DERIVATION OF ACUTE AND CHRONIC TOXICITY CRITERIA FOR CADMIUM

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ACUTE TOXICITY CRITERIA

EPA SPECIES MEAN ACUTE VALUES

NOTE: Normalized hardness and cadmium 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).

Tubificid worm, *Branchiura sowerbyi*

HARDNESS (PPM)	VALUE (ug/L)	METHOD		NORMALIZED HARDNESS	NORMALIZED VALUE	REFERENCE
5.3	240	S	M			Chapman, et al. 1982
5.3	240					**GEO MEAN** (1 result)

Tubificid worm, *Limnodrilus hoffmeisteri*

HARDNESS (PPM)	VALUE (ug/L)	METHOD		NORMALIZED HARDNESS	NORMALIZED VALUE	REFERENCE
5.3	170	S	M			Chapman, et al. 1982
5.3	170					**GEO MEAN** (1 result)

Tubificid worm, *Quistadrilus multisetosus*

HARDNESS (PPM)	VALUE (ug/L)	METHOD		NORMALIZED HARDNESS	NORMALIZED VALUE	REFERENCE
5.3	320	S	M			Chapman, et al. 1982
5.3	320					**GEO MEAN** (1 result)

Tubificid worm, *Rhyacodrilus montana*

HARDNESS (PPM)	VALUE (ug/L)	METHOD		NORMALIZED HARDNESS	NORMALIZED VALUE	REFERENCE
5.3	630	S	M			Chapman, et al. 1982
5.3	630					**GEO MEAN** (1 result)

Tubificid worm, *Spirosperma ferox*

HARDNESS (PPM)	VALUE (ug/L)	METHOD		NORMALIZED HARDNESS	NORMALIZED VALUE	REFERENCE
5.3	350	S	M			Chapman, et al. 1982
5.3	350					**GEO MEAN** (1 result)

Tubificid worm, *Spirosperma nikolskyi*

HARDNESS (PPM)	VALUE (ug/L)	METHOD		NORMALIZED HARDNESS	NORMALIZED VALUE	REFERENCE
5.3	450	S	M			Chapman, et al. 1982
5.3	450					**GEO MEAN** (1 result)

Tubificid worm, *Stylodrilus heringianus*

HARDNESS (PPM)	VALUE (ug/L)	METHOD		NORMALIZED HARDNESS	NORMALIZED VALUE	REFERENCE
5.3	550	S	M			Chapman, et al. 1982
5.3	550					**GEO MEAN** (1 result)

Tubificid worm, *Tubifex tubifex*

HARDNESS (PPM)	VALUE (ug/L)	METHOD		NORMALIZED HARDNESS	NORMALIZED VALUE	REFERENCE
5.3	320	S	M			Chapman, et al. 1982
5.3	320					**GEO MEAN** (1 result)

Tubificid worm, *Varichaeta pacifica*

HARDNESS (PPM)	VALUE (ug/L)	METHOD		NORMALIZED HARDNESS	NORMALIZED VALUE	REFERENCE
5.3	380	S	M			Chapman, et al. 1982
5.3	380					**GEO MEAN** (1 result)

Snail, *Aplexa hypnorum*

HARDNESS (PPM)	VALUE (ug/L)	METHOD		NORMALIZED HARDNESS	NORMALIZED VALUE	REFERENCE
45.3	93	F	M			Holcombe, et al. 1984
45.3	93					**GEO MEAN** (1 result)

Snail, *Physa gyrina*

HARDNESS (PPM)	VALUE (ug/L)	METHOD		NORMALIZED HARDNESS	NORMALIZED VALUE	REFERENCE
200	410	S	M			Wier and Walter, 1976
200	1370	S	M			Wier and Walter, 1976
200	749.47					**GEO MEAN** (2 results)

Cladoceran, *Ceriodaphnia reticulata*

HARDNESS (PPM)	VALUE (ug/L)	METHOD		NORMALIZED HARDNESS	NORMALIZED VALUE	REFERENCE
240	184	S	U			Elnabarawy, et al. 1986
67	129	S	U			Spehar & Carlson, 1984
45	66	S	U			Mount & Norberg, 1984
89.78	116.14					**GEO MEAN** (3 results)

Cladoceran, *Simocephalus serrulatus*

HARDNESS (PPM)	VALUE (ug/L)	METHOD		NORMALIZED HARDNESS	NORMALIZED VALUE	REFERENCE
11.1	7					Giesy, et al. 1977
67	123					Spehar and Carlson, 1984
31.86	27.63					**GEO MEAN** (2 results)

Cladoceran, *Simocephalus vetulus*

HARDNESS (PPM)	VALUE (ug/L)	METHOD		NORMALIZED HARDNESS	NORMALIZED VALUE	REFERENCE
67	89.3					Spehar & Carlson, 1984
45	24					Mount & Norberg, 1984
54.91	46.29					**GEO MEAN** (2 results)

Cladoceran, *Moina macrocopa*

HARDNESS (PPM)	VALUE (ug/L)	METHOD		NORMALIZED HARDNESS	NORMALIZED VALUE	REFERENCE
82	71.25	S	U			Hatakeyama and Yasuno, 1981
82	71.25					**GEO MEAN** (1 result)

Cladoceran, *Daphnia pulex*

HARDNESS (PPM)	VALUE (ug/L)	METHOD		NORMALIZED HARDNESS	NORMALIZED VALUE	REFERENCE
57	47					Bertram and Hart, 1979
200	50					Hall, et al. 1986
120	70					Hall, et al. 1986
200	100					Hall, et al. 1986
45	68					Mount & Norberg, 1984
240	319					Elnabarawy, 1986
119.79	84.22					**GEO MEAN** (6 results)

