Fact Sheet Date: **March 12, 1998**

NEW YORK STATE
- AQUATIC FACT SHEET -

Ambient Water Quality Values for Protection of Aquatic Life

SUBSTANCE: Nickel, dissolved **CAS REGISTRY NUMBER:** Not Applicable

TYPE:	BASIS:	AMBIENT WATER QUALITY VALUE (µg/L): FRESHWATER	SALTWATER
Chronic	Propagation	*	8.2
Acute	Survival	**	74

REMARKS:

* $(0.997)\ e^{(0.846\ [\ln(\text{ppm hardness})] + 0.0584)}$

** $(0.998)\ e^{(0.846\ [\ln(\text{ppm hardness})] + 2.255)}$

SUMMARY OF INFORMATION

The New York State water quality standards for dissolved nickel are based primarily upon the national ambient water quality criteria for nickel promulgated by the U.S. EPA. For consistency with EPA documents and to clarify the language in this fact sheet, the following conventions are observed: The Fish Propagation standard will be referred to as the "chronic" standard, and is analogous with the EPA's criterion continuous concentration (CCC). The Fish Survival standard will be referred to as the "acute" standard, and is analogous with the EPA's criterion maximum concentration (CMC).

Nickel is a silvery-white metal in the iron-cobalt family. It is hard, malleable, and ductile. In combination, nickel exhibits an oxidation state of +2 almost exclusively. The important soluble salts of nickel are the acetate, chloride, nitrate, sulfate, and the hexaminenickel(II) sulfate. Ammoniacal solutions of the latter compound are used in nickel-electroplating baths (Nebergall et al, 1968). Nickel is one of the most common of the metals occurring in surface waters. Natural sources of nickel include weathering of rocks, inflow of particulate mater, and precipitation. Anthropogenic sources of nickel include the burning of coal and other fossil fuels, and discharges from such industries as electroplating and smelting (U.S. EPA, 1986). This metal normally occurs in surface waters at low concentrations unless present from a source such as liquid wastes from the metal-plating industry. Nickel can be toxic to aquatic life. The tolerance of fish species varies widely and depends upon synergism, species, pH, and other factors (Pickering, 1974). Data from toxicity tests with Daphnia magna, fathead minnows, striped bass, and bluegill sunfish show that nickel toxicity is hardness-dependent (U.S. EPA, 1986). The acute toxicity of nickel to sensitive aquatic species used in the development of water quality standards is summarized in Appendix 1. Similarly, chronic toxicity data is summarized in Appendix 2.

DERIVATION OF VALUES

In 1985, New York State adopted the national water quality criteria for nickel that was promulgated by the EPA in 1980 (DoW, 1984). That water quality standard was applied to the acid-soluble fraction of nickel in surface waters. After considerable study, the EPA determined that the dissolved fraction of metals in surface waters provided the best correlation with toxicity, and adopted the policy that the water quality criteria should be applied to the dissolved fraction (Prothro, 1994). To support that change, the EPA developed conversion factors (CF) for changing criteria and standards derived from total-recoverable metals data to dissolved metal criteria and standards (Federal Register, 1995). Even though the freshwater standard for nickel is hardness-dependent, the conversion factor is not. The freshwater acute standard conversion factor for nickel 0.998; the freshwater chronic standard conversion factor is 0.997. The saltwater conversion factor for dissolved nickel is 0.990 for both the acute and chronic standards.

The U.S. EPA AQUIRE database was reviewed to identify new aquatic toxicity data that may have been added to the literature since the national criteria document for nickel was published in 1985. Only one new study found. Wong, et al (1993) examined the effects of nickel on the feeding behavior and survival of the greasyback shrimp (Metapenaeus ensis), a marine species. This study was not used to revise the nickel water quality standard because the greasyback shrimp is not indigenous to north american waters. Inclusion of this species would only change the resulting saltwater quality standards slightly.

