DERIVATION OF ACUTE AND CHRONIC TOXICITY CRITERIA FOR ZINC (1997)
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ACUTE TOXICITY CRITERIA

EPA SPECIES MEAN ACUTE VALUES

(values from 2/87 EPA AWQC document, EPA 440/5-87-003 and 3/95 GLWQI Criteria Document for the Protection of Aquatic Life in Ambient Water)

NOTE: Normalized hardness and zinc 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).

Frog, *Xenopus laevis*

HARDNESS (PPM)	VALUE (ug/L)	METHOD		NORMALIZED HARDNESS	NORMALIZED VALUE	REFERENCE
100	34500	S	M			Dawsin, et al. 1988
100	34500					**GEO MEAN** (1 result)

Worm, *Lumbriculus variegatus*

HARDNESS (PPM)	VALUE (ug/L)	METHOD		NORMALIZED HARDNESS	NORMALIZED VALUE	REFERENCE
30	6300	S	U			Bailey and Liu, 1980
30	6300					**GEO MEAN** (1 result)

Tubificid worm, *Limnodrilus hoffmeisteri*

HARDNESS (PPM)	VALUE (ug/L)	METHOD		NORMALIZED HARDNESS	NORMALIZED VALUE	REFERENCE
100	> 2274	S	U			Wurtz and Bridges, 1961
100	2274					**GEO MEAN** (1 result)

Worm, *Nais sp.*

HARDNESS (PPM)	VALUE (ug/L)	METHOD		NORMALIZED HARDNESS	NORMALIZED VALUE	REFERENCE
50	18400	S	M			Rehwoldt, et al. 1973
50	18400					**GEO MEAN** (1 result)

Snail, *Amnicola sp.*

HARDNESS (PPM)	VALUE (ug/L)	METHOD		NORMALIZED HARDNESS	NORMALIZED VALUE	REFERENCE
50	18400	S	M			Rehwoldt, et al. 1973 (embryo)
50	14000	S	M			Rehwoldt, et al. 1973 (adult)
50	16820					**GEO MEAN** (2 results)

Normally, EPA would use the most sensitive life stage to calculate a GMV, but in this case a mean of both results was used instead of the result for the adult snail. It won't affect the criterion calculation since this organism is not among the most sensitive to zinc.

Snail, *Helisoma campanulatum*

HARDNESS (PPM)	VALUE (ug/L)	METHOD		NORMALIZED HARDNESS	NORMALIZED VALUE	REFERENCE
20	870	S	U			Wurtz, 1962 (adult, 12.8 C)
20	1270	S	U			Wurtz, 1962 (adult, 22.8 C)
100	3030	S	U			Wurtz, 1962 (adult, 12.8 C)
100	1270	S	U			Wurtz, 1962 (adult, 22.8 C)
44.72	1435.96					**GEO MEAN** (4 results)

Snail, *Physa gyrina*

HARDNESS (PPM)	VALUE (ug/L)	METHOD		NORMALIZED HARDNESS	NORMALIZED VALUE	REFERENCE
36	1274	FT	M			Nebeker, et al. 1986
36	1274					**GEO MEAN** (1 result)

Snail, *Physa heterostropha*

HARDNESS (PPM)	VALUE (ug/L)	METHOD		NORMALIZED HARDNESS	NORMALIZED VALUE	REFERENCE
45	1800	S	U	0.805	1.505	Cairns and Scheier, 1958, ANS, 1960
45	1000	S	U	0.805	0.836	Cairns and Scheier, 1958, ANS, 1960
170	6200	S	U	3.040	5.184	Cairns and Scheier, 1958, ANS, 1960
170	7100	S	U	3.040	5.936	Cairns and Scheier, 1958, ANS, 1960
20	1110	S	U	0.358	0.928	Wurtz and Bridges, 1961, Wurtz, 1962 (adult)
100	3160	S	U	1.788	2.642	Wurtz and Bridges, 1961, Wurtz, 1962 (adult)
20	303	S	U	0.358	0.253	Wurtz, 1962 (young)
20	434	S	U	0.358	0.363	Wurtz, 1962 (young)
20	350	S	U	0.358	0.293	Wurtz, 1962 (young)
100	434	S	U	1.788	0.363	Wurtz, 1962 (young)
100	1390	S	U	1.788	1.162	Wurtz, 1962 (young)
100	1110	S	U	1.788	0.928	Wurtz, 1962 (young)
55.93	1196.00					**GEO MEAN** (12 results)

Asiatic clam, *Corbicula fluminea*

HARDNESS (PPM)	VALUE (ug/L)	METHOD		NORMALIZED HARDNESS	NORMALIZED VALUE	REFERENCE
64	6040	S	M			Cherry, et al. 1980, Rodgers, et al. 1980
64	6040					**GEO MEAN** (1 result)

