DERIVATION OF ACUTE AND CHRONIC TOXICITY CRITERIA FOR NICKEL

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ACUTE TOXICITY CRITERIA

EPA SPECIES MEAN ACUTE 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)

NOTE: Normalized hardness and nickel 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	14100	S	M			Rehwoldt, et al. 1973
50	14100					**GEO MEAN** (1 result)

Snail, *Amnicola sp.*

HARDNESS (PPM)	VALUE (ug/L)	METHOD		NORMALIZED HARDNESS	NORMALIZED VALUE	REFERENCE
50	11400	S	M			Rehwoldt, et al. 1973
50	14300	S	M			Rehwoldt, et al. 1973
50	12767.9					**GEO MEAN** (2 results)

Snail, *Physa gyrina*

HARDNESS (PPM)	VALUE (ug/L)	METHOD		NORMALIZED HARDNESS	NORMALIZED VALUE	REFERENCE
26	239	FT	U			Nebeker, et al. 1986
26	239					**GEO MEAN** (1 result)

Cladoceran, *Daphnia magna*

HARDNESS (PPM)	VALUE (ug/L)	METHOD		NORMALIZED HARDNESS	NORMALIZED VALUE	REFERENCE
45.3	510	S	U	0.570	0.312	Biesinger and Christensen, 1972
51.1	915	S	M	0.643	0.561	Call, et al. 1983
51	1800	S	M	0.641	1.103	Chapman, et al. Manuscript
100	2360	S	M	1.257	1.446	Chapman, et al. Manuscript
104	1920	S	M	1.308	1.176	Chapman, et al. Manuscript
206	4970	S	M	2.590	3.045	Chapman, et al. Manuscript
79.52	1632.32					**GEO MEAN** (6 results)

Cladoceran, *Daphnia pulicaria*

HARDNESS (PPM)	VALUE (ug/L)	METHOD		NORMALIZED HARDNESS	NORMALIZED VALUE	REFERENCE
48	2182	S	M			Lind, et al. Manuscript
48	1813	S	M			Lind, et al. Manuscript
44	1836	S	M			Lind, et al. Manuscript
47	1901	S	M			Lind, et al. Manuscript
46.72	1927.64					**GEO MEAN** (4 results)

Amphipod, *Gammarus sp.*

HARDNESS (PPM)	VALUE (ug/L)	METHOD		NORMALIZED HARDNESS	NORMALIZED VALUE	REFERENCE
50	13000	S	M			Rehwoldt, et al. 1973
50	13000					**GEO MEAN** (1 result)

Amphipod, *Crangonyx pseudogracilis*

HARDNESS (PPM)	VALUE (ug/L)	METHOD		NORMALIZED HARDNESS	NORMALIZED VALUE	REFERENCE
50	66100	S	U			Martin and Holdich, 1986
50	66100					**GEO MEAN** (1 result)

Midge, *Chironomus riparis*

HARDNESS (PPM)	VALUE (ug/L)	METHOD		NORMALIZED HARDNESS	NORMALIZED VALUE	REFERENCE
55	72400	S	U			Fowlesland and George, 1986 (1st inst.)
55	81300	S	U			Fowlesland and George, 1986 (1st inst.)
55	84900	S	U			Fowlesland and George, 1986 (1st inst.)
55	184000	S	U			Fowlesland and George, 1986 (2nd inst.)
55	150000	S	U			Fowlesland and George, 1986 (2nd inst.)
55	174000	S	U			Fowlesland and George, 1986 (2nd inst.)
55	79355.8					**GEO MEAN** (3 results, only 1st instar was used to calculate SMAV)

Mayfly, *Ephemerella subvaria*

HARDNESS (PPM)	VALUE (ug/L)	METHOD		NORMALIZED HARDNESS	NORMALIZED VALUE	REFERENCE
42	4000	S	U			Warnick and Bell, 1969
42	4000					**GEO MEAN** (1 result)

Damselfly - unidentified

HARDNESS (PPM)	VALUE (ug/L)	METHOD		NORMALIZED HARDNESS	NORMALIZED VALUE	REFERENCE
50	21200	S	M			Rehwoldt, et al. 1973
50	21200					**GEO MEAN** (1 result)

Stonefly, *Acroneuria lycorias*

HARDNESS (PPM)	VALUE (ug/L)	METHOD		NORMALIZED HARDNESS	NORMALIZED VALUE	REFERENCE
40	33500	S	U			Warnick and Bell, 1969
40	33500					**GEO MEAN** (1 result)

Caddisfly – unidentified

HARDNESS (PPM)	VALUE (ug/L)	METHOD		NORMALIZED HARDNESS	NORMALIZED VALUE	REFERENCE
50	30200	S	M			Rehwoldt, et al. 1973
50	30200					**GEO MEAN** (1 result)