On 23 March 1995, the Federal Register published the Final Water Quality Guidance for the Great Lakes System; Final Rule (Great Lakes Water Quality Inititive, or GLWQI) (FR, 1995). This rule requires Great Lakes states to adopt numeric water quality standards consistent with the GLWQI criteria. The GLWQI published a Tier 1 water quality criterion for nickel, so the GLWQI technical support document (U.S. EPA, 1995) was also reviewed for toxicity data. Additional acute toxicity data for nickel were found, and are listed in Table 1-2 of Appendix 1. The nickel toxicity database used to develop the EPA water quality standard for nickel (U.S. EPA, 1986) and the additional data from the GLWQI (U.S. EPA, 1995) was used to calculate the New York state standard, following the methodology of Stephan et al (1985) and GLWQI Tier 1 methodologies (FR, 1995a). The resulting freshwater standard for the protection of fish survival **before** application of the dissolved nickel conversion factor is $e^{(0.846\,[\ln(\text{ppm hardness})] + 2.255)}$. The numeric calculations for deriving the acute standard are summarized in Appendix 1.

No additional chronic nickel toxicity data was found in the EPA AQUIRE database that could be used to revise the chronic standard for nickel. Similarly, the GLWQI provided no additional chronic toxicity data for nickel (U.S. EPA, 1995). This standard was calculated using the acute:chronic ratio methodology of Stephan et al (1985). The resulting freshwater chronic standard **before** the application of the dissolved nickel conversion factor is $e^{(0.846\,[\ln(\text{ppm hardness})] + 0.0584)}$. The numeric calculations for deriving the chronic standard are summarized in Appendix 2. When the dissolved nickel conversion factor is applied, the resulting freshwater standards for dissolved nickel are:

Fish survival (acute): $(0.998)\, e^{(0.846\,[\ln(\text{ppm hardness})] + 2.255)}$

Fish propagation (chronic): $(0.997)\, e^{(0.846\,[\ln(\text{ppm hardness})] + 0.0584)}$

The freshwater dissolved nickel standards calculated at various levels of hardness are:

Hardness ppm	**Fish Survival**	**Fish Propagation**
25	145 µg/L	16 µg/L
50	260 µg/L	29 µg/L
75	367 µg/L	41 µg/L
100	468 µg/L	52 µg/L
150	660 µg/L	73 µg/L
200	842 µg/L	93 µg/L

In saltwater, nickel toxicity is not hardness dependent. Using the EPA Nickel toxicity database (U.S. EPA, 1986) the acute and chronic saltwater standards were recalculated in accordance with Stephan et al (1985). The acute and chronic saltwater standards **before** the application of the dissolved nickel conversion factor are 74.6 and 8.29 µg/L nickel respectively. The derivation of the saltwater acute standard is described in Appendix 1. The derivation of the saltwater chronic standard is described in Appendix 2. The EPA dissolved nickel conversion factor, 0.990, similarly is not hardness dependent (Federal Register, 1995). When the dissolved nickel conversion factor is applied, the revised saltwater standards for dissolved nickel are:

Fish survival = (0.990) (74.6) = 73.854 ≈ 74 µg/L

Fish propagation = (0.990) (8.29) = 8.207 ≈ 8.2 µg/L

REFERENCES

DoW, 1984. New York Department of Environmental Conservation, Division of Water, Fact Sheet: Surface Water Quality Standard Documentation for Nickel, Dated 26 July 1984.

Federal Register, 1995. Water quality standards; establishment of numeric criteria for priority toxic pollutants; states compliance - revision of metals criteria. Environmental Protection Agency. Federal Register 60(86): 22229-22237, Thursday, May 4, 1995

Federal Register, 1995a. Final Water Quality Guidance fpr the Great Lakes System; Final Rule. Environmental Protection Agency. Federal Register 60(56):15336-15425, Thursday, 23 March 1995.

Nebergall, W.H., Schmidt, F.C., Holtzclaw, H.F. Jr, and Bailar, J.C. Jr., 1968. General Chemistry. D.C. Heath and Company, Lexington, Mass.