Cladoceran, *Daphnia magna*

HARDNESS (PPM)	VALUE (ug/L)	METHOD		NORMALIZED HARDNESS	NORMALIZED VALUE	REFERENCE
51	9.9	S	M	0.384	0.232	Chapman, et al. Manuscript
104	33	S	M	0.783	0.722	Chapman, et al. Manuscript
105	34	S	M	0.790	0.795	Chapman, et al. Manuscript
197	63	S	M	1.483	1.474	Chapman, et al. Manuscript
209	49	S	M	1.573	1.146	Chapman, et al. Manuscript
45	65	S	U			Biesinger and Christensen, 1972
105	30	R	M			Canton and Slooff, 1982
209.2	30	R	M			Canton and Slooff, 1982
120	20	S	U			Hall, et al. 1986
120	40	S	U			Hall, et al. 1986
240	178	S	U	1.806	4.164	Chapman, et al. Manuscript
170	3.6	S	M			Baird, et al. 1991
170	9	S	M			Baird, et al. 1991
170	9	S	M			Baird, et al. 1991
170	27.1	S	M			Baird, et al. 1991
170	115.9	S	M			Baird, et al. 1991
170	4.5	S	M			Baird, et al. 1991
170	24.5	S	M			Stuhlbacher, et al. 1992
170	129.4	S	M			Stuhlbacher, et al. 1992
250	280	S	U			Crisinet, et al. 1994
170	9.5	S	U			Guillhermino, et al. 1996
46.1	112	S	M			Barata, et al. 1998
90.7	106	S	M			Barata, et al. 1998
179	233	S	M			Barata, et al. 1998
46.1	30.1	S	M			Barata, et al. 1998
90.7	23.4	S	M			Barata, et al. 1998
179	23.6	S	M			Barata, et al. 1998
130	58	F	M			Attar and Maly, 1982
132.87	42.75					**GEO MEAN** (6 results)

EPA only used the Chapman data for the slope calculation because those were considered the most sensitive life stage (< 24 hrs. old) and because the data from Chapman, et al. were over a wide range of hardness values. Those six pairs of results were used to calculate the SMAV, the other information was not used.

Isopod, *Asellus bicrenata*

HARDNESS (PPM)	VALUE (ug/L)	METHOD		NORMALIZED HARDNESS	NORMALIZED VALUE	REFERENCE
220	2129	FT	M			Bosnak and Morgan, 1981
220	2129					**GEO MEAN** (1 result)

Isopod, *Lirceus alabamae*

HARDNESS (PPM)	VALUE (ug/L)	METHOD		NORMALIZED HARDNESS	NORMALIZED VALUE	REFERENCE
152	150	FT	M			Bosnak and Morgan, 1981
152	150					**GEO MEAN** (1 result)

Amphipod, *Crangonyx pseudogracilis*

HARDNESS (PPM)	VALUE (ug/L)	METHOD		NORMALIZED HARDNESS	NORMALIZED VALUE	REFERENCE
50	1700	R	U			Martin and Holdich, 1986
50	1700					**GEO MEAN** (1 result)

Amphipod, *Gammarus pseudolimnaeus*

HARDNESS (PPM)	VALUE (ug/L)	METHOD		NORMALIZED HARDNESS	NORMALIZED VALUE	REFERENCE
67	54.4	S	M			Spehar and Carlson, 1984
43.5	68.3	S	M			Spehar and Carlson, 1984
53.99	60.96					**GEO MEAN** (2 results)

Crayfish, *Orconectes virilis*

HARDNESS (PPM)	VALUE (ug/L)	METHOD		NORMALIZED HARDNESS	NORMALIZED VALUE	REFERENCE
26	6100	FT	M			Mirenda, 1986
26	6100					**GEO MEAN** (1 result)

Worm, *Nais sp.*

HARDNESS (PPM)	VALUE (ug/L)	METHOD		NORMALIZED HARDNESS	NORMALIZED VALUE	REFERENCE
50	1700	S	U			Rehwoldt, et al. 1973
50	1700					**GEO MEAN** (1 result)

Snail, *Amnicola sp.*

HARDNESS (PPM)	VALUE (ug/L)	METHOD		NORMALIZED HARDNESS	NORMALIZED VALUE	REFERENCE
50	3800	S	U			Rehwoldt, et al. 1973
50	3800					**GEO MEAN** (1 result)

Damselfly, unidentified sp.

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

Caddisfly, unidentified sp.

HARDNESS (PPM)	VALUE (ug/L)	METHOD		NORMALIZED HARDNESS	NORMALIZED VALUE	REFERENCE
50	3400	S	U			Rehwoldt, et al. 1973
50	3400					**GEO MEAN** (1 result)

Midge, *Chironomus* sp.

