DERIVATION OF ACUTE AND CHRONIC TOXICITY CRITERIA FOR CHROMIUM (+3)

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August, 2001

ACUTE TOXICITY CRITERIA

EPA SPECIES MEAN ACUTE VALUES

(values from 1/85 EPA AWQC document, EPA 440/5-84-029 and 3/95 GLWQI Criteria Document for the Protection of Aquatic Life in Ambient Water)

NOTE: Normalized hardness and chromium (+3) 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 *(Nais* sp.*)*

HARDNESS (PPM)	VALUE (ug/L)	METHOD		NORMALIZED HARDNESS	NORMALIZED VALUE	REFERENCE
50	9300	S	M			Rehwoldt, et al. 1973
50	9300					**GEO MEAN** (1 result)

Snail *(Amnicola* sp.*)*

HARDNESS (PPM)	VALUE (ug/L)	METHOD		NORMALIZED HARDNESS	NORMALIZED VALUE	REFERENCE
50	12400	S	M			Rehwoldt, et al. 1973 (embryo)
50	8400	S	M			Rehwoldt, et al. 1973 (adult)
50	10205.9					**GEO MEAN** (2 results)

EPA did not consider the adult lifestage as most sensitive. The data are only segregated when a younger lifestage is found to be more sensitive than the adults; this did not happen here so all results were used to calculate the SMAV.

Cladoceran *(Daphnia magna)*

HARDNESS (PPM)	VALUE (ug/L)	METHOD		NORMALIZED HARDNESS	NORMALIZED VALUE	REFERENCE
not given	1200	S	U			Anderson, 1948
52	16800	S	M	0.437	0.516	Chapman, et al. Manuscript
99	27400	S	M	0.833	0.842	Chapman, et al. Manuscript
110	26300	S	M	0.925	0.808	Chapman, et al. Manuscript
195	51400	S	M	1.640	1.579	Chapman, et al. Manuscript
215	58700	S	M	1.809	1.803	Chapman, et al. Manuscript
118.88	32547.9					**GEO MEAN** (5 results with hardness data and measured Cr concentrations)

Amphipod *(Crangonyx pseudogracilis)*

HARDNESS (PPM)	VALUE (ug/L)	METHOD		NORMALIZED HARDNESS	NORMALIZED VALUE	REFERENCE
50	291000	S	U			Martin and Holdich, 1986
50	291000					**GEO MEAN** (1 result)

Amphipod *(Gammarus* sp.*)*

HARDNESS (PPM)	VALUE (ug/L)	METHOD		NORMALIZED HARDNESS	NORMALIZED VALUE	REFERENCE
50	3200	S	M			Rehwoldt, et al. 1973
50	3200					**GEO MEAN** (1 result)

Crayfish *(Orconectes limosus)*

HARDNESS (PPM)	VALUE (ug/L)	METHOD		NORMALIZED HARDNESS	NORMALIZED VALUE	REFERENCE
not given	6600	S	M			Boutet and Chalsemartin, 1973
						not used since hardness result was not provided

Mayfly *(Ephemerella subvaria)*

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)

Damselfly *(*unidentified species*)*

HARDNESS (PPM)	VALUE (ug/L)	METHOD		NORMALIZED HARDNESS	NORMALIZED VALUE	REFERENCE
50	43100	S	M			Rehwoldt, et al. 1973
50	43100					**GEO MEAN** (1 result)

Caddisfly *(Hydropsyche betteni)*

HARDNESS (PPM)	VALUE (ug/L)	METHOD		NORMALIZED HARDNESS	NORMALIZED VALUE	REFERENCE
44	64000	S	U			Warnick and Bell, 1969
44	64000					**GEO MEAN** (1 result)

Caddisfly *(*unidentified species*)*

HARDNESS (PPM)	VALUE (ug/L)	METHOD		NORMALIZED HARDNESS	NORMALIZED VALUE	REFERENCE
50	50000	S	M			Rehwoldt, et al. 1973
50	50000					**GEO MEAN** (1 result)

Midge *(Chironomus* sp.*)*

HARDNESS (PPM)	VALUE (ug/L)	METHOD		NORMALIZED HARDNESS	NORMALIZED VALUE	REFERENCE
50	11000	S	M			Rehwoldt, et al. 1973
50	11000					**GEO MEAN** (1 result)

