calculations (all values in micrograms per liter)

Chemical name/data type	Value	Species	Source
<i>Inorganics</i>			
Antimony			
Acute values	9,000	<i>Daphnia magna</i>	EPA 1980a
	18,800	<i>Daphnia magna</i>	<i>ibid.</i>
	21,900	Fathead minnow	<i>ibid.</i>
Pesticide Acute Value	220		
Acute-Chronic ratios	3.481	<i>Daphnia magna</i>	Kimball n.d.
	13.69	Fathead minnow	<i>ibid.</i>
Pesticide A-C ratio	12.4		
PAV / PACR	18		
Arsenic V			
Acute values	<8,100	<i>Daphnia magna</i>	Epa 1985a
	7,400	<i>Daphnia magna</i>	<i>ibid.</i>
	3,600	<i>Daphnia pulex</i>	<i>ibid.</i>
	49,600	<i>Daphnia pulex</i>	<i>ibid.</i>
	850	<i>Bosmina longirostris</i>	<i>ibid.</i>
	10,800	Rainbow trout	<i>ibid.</i>
	25,600	Fathead minnow	<i>ibid.</i>
	49,000	Mosquitofish	<i>ibid.</i>
PAV	27		
Acute-Chronic ratios	28.7	Fathead minnow	DeFoe 1982
PACR	35.8		
PAV / PACR	0.77		
Barium			
Acute values	410,000	<i>Daphnia magna</i>	(AQUIRE)*
PAV	4,362		
PACR	40		
PAV / PACR	110		

Table A-1 (continued)

Chemical name/data type	Value	Species	Source
<i>Inorganics (continued)</i>			
Beryllium			
Acute values	7,900	<i>Daphnia magna</i>	EPA 1980e
	2,500	<i>Daphnia magna</i>	<i>ibid.</i>
	4,800	Goldfish	<i>ibid.</i>
	3,250	Fathead minnow	<i>ibid.</i>
	200	Fathead minnow	<i>ibid.</i>
	150	Fathead minnow	<i>ibid.</i>
	150	Fathead minnow	<i>ibid.</i>
	11,000	Fathead minnow	<i>ibid.</i>
	20,000	Fathead minnow	<i>ibid.</i>
	15,000	Fathead minnow	<i>ibid.</i>
	18,000	Fathead minnow	<i>ibid.</i>
	4,400	Flagfish	<i>ibid.</i>
	3,530	Flagfish	<i>ibid.</i>
	3,530	Flagfish	<i>ibid.</i>
	32,000	Guppy	<i>ibid.</i>
	28,000	Guppy	<i>ibid.</i>
	32,000	Guppy	<i>ibid.</i>
	24,000	Guppy	<i>ibid.</i>
	160	Guppy	<i>ibid.</i>
	19,000	Guppy	<i>ibid.</i>
	450	Guppy	<i>ibid.</i>
	130	Guppy	<i>ibid.</i>
	200	Guppy	<i>ibid.</i>
	20,000	Guppy	<i>ibid.</i>
	13,700	Guppy	<i>ibid.</i>
	6,100	Guppy	<i>ibid.</i>
	160	Guppy	<i>ibid.</i>
	12,000	Bluegill	<i>ibid.</i>
	1,300	Bluegill	<i>ibid.</i>
PAV	55		
Acute-Chronic ratios	472	<i>Daphnia magna</i>	Kimball n.d.
PACR	91.1		
PAV / PACR	0.61		
Cobalt			
Acute values	5,990	<i>Daphnia magna</i>	Kimball n.d.
	3,610	Fathead minnow	<i>ibid.</i>

Table A-1 (continued)

Chemical name/data type	Value	Species	Source
<i>Inorganics (continued)</i>			
Acute values (cont.)	531	Fathead minnow	Lind et al. 1978
PAV	24		
Acute-Chronic ratios	1,175 290	<i>Daphnia magna</i> Fathead minnow	Kimball n.d. Kimball n.d.
PACR	83.6		
PAV / PACR	0.29		
Fluoride			
Acute values	98,000 251,000 390,247 200,000 245,987 125,000	<i>Daphnia magna</i> <i>Daphnia magna</i> Stickleback Rainbow trout Fathead minnow Brown trout	Dave 1984b Fieser et al. 1986 Smith et al. 1985 <i>ibid.</i> <i>ibid.</i> (AQUIRE)*
PAV	3,734		
Acute-Chronic ratios	8.33 22.27	<i>Daphnia magna</i> <i>Daphnia magna</i>	Fieser et al. 1986 Dave 1984b
PACR	19.5		
PAV / PACR	191		
Magnesium			
Acute values	64,700	Scud	(AQUIRE)*
PAV	6.5		
PACR	40		
PAV / PACR	0.16		
Manganese			
Acute values	19,400 33,800	<i>Daphnia magna</i> Fathead minnow	Kimball n.d. <i>ibid.</i>

Table A-1 (continued)