Cladoceran, *Ceriodaphnia dubia*

HARDNESS (PPM)	VALUE (ug/L)	METHOD		NORMALIZED HARDNESS	NORMALIZED VALUE	REFERENCE
52	180	R	M			Carlson, et al. 1986
52	180					**GEO MEAN** (1 result)

Cladoceran, *Ceriodaphnia reticulata*

HARDNESS (PPM)	VALUE (ug/L)	METHOD		NORMALIZED HARDNESS	NORMALIZED VALUE	REFERENCE
45	76	S	U			Mount and Norberg, 1984
45	41	S	U			Carlson and Roush, 1985
45	32	S	M			Carlson and Roush, 1985
45	46.37					**GEO MEAN** (3 results)

Cladoceran, *Daphnia pulex*

HARDNESS (PPM)	VALUE (ug/L)	METHOD		NORMALIZED HARDNESS	NORMALIZED VALUE	REFERENCE
45	500	S	M			Cairns, et al. 1978
45	107	S	U			Mount and Norberg, 1984
45	231.30					**GEO MEAN** (2 results)

Cladoceran, *Daphnia magna*

HARDNESS (PPM)	VALUE (ug/L)	METHOD		NORMALIZED HARDNESS	NORMALIZED VALUE	REFERENCE
300	1100	S	U	3.367	3.206	Berglind and Dave, 1984
45.3	100	S	U	0.508	0.291	Biesinger and Christensen, 1972
45	280	S	M	0.505	0.816	Cairns, et al. 1978
45	68	S	U	0.505	0.198	Mount and Norberg, 1984
54	334	S	M	0.606	0.973	Chapman, et al. Manuscript
105	525	S	M	1.178	1.530	Chapman, et al. Manuscript
196	655	S	M	2.200	1.909	Chapman, et al. Manuscript
130	798.9	FT	M	1.459	2.329	Attar and Maly, 1982
130	798.9					**GEO MEAN** (1 FT result)

The static test results were NOT used in the slope calculation.

Isopod, *Asellus bicrenata*

HARDNESS (PPM)	VALUE (ug/L)	METHOD		NORMALIZED HARDNESS	NORMALIZED VALUE	REFERENCE
220	20110	FT	M			Bosnak and Morgan, 1981
220	20110					**GEO MEAN** (1 result)

Isopod, *Asellus communis*

HARDNESS (PPM)	VALUE (ug/L)	METHOD		NORMALIZED HARDNESS	NORMALIZED VALUE	REFERENCE
20	12754	S	U			Wurtz and Bridges, 1961
100	8755	S	U			Wurtz and Bridges, 1961
44.72	10567.0					**GEO MEAN** (2 results)

Isopod, *Lirceus alabamae*

HARDNESS (PPM)	VALUE (ug/L)	METHOD		NORMALIZED HARDNESS	NORMALIZED VALUE	REFERENCE
152	8375	FT	M			Bosnak and Morgan, 1981
152	8375					**GEO MEAN** (1 result)

Amphipod, *Crangonyx pseudogracilis*

HARDNESS (PPM)	VALUE (ug/L)	METHOD		NORMALIZED HARDNESS	NORMALIZED VALUE	REFERENCE
50	19800	R	U			Martin and Holdich, 1986
50	19800					**GEO MEAN** (1 result)

Amphipod, *Gammarus sp.*

HARDNESS (PPM)	VALUE (ug/L)	METHOD		NORMALIZED HARDNESS	NORMALIZED VALUE	REFERENCE
50	8100	S	M			Rehwoldt, et al. 1973
50	8100					**GEO MEAN** (1 result)

Damselfly, *Argia sp.*

HARDNESS (PPM)	VALUE (ug/L)	METHOD		NORMALIZED HARDNESS	NORMALIZED VALUE	REFERENCE
20	40950	S	U			Wurtz and Bridges, 1961
20	40950					**GEO MEAN** (1 result)

Bryozoan, *Pectinatella magnifica*

HARDNESS (PPM)	VALUE (ug/L)	METHOD		NORMALIZED HARDNESS	NORMALIZED VALUE	REFERENCE
190 – 220	4310	S	U			Pardue and Wood, 1980
205	4310					**GEO MEAN** (1 result)

Bryozoan, *Lophopodella carteri*

HARDNESS (PPM)	VALUE (ug/L)	METHOD		NORMALIZED HARDNESS	NORMALIZED VALUE	REFERENCE
190 – 220	5630	S	U			Pardue and Wood, 1980
205	5630					**GEO MEAN** (1 result)

Bryozoan, *Plumatella emarginata*

HARDNESS (PPM)	VALUE (ug/L)	METHOD		NORMALIZED HARDNESS	NORMALIZED VALUE	REFERENCE
190 – 220	5300	S	U			Pardue and Wood, 1980
205	5300					**GEO MEAN** (1 result)

American eel, *Anguilla rostrata*

HARDNESS (PPM)	VALUE (ug/L)	METHOD		NORMALIZED HARDNESS	NORMALIZED VALUE	REFERENCE
55	14500	S	M			Rehwoldt, et al. 1972
53	14600	S	M			Rehwoldt, et al. 1973
53.99	14549.9					**GEO MEAN** (2 results)