Pickering, Q.H., 1974. Chronic toxicity of nickel to the fathead minnow. Journal of the Water Pollution Control Federation 46(4):760-765 April 1974.

Prothro, M.G., 1993. U.S. EPA Memorandum dated 1 October 1993, from Martha G. Prothro, subject: Office of Water Policy and Technical Guidance on Interpretation and Implementation of Aquatic Life Metals Criteria.

Stephan, C.E., Mount, D.I., Hansen, D.J., Gentile, J.H., Chapman, G.A., and W.A. Brungs, 1985. Guidelines for deriving national water quality criteria for the protection of aquatic organisms and their uses. U.S. EPA, Office of Research and Development, Environmental Research Laboratories, Duluth, Minnesota, Narragansett, Rhode Island, Corvallis, Oregon.

U.S. EPA, 1986. Ambient water quality criteria for nickel - 1986. U.S. Environmental Protection Agency, Office of Water Regulations and Standards, Criteria and Standards Division, Washington D.C, 20460, September 1986.

U.S. EPA, 1995. Great Lakes Water Quality Initiative Criteria Documents for the Protection of Aquatic Life in Ambient Water. U.S. Environmental Protection Agency, Office of Water 4301, EPA-820-B-95-004 March, 1995

Wong, C.K., Chu, K.H., Tang, K.W., Tam, T.W., and L.J. Wong, 1993. Effects of chromium, copper, and nickel on survival and feeding behaviour of Metapenaeus ensis larvae and postlarvae. Mar. Environ. Res. 36(2):63-78.

Appendix 1. Numeric derivation of Fish Survival (acute) water quality standard for dissolved nickel in freshwater and saltwater.

A. Freshwater standard derivation

Table 1-1. Representative acute toxicity of nickel to aquatic and marine organisms. All data are taken from Table 1, U.S. EPA (1986).

SPECIES	Freshwater or Marine	HARDNESS mg/L as $CaCO_3$	LC_{50} µg/L	SMAV[1] µg/L	GMAV[1] µg/L
Cladoceran, <u>Daphnia</u> <u>magna</u>	freshwater	45.3 - 206	510 - 4970	1102	1500
Cladoceran, <u>Daphnia</u> <u>pullicaria</u>	freshwater	44 - 48	1813 - 2182	2042	
Rock bass <u>Ambloplites</u> <u>rupestris</u>	freshwater	26	2480	4312	4312
Mayfly <u>Ephemerella</u> <u>subvaria</u>	freshwater	42	4000	4636	4636
Fathead minnow <u>Pimephales</u> <u>promelas</u>	freshwater	20 - 360	5163 - 44500	8062	8062
Mysid <u>Heteromysis</u> <u>formosa</u>	marine	-	151.7	151.7	151.7
Quahog clam (embryo) <u>Mercenaroa</u> <u>mercenaria</u>	marine	-	310	310	310
Mysid (juvenile) <u>Mysidopsis</u> <u>bigelowi</u>	marine	-	634	634	567.5
Mysid (juvenile) <u>Mysidopsis</u> <u>bahia</u>	marine	-	508	508	
Eastern oyster (embryo) <u>Crassostrea</u> <u>virginica</u>	marine	-	1180	1180	1180

[1]SMAV = Species Mean Acute Value, GMAV = Genus Mean Acute Value. See U.S. EPA 1986.

Additional nickel toxicity data was used to derive a Tier 1 water quality criterion for the Great Lakes Water Quality intitive (GLWQI) (U.S. EPA, 1995). This additional data is listed in table T-2. U.S. EPA actually listed three studies for 1st instar midge larvae and three studies for 2nd instar midge larvae. However, Stephan et al (1985) states that when toxicity tests for multiple life stages of the same organism are available, only the most sensitive life stage data should be used in the development of a water quality criterion. For that reason the data on the 2nd instar midge larvae was omitted.

Table 1-2. Additional acute freshwater toxicity data for nickel, from U.S. EPA (1995).