Chemical name/data type	Value	Species	Source
<i>Inorganics (continued)</i>			
PAV	330		
Acute-Chronic ratios	19.10	Fathead minnow	Kimball n.d.
PACR	31.3		
	11		
PAV / PACR			
Mercury, methyl			
Acute values	25	Rainbow trout	EPA 1985c
	24	Rainbow trout	<i>ibid.</i>
	42	Rainbow trout	<i>ibid.</i>
	24	Rainbow trout	<i>ibid.</i>
	84	Brook trout	<i>ibid.</i>
	65	Brook trout	<i>ibid.</i>
PAV	0.016		
Acute-Chronic ratios	142.3	Brook trout	EPA 1985c
PACR	61.1		
PAV / PACR	0.00027		
Molybdenum			
Acute values	206,800	<i>Daphnia magna</i>	Kimball n.d.
PAV	2,200		
Acute-Chronic ratios	235	<i>Daphnia magna</i>	Kimball n.d.
PACR	72.2		
PAV / PACR	30		
Acute values	53,200	Scud	(AQUIRE)*
PAV	5.3		

Table A-1 (continued)

Chemical name/data type	Value	Species	Source
<i>Inorganics (continued)</i>			
PACR	40		
PAV / PACR	0.13		
Silver			
Final Acute Value	4.1		EPA 1980u
Acute-Chronic ratios	2.0 54		EPA 1980u <i>ibid.</i>
PACR	65.1		
FAV / PACR	0.063		
Sodium			
Acute values	1,820,000	<i>Daphnia magna</i>	(AQUIRE)*
PAV	19,000		
PACR	40		
PAV / PACR	480		
Thallium			
Acute values	2,180 910 1,800 132,000 121,000	<i>Daphnia magna</i> <i>Daphnia magna</i> Fathead minnow Bluegill Bluegill	EPA 1980x <i>ibid.</i> <i>ibid.</i> <i>ibid.</i> <i>ibid.</i>
PAV	27		
Acute-Chronic ratios	7.0 31.58	<i>Daphnia magna</i> Fathead minnow	Kimball n.d. <i>ibid.</i>
PACR	10.8		
PAV / PACR	2.5		
Uranium			
Acute values	2,800	Fathead minnow	Cushman et al. 1977

Table A-1 (continued)

Chemical name/data type	Value	Species	Source
<i>Inorganics (continued)</i>			
Acute values (cont.)	3,100	Fathead minnow	<i>ibid.</i>
	3,700	Fathead minnow	<i>ibid.</i>
	135,000	Fathead minnow	<i>ibid.</i>
PAV	0.28		
PACR	40		
PAV / PACR	0.007		
Vanadium			
Acute values	1,520	<i>Daphnia magna</i>	Kimball n.d.
	1,850	Fathead minnow	<i>ibid.</i>
	7,000	Brook trout	Ernst and Garside 1986
	11,200	Flagfish	Holdway and Sprague 1979
	4,060	<i>Daphnia magna</i>	Beusen and Neven 1987
PAV	44		
Acute-Chronic ratios	10.88	Fathead minnow	Kimball n.d.
	140	Flagfish	Holdway and Sprague 1979
	2.137	<i>Daphnia magna</i>	Beusen and Neven 1987
Final A-C ratio	14.8		
PAV / FACR	2.97		
Zirconium			
Acute values	14,000	Fathead minnow	Cushman et al. 1977
	18,000	Fathead minnow	<i>ibid.</i>
	115,000	Fathead minnow	<i>ibid.</i>
	240,000	Fathead minnow	<i>ibid.</i>
	15,000	Bluegill	<i>ibid.</i>
	270,000	Bluegill	<i>ibid.</i>

Table A-1 (continued)

Chemical name/data type	Value	Species	Source
<i>Inorganics (continued)</i>			
PAV	8.52		
PACR	40		
PAV / PACR	0.213		
<i>Organics</i>			
Acenaphthene			
Acute values	41,200 1,700	<i>Daphnia magna</i> Bluegill	EPA 1980a <i>ibid.</i>
PAV	29		
Acute-Chronic ratios	1.472	Fathead minnow	Cairns and Nebeker 1982
PACR	13.3		
PAV / PACR	2.2		
Acetone			
Acute values	8,300,000 8,300,000 1,300,000 8,140,000 7,310,000 5,540,000 13,500,000 12,600,000 13,300,000 12,100,000 8,800,000 7,460,000 7,810,000	Bluegill Bluegill Mosquitofish Fathead minnow Fathead minnow Rainbow trout <i>Daphnia magna</i> <i>Daphnia magna</i> <i>Daphnia magna</i> <i>Daphnia magna</i> <i>Daphnia pulex</i> <i>Daphnia cucullata</i> <i>Daphnia cucullata</i>	(AQUIRE)* <i>ibid.</i> <i>ibid.</i> <i>ibid.</i> <i>ibid.</i> <i>ibid.</i> <i>ibid.</i> <i>ibid.</i> <i>ibid.</i> <i>ibid.</i> <i>ibid.</i> <i>ibid.</i> <i>ibid.</i>
PAV	31,000		
PACR	40		
PAV / PACR	775		

