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ACUTE TOXICITY CRITERIA

EPA SPECIES MEAN ACUTE VALUES

(values from 1/85 EPA AWQC document, EPA 440/5-84-031 and 3/95 GLWQI Criteria Document for the Protection of Aquatic Life in Ambient Water)

NOTE: Normalized hardness and copper values are listed for a species when information was available over a sufficient hardness range (EPA: maximum hardness > 3 X lowest hardness and > 100 PPM above lowest hardness). Normalized value equals individual result / geometric mean result (rounded to 3 dec. places).

Worm, *Lumbriculus variegatus*

HARDNESS (PPM)	VALUE (ug/L)	METHOD		NORMALIZED HARDNESS	NORMALIZED VALUE	REFERENCE
30	150	S	U			Bailey and Liu, 1980
30	150					**GEO MEAN** (1 result)

Tubificid worm, *Limnodrilus hoffmeisteri*

HARDNESS (PPM)	VALUE (ug/L)	METHOD		NORMALIZED HARDNESS	NORMALIZED VALUE	REFERENCE
100	102	S	U			Wurtz and Bridges, 1961
100	102					**GEO MEAN** (1 result)

Worm, *Nais sp.*

HARDNESS (PPM)	VALUE (ug/L)	METHOD		NORMALIZED HARDNESS	NORMALIZED VALUE	REFERENCE
50	90	S	M			Rehwoldt, et al. 1973
50	90					**GEO MEAN** (1 result)

Snail, *Campeloma decisum*

HARDNESS (PPM)	VALUE (ug/L)	METHOD		NORMALIZED HARDNESS	NORMALIZED VALUE	REFERENCE
45	1700	FT	M			Arthur & Leonard, 1970
45	1700					**GEO MEAN** (1 result)

Snail, *Amnicola sp.*

HARDNESS (PPM)	VALUE (ug/L)	METHOD		NORMALIZED HARDNESS	NORMALIZED VALUE	REFERENCE
50	9300	S	M			Rehwoldt, et al. 1973 (embryo)
50	900	S	M			Rehwoldt, et al. 1973 (adult)
50	900					**GEO MEAN** (1 result, for the most sensitive life stage)

Snail, *Goniobasis livescens*

HARDNESS (PPM)	VALUE (ug/L)	METHOD		NORMALIZED HARDNESS	NORMALIZED VALUE	REFERENCE
154	590	S	M			Paulson, et al. 1983
154	390	S	M			Paulson, et al. 1983
154	479.69					**GEO MEAN** (XYZ results)

All four results were used in the slope calculation, normalized values were based on a mean hardness = 51.54 and mean LC50 = 12356.10.

Snail, *Gyraulus circumstriatus*

HARDNESS (PPM)	VALUE (ug/L)	METHOD		NORMALIZED HARDNESS	NORMALIZED VALUE	REFERENCE
100	108	S	U			Wurtz and Bridges, 1961
100	108					**GEO MEAN** (1 result)

Snail, *Physa integra*

HARDNESS (PPM)	VALUE (ug/L)	METHOD		NORMALIZED HARDNESS	NORMALIZED VALUE	REFERENCE
45	39	FT	M			Arthur and Leonard, 1970
45	39					**GEO MEAN** (1 result)

Snail, *Physa heterostropha*

HARDNESS (PPM)	VALUE (ug/L)	METHOD		NORMALIZED HARDNESS	NORMALIZED VALUE	REFERENCE
100	69	S	U			Wurtz and Bridges, 1961
100	69					**GEO MEAN** (1 result)

Asiatic clam, *Corbicula fluminea*

HARDNESS (PPM)	VALUE (ug/L)	METHOD		NORMALIZED HARDNESS	NORMALIZED VALUE	REFERENCE
64	40	S	U			Rodgers, et al. 1980
64	490	FT	U			Rodgers, et al. 1980
						GEO MEAN not calculated, EPA considered the two results to be too divergent

Asiatic clam, *Corbicula manilensis*

HARDNESS (PPM)	VALUE (ug/L)	METHOD		NORMALIZED HARDNESS	NORMALIZED VALUE	REFERENCE
17	>2600	FT	M			Harrison, et al. 1984
17	2600					**GEO MEAN** (1 result)

Cladoceran, *Ceriodaphnia reticulata*

HARDNESS (PPM)	VALUE (ug/L)	METHOD		NORMALIZED HARDNESS	NORMALIZED VALUE	REFERENCE
45	17	S	U	0.433	0.860	Mount and Norberg, 1984
240	23	S	U	2.309	1.163	Elnabarawy, et al. 1986
103.92	19.77					**GEO MEAN** (2 results)

Cladoceran, *Daphnia pulex*

HARDNESS (PPM)	VALUE (ug/L)	METHOD		NORMALIZED HARDNESS	NORMALIZED VALUE	REFERENCE
45	53	S	U	0.572	2.085	Mount and Norberg, 1984
45	10	S	U	0.572	0.393	Cairns, et al. 1978
240	31	S	U	3.053	1.219	Elnabarawy, et al. 1986
78.62	25.42					**GEO MEAN** (3 results)

Cladoceran, *Daphnia magna*

HARDNESS (PPM)	VALUE (ug/L)	METHOD		NORMALIZED HARDNESS	NORMALIZED VALUE	REFERENCE
240	41	S	U	2.433	1.087	Elnabarawy, et al. 1986
226	200	S	U	2.291	5.304	Cabajszak and Stasiak, 1960
45.3	9.8	S	U	0.459	0.260	Biesinger and Christenson, 1982
99	85	S	U	1.004	2.254	Adema and DeGroot-Van Ziji, 1972
99	50	S	U	1.004	1.326	Adema and DeGroot-Van Ziji, 1972
52	26	S	M	0.527	0.689	Chapman, et al. Manuscript
105	30	S	M	1.065	0.796	Chapman, et al. Manuscript
106	38	S	M	1.075	1.008	Chapman, et al. Manuscript
207	69	S	M	2.099	1.830	Chapman, et al. Manuscript
45	10	S	U	0.456	0.265	Cairns, et al. 1978
100	31.8	S	M	1.014	0.843	Borgmann and Ralph, 1983
143	26	S	M	1.450	0.689	Lewis, 1983
45	54	S	U	0.456	1.432	Mount and Norberg, 1984
98.63	37.71					**GEO MEAN** (13 results)

Cladoceran, *Daphnia pulicaria*

HARDNESS (PPM)	VALUE (ug/L)	METHOD		NORMALIZED HARDNESS	NORMALIZED VALUE	REFERENCE
48	11.4	S	M	0.665	0.871	Lind, et al. Manuscript
48	9.06	S	M	0.665	0.692	Lind, et al. Manuscript
48	7.24	S	M	0.665	0.553	Lind, et al. Manuscript
44	10.8	S	M	0.609	0.825	Lind, et al. Manuscript
45	9.3	S	M	0.623	0.710	Lind, et al. Manuscript
95	17.8	S	M	1.315	1.359	Lind, et al. Manuscript
145	23.7	S	M	2.008	1.810	Lind, et al. Manuscript
245	27.3	S	M	3.393	2.085	Lind, et al. Manuscript
72.21	13.10					**GEO MEAN** (8 results)

