DERIVATION OF ACUTE AND CHRONIC TOXICITY CRITERIA FOR LEAD

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ACUTE TOXICITY CRITERIA

EPA SPECIES MEAN ACUTE VALUES

(values from 1/85 EPA AWQC document, EPA 440/5-84-027 and proposed 1991 GLI Updates)

NOTE: Normalized hardness and lead 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).

Rainbow trout, *Onchorhynchus mykiss*

HARDNESS (PPM)	VALUE (ug/L)	METHOD		NORMALIZED HARDNESS	NORMALIZED VALUE	REFERENCE
290	542,000	S	U			Goettl, et al. 1972
353	471,000	S	U			Goettl, et al. 1972
28	1170	FT	M			Goettl, et al. 1972
28	1170					**1 (only FT value used)**

Fathead minnow, *Pimephales promelas*

HARDNESS (PPM)	VALUE (ug/L)	METHOD		NORMALIZED HARDNESS	NORMALIZED VALUE	REFERENCE
44	2100	FT	M			Spehar & Fiandt, 1986
20	5580	S	U			Pickering & Henderson, 1966
20	7330	S	U			Pickering & Henderson, 1966
360	482,000	S	U			Pickering & Henderson, 1966
44	2100					**1 (only FT value used)**

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

Amphipod, *Gammarus pseudolimnaeus*

HARDNESS (PPM)	VALUE (ug/L)	METHOD		NORMALIZED HARDNESS	NORMALIZED VALUE	REFERENCE
46	124	FT	M			Spehar et al. 1978
48	140	FT	M			Call et al. 1983
46.99	131.76					**2 values**

Cladoceran, *Daphnia magna*

HARDNESS (PPM)	VALUE (ug/L)	METHOD		NORMALIZED HARDNESS	NORMALIZED VALUE	REFERENCE
54	612	R	M	0.4451	0.5134	Chapman, et al. Manuscript
240	1815			1.9781	1.5225	Elnabarawy et al. 1986
110	612	R	M	0.9066	0.7986	Chapman, et al. Manuscript
152	952	R	M	1.2528	1.6022	Chapman, et al. Manuscript
121.33	1192.13					**4 values**

Bluegill, *Lepomis macrochirus*

HARDNESS (PPM)	VALUE (ug/L)	METHOD		NORMALIZED HARDNESS	NORMALIZED VALUE	REFERENCE
20	23,800	S	U	0.2357	0.2320	Pickering & Henderson, 1966
360	442,000	S	U	4.2426	4.3095	Pickering & Henderson, 1966
84.85	102565					**2 values**

Results for species with single test results:

Organism	Hardness (PPM)	Value (ug/L)	Method	Reference
Snail (*Aplexa hypnorum*)	61	1340	FT M	Call, et al. 1981
Midge (*Tanytarsus dissimilis*)	48	224,000	FT M	Call, et al. 1983
Brook trout (*Salvelinus fontinalis*)	44	4100	FT M	Holcombe, et al. 1978
Goldfish (*Carassius auratus*)	20	31,500	S U	Pickering & Henderson, 1966
Guppy (*Poecilia reticulata*) *	20	20,600	S U	Pickering & Henderson, 1966
Cladoceran (*Ceriodaphnia reticulata*)	240	1878		Elnabarawy, et al. 1986
Cladoceran (*Daphnia pulex*)	240	2003		Elnabarawy, et al. 1986
Cladoceran (*Ceriodaphnia dubia*)	100	248		Spehar & Fiandt, 1986
Amphipod (*Crangonyx pseudogracilis*)	50	27,600		Martin & Holdich, 1986
Worm (*Lumbriculus variegatus*)	49	580		
Bullfrog (*Rana catesbiana*)	48.2	13,500		

NOTE: There are gaps in the references and test methods, due to the lack of a published EPA criteria document since 1991.
* = Not resident to Great Lakes states or Iowa, applied only to the coldwater classification in order to be consistent with national freshwater database since this is not among the most sensitive organisms.

HARDNESS DATA: Geometric mean of all results = 96.30
Mean + 2 standard deviations (calculated on log scale) = 356
Mean - 2 standard deviations (calculated on log scale) = 12
Range over which acute criteria are applied = 12 – 356 PPM

SLOPE OF ATC EQUATION (from normalized data) = 0.9662 (r-squared = 0.969).

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. Midge *(T. dissimilis)*
6. Fathead minnow, family Cyprinidae
7. Snail (*A. hypnorum*)
8. Bullfrog

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

Normalize mean toxicity values to intercepts @ hardness = 1 PPM using the slope of 0.9662 relating ln LC50 to ln hardness. Species are arranged in the following table by genus names.

Genus/species	Mean hardness	Mean LC50/EC50	SMAI (LC50/EC50 @ hardness = 1)
Daphnia magna	121.33	1192.13	11.5557
Daphnia pulex	240	2003	10.0442
Amphipod (*Gammarus*)	46.99	131.76	3.1936
Fathead minnow (*Pimephales*)	44	2100	54.2390
Bluegill (*Lepomis*)	84.85	102565.10	1404.49
Snail (*Aplexa*)	61	1340	25.2415
Midge (*Tanytarsus*)	48	224000	5318.99
Rainbow trout (*Onchorrhynchus*)	28	1170	46.7669
Brook trout (*Salvelinus*)	44	4100	105.895
Goldfish (*Carassius*)	20	31500	1742.82
Guppy (*Poecilia*)	20	20600	1139.75
Ceriodaphnia reticulata	240	1878	9.4174
Ceriodaphnia dubia	100	248	2.8977
Amphipod (*Crangonyx*)	50	27600	630.030
Worm (*Lumbriculus*)	49	580	13.5007
Bullfrog (*Rana*)	48.2	13500	319.279