Table A-1 (continued)

Chemical name/data type	Value	Species	Source
<i>Organics (continued)</i>			
Anthracene			
Acute values	11.92	Sunfish	(AQUIRE)*
	2.78	Bluegill	<i>ibid.</i>
PAV	0.00058		
PACR	40		
PAV / PACR	0.00001		
	4		
Benze			
Acute values	203,000	<i>Daphnia magna</i>	EPA 1980c
	400,000	<i>Daphnia magna</i>	<i>ibid.</i>
	620,000	<i>Daphnia magna</i>	<i>ibid.</i>
	412,000	<i>Daphnia magna</i>	<i>ibid.</i>
	412,000	<i>Daphnia magna</i>	<i>ibid.</i>
	356,000	<i>Daphnia magna</i>	<i>ibid.</i>
	356,000	<i>Daphnia magna</i>	<i>ibid.</i>
	345,000	<i>Daphnia pulex</i>	<i>ibid.</i>
	265,000	<i>Daphnia pulex</i>	<i>ibid.</i>
	5,300	Rainbow trout	<i>ibid.</i>
	34,420	Goldfish	<i>ibid.</i>
	33,470	Fathead minnow	<i>ibid.</i>
	32,000	Fathead minnow	<i>ibid.</i>
	36,600	Guppy	<i>ibid.</i>
	386,000	Mosquitofish	<i>ibid.</i>
	22,490	Bluegill	<i>ibid.</i>
PAV	126		
PACR	40		
PAV / PACR	3.15		
Benzidene			
Acute values	7,400	Rainbow trout	EPA 1980b
	4,350	Lake trout	<i>ibid.</i>
	2,500	Red shiner	<i>ibid.</i>
	16,200	Flagfish	<i>ibid.</i>

Table A-1 (continued)

Chemical name/data type	Value	Species	Source
<i>Organics (continued)</i>			
PAV	5.95		
PACR	40		
PAV / PACR	0.15		
Benzo(a)anthracene			
Acute values	10*	<i>Daphnia pulex</i>	(AQUIRE)*
PAV	0.11		
PACR	40		
PAV / PACR	0.0027		
Benzo(a)pyrene			
Acute values	5*	<i>Daphnia pulex</i>	(AQUIRE)*
PAV	0.053		
PACR	40		
PAV / PACR	0.0013		
Benzoic acid			
Acute values	180,000	Mosquitofish	(AQUIRE)*
PAV	18		
PACR	40		
PAV / PACR	0.45		
Benzylalcohol			
Acute values	10,000 460,000	Bluegill Fathead minnow	(AQUIRE)* <i>ibid.</i>
PAV	5.88		
PACR	40		

Table A-1 (continued)

Chemical name/data type	Value	Species	Source
<i>Organics (continued)</i>			
PAV / PACR	0.147		
BHC (other)			
Acute values	1,000	<i>Daphnia magna</i>	(AQUIRE)*
	800	<i>Daphnia magna</i>	<i>ibid.</i>
PAV	9.5		
PACR	40		
PAV / PACR	0.24		
Bis(2-ethylhexyl)phthalate			
Acute values	11,000	<i>Daphnia magna</i>	(AQUIRE)*
	133	<i>Daphnia pulex</i>	<i>ibid.</i>
	690	Channel catfish	<i>ibid.</i>
	6,180	Goldfish	<i>ibid.</i>
	42,100	Largemouth bass	<i>ibid.</i>
	32,900	Largemouth bass	<i>ibid.</i>
	139,500	Rainbow trout	<i>ibid.</i>
	149,200	Rainbow trout	<i>ibid.</i>
PAV	3.17		
Acute-Chronic ratios	38.73	<i>Daphnia magna</i>	Knowles et al. 1987†
	17,175	Rainbow trout	Mehrle and Mayer 1976†
PACR	299		
PAV / PACR	0.0106		
2-Butanone			
Acute values	5,600,000	Mosquitofish	(AQUIRE)*
	3,200,000	Fathead minnow	<i>ibid.</i>
	5,091,000	<i>Daphnia magna</i>	<i>ibid.</i>
PAV	62,745		
PACR	40		
PAV / PACR	1,569		

Table A-1 (continued)