Amphipod, *Gammarus pseudolimnaeus*

HARDNESS (PPM)	VALUE (ug/L)	METHOD		NORMALIZED HARDNESS	NORMALIZED VALUE	REFERENCE
45	20	FT	M			Arthur and Leonard, 1970
45	20					**GEO MEAN** (1 result)

Amphipod, *Crangonyx pseudogracilis*

HARDNESS (PPM)	VALUE (ug/L)	METHOD		NORMALIZED HARDNESS	NORMALIZED VALUE	REFERENCE
50	1290	S	U			Martin and Holdich, 1986
50	1290					**GEO MEAN** (1 result)

Crayfish, *Orconectus rusticus*

HARDNESS (PPM)	VALUE (ug/L)	METHOD		NORMALIZED HARDNESS	NORMALIZED VALUE	REFERENCE
112.5	3000	FT	M			Hubschman, 1967
112.5	3000					**GEO MEAN** (1 result)

Crayfish, *Procambarus clarkii*

HARDNESS (PPM)	VALUE (ug/L)	METHOD		NORMALIZED HARDNESS	NORMALIZED VALUE	REFERENCE
17	720	FT	M			Rice and Harrison, 1983
17	720					**GEO MEAN** (1 result)

Damselfly, Unidentified

HARDNESS (PPM)	VALUE (ug/L)	METHOD		NORMALIZED HARDNESS	NORMALIZED VALUE	REFERENCE
50	4600	S	M			Rehwoldt, et al. 1973
50	4600					**GEO MEAN** (1 result)

Stonefly, *Acroneuria lycorias*

HARDNESS (PPM)	VALUE (ug/L)	METHOD		NORMALIZED HARDNESS	NORMALIZED VALUE	REFERENCE
40	8300	S	M			Warnick and Bell, 1969
40	8300					**GEO MEAN** (1 result)

Caddisfly, Unidentified

HARDNESS (PPM)	VALUE (ug/L)	METHOD		NORMALIZED HARDNESS	NORMALIZED VALUE	REFERENCE
50	6200	S	M			Rehwoldt, et al. 1973
50	6200					**GEO MEAN** (1 result)

Midge, *Chironomus tentans*

HARDNESS (PPM)	VALUE (ug/L)	METHOD		NORMALIZED HARDNESS	NORMALIZED VALUE	REFERENCE
77.5	298	FT	M			Nebeker, et al. 1984 (1st instar)
77.5	298					**GEO MEAN** (1 result)

Midge, *Chironomus sp.*

HARDNESS (PPM)	VALUE (ug/L)	METHOD		NORMALIZED HARDNESS	NORMALIZED VALUE	REFERENCE
50	30	S	M			Rehwoldt, et al. 1973
50	30					**GEO MEAN** (1 result)

Midge, *Chironomus decorus*

HARDNESS (PPM)	VALUE (ug/L)	METHOD		NORMALIZED HARDNESS	NORMALIZED VALUE	REFERENCE
44	739	S	M			Kosalwat and Knight, 1987
44	739					**GEO MEAN** (1 result)

Bryozoan, *Pectinatella magnifica*

HARDNESS (PPM)	VALUE (ug/L)	METHOD		NORMALIZED HARDNESS	NORMALIZED VALUE	REFERENCE
205	510	S	U			Pardue and Wood, 1980
205	510					**GEO MEAN** (1 result)

Bryozoan, *Lophopodella carteri*

HARDNESS (PPM)	VALUE (ug/L)	METHOD		NORMALIZED HARDNESS	NORMALIZED VALUE	REFERENCE
205	140	S	U			Pardue and Wood, 1980
205	140					**GEO MEAN** (1 result)

Bryozoan, *Plumatella emarginata*

HARDNESS (PPM)	VALUE (ug/L)	METHOD		NORMALIZED HARDNESS	NORMALIZED VALUE	REFERENCE
205	140	S	U			Pardue and Wood, 1980
205	140					**GEO MEAN** (1 result)

American eel, *Anguilla rostrata*

HARDNESS (PPM)	VALUE (ug/L)	METHOD		NORMALIZED HARDNESS	NORMALIZED VALUE	REFERENCE
53	6400	S	M			Rehwoldt, et al. 1971
55	6000	S	M			Rehwoldt, et al. 1972
44	3200	S	U			Hinton and Eversole, 1978
44	2540	S	U			Hinton and Eversole, 1978
48.74	4203.19					**GEO MEAN** (4 results)

Coho salmon, *Onchorhynchus kisutch*

HARDNESS (PPM)	VALUE (ug/L)	METHOD		NORMALIZED HARDNESS	NORMALIZED VALUE	REFERENCE
20	46	FT	M			Chapman and Stevens, 1978
23	33	FT	M			Chapman, 1975 (parr)
23	42.9	FT	M			Chapman, 1975
94	74	S	M			Lorz and PcPherson, 1976 (yearling)
94	70	S	M			Lorz and PcPherson, 1976 (yearling)
94	60	S	M			Lorz and PcPherson, 1976 (smolt)
33	164	R	M			Buckley, 1983 (juvenile)
21.95	40.23					**GEO MEAN** (3 results, only the FT results were used to calculate the GMAV)

Sockeye salmon, *Onchorhynchus nerka*

HARDNESS (PPM)	VALUE (ug/L)	METHOD		NORMALIZED HARDNESS	NORMALIZED VALUE	REFERENCE
41	240	R	M			Davis and Shand, 1978 (smolt)
41	103	R	M			Davis and Shand, 1978 (smolt)
41	220	R	M			Davis and Shand, 1978 (fingerling)
41	210	R	M			Davis and Shand, 1978 (fingerling)
41	240	R	M			Davis and Shand, 1978 (fingerling)
41	193.90					**GEO MEAN** (5 results)

Chinook salmon, *Onchorhynchus tshawytscha*

HARDNESS (PPM)	VALUE (ug/L)	METHOD		NORMALIZED HARDNESS	NORMALIZED VALUE	REFERENCE
23	26	FT	M	0.611	0.804	Chapman, 1975, 1978
23	19	FT	M	0.611	0.587	Chapman, 1975, 1978
23	38	FT	M	0.611	1.175	Chapman, 1975, 1978
23	26	FT	M	0.611	0.804	Chapman, 1975, 1978
25	33.1	FT	M	0.664	1.023	Chapman, 1982
13	10	FT	M	0.345	0.310	Chapman and McCrady, 1977
46	22	FT	M	1.221	0.680	Chapman and McCrady, 1977
182	85	FT	M	4.833	2.627	Chapman and McCrady, 1977
359	130	FT	M	9.533	4.078	Chapman and McCrady, 1977
21	32	FT	M	0.558	0.989	Finlayson and Verrue, 1982
37.66	32.35					**GEO MEAN** (10 results)