HARDNESS (PPM)	VALUE (ug/L)	METHOD		NORMALIZED HARDNESS	NORMALIZED VALUE	REFERENCE
50	1200	S	U			Rehwoldt, et al. 1973
50	1200					**GEO MEAN** (1 result)

Mayfly, *Ephemerella grandis*

HARDNESS (PPM)	VALUE (ug/L)	METHOD		NORMALIZED HARDNESS	NORMALIZED VALUE	REFERENCE
44	2000	S	U			Warnick and Bell, 1969
44	2000					**GEO MEAN** (1 result)

Bryozoan, *Pectinatella magnifica*

HARDNESS (PPM)	VALUE (ug/L)	METHOD		NORMALIZED HARDNESS	NORMALIZED VALUE	REFERENCE
205	700	S	U			Pardue and Wood, 1980
205	700					**GEO MEAN** (1 result)

Bryozoan, *Lophopodella carteri*

HARDNESS (PPM)	VALUE (ug/L)	METHOD		NORMALIZED HARDNESS	NORMALIZED VALUE	REFERENCE
205	150	S	U			Pardue and Wood, 1980
205	150					**GEO MEAN** (1 result)

Bryozoan, *Plumatella emarginata*

HARDNESS (PPM)	VALUE (ug/L)	METHOD		NORMALIZED HARDNESS	NORMALIZED VALUE	REFERENCE
205	1090	S	U			Pardue and Wood, 1980
205	1090					**GEO MEAN** (1 result)

Coho salmon, *Onchorhynchus kisutch*

HARDNESS (PPM)	VALUE (ug/L)	METHOD		NORMALIZED HARDNESS	NORMALIZED VALUE	REFERENCE
90	10.4					Lorz, et al. 1978 (1 yr)
23	2.7					Chapman, et al. 1975
45.5	5.3					**GEO MEAN** (2 results)

Chinook salmon, *Onchorhynchus tshawytscha*

HARDNESS (PPM)	VALUE (ug/L)	METHOD		NORMALIZED HARDNESS	NORMALIZED VALUE	REFERENCE
23	1.8	FT	M	0.441	0.365	Chapman, 1975 + 1978 (swimup)
23	3.5	FT	M	0.441	0.709	Chapman, 1975 + 1978 (parr)
25	1.41	FT	M	0.479	0.286	Chapman, 1982 (juv)
21	1.1	FT	M	0.403	0.223	Finlayson and Verrue, 1982 (juv)
22.96	1.77					**GEO MEAN** (4 results)

Rainbow trout, *Onchorhynchus mykiss*

HARDNESS (PPM)	VALUE (ug/L)	METHOD		NORMALIZED HARDNESS	NORMALIZED VALUE	REFERENCE
43.5	2.3					Spehar and Carlson, 1984
50	30					Van Leeuwen, et al. 1985
50	10					Van Leeuwen, et al. 1985
23	1.3					Chapman, 1975 + 1978 (swimup)
23	1.0					Chapman, 1978 (parr)
23	4.1					Chapman, 1978 (smolt)
31	1.75					Davies, 1976
9.2	< 0.5					Cusimano, et al. 1986 (fry)
28.0	2.74					**GEO MEAN** (8 results)

NOTE: The values were not used for the slope calculation because there wasn't a wide enough hardness range.

Brown trout, *Salmo trutta*

HARDNESS (PPM)	VALUE (ug/L)	METHOD		NORMALIZED HARDNESS	NORMALIZED VALUE	REFERENCE
43.5	1.4	S	M			Spehar and Carlson, 1984
43.5	1.4					**GEO MEAN** (1 result)

Goldfish, *Carassius auratus*

HARDNESS (PPM)	VALUE (ug/L)	METHOD		NORMALIZED HARDNESS	NORMALIZED VALUE	REFERENCE
20	2340	S	U	0.523	0.380	Pickering and Henderson, 1966
20	2130	S	M	0.523	0.346	McCarty, et al. 1978
140	46800	S	M	3.659	7.603	McCarty, et al. 1978
38.3	6155.74					**GEO MEAN** (3 results)

Carp, *Cyprinus carpio*

HARDNESS (PPM)	VALUE (ug/L)	METHOD		NORMALIZED HARDNESS	NORMALIZED VALUE	REFERENCE
55	240					Rehwoldt, et al. 1972
55	240					**GEO MEAN** (1 result)

Fathead minnow, *Pimephales promelas*

HARDNESS (PPM)	VALUE (ug/L)	METHOD		NORMALIZED HARDNESS	NORMALIZED VALUE	REFERENCE
20	1050			0.174	0.227	Pickering and Henderson, 1966
20	630			0.174	0.136	Pickering and Henderson, 1966
360	72600			3.127	15.722	Pickering and Henderson, 1966
360	73500			3.127	15.917	Pickering and Henderson, 1966
201	11200			1.746	2.425	Pickering and Gast, 1972
201	12000			1.746	2.599	Pickering and Gast, 1972
201	6400			1.746	1.386	Pickering and Gast, 1972
201	2000			1.746	0.433	Pickering and Gast, 1972
201	4500			1.746	0.975	Pickering and Gast, 1972
103	2900			0.895	0.628	Birge, et al. 1983 (adult)
103	3100			0.895	0.671	Birge, et al. 1983 (adult)
262.5	7160			2.280	1.551	Birge, et al. 1983 (adult)
67	3390			0.582	0.734	Spehar and Carlson, 1984
43.5	1280			0.378	0.277	Spehar and Carlson, 1984
67	1830			0.582	0.396	Spehar and Carlson, 1984
103	3060			0.895	0.663	Birge, et al. 1983 (adult)
40	**21.5**	**S**	**M**			**Spehar, 1982 (fry)**
48	**11.7**	**S**	**M**			**Spehar, 1982 (fry)**
39	**19.3**	**S**	**M**			**Spehar, 1982 (fry)**
45	**42.4**	**S**	**M**			**Spehar, 1982 (fry)**
47	**54.2**	**S**	**M**			**Spehar, 1982 (fry)**
44	**29.0**	**S**	**M**			**Spehar, 1982 (fry)**
43.7	**26.2**					**GEO MEAN** (6 results, only the young fish with the low LC50s were used to calculate SMAV, those are **boldfaced**)

The remaining 16 results not used for SMAV calculation were used for the slope calculation since they were obtained over a wide range of hardness, the Hall, et al result was not used by EPA for either calculation because it was a "greater than" value. Normalized values were calculated based upon mean hardness = 115.13 and LC50 = 4617.71).