Chemical name/data type	Value	Species	Source
<i>Organics (continued)</i>			
Carbon disulfide			
Acute values	2,100 135,000	<i>Daphnia magna</i> Mosquitofish	(AQUIRE)* <i>ibid.</i>
PAV	36		
PACR	40		
PAV / PACR	0.91		
Carbon tetrachloride			
Acute values	35,200 43,100 125,000 27,300	<i>Daphnia magna</i> Fathead minnow Bluegill Bluegill	EPA 1980f <i>ibid.</i> <i>ibid.</i> <i>ibid.</i>
PAV	690		
Acute-Chronic ratios	0.8273	Fathead minnow	Kimball n.d.
PACR	11.0		
PAV / PACR	63		
Chlorobenzene			
Acute values	86,000 51,620 33,930 29,120 33,930 45,530 24,000 15,900	<i>Daphnia magna</i> Goldfish Fathead minnow Fathead minnow Fathead minnow Guppy Bluegill Bluegill	EPA 1980g <i>ibid.</i> <i>ibid.</i> <i>ibid.</i> <i>ibid.</i> <i>ibid.</i> <i>ibid.</i> <i>ibid.</i>
PAV	464		
PACR	40		
PAV / PACR	12		
Chloroform			
Acute values	28,900	<i>Daphnia magna</i>	EPA 1980

Table A-1 (continued)

Chemical name/data type	Value	Species	Source
<i>Organics (continued)</i>			
Acute values (cont.)	66,800	Rainbow trout	<i>ibid.</i>
	43,800	Rainbow trout	<i>ibid.</i>
	115,000	Bluegill	<i>ibid.</i>
	100,000	Bluegill	<i>ibid.</i>
PAV	570		
PACR	40		
PAV / PACR	14		
p,p'DDD			
Acute values	2.5	Striped bass	(AQUIRE)*
	380	Stonefly	<i>ibid.</i>
	380	Stonefly	<i>ibid.</i>
	0.60	Scud	<i>ibid.</i>
	0.64	Scud	<i>ibid.</i>
	0.60	Scud	<i>ibid.</i>
	0.86	Scud	<i>ibid.</i>
	0.68	Grass shrimp	<i>ibid.</i>
	2.4	Grass shrimp	<i>ibid.</i>
	10	Aquatic sowbug	<i>ibid.</i>
	16	Aquatic sowbug	<i>ibid.</i>
	140	Fowler's toad	<i>ibid.</i>
	740	Turbellarian	<i>ibid.</i>
	70	Rainbow trout	<i>ibid.</i>
	4,400	Fathead minnow	<i>ibid.</i>
	1,500	Channel catfish	<i>ibid.</i>
	42	Largemouth bass	<i>ibid.</i>
	14	Walleye	<i>ibid.</i>
	42	Bluegill	<i>ibid.</i>
PAV	0.017		
PACR	40		
PAV / PACR	0.00042		
Decane			
Acute values	48,000	<i>Daphnia magna</i>	(AQUIRE)*
PAV	190		

Table A-1 (continued)

Chemical name/data type	Value	Species	Source
<i>Organics (continued)</i>			
PACR	40		
PAV / PACR	4.8		
Di-n-butyl phthalate			
Acute values	1,200	Bluegill	(AQUIRE)*
	731	Bluegill	<i>ibid.</i>
	2,100	Bluegill	<i>ibid.</i>
	760	Bluegill	<i>ibid.</i>
	700	Bluegill	<i>ibid.</i>
	1,300	Fathead minnow	<i>ibid.</i>
	1,300	Fathead minnow	<i>ibid.</i>
	2,020	Fathead minnow	<i>ibid.</i>
	2,910	Channel catfish	<i>ibid.</i>
	2,910	Channel catfish	<i>ibid.</i>
	2,900	Channel catfish	<i>ibid.</i>
	6,470	Rainbow trout	<i>ibid.</i>
	6,470	Rainbow trout	<i>ibid.</i>
	2,600	Rainbow trout	<i>ibid.</i>
	2,100	Scud	<i>ibid.</i>
	10,000	Crayfish	<i>ibid.</i>
	3,700	<i>Daphnia magna</i>	<i>ibid.</i>
	5,200	<i>Daphnia magna</i>	<i>ibid.</i>
PAV	45		
Acute-Chronic ratios	2.817	Fathead minnow	McCarthy and Whitmore 1985
	9.437	<i>Daphnia magna</i>	<i>ibid.</i>
PACR	10.2		
PAV / PACR	4.4		
Diebenzofuran			
Acute values	7,500*	<i>Daphnia magna</i>	(AQUIRE)*
PAV	80		
PACR	40		
PAV / PACR	2.0		

Table A-1 (continued)

Chemical name/data type	Value	Species	Source
<i>Organics (continued)</i>			
1,1-Dichloroethane			
Acute values	202,000	Guppy	(AQUIRE)*
PAV	20		
PACR	40		
PAV / PACR	0.51		
1,2-Dichloroethane			
Acute values	270,000	<i>Daphnia magna</i>	Richter et al. 1983
	218,000	<i>Daphnia magna</i>	EPA 1980h
	118,000	Fathead minnow	<i>ibid.</i>
	550,000	Bluegill	<i>ibid.</i>
	431,000	Bluegill	<i>ibid.</i>
PAV	2,314		
Acute-Chronic ratios	5.9	Fathead minnow	Ahmed et al. 1984
	17.76	<i>Daphnia magna</i>	Richter et al. 1983
PACR	16.1		
PAV / PACR	144		
1,1-Dichloroethene			
Acute values	11,600	<i>Daphnia magna</i>	EPA 1980k
	79,000	<i>Daphnia magna</i>	<i>ibid.</i>
	169,000	Fathead minnow	<i>ibid.</i>
	108,000	Fathead minnow	<i>ibid.</i>
	73,900	Bluegill	<i>ibid.</i>
PAV	594		
PACR	40		
PAV / PACR	15		
1,2-Dichloroethene			
Acute values	135,000	Bluegill	EPA 1980k