Rainbow trout, *Onchorhynchus mykiss*

HARDNESS (PPM)	VALUE (ug/L)	METHOD		NORMALIZED HARDNESS	NORMALIZED VALUE	REFERENCE
290	890	S	M	2.951	11.388	Calamari and Marchetti, 1973
90	190			0.916	2.431	Giles and Klaverkamp, 1982
30	19.9	FT	M	0.305	0.255	Howarth and Sprague, 1978
32	22.4	FT	M	0.326	0.287	Howarth and Sprague, 1978
31	28.9	FT	M	0.315	0.370	Howarth and Sprague, 1978
31	30	FT	M	0.315	0.384	Howarth and Sprague, 1978
30	30	FT	M	0.305	0.384	Howarth and Sprague, 1978
101	176	FT	M	1.028	2.252	Howarth and Sprague, 1978
101	40	FT	M	1.028	0.512	Howarth and Sprague, 1978
99	33.1	FT	M	1.007	0.424	Howarth and Sprague, 1978
102	30.7	FT	M	1.038	0.393	Howarth and Sprague, 1978
101	46.3	FT	M	1.028	0.592	Howarth and Sprague, 1978
99	47.9	FT	M	1.007	0.613	Howarth and Sprague, 1978
100	48.1	FT	M	1.018	0.615	Howarth and Sprague, 1978
100	81.1	FT	M	1.018	1.038	Howarth and Sprague, 1978
98	85.9	FT	M	0.997	1.099	Howarth and Sprague, 1978
370	232	FT	M	3.765	2.968	Howarth and Sprague, 1978
366	70	FT	M	3.724	0.896	Howarth and Sprague, 1978
371	82.2	FT	M	3.775	1.052	Howarth and Sprague, 1978
361	298	FT	M	3.673	3.813	Howarth and Sprague, 1978
194	169	FT	M	1.974	2.162	Chakomoukos, et al. 1979
194	85.3	FT	M	1.974	1.091	Chakomoukos, et al. 1979
194	83.3	FT	M	1.974	1.066	Chakomoukos, et al. 1979
194	103	FT	M	1.974	1.318	Chakomoukos, et al. 1979
194	274	FT	M	1.974	3.506	Chakomoukos, et al. 1979
194	128	FT	M	1.974	1.638	Chakomoukos, et al. 1979
194	221	FT	M	1.974	2.828	Chakomoukos, et al. 1979
194	165	FT	M	1.974	2.111	Chakomoukos, et al. 1979
194	197	FT	M	1.974	2.521	Chakomoukos, et al. 1979
194	514	FT	M	1.974	6.577	Chakomoukos, et al. 1979
194	243	FT	M	1.974	3.109	Chakomoukos, et al. 1979
23	28	FT	M	0.234	0.358	Chapman, 1975, 1978
23	17	FT	M	0.234	0.218	Chapman, 1975, 1978
23	18	FT	M	0.234	0.230	Chapman, 1975, 1978
23	29	FT	M	0.234	0.371	Chapman, 1975, 1978
42	57	FT	M	0.427	0.729	Chapman, 1975, 1978
125	200	FT	M	1.272	2.559	Spear, 1977
125	190	FT	M	1.272	2.431	Spear, 1977
125	210	FT	M	1.272	2.687	Spear, 1977
120	80	FT	M	1.221	1.024	Seim, et al. 1984
9.2	2.8	FT	M	0.094	0.036	Cusimano and Brakke, 1986
95.81	71.78					**GEO MEAN** (39 FT results)

All 41 results were used in the slope calculation, normalized values were based on a mean hardness = 98.28 and mean LC50 = 78.16.

Atlantic salmon, Salmo salar

HARDNESS (PPM)	VALUE (ug/L)	METHOD		NORMALIZED HARDNESS	NORMALIZED VALUE	REFERENCE
20	48	FT	M			Sprague, 1964
9	125	S	M			Wilson, 1972
14	32	FT	M			Sprague and Ramsey, 1965
16.73	39.19					**GEO MEAN** (2 FT results)

Cutthroat trout, *Salmo clarki*

HARDNESS (PPM)	VALUE (ug/L)	METHOD		NORMALIZED HARDNESS	NORMALIZED VALUE	REFERENCE
205	367	FT	M	2.918	4.020	Chakomoukos, et al. 1979
70	186	FT	M	0.996	2.037	Chakomoukos, et al. 1979
18	36.8	FT	M	0.256	0.403	Chakomoukos, et al. 1979
204	232	FT	M	2.903	2.541	Chakomoukos, et al. 1979
83	162	FT	M	1.181	1.224	Chakomoukos, et al. 1979
31	73.6	FT	M	0.441	0.806	Chakomoukos, et al. 1979
160	91	FT	M	2.277	0.997	Chakomoukos, et al. 1979
74	44.4	FT	M	1.053	0.486	Chakomoukos, et al. 1979
26	15.7	FT	M	0.370	0.172	Chakomoukos, et al. 1979
70.26	91.30					**GEO MEAN** (9 results)

Brook trout, *Salvelinus fontinalis*

HARDNESS (PPM)	VALUE (ug/L)	METHOD		NORMALIZED HARDNESS	NORMALIZED VALUE	REFERENCE
45	100	FT	M			McKim and Benoit, 1971
45	100					**GEO MEAN** (1 result)

Central stoneroller, *Campostoma anomalum*

HARDNESS (PPM)	VALUE (ug/L)	METHOD		NORMALIZED HARDNESS	NORMALIZED VALUE	REFERENCE
200	290	FT	M			Geckler, et al. 1976
200	290					**GEO MEAN** (1 result)

Goldfish, *Carassius auratus*

HARDNESS (PPM)	VALUE (ug/L)	METHOD		NORMALIZED HARDNESS	NORMALIZED VALUE	REFERENCE
20	36	S	U			Pickering and Henderson, 1966
52	300	FT	M			Tsai and McKee, 1978 + 1980
32.25	103.92					**GEO MEAN** (1 FT result)

EPA used both values to calculate the species and genus mean acute values. It is not clear why this was done because of the apparent inconsistency to how other species data were handled, but to be consistent with the EPA approach both values are considered here. It is noted that this is not among the most sensitive species, so the choice does not affect the calculated criteria.

Carp, *Cyprinus carpio*

HARDNESS (PPM)	VALUE (ug/L)	METHOD		NORMALIZED HARDNESS	NORMALIZED VALUE	REFERENCE
53	810	S	M			Rehwoldt, et al. 1971
55	800	S	M			Rehwoldt, et al. 1972
166	117.5	S	U			Deshmukh and Marathe, 1980
166	530	S	U			Deshmukh and Marathe, 1980
19	63	R	U			Khangarot, et al. 1983
19	63					**GEO MEAN** (1 R result)

In the 1985 and 1995 documents, EPA only used the renewal test result to calculate the GMAV.

