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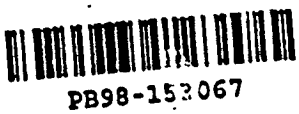
1995 Updates:



Water Quality Criteria Documents for the Protection of Aquatic Life in Ambient Water

CONTENTS

INTRODUCTION

The purpose of these updates is to apply the methodology and datasets used in the derivation of the GLI aquatic life criteria to the national aquatic life criteria for these pollutants in fresh water. The methodology is that described for Tier I in Appendix A to Part 132: Great Lakes Water Quality Initiative Methodologies for Development of Aquatic Life Criteria and Values (Federal Register 60:15393-15399; March 23, 1995). This methodology differs from that described in the 1985 Guidelines (U.S. EPA 1985) in the following important ways:

a. The GLI methodology gives preference to species that are resident in the Great Lakes System. This has no impact on these criteria, however, because the sensitive species in these datasets that are considered commercially or recreationally important for the purposes of deriving national aquatic life criteria are the same as the sensitive species in these datasets that are considered commercially or recreationally important for the purposes of deriving GLI aquatic life criteria.
b. The GLI methodology does not use the Final Residue Value (FRV) that was used in the 1985 Guidelines. Instead of using the FRV in the derivation of aquatic life criteria, human health and wildlife criteria are to be derived using guidelines that are designed to provide adequate protection to human health and wildlife.
c. Acute-Chronic Ratios (ACRs) for saltwater species are not used in the derivation of criteria for freshwater species if the Minimum Data Requirements for chronic data are satisfied by data for freshwater species..

Other aspects of the methodology are generally identical to those presented in the 1985 Guidelines.

Although it is not part of the methodology, if the range of Species Mean Acute Values (SMAVs) or Species Mean Chronic Values (SMCVs) within a genus was greater than a factor of five, the Genus Mean Acute Value or Genus Mean Chronic Value was set equal to the lowest SMAV or SMCV in that genus to provide adequate protection to the tested species in the genus. Whenever this was done, it is footnoted in the relevant table.

The datasets used in these updates used new data that were considered to be of acceptable quality along with the data in the criteria documents previously published by the U.S. EPA, which are referenced in the section for each pollutant. "New data" are data that became available since the last literature search used in the preparation of the criteria document by U.S. EPA and prior

to January 1993. Some errors in the U.S. EPA criteria documents were corrected and the new taxonomy for salmonids was used; some SMAVs and GMAVs are different from those in the U.S. EPA criteria documents due to the preference for results of "flow-through, measured" tests. Although some new data could have been used to revise the slopes relating acute and/or chronic toxicity to hardness or pH, it was decided that revision was not necessary at this time. Thus all of the slopes used herein are the same as those used in the criteria documents previously published by the U.S. EPA.

These updates affect criterion concentrations (i.e., Criterion Maximum Concentrations and/or Criterion Continuous Concentrations), but not averaging periods or frequencies of allowed exceedances. Four digits are given in the criterion concentrations because these are intermediate values in the derivation of permit limits.

The following abbreviations are used in this document:

ACR = Acute-Chronic Ratio
CCC = Criterion Continuous Concentration
CMC = Criterion Maximum Concentration
FAV = Final Acute Value
FCV = Final Chronic Value
GMAV = Genus Mean Acute Value
GMCV = Genus Mean Chronic Value
FACR = Final Acute-Chronic Ratio
SMACR = Species Mean Acute-Chronic Ratio
SMAV = Species Mean Acute Value
SMCV = Species Mean Chronic Value

1995 UPDATE:
Freshwater Aquatic Life Criterion for Arsenic(III)

The new acceptable acute and chronic data for arsenic(III) are given in Tables A1 and A2. These new data were used with those given in Tables 1 and 2 of the criteria document for arsenic (U.S. EPA 1985) to obtain the values given in Table A3.

Criterion Maximum Concentration (CMC)

The Final Acute Value (FAV) was calculated using the four lowest Genus Mean Acute Values given in Table A3, resulting in a FAV of 679.6 ug/L. This value did not need to be lowered to protect a commercially or recreationally important species. The CMC was calculated by dividing the FAV by 2, resulting in a CMC of 339.8 ug/L, as total recoverable arsenic(III).

Criterion Continuous Concentration (CCC)

Insufficient chronic toxicity data were available to calculate a Final Chronic Value (FCV) using the eight-family procedure. Sufficient chronic data were available to calculate a FCV by dividing the FAV by the Final Acute-Chronic Ratio (FACR). The new chronic test gave an ACR of 3.784; the geometric mean of this value and the ACR in U.S. EPA (1985) for the same species was 4.199. This and the two other Species Mean ACRs in U.S. EPA (1985) are given in Table A3; the three ACRs were within a factor of 1.2. The FACR was calculated as the geometric mean of the three ACRs and was 4.594. The FCV = FAV/FACR = (679.6 ug/L)/(4.594) = 147.9 ug/L. This value did not need to be lowered to protect a commercially or recreationally important species. The CCC was 147.9 ug/L, as total recoverable arsenic(III).

The Criterion

The procedures described in the methodology indicate that, except possibly where a locally important species is very sensitive, freshwater aquatic organisms should not be affected unacceptably if the four-day average concentration of arsenic(III) does not exceed 147.9 ug/L more than once every three years on the average and if the one-hour average concentration does not exceed 339.8 ug/L more than once every three years on the average.

Table A1. New Acute Values for Arsenic(III)

Species	Method*	Chemical	Test Duration (hrs)	Acute Value (ug/L)	Reference
Fathead minnow, Pimephales promelas	FT,M	Sodium arsenite	96	12,600	Spehar and Fiandt 1986
Cladoceran, Daphnia magna	S,U	Sodium arsenite	48	4,501	Elnabarawy et al. 1986
Cladoceran, Daphnia pulex	S,U	Sodium arsenite	48	2,366	Elnabarawy et al. 1986
Cladoceran, Ceriodaphnia reticulata	S,U	Sodium arsenite	48	1,269	Elnabarawy et al. 1986

* FT = flow-through, M = measured, S = static, U = unmeasured.

Table A2. New Chronic Values for Arsenic(III)

Species	Test*	Acute Value (ug/L)	Chronic Value (ug/L)	Acute-Chronic Ratio	Reference
Fathead minnow, Pimephales promelas	ELS	12,600	3,330	3.784	Spehar and Fiandt 1986

* ELS = early life stage.

Table A3. Ranked Genus Mean Acute Values for Arsenic(III)

Rank*	Genus Mean Acute Value (ug/L)	Species	Species Mean Acute Value (ug/L)	Species Mean Acute-Chronic Ratio
14	97,000	Midge, Tanytarsus dissimilis	97,000	-----
13	41,760	Bluegill, Lepomis macrochirus	41,760	-----
12	26,040	Goldfish, Carassius auratus	26,040	-----
11	24,500	Snail, Aplexa hypnorum	24,500	-----
10	22,040	Stonefly, Pteronarcys californica	22,040	-----
9	20,130	Flagfish, Jordanella floridae	20,130	4.862
8	18,100	Channel catfish Ictalurus punctatus	18,100	-----
7	14,960	Brook trout, Salvelinus fontinalis	14,960	-----
6	14,065	Fathead minnow, Pimephales promelas	14,065	4.199
5	13,340	Rainbow trout, Oncorhynchus mykiss	13,340	-----
4	2,690	Cladoceran, Daphnia magna	4,449	4.748
		Cladoceran, Daphnia pulex	1,626	-----
3	1,511	Cladoceran, Ceriodaphnia reticulata	1,511	-----
2	1,175	Cladoceran, Simocephalus serrulatus	812	-----
		Cladoceran, Simocephalus vetulus	1,700	-----
1	874	Amphipod, Gammarus pseudolimnaeus	874	-----

- Ranked from most resistant to most sensitive based on Genus Mean Acute Value.

FAV = 679.6 ug/L

CMC = FAV/2 = 339.8 ug/L

FACR = 4.594

FCV = FAV/FACR = (679.6 ug/L)/(4.594) = 147.9 ug/L = CCC

References

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.

Spehar, R.L., and J.T. Fiandt. 1986. Acute and Chronic Effects of Water Quality Criteria-based Metal Mixtures on Three Aquatic Species. Environ. Toxicol. Chem. 5:917-931.

U.S. EPA. 1985. Ambient Water Quality Criteria for Arsenic - 1984. EPA 440/5-84-033. National Technical Information Service, Springfield, VA.

1995 UPDATE:
Freshwater Aquatic Life Criterion for Cadmium

The new acceptable acute and chronic data for cadmium are given in Tables B1 and B2. These new data were used with those given in Tables 1 and 2 of the criteria document for cadmium (U.S. EPA 1985) to obtain the values given in Tables B3 and B4. Because the toxicity of cadmium is hardness-dependent, all acute and chronic values in Tables B3 and B4 have been adjusted to a hardness of 50 mg/L.