Northern squawfish, *Ptychochelius oregonensis*

HARDNESS (PPM)	VALUE (ug/L)	METHOD		NORMALIZED HARDNESS	NORMALIZED VALUE	REFERENCE
25	1092	FT	M			Andros & Garton, 1980
25	1104	FT	M			Andros & Garton, 1980
25	1097.98					**GEO MEAN** (2 results)

White sucker, *Catostomus commersoni*

HARDNESS (PPM)	VALUE (ug/L)	METHOD		NORMALIZED HARDNESS	NORMALIZED VALUE	REFERENCE
18	1110	FT	M			Duncan and Klaverkamp, 1983
18	1110					**GEO MEAN** (1 result)

Mosquitofish, *Gambusia affinis*

HARDNESS (PPM)	VALUE (ug/L)	METHOD		NORMALIZED HARDNESS	NORMALIZED VALUE	REFERENCE
11.1	900	FT	M			Giesy, et al. 1977
11.1	2200	FT	M			Giesy, et al. 1977
11.1	1407.12					**GEO MEAN** (2 results)

This species was used for a GMAV calculation because it is resident within the Great Lakes states and/or Iowa.

Threespine stickleback, *Gasterosteus aculeatus*

HARDNESS (PPM)	VALUE (ug/L)	METHOD		NORMALIZED HARDNESS	NORMALIZED VALUE	REFERENCE
115	6500	S	U			Pascoe and Cram, 1977
107	23000	R	M			Pascoe and Mattey, 1977
110.93	12227.0					**GEO MEAN** (2 results)

Striped bass, *Morone saxatilis*

HARDNESS (PPM)	VALUE (ug/L)	METHOD		NORMALIZED HARDNESS	NORMALIZED VALUE	REFERENCE
34.5	1	S	U	0.568	0.334	Hughes, 1973 (larva)
34.5	2	S	U	0.568	0.669	Hughes, 1973 (fingerling)
40	4	S	U	0.659	1.337	Pawlawski, et al. 1985 (63 d)
285	10	S	U	4.696	3.344	Pawlawski, et al. 1985 (63 d)
106.77	6.32					**GEO MEAN** (2 results)

This species was used for a GMAV calculation because other species in the genus are resident to Wisconsin. All four results are used for the slope calculation (for normalizing, mean hardness = 60.69 and mean LC50 = 2.99).

Green sunfish, *Lepomis cyanellus*

HARDNESS (PPM)	VALUE (ug/L)	METHOD		NORMALIZED HARDNESS	NORMALIZED VALUE	REFERENCE
20	2840			0.149	0.181	Pickering and Henderson, 1966
360	66000			2.684	4.214	Pickering and Henderson, 1966
335	20500			2.498	1.309	Jude, 1973
134.11	15662.9					**GEO MEAN** (3 results)

Bluegill, *Lepomis macrochirus*

HARDNESS (PPM)	VALUE (ug/L)	METHOD		NORMALIZED HARDNESS	NORMALIZED VALUE	REFERENCE
20	1940			0.584	0.427	Pickering and Henderson, 1966
18	3860			0.525	0.849	Bishop and McIntosh, 1981
18	2800			0.525	0.616	Bishop and McIntosh, 1981
18	2260			0.525	0.497	Bishop and McIntosh, 1981
207	21100			6.042	4.643	Pickering and Henderson, 1966
67	8810			1.956	1.939	Spehar & Carlson, 1984
34.26	4544.5					**GEO MEAN** (6 results)

American eel, *Anguilla rostrata*

HARDNESS (PPM)	VALUE (ug/L)	METHOD		NORMALIZED HARDNESS	NORMALIZED VALUE	REFERENCE
55	820	S	M			Rehwoldt, et al. 1972
55	820					**GEO MEAN** (1 result)

Banded killifish, *Fundulus diaphanus*

HARDNESS (PPM)	VALUE (ug/L)	METHOD		NORMALIZED HARDNESS	NORMALIZED VALUE	REFERENCE
55	110	S	M			Rehwoldt, et al. 1972
55	110					**GEO MEAN** (1 result)

Flagfish, *Jordanella floridae*

HARDNESS (PPM)	VALUE (ug/L)	METHOD		NORMALIZED HARDNESS	NORMALIZED VALUE	REFERENCE
44	2500	FT	M			Spehar, et al.
44	2500					**GEO MEAN** (1 result)

Guppy, *Poecilia reticulata*

HARDNESS (PPM)	VALUE (ug/L)	METHOD		NORMALIZED HARDNESS	NORMALIZED VALUE	REFERENCE
20	1270	S	U			Pickering & Henderson, 1966
20	1270					**GEO MEAN** (1 result)

White perch, Morone sp.

HARDNESS (PPM)	VALUE (ug/L)	METHOD		NORMALIZED HARDNESS	NORMALIZED VALUE	REFERENCE
55	8400	S	M			Rehwoldt, et al. 1972
55	8400					**GEO MEAN** (1 result)

Pumpkinseed, *Lepomis gibbosus*

HARDNESS (PPM)	VALUE (ug/L)	METHOD		NORMALIZED HARDNESS	NORMALIZED VALUE	REFERENCE
55	1500	S	M			Rehwoldt, et al. 1972
55	1500					**GEO MEAN** (1 result)

HARDNESS DATA: Geometric mean of all results = 50.6 (only the results used for SMAV calculation)
Mean + 2 standard deviations (calculated on log scale) = 457
Mean - 2 standard deviations (calculated on log scale) = 6
Range over which acute criteria are applied = 6 – 457 PPM

SLOPE OF ATC EQUATION (from normalized data) = 1.147 (r-squared = 0.765).