Striped shiner, *Notropis chrysocephalus*

HARDNESS (PPM)	VALUE (ug/L)	METHOD		NORMALIZED HARDNESS	NORMALIZED VALUE	REFERENCE
200	790	FT	M			Geckler, et al. 1976
200	1900	FT	M			Geckler, et al. 1976
200	1225.15					**GEO MEAN** (2 results)

Bluntnose minnow, *Pimephales notatus*

HARDNESS (PPM)	VALUE (ug/L)	METHOD		NORMALIZED HARDNESS	NORMALIZED VALUE	REFERENCE
200	290	FT	M			Geckler, et al. 1976
200	260	FT	M			Geckler, et al. 1976
200	260	FT	M			Geckler, et al. 1976
200	280	FT	M			Geckler, et al. 1976
200	340	FT	M			Geckler, et al. 1976
194	210	FT	M			Horning and Neiheisel, 1979
194	220	FT	M			Horning and Neiheisel, 1979
194	270	FT	M			Horning and Neiheisel, 1979
197.73	263.56					**GEO MEAN** (8 results)

Fathead minnow, *Pimephales promelas*

HARDNESS (PPM)	VALUE (ug/L)	METHOD		NORMALIZED HARDNESS	NORMALIZED VALUE	REFERENCE
43.9	96	FT	M	0.521	0.509	Spehar and Fiandt, 1986
20	50	S	U	0.237	0.265	Tarzwell and Henderson, 1960
400	1400	S	U	4.746	7.430	Tarzwell and Henderson, 1960
202	460	FT	M	2.397	2.441	Pickering, et al. 1977
202	490	FT	M	2.397	2.600	Pickering, et al. 1977
200	790	FT	M	2.373	4.192	Andrew, 1976
45	200	FT	M	0.534	1.061	Andrew, 1976
20	25	S	U	0.237	0.133	Pickering and Henderson, 1966
20	23	S	U	0.237	0.122	Pickering and Henderson, 1966
20	23	S	U	0.237	0.122	Pickering and Henderson, 1966
20	22	S	U	0.237	0.117	Pickering and Henderson, 1966
360	1760	S	U	4.271	9.340	Pickering and Henderson, 1966
360	1140	S	U	4.271	6.050	Pickering and Henderson, 1966
200	430	S	U	2.373	2.282	Mount, 1968
200	470	FT	M	2.373	2.494	Mount, 1968
31	84	S	U	0.368	0.446	Mount and Stephan, 1969
31	75	FT	M	0.368	0.398	Mount and Stephan, 1969
200	440	FT	M	2.373	2.335	Geckler, et al. 1976
200	490	FT	M	2.373	2.600	Geckler, et al. 1976
48	114	FT	M	0.570	0.605	Lind, et al. Manuscript
45	121	FT	M	0.534	0.642	Lind, et al. Manuscript
46	88.5	FT	M	0.546	0.470	Lind, et al. Manuscript
103	210	S	M	1.222	1.114	Birge, et al. 1983
103	310	S	M	1.222	1.645	Birge, et al. 1983
103	120	S	M	1.222	0.637	Birge, et al. 1983
262.5	390	S	M	3.115	2.070	Birge, et al. 1983
92.60	237.20					**GEO MEAN** (12 FT results)

All 26 results were used in the slope calculation, normalized values were based on a mean hardness = 84.28 and mean LC50 = 188.44.

Northern squawfish (genus *Ptychochelius*), chiselmouth (genus *Acrocheilus*) and Guppy (genus (*Poecilia*) were not used in the GMAV calculations since they are not resident to Wisconsin or the other Great Lakes states or Iowa. However, EPA used the guppy data as part of the slope calculation.

Guppy, *Poecilia reticulata*

HARDNESS (PPM)	VALUE (ug/L)	METHOD		NORMALIZED HARDNESS	NORMALIZED VALUE	REFERENCE
20	36	S	U	0.218	0.163	Chynoweth, et al. 1976
230	1230	S	U	2.508	5.575	Khangarot, 1981
240	764	S	U	2.617	3.463	Khangarot, et al. 1981
87.5	112	FT	M	0.954	0.508	Black, 1974
67.2	138	FT	M	0.733	0.625	Black, 1974
						GEO MEAN not used for GMAV

All 5 results were used in the slope calculation, normalized values were based on a mean hardness = 91.72 and mean LC50 = 220.64. The geometric mean was not used for the GMAV calculation because it is non-resident (see above). The hardness vs. LC50 information is useful for defining the relationship in all freshwater species.

Blacknose dace, *Rhinichthys atratulus*

HARDNESS (PPM)	VALUE (ug/L)	METHOD		NORMALIZED HARDNESS	NORMALIZED VALUE	REFERENCE
200	320	FT	M			Geckler, et al. 1976
200	320					**GEO MEAN** (1 result)

Creek chub, *Semotilus atromaculatus*

HARDNESS (PPM)	VALUE (ug/L)	METHOD		NORMALIZED HARDNESS	NORMALIZED VALUE	REFERENCE
200	310	FT	M			Geckler, et al. 1976
200	310					**GEO MEAN** (1 result)

Brown bullhead, *Ictalurus nebulosus*

HARDNESS (PPM)	VALUE (ug/L)	METHOD		NORMALIZED HARDNESS	NORMALIZED VALUE	REFERENCE
202	170	FT	M			Brungs, et al. 1973
202	190	FT	M			Brungs, et al. 1973
200	540	FT	M			Geckler, et al. 1976
201.33	259.34					**GEO MEAN** (3 results)

Banded killifish, *Fundulus diaphanus*

HARDNESS (PPM)	VALUE (ug/L)	METHOD		NORMALIZED HARDNESS	NORMALIZED VALUE	REFERENCE
53	860	S	M			Rehwoldt, et al. 1971
55	840	S	M			Rehwoldt, et al. 1972
53.99	849.94					**GEO MEAN** (2 results)

Mosquitofish, *Gambusia affinis*

HARDNESS (PPM)	VALUE (ug/L)	METHOD		NORMALIZED HARDNESS	NORMALIZED VALUE	REFERENCE
34	93	S	U			Joski and Rege, 1980
34	200	S	U			Joski and Rege, 1980
34	136.38					**GEO MEAN** (2 results)

Mosquitofish is not resident to Wisconsin, but is resident in Iowa and elsewhere in the Great Lakes basin.

White perch, *Morone americana*

HARDNESS (PPM)	VALUE (ug/L)	METHOD		NORMALIZED HARDNESS	NORMALIZED VALUE	REFERENCE
53	6200	S	M			Rehwoldt, et al. 1971
55	6400	S	M			Rehwoldt, et al. 1972
						GEO MEAN not used

EPA did not use the white perch data to calculate a GMAV because the striped bass was much more sensitive, the two species mean values were considered by EPA to be too divergent but the more sensitive one was used.