Criterion Maximum Concentration (CMC)

The SMAVs given in Table B3 for the green sunfish, bluegill, coho salmon, and rainbow trout were derived from U.S. EPA (1985) by giving preference to results of "FT,M" tests. Several SMAVs given in U.S. EPA (1985) were changed or eliminated due to deletion of tests that were conducted in river water by Spehar and Carlson (1984a,b).

The Final Acute Value (FAV) was calculated using the four lowest Genus Mean Acute Values in Table B3, resulting in an FAV of 4.134 ug/L at a hardness of 50 mg/L. This value did not need to be lowered to protect a commercially or recreationally important species. The CMC was calculated by dividing the FAV by 2, resulting in a CMC of 2.067 ug/L, as total recoverable cadmium, at a hardness of 50 mg/L. The CMC was related to hardness using the slope of 1.128 that was derived in U.S. EPA (1985):

$$CMC = e^{1.128(\ln \text{hardness}) - 3.6867}$$

Criterion Continuous Concentration (CCC)

Two chronic values given in U.S. EPA (1985) were not used here because the tests were conducted in river water by Spehar and Carlson (1984a,b). The chronic value given in U.S. EPA (1985) for *Moina macrocopa* was not used here because the concentrations of cadmium were not measured.

Chronic toxicity tests have been conducted on cadmium with a wide variety of aquatic species and the resulting ACRs have a wide range, even within sensitive species (U.S. EPA 1985). Therefore, the Final Chronic Value (FCV) was calculated using the eight-family procedure that was used to calculate the FAV and was used to calculate the FCV for cadmium in U.S. EPA (1985). As in U.S.

EPA (1985), the FCV was calculated using the value of n used in the calculation of the FAV (i.e., n = 43). The FCV was 1.4286 ug/L at a hardness of 50 mg/L. This value did not need to be lowered to protect a commercially or recreationally important species. Thus the CCC was 1.4286 ug/L, as total recoverable cadmium, at a hardness of 50 mg/L. The CCC was related to hardness using the slope of 0.7852 that was derived in U.S. EPA (1985):

$$CCC = e^{0.7852(\ln \text{hardness}) - 2.715}$$

The Criterion

The procedures described in the methodology indicate that, except possibly where a locally important species is very sensitive, freshwater aquatic organisms should not be affected unacceptably if the four-day average concentration of cadmium does not exceed the numerical value (in ug/L) given by the equation

$$CCC = e^{0.7852(\ln \text{hardness}) - 2.715}$$

more than once every three years on the average and if the one-hour average concentration does not exceed the numerical value (in ug/L) given by the equation

$$CMC = e^{1.128(\ln \text{hardness}) - 3.6867}$$

more than once every three years on the average.

Table B1. New Acute Values for Cadmium

Species	Method*	Hardness (mg/L as $CaCO_3$)	Acute Value (ug/L)	Adjusted Acute Value (ug/L)**	Reference
Cladoceran, Ceriodaphnia reticulata	S,U	240	184	31.36	Elnabarawy et al. 1986
Cladoceran, Daphnia pulex	S,U	120	70	26.07	Hall et al. 1986
Cladoceran, Daphnia pulex	S,U	200	50	10.47	Hall et al. 1986
Cladoceran, Daphnia pulex	S,U	200	100	20.94	Hall et al. 1986
Cladoceran, Daphnia pulex	S,U	240	319	54.37	Elnabarawy et al. 1986
Cladoceran, Daphnia magna	S,U	240	178	30.3	Elnabarawy et al. 1986
Amphipod, Crangonyx pseudogracilis	S,U	50	1700	1700	Martin and Holdich 1986
Crayfish, Orconectes virilis	S,U	26	6100	12755	Mirenda 1986
Rainbow trout, Oncorhynchus mykiss	FT,M	9.2	<0.9	<3.37	Cusimano and Brakke 1986
Rainbow trout, Oncorhynchus mykiss	FT,M	50	30	30	Van Leeuwen et al. 1985
Rainbow trout, Oncorhynchus mykiss	FT,M	50	10	10	Van Leeuwen et al. 1985
Rainbow trout (28-day egg), Oncorhynchus mykiss	FT,M	50	9200	9200***	Van Leeuwen et al. 1985
Rainbow trout (14-day egg), Oncorhynchus mykiss	FT,M	50	7500	7500***	Van Leeuwen et al. 1985
Rainbow trout (24-hr. egg), Oncorhynchus mykiss	FT,M	50	13000	13000***	Van Leeuwen et al. 1985
Rainbow trout (0-hr. egg), Oncorhynchus mykiss	FT,M	50	13000	13000***	Van Leeuwen et al. 1985

Table B1. (Cont.)

Species	Method*	Hardness (mg/L as $CaCO_3$)	Acute Value (ug/L)	Adjusted Acute Value (ug/L)**	Reference
Striped bass, Morone saxatilis	S,U	40	4	5.14	Palawski et al. 1985
Striped bass, Morone saxatilis	S,U	285	10	1.4	Palawski et al. 1985

* FT = flow-through, M = measured, S = static, U = unmeasured.
** Adjusted to a hardness of 50 mg/L using a slope of 1.128.
*** Not used in the calculation of the SMAV because data were available for a more sensitive life stage.

Table B2. New Chronic Values for Cadmium

Species	Test*	Hardness (mg/L as $CaCO_3$)	Chronic Value (ug/L)	Adjusted Chronic Value (ug/L)**	Reference
Cladoceran, Ceriodaphnia reticulata	LC	240	0.4	0.12***	Elnabarawy et al. 1986
Cladoceran, Daphnia magna	LC	240	4.3	1.25***	Elnabarawy et al. 1986
Cladoceran, Daphnia pulex	LC	106	7.07	3.919	Ingersoll and Winner 1982
Cladoceran, Daphnia pulex	LC	65	7.49	6.096	Niederlehner 1984
Cladoceran, Daphnia pulex	LC	240	13.7	4***	Elnabarawy et al. 1986
Oligochaete, Aeolosoma headleyi	LC	65	25.19	20.50	Niederlehner 1984

* LC = life cycle.
** Adjusted to a hardness of 50 mg/L using a slope of 0.7852.
*** Not used in derivation of the criterion because the concentrations of cadmium were not measured.

Table B3. Ranked Genus Mean Acute Values for Cadmium

Rank*	Genus Mean Acute Value (ug/L)**	Species	Species Mean Acute Value (ug/L)**
43	12755	Crayfish, Orconectes virilis	12755
42	8325	Goldfish, Carassius auratus	8325
41	8100	Damselfly, (Unidentified)	8100
40	7921	Tubificid worm, Rhyacodrilus montana	7921
39	7685	Mosquitofish, Gambusia affinis	7685
38	6915	Tubificid worm, Stylodrilus heringianus	6915
37	4990	Tubificid worm, Spirosperma ferox	4401
		Tubificid worm, Spirosperma nikolskyi	5658
36	4977	Threespine stickleback Gasterosteus aculeatus	4977
35	4778	Tubificid worm, Varichaeta pacifica	4778
34	4024	Tubificid worm, Tubifex tubifex	4024
33	4024	Tubificid worm, Quistradilus multisetosus	4024
32	3800	Snail, Amnicola sp.	3800
31	3570	Guppy, Poecilia reticulata	3570
30	3514	White sucker, Catostomus commersoni	3514
29	3400	Caddisfly, (Unidentified)	3400
28	3018	Tubificid worm, Branchiura sowerbyi	3018

Table B3. (Cont.)

Rank*	Genus Mean Acute Value (ug/L)**	Species	Species Mean Acute Value (ug/L)**
27	2888	Flagfish, Jordanella floridae	2888
26	2400	Northern sq... ish, Ptychocheilus oregonensis	2400
25	2395	Green sunfish, Lepomis cyanellus	2399
		Pumpkinseed, Lepomis gibbosus	1347
		Bluegill, Lepomis macrochirus	4249
24	2310	Mayfly, Ephemerella grandis	2310
23	2137	Tubificid worm, Limnodrilus hoffmeisteri	2137
22	1700	Worm, Nais sp.	1700
21	1700	Amphipod, Crangonyx pseudogracilis	1700
20	1200	Midge, Chironomus sp.	1200
19	736	American eel, Anguilla rostrata	736
18	401	Isopod, Asellus bicrenata	401
17	221.9	Bryozoan, Plumatella emarginata	221.9
16	215.5	Common carp, Cyprinus carpio	215.5
15	156.9	Snail, Physa gyrina	156.9
14	142.5	Bryozoan, Pectinatella magnifica	142.5
13	104.0	Snail, Aplexa hypnorum	104.0

Table B3. (Cont.)