American eel *(Anguilla rostratus)*

HARDNESS (PPM)	VALUE (ug/L)	METHOD		NORMALIZED HARDNESS	NORMALIZED VALUE	REFERENCE
55	13900	S	M			Rehwoldt, et al. 1972
55	13900					**GEO MEAN** (1 result)

Rainbow trout *(Onchorhynchus mykiss)*

HARDNESS (PPM)	VALUE (ug/L)	METHOD		NORMALIZED HARDNESS	NORMALIZED VALUE	REFERENCE
not given	24100	FT	M			Hale, 1977
44	11200	S	U			Bills, et al. 1977
26	4400	FT	M			Stevens and Chapman, 1984
33.82	7019.97					**GEO MEAN** (2 results)

Both results were used in the SMAV calculation despite only one of the values being a flow-through, measured test result.

Goldfish *(Carassius auratus)*

HARDNESS (PPM)	VALUE (ug/L)	METHOD		NORMALIZED HARDNESS	NORMALIZED VALUE	REFERENCE
20	4100	S	U			Pickering and Henderson, 1966
20	4100					**GEO MEAN** (1 result)

Carp *(Cyprinus carpio)*

HARDNESS (PPM)	VALUE (ug/L)	METHOD		NORMALIZED HARDNESS	NORMALIZED VALUE	REFERENCE
55	14300	S	M			Rehwoldt, et al. 1972
55	14300					**GEO MEAN** (1 result)

Fathead minnow *(Pimephales promelas)*

HARDNESS (PPM)	VALUE (ug/L)	METHOD		NORMALIZED HARDNESS	NORMALIZED VALUE	REFERENCE
20	5070	S	U	0.152	0.223	Pickering and Henderson, 1966
360	67400	S	U	2.743	2.963	Pickering and Henderson, 1966
203	29000	FT	M	1.547	1.275	Pickering, Manuscript
203	27000	FT	M	1.547	1.187	Pickering, Manuscript
131.24	22743.5					**GEO MEAN** (2 results)

All four results were used in the SMAV calculation despite only two of the values being flow-through, measured test results. It may very well be that this was done because the static test results were at higher and lower hardness values than the FT results, and the mid-range FT results generated LC50 values that were consistent (in terms of slope) with the other species having multiple results.

Banded killifish *(Fundulus diaphanus)*

HARDNESS (PPM)	VALUE (ug/L)	METHOD		NORMALIZED HARDNESS	NORMALIZED VALUE	REFERENCE
55	16900	S	M			Rehwoldt, et al. 1972
55	16900					**GEO MEAN** (1 result)

Guppy *(Poecilia reticulata)*

HARDNESS (PPM)	VALUE (ug/L)	METHOD		NORMALIZED HARDNESS	NORMALIZED VALUE	REFERENCE
20	3330	S	U			Pickering and Henderson, 1966
						not used to calculate GMAV since species is non-resident

The guppy result was not used in Wisconsin because genus Poecilia is not resident to the Great Lakes states or Iowa.

White perch *(Morone americana)*

HARDNESS (PPM)	VALUE (ug/L)	METHOD		NORMALIZED HARDNESS	NORMALIZED VALUE	REFERENCE
55	14400	S	M			Rehwoldt, et al. 1972
55	14400					**GEO MEAN** (1 result)

Striped bass *(Morone saxatilis)*

HARDNESS (PPM)	VALUE (ug/L)	METHOD		NORMALIZED HARDNESS	NORMALIZED VALUE	REFERENCE
55	17700	S	M			Rehwoldt, et al. 1972
55	17700					**GEO MEAN** (1 result)

Pumpkinseed *(Lepomis gibbosus)*

HARDNESS (PPM)	VALUE (ug/L)	METHOD		NORMALIZED HARDNESS	NORMALIZED VALUE	REFERENCE
55	17000	S	M			Rehwoldt, et al. 1972
55	17000					**GEO MEAN** (1 result)

Bluegill *(Lepomis macrochirus)*

HARDNESS (PPM)	VALUE (ug/L)	METHOD		NORMALIZED HARDNESS	NORMALIZED VALUE	REFERENCE
20	7460	S	U	0.236	0.322	Pickering and Henderson, 1966
360	71900	S	U	4.243	3.105	Pickering and Henderson, 1966
84.85	23159.7					**GEO MEAN** (2 results)

HARDNESS DATA: Geometric mean of all results = 89.19
Mean + 2 standard deviations (calculated on log scale) = 301
Mean - 2 standard deviations (calculated on log scale) = 13
Range over which acute criteria are applied = 13 – 301 PPM

SLOPE OF ATC EQUATION (from normalized data) = 0.8190 (r-squared = 0.978).
This agrees with EPA's calculation.