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
Tanytarsus	5318.99	x	x	x	x
Carassius	1742.82	x	x	x	
Lepomis	1404.49	x	x		
Poecilia	1139.75	x			
Crangonyx	630.030	x	x	x	x
Rana	319.279	x	x	x	x
Salvelinus	105.895	x			
Pimephales	54.2390	x	x	x	
Onchorhynchus	46.7669	x			
Aplexa	25.2415	x	x	x	x
Lumbriculus	13.5007	x	x	x	x
Daphnia	10.7735	x	x	x	x
Ceriodaphnia	5.2238	x	x	x	x
Gammarus	3.1936	x	x	x	x
TOTAL NUMBER REPRESENTED:		14	11	10	8

* - 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	13.500728	13.500728	13.500728	13.500728
3	10.773506	10.773506	10.773506	10.773506
2	5.223832	5.223832	5.223832	5.223832
1	3.193637	3.193637	3.193637	3.193637
n	14	11	10	8
ln GMAI				
4	2.602744			
3	2.377090			
2	1.653231			
1	1.161160			
(ln GMAI)^2				
4	6.774274			
3	5.650557			
2	2.733174			
1	1.348294			
P				
4	0.266667			
3	0.2			
2	0.133333			
1	0.066667			
sq rt P				
4	0.516398			
3	0.447214			
2	0.365148			
1	0.258199			
EV	7.794225			
EW	16.506299			
EP	0.666667			
EPR	1.586959			
J	0.05			
S	5.965609			
L	-0.418237			
A	0.915713			
FAI	2.498557			
ACI	1.249278			

ln ACI	0.222566	< 0.222566	< 0.222566	< 0.222566

TOTAL LEAD
ACUTE CRITERION EQUATIONS:

	CW	WW	LFF	LAL
SLOPE	0.9662			
ln ACI	0.2226			
		< CW	< CW	< CW

mean H + 2SD	356
mean H - 2 SD	12

TOTAL REC. Pb
ATC (in ug/L)

@ hardness =	
50	54.7
100	106.9
200	208.9
356	364.7

Since the same four genera are the most sensitive in each classification, the coldwater criterion is considered to be protective of all four. No relief in the criteria are provided by the other designated uses.

Acute toxicity criteria for lead (in ug/L as total recoverable):
all classifications: ATC = EXP(0.9662 X ln(hardness) + 0.2226)
where EXP = e raised to the power of the term in parentheses

CHRONIC TOXICITY CRITERIA

EPA SPECIES MEAN CHRONIC VALUES

(values from 1/85 EPA AWQC document, EPA 440/5-84-027 and proposed 1991 GLI Updates)

Cladoceran, *Daphnia magna*

HARDNESS (ppm)	VALUE (ug/L)	TYPE OF TEST	NORMALIZED HARDNESS	NORMALIZED VALUE	REFERENCE
52	12.26	LC			Chapman, et al. Manuscript
102	118.8	LC			Chapman, et al. Manuscript
151	128.1	LC			Chapman, et al. Manuscript
					GEO MEAN (3 results)

Brook trout, *Salvelinus fontinalis*

HARDNESS (ppm)	VALUE (ug/L)	TYPE OF TEST	NORMALIZED HARDNESS	NORMALIZED VALUE	REFERENCE
44	83.08	LC			Holcombe et al. 1976

Fathead minnow, *Pimephales promelas*

HARDNESS (ppm)	VALUE (ug/L)	TYPE OF TEST	NORMALIZED HARDNESS	NORMALIZED VALUE	REFERENCE
44	2100				Spehar & Fiandt, 1986

Rainbow trout, *Onchorhynchus mykiss*

HARDNESS (ppm)	VALUE (ug/L)	TYPE OF TEST	NORMALIZED HARDNESS	NORMALIZED VALUE	REFERENCE
28	1170	ELS			Goettl et al. 1972

Cladoceran, *Ceriodaphnia dubia*

HARDNESS (ppm)	VALUE (ug/L)	TYPE OF TEST	NORMALIZED HARDNESS	NORMALIZED VALUE	REFERENCE
100	248				Spehar & Fiandt, 1986

EPA ACUTE-CHRONIC RATIOS:

Only four freshwater species have chronic data. Not enough data are available to permit the calculation of independent chronic toxicity criteria (see table below) 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 = 52-54)	612	12.26	49.92	
(hard. = 102-110)	952	118.8	8.01	
(hard. = 151-152)	1910	128.1	14.91	18.14
Fathead minnow	2100	329	6.38	6.38
Rainbow trout	1170	18.88	61.97	61.97
Brook trout	4100	83.08	49.35	49.35
Ceriodaphnia dubia	248	52	4.77	4.77

FACR = 4.77
Since there is a tendency for the ratios to increase as the acute values increase, the ratio for the genus with a GMAI closest to the criterion intercept is used as the final ACR.
CCI = ln(FAI/FACR) = ln(2.498557/4.77) = -0.6466

Chronic toxicity criteria for lead (in ug/L as total recoverable):
CTC = EXP(0.9662 X ln(hardness) – 0.6466)
where EXP = e raised to the power of the term in parentheses

NOTE: The criterion in NR 105 was calculated incorrectly. When NR 105 is next revised, the correct calculation should be made (based on current toxicity data, of course). This is not considered to be a significant correction need at this time, since chronic-based lead limits are rarely if ever needed in permits, even based on the NR 105 version which is too low of a criterion (subtraction in the rule is -1.1171 instead of -0.6466).

Incorrect:
-1.1171 = ln (EXP (0.2226 X 2)/4.77)
Correct:
-0.6466 = ln((2 X EXP(0.2226))/4.77)