Rank*	Genus Mean Acute Value (ug/L)**	Species	Species Mean Acute Value (ug/L)**
12	98.79	Banded killifish, Fundulus diaphanus	98.79
11	74.99	Amphipod, Gammarus pseudolimnaeus	80.33
		Amphipod, Gammarus sp.	70.00
10	48.28	Cladoceran, Ceriodaphnia reticulata	48.28
9	42.8	Isopod, Lirceus alabamae	42.8
8	40.78	Cladoceran, Moina macrocopa	40.78
7	30.54	Bryozoan, Lophopodella carteri	30.54
6	30.50	Fathead minnow, Pimephales promelas	30.50
5	29.96	Cladoceran, Simocephalus serrulatus	33.2
		Cladoceran, Simocephalus vetulus	27.03
4	21.13	Cladoceran, Daphnia magna	14.2
		Cladoceran, Daphnia pulex	31.43
3	5.421	Coho salmon, Oncorhynchus kisutch	6.48
		Chinook salmon, Oncorhynchus tshawytscha	4.254
		Rainbow trout, Oncorhynchus mykiss	5.78
2	2.682***	White perch, Morone americana	7544
		Striped bass, Morone saxatilis	2.682****

Table B3. (Cont.)

Rank*	Genus Mean Acute Value (ug/L)**	Species	Species Mean Acute Value (ug/L)**
1	1.647	Brown trout, Salmo trutta	1.647

* Ranked from most resistant to most sensitive based on Genus Mean Acute Value.
** At hardness = 50 mg/L.
*** The GMAV was set equal to the lower SMAV due to the large range in the SMAVs in this genus.
**** This SMAV was based on the results reported by Palawski et al. (1985) because they were considered better data than those given in U.S. EPA (1985), although the data reported by Hughes (1973) supported the newer data.

At hardness = 50 mg/L:

$$FAV = 4.134 \text{ ug/L}$$

$$CMC = FAV/2 = 2.067 \text{ ug/L}$$

As a function of hardness:

$$CMC = e^{1.128(\ln \text{hardness}) - 3.6867}$$

Table B4. Ranked Genus Mean Chronic Values for Cadmium

Rank*	Genus Mean Chronic Value (ug/L)**	Species	Species Mean Chronic Value (ug/L)**
12	20.50	Oligochaete, Aeolosoma headleyi	20.50
11	16.32	Bluegill, Lepomis macrochirus	16.32
10	15.40	Fathead minnow, Pimephales promelas	15.40
9	8.170	Smallmouth bass, Micropterus dolomieu	8.170
8	8.138	Northern pike, Esox lucius	8.138
7	7.849	White sucker, Catostomus commersoni	7.849
6	7.771	Atlantic salmon, Salmo salar	8.192
		Brown trout, Salmo trutta	7.372
5	5.336	Flagfish, Jordanella floridae	5.336
4	4.841	Snail, Aplexa hypnorum	4.841
3	4.383	Brook trout, Salvelinus fontinalis	2.362
		Lake trout, Salvelinus namaycush	8.134
2	3.399	Coho salmon, Oncorhynchus kisutch	4.289
		Chinook salmon, Oncorhynchus tshawytscha	2.694
1	0.1354***	Cladoceran, Daphnia magna	0.1354
		Cladoceran, Daphnia pulex	4.888

* Ranked from most resistant to most sensitive based on Genus Mean Chronic Value.
** At hardness = 50 mg/L.
*** The GMCV was set equal to the lower SMCV due to the large range in the SMCVs for this genus.

At hardness = 50 mg/L:

FCV = 1.4286 ug/L = CCC (calculated using n = 43)

As a function of hardness:

$$CCC = e^{0.7852(\ln \text{hardness}) - 2.715}$$

References

Cusimano, R.F., D.F. Brakke, and G.A. Chapman. 1986. Effects of pH on the Toxicities of Cadmium, Copper and Zinc to Steelhead Trout (Salmo gairdneri). Can. J. Fish. Aquat. Sci. 43:1497-1503.

Elnabarawy, M.R., A.N. Wetter, and R.R. Robideau. 1986. Relative Sensitivity of Three Daphnid Species to Selected Organic and Inorganic Chemicals. Environ. Toxicol. Chem. 5:393-398.

Hall, W.S., R.L. Paulson, L.W. Hall, Jr., and D.T. Burton. 1986. Acute Toxicity of Cadmium and Sodium Pentachlorophenate to Daphnids and Fish. Bull. Environ. Contam. Toxicol. 37:308-316.

Hughes, J.S. 1973. Acute Toxicity of Thirty Chemicals to Striped Bass (Morone saxatilis). Western Assoc. State Game Fish Comm., Salt Lake City, UT. July.

Ingersoll, C.G., and R.W. Winner. 1982. Effect on Daphnia pulex (DeGeer) of Daily Pulse Exposures to Copper or Cadmium. Environ. Toxicol. Chem. 1:321-327.

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.

Mirenda, R.J. 1986. Toxicity and Accumulation of Cadmium in the Crayfish, Orconectes virilis (Hagen). Arch. Environ. Contam. Toxicol. 15:401-407.

Niederlehner, B. 1984. A Comparison of Techniques for Estimating the Hazard of Chemicals in the Aquatic Environment. M.S. Thesis. Virginia Polytechnic Institute and State University.

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.

Spehar, R.L., and A.R. Carlson. 1984a. Derivation of Site-Specific Water Quality Criteria for Cadmium and the St. Louis River Basin, Duluth, Minnesota. PB84-153196. National Technical Information Service, Springfield, VA.

Spehar, R.L., and A.R. Carlson. 1984b. Derivation of Site-Specific Water Quality Criteria for Cadmium and the St. Louis River Basin, Duluth, Minnesota. Environ. Toxicol. Chem. 3:651-665.

U.S. EPA. 1985. Ambient Aquatic Life Water Quality Criteria for Cadmium. EPA 440/5-84-032. National Technical Information Service, Springfield, VA.

Van Leeuwen, C.J., P.S. Griffioen, W.H.A. Vergouw, and J.L. Maas-Diepeveen. 1985. Differences in Susceptibility of Early Life Stages of Rainbow Trout (Salmo gairdneri) to Environmental Pollutants. Aquatic Toxicol. 7:59-78.

1995 UPDATE:
Freshwater Aquatic Life Criterion for Chromium(III)

The new acceptable acute data for chromium(III) are given in Table C1; no new acceptable chronic data were found. These data were used with those given in Tables 1 and 2 of the criteria document for chromium (U.S. EPA 1984) to obtain the values given in Table C2. Because the toxicity of chromium(III) is hardness-dependent, all acute values in Table C2 have been adjusted to a hardness of 50 mg/L.

Criterion Maximum Concentration (CMC)

The Final Acute Value (FAV) was calculated using the four lowest Genus Mean Acute Values in Table C2, resulting in an FAV of 2044 ug/L at a hardness of 50 mg/L. This value did not need to be lowered to protect a commercially or recreationally important species. The CMC was calculated by dividing the FAV by 2, resulting in a CMC of 1022 ug/L, as total recoverable chromium(III), at a hardness of 50 mg/L. The CMC was related to hardness using the slope of 0.819 that was derived in U.S. EPA (1985):

$$CMC = e^{0.819(\ln \text{hardness}) + 3.7256}$$

Criterion Continuous Concentration (CCC)

Insufficient chronic toxicity data were available to calculate a Final Chronic Value (FCV) using the eight-family procedure. Sufficient chronic data were available to calculate a FCV by dividing the FAV by the Final Acute-Chronic Ratio (FACR). SMACRs were available for three species (Table C2) and the highest SMACR was obtained with the most resistant of the three. The other two SMACRs were within a factor of 2.4. The FACR was calculated as the geometric mean of the two ACRs and was 41.84. The FCV = FAV/FACR = (2044 ug/L)/(41.84) = 48.85 ug/L at a hardness of 50 mg/L. This value did not need to be lowered to protect a commercially or recreationally important species. Thus the CCC was 48.85 ug/L, as total recoverable chromium(III), at a hardness of 50 mg/L. The CCC, was related to hardness using the slope of 0.819:

$$CCC = e^{0.819(\ln \text{hardness}) + 0.6848}$$

The Criterion

The procedures described in the methodology indicate that, except possibly where a locally important species is very sensitive, freshwater aquatic organisms should not be affected unacceptably if the four-day average concentration of chromium(III) does not exceed the numerical value (in ug/L) given by the equation

$$CCC = e^{0.819(\ln \text{hardness}) + 0.6848}$$

more than once every three years on the average and if the one-hour average concentration does not exceed the numerical value (in ug/L) given by the equation

$$CMC = e^{0.819(\ln \text{hardness}) + 3.7256}$$

more than once every three years on the average.

Table C1. New Acute Values for Chromium(III)

Species	Method*	Hardness (mg/L as $CaCO_3$)	Acute Value (ug/L)	Adjusted Acute Value (ug/L)**	Reference
Amphipod, Crangonyx pseudogracilis	S,U	50	291,000	291,000	Martin and Holdich 1986

* S = static, U = unmeasured.
** Adjusted to a hardness of 50 mg/L using a slope of 0.819.