SPECIES	**hardness mg/L as $CaCO_3$**	**LC_{50} µg/L**	**SMAV µg/L**
Snail, Physa gyrina	26	239	416
Amphipod Crangonyx pseudogracilis	50	66,100	66,100
Midge (1st instar) Chironomus riparis	55	72,400	73,208
Midge (1st instar) Chironomus riparis	55	81,300	
Midge (1st instar) Chironomus riparis	55	84,900	

[1]SMAV = Species Mean Acute Value, See U.S. EPA (1986).

The derivation of the Fish Survival, or "acute" standard followed the procedure developed by Stephan et al (1985) for deriving the EPA CMC criterion. Data for Daphnia magna, striped bass, fathead minnows, and bluegill sunfish showed that toxicity was directly related to hardness of the water. The initial step was to determine the pooled slope of the toxicity vs hardness regression, so the LC_{50}s could be adjusted to a common value of hardness. For each species, the acute LC_{50}s and the different hardness concentrations were normalized by dividing them by their geometric mean. A least-squares regression was performed of the $\log_e$ normalized LC_{50}s on the corresponding $\log_e$ normalized values of hardness. The pooled slope value was found by treating all of the normalized data as a single species, and performing the least squares regression of toxicity on hardness with all of the data. The data used for determining the pooled slope is summarized in Table 1-3.

Once the pooled slope was determined, the acute LC_{50} for each species was adjusted to its equivalent at 50 ppm of hardness. This adjusted LC_{50} is the species mean acute value (SMAV) and is found using the formula:

$$\ln SMAV \text{ @ hardness}(Z) = \ln W - V(\ln X - \ln Z)$$

where Z = 50 ppm;
W= Acute LC_{50} µg/L;
X = hardness at which W was measured.;
V = pooled slope.

Table 1-3. Summary of data used to calculate pooled slope.

Species	HARDNESS ppm	LC50 µg/L	NORMALIZED HARDNESS	NORMALIZED LC50	LN NORMALIZED HARDNESS	LN NORMALIZED LC50	SLOPE
Daphnia magna	45.3	510	0.569639	0.312439	-0.562752	-1.163347	1.180991
	51.1	915	0.642573	0.560552	-0.442274	-0.578834	
	51	1800	0.641316	1.102724	-0.444233	0.097784	
	100	2360	1.257482	1.445794	0.229111	0.368659	
	104	1920	1.307781	1.176239	0.268332	0.162322	
	206	4970	2.590413	3.044744	0.951817	1.113417	
Bluegill Sunfish	20	5180	0.388052	0.419226	-0.946615	-0.869345	0.690863
	20	5360	0.388052	0.433794	-0.946615	-0.835186	
	360	39600	6.984943	3.204895	1.943757	1.164679	
	49	21200	0.950728	1.715752	-0.050527	0.539851	
Striped Bass	53	6200	0.698056	0.736316	-0.359457	-0.306096	1.045949
	53	6300	0.724397	0.748192	-0.322415	-0.290096	
	40	3900	0.526834	0.463166	-0.640869	-0.769669	
	285	33000	3.753695	3.919099	1.322741	1.365862	
Fathead Minnow	20	5180	0.186642	0.337163	-1.678563	-1.087189	0.829410
	20	4580	0.186642	0.298110	-1.678563	-1.210293	
	360	42400	3.359555	2.759792	1.211809	1.015155	
	360	44500	3.359555	2.896480	1.211809	1.063496	
	210	27000	1.959470	1.757415	0.672812	0.563844	
	210	32200	1.959470	2.095880	0.672812	0.739974	
	210	28000	1.959470	1.882504	0.672812	0.600211	
	210	25000	1.959470	1.627236	0.672812	0.486883	
	45	5209	0.419944	0.339051	-0.867634	-1.081605	
	44	5163	0.410612	0.336057	-0.890107	-1.090474	
All data							0.845956