Table A-1 (continued)

Chemical name/data type	Value	Species	Source
<i>Organics (continued)</i>			
PAV	14		
PACR	40		
PAV / PACR	0.34		
1,3-Dichloropropene (total)			
Acute values	6,150 6,060	<i>Daphnia magna</i> Bluegill	EPA 1980l <i>ibid.</i>
PAV	100		
PACR	40		
PAV / PACR	2.6		
Diethylphthalate			
Acute values	120,000* 52,000* 75,000*	Bluegill <i>Daphnia magna</i> <i>Daphnia magna</i>	(AQUIRE)* <i>ibid.</i> <i>ibid.</i>
PAV	1,100		
PACR	40		
PAV / PACR	27		
Ethylbenzene			
Acute values	75,000 94,440 48,510 42,330 97,100 32,000 155,000	<i>Daphnia magna</i> Goldfish Fathead minnow Fathead minnow Guppy Bluegill Bluegill	EPA 1980m <i>ibid.</i> <i>ibid.</i> <i>ibid.</i> <i>ibid.</i> <i>ibid.</i> <i>ibid.</i>
PAV	1,079		
PACR	40		
PAV / PACR	27		

Table A-1 (continued)

Chemical name/data type	Value	Species	Source
<i>Organics (continued)</i>			
Fluoranthene			
Acute values	325,000 3,980	<i>Daphnia magna</i> Bluegill	EPA 1980n <i>ibid.</i>
PAV	69		
PACR	40		
PAV / PACR	1.7		
Hexane			
Acute values	150,000‡ 4,480,000‡	Golden orfe Golden orfe	(AQUIRE)* <i>ibid.</i>
PAV	82		
PACR	40		
PAV / PACR	2.1		
2-Hexanone			
Acute values	428,000‡	Fathead minnow	(AQUIRE)*
PAV	43		
PACR	40		
PAV / PACR	1.1		
1-Methylnaphthalene			
Acute values	9,000	Fathead minnow	(AQUIRE)*
PAV	0.90		
PACR	40		
PAV / PACR	0.023		
4-Methyl-2-pentanone			
Acute values	509,000	Fathead minnow	(AQUIRE)*

Table A-1 (continued)

Chemical name/data type	Value	Species	Source
<i>Organics (continued)</i>			
PAV	51		
Acute-Chronic ratios	608	Fathead minnow	Veith et al. 1983
PACR	22.2		
PAV / PACR	2.3		
2-Methylphenol			
Acute values	12,550	Fathead minnow	(AQUIRE)*
	13,420	Fathead minnow	<i>ibid.</i>
	18,200	Fathead minnow	<i>ibid.</i>
	20,780	Bluegill	<i>ibid.</i>
	23,250	Goldfish	<i>ibid.</i>
	8,400	Rainbow trout	<i>ibid.</i>
	17,400	<i>Daphnia cucullata</i>	<i>ibid.</i>
	15,500	<i>Daphnia cucullata</i>	<i>ibid.</i>
	9,800	<i>Daphnia magna</i>	<i>ibid.</i>
	8,600	<i>Daphnia magna</i>	<i>ibid.</i>
	23,800	<i>Daphnia magna</i>	<i>ibid.</i>
	23,100	<i>Daphnia magna</i>	<i>ibid.</i>
	15,100	<i>Daphnia magna</i>	<i>ibid.</i>
	15,800	<i>Daphnia magna</i>	<i>ibid.</i>
	15,800	<i>Daphnia magna</i>	<i>ibid.</i>
	5,000	<i>Daphnia magna</i>	<i>ibid.</i>
	14,000	<i>Daphnia magna</i>	<i>ibid.</i>
	10,800	<i>Daphnia pulex</i>	<i>ibid.</i>
	8,500	<i>Daphnia pulex</i>	<i>ibid.</i>
PAV	310		
PACR	40		
PAV / PACR	7.7		

Table A-1 (continued)