Sockeye salmon, *Onchorhynchus nerka*

HARDNESS (PPM)	VALUE (ug/L)	METHOD		NORMALIZED HARDNESS	NORMALIZED VALUE	REFERENCE
22	749	FT	M			Chapman, 1975 and 1978
22	749					**GEO MEAN** (1 result)

Coho salmon, *Onchorhynchus kisutch*

HARDNESS (PPM)	VALUE (ug/L)	METHOD		NORMALIZED HARDNESS	NORMALIZED VALUE	REFERENCE
94	4600	R	M			Lorz and McPherson, 1976 + 1977
25	905	FT	M			Chapman and Stevens, 1978
25	905					**GEO MEAN** (1 FT result)

Chinook salmon, *Onchorhynchus tshawytscha*

HARDNESS (PPM)	VALUE (ug/L)	METHOD		NORMALIZED HARDNESS	NORMALIZED VALUE	REFERENCE
21	84	FT	M			Finlayson and Verrue, 1982
23	97	FT	M			Chapman, 1975 + 1978
23	463	FT	M			Chapman, 1975 + 1978
23	701	FT	M			Chapman, 1975 + 1978
22.48	226.77					**GEO MEAN** (4 results)

Rainbow trout, *Onchorhynchus mykiss*

HARDNESS (PPM)	VALUE (ug/L)	METHOD		NORMALIZED HARDNESS	NORMALIZED VALUE	REFERENCE
330	7210	FT	M	6.548	9.622	Sinley, et al. 1974 (juv)
25	430	FT	M	0.496	0.574	Sinley, et al. 1974 (juv)
30	430	FT	M	0.595	0.574	Goettl, et al. 1974 (30.5 g)
30	810	FT	M	0.595	1.081	Goettl, et al. 1974 (22.6 g)
30	410	FT	M	0.595	0.547	Goettl, et al. 1974 + 1976 (29.7 g)
312	4520	FT	M	6.191	6.032	Goettl, et al. 1974 + 1976 (18.3 g)
312	1190	FT	M	6.191	1.588	Goettl, et al. 1974 + 1976 (2 g)
23	560	FT	M	0.456	0.747	Goettl, et al. 1974 + 1976 (34.6 g)
22	240	FT	M	0.437	0.320	Goettl, et al. 1974 + 1976 (4.9 g)
30	830	FT	M	0.595	1.108	Goettl, et al. 1974 + 1976 (52.1 g)
314	7210	FT	M	6.231	9.622	Goettl, et al. 1974 + 1976 (15.4 g)
102	1000	FT	M	2.024	1.335	Goettl, et al. 1974 + 1976 (72 g)
5	280	R	U	0.099	0.374	McLeay, 1976 (juv)
23	815	FT	M	0.456	1.088	Chapman, 1975 + 1978 (alevin)
23	93	FT	M	0.456	0.124	Chapman, 1975 + 1978 (swimup)
23	136	FT	M	0.456	0.181	Chapman, 1975 + 1978 (parr)
83	1755	FT	M	1.647	2.342	Chapman and Stevens, 1978 (adult)
46.8	370	FT	M	0.929	0.494	Holcombe and Andrew, 1978 (juv)
47	517	FT	M	0.933	0.690	Holcombe and Andrew, 1978 (juv)
44.4	756	FT	M	0.881	1.009	Holcombe and Andrew, 1978 (juv)
178	2510	FT	M	3.532	3.350	Holcombe and Andrew, 1978 (juv)
179	2960	FT	M	3.552	3.950	Holcombe and Andrew, 1978 (juv)
170	1910	FT	M	3.323	2.549	Holcombe and Andrew, 1978 (juv)
14	560	S	M	0.278	0.747	Spry and Wood, 1984 (fingerling)
9.2	66	FT	M	0.183	0.088	Cusimano, et al. 1986 (fry)
58.91	792.06					**GEO MEAN** (23 FT results)

The 23 FT results were used for the slope calculation.

Atlantic salmon, *Salmo salar*

HARDNESS (PPM)	VALUE (ug/L)	METHOD		NORMALIZED HARDNESS	NORMALIZED VALUE	REFERENCE
14	740	FT	M			Carson and Carson, 1972
14	740					**GEO MEAN** (1 result)

Brook trout, *Salvelinus fontinalis*

HARDNESS (PPM)	VALUE (ug/L)	METHOD		NORMALIZED HARDNESS	NORMALIZED VALUE	REFERENCE
46.8	1550	FT	M	0.520	0.449	Holcombe and Andrew, 1978 (juv)
47	2120	FT	M	0.523	0.614	Holcombe and Andrew, 1978 (juv)
44.4	2420	FT	M	0.494	0.701	Holcombe and Andrew, 1978 (juv)
178	6140	FT	M	1.979	1.778	Holcombe and Andrew, 1978 (juv)
179	6980	FT	M	1.990	2.021	Holcombe and Andrew, 1978 (juv)
170	4980	FT	M	1.890	1.442	Holcombe and Andrew, 1978 (juv)
89.93	3453.74					**GEO MEAN** (6 results)