For species with several LC_{50}s at different values of hardness, W is the geometric mean of LC_{50}s and X is the geometric mean of hardnesses. For species with a single LC_{50} value at a single value of hardness, W and X are the single values. When there are more than one species in the same genus, the Genus Mean Acute Value is determined by taking the geometric mean of the adjusted SMAVs. Thus Daphnia magna and Daphnia pullcaria were combined; striped bass (Marone saxatilis) and white perch (Marone americana) were combined; and bluegill (Lepomis gibbosus) and pumpkinseed sunfish (Lepomis macrochirus) were combined. Once the SMAV/GMAVs have been determined, they are arranged in order and ranked from lowest to highest i.e., 1 = lowest, 2=next lowest, etc. For each species the cumulative probability P is calculated using the formula:

P = R/N + 1; where R = each species rank, and N = the total number of species. The data used to calculate SMAV/GMAVs and the ranks and cumulative probabilities ares summarized in Table 1-4.

Table 1-4. Summary of data used to calculate species mean acute values (SMAVs) and genus mean acute value (GMAVs).

SPECIES	VALUES FOR X		VALUES FOR W		RANK	P	SMAV/ GMAV µg/L
	HARDNESS PPM	GM HARDNESS PPM	LC50 µg/L	GM LC50 µg/L			
Snail	26		239		1	0.045	416
Daphnia spp		50		1500	2	0.091	1500
Rock bass	26		2480		3	0.136	4312
Mayfly	42		4000		4	0.182	4636
fathead minnow		107		15363	5	0.227	8062
Marone spp		50		8696	6	0.273	8696
Lepomis spp		50		9531	7	0.318	9531
Guppy	20		4450		8	0.364	9661
Carp	54		10500		9	0.409	9838
Eel	54		13000		10	0.455	12181
Snail	50		12768		11	0.500	12768
Amphipod	50		13000		12	0.545	13000
Rainbow trout	33		9415		13	0.591	13381
Worm	50		14100		14	0.636	14100
Damselfly	50		21200		15	0.682	21200
Goldfish	20		9820		16	0.727	21319
Caddisfly	50		30200		17	0.773	30200
Stonefly	40		33500		18	0.818	40460
Killifish	54		46150		19	0.864	43241
Amphipod	50		66100		20	0.909	66100
Midge		55		79355	21	0.955	73208

The procedure then uses the four lowest SMAV/GMAVs to calculate the final acute value (FAV) at hardness = Z using the following equations:

$$S^2 = \frac{\sum ((\ln SMAV)^2) - ((\sum (\ln SMAV))^2 / 4)}{\sum (P) - ((\sum (\sqrt{P}))^2/4)};$$

$$L = (\sum (\ln SMAV) - S (\sum (\sqrt{P}))) /4 \;;$$
$$A = S (\sqrt{0.05}) + L \;;$$
$$FAV\ (@\ hardness = 50) = e^{A}.$$

Stephan et al (1985) provides a BASIC computer program for calculating FAV. Using that program and the data presented above, the nickel FAV = 522. The FAV is then divided by 2. The final acute equation can then be written as:

$e^{(V [\ln (hardness)] + \ln A - V (\ln Z))}$, where V = the pooled slope,;
A = (FAV @ hardness = Z) / 2
Z = 50

Using the data above:

$$e^{(0.846 [\ln (hardness, ppm)] + \ln (522 /2) - 0.846 (\ln 50))} =$$
$$e^{(0.846 [\ln (hardness, ppm)] + 5.565 - 0.846 (3.912))} =$$
$$e^{(0.846 [\ln (hardness, ppm)] + 2.255)}$$

The saltwater acute standard is calculated in the same manner. However, the data show that nickel toxicity in saltwater is not hardness dependent, so a pooled slope does not have to be calculated, and the acute toxicity values do not have to be adjusted to a common value of hardness. The ranks and cumulative probabilities are listed in Table 1-5.

Table 1-5. Acute toxicity data used to calculate the saltwater nickel water quality standard. Data from tables 1 and 3, U.S. EPA (1986).