Table C2. Ranked Genus Mean Acute Values for Chromium(III)

Rank*	Genus Mean Acute Value (ug/L)**	Species	Species Mean Acute Value (ug/L)**	Species Mean Acute-Chronic Ratio
19	291,000	Amphipod, Crangonyx pseudogracilis	291,000	-----
18	71060	Caddisfly, Hydropsyche betteni	71060	-----
17	50000	Caddisfly, Unidentified sp.	50000	-----
16	43100	Damselfly, Unidentified sp.	43100	-----
15	16010	Cladoceran, Daphnia magna	16010	>356.4***
14	15630	Banded killifish, Fundulus diaphanus	15630	-----
13	15370	Pumpkinseed, Lepomis gibbosus	15720	-----
		Bluegill, Lepomis macrochirus	15020	-----
12	14770	White perch, Morone americana	13320	-----
		Striped bass, Morone saxatilis	16370	-----
11	13230	Common carp, Cyprinus carpio	13230	-----
10	12860	American eel, Anguilla rostrata	12860	-----
9	11000	Midge, Chironomus sp.	11000	-----
8	10320	Fathead minnow, Pimephales promelas	10320	27.30
7	10210	Snail, Amnicola sp.	10210	-----
6	9669	Rainbow trout, Oncorhynchus mykiss	9669	64.11
5	9300	Worm, Nais sp.	9300	-----

Table C2. (Cont.)

Rank*	Genus Mean Acute Value (ug/L)**	Species	Species Mean Acute Value (ug/L)**	Species Mean Acute-Chronic Ratio
4	8684	Goldfish, Carassius auratus	8684	-----
3	7053	Guppy, Poecilia reticulata	7053	-----
2	3200	Amphipod, Gammarus sp.	3200	-----
1	2221	Mayfly, Ephemerella subvaria	2221	-----

* Ranked from most resistant to most sensitive based on Genus Mean Acute Value.
** At hardness = 50 mg/L.
*** Not used in the calculation of the Final Acute-Chronic Ratio.

At hardness = 50 mg/L:

FAV = 2044 ug/L

CMC = FAV/2 = 1022 ug/L

As a function of hardness:

$$CMC = e^{0.819(\ln \text{hardness}) + 3.7256}$$

FACR = 41.84

At hardness = 50 mg/L:

FCV = FAV/FACR = (2044 mg/L)/(41.84) = 48.85 ug/L = CCC

As a function of hardness:

$$CCC = e^{0.819(\ln \text{hardness}) + 0.6848}$$

References

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.

U.S. EPA. 1985. Ambient Aquatic Life Water Quality Criteria for Chromium(III) - 1984. EPA 440/5-84-029. National Technical Information Service, Springfield, VA.

1995 UPDATE:
Freshwater Aquatic Life Criterion for Chromium(VI)

The new acceptable acute data for chromium(VI) are given in Table D1; no new acceptable chronic data were used. These new data were used with those given in Tables 1 and 2 of the criteria document for chromium (U.S. EPA 1985) to obtain the values given in Table D2.

Criterion Maximum Concentration (CMC)

The Final Acute Value (FAV) was calculated using the four lowest Genus Mean Acute Values given in Table D2, resulting in a FAV of 32.04 ug/L. This value did not need to be lowered to protect a commercially or recreationally important species. The CMC was calculated by dividing the FAV by 2, resulting in a CMC of 16.02 ug/L, as total recoverable chromium(VI).

Criterion Continuous Concentration (CCC)

Insufficient chronic toxicity data were available to calculate a Final Chronic Value (FCV) using the eight-family procedure. Sufficient chronic data were available to calculate a FCV by dividing the FAV by the Final Acute-Chronic Ratio (FACR). Eight SMACRs were available (Table D2), but three were high SMACRs that were obtained with resistant species and one was a "greater than" value. Of the eight, only four were appropriate for use in calculating the FACR and the four were within a factor of 6. The FACR was calculated as the geometric mean of these four and was 2.917. The FCV = FAV/FACR = (32.04 ug/L)/(2.917) = 10.98 ug/L. This value did not need to be lowered to protect a commercially or recreationally important species. The CCC was 10.98 ug/L, as total recoverable chromium(VI).

The Criterion

The procedures described in the methodology indicate that, except possibly where a locally important species is very sensitive, freshwater aquatic organisms should not be affected unacceptably if the four-day average concentration of chromium(VI) does not exceed 10.98 ug/L more than once every three years on the average and if the one-hour average concentration does not exceed 16.02 ug/L more than once every three years on the average.

Table D1. New Acute Values for Chromium(VI)

Species	Method*	Chemical	Acute Value (ug/L)	Reference
Cladoceran, Daphnia magna	S,U	K-dichromate	900**	Berglind and Dave 1984
Cladoceran, Daphnia magna	S,U	Na-dichromate	112**	Elnabarawy et al. 1986
Cladoceran, Daphnia pulex	S,M	K-dichromate	170**	Dorn et al. 1987
Cladoceran, Daphnia pulex	S,U	K-dichromate	190**	Dorn, et al. 1987
Cladoceran, Daphnia pulex	S,M	K-dichromate	20**	Dorn, et al. 1987
Cladoceran, Daphnia pulex	S,U	K-dichromate	20**	Dorn, et al. 1987
Cladoceran, Daphnia pulex	S,M	K-dichromate	40**	Dorn, et al. 1987
Cladoceran, Daphnia pulex	S,U	K-dichromate	40**	Dorn, et al. 1987
Cladoceran, Daphnia pulex	S,U	Na-dichromate	122**	Elnabarawy et al. 1986
Cladoceran, Daphnia pulex	S,M	K-dichromate	180**	Jop et al. 1987
Cladoceran, Daphnia pulex	S,M	K-dichromate	180**	Jop et al. 1987
Amphipod, Crangonyx pseudogracilis	R,U	K-dichromate	420	Martin and Holdich 1986
Amphipod, Crangonyx pseudogracilis	R,U	K-dichromate	810	Martin and Holdich 1986
Bluegill, Lepomis macrochirus	S,M	K-dichromate	182,000**	Jop et al. 1987
Bluegill, Lepomis macrochirus	S,M	K-dichromate	154,000**	Jop et al. 1987
Bluegill, Lepomis macrochirus	S,M	K-dichromate	201,240**	Dorn et al. 1987

Table D1. (Cont.)

Species	Method*	Chemical	Acute Value (ug/L)	Reference
Bluegill, Lepomis macrochirus	S,U	K-dichromate	164,730**	Dorn et al. 1987
Bluegill, Lepomis macrochirus	S,M	K-dichromate	199,200**	Dorn et al. 1987
Bluegill, Lepomis macrochirus	S,U	K-dichromate	158,360**	Dorn et al. 1987
Bluegill, Lepomis macrochirus	S,M	K-dichromate	148,310**	Dorn et al. 1987
Bluegill, Lepomis macrochirus	S,U	K-dichromate	146,530**	Dorn et al. 1987
Fathead minnow, Pimephales promelas	S,M	K-dichromate	46,000**	Jop et al. 1987
Fathead minnow, Pimephales promelas	S,M	K-dichromate	34,000**	Jop et al. 1987
Fathead minnow, Pimephales promelas	S,U	K-dichromate	26,130**	Dorn et al. 1987
Fathead minnow, Pimephales promelas	S,M	K-dichromate	26,410**	Dorn et al. 1987

* S = static, FT = flow-through, M = measured, U = unmeasured.
** Not used in the calculation of the SMAV because data were available for this species from a "FT,M" test.

Table D2. Ranked Genus Mean Acute Values for Chromium(VI)

Rank*	Genus Mean Acute Value (ug/L)	Species	Species Mean Acute Value (ug/L)	Species Mean Acute-Chronic Ratio
28	1,870,000	Stonefly, Neophasganophora capitata	1,870,000	-----
27	176,000	Crayfish, Orconectes rusticus	176,000	-----
26	140,000	Damselfly, Enallagma aspersum	140,000	-----
25	123,500	Green sunfish, Lepomis cyanellus	114,700	-----
		Bluegill, Lepomis macrochirus	132,900	-----
24	119,500	Goldfish, Carassius auratus	119,500	-----
23	72,600	White crappie, Pomoxis annularis	72,600	-----
22	69,000	Rainbow trout, Oncorhynchus mykiss	69,000	260.8**
21	67,610	Emerald shiner, Notropis atherinoides	48,400	-----
		Striped shiner, Notropis chrysocephalus	85,600	-----
		Sand shiner, Notropis stramineus	74,600	-----
20	61,000	Midge, Chironomus tentans	61,000	-----
19	59,000	Brook trout, Salvelinus fontinalis	59,000	223**
18	57,300	Midge, Tanytarsus dissimilis	57,300	-----
17	51,250	Central stoneroller, Campostoma anomalum	51,250	-----
16	49,600	Silverjaw minnow, Ericymba buccata	49,600	-----

Table D2. (Cont.)