Goldfish, *Carassius auratus*

HARDNESS (PPM)	VALUE (ug/L)	METHOD		NORMALIZED HARDNESS	NORMALIZED VALUE	REFERENCE
50	7500	S	U			Cairns, et al. 1969
20	6440	S	U			Pickering and Henderson, 1966
31.62	6949.82					**GEO MEAN** (2 results)

Golden shiner, *Notemigenous crysoleucas*

HARDNESS (PPM)	VALUE (ug/L)	METHOD		NORMALIZED HARDNESS	NORMALIZED VALUE	REFERENCE
50	6000	S	U			Cairns, et al. 1969
50	6000					**GEO MEAN** (1 result)

Fathead minnow, *Pimephales promelas*

HARDNESS (PPM)	VALUE (ug/L)	METHOD		NORMALIZED HARDNESS	NORMALIZED VALUE	REFERENCE
174 – 198 (185.6)	1820	FT	M	1.939	0.314	Pickering and Vigor, 1965 (embryo)
174 – 198 (185.6)	1850	FT	M	1.939	0.319	Pickering and Vigor, 1965 (embryo)
174 – 198 (185.6)	870	FT	M	1.939	0.150	Pickering and Vigor, 1965 (fry)
20	2550	S	U	0.208	0.439	Pickering and Henderson, 1966 (1–2 g)
20	2330	S	U	0.208	0.401	Pickering and Henderson, 1966 (1–2 g)
20	770	S	U	0.208	0.133	Pickering and Henderson, 1966 (1–2 g)
20	960	S	U	0.208	0.165	Pickering and Henderson, 1966 (1–2 g)
360	33400	S	U	3.752	5.754	Pickering and Henderson, 1966 (1–2 g)
63	12500	FT	M	0.657	2.153	Mount, 1966 (1-2 g)
54	13800	FT	M	0.563	2.377	Mount, 1966 (1-2 g)
97	18500	FT	M	1.011	3.187	Mount, 1966 (1-2 g)
103	25000	FT	M	1.074	4.307	Mount, 1966 (1-2 g)
212	29000	FT	M	2.210	4.996	Mount, 1966 (1-2 g)
208	35500	FT	M	2.168	6.116	Mount, 1966 (1-2 g)
54	13700	FT	M	0.563	2.360	Mount, 1966 (1-2 g)
63	6200	FT	M	0.657	1.068	Mount, 1966 (1-2 g)
100	12500	FT	M	1.042	2.153	Mount, 1966 (1-2 g)
99	12500	FT	M	1.032	2.153	Mount, 1966 (1-2 g)
186	19000	FT	M	1.939	3.273	Mount, 1966 (1-2 g)
195	13600	FT	M	2.033	2.343	Mount, 1966 (1-2 g)
54	4700	FT	M	0.563	0.810	Mount, 1966 (1-2 g)
49	5100	FT	M	0.511	0.879	Mount, 1966 (1-2 g)
98	8100	FT	M	1.021	1.395	Mount, 1966 (1-2 g)
102	9900	FT	M	1.063	1.706	Mount, 1966 (1-2 g)
193	8200	FT	M	2.012	1.413	Mount, 1966 (1-2 g)
216	15500	FT	M	2.251	2.670	Mount, 1966 (1-2 g)
166	7630	S	U	1.730	1.314	Rachlin and Perlmutter, 1968 (44.6 mm)
203	8400	FT	M	2.116	1.447	Brungs, 1969 (2-3 g)
203	10000	FT	M	2.116	1.723	Brungs, 1969 (2-3 g)
203	12000	S	U	2.116	2.067	Brungs, 1969 (2-3 g)
203	13000	S	U	2.116	2.240	Brungs, 1969 (2-3 g)
46	600	FT	M	0.479	0.103	Benoit and Holcombe, 1978 (4 wk)
45	3100	S	M	0.469	0.534	Judy and Davies, 1979 (1-2 g)
220	2610	FT	M	2.293	0.450	Broderius and Smith, 1979 (juv)
45	396	S	M	0.469	0.068	Carlson and Roush, 1985 (larva)
52	551	S	M	0.542	0.094	Carlson, et al. 1986 (< 24 hr)
117.31	7887.53					**GEO MEAN** (25 FT results)

The 25 FT results were used for the slope calculation.

When a hardness range is given, the geometric mean of the endpoints is used as the entry for the slope calculation.