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. Mayfly *(E. subvaria)*
6. Fathead minnow, family Cyprinidae
7. Snail (Amnicola sp.)
8. Banded killifish, family Cyprinodontidae

CONCLUSION: An acute toxicity criterion can be calculated for chromium (+3) according to ch. NR 105.

Normalize mean toxicity values to intercepts @ hardness = 1 PPM using the slope of 0.8190 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	10205.88	414.40	
Anguilla (american eel)		55.00	13900.00	522.01
Caddisfly (unidentified genus)		50.00	50000.00	2030.19
Carassius (goldfish)		20.00	4100.00	352.58
Crangonyx (amphipod)		50.00	291000.00	11815.72
Cyprinus (carp)		55.00	14300.00	537.04
Damselfly (unidentified genus)		50.00	43100.00	1750.03
Daphnia (cladoceran)		118.88	32547.93	650.20
Ephemerella (mayfly)		44.00	2000.00	90.17
Fundulus (banded killifish)		55.00	16900.00	634.68
Gammarus (amphipod)		50.00	3200.00	129.93
Hydropsyche (caddisfly)		44.00	64000.00	2885.46
Lepomis (pumpkinseed)		55.00	17000.00	638.43
Lepomis (bluegill)		84.85	23159.75	609.79
Morone (white perch)		55.00	14400.00	540.79
Morone (striped bass)		55.00	17700.00	664.72
Nais (worm)		50.00	9300.00	377.62
Onchorhynchus (rainbow trout)		33.82	7019.97	392.58
Pimephales (fathead minnow)		131.24	22743.51	418.97

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.

GENUS NAME		GMAI (ug/L)		CLASSIFICATIONS * CW	WW	LFF	LAL
Crangonyx		11815.72		x	x	x	x
Hydropsyche		2885.46		x	x	x	x
Caddisfly (unid.)		2030.19		x	x	x	x
Damselfly (unid.)		1750.03		x	x	x	x
Daphnia		650.20		x	x	x	x
Fundulus		634.68		x	x		
Lepomis		623.95		x	x		
Morone		599.56		x	x		
Cyprinus		537.04		x	x	x	
Anguilla	522.01		x	x			
Chironomus		446.64		x	x	x	x
Pimephales		418.97		x	x	x	
Amnicola		414.40		x	x	x	x
Onchorhynchus		392.58		x			
Nais		377.62		x	x	x	x
Carassius		352.58		x	x	x	
Gammarus		129.93		x	x	x	x
Ephemerella		90.17		x	x	x	x
TOTAL NUMBER REPRESENTED:				18	17	13	10

* - 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	377.61595	377.61595	377.61595	414.39821
3	352.58069	352.58069	352.58069	377.61595
2	129.93237	129.93237	129.93237	129.93237
1	90.170669	90.170669	90.170669	90.170669
n	18	17	13	10
ln GMAI				
4	5.9338777	5.9338777	5.9338777	6.0268274
3	5.8652795	5.8652795	5.8652795	5.9338777
2	4.8670141	4.8670141	4.8670141	4.8670141
1	4.5017042	4.5017042	4.5017042	4.5017042
(ln GMAI)^2				
4	35.210904	35.210904	35.210904	36.322648
3	34.401504	34.401504	34.401504	35.210904
2	23.687826	23.687826	23.687826	23.687826
1	20.265341	20.265341	20.265341	20.265341
P				
4	0.2105263	0.2222222	0.2857143	0.3636364
3	0.1578947	0.1666667	0.2142857	0.2727273
2	0.1052632	0.1111111	0.1428571	0.1818182
1	0.0526316	0.0555556	0.0714286	0.0909091
sq rt P				
4	0.4588315	0.4714045	0.5345225	0.6030227
3	0.3973597	0.4082483	0.46291	0.522233
2	0.3244428	0.3333333	0.3779645	0.4264014
1	0.2294157	0.2357023	0.2672612	0.3015113
EV	21.167875	21.167875	21.167875	21.329423
EW	113.56557	113.56557	113.56557	115.48672
EP	0.5263158	0.5555556	0.7142857	0.9090909
EPR	1.4100498	1.4486884	1.6426582	1.8531684
J	0.05	0.05	0.05	0.05
S	7.2690302	7.0751544	6.2396997	5.8859036
L	2.7295453	2.7295453	2.7295453	2.6054631
A	4.3549499	4.3115979	4.1247846	3.9215912
FAI	77.862923	74.559536	61.854484	50.480705
ACI	38.931461	37.279768	30.927242	25.240353
ln ACI	3.6618027	3.6184508	3.4316374	3.228444