Striped bass, *Morone saxatilis*

HARDNESS (PPM)	VALUE (ug/L)	METHOD		NORMALIZED HARDNESS	NORMALIZED VALUE	REFERENCE
285	270	S	U			Palawski, et al. 1985
285	270					**GEO MEAN** (1 result)

Pumpkinseed, *Lepomis gibbosus*

HARDNESS (PPM)	VALUE (ug/L)	METHOD		NORMALIZED HARDNESS	NORMALIZED VALUE	REFERENCE
53	2400	S	M			Rehwoldt, et al. 1971
55	2700	S	M			Rehwoldt, et al. 1972
125	1240	FT	M			Spear, 1977
125	1300	FT	M			Spear, 1977
125	1670	FT	M			Spear, 1977
125	1940	FT	M			Spear, 1977
125	1240	FT	M			Spear, 1977
125	1660	FT	M			Spear, 1977
125	1740	FT	M			Spear, 1977
125	1519.53					**GEO MEAN** (7 FT results)

Bluegill, *Lepomis macrochirus*

HARDNESS (PPM)	VALUE (ug/L)	METHOD		NORMALIZED HARDNESS	NORMALIZED VALUE	REFERENCE
52	400	S	U	0.736	0.298	Inglis and Davis, 1972
209	680	S	U	2.960	0.507	Inglis and Davis, 1972
365	1020	S	U	5.169	0.760	Inglis and Davis, 1972
45	1100	FT	M	0.637	0.820	Benoit, 1975
200	8300	FT	M	2.833	6.188	Geckler, et al. 1976
200	10000	FT	M	2.833	7.455	Geckler, et al. 1976
20	200	S	U	0.283	0.149	Tarzwell and Henderson, 1960
400	10000	S	U	5.665	7.455	Tarzwell and Henderson, 1960
43	770	S	U	0.609	0.574	ANS, 1960
43	1250	S	U	0.609	0.932	ANS, 1960
20	660	S	U	0.283	0.492	Pickering and Henderson, 1966
360	10200	S	U	5.099	7.604	Pickering and Henderson, 1966
35	2400	FT	M	0.496	1.789	O'Hara, 1971
40	1000	FT	M	0.567	0.746	Thompson, et al. 1980
26	1000	FT	M	0.368	0.746	Cairns, et al. 1981
31.2	340	S	M	0.442	0.253	Bailey, et al. 1985
31.2	550	FT	M	0.442	0.410	Bailey, et al. 1985
57.36	1982.86					**GEO MEAN** (7 FT results)

All 17 results were used in the slope calculation, normalized values were based on a mean hardness = 70.61 and mean LC50 = 1341.36.

Rainbow darter, *Etheostoma caerulum*

HARDNESS (PPM)	VALUE (ug/L)	METHOD		NORMALIZED HARDNESS	NORMALIZED VALUE	REFERENCE
200	320	FT	M			Geckler, et al. 1976
200	320					**GEO MEAN** (1 result)

Orangethroat darter, *Etheostoma spectabile*

HARDNESS (PPM)	VALUE (ug/L)	METHOD		NORMALIZED HARDNESS	NORMALIZED VALUE	REFERENCE
200	850	FT	M			Geckler, et al. 1976
200	850					**GEO MEAN** (1 result)

Tilapia, *Tilapia mossambica*

HARDNESS (PPM)	VALUE (ug/L)	METHOD		NORMALIZED HARDNESS	NORMALIZED VALUE	REFERENCE
115	1500	S	U			Qureshi and Saksema, 1980
115	1500					**GEO MEAN** (1 result)

HARDNESS DATA: Geometric mean of all results = 79.90
Mean + 2 standard deviations (calculated on log scale) = 495
Mean - 2 standard deviations (calculated on log scale) = 13
Range over which acute criteria are applied = 13 - 495 PPM

SLOPE OF ATC EQUATION (from normalized data) = 0.9436 (r-squared = 0.672).
This is slightly different than EPA's 1985 slope due to some additional data on the species with enough data for a slope calculation (*D. magna*, rainbow trout, bluegill)

MINIMUM DATABASE REQUIREMENT EVALUATION
According to s. NR 105.05(1)(a), acute toxicity criteria can be calculated if data are available on one or more species of freshwater animal in at least 8 different families, provided that of the 8 species:

1. At least one is a salmonid fish in the family Salmonidae in the class Osteichthyes,
2. At least one is a non-salmonid fish from another family in the class Osteichthyes, preferably a commercially or recreationally important species,
3. At least one is a planktonic crustacean (e.g., cladoceran, copepod),
4. At least one is a benthic crustacean (e.g., ostracod, isopod, amphipod, crayfish),
5. At least one is an insect (e.g., mayfly, dragonfly, damselfly, stonefly, caddisfly, mosquito, midge),
6. At least one is a fish or amphibian from a family in the phylum Chordata not already represented in one of the other subdivisions,
7. At least one is an organism from a family in a phylum other than Arthropoda or Chordata (e.g., Rotifera, Annelida, Mollusca), and
8. At least one is an organism from a family in any order of insect or any other phylum not already represented in subds. 1. to 7.

Using the above numbering scheme, the following species are represented in the minimum database requirements for criteria calculation. If any of the 8 categories are not represented in the database, a criterion cannot be calculated under ch. NR 105. Instead, a secondary value must be calculated.

1. Rainbow trout
2. Bluegill
3. Cladoceran *(D. magna)*
4. Amphipod (*Gammarus pseudolimnaeus*)
5. Stonefly *(Acroneuria lycorias)*
6. Fathead minnow, family Cyprinidae
7. Snail (Amnicola sp.)
8. Banded killifish, family Cyprinodontidae

CONCLUSION: An acute toxicity criterion can be calculated for copper according to ch. NR 105.

Normalize mean toxicity values to intercepts @ hardness = 1 PPM using the slope of 0.9436 relating ln LC50 to ln hardness. Species are arranged in the following table by genus names in alphabetical order).