Rank*	Genus Mean Acute Value (ug/L)	Species	Species Mean Acute Value (ug/L)	Species Mean Acute-Chronic Ratio
15	47,180	Bluntnose minnow, Pimephales notatus	54,225	-----
		Fathead minnow, Pimephales promelas	41,050	18.55**
14	46,000	Johnny darter, Etheostoma nigrum	46,000	-----
13	36,300	Yellow perch, Perca flavescens	36,300	-----
12	30,450	Striped bass, Morone saxatilis	30,450	-----
11	30,000	Guppy, Poecilia reticulata	30,000	-----
10	23,010	Snail, Physa heterostropha	23,010	-----
9	1,560	Bryozoan, Lophopodella carteri	1,560	-----
8	1,440	Bryozoan, Pectinatella magnifica	1,440	-----
7	650	Bryozoan, Plumatella emarginata	650	-----
6	630	Amphipod, Hyalella azteca	630	-----
5	583	Amphipod, Crangonyx pseudogracilis	583	-----
4	67.1	Amphipod, Gammarus pseudolimnaeus	67.1	-----
3	45.1	Cladoceran, Ceriodaphnia reticulata	45.1	1.13
2	36.35	Cladoceran, Simocephalus serrulatus	40.9	2.055
		Cladoceran, Simocephalus vetulus	32.3	5.267

Table D2. (Cont.)

Rank*	Genus Mean Acute Value (ug/L)	Species	Species Mean Acute Value (ug/L)	Species Mean Acute-Chronic Ratio
1	28.94	Cladoceran, Daphnia magna	23.07	>6.957**
		Cladoceran, Daphnia pulex	36.3	5.92

* Ranked from most resistant to most sensitive based on Genus Mean Acute Value.
** Not used in the calculation of the Final Acute-Chronic Ratio.

FAV = 32.04 ug/L

CMC = FAV/2 = 16.02 ug/L

FACR = 2.917

FCV = FAV/FACR = (32.04 ug/L)/(2.917) = 10.98 ug/L = CCC

References

Berglind, R., and G. Dave. 1984. Acute Toxicity of Chromate, DDT, PCP, TPBS, and Zinc to Daphnia magna Cultured in Hard and Soft Water. Bull. Environ. Contam. Toxicol. 33:63-68.

Dorn, P.B., J.H. Rodgers, Jr., K.M. Jop, J.C. Raia, and K.L. Dickson. 1987. Hexavalent Chromium as a Reference Toxicant in Effluent Toxicity Tests. Environ. Toxicol. Chem. 6:435-444.

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.

Jop, K.M., T.F. Parkerton, J.H. Rodgers, and K.L. Dickson. 1987. Comparative Toxicity and Speciation of Two Hexavalent Chromium Salts in Acute Toxicity Tests. Environ. Toxicol. Chem. 6:697-703.

Martin, J.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.

U.S. EPA. 1985. Ambient Water Quality Criteria for Chromium - 1984. EPA 440/5-84-029. National Technical Information Service, Springfield, VA.

1995 UPDATE:
Freshwater Aquatic Life Criterion for Copper

The new acceptable acute and chronic data for copper are given in Tables E1 and E2. These new data were used with those given in Tables 1 and 2 of the criteria document for copper (U.S. EPA 1985) to obtain the values given in Table E3. Because the toxicity of copper is hardness-dependent, all acute values in Table E3 have been adjusted to a hardness of 50 mg/L.

Criterion Maximum Concentration (CMC)

Data given in U.S. EPA (1985) for the species *Gammarus pulex* were not used because this species is not resident in North America. Several SMAVs given in Table E3 were derived from U.S. EPA (1985) by giving preference to results of "FT,M" tests.

The Final Acute Value (FAV) was calculated using the four lowest Genus Mean Acute Values in Table E3, resulting in an FAV of 14.57 ug/L at a hardness of 50 mg/L. This value did not need to be lowered to protect a commercially or recreationally important species. The CMC was calculated by dividing the FAV by 2, resulting in a CMC of 7.285 ug/L, as total recoverable copper, at a hardness of 50 mg/L. The CMC was related to hardness using the slope of 0.9422 that was derived in U.S. EPA (1985):

$$CMC = e^{0.9422(\ln \text{hardness}) - 1.700}$$

Criterion Continuous Concentration (CCC)

Insufficient chronic toxicity data were available to calculate a Final Chronic Value (FCV) using the eight-family procedure. Sufficient chronic data were available to calculate a FCV by dividing the FAV by the Final Acute-Chronic Ratio (FACR). The new chronic test gave an ACR of 15.48 with the fathead minnow; the geometric mean of this value and the four ACRs for this species in U.S. EPA (1985) was 11.20. SMACRs were available for nine species (Table E3) and were higher for resistant species. To make the FACR appropriate for sensitive species, it was calculated from the two SMACRs that were determined with species whose SMAVs were close to the FAV. Thus the FACR was calculated as the geometric mean of 3.297 and 2.418 and was 2.823. The FCV = FAV/FACR = (14.57 ug/L)/(2.823) = 5.161 ug/L at a hardness of 50 mg/L. This value did not need to be lowered to protect a commercially or recreationally important species. Thus the CCC

was 5.161 ug/L, as total recoverable copper, at a hardness of 50 mg/L. The CCC was related to hardness using the slope of 0.8545 that was derived in U.S. EPA (1985):

$$CCC = e^{0.8545(\ln \text{hardness}) - 1.702}$$

The Criterion

The procedures described in the methodology indicate that, except possibly where a locally important species is very sensitive, freshwater aquatic organisms should not be affected unacceptably if the four-day average concentration of copper does not exceed the numerical value (in ug/L) given by the equation

$$CCC = e^{0.8545(\ln \text{hardness}) - 1.702}$$

more than once every three years on the average and if the one-hour average concentration does not exceed the numerical value (in ug/L) given by the equation

$$CMC = e^{0.9422(\ln \text{hardness}) - 1.700}$$

more than once every three years on the average.

Table E1. New Acute Values for Copper

Species	Method*	Hardness (mg/L as $CaCO_3$)	Acute Value (ug/L)	Adjusted Acute Value (ug/L)**	Reference
Cladoceran, Ceriodaphnia reticulata	S,U	240	23	5.2	Elnabarawy et al. 1986
Cladoceran, Daphnia magna	S,U	240	41	9.4	Elnabarawy et al. 1986
Cladoceran, Daphnia pulex	S,U	240	31	7.1	Elnabarawy et al. 1986
Amphipod, Crangonyx pseudogracilis	S,U	50	1290	1290	Martin and Holdich 1986
Asiatic clam, Corbicula manilensis	FT,M	17	>2600	>7184	Harrison et al. 1984
Midge, Chironomus decorus	S,M	44	739	834	Kosalwat and Knight 1987
Fathead minnow, Pimephales promelas	FT,M	43.9	96	109	Spehar and Fiandt 1986
Bluegill, Lepomis macrochirus	S,M	31.2	340	530***	Bailey et al. 1985
Bluegill, Lepomis macrochirus	FT,M	31.2	550	858	Bailey et at. 1985
Rainbow trout, Oncorhynchus mykiss	FT,M	9.2	2.8	14	Cusimano and Brakke 1986
Striped bass, Morone saxatilis	S,U	285	270	52	Palawski et al. 1985

* S = static, FT = flow-through, U = unmeasured, M = measured.
** Adjusted to a hardness of 50 mg/L using the slope of 0.9422.
*** Not used in the calculation of the SMAV because data were available for this species from a "FT,M" test.

Table E2. New Chronic Values for Copper

Species	Test*	Acute Value (ug/L)	Chronic Value (ug/L)	Acute-Chronic Ratio	Reference
Fathead minnow, Pimephales promelas	ELS	96	6.2	15.48	Spehar and Fiandt 1986

* ELS = early life stage.

Table E3. Ranked Genus Mean Acute Values for Copper

Rank*	Genus Mean Acute Value (ug/L)**	Species	Species Mean Acute Value (ug/L)**	Species Mean Acute-Chronic Ratio
43	10240	Stonefly, Acroneuria lycorias	10240	-----
42	> 7184	Asiatic clam, Corbicula manilensis	> 7184	-----
41	6200	Caddisfly, Unidentified sp.	6200	-----
40	4600	Damselfly, Unidentified sp.	4600	-----
39	4305	American eel, Anguilla rostrata	4305	-----
38	1990	Crayfish, Procambarus clarkii	1990	-----
37	1877	Snail, Campeloma decisum	1877	156.2***
36	1397	Crayfish, Orconectes rusticus	1397	-----
35	1290	Amphipod, Crangonyx pseudogracilis	1290	-----
34	1057	Pumpkinseed, Lepomis gibbosus	640.9	-----
		Bluegill, Lepomis macrochirus	1742	37.96***
33	900	Snail, Amnicola sp.	900	-----
32	790.6	Banded killifish, Fundulus diaphanus	790.6	-----
31	684.3	Mozambique tilapia Tilapia mossambica	684.3	-----
30	331.8	Striped shiner, Notropis chrysocephalus	331.8	-----
29	289	Goldfish, Carassius auratus	289	-----
28	242.7	Worm, Lumbriculus variegatus	242.7	-----

Table E3. (Cont.)