Chemical name/data type	Value	Species	Source
<i>Organics (continued)</i>			
Mercury, methyl			
Acute values	25	Rainbow trout	EPA 1985c
	24	Rainbow trout	<i>ibid.</i>
	42	Rainbow trout	<i>ibid.</i>
	24	Rainbow trout	<i>ibid.</i>
	84	Brook trout	<i>ibid.</i>
	65	Brook trout	<i>ibid.</i>
PAV	0.016		
Acute-Chronic ratios	142.3	Brook trout	EPA 1985c
Methylene chloride			
Acute values	220,000	Bluegill	(AQUIRE)*
	193,000	Fathead minnow	<i>ibid.</i>
	502,000	Fathead minnow	<i>ibid.</i>
	220,000	<i>Daphnia magna</i>	<i>ibid.</i>
PAV	4,314		
Acute-Chronic ratios	4.65	Fathead minnow	Dill et al. 1987
PACR	19.5		
PAV / PACR	221		
Naphthalene			
Acute values	8,570	<i>Daphnia magna</i>	EPA 1980q
	2,300	Rainbow trout	<i>ibid.</i>
	4,900	Fathead minnow	<i>ibid.</i>
	8,900	Fathead minnow	<i>ibid.</i>
	150,000	Mosquitofish	<i>ibid.</i>
PAV	55		
Acute-Chronic ratios	10.65	Fathead minnow	DeGraeve et al. 1982
PACR	25.7		
PAV / PACR	2.1		

Table A-1 (continued)

Chemical name/data type	Value	Species	Source
<i>Organics (continued)</i>			
4-Nitrophenol			
Acute values	8,300	Bluegill	(AQUIRE)*
	59,000	Fathead minnow	<i>ibid.</i>
	62,000	Fathead minnow	<i>ibid.</i>
	41,000	Fathead minnow	<i>ibid.</i>
	7,900	Rainbow trout	<i>ibid.</i>
	15,000	Channel catfish	<i>ibid.</i>
	22,000	<i>Daphnia magna</i>	<i>ibid.</i>
	8,400	<i>Daphnia magna</i>	<i>ibid.</i>
	20,000	<i>Daphnia magna</i>	<i>ibid.</i>
	8,400	<i>Daphnia magna</i>	<i>ibid.</i>
	7,680	<i>Daphnia magna</i>	<i>ibid.</i>
	13,200	River snail	<i>ibid.</i>
PAV	255		
Acute-Chronic ratios	2.83	<i>Daphnia magna</i>	Francis et al. 1986†
PACR	16.5		
PAV / PACR	15		
N-Nitrosodiphenylamine			
Acute values	5,800	Bluegill	(AQUIRE)*
	7,800	<i>Daphnia magna</i>	<i>ibid.</i>
PAV	100		
PACR	40		
PAV / PACR	2.5		
3-Octanone			
Acute values	80,000*	Goldfish	(AQUIRE)*
	517,000*	<i>Daphnia magna</i>	<i>ibid.</i>
PAV	1,400		
PACR	40		
PAV / PACR	34		

Table A-1 (continued)

Chemical name/data type	Value	Species	Source
<i>Organics (continued)</i>			
PCBs: Aroclor^o 1221			
Acute values	1,200	Cutthroat trout	(AQUIRE)*
	1,170	Cutthroat trout	<i>ibid.</i>
	1,170	Cutthroat trout	<i>ibid.</i>
PAV	0.12		
PACR	40		
PAV / PACR	0.0029		
PCBs: Aroclor^o 1232			
Acute values	2,500	Cutthroat trout	(AQUIRE)*
	2,500	Cutthroat trout	<i>ibid.</i>
	2,500	Cutthroat trout	<i>ibid.</i>
	1,900	Cutthroat trout	<i>ibid.</i>
PAV	0.23		
PACR	40		
PAV / PACR	0.0058		
PCBs: Aroclor^o 1242			
Acute values	73	Scud	EPA 1980t
	10	Scud	<i>ibid.</i>
	400	Damselfly	<i>ibid.</i>
	15	Fathead minnow	<i>ibid.</i>
	300	Fathead minnow	<i>ibid.</i>
PAV	0.21		
Acute-Chronic ratios	14.90	Scud	EPA 1980t
	7.454	Fathead minnow	<i>ibid.</i>
PACR	16.4		
PAV / PACR	0.01		
PCBs: Aroclor^o 1248			
Acute values	52	Scud	EPA 1980t

Table A-1 (continued)

Chemical name/data type	Value	Species	Source
<i>Organics (continued)</i>			
Acute values (cont.)	29	Scud	<i>ibid.</i>
PAV	0.004		
Acute-Chronic ratios	8.788	Scud	EPA 1980t
PACR	24.1		
PAV / PACR	0.0002		
PCBs: Aroclor® 1254			
Acute values	2,400	Scud	EPA 1980t
	200	Damselfly	<i>ibid.</i>
	7.7	Fathead minnow	<i>ibid.</i>
PAV	0.37		
Acute-Chronic ratios	2.655	Fathead minnow	EPA 1980t
PACR	16.20		
PAV / PACR	0.02		
PCBs: Aroclor® 1260			
Acute values	60,900	Cutthroat trout	(AQUIRE)*
	61,000	Cutthroat trout	<i>ibid.</i>
	25,000	Cutthroat trout	<i>ibid.</i>
PAV	4.5		
PACR	40		
PAV / PACR	0.11		
1-Pentanol			
Acute values	650,000	Bluegill	(AQUIRE)*
	400,000	Rainbow trout	<i>ibid.</i>
PAV	240		
PACR	40		