Genus / species		Mean hardness		Mean LC50/EC50		SMAI (LC50/EC50 @ hardness = 1)
Acroneuria (Stonefly)		40.00		8300.00		255.5196
Amnicola (Snail)		50.00		900.00		22.4464
Anguilla (American eel)		48.74		4203.19		107.3846
(Caddisfly, unidentified genus)		50.00		6200.00		154.6310
Campelona (Snail, C. decisum)		45.00		1700.00		46.8305
Campostoma (Central stoneroller)		200.00		290.00		1.9553
Carassius (Goldfish)		32.25		103.92		3.9203
Ceriodaphnia (Cladoceran)	103.92		19.77		0.2473	
Chironomus (Midge, C. tentans)		77.50		298.00		4.9151 *
Chironomus (Midge, C. decorus)		44.00		739.00		20.7938 *
Chironomus (Midge, unidentified)		50.00		30.00		0.7482 *
Corbicula (Asiatic clam, C. manilensis)		17.00		2600.00		179.4568
Crangonyx (Amphipod, C. pseudogra.)		50.00		1290.00		32.1732
Cyprinus (Carp)		19.00		63.00		3.9152
(Damselfly, unidentified genus)		50.00		4600.00		114.7262
Daphnia (Cladoceran, D. magna)		98.63		37.71		0.4954
Daphnia (Cladoceran, D. pulex)		78.62		25.42		0.4137
Daphnia (Cladoceran, D. pulicaria)		72.21		13.10		0.2309
Etheostoma (Rainbow darter)		200.00		320.00		2.1576
Etheostoma (Orangethroat darter)		200.00		850.00		5.7311
Fundulus (Banded killifish)		53.99		849.94		19.7163
Gambusia (Mosquitofish)		34.00		136.38		4.8944
Gammarus (Amphipod, G. pseudolim.)		45.00		20.00		0.5509
Goniobasis (Snail, G. livescens)		154.00		479.69		4.1389
Gyarulus (Snail, G. circumstriatus)		100.00		108.00		1.4005
Ictalurus (Brown bullhead)		201.33		259.34		1.7377
Lepomis (Bluegill)	57.36		1982.86		43.4398	
Lepomis (Pumpkinseed)		125.00		1519.53		15.9636
Limnodrilus (Worm, L. hoffmeisteri)		100.00		102.00		1.3227
Lophopodella (Bryozoan, L. carteri)		205.00		140.00		0.9222
Lumbriculus (Worm, L. variegatus)		30.00		150.00		6.0579
Morone (Striped bass)		285.00		270.00		1.3033
Nais (Worm)		50.00		90.00		2.2446
Notropis (Striped shiner)		200.00		1225.15		8.2606
Onchorhynchus (Sockeye salmon)		41.00		193.90		5.8319
Onchorhynchus (Coho salmon)		21.95		40.23		2.1816
Onchorhynchus (Rainbow trout)		98.28		78.16		0.9692
Onchorhynchus (Chinook salmon)		37.66		32.35		1.0543
Orconectes (Crayfish, O. rusticus)		112.50		3000.00		34.8111
Pectinatella (Bryozoan, P. emarginata)		205.00		510.00		3.3595
Physa (Snail, P. integra)		45.00		39.00		1.0743
Physa (Snail, P. heterostropha)		100.00		69.00		0.8948
Pimephales (Fathead minnow)		92.60		237.20		3.3075
Pimephales (Bluntnose minnow)		197.73		263.56		1.7963
Plumatella (Bryozoan, P. emarginata)		205.00		140.00		0.9222
Procambarus (Crayfish, P. clarkii)		17.00		720.00		49.6957
Rhinichthys (Blacknose dace)		200.00		320.00		2.1576
Salmo (Cutthroat trout)		70.26		91.30		1.6518
Salmo (Atlantic salmon)		13.61		57.69		4.9123
Salvelinus (Brook trout)		45.00		100.00		2.7547
Semotilus (Creek chub)		200.00		310.00		2.0902
Tilapia (Tilapia)		115.00		1500.00		17.0483

* - EPA guidelines question the calculation of a genus mean value when the species mean values vary by more than a factor of 10, but EPA did it anyway for this genus, so a GMAI is calculated here using all indicated species within the genus. NOTE: EPA did not do this for genus *Morone*.

Genus Mean Acute Intercept calculations from above table (geometric means calculated if more than one species in a genus has data). The GMAIs are sorted from high to low and the representative receiving water classifications in Wisconsin are also noted.

			GMAI		CLASSIFICATIONS *			
GENUS NAME			(ug/L)		CW	WW	LFF	LAL
Acroneuria			225.5196		x	x	x	x
Corbicula			179.4568		x	x	x	x
Caddisfly genus			154.6310		x	x	x	x
Damselfly genus			114.7262		x	x	x	x
Anguilla			107.3846		x	x		
Procambarus			49.6957		x	x	x	x
Campelona			46.8305		x	x	x	x
Orconectes			34.8111		x	x	x	x
Crangonyx			32.1732		x	x	x	x
Lepomis			26.3335		x	x		
Amnicola			22.4464		x	x	x	x
Fundulus			19.7163		x	x		
Tilapia			17.0483		x	x		
Notropis			8.2606		x	x	x	
Lumbriculus			6.0579		x	x	x	x
Gambusia			4.8944		x	x		
Chironomus			4.2445		x	x	x	x
Goniobasis			4.1389		x	x	x	x
Carassius			3.9203		x	x	x	
Cyprinus			3.9152		x	x	x	
Etheostoma			3.5164		x	x	x	
Pectinatella			3.3595		x	x	x	x
Salmo			2.8485		x			
Salvelinus			2.7547		x			
Pimephales			2.4375		x	x	x	
Nais			2.2446		x	x	x	x
Rhinichthys			2.1576		x	x		
Semotilus			2.0902		x	x		
Campostoma			1.9553		x	x	x	
Onchorhynchus			1.8988		x			
Ictalurus			1.7377		x	x		
Gyraulus	1.4005			x	x	x	x	
Limnodrilus			1.3227		x	x	x	x
Morone			1.3033		x	x		
Physa			0.9805		x	x	x	x
Lophopodella			0.9222		x	x	x	x
Plumatella			0.9222		x	x	x	x
Gammarus			0.5509		x	x	x	x
Daphnia			0.3617		x	x	x	x
Ceriodaphnia			0.2473		x	x	x	x
TOTAL NUMBER REPRESENTED:					40	37	28	22

* - KEY TO CLASSIFICATIONS (an x is listed for species considered in each):

CW = Coldwater community, all genera are considered here.

WW = Warmwater sportfish community, only the coldwater fish are excluded from this database (also includes warmwater forage).

LFF = Limited forage fish community, all sport fish are excluded from this database.

LAL = Limited aquatic life, all fish are excluded from this database.

The four most sensitive genera in each classification are used to calculate the criteria under each classification, pursuant to s. NR 105.05 (2). Based on the above, the same four genera are the most sensitive in each classification. Therefore, the criteria based on all genera shall be applied to all surface waters, no relaxed criteria are possible under the calculation procedure. From this point, the results of the calculation are shown using the variables listed in sub. (2).

CRITERIA CALCULATION:

	all waters
GMAI RANKS	
4	0.9222084
3	0.5509474
2	0.3617011
1	0.2472759
n	40
ln GMAI	
4	-0.080984
3	-0.596116
2	-1.016937
1	-1.39725
(ln GMAI)^2	
4	0.0065584
3	0.3553542
2	1.0341613
1	1.9523089
P	
4	0.097561
3	0.0731707
2	0.0487805
1	0.0243902
sq rt P	
4	0.3123475
3	0.2705009
2	0.2208631
1	0.1561738
EV	-3.091288
EW	3.3483828
EP	0.2439024
EPR	0.9598852
J	0.05
S	8.4120599
L	-2.791475
A	-0.910481
FAI	0.4023306
ACI	0.2011653
ln ACI	-1.603628

Acute toxicity criteria for copper (in ug/L as total recoverable):

all classifications: ATC = EXP(0.9436 X ln(hardness) – 1.6036)

where EXP = e raised to the power of the term in parentheses

HARDNESS RANGE = 13 - 495

EXAMPLE CRITERIA:

Hardness (PPM)	ATC (ug/L)
50	8.1
100	15.5
200	29.8
400	57.4

The resulting criteria are slightly greater than the EPA criteria published as part of the 1995 Great Lakes Water Quality Initiative. The difference is primarily the result of excluding data on one of the most sensitive genera (northern squawfish, genus *Ptychocheilus*) since it is not resident to the Great Lakes states, this would raise the calculated criteria. The other non-resident genera that were excluded (*Acrocheilus* and *Poecilia*) are not among the most sensitive, so the reduced database size would actually lower the criteria, but not enough to offset the exclusion of the northern squawfish data.