American eel, *Anguilla rostrata*

HARDNESS (PPM)	VALUE (ug/L)	METHOD		NORMALIZED HARDNESS	NORMALIZED VALUE	REFERENCE
53	13000	S	M			Rehwoldt, et al. 1971
55	13000	S	M			Rehwoldt, et al. 1972
53.99	13000					**GEO MEAN** (2 results)

Rainbow trout, *Onchorhynchus mykiss*

HARDNESS (PPM)	VALUE (ug/L)	METHOD		NORMALIZED HARDNESS	NORMALIZED VALUE	REFERENCE
33	10000	FT	M			Nebeker, et al. 1985
33	10900	FT	M			Nebeker, et al. 1985
33	8900	FT	M			Nebeker, et al. 1985
33	8100	FT	M			Nebeker, et al. 1985
33	9415.11					**GEO MEAN** (4 results)

Goldfish, *Carassius auratus*

HARDNESS (PPM)	VALUE (ug/L)	METHOD		NORMALIZED HARDNESS	NORMALIZED VALUE	REFERENCE
20	9820	S	U			Pickering and Henderson, 1966
20	9820					**GEO MEAN** (1 result)

Carp, *Cyprinus carpio*

HARDNESS (PPM)	VALUE (ug/L)	METHOD		NORMALIZED HARDNESS	NORMALIZED VALUE	REFERENCE
53	10600	S	M			Rehwoldt, et al. 1971
55	10400	S	M			Rehwoldt, et al. 1972
53.99	10499.5					**GEO MEAN** (2 results)

Fathead minnow, *Pimephales promelas*

HARDNESS (PPM)	VALUE (ug/L)	METHOD		NORMALIZED HARDNESS	NORMALIZED VALUE	REFERENCE
20	5180	S	U	0.187	0.337	Pickering and Henderson, 1966
20	4580	S	U	0.187	0.298	Pickering and Henderson, 1966
360	42400	S	U	3.360	2.760	Pickering and Henderson, 1966
360	44500	S	U	3.360	2.896	Pickering and Henderson, 1966
210	27000	S	U	1.960	1.757	Pickering, 1974
210	32200	S	M	1.960	2.096	Pickering, 1974
210	28000	FT	M	1.960	1.823	Pickering, 1974
210	25000	FT	M	1.960	1.627	Pickering, 1974
45	5209	FT	M	0.420	0.339	Lind, et al. Manuscript
44	5163	FT	M	0.411	0.336	Lind, et al. Manuscript
96.67	11713.6					**GEO MEAN** (4 results, FT only)

All ten results were used in the slope calculation, normalized values were based on a mean hardness = 107.16 and mean LC50 = 15363.48.

Banded killifish, *Fundulus diaphanus*

HARDNESS (PPM)	VALUE (ug/L)	METHOD		NORMALIZED HARDNESS	NORMALIZED VALUE	REFERENCE
53	46200	S	M			Rehwoldt, et al. 1971
55	46100	S	M			Rehwoldt, et al. 1972
53.99	46150.0					**GEO MEAN** (2 results)

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
53	13600	S	M			Rehwoldt, et al. 1971
55	13700	S	M			Rehwoldt, et al. 1972
53.99	13649.9					**GEO MEAN** (2 results)

Striped bass, *Morone saxatilis*

HARDNESS (PPM)	VALUE (ug/L)	METHOD		NORMALIZED HARDNESS	NORMALIZED VALUE	REFERENCE
53	6200	S	M	0.698	0.736	Rehwoldt, et al. 1971
55	6300	S	M	0.724	0.748	Rehwoldt, et al. 1972
40	3900	S	U	0.527	0.463	Palawski, et al. 1985
285	33000	S	U	3.754	3.919	Palawski, et al. 1985
75.93	8420.30					**GEO MEAN** (4 results)

Rock bass, *Ambloplites rupestris*

HARDNESS (PPM)	VALUE (ug/L)	METHOD		NORMALIZED HARDNESS	NORMALIZED VALUE	REFERENCE
26	2480	FT	M			Lind, et al. Manuscript
26	2480					**GEO MEAN** (1 result)

Pumpkinseed, *Lepomis gibbosus*

HARDNESS (PPM)	VALUE (ug/L)	METHOD		NORMALIZED HARDNESS	NORMALIZED VALUE	REFERENCE
53	8100	S	M			Rehwoldt, et al. 1971
55	8200	S	M			Rehwoldt, et al. 1972
53.99	8049.84					**GEO MEAN** (2 results)