Rank*	Genus Mean Acute Value (ug/L)**	Species	Species Mean Acute Value (ug/L)**	Species Mean Acute-Chronic Ratio
27	196.1	Mosquitofish, Gambusia affinis	196.1	-----
26	170.2-	Midge, Chironomus tentans	197	-----
		Midge, Chironomus decorus	834	-----
		Midge, Chironomus sp.	30	-----
25	166.2	Snail, Goniobasis livescens	166.2	-----
24	156.8	Common carp, Cyprinus carpio	156.8	-----
23	141.2	Rainbow darter Etheostoma caeruleum	86.67	-----
		Orangethroat darter, Etheostoma spectabile	230.2	-----
22	135	Bryozoan, Pectinatella magnifica	135	-----
21	133	Chiselmouth, Acrocheilus alutaceus	133	-----
20	110.4	Brook trout, Salvelinus fontinalis	110.4	7.776***
19	109.9	Atlantic salmon, Salmo salar	109.9	-----
18	97.9	Bluntnose minnow, Pimephales notatus	72.16	26.36***
		Fathead minnow, Pimephales promelas	132.9	11.20***
17	90	Worm, Nais sp.	90	-----
16	86.67	Blacknose dace, Rhinichthys atratulus	86.67	-----

Table E3. (Cont.)

Rank*	Genus Mean Acute Value (ug/L)**	Species	Species Mean Acute Value (ug/L)**	Species Mean Acute-Chronic Ratio
15	83.97	Creek chub, Semotilus atromaculatus	83.97	-----
14	83	Guppy, Poecilia reticulata	83	-----
13	78.55	Central stoneroller, Campostoma anomalum	78.55	-----
12	73.99	Coho salmon, Oncorhynchus kisutch	87.1	-----
		Sockeye salmon, Oncorhynchus nerka	233.8	-----
		Cutthroat trout, Oncorhynchus clarki	66.26	-----
		Chinook salmon, Oncorhynchus tshawytscha	42.26	> 4.473***
		Rainbow trout, Oncorhynchus mykiss	38.89	-----
11	69.81	Brown bullhead, Ictalurus nebulosus	69.81	-----
10	56.21	Snail, Gyraulus circumstriatus	56.21	-----
9	53.08	Worm, Limnodrilus hoffmeisteri	53.08	-----
8	52---	White perch, Morone americanus	5860	-----
		Striped bass, Morone saxatilis	52---	-----
7	39.33	Snail, Physa heterostropha	35.91	-----
		Snail, Physa integra	43.07	3.585***
6	37.05	Bryozoan, Lophopodella carteri	37.05	-----
5	37.05	Bryozoan, Plumatella emarginata	37.05	-----

Table E3. (Cont.)

Rank*	Genus Mean Acute Value (ug/L)**	Species	Species Mean Acute Value (ug/L)**	Species Mean Acute-Chronic Ratio
4	22.09	Amphipod, Gammarus pseudolimnaeus	22.09	3.297
3	16.74	Northern squawfish, Ptychocheilus oregonensis	16.74	-----
2	14.48	Cladoceran, Daphnia magna	19.88	2.418
		Cladoceran, Daphnia pulex	16.5	-----
		Cladoceran, Daphnia pulicaria	9.263	-----
1	9.92	Cladoceran, Ceriodaphnia reticulata	9.92	-----

* Ranked from most resistant to most sensitive based on Genus Mean Acute Value.
** At hardness = 50 mg/L.
*** Not used in the calculation of the Final Acute-Chronic Ratio.
~ This GMAV was not set equal to the lowest SMAV because the species was not identified and so might have been C. tentans or C. decorus.
~~ This GMAV was set equal to the lower SMAV due to the large range in the SMAVs in this genus.
~~~ This SMAV was based on the results reported by Palawaki et al. (1985) because they were considered better data than those given in U.S. EPA (1985), although the data reported by Hughes (1973) supported the newer data.

At hardness = 50 mg/L:

FAV = 14.57 ug/L

CMC = FAV/2 = 7.285 ug/L

As a function of hardness:

$$CMC = e^{0.9422(\ln \text{hardness}) - 1.700}$$

FACR = 2.823

At hardness = 50 mg/L:
~~~

FCV = FAV/FACR = (14.57 ug/L)/(2.823) = 5.161 ug/L = CCC

As a function of hardness:

$$CCC = e^{0.8545(\ln \text{hardness}) - 1.702}$$

References

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: Aquatic Toxicology and Hazard Assessment: Eighth Symposium. Bahner, R.C., and D.J. Hansen, Eds. ASTM STP 981. American Society for Testing and Materials, Phildelphia, PA. pp. 193-212.

Cusimano, R.F., and D.F. Brakke. 1986. Effects of pH on the Toxicities of Cadmium, Copper, and Zinc to Steelhead Trout (Salmo gairdneri). Can. J. Fish. Aquat. Sci. 43:1497-1503.

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.

Harrison, F.L., J.P. Knezovich, and D.W. Rice, Jr. 1984. The Toxicity of Copper to Adult and Early Life Stages of the Freshwater Clam, Corbicula manilensis. Arch. Environ. Contam. Toxicol. 13:85-92.

Hughes, J.S. 1973. Acute Toxicity of Thirty Chemicals to Striped Bass (Morone saxatilis). Western Assoc. State Game Fish Comm., Salt Lake City, UT. July.

Kosalwat, P., and A.W. Knight. 1987. Acute Toxicity of Aqueous and Substrate-Bound Copper to the Midge, Chironomus decorus. Arch. Environ. Contam. Toxicol. 16:275-282.

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.

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.

Spehar, R.L., and J.T. Fiandt. 1986. Acute and Chronic Effects of Water Quality Criteria-Based Metal Mixtures on Three Aquatic Species. Environ. Toxicol. Chem. 5:917-931.

U.S. EPA. 1985. Ambient Aquatic Life Water Quality Criteria for Copper. EPA 440/5-84-031. National Technical Information Service, Springfield, VA.

1995 UPDATE:
Freshwater Aquatic Life Criterion for Cyanide

No new acceptable acute or chronic data were found for cyanide. Therefore, the data in the existing criteria document for cyanide (U.S. EPA 1985) were used as the basis for the derivation of this criterion. The new taxonomy for salmonids was used (Table F1), but this did not cause a change in the criterion for cyanide.

Criterion Maximum Concentration (CMC)

The Final Acute Value (FAV) was calculated using the four lowest Genus Mean Acute Values given in Table F1, resulting in a FAV of 45.77 ug/L. Because the SMAV of the commercially and recreationally important rainbow trout was 44.73 ug/L, the FAV was lowered to 44.73 ug/L. The CMC was calculated by dividing the FAV by 2, resulting in a CMC of 22.36 ug free cyanide (as CN)/L.

Criterion Continuous Concentration (CCC)

Insufficient chronic toxicity data were available to calculate a Final Chronic Value (FCV) using the eight-family procedure. Sufficient chronic data were available to calculate a FCV by dividing the FAV by the Final Acute-Chronic Ratio (FACR). Five SMACRs are available (Table F1), but one was a high SMACR that was obtained with a resistant species; the other four were within a factor of 1.5. The FACR was calculated as the geometric mean of these four and was 8.568. The FCV = FAV/FACR = (44.73 ug/L)/(8.568) = 5.221 ug/L. This value does not need to be lowered to protect a commercially or recreationally important species. The CCC was 5.221 ug free cyanide (as CN)/L.

The Criterion

The procedures described in the methodology indicate that, except possibly where a locally important species is very sensitive, freshwater aquatic organisms should not be affected unacceptably if the four-day average concentration of free cyanide (as CN) does not exceed 5.221 ug/L more than once every three years on the average and if the one-hour average concentration does not exceed 22.36 ug/L more than once every three years on the average.

Table F1. Ranked Genus Mean Acute Values for Cyanide

Rank*	Genus Mean Acute Value (ug/L)	Species	Species Mean Acute Value (ug/L)	Species Mean Acute-Chronic Ratio
16	2490	Midge, Tanytarsus dissimilis	2490	-----
15	2326	Isopod, Asellus communis	2326	68.29**
14	432	Snail, Physa heterostropha	432	-----
13	426	Stonefly, Pteronarcys dorsata	426	-----
12	318	Goldfish, Carassius auratus	318	-----
11	167	Amphipod, Gammarus pseudolimnaeus	167	9.111
10	147	Guppy, Poecilia reticulata	147	-----
9	125.1	Fathead minnow, Pimephales promelas	125.1	7.633
8	123.6	Cladoceran, Daphnia magna	160	-----
		Cladoceran, Daphnia pulex	95.55	-----
7	102	Largemouth bass, Micropterus salmoides	102	-----
6	102	Black crappie, Pomoxis nigromaculatus	102	-----
5	99.28	Bluegill, Lepomis macrochirus	99.28	7.316
4	92.64	Yellow perch, Perca flavescens	92.64	-----
3	90.00	Atlantic salmon, Salmo salar	90.00	-----
2	85.80	Brook trout, Salvelinus fontinalis	85.80	10.59
1	44.73	Rainbow trout Oncorhynchus mykiss	44.73	-----

* Ranked from most resistant to most sensitive based on Genus Mean Acute Value.
** Not used in the calculation of the Final Acute-Chronic Ratio.