Northern squawfish, *Ptychohelius oregonensis*

HARDNESS (PPM)	VALUE (ug/L)	METHOD		NORMALIZED HARDNESS	NORMALIZED VALUE	REFERENCE
20 – 30 (24.5)	3498	FT	M			Andros and Gerton, 1980 (juv)
20 – 30 (24.5)	3693	FT	M			Andros and Gerton, 1980 (juv)
25	3594.18					**GEO MEAN** (2 results)

White sucker, *Catostomus commersoni*

HARDNESS (PPM)	VALUE (ug/L)	METHOD		NORMALIZED HARDNESS	NORMALIZED VALUE	REFERENCE
18	2200	FT	M			Duncan and Klaverkamp, 1983 (17.7 g)
18	2200					**GEO MEAN** (1 result)

Banded killifish, *Fundulus diaphanus*

HARDNESS (PPM)	VALUE (ug/L)	METHOD		NORMALIZED HARDNESS	NORMALIZED VALUE	REFERENCE
53	19100	S	M			Rehwoldt, et al. 1971
55	19200	S	M			Rehwoldt, et al. 1972
53.99	19149.9					**GEO MEAN** (2 results)

Flagfish, *Jordanella floridae*

HARDNESS (PPM)	VALUE (ug/L)	METHOD		NORMALIZED HARDNESS	NORMALIZED VALUE	REFERENCE
44	1500	FT	M			Spehar, 1976 (juv)
44	1500					**GEO MEAN** (1 result)

Guppy, *Poecilia reticulata*

HARDNESS (PPM)	VALUE (ug/L)	METHOD		NORMALIZED HARDNESS	NORMALIZED VALUE	REFERENCE
20	1270	S	U			Pickering and Henderson, 1966 (6 mo)
120	30000	S	U			Cairns, et al. 1969
30	1740	S	M			Pierson, 1981 (fry)
30	5050	S	M			Pierson, 1981
30	6400	S	M			Pierson, 1981
36.50	4636.49					**GEO MEAN** (5 results)

Southern platyfish, *Xiphophorous maculatus*

HARDNESS (PPM)	VALUE (ug/L)	METHOD		NORMALIZED HARDNESS	NORMALIZED VALUE	REFERENCE
166	12000	S	U			Rachlin and Perlmutter, 1968 (20.8 mm)
166	12000					**GEO MEAN** (1 result)

White perch, *Morone americana*

HARDNESS (PPM)	VALUE (ug/L)	METHOD		NORMALIZED HARDNESS	NORMALIZED VALUE	REFERENCE
53	14300	S	M			Rehwoldt, et al. 1971 (< 20 cm)
55	14400	S	M			Rehwoldt, et al. 1972
						GEO MEAN not used

Although this genus is resident in the Great Lakes basin, the result was not used because another species in the same genus had a much more sensitive life stage (see below).

Striped bass, *Morone saxatilis*

HARDNESS (PPM)	VALUE (ug/L)	METHOD		NORMALIZED HARDNESS	NORMALIZED VALUE	REFERENCE
53	6700	S	M			Rehwoldt, et al. 1971 (fingerling)
55	6800	S	M			Rehwoldt, et al. 1972
40	120	S	U	0.375	0.528	Palawski, et al. 1985 (63 d)
285	430	S	U	2.669	1.893	Palawski, et al. 1985 (63 d)
106.77	227.16					**GEO MEAN** (2 Palawski results)

Pumpkinseed, *Lepomis gibbosus*

HARDNESS (PPM)	VALUE (ug/L)	METHOD		NORMALIZED HARDNESS	NORMALIZED VALUE	REFERENCE
53	20000	S	M			Rehwoldt, et al. 1971
55	20100	S	M			Rehwoldt, et al. 1972
53.99	20049.9					**GEO MEAN** (2 results)

Bluegill, *Lepomis macrochirus*

HARDNESS (PPM)	VALUE (ug/L)	METHOD		NORMALIZED HARDNESS	NORMALIZED VALUE	REFERENCE
45	4200	S	U	0.956	0.619	Cairns and Scheier, 1957, ANS, 1960 (3.5 – 3.9 g)
45	3500	S	U	0.956	0.516	Cairns and Scheier, 1957, ANS, 1960 (3.5 – 3.9 g)
170	12900	S	U	3.610	1.901	Cairns and Scheier, 1957, ANS, 1960 (3.5 – 3.9 g)
170	12500	S	U	3.610	1.842	Cairns and Scheier, 1957, ANS, 1960 (3.5 – 3.9 g)
45	8020	S	U	0.956	1.182	Cairns and Scheier, 1957, ANS, 1960 (2.5 – 3.9 g)
45	3573	FT	M	0.956	0.526	Cairns and Scheier, 1959 (0.96 g)
45	3453	FT	M	0.956	0.509	Cairns and Scheier, 1959 (2.8 g)
45	3314	FT	M	0.956	0.488	Cairns and Scheier, 1959 (54 g)
20	6440	S	U	0.425	0.949	Pickering and Henderson, 1966 (1-2 g)
20	5460	S	U	0.425	0.804	Pickering and Henderson, 1966 (1-2 g)
20	4850	S	U	0.425	0.715	Pickering and Henderson, 1966 (1-2 g)
20	5820	S	U	0.425	0.857	Pickering and Henderson, 1966 (1-2 g)
20	5370	S	U	0.425	0.791	Pickering and Henderson, 1966 (1-2 g)
360	40900	S	U	7.645	6.026	Pickering and Henderson, 1966 (1-2 g)
46	9900	FT	M	0.977	1.459	Cairns, et al. 1971
46	12100	FT	M	0.977	1.783	Cairns, et al. 1971
45.40	5470.17					**GEO MEAN** (5 FT results)

The 5 FT results were used for the SMAV calculation, but no results were used for the slope calculation since the FT results were over a narrow hardness range.