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 (*G. pseudolimnaeus*)
5. Mayfly *(E. grandis)*
6. Fathead minnow, family Cyprinidae
7. Mussel (genus *Lampsilis*)
8. Channel catfish, family Ictaluridae

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

Normalize mean toxicity values to intercepts @ hardness = 1 PPM using the slope of 1.127 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)
Amnicola (snail)	50.00	3800.00	42.706
Anguilla (American eel)	55.00	820.00	8.269
Aplexa (snail)	45.30	93.00	1.171
Asellus (isopod)	220.00	2130.00	4.373
Branchiura (worm)	5.30	240.00	35.418
Caddisfly	50.00	3400.00	38.210
Carassius (goldfish)	38.26	6155.74	94.049
Catostomus (white sucker)	18.00	1110.00	40.281
Ceriodaphnia (cladoceran)	89.78	116.14	0.667
Chironomus (midge)	50.00	1200.00	13.486
Crangonyx (amphipod)	50.00	1700.00	19.105
Cyprinus (carp)	55.00	240.00	2.418
Damselfly	50.00	8100.00	91.031
Daphnia (cladoceran, D. pulex)	119.79	84.22	0.347
Daphnia (cladoceran, D. magna)	132.87	42.75	0.157
Ephemerella (mayfly)	44.00	2000.00	26.027
Fundulus (banded killifish)	55.00	110.00	1.108
Gambusia (mosquitofish)	11.10	1407.12	88.919
Gammarus (amphipod)	53.99	60.96	0.627
Gasterosterus (thr. stickleback)	110.93	12227.02	55.076
Jordanella (flagfish)	44.00	2500.00	32.534
Lepomis (pumpkinseed)	55.00	1500.00	15.111
Lepomis (bluegill)	34.26	4544.50	78.801
Lepomis (green sunfish)	134.11	15662.90	56.749
Limnodrilus (worm)	5.30	170.00	25.088
Lirceus (isopod)	152.00	150.00	0.471
Lophopodella (bryozoan)	205.00	150.00	0.334
Moina (cladoceran)	82.00	71.25	0.454
Morone (white perch)	55.00	8400.00	84.624
Morone (striped bass)	60.69	2.99	0.0269
Nais (worm)	50.00	1700.00	19.105
Onchorhynchus (chinook salmon)	22.96	1.77	0.0485
Onchorhynchus (coho salmon)	45.50	5.30	0.0664
Onchorhynchus (rainbow trout)	28.00	2.74	0.0600
Orconectes (crayfish)	26.00	6100.00	145.170
Pectinatella (bryozoan)	205.00	700.00	1.559
Physa (snail)	200.00	749.47	1.717
Pimephales (fathead minnow)	43.70	26.20	0.344
Plumatella (bryozoan)	205.00	1090.00	2.427
Poecilia (guppy)	20.00	1270.00	40.840
Ptychochelius (northern squawfish)	25.00	1097.98	27.333
Quistradilus (worm)	5.30	320.00	47.224
Rhyacodrilus (worm)	5.30	630.00	92.972
Salmo (brown trout)	43.50	1.40	0.0185
Simocephalus (cladoceran, s. serrulatus)	31.86	27.63	0.521
Simocephalus (cladoceran, s. vetulus)	54.91	46.29	0.467
Spirosparma (worm, s. nikolskyi)	5.30	450.00	66.408
Spirosparma (worm, s. ferox)	5.30	350.00	51.651
Stylodrilus (worm)	5.30	550.00	81.166
Tubifex (worm)	5.30	320.00	47.224
Variechaeta (worm)	5.30	380.00	56.078

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
Orconectes	145.170	x	x	x	x
Carassius	94.049	x	x	x	x
Rhyacodrilus	92.972	x	x	x	x
Damselfly, unid.	91.031	x	x	x	x
Gambusia	88.919	x			
Stylodrilus	81.166	x	x	x	x
Spirosperma	58.567	x	x	x	x
Lepomis (gr. sunfish)	56.749			x	
Varichaeta	56.078	x	x	x	x
Gasterosteus	55.076	x	x	x	x
Quistradilus	47.224	x	x	x	x
Tubifex	47.224	x	x	x	x
Amnicola	42.706	x	x	x	x
Poecilia	40.840	x			
Lepomis (others)	40.732	x	x		
Catostomus	40.281	x	x	x	
Caddisfly, unid.	38.211	x	x	x	x
Branchiura	35.418	x	x	x	x
Jordanella	32.534	x			
Ptychochelius	27.333	x			
Ephemerella	26.027	x	x	x	x
Limnodrilus	25.088	x	x	x	x
Crangonyx	19.105	x	x	x	x
Nais	19.105	x	x	x	x
Chironomus	13.486	x	x	x	x
Anguilla	8.261	x	x		
Asellus	4.373	x	x	x	x
Plumatella	2.427	x	x	x	x
Cyprinus	2.418	x	x	x	
Physa	1.717	x	x	x	x
Pectinatella	1.559	x	x	x	x
Aplexa	1.171	x	x	x	x
Fundulus	1.108	x	x	x	
Gammarus	0.7025	x	x	x	x
Ceriodaphnia	0.6669	x	x	x	x
Simocephalus	0.4933	x	x	x	x
Lirceus	0.4707	x	x	x	x
Moina	0.4539	x	x	x	x
Pimephales	0.3436	x	x	x	
Lophopodella	0.3340	x	x	x	
Daphnia	0.2332	x	x	x	
Oncorhynchus	0.05782	x			
Morone	0.02691	x	x		
Salmo	0.01846	x			
TOTAL NUMBER REPRESENTED:		43	37	35	30

* - 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.