Table A-1 (continued)

Chemical name/data type	Value	Species	Source
<i>Organics (continued)</i>			
PAV / PACR	5.9		
Phenanthrene			
Acute values	960	<i>Daphnia pulex</i>	(AQUIRE)*
	490	Midge	<i>ibid.</i>
	700	<i>Daphnia magna</i>	<i>ibid.</i>
	843	<i>Daphnia magna</i>	<i>ibid.</i>
	734	<i>Daphnia magna</i>	<i>ibid.</i>
PAV	8.4		
Acute-Chronic ratios	4.8	<i>Daphnia pulex</i>	Geiger and Buikema 1982
PACR	19.8		
PAV / PACR	0.43		
Phenol			
Acute values ^a	248,000	Rotifer	EPA 1980s
	94,000	Snail	<i>ibid.</i>
	14,000	<i>Daphnia longispina</i>	<i>ibid.</i>
	36,400	<i>Daphnia magna</i>	<i>ibid.</i>
	58,100	<i>Daphnia pulex</i>	<i>ibid.</i>
	57,000	<i>Polyphemus pediculus</i>	<i>ibid.</i>
	122,000	<i>Cyclops vernalis</i>	<i>ibid.</i>
	108,000	<i>Mesocyclops leukarti</i>	<i>ibid.</i>
	8,032	Rainbow trout	<i>ibid.</i>
	44,500	Goldfish	<i>ibid.</i>
	35,000	Fathead minnow	<i>ibid.</i>
	16,700	Channel catfish	<i>ibid.</i>
	36,300	Flagfish	<i>ibid.</i>
	26,000	Mosquitofish	<i>ibid.</i>
	34,900	Guppy	<i>ibid.</i>
	16,400	Bluegill	<i>ibid.</i>
	19,000	Mozambique mouthbrooder	<i>ibid.</i>
PAV	448		

^aBecause the list of acute values for phenol is so long, the species mean acute values have been substituted here.

Table A-1 (continued)

Chemical name/data type	Value	Species	Source
<i>Organics (continued)</i>			
Acute-Chronic ratios	14.06	Fathead minnow	EPA 1980s†
	18.19	Fathead minnow	DeGraeve et al. 1980
PACR	21.7		
PAV / PACR	21		
2-Propanol			
Acute values	11,130,000	Fathead minnow	(AQUIRE)*
	10,000	Fathead minnow	<i>ibid.</i>
	9,610,000	Fathead minnow	<i>ibid.</i>
PAV	100		
PACR	40		
PAV / PACR	2.6		
1,1,2,2-Tetrachloroethane			
Acute values	21,000	Bluegill	(AQUIRE)*
	20,300	Fathead minnow	<i>ibid.</i>
	20,400	Fathead minnow	<i>ibid.</i>
	62,000	<i>Daphnia magna</i>	<i>ibid.</i>
	9,320	<i>Daphnia magna</i>	EPA 1980h
	20,300	Fathead minnow	<i>ibid.</i>
	21,300	Bluegill	<i>ibid.</i>
PAV	399		
Acute-Chronic ratios	8.46	Fathead minnow	Ahmed et al. 1984
	6.289	<i>Daphnia magna</i>	Richter et al. 1983
PACR	12.9		
PAV / PACR	31		
Tetrachloroethene			
Acute values	8,500	<i>Daphnia magna</i>	Richter et al. 1983
	17,700	<i>Daphnia magna</i>	EPA 1980v
	30,840	<i>Tanytarsus dissimilis</i>	<i>ibid.</i>
	4,800	Rainbow trout	<i>ibid.</i>
	5,800	Rainbow trout	<i>ibid.</i>

Table A-1 (continued)

Chemical name/data type	Value	Species	Source
<i>Organics (continued)</i>			
Acute values (cont.)	13,460	Fathead minnow	<i>ibid.</i>
	18,400	Fathead minnow	<i>ibid.</i>
	21,400	Fathead minnow	<i>ibid.</i>
	12,900	Bluegill	<i>ibid.</i>
PAV	170		
Acute-Chronic ratios	16.02	Fathead minnow	Ahmed et al. 1984
	11.35	<i>Daphnia magna</i>	Richter et al. 1983
PACR	19.4		
PAV / PACR	8.8		
Toluene			
Acute values	60,000	<i>Daphnia magna</i>	EPA 1980y
	313,000	<i>Daphnia magna</i>	<i>ibid.</i>
	22,800	Goldfish	<i>ibid.</i>
	57,680	Goldfish	<i>ibid.</i>
	34,270	Fathead minnow	<i>ibid.</i>
	42,330	Fathead minnow	<i>ibid.</i>
	59,300	Guppy	<i>ibid.</i>
	24,000	Bluegill	<i>ibid.</i>
	17,500	Bluegill	<i>ibid.</i>
PAV	417		
PACR	40		
PAV / PACR	10.4		
1,1,1-Trichloroethane			
Acute values	40,000	Bluegill	(AQUIRE)*
	52,800	Fathead minnow	<i>ibid.</i>
	105,000	Fathead minnow	<i>ibid.</i>
PAV	24		
Acute-Chronic ratios	3.057 ^b	<i>Daphnia magna</i>	Thompson & Carmichael 1989

^bbased on a 17-d
LC₅₀ (standard is 48 h).