SPECIES	SMAV/GMAV µg/L	RANK	P
Mysid, Heteromysis formosa	151.7	1	0.048
Quahog clam	310	2	0.095
Mysid, Mysidopsis spp	567.5	3	0.143
Eastern oyster	1180	4	0.190
Copepod, Acartia clausi	3466	5	0.238
Copepod, Nitocra spinipes	6000	6	0.286
Copepod, Eurytemora affinis	11240	7	0.333
Amphipod	18950	8	0.381
Polycheate worm, Ctenodrilus serratus	17000	9	0.429
Silversides, Menidia spp	17390	10	0.476
Striped bass	21000	11	0.524
Polychaete worm, Nereis spp	35000	12	0.571
Hermit crab	47000	13	0.619
Polychaete worm, Capitella capitata	50000	14	0.667
Spot	70000	15	0.714
Mud snail	72000	16	0.762
mummichog	149900	17	0.810
Starfish	150000	18	0.857
Clam	294500	19	0.905
Soft-shell clam	320000	20	0.952

When these values are input to the FAV computer program described by Stephan et al (1985) or analyzed using the formulas listed above, the resultant FAV is 149.155 ≈ 149.2. This value is divided by two in order to obtain the Fish Survival Standard before application of the dissolved nickel conversion factor of 74.6 µg/L. When the dissolved nickel conversion factor is applied, the final dissolved nickel saltwater standard for the protection of Fish Survival is:

$$(0.990)\ (74.6) = 73.854 \approx 73.9\ \mu g/L$$

The FR (1995a) requires that states adopt numeric criteria at least as stringent as the

GLWQI crtieria, and that the methodologies be consistent with the GLWQI Tier 1 methodologies. For nickel, the final freshwater criteria derived in this fact sheet are identical to the GLWQI Tier 1 water quality criterion for nickel. The method of derivation is identical, as both the GLWQI and New York State follow the Stephan et al (1985) methodology (6NYCRR Part 702.10(b)(1)). However, there was an important difference in the derivation of the nickel standard by New York and the Tier 1 nickel criterion by the GLWQI. When deriving SMAVs and GMAVs, the GLWQI chose to omit data from static toxicity tests when data from both static and flowthrough toxicity tests were available (U.S. EPA, 1995). This resulted in a different SMAV for fathead minnows and a different GMAV for Lepomis spp (bluegill SMAV). The omission of the static toxicity data is presumbably based upon the assumption that since the toxicant concentration was not refreshed during the test, and that metallic ions are easily bound to dissolved or suspended material in the test water, the concentration of bioavailable nickel in the water may have decreased over the 96 hours of the test period. This would result in nickel appearing to be less toxic than the tests actually indicated, because toxicity would have occurred at lower concentrations than were thought to be present. However, the data suggest otherwise. U.S. EPA (1986) included two static toxicity tests for fathead minnows conducted with a water hardness of 210 ppm, and two flowthrough toxicity tests for fathead minnows conducted with a water hardness of 210 ppm. If the assumption stated above was correct, the mean of the LC_{50}s in the static tests should be higher than the mean of the LC_{50}s in the flowthrough tests. Instead, a one-way analysis of variance shows no difference in the means of the static vs flowthrough LC_{50}s. The lack of a difference between the means is evidence that the static test data should not be arbitrarily omitted.

Furthermore, the U.S. EPA (1995) was not consistent in omitting static toxicity test data. The same static test data that was omitted in deriving SMAVs was used in deriving the pooled slope. If the static test data was omitted from the derivation of the pooled slope, three of four bluegill tests and six of ten fathead minnow tests would have to be omitted from the pooled slope calculation. If so, the resulting pooled slope would be 1.091 instead of 0.846. Finally, toxicity data from both static and flow through tests are combined throughout the criteria derivation process. It is scientifically indefensible to selectively not use static toxicity data unless all static test toxicity data is omitted, particularly when the data show that there is no difference in the results of the static vs the flowthrough tests (fathead minnow data described above). The omission of static test data, and the different SMAV/GMAVs for the fathead minnow and lepomis spp. did not affect the standard derivation in the case of nickel because the Stephan et al (1985) methodology only uses the four lowest SMAV/GMAVs to derive the final acute value. This variance is noted here because the ranked SMAV/GMAVs in U.S. EPA (1985) will not match the corresponding list in Table 1-4 of this Fact Sheet.