Tilapia, *Tilapia mossambica*

HARDNESS (PPM)	VALUE (ug/L)	METHOD		NORMALIZED HARDNESS	NORMALIZED VALUE	REFERENCE
115	1600	S	U			Qureshi and Saksena, 1980
115	1600					**GEO MEAN** (1 result)

Longfin dace, *Agosia chrysogaster*

HARDNESS (PPM)	VALUE (ug/L)	METHOD		NORMALIZED HARDNESS	NORMALIZED VALUE	REFERENCE
217	790					Lewis, 1978
217	790					**GEO MEAN** (1 result)

Carp, *Cyprinus carpio*

HARDNESS (PPM)	VALUE (ug/L)	METHOD		NORMALIZED HARDNESS	NORMALIZED VALUE	REFERENCE
55	7800					Rehwoldt, et al. 1971
53	7800					Rehwoldt, et al. 1972
19	3120					Khangarot, et al. 1983
38.12	5747.09					**GEO MEAN** (1 result)

HARDNESS DATA: Geometric mean of all results = 88.25
Mean + 2 standard deviations (calculated on log scale) = 333
Mean - 2 standard deviations (calculated on log scale) = 12
Range over which acute criteria are applied = 12 - 333 PPM

SLOPE OF ATC EQUATION (from normalized data) = 0.8745 (r-squared = 0.433).
This does not exactly agree with EPA's calculation because of one additional result for *d. magna* that was added as part of the GLI update in 1995.

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*)
5. Damselfly *(*genus *Argia)*
6. Fathead minnow, family Cyprinidae
7. Snail (P. gyrina)
8. Banded killifish, family Cyprinodontidae

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

Normalize mean toxicity values to intercepts @ hardness = 1 PPM using the slope of 0.8745 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)
Agosia (Longfin dace)	217.00	790.00	7.1524
Amnicola (Snail)	50.00	16816.66	549.58
Anguilla (American eel)	53.99	14549.91	444.62
Argia (Damselfly)	20.00	40950.00	2982.20
Asellus (Isopod, A. communis)	44.72	10566.99	380.73
Asellus (Isopod, A. bicrenata)	220.00	20110.00	179.90
Carassius (Goldfish)	31.62	6949.82	339.05
Catostomus (White sucker)	18.00	2200.00	175.68
Ceriodaphnia (Cladoceran, C. dubia)	52.00	180.00	5.6842
Ceriodaphnia (Cladoceran, C. reticulata)	45.00	46.37	1.6617
Corbicula (Asiatic clam)	64.00	6040.00	159.07
Crangonyx (Amphipod)	50.00	19800.00	647.08
Cyprinus (Carp)	38.12	5747.09	238.12
Daphnia (Cladoceran, D. magna)	130.00	798.90	11.321
Daphnia (Cladoceran, D. pulex)	45.00	231.30	8.2887
Fundulus (Banded killifish)	53.99	19149.93	585.19
Gammarus (Amphipod)	50.00	8100.00	264.72
Helisoma (Snail, H. campanulatum)	44.72	1435.96	51.738
Jordanella (Flagfish)	44.00	1500.00	54.819
Lepomis (Bluegill)	45.40	5470.17	194.52
Lepomis (Pumpkinseed)	53.99	20049.94	612.69
Limnodrilus (Tubificid worm)	100.00	2274.00	40.536
Lirceus (Isopod)	152.00	8375.00	103.52
Lophopodella (Bryozoan)	205.00	5630.00	53.572
Lumbriculus (Worm)	30.00	6300.00	321.84
Morone (Striped bass)	106.77	227.16	3.8238*
Morone (White perch)	53.99	14349.91	438.51
Nais (Worm)	50.00	18400.00	601.33
Notemigenous (Golden shiner)	50.00	6000.00	196.09
Onchorhynchus (Coho salmon)	25.00	905.00	54.223
Onchorhynchus (Sockeye salmon)	22.00	749.00	50.184
Onchorhynchus (Chinook salmon)	22.48	226.77	14.908
Onchorhynchus (Rainbow trout)	58.91	792.06	22.427
Pectinatella (Bryozoan)	205.00	4310.00	41.012
Physa (Snail, P. gyrina)	36.00	1274.00	55.491
Physa (Snail, P. heterostropha)	55.93	1196.00	35.439
Pimephales (Fathead minnow)	117.29	7887.53	122.28
Plumatella (Bryozoan)	205.00	5300.00	50.432
Poecilia (Guppy)	36.50	4636.49	199.52
Ptychochelius (Northern squawfish)	25.00	3594.18	215.35
Salmo (Atlantic salmon)	14.00	740.00	73.616
Salvelinus (Brook trout)	89.93	3453.74	67.553
Tilapia (Tilapia)	115.00	1600.00	25.240
Xenopus (Frog)	100.00	34500.00	614.99
Xiphophorus (southern platyfish)	166.00	12000.00	137.33

* - Only the striped bass was used to calculate the GMAI for genus Morone due to the large difference in SMAIs within the genus.