Table A-1 (continued)

Chemical name/data type	Value	Species	Source
<i>Organics (continued)</i>			
PACR	17.0		
PAV / PACR	1.386		
1,1,2-Trichloroethane			
Acute values	81,700	Fathead minnow	(AQUIRE)*
	18,000	<i>Daphnia magna</i>	<i>ibid.</i>
	43,000	<i>Daphnia magna</i>	<i>ibid.</i>
	190,000	<i>Daphnia magna</i>	<i>ibid.</i>
	170,000	<i>Daphnia magna</i>	<i>ibid.</i>
	170,000	Great pond snail	<i>ibid.</i>
PAV	1,400		
Acute-Chronic ratios	8.691	Fathead minnow	Ahmed et al. 1984
	9.776	<i>Daphnia magna</i>	Richter et al. 1983
PACR	15.0		
PAV / PACR	92		
Trichloroethene			
Acute values	85,200	<i>Daphnia magna</i>	EPA 1980z
	100,000	<i>Daphnia magna</i>	<i>ibid.</i>
	94,000	<i>Daphnia magna</i>	<i>ibid.</i>
	41,000	<i>Daphnia magna</i>	<i>ibid.</i>
	43,000	<i>Daphnia magna</i>	<i>ibid.</i>
	55,000	<i>Daphnia magna</i>	<i>ibid.</i>
	56,000	<i>Daphnia magna</i>	<i>ibid.</i>
	51,000	<i>Daphnia pulex</i>	<i>ibid.</i>
	39,000	<i>Daphnia pulex</i>	<i>ibid.</i>
	40,700	Fathead minnow	<i>ibid.</i>
	66,800	Fathead minnow	<i>ibid.</i>
	44,700	Bluegill	<i>ibid.</i>
	28,280	Flagfish	Smith et al. 1991
PAV	877		
Acute-Chronic ratios	2.558	Flagfish	Smith et al. 1991
PACR	16.0		
PAV / PACR	55		

Table A-1 (continued)

Chemical name/data type	Value	Species	Source
<i>Organics (continued)</i>			
Vinyl acetate			
Acute values	13,465 ^c	Fathead minnow	(AQUIRE)*
	18,000	Bluegill	<i>ibid.</i>
	42,330	Goldfish	<i>ibid.</i>
	31,080	Guppy	<i>ibid.</i>
PAV	32		
PACR	40		
PAV / PACR	0.80		
Vinyl chloride			
Acute values	356,000‡	Golden orfe	(AQUIRE)*
	406,000‡	Golden orfe	<i>ibid.</i>
PAV	38		
PACR	40		
PAV / PACR	0.95		
Xylene			
Acute values	780,000	Common carp	(AQUIRE)*
	99,500	Calanoid copepod	<i>ibid.</i>
PAV	59		
PACR	40		
PAV / PACR	1.5		

^cWater hardness was varied in this test; a logarithmic regression was performed according to the National Guidelines, and 13,465 µg/L is the intercept value.

*These acute tests were of a non-standard duration. Standard durations are 48 h. for daphnids and midges, and 96 h. for all other aquatic animals.

†These reports contained no acute value to accompany the chronic values, so a species mean acute value derived from other available studies was used to calculate the ratio.

‡These test results are unreliable in that either a test duration was not specified or the experimental methods were not usual or not consistent, but they are the best data available.

Appendix B

FACTORS FOR ESTIMATION OF THE PESTICIDE ACUTE VALUE

Table B-1. Factors for estimation of the PAV (Erickson and Stephan n.d.)

Number of LC ₅₀ s ^a	Factor for data sets that include a LC ₅₀ ^a for a daphnid ^b	Factors for data sets that do not include a LC ₅₀ ^a for a daphnid ^b
1	94	10,000
2	58	1,700
3	51	420
4	42	180
5	31	110
6	22	64
7	13	40

^aAll LC₅₀s should be from different families and otherwise should meet the requirements of data used to calculate final acute values (Stephan et al. 1985, EPA 1985a). Multiple LC₅₀s for a species should be geometrically averaged to generate a species mean LC₅₀. Species mean LC₅₀s for congeneric species should be geometrically averaged and those genus mean LC₅₀s should be used in the calculations.

^bDaphnids includes members of the genera *Daphnia*, *Ceriodaphnia*, and *Simocephalus*.

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