TOTAL CHROMIUM (+3)
ACUTE CRITERION EQUATIONS:

	CW	WW	LFF	LAL
SLOPE	0.8190	0.8190	0.8190	0.8190
ln ACI	3.6618	3.6184	3.4316	3.2284
	< EPA	< CW	< CW	< CW
adj. ln ACI	3.7256	3.7256	3.7256	3.7256

mean H + 2SD	301
mean H - 2 SD	13

TOTAL REC. Cr ATC (in ug/L) @ hardness =

50	1022
100	1803
200	3181
301+	4446

The calculated criteria for the non-coldwater classifications were all less than the coldwater criterion, and all four were less than the EPA criterion because of the non-resident species (Guppy, genus Poecilia) used by EPA. Since Wisconsin's database is a subset of EPA's, the criterion was raised to equal EPA's (ln ACI = 2.255).

Acute toxicity criteria for chromium (+3) (in ug/L as total recoverable):
all classifications: ATC = EXP(0.819 X ln(hardness) + 3.7256)
where EXP = e raised to the power of the term in parentheses
Hardness range = 13 - 301

CHRONIC TOXICITY CRITERIA

EPA SPECIES MEAN CHRONIC VALUES

(values from 1/85 EPA AWQC document, EPA 440/5-85-029 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	66.11	LC			Chapman, et al. Manuscript
100	193.7	LC			Chapman, et al. Manuscript
206	< 44 *	LC			Chapman, et al. Manuscript
102.32	< 82.59				**GEO MEAN** (3 results)

* - Adverse impacts were observed at all concentrations tested; a no observable effect concentration could not be calculated.

Rainbow trout, *Onchorhynchus mykiss*

HARDNESS (ppm)	VALUE (ug/L)	TYPE OF TEST	NORMALIZED HARDNESS	NORMALIZED VALUE	REFERENCE
26	68.53	ELS			Stevens and Chapman, 1984
26	68.53				**GEO MEAN** (1 result)

Fathead minnow, *Pimephales promelas*

HARDNESS (ppm)	VALUE (ug/L)	TYPE OF TEST	NORMALIZED HARDNESS	NORMALIZED VALUE	REFERENCE
203	1025	LC			Pickering, Manuscript
203	1025				**GEO MEAN** (1 result)

EPA ACUTE-CHRONIC RATIOS:

Only three freshwater species have chronic data. 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				
(hardness = 52)	16800	66.11	254.1	
(hard. = 100)	27400	193.7	141.5	
(hard. = 206)	55380*	< 44	> 1259	> 356.4
Rainbow trout				
(hard. = 26)	4400	68.63	64.11	64.11
Fathead minnow				
(hard. = 203)	27980#	1025	27.3	27.3

* - extrapolated from acute results @ hardness = 195 & 215 by same author

- mean of two results by same author at this hardness

The ACRs for rainbow trout and fathead minnow were used to calculate the FACRs because they are much more sensitive to chromium than the daphnid. Since the same acute criterion was applied to each classification, the Daphnia ratio would result in more stringent criteria for the LAL classification (which

doesn't include fish), so it is just set equal to the criterion for the higher classification.

Coldwater FACR = Geometric mean of 64.11 and 27.3 = 41.84
Warmwater and limited forage FACR = 27.3 (only the fathead minnow ratio applies)
Limited aqu. life FACR = 27.3, set equal to warmwater & LFF ratio

CW CCI = 3.7256 + ln(2) – ln(41.84) = 0.6851
WW CCI = 3.7256 + ln(2) – ln(27.3) = 1.112

Chronic toxicity criteria for chromium (+3) (in ug/L as total recoverable):
CW: CTC = EXP(0.819 X ln(hardness) + 0.6851)
LAL: CTC = EXP(0.819 X ln(hardness) + 1.112)
where EXP = e raised to the power of the term in parentheses
hardness range = 13 - 301

TOTAL RECOVERABLE Cr CTC (in ug/L):

hardness	CW	WW, LFF, LAL
50	48.9	74.9
100	86.2	132.1
200	152.1	233.1
301+	212.6	325.7