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
Argia	2982.2	x	x	x	x
Crangonyx	647.08	x	x	x	x
Xenopus	614.99	x	x	x	x
Nais	601.33	x	x	x	x
Fundulus	585.19	x	x		
Amnicola	549.58	x	x	x	x
Anguilla	444.62	x	x		
Lepomis	345.23	x	x		
Carassius	339.05	x	x	x	
Lumbriculus	321.84	x	x	x	x
Gammarus	264.72	x	x	x	x
Asellus	261.71	x	x	x	x
Cyprinus	238.12	x	x	x	
Ptychochelius	215.35	x			
Poecilia	199.52	x			
Notemigenous	196.09	x	x	x	x
Catostomus	175.68	x	x	x	
Corbicula	159.07	x			
Xiphophorus	137.33	x			
Pimephales	122.28	x	x	x	
Lirceus	103.52	x	x	x	x
Salmo	73.616	x			
Salvelinus	67.553	x			
Jordanella	54.819	x			
Lophopodella	53.572	x	x	x	x
Helisoma	51.738	x	x	x	x
Plumatella	50.432	x	x	x	x
Physa	44.346	x	x	x	x
Pectinatella	41.012	x	x	x	x
Limnodrilus	40.536	x	x	x	x
Onchorhynchus	30.884	x			
Tilapia	25.240	x			
Daphnia	9.6871	x	x	x	x
Agosia	7.1524	x			
Morone	3.8238	x	x		
Ceriodaphnia	3.0734	x	x	x	x
TOTAL NUMBER REPRESENTED:		36	26	22	18

* - 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). From this point, the results of the calculation are shown using the variables listed in sub. (2).

CRITERIA CALCULATION:

	CW	WW	LFF	LAL
GMAI RANKS				
4	9.6871077	40.536087	41.011711	41.011711
3	7.1524209	9.6871077	40.536087	40.536087
2	3.8238012	3.8238012	9.6871077	9.6871077
1	3.0733672	3.0733672	3.0733672	3.0733672
n	36	26	22	18
ln GMAI				
4	2.2707959	3.7021926	3.7138577	3.7138577
3	1.9674509	2.2707959	3.7021926	3.7021926
2	1.3412450	1.3412450	2.2707959	2.2707959
1	1.1227738	1.1227738	1.1227738	1.1227738
(ln GMAI)^2				
4	5.156514	13.70623	13.792739	13.792739
3	3.870863	5.156514	13.70623	13.70623
2	1.7989381	1.7989381	5.156514	5.156514
1	1.260621	1.260621	1.260621	1.260621
P				
4	0.1081081	0.1481481	0.173913	0.2105263
3	0.0810811	0.1111111	0.1304348	0.1578947
2	0.0540541	0.0740741	0.0869565	0.1052632
1	0.027027	0.037037	0.0434783	0.0526316
sq rt P				
4	0.328798	0.3849002	0.4170288	0.4588315
3	0.2847474	0.3333333	0.3611576	0.3973597
2	0.2324953	0.2721655	0.2948839	0.3244428
1	0.164399	0.1924501	0.2085144	0.2294157
EV	6.7022656	8.4370073	10.80962	10.80962
EW	12.086936	21.922303	33.916104	33.916104
EP	0.2702703	0.3703704	0.4347826	0.5263158
EPR	1.0104396	1.1828491	1.2815847	1.4100498
J	0.05	0.05	0.05	0.05
S	7.5521375	14.157685	13.951521	12.680443
L	-0.232178	-2.07735	-1.767609	-1.767609
A	1.4565309	1.0884051	1.3520459	1.0678243
FAI	4.2910476	2.9695341	3.8653255	2.9090434
ACI	2.1455238	1.4847671	1.9326628	1.4545217
ln ACI	0.7634	0.3953	0.6589	0.3747

The smaller databases for the warmwater, LFF, and LAL classifications result in lower calculated criteria than coldwater, even with other genera being the most sensitive in the latter two classifications. As a result, all criteria are set equal to the coldwater criteria, meaning no criteria relief is available in the other classifications.