Gambusia, poecilia, jordanella, ptychochelius are not Wisconsin- or Great Lakes-resident. They are included in the overall (coldwater) database but not included in the other classifications since they are also not among the most sensitive organisms. Including them in the overall database should give a criterion result that more closely approximates EPA's criterion (and thereby reducing the possibility of criteria more stringent than EPA's, which is what would happen with a smaller database but the same organisms as most sensitive).

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 (values here are rounded, un-rounded values are used in the actual calculation of criteria):

		CW	WW	LFF	LAL
GMAI RANKS					
	4	0.2332	0.3436	0.4539	0.4707
	3	0.05782	0.3340	0.3436	0.4539
	2	0.02691	0.2332	0.3340	0.3340
	1	0.01846	0.02691	0.2332	0.2332
n		43	37	35	30
ln GMAI					
	4	-1.456	-1.068	-0.7898	-0.7535
	3	-2.851	-1.097	-1.068	-0.7898
	2	-3.615	-1.456	-1.097	-1.097
	1	-3.992	-3.615	-1.456	-1.456
(ln GMAI)^2					
	4	2.120	1.141	0.6238	0.5677
	3	8.125	1.203	1.141	0.8238
	2	13.070	2.120	1.203	1.203
	1	15.937	13.070	2.120	2.120
P					
	4	0.0909	0.105	0.111	0.129
	3	0.0682	0.0789	0.0833	0.0968
	2	0.0455	0.0526	0.0556	0.0645
	1	0.0227	0.0263	0.0278	0.0323
sq rt P					
	4	0.302	0.324	0.333	0.359
	3	0.261	0.281	0.289	0.311
	2	0.213	0.229	0.236	0.254
	1	0.151	0.162	0.167	0.180
EV		-11.914	-7.236	-4.411	-4.096
EW		39.253	17.534	5.087	4.514
EP		0.227	0.263	0.278	0.323
EPR		0.927	0.997	1.024	1.104
J		0.05	0.05	0.05	0.05
S		17.269	17.429	3.808	4.224
L		-6.979	-6.153	-2.078	-2.190
A		-3.117	-2.256	-1.226	-1.245
FAI		0.0443	0.105	0.293	0.288
ACI		0.0221	0.0524	0.147	0.144
ln ACI		-3.8104	-2.9493	-1.9195	-1.9383

The LAL criterion is set equal to the LFF criterion. The calculated LAL equation resulted in more stringent criteria, but since the organisms in LAL are already protected within the LFF criteria, there was no need to make criteria more protective for LAL waters. The classification-specific criteria are only used when less stringent criteria are adequately protective.

TOTAL CADMIUM
ACUTE CRITERION EQUATIONS:

	CW	WW	LFF & LAL
SLOPE	**1.147**	**1.147**	**1.147**
ln ACI	-3.8104	**-2.9493**	**-1.9195**

mean H + 2SD		457
MEAN H - 2 SD		6

TOTAL Cd
ATC (in ug/L)

@ **hardness =**	CW	WW	LFF & LAL
50	**2.0**	**4.6**	**13.0**
100	**4.4**	**10.3**	**28.9**
200	**9.6**	**22.8**	**63.9**
400	**21.4**	**50.6**	**141.8**

Acute toxicity criteria for cadmium (in ug/L as total recoverable):
Coldwater: ATC = EXP (1.147 X ln (hardness) – 3.8104)
Warmwater: ATC = EXP (1.147 X ln (hardness) – 2.9493)
Limited forage fish and
Limited aquatic life: ATC = EXP (1.147 X ln (hardness) – 1.9195)
where EXP = e raised to the power of the term in parentheses

CHRONIC TOXICITY CRITERIA

EPA SPECIES MEAN CHRONIC VALUES

(values from 4/01 EPA AWQC document, EPA 822-R-01-001)

NOTE: Normalized hardness and cadmium 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).

Oligochaete, *Aeolosoma headleyi*

HARDNESS (ppm)	VALUE (ug/L)	TYPE OF TEST	NORMALIZED HARDNESS	NORMALIZED VALUE	REFERENCE
65	25.19	LC			Neiderlehner, 1984
65	25.19				**GEO MEAN** (1 result)

Snail, *Aplexa hypnorum*

HARDNESS (ppm)	VALUE (ug/L)	TYPE OF TEST	NORMALIZED HARDNESS	NORMALIZED VALUE	REFERENCE
45.3	5.801	LC			Holcombe, et al. 1984
45.3	3.460	LC			Holcombe, et al. 1984
45.3	4.48				**GEO MEAN** (2 results)

Cladoceran, *Daphnia magna*

HARDNESS (ppm)	VALUE (ug/L)	TYPE OF TEST	NORMALIZED HARDNESS	NORMALIZED VALUE	REFERENCE
53	0.1523	LC	0.507	0.631	Chapman, et al. Manuscript
103	0.2117	LC	0.986	0.876	Chapman, et al. Manuscript
209	0.4371	LC	2.000	1.870	Chapman, et al. Manuscript
114.49	0.24				**GEO MEAN** (3 results)