Bluegill, *Lepomis macrochirus*

HARDNESS (PPM)	VALUE (ug/L)	METHOD		NORMALIZED HARDNESS	NORMALIZED VALUE	REFERENCE
20	5180	S	U	0.388	0.419	Pickering and Henderson, 1966
20	5360	S	U	0.388	0.434	Pickering and Henderson, 1966
360	39600	S	U	6.985	3.205	Pickering and Henderson, 1966
49	21200	FT	M	0.951	1.716	Cairns, et al. 1981
49	21200					**GEO MEAN** (1 result, FT only)

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

HARDNESS DATA: Geometric mean of all results = 60.21
Mean + 2 standard deviations (calculated on log scale) = 268
Mean - 2 standard deviations (calculated on log scale) = 14
Range over which acute criteria are applied = 14 – 268 PPM

SLOPE OF ATC EQUATION (from normalized data) = 0.8460 (r-squared = 0.886).
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. Stonefly *(A. lycorias)*
6. Fathead minnow, family Cyprinidae
7. Snail (P. gyrina)
8. Banded killifish, family Cyprinodontidae

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

Normalize mean toxicity values to intercepts @ hardness = 1 PPM using the slope of 0.846 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)
Stonefly (Acroneuria lycorias)	40.00	33500	1478.34
Rock bass (Ambloplites rupestris)	26.00	2480	157.56
Snail (Amnicola sp.)	50.00	12767.93	466.52
American eel (Anguilla rostrata)	53.99	13000	445.12
Caddisfly (genus unidentified)	50.00	30200	1103.45
Goldfish (Carassius auratus)	20.00	9820	778.93
Midge (Chironomus riparis)	55.00	79355.85	2674.91
Amphipod (Cran. pseudogracilis)	50.00	66100	2415.17
Carp (Cyprinus carpio)	53.99	10499.52	359.50
Damselfly (genus unidentified)	50.00	21200	774.61
Cladoceran (Daphnia magna)	79.52	1632.32	40.28
Cladoceran (Daphnia pulicaria)	46.72	1927.64	74.59
Mayfly (Ephemerella subvaria)	42.00	4000	169.38
Banded killifish (Fundulus diaphanus)	53.99	46149.97	1580.18
Amphipod (Gammarus sp.)	50.00	13000	475.00
Bluegill (Lepomis macrochirus)	49.00	21200	787.96
Pumpkinseed (Lepomis gibbosus)	53.99	8049.84	275.63
Striped bass (Morone saxatilis)	75.93	8420.30	216.07
White perch (Morone americana)	53.99	13649.91	467.37
Worm (Nais sp.)	50.00	14100	515.19
Rainbow trout (Onch. mykiss)	33.00	9415.11	488.91
Snail (Physa gyrina)	26.00	239.00	15.18
Fathead minnow (Pimeph. promelas)	96.67	11713.55	245.04

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
Chironomus	2674.91	x	x	x	x
Crangonyx	2415.17	x	x	x	x
Fundulus	1580.18	x	x		
Acroneuria	1478.34	x	x	x	x
Caddisfly	1103.45	x	x	x	x
Carassius	778.93	x	x	x	
Damselfly	774.61	x	x	x	x
Nais	515.19	x	x	x	x
Onchorhynchus	488.91	x			
Gammarus	475.00	x	x	x	x
Amnicola	466.52	x	x	x	x
Lepomis	466.03	x	x		
Anguilla	445.12	x	x		
Cyprinus	359.50	x	x	x	
Morone	317.79	x	x		
Pimephales	245.04	x	x	x	
Ephemerella	169.38	x	x	x	x
Ambloplites	157.56	x	x		
Daphnia	54.81	x	x	x	x
Physa	15.18	x	x	x	x
TOTAL NUMBER REPRESENTED:		20	19	14	11

* - 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	169.3803	169.3803	245.03775	466.51646
3	157.56031	157.56031	157.56031	169.3803
2	54.812849	54.812849	54.812849	54.812849
1	15.184239	15.184239	15.184239	15.184239
n	20	19	14	11
ln GMAI				
4	5.1321465	5.1321465	5.5014123	6.1452933
3	5.0598083	5.0598083	5.0598083	5.1321465
2	4.0039246	4.0039246	4.0039246	4.0039246
1	2.720258	2.720258	2.720258	2.720258
(ln GMAI)^2				
4	26.338927	26.338927	30.265537	37.76463
3	25.60166	25.60166	25.60166	26.338927
2	16.031413	16.031413	16.031413	16.031413
1	7.3998035	7.3998035	7.3998035	7.3998035
P				
4	0.1904762	0.2	0.2666667	0.3333333
3	0.1428571	0.15	0.2	0.25
2	0.0952381	0.1	0.1333333	0.1666667
1	0.047619	0.05	0.0666667	0.0833333
sq rt P				
4	0.4364358	0.4472136	0.5163978	0.5773503
3	0.3779645	0.3872983	0.4472136	0.5
2	0.3086067	0.3162278	0.3651484	0.4082483
1	0.2182179	0.2236068	0.2581989	0.2886751
EV	16.916137	16.916137	17.285403	18.001622
EW	75.371803	75.371803	79.298413	87.534773
EP	0.4761905	0.5	0.6666667	0.8333333
EPR	1.3412248	1.3743465	1.5869586	1.7742737
J	0.05	0.05	0.05	0.05
S	12.033444	11.743439	11.144037	11.864186
L	0.1941457	0.1941457	-0.099931	-0.762173
A	2.8849057	2.8200586	2.3919518	1.8907399
FAI	17.901879	16.777833	10.934816	6.6242681
ACI	8.9509395	8.3889166	5.4674078	3.312134
ln ACI	2.1917585	2.1269114	1.6988046	1.1975927