Calculated FAV = 45.77 ug/L

Lowered to protect rainbow trout:

FAV = 44.73 ug/L

CMC = FAV/2 = 22.36 ug/L

FACR = 8.568

FCV = FAV/FACR = (44.73 ug/L)/(8.568) = 5.221 ug/L = CCC

References

U.S. EPA. 1985. Ambient Water Quality Criteria for Cyanide - 1984. EPA 440/5-84-028. National Technical Information Service, Springfield, VA.

1995 UPDATE:
Freshwater Aquatic Life Criterion for Mercury(II)

The new acceptable acute data for mercury(II) are given in Table J1; no new chronic data were used. These new data were used with those given in Tables 1 and 2 of the criteria document for mercury(II) (U.S. EPA 1985) to obtain the values given in Table J2.

Criterion Maximum Concentration (CMC)

The Final Acute Value (FAV) was calculated using the four lowest Genus Mean Acute Values given in Table J2, resulting in a FAV of 3.388 ug/L. This value did not need to be lowered to protect a commercially or recreationally important species. The CMC was calculated by dividing the FAV by 2, resulting in a CMC of 1.694 ug/L as total recoverable mercury(II).

Criterion Continuous Concentration (CCC)

Insufficient chronic toxicity data were available to calculate a Final Chronic Value (FCV) using the eight-family procedure. Sufficient chronic data were available to calculate a FCV by dividing the FAV by the Final Acute-Chronic Ratio (FACR). ACRs were given for two freshwater species and one saltwater species in U.S. EPA (1985). The ACR obtained with the more resistant fathead minnow was much higher than the other two. The ACR obtained with the saltwater mysid was 3.095 and was similar to the Species Mean Acute-Chronic Ratio of 4.498 for *Daphnia magna*. The FACR was calculated as the geometric mean of the two SMACRs and was 3.731. The FCV = FAV/FACR = (3.388 ug/L)/(3.731) = 0.9081 ug/L. This value did not need to be lowered to protect a commercially or recreationally important species. The CCC was 0.9081 ug/L as total recoverable mercury(II).

The SMACR of >649.2 for the fathead minnow (Table J2) was not used in the calculation of the FACR because this species is acutely resistant to mercury(II). This SMACR is the geometric mean of >646.2, which was based on a life-cycle test, and >652.2, which was based on an early life-stage test. These two ACRs are so large that the two chronic values of <0.26 and <0.23 ug/L are both lower than the CCC of 0.9081 ug/L. Because the high SMACR was based on two tests with a fish and the two low SMACRs were obtained with invertebrates, it is quite possible that other fishes have SMACRs close to 649.2. The following estimated

chronic values were obtained using Species Mean Acute Values from Table J2 and an estimated ACR of 649.2:

Species	Species Mean Acute Value	Estimated Chronic Value
Rainbow trout	275 ug/L	0.42 ug/L
Coho salmon	240 ug/L	0.37 ug/L
Bluegill	160 ug/L	0.25 ug/L

All three of these estimated chronic values are for important species and are more than a factor of two lower than the FCV of 0.9081 ug/L. In addition, the SMACR for the fathead minnow is greater than 649.2. Thus the CCC of 0.9081 ug/L might not adequately protect such important fishes as the rainbow trout, coho salmon, and bluegill.

The Criterion

The procedures described in the methodology indicate that, except possibly where a locally important species is very sensitive, freshwater aquatic organisms should not be affected unacceptably if the four-day average concentration of mercury(II) does not exceed 0.9081 ug/L more than once every three years on the average and if the one-hour average concentration does not exceed 1.694 ug/L more than once every three years on the average. The concentration of 0.9081 ug/L might not adequately protect such important fishes as the rainbow trout, coho salmon, and bluegill.

Table J1. New Acute Values for Mercury(II)

Species	Method*	Acute Value (ug/L)	Reference
Cladoceran, Ceriodaphnia reticulata	S,U	2.9	Elnabarawy et al. 1986
Cladoceran, Daphnia magna,	S,U	9.6	Elnabarawy et al. 1986
Cladoceran, Daphnia pulex	S,U	3.8	Elnabarawy et al. 1986
Amphipod, Crangonyx pseudogracilis	S,U	1.0**	Martin and Holdich 1986
Midge, Chironomus riparius	S,M	750	Rossaro et al. 1986
Mosquitofish, Gambusia affinis	S,U	230	Paulose 1988
Walking catfish, Clarias batrachus	S,U	375	Kirubagaran and Joy 1988
Fathead minnow, Pimephales promelas	FT,M	172	Spehar and Fiandt 1986
Guppy, Poecilia reticulata	R,U	26	Khangarot and Ray 1987

* S = static, R = renewal, FT = flow-through, U = unmeasured, M = measured.
** Not used in the derivation of the criterion because the corresponding 48-hr LC50 is 470 ug/L, which is an unusually large decrease in the LC50 from 48 to 96 hours.

Table J2. Ranked Genus Mean Acute Values for Mercury(II)

Rank*	Genus Mean Acute Value (ug/L)	Species	Species Mean Acute Value (ug/L)	Species Mean Acute-Chronic Ratio
29	2000	Stonefly, Acroneuria lycorias	2000	-----
28	2000	Mayfly, Ephemerella subvaria	2000	-----
27	2000	Caddisfly, Hydropsyche betteni	2000	-----
26	1200	Caddisfly, (Unidentified)	1200	-----
25	1200	Damselfly, (Unidentified)	1200	-----
24	1000	Worm, Nais sp.	1000	-----
23	1000	Mozambique tilapia Tilapia mossambica	1000	-----
22	406.2	Tubificid worm, Spirosperma ferox	330	-----
		Tubificid worm, Spirosperma rikolskyi	500	-----
21	375	Walking catfish, Clarias batrachus	375	-----
20	370	Snail, Aplexa hypnorum	370	-----
19	257	Coho salmon, Oncorhynchus kisutch	240	-----
		Rainbow trout, Oncorhynchus mykiss	275	-----
18	250	Tubificid worm, Quistadrilus multisetosus	250	-----
17	240	Tubificid worm, Rhyacodrilus montana	240	-----
16	203	Mosquitofish, Gambusia affinis	203	-----
15	180	Tubificid worm, Limnodrilus hoffmeisteri	180	-----

Table J2. (Cont.)

Rank*	Genus Mean Acute Value (ug/L)	Species	Species Mean Acute Value (ug/L)	Species Mean Acute-Chronic Ratio
14	163	Fathead minnow, Pimephales promelas	163	> 649.2**
13	160	Bluegill, Lepomis macrochirus	160	-----
12	140	Tubificid worm, Tubifex tubifex	140	-----
11	140	Tubificid worm, Stylodrilus heringianus	140	-----
10	122***	Midge, Chironomus sp.	20	-----
		Midge, Chironomus riparius	750	-----
9	100	Tubificid worm, Varichaeta pacifica	100	-----
8	80	Tubificid worm, Branchiura sowerbyi	80	-----
7	80	Snail, Amnicola sp.	80	-----
6	50	Crayfish, Orconectes limosus	50	-----
5	28	Guppy, Poecilia reticulata	28	-----
4	20	Crayfish, Faxonella clypeatus	20	-----
3	10	Amphipod, Gammarus sp.	10	-----
2	3.3	Cladoceran, Daphnia magna	3.7	4.498
		Cladoceran, Daphnia pulex	2.9	-----
1	2.9	Cladoceran, Ceriodaphnia reticulata	2.9	-----

* Ranked from most resistant to most sensitive based on Genus Mean Acute Value.
** Not used in the calculation of the Final Acute-Chronic Ratio.
*** This GMAV was not set equal to the lowest SMAV because the species was not identified and so might have been C. riparius.

FAV = 3.388 ug/L

CMC = FAV/2 = 1.694 ug/L

FACR = 3.731

FCV = FAV/FACR = (3.388 ug/L)/(3.731) = 0.9081 ug/L = CCC

The CCC of 0.9081 ug/L might not adequately protect such important fishes as the rainbow trout, coho salmon, and bluegill (see above).

References

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.

Khangarot, B.S., and P.K. Ray. 1987. Studies on the Acute Toxicity of Copper and Mercury Alone and in Combination to the Common Guppy, Poecilia reticulata (Peters). Arch. Hydrobiol. 110:303-314.

Kirubagaran, R., and K.P. Joy. 1988. Toxic Effects of Three Mercurial Compounds on Survival and Histology of the Kidney of the Catfish Clarias batrachus (L.). Ecotoxicol. Environ. Safety 15:171-179.