CHRONIC TOXICITY CRITERIA

EPA SPECIES MEAN CHRONIC VALUES

(values from 1/85 EPA AWQC document, EPA 440/5-84-031 and 3/95 GLWQI Criteria Document for the Protection of Aquatic Life in Ambient Water)

Snail, *Campeloma decisum*

HARDNESS (ppm)	VALUE (ug/L)	TYPE OF TEST	NORMALIZED HARDNESS	NORMALIZED VALUE	REFERENCE
45	10.88	LC			Arthur and Leonard, 1970
45	10.88				**GEO MEAN** (1 result)

Snail, *Physa integra*

HARDNESS (ppm)	VALUE (ug/L)	TYPE OF TEST	NORMALIZED HARDNESS	NORMALIZED VALUE	REFERENCE
45	10.88	LC			Arthur and Leonard, 1970
45	10.88				**GEO MEAN** (1 result)

Cladoceran, *Daphnia magna*

HARDNESS (ppm)	VALUE (ug/L)	TYPE OF TEST	NORMALIZED HARDNESS	NORMALIZED VALUE	REFERENCE
51	13.63	LC			Chapman, et al. Manuscript
104	29.33	LC			Chapman, et al. Manuscript
211	9.525	LC			Chapman, et al. Manuscript
103.82	15.62				**GEO MEAN** (3 results)

Amphipod, *Gammarus pseudolimnaeus*

HARDNESS (ppm)	VALUE (ug/L)	TYPE OF TEST	NORMALIZED HARDNESS	NORMALIZED VALUE	REFERENCE
45	6.066	LC			Arthur and Leonard, 1970
45	6.066				**GEO MEAN** (1 result)

Caddisfly, *Clistornia magnifica*

HARDNESS (ppm)	VALUE (ug/L)	TYPE OF TEST	NORMALIZED HARDNESS	NORMALIZED VALUE	REFERENCE
26	10.39	LC			Nebeker, et al. 1984
26	10.39				**GEO MEAN** (1 result)

Chinook salmon, *Onchorhynchus tshawytscha*

HARDNESS (ppm)	VALUE (ug/L)	TYPE OF TEST	NORMALIZED HARDNESS	NORMALIZED VALUE	REFERENCE
23	< 7.4	ELS			Chapman, 1975 + 1982
23	< 7.4				**GEO MEAN** (1 result)

Rainbow trout, *Onchorhynchus mykiss*

HARDNESS (ppm)	VALUE (ug/L)	TYPE OF TEST	NORMALIZED HARDNESS	NORMALIZED VALUE	REFERENCE
45.4	19.01	ELS			McKim, et al. 1978
45.4	19.01				**GEO MEAN** (1 result)

Brown trout, *Salmo trutta*

HARDNESS (ppm)	VALUE (ug/L)	TYPE OF TEST	NORMALIZED HARDNESS	NORMALIZED VALUE	REFERENCE
45.4	30.83	ELS			McKim, et al. 1978
45.4	30.83				**GEO MEAN** (1 result)

Brook trout, *Salvelinus fontinalis*

HARDNESS (ppm)	VALUE (ug/L)	TYPE OF TEST	NORMALIZED HARDNESS	NORMALIZED VALUE	REFERENCE
45	12.86	LC			McKim and Benoit, 1971
45.4	31.15	ELS			McKim, et al. 1978
37.5	3.873	ELS			Sauter, et al. 1976
42.47	11.58				**GEO MEAN** (3 results)

Lake trout, *Salvelinus namaycush*

HARDNESS (ppm)	VALUE (ug/L)	TYPE OF TEST	NORMALIZED HARDNESS	NORMALIZED VALUE	REFERENCE
45.4	30.51	ELS			McKim, et al. 1978
45.4	30.51				**GEO MEAN** (1 result)

Northern pike, *Esox lucius*

HARDNESS (ppm)	VALUE (ug/L)	TYPE OF TEST	NORMALIZED HARDNESS	NORMALIZED VALUE	REFERENCE
45.4	60.36	ELS			McKim, et al. 1978
45.4	60.36				**GEO MEAN** (1 result)

Bluntnose minnow, *Pimephales notatus*

HARDNESS (ppm)	VALUE (ug/L)	TYPE OF TEST	NORMALIZED HARDNESS	NORMALIZED VALUE	REFERENCE
194	8.798	LC			Horning and Neiheisel, 1979
194	8.798				**GEO MEAN** (1 result)

Fathead minnow, *Pimephales promelas*

HARDNESS (ppm)	VALUE (ug/L)	TYPE OF TEST	NORMALIZED HARDNESS	NORMALIZED VALUE	REFERENCE
43.9	6.2	ELS			Spehar and Fiandt, 1986
198	21.87	LC			Mount,1968
30	13.97	LC			Mount and Stephan, 1969
200	27.71	LC			Pickering, et al. 1977
84.98	15.14				**GEO MEAN** (4 results)

White sucker, *Catostomus commersoni*

HARDNESS (ppm)	VALUE (ug/L)	TYPE OF TEST	NORMALIZED HARDNESS	NORMALIZED VALUE	REFERENCE
45.4	20.88	ELS			McKim, et al. 1978
45.4	20.88				**GEO MEAN** (1 result)

Bluegill, *Lepomis macrochirus*

HARDNESS (ppm)	VALUE (ug/L)	TYPE OF TEST	NORMALIZED HARDNESS	NORMALIZED VALUE	REFERENCE
45	28.98	LC			Benoit, 1975
45	28.98				**GEO MEAN** (1 result)

MINIMUM DATABASE REQUIREMENT EVALUATION

Fifteen freshwater species have chronic data. According to s. NR 105.06(1)(a), chronic toxicity criteria can be calculated independently from acute only if data are available on one or more species of freshwater animal in at least 8 different families, provided that of the 8 species:

1. At least one is a salmonid fish in the family Salmonidae in the class Osteichthyes,
2. At least one is a non-salmonid fish from another family in the class Osteichthyes, preferably a commercially or recreationally important species,

3. At least one is a planktonic crustacean (e.g., cladoceran, copepod),
4. At least one is a benthic crustacean (e.g., ostracod, isopod, amphipod, crayfish),
5. At least one is an insect (e.g., mayfly, dragonfly, damselfly, stonefly, caddisfly, mosquito, midge),
6. At least one is a fish or amphibian from a family in the phylum Chordata not already represented in one of the other subdivisions,
7. At least one is an organism from a family in a phylum other than Arthropoda or Chordata (e.g., Rotifera, Annelida, Mollusca), and
8. At least one is an organism from a family in any order of insect or any other phylum not already represented in subds. 1. to 7.

Using the above numbering scheme, the following species are represented in the minimum database requirements for criteria calculation. If any of the 8 categories are not represented in the database, a criterion cannot be calculated under ch. NR 105. Instead, chronic criteria may be calculated using acute-chronic ratios and if that isn't possible, a secondary value must be calculated.