TOTAL ZINC
ACUTE CRITERION EQUATIONS:

	1995 EPA EQUATION	WI EQUATION
SLOPE	0.8473	0.8745
ln ACI	0.884	0.7634
mean H + 2SD		333
mean H - 2 SD		12
TOTAL REC. Zn ATC (in ug/L) @ hardness =		
50	73.35	65.66
100	119.92	120.4
200	196.06	220.7

Acute toxicity criteria for zinc (in ug/L as total recoverable):
all classifications: ATC = EXP(0.8745 X ln(hardness) + 0.7634)
where EXP = e raised to the power of the term in parentheses
Hardness range = 12 – 333 PPM

CHRONIC TOXICITY CRITERIA

EPA SPECIES MEAN CHRONIC VALUES

(values from 3/86 EPA AWQC document, EPA 440/5-86-004 and 3/95 GLWQI Criteria Document for the Protection of Aquatic Life in Ambient Water)

Cladoceran, *Daphnia magna*

HARDNESS (ppm)	VALUE (ug/L)	TYPE OF TEST	NORMALIZED HARDNESS	NORMALIZED VALUE	REFERENCE
52-54	135.8	LC			Chapman, et al. Manuscript
104-105	47.29	LC			Chapman, et al. Manuscript
196-211	46.73	LC			Chapman, et al. Manuscript
104.07	66.95				**GEO MEAN** (3 results)

Chinook salmon, *Onchorhynchus tshawytscha*

HARDNESS (ppm)	VALUE (ug/L)	TYPE OF TEST	NORMALIZED HARDNESS	NORMALIZED VALUE	REFERENCE
23-25	371.1	ELS			Chapman, 1975
24	371.1				**GEO MEAN** (1 result)

Rainbow trout, *Onchorhynchus mykiss*

HARDNESS (ppm)	VALUE (ug/L)	TYPE OF TEST	NORMALIZED HARDNESS	NORMALIZED VALUE	REFERENCE
25-26	276.7	ELS			Sinley, et al. 1974
25.5	276.7				**GEO MEAN** (2 results)

Brook trout, *Salvelinus fontinalis*

HARDNESS (ppm)	VALUE (ug/L)	TYPE OF TEST	NORMALIZED HARDNESS	NORMALIZED VALUE	REFERENCE
45.9	854.7	LC			Holcombe, et al. 1979
45.9	854.7				**GEO MEAN** (1 result)

Fathead minnow, *Pimephales promelas*

HARDNESS (ppm)	VALUE (ug/L)	TYPE OF TEST	NORMALIZED HARDNESS	NORMALIZED VALUE	REFERENCE
46	106.3	LC			Benoit and Holcombe, 1978
46	106.3				**GEO MEAN** (1 result)

Flagfish, *Jordanella floridae*

HARDNESS (ppm)	VALUE (ug/L)	TYPE OF TEST	NORMALIZED HARDNESS	NORMALIZED VALUE	REFERENCE
44	36.41	LC			Spehar, 1976
					GEO MEAN (1 result)

EPA ACUTE-CHRONIC RATIOS:

Only nine 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. Fathead minnow
3. Cladoceran *(D. magna)*
4. NOT REPRESENTED
5. NOT REPRESENTED
6. Flagfish
7. NOT REPRESENTED
8. NOT REPRESENTED

CONCLUSION: A chronic toxicity criterion cannot be directly calculated for copper according to ch. NR 105. Not enough data are available to permit the calculation of independent chronic toxicity criteria because the minimum database requirement was not met. Instead, acute-chronic ratios (ACRs) must be 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	ACUTE VALUE	CHRONIC VALUE	TEST ACR	SMACR
Daphnia magna				
(hard. = 52-54)	334	135.8	2.459	
(hard. = 104-105)	525	47.29	11.10	
(hard. = 196-211)	655	46.73	14.02	7.26
Chinook salmon				
(hard. = 23-25)	97 – 701#	371.1	0.26 – 1.89	0.70
Rainbow trout				
(hard. = 25-26)	430	276.7	1.55	1.55
Brook trout				
(hard. = 45.9)	1996 *	854.7	2.335	2.335
Fathead minnow				
(hard. = 46)	600	106.3	5.644	5.644
Flagfish				
(hard. = 44)	1500	36.41	41.2	41.2

- Range of values given for juveniles (Chapman, 1975 + 1978)
* - mean of three values (Holcombe and Andrew, 1978)

The SMACRs for rainbow trout, chinook salmon, and Daphnia magna were used to calculate the FACR since those represented the species that are most sensitive on an acute basis that have ratios The other ratios were for species that are not relatively sensitive to zinc on an acute basis.

Coldwater FACR = Geo. mean of 7.26, 0.70, and 1.55 = 1.99. EPA set the FACR equal to 2 so that the

chronic criteria would be equal to the acute criteria.

Chronic toxicity criteria for zinc (in ug/L as total recoverable):
ALL CLASSIFICATIONS, CTC = EXP(0.8745 X ln(hardness) + 0.7634)
where EXP = e raised to the power of the term in parentheses
Hardness range = 12 – 333 PPM (same as acute)