TOTAL NICKEL
ACUTE CRITERION EQUATIONS:

	CW	WW	LFF	LAL
SLOPE	0.8460	0.8460	0.8460	0.8460
ln ACI	2.1918	2.1269	1.6988	1.1976
		< CW	< CW	< CW
adj. ln ACI	2.2551	2.2551	2.2551	2.2551

mean H + 2SD	268
mean H - 2 SD	14

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

50	184.39
100	331.42
200	595.72
268	763.08

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 nickel (in ug/L as total recoverable):
all classifications: ATC = EXP(0.846 X ln(hardness) + 2.255)
where EXP = e raised to the power of the term in parentheses

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
51	14.77	LC			Chapman, et al. Manuscript
105	123.1	LC			Chapman, et al. Manuscript
205	356.6	LC			Chapman, et al. Manuscript
103.16	86.55				**GEO MEAN** (3 results)

Caddisfly, *Clistoronia magnifica*

HARDNESS (ppm)	VALUE (ug/L)	TYPE OF TEST	NORMALIZED HARDNESS	NORMALIZED VALUE	REFERENCE
54	128.4	LC			Nebeker, et al. 1984
54	128.4				**GEO MEAN** (1 result)

Rainbow trout, *Onchorhynchus mykiss*

HARDNESS (ppm)	VALUE (ug/L)	TYPE OF TEST	NORMALIZED HARDNESS	NORMALIZED VALUE	REFERENCE
53	< 35	ELS			Nebeker, et al. 1985
52	91.15	ELS			Nebeker, et al. 1985
49	240.3	ELS			Nebeker, et al. 1985
51.30	91.52				**GEO MEAN** (3 results)

Fathead minnow, *Pimephales promelas*

HARDNESS (ppm)	VALUE (ug/L)	TYPE OF TEST	NORMALIZED HARDNESS	NORMALIZED VALUE	REFERENCE
210	526.7	LC			Pickering, 1974
44 – 45	217.3	ELS			Lind, et al. Manuscript
96.67	338.31				**GEO MEAN** (3 results)

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 = 51)	1800	14.77	121.9	
(hard. = 104-105)	1920	123.1	15.60	
(hard. = 205-206)	4970	356.6	13.94	29.86
Fathead minnow				
(hard. = 44-45)	5186#	217.3	23.87	
(hard. = 210)	27950*	526.7	53.03	35.58
Mysid	508	92.74	5.48	5.48

- mean of two values (Lind, et al. Manuscript)
* - mean of four values (Pickering, 1974)

The mysid shrimp ratio was used because there were only two freshwater species with ACRs.
FACR:
Coldwater, warmwater, limited forage = Geo. mean of 29.86, 35.58, 5.48 = 17.98
Limited aqu. life = Geo. mean of 29.86 and 5.48 = 12.79

Chronic toxicity criteria for nickel (in ug/L as total recoverable):
CW, WWSF, LFF: CTC = EXP(0.846 X ln(hardness) + 0.0591)
LAL: CTC = EXP(0.846 X ln(hardness) + 0.4004)
where EXP = e raised to the power of the term in parentheses

NOTE: The coldwater equation does not exactly agree with EPA's, equation intercept is 0.0591 instead of 0.0584. EPA's FACR is based on an ACR of 122.4 for the cladoceran test at hardness 51 PPM, but based on the values reported in EPA's criteria document, the ratio calculated out as 121.9 (1800 / 14.77). This reduces the FACR by a small amount and results in a slightly relaxed criterion. The difference is considered to be insignificant (see summary below).

TOTAL RECOVERABLE Ni CTC (in ug/L):

hardness	EPA	CW, WW, LFF	LAL
50	29.01	29.03	40.84
100	52.15	52.19	73.42
200	93.74	93.81	131.96
268	120.08	120.16	169.03