1. Rainbow trout
2. Bluegill
3. Cladoceran *(D. magna)*
4. Amphipod (*G. pseudolimnaeus*)
5. Caddisfly *(C. magnifica)*
6. Fathead minnow, family Cyprinidae
7. Snail (*P. integra*)
8. NOT REPRESENTED

CONCLUSION: A chronic toxicity criterion cannot be directly calculated for copper according to ch. NR 105. Acute-chronic ratios must be used to calculate chronic criteria.

EPA ACUTE-CHRONIC RATIOS:

Acute-chronic ratios (ACRs) were developed such that the chronic criterion equals the final acute value divided by the appropriate ACR. The following table summarizes the calculation procedure for the ACRs using the procedure in s. NR 105.06 (5).

SPECIES/ REFERENCE	ACUTE VALUE	CHRONIC VALUE	TEST ACR	SMACR
Campeloma decisum (Arthur & Leonard, 1970):				
(hardness = 45)	1700	10.88	156.25	156.25
Physa integra (Arthur & Leonard, 1970):				
(hardness = 45)	39	10.88	3.58	3.58
Daphnia magna (all Chapman, et al. Manuscript):				
(hardness = 51-52)	26	13.63	1.91	
(hardness = 104-105)	30	29.33	1.02	
(hardness = 207-211)	69	9.525	7.24	2.42
Gammarus pseudolimnaeus (Arthur and Leonard, 1970):				
(hardness = 35-55)	20	6.066	3.30	3.30
Brook trout (McKim and Benoit, 1971):				
(hardness = 45)	100	12.86	7.78	7.78

{continued}

SPECIES/ REFERENCE	ACUTE VALUE	CHRONIC VALUE	TEST ACR	SMACR
Bluntnose minnow (Horning and Neiheisel, 1979):				
(hardness = 194)	231.9 (1)	8.798	26.36	26.36
Fathead minnow (Spehar and Fiandt, 1986)				
(hardness = 43.9)	96	6.2	15.48	
Fathead minnow (Mount, 1968):				
(hardness = 198-200)	470	21.87	21.49	
Fathead minnow (Mount and Stephan, 1969):				
(hardness = 30-31)	75	13.97	5.37	
Fathead minnow (Pickering, et al. 1977):				
(hardness = 200)	474.8 (2)	27.71	17.13	
Fathead minnow (Lind, et al. Manuscript)				
(hardness = 45-48)	106.7 (3)	106.9	18.53	11.20
Bluegill (Benoit, 1975):				
(hardness = 45)	1100	28.98	37.96	37.96

(1) = Geometric mean of three results (210, 220, 270 ug/L)
(2) = Geometric mean of two results (460, 490 ug/L)
(3) = Geometric mean of three results (114, 121, 88.5 ug/L)

The SMACRs are very highly divergent, so the preferred approach by both EPA and in s. NR 105.06(5)(e) is to calculate the Final ACR based on the SMACRs for species with sensitivity closest to the calculated acute criterion. In this case, the cladoceran *Daphnia magna* and the amphipod *Gammarus pseudolimnaeus* are part of two of the four most acutely sensitive genera such that the GMAVs were directly used to calculate criteria. As a result, the FACR for copper in all classifications (since both of those species are invertebrates that are representative of all surface water classifications in Wisconsin) is the geometric mean of the ratios of 2.42 and 3.30, or 2.82. This ratio is used by EPA as well.

However, EPA made one additional adjustment to its chronic criteria calculation approach. If the "typical" chronic criteria approach was used, defining the chronic criterion as the Final Acute Value (2 X ATC) divided by the FACR, the chronic criteria equation would be CTC = EXP (0.9436 X ln(hardness) – 1.9472). This would result in an example chronic criterion of 21 ug/L at 200 PPM hardness. This was a concern to EPA based on test results for *Daphnia magna* and especially bluntnose minnow around that hardness. EPA's concern was that the limited database for bluntnose minnow suggested a SMACR much greater than the mean of 2.82 for the sensitive species. Bluntnose minnow is fairly tolerant to copper on an acute basis, but if the SMACR is high, it may turn out to be fairly sensitive on a chronic basis and may not be protected using an FACR based on the most sensitive acute species.

The approach EPA took in it s criteria development document was to create a hybrid chronic toxicity criterion equation using a line on a double-log scale that connected the Acute Toxicity Criterion at a hardness of 1 PPM (EXP(-1.6036) = 0.201 ug/L) to the Final Acute Value divided by 2.82 at a hardness of 50 PPM (15.5 ug/L X 2 / 2.82 = 5.7 ug/L). The selection of the 50 PPM hardness in this case was apparently totally arbitrary, since the intent was to generate lower chronic criteria in harder waters where the low chronic values for bluntnose minnow were reported. The following table summarizes the impact of this calculation, using both the 1985 and 1995 EPA chronic criteria equations, the equation based solely on the FACR, and the Wisconsin equation generated from this hybrid approach.

	WI Acute Criterion (ug/L)	1985 EPA Chronic Criterion (ug/L)	1995 EPA/GLI Chronic Criterion (ug/L)	FACR-based WI Chronic Criterion (ug/L)	WI "Hybrid" Chronic Criterion (ug/L)
Equation Slope (X ln hardness)	0.9436	0.8545	0.8545	0.9436	0.8557
Equation Intercept	-1.6036	-1.465	-1.702	-1.6036 + ln(2) - ln(2.82) = -1.9472	-1.6036
Value (ug/L) @ hardness =					
1 PPM	0.20	0.23	0.18	0.14	0.20
50 PPM	8.1	6.5	5.2	5.7	5.7
100 PPM	15.5	11.8	9.3	11.0	10.4
200 PPM	29.7	21.4	16.9	21.2	18.7
400 PPM	57.4	38.7	30.5	40.7	33.9

The Wisconsin "hybrid" chronic criterion is still greater than EPA's 1995 chronic criterion, but that difference is due to the adjustment in the acute criteria by the exclusion of the northern squawfish data for being non-resident. The result is still less than the strict application of the FACR to the Final Acute Value, though. The results at a hardness of 200 PPM are still well above the reported results of 9.525 ug/L for *Daphnia magna* (at a hardness of 211 PPM) and 8.798 ug/L for bluntnose minnow (at a hardness of 194 PPM). As concluded by EPA in its 1985 criteria document, the lower result using the "hybrid" equation approach in harder water "seems more appropriate." This hardly seems like a scientific term, but since the difference in criteria is minimal in softer waters, which is where chronic toxicity-based copper limits are more likely to be imposed in Wisconsin, especially for municipal dischargers, the "hybrid" approach is used for Wisconsin's criteria as well. This at least provides an application that is consistent with EPA's method even though the results are still different due to Wisconsin's state-specific adjustment as allowed in the GLI.

Chronic toxicity criteria for copper (in ug/L as total recoverable):

all classifications: CTC = EXP(0.8557 X ln(hardness) – 1.6036)

where EXP = e raised to the power of the term in parentheses
HARDNESS RANGE = 13 - 495

EXAMPLE CRITERIA:

Hardness (PPM)	CTC (ug/L)
50	5.7
100	10.4
200	18.7
400	33.9

The chronic equation is applied over the same range as the acute equation because the acute database was used for both equations and it is much larger and more diverse in terms of hardness than the chronic database.