Martin, T.R., and D.M. Holdich. 1986. The Acute Lethality of Heavy Metals to Peracarid Crustaceans (with Particular Reference to Fresh-Water Asellids and Gammarids). Water Res. 20:1137-1147.

Paulose, P.V. 1988. Comparative Study of Inorganic and Organic Mercury Poisoning on Selected Freshwater Organisms. J. Environ. Biol. 9:203-206.

Rossaro, B., G.F. Gaggino, and R. Marchetti. 1986. Accumulation of Mercury in Larvae and Adults, Chironomus riparius (Meigen). Bull. Environ. Contam. Toxicol. 37:402-406.

Spehar, R.L., and J.T. Fiandt. 1986. Acute and Chronic Effects of Water Quality Criteria-Based Metal Mixtures on Three Aquatic Species. Environ. Toxicol. Chem. 5:917-931.

U.S. EPA. 1985. Ambient Water Quality Criteria for Mercury - 1984. EPA 440/5-84-026. National Technical Information Service, Springfield, VA.

1995 UPDATE:
Freshwater Aquatic Life Criterion for Selenium

The new acceptable acute data for selenium are given in Table N1; no new acceptable chronic data were found. These new data were used with those given in Tables 1 and 2 of the criteria document for selenium (U.S. EPA 1987) to obtain the values given in Tables N2 and N3.

Selenium(IV):

Criterion Maximum Concentration (CMC)

The Final Acute Value (FAV) was calculated using the four lowest Genus Mean Acute Values given in Table N2, resulting in a FAV of 371.8 ug/L. This value did not need to be lowered to protect a commercially or recreationally important species. The CMC was calculated by dividing the FAV by 2, resulting in a CMC of 185.9 ug/L.

Criterion Continuous Concentration (CCC)

Insufficient chronic toxicity data were available to calculate a Final Chronic Value (FCV) using the eight-family procedure. Sufficient chronic data were available to calculate a FCV by dividing the FAV by the Final Acute-Chronic Ratio (FACR). Four Species Mean ACRs were available (Table N2), but the one determined with the acutely resistant species was higher than the other three; the three were within a factor of 2.4. The FACR was calculated as the geometric mean of the three and was 7.998. The FCV = FAV/FACR = (371.8 ug/L)/(7.998) = 46.49 ug/L. As in U.S. EPA (1987), this value was lowered to 27.6 ug/L to protect the commercially and recreationally important rainbow trout. The CCC was 27.6 ug/L.

Selenium(VI):

Criterion Maximum Concentration (CMC)

The Final Acute Value (FAV) was calculated using the four lowest Genus Mean Acute Values given in Table N3, resulting in a FAV of 25.066 ug/L. This value did not need to be lowered to protect a commercially or recreationally important species. The CMC was calculated by dividing the FAV by 2, resulting in a CMC of 12.533 ug/L.

Criterion Continuous Concentration (CCC)

Insufficient chronic toxicity data were available to calculate a Final Chronic Value (FCV) using the eight-family procedure. Sufficient chronic data were available to calculate a FCV by dividing the FAV by the Final Acute-Chronic Ratio (FACR). Three Species Mean ACRs were available (Table N3), and they increased as the acute sensitivities of the species increased. To make the FACR appropriate for sensitive species, it was set equal to the SMACR of 2.651 for the sensitive Daphnia magna. The FCV = FAV/FACR = (25.066 ug/L)/(2.651) = 9.455 ug/L. This value did not need to be lowered to protect a commercially or recreationally important species. The CCC was 9.455 ug/L.

Total selenium:

As discussed in U.S. EPA (1987), field studies conducted on Belews Lake in North Carolina suggested that selenium might be more toxic to certain species of freshwater fish than had been observed in laboratory chronic toxicity tests. Based upon these field studies and some laboratory studies, the CCC for total selenium was set at 5 ug/L. The Final Acute-Chronic Ratio for total selenium was calculated as the geometric mean of the six ACRs in Tables N2 and N3 that are between 2.5 and 16.5 and was 7.737. The FAV was calculated by multiplying the CCC by the FACR and was 38.68 ug/L. The CMC was calculated by dividing the FAV by 2, resulting in a CMC of 19.34 ug/L as total recoverable selenium.

The Criterion

The procedures described in the methodology indicate that, except possibly where a locally important species is very sensitive, freshwater aquatic organisms should not be affected unacceptably if the four-day average concentration of selenium does not exceed 5 ug/L more than once every three years on the average and if the one-hour average concentration does not exceed 19.34 ug/L more than once every three years on the average.

Table N1. New Acute Values for Selenium

Species	Method*	Chemical	Acute Value (ug/L)	Reference
Cladoceran, Daphnia magna	S,U	Na-selenite [Selenium(IV)]	680	Johnston 1987
Cladoceran, Daphnia magna	S,U	Na-selenate [Selenium(VI)]	750	Johnston 1987

* S = static, U = unmeasured.

Table N2. Ranked Genus Mean Acute Values for Selenium(IV)

Rank*	Genus Mean Acute Value (ug/L)	Species	Species Mean Acute Value (ug/L)	Species Mean Acute-Chronic Ratio
22	203000	Leech, Nephelopsis obscure	203000	-----
21	42500	Midge, Tanytarsus dissimilis	42500	-----
20	35000	Common carp, Cyprinus carpio	35000	-----
19	34910	Snail, Aplexa hypnorum	34910	-----
18	30176	White sucker, Catostomus commersoni	30176	-----
17	28500	Bluegill, Lepomis macrochirus	28500	-----
16	26100	Goldfish, Carassius auratus	26100	-----
15	25934	Midge, Chironomus plumosus	25934	-----
14	24100	Snail, Physa sp.	24100	-----
13	13600	Channel catfish, Ictalurus punctatus	13600	-----
12	12600	Mosquitofish, Gambusia affinis	12600	-----
11	11700	Yellow Perch, Perca flavescens	11700	-----
10	10490	Rainbow Trout, Oncorhynchus mykiss	10490	141.5**
9	10200	Brook trout, Salvelinus fontinalis	10200	-----
8	6500	Flagfish, Jordanella floridae	6500	-----
7	2704	Amphipod, Gammarus pseudolimnaeus	2704	-----

Table N2. (Cont.)

Rank*	Genus Mean Acute Value (ug/L)	Species	Species Mean Acute Value (ug/L)	Species Mean Acute-Chronic Ratio
6	1796	Cladoceran, Daphnia magna	834	13.31
		Cladoceran, Daphnia pulex	3870	5.586
5	1783	Striped bass, Morone saxatilis	1783	-----
4	1700	Hydra, Hydra sp.	1700	-----
3	1601	Fathead minnow, Pimephales promelas	1601	6.881
2	<603.6	Cladoceran, Ceriodaphnia affinis	<603.6	-----
1	340	Amphipod, Hyalella azteca	340	-----

* Ranked from most resistant to most sensitive based on Genus Mean Acute Value.
** Not used in the calculation of the Final Acute-Chronic Ratio.

FAV = 371.8 ug/L

CMC = FAV/2 = 185.9 ug/L

FACR = 7.998

FCV = FAV/FACR = (371.8 ug/L)/(7.998) = 46.49 ug/L

Lowered to protect rainbow trout:

FCV = 27.6 ug/L = CCC

Table N3. Ranked Genus Mean Acute Values for Selenium(VI)

Rank*	Genus Mean Acute Value (ug/L)	Species	Species Mean Acute Value (ug/L)	Species Mean Acute-Chronic Ratio
11	442000	Leech, Hephelopsis obscura	442000	-----
10	193000	Snail, Aplexa hypnorum	193000	-----
9	66000	Channel catfish, Ictalurus punctatus	66000	-----
8	63000	Bluegill, Lepomis macrochirus	63000	-----
7	47000	Rainbow trout, Oncorhynchus mykiss	47000	16.26
6	20000	Midge, Paratanytarsus parthenogeneticus	20000	-----
5	7300	Hydra, Hydra sp.	7300	-----
4	5500	Fathead minnow, Pimephales promelas	5500	9.726
3	760	Amphipod, Hyalella azteca	760	-----
2	550.1	Cladoceran, Daphnia magna	1230	2.651
		Cladoceran, Daphnia pulicaria	246	-----
1	65.38	Amphipod, Gammarus pseudolimnaeus	65.38	-----

* Ranked from most resistant to most sensitive based on Genus Mean Acute Value.

FAV = 25.066 ug/L

CMC = FAV/2 = 12.533 ug/L

FACR = 2.651

FCV = FAV/FACR = (25.066 ug/L)/(2.651) = 9.455 ug/L = CCC

References

Johnston, P.A. 1987. Acute Toxicity of Inorganic Selenium to Daphnia magna (Straus) and the Effect of Sub-acute Exposure upon Growth and Reproduction. Aquatic Toxicol. 10:335-352.

U.S. EPA. 1987. Ambient Aquatic Life Water Quality Criteria for Selenium. EPA 440/5-87-006. National Technical Information Service, Springfield, VA.