Appendix 2. Numeric derivation of Fish Propagation (chronic) water quality standard for dissolved nickel.

Table 2-1. Chronic toxicity of nickel to aquatic and marine organisms. All entries taken from Tables 1, 2 and 3, U.S. EPA (1985).

SPECIES	**Freshwater or Marine**	**Acute value µg/L**	**NOEL - LOEL µg/L**	**Chronic value; µg/L**	**Acute: Chronic ratio**
Cladoceran, Daphnia magna	freshwater	1800	10.2 - 21.4	14.77	122.4
Cladoceran, Daphnia magna	freshwater	1920	101 - 150	123.1	15.6
Cladoceran, Daphnia magna	freshwater	4970	220 - 578	356.6	13.94
Fathead minnow	freshwater	27930	380 - 730	523.7	53.03
Fathead minnow	freshwater	5186	108.9 -433.5	217.3	23.87
Mysid, Mysidopsis bahia	saltwater	508	61 - 141	92.74	5.478

The Fish Propagation, or "chronic" standard, can be computed in the same manner as the acute standard if enough adequate data is available. With nickel, there was not enough data to perform that calculation, so an alternative method was employed; the acute:chronic ratio method (Stephan et al, 1985).

The acute:chronic ratio method can only be used when studies are available that measured both acute and chronic toxicity with the same species at the same time. Several such studies of nickel toxicity were identified by the US EPA (US EPA, 1986). In Table 2-1 above, column 4 lists the NOEL and the LOEL for chronic toxicity tests. Column 5, the Chronic Value, is the geometric mean of the NOEL and LOEL. Column 3 shows the acute LC_{50} determined in the same study, and column 6 shows the ratio of acute toxicity to chronic toxicity. When more than one acute:chronic ratio for a species was calculated, the final acute:chronic ratio is the geometric mean of all of the acute:chronic ratios for that species:

Final acute:chronic ratio, Daphnia magna = (122.4) (15.60) (13.94) = 26617.594; $\sqrt[3]{26617.594}$ = 29.86; Final acute:chronic ratio, fathead minnows = (53.03) (23.87) = 1265.826; $\sqrt{1265.826}$ = 35.58; The final acute:chronic ratio is the geometric mean of all acute:chronic ratios for both freshwater and saltwater alike:

$$(29.86)\ (35.58)\ (5.478) = 5819.93;\quad \sqrt[3]{5819.93} = 17.99$$

Since nickel toxicity is hardness dependent, a final chronic equation must be derived. The slope of the equation is the same pooled slope found using the acute data (Appendix 1). The $\log_e$ final chronic intercept (FCI) of the final chronic equation is found by dividing the final acute value from Appendix 1 at a given value of 50 ppm hardness by the final acute:chronic ratio, and applying that result, FCI, to the formula:

$$\ln \text{(Final Chronic Intercept)} = \ln \text{(FCI)} - [\text{pooled slope} \times \ln (50)]$$

$$\ln \text{(Final Chronic Intercept)} = \ln (522 / 17.99) - [(0.846)\ (3.912)]$$

$$\ln \text{(Final Chronic Intercept)} = 3.367985 - 3.309571 = 0.058414$$

This results in the freshwater chronic water quality standard before the application of the dissolved nickel conversion factor of:

$$e^{(0.846 [\ln \text{(ppm hardness)}] - 0.0584)}$$

When the dissolved nickel conversion factor is applied, the resulting dissolved nickel freshwater quality standard for the protection of Fish Propagation is:

$$(0.997)\ e^{(0.846 [\ln \text{(ppm hardness)}] - 0.0584)}\ \mu g/L$$

In saltwater, nickel toxicity is not hardness dependent. The final saltwater acute value is divided by the final acute:chronic ratio to obtain the saltwater chronic standard:

$$149