Cladoceran, *Daphnia pulex*

HARDNESS (ppm)	VALUE (ug/L)	TYPE OF TEST	NORMALIZED HARDNESS	NORMALIZED VALUE	REFERENCE
65	7.49	LC			Niederlehner, 1984
65	7.49				**GEO MEAN** (1 result)

Coho salmon, *Onchorhynchus kisutch*

HARDNESS (ppm)	VALUE (ug/L)	TYPE OF TEST	NORMALIZED HARDNESS	NORMALIZED VALUE	REFERENCE
44	2.102	ELS			Eaton, et al. 1978
44	7.159	ELS			Eaton, et al. 1978
44	3.88				**GEO MEAN** (2 results)

Chinook salmon, *Onchorhynchus tshawytscha*

HARDNESS (ppm)	VALUE (ug/L)	TYPE OF TEST	NORMALIZED HARDNESS	NORMALIZED VALUE	REFERENCE
25	1.563	ELS			Chapman, 1975
25	1.563				**GEO MEAN** (1 result)

Atlantic salmon, *Salmo salar*

HARDNESS (ppm)	VALUE (ug/L)	TYPE OF TEST	NORMALIZED HARDNESS	NORMALIZED VALUE	REFERENCE
23.5	4.528	ELS			Rombrough and Garside, 1982
23.5	4.528				**GEO MEAN** (1 result)

Not resident to Wisconsin, but this result was used because it is in the same genus as other resident fish.

Brown trout, *Salmo trutta*

HARDNESS (ppm)	VALUE (ug/L)	TYPE OF TEST	NORMALIZED HARDNESS	NORMALIZED VALUE	REFERENCE
44	6.668	ELS	0.420	0.636	Eaton, et al. 1978
44	6.668				**GEO MEAN** (1 result)

Brook trout, *Salvelinus fontinalis*

HARDNESS (ppm)	VALUE (ug/L)	TYPE OF TEST	NORMALIZED HARDNESS	NORMALIZED VALUE	REFERENCE
44	2.045	ELS			Eaton, et al. 1978
37	1.732	ELS			Sauter, et al. 1976
44	2.404	LC			Benoit, et al. 1976
44	2.404				**GEO MEAN** (1 result)

Only the life-cycle test result was used for the SMCV calculation.

Lake trout, *Salvelinus namaycush*

HARDNESS (ppm)	VALUE (ug/L)	TYPE OF TEST	NORMALIZED HARDNESS	NORMALIZED VALUE	REFERENCE
44	7.357	ELS			Eaton, et al. 1978
44	7.357				**GEO MEAN** (1 result)

Northern pike, *Esox lucius*

HARDNESS (ppm)	VALUE (ug/L)	TYPE OF TEST	NORMALIZED HARDNESS	NORMALIZED VALUE	REFERENCE
44	7.361	ELS			Eaton, et al. 1978
44	7.361				**GEO MEAN** (1 result)

Fathead minnow, *Pimephales promelas*

HARDNESS (ppm)	VALUE (ug/L)	TYPE OF TEST	NORMALIZED HARDNESS	NORMALIZED VALUE	REFERENCE
67	18.92	ELS	0.577	0.642	Spehar and Carlson, 1984
201	45.92	LC	1.732	1.558	Pickering and Gast, 1972
116.06	29.48				**GEO MEAN** (1 result)

White sucker, *Catostomus commersoni*

HARDNESS (ppm)	VALUE (ug/L)	TYPE OF TEST	NORMALIZED HARDNESS	NORMALIZED VALUE	REFERENCE
44	7.099	ELS			Eaton, et al. 1978
44	7.099				**GEO MEAN** (1 result)

Bluegill, *Lepomis macrochirus*

HARDNESS (ppm)	VALUE (ug/L)	TYPE OF TEST	NORMALIZED HARDNESS	NORMALIZED VALUE	REFERENCE
207	49.80	LC			Eaton, 1974
207	49.80				**GEO MEAN** (1 result)

Smallmouth bass, *Micropterus dolomeui*

HARDNESS (ppm)	VALUE (ug/L)	TYPE OF TEST	NORMALIZED HARDNESS	NORMALIZED VALUE	REFERENCE
44	7.39	ELS			Eaton, et al. 1978
44	7.39				**GEO MEAN** (1 result)

Flagfish, *Jordanella floridae*

HARDNESS (ppm)	VALUE (ug/L)	TYPE OF TEST	NORMALIZED HARDNESS	NORMALIZED VALUE	REFERENCE
44	5.763	LC			Spehar, 1974
47.4	4.416	LC			Carlson, et al. 1982
47.4	4.982	LC			Carlson, et al. 1982
46.2	5.02				**GEO MEAN** (3 results)

HARDNESS DATA: Geometric mean of all results = 55
Mean + 2 standard deviations (calculated on log scale) = 173
Mean - 2 standard deviations (calculated on log scale) = 18
Range over which acute criteria are applied = 18 – 173 PPM

SLOPE OF ATC EQUATION (from normalized data) = 0.7852 (r-squared = 0.977).

MINIMUM DATABASE REQUIREMENT EVALUATION
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 (*H. azteca*)
5. see below
6. Fathead minnow, family Cyprinidae
7. Snail (genus *Aplexa*)
8. White sucker, family Catostomidae

CONCLUSION: The minimum database was not satisfied as no insects were represented, but since

insects weren't among the most acutely sensitive species, EPA calculated a criterion that was independent of acute (no acute-chronic ratios) anyway.

Normalize mean chronic values to intercepts @ hardness = 1 PPM using the slope of 0.7852 relating ln chronic value to ln hardness. Species are arranged in the following table by genus names in alphabetical order).

Genus/species	Mean hardness	Mean CV	SMCI (CV @ hardness = 1)
Oligochaete (Aeolosoma headleyi)	65	20.50	0.7731
Snail (Aplexa hypnorum)	45.3	4.48	0.2243
White sucker (Catost. commersoni)	44	7.10	0.3637
Cladoceran (Daphnia magna)	104.49	0.24	0.006275
Cladoceran (Daphnia pulex)	65	7.49	0.2825
Northern pike (Esox lucius)	44	7.36	0.3771
Flagfish (Jordanella floridae)	46.24	5.02	0.2475
Bluegill (Lepomis macrochirus)	207	49.8	0.7563
Smallmouth bass (Microp. dolomieui)	44	7.39	0.3786
Chinook salmon (Onch. tashawytscha)	25	1.56	0.1248
Coho salmon (Onchorhynchus kisutch)	44	3.88	0.1987
Fathead minnow (Pimeph. promelas)	116.05	29.48	0.7051
Atlantic salmon (Salmo salar)	23.1	4.53	0.3847
Brown trout (Salmo trutta)	44	6.67	0.3416
Brook trout (Salvelinus fontinalis)	41.53	2.04	0.1095
Lake trout (salvelinus namaycush)	44	7.36	0.3769

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

GENUS NAME	GMCI (ug/L)	CLASSIFICATIONS * CW	WW	LFF	LAL
Aeolosoma	0.7731	x	x	x	x
Lepomis	0.7563	x	x		
Pimephales	0.7051	x	x	x	
Micropterus	0.3786	x	x		
Esox	0.3771	x	x		
Catostomus	0.3637	x	x	x	
Salmo	0.3625	x			
Jordanella	0.2475	x (non-resident)			
Aplexa	0.2243	x	x	x	x
Salvelinus	0.2031	x			
Oncorhynchus	0.1575	x			
Daphnia	0.0063	x	x	x	x
TOTAL NUMBER REPRESENTED:		12	8	5	3

* - 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.

- Only the Daphnia magna result was used to calculate the GMCI. The D. pulex result was rejected by EPA because it was more than ten times the D. magna intercept.

The four most sensitive genera in each classification are used to calculate the criteria under each classification, pursuant to s. NR 105.06 (3). Since LAL only had three genera represented, no criterion was calculated; the LAL criterion was set equal to LFF.

In its 1984 criteria document, EPA chose to use an N value in the criteria calculations based on the total number of genera with acute data rather than chronic, so based on the calculations earlier in this document, that would be n = 43 for coldwater, n = 37 for warmwater, etc., instead of n = 12 for coldwater and n = 8 for warmwater, etc. EPA's rationale was that since five of the six freshwater genera that were acutely most sensitive to cadmium were also in the chronic database, the use of the smaller n value would be over-protective. The same approach is used here in order to get results similar to EPA criteria.

From this point, the results of the calculation are shown using the variables listed in sub. (3).

CRITERION CALCULATION **(values here are rounded, un-rounded values are used in the actual calculation of criteria):**

		CW	WW	LFF
GMAI RANKS				
	4	0.2243	0.3771	0.7051
	3	0.2031	0.3637	0.3637
	2	0.1575	0.2243	0.2243
	1	0.0063	0.0063	0.0063
n (adjusted)		43	37	35
ln GMAI				
	4	-1.4946	-0.9752	-0.3494
	3	-1.5939	-1.0114	-1.0114
	2	-1.8483	-1.4946	-1.4946
	1	-5.0713	-5.0713	-5.0713
(ln GMAI)^2				
	4	2.2339	0.9510	0.1220
	3	2.5406	1.0230	1.0230
	2	3.4164	2.2339	2.2339
	1	25.7176	25.7176	25.7176
P				
	4	0.0909	0.1053	0.1111
	3	0.0682	0.0789	0.0833
	2	0.0455	0.0526	0.0556
	1	0.0227	0.0263	0.0278
sq rt P				
	4	0.3015	0.3244	0.3333
	3	0.2611	0.2810	0.2887
	2	0.2132	0.2294	0.2357
	1	0.1508	0.1622	0.1667
EV		-10.0081	-8.5525	-7.9267
EW		33.9085	29.9255	29.0966
EP		0.2273	0.2632	0.2778
EPR		0.9266	0.9971	1.0244

continued

	CW	WW	LFF
J	0.05	0.05	0.05
S	26.4942	28.2078	29.4466
L	-8.6393	-9.1693	-9.5228
A	-2.7150	-2.8619	-2.9383
CCI	0.0662	0.0572	0.0530
ln CCI	-2.7150	-2.8619	-2.9383

Since the WW and LFF criteria were more stringent than the CW criterion, no adjustment is made to the coldwater criterion to reflect the other classifications. The warmwater sportfish, limited forage fish, and invertebrate data are already part of the coldwater database and are adequately protected by the calculated criterion.

Also, since there were only three invertebrate genera with data, the criterion calculation approach could not be applied to LAL waters (requires 4 results). The LAL criterion is, therefore, also set equal to the coldwater criterion.

TOTAL CADMIUM
CHRONIC CRITERION EQUATIONS:

	all
SLOPE	**0.7852**
ln CCI	-2.7150

mean H + 2SD	173
MEAN H - 2 SD	18

TOTAL Cd

CTC @ H =	all
50	**1.43**
100	**2.46**
200	**3.82**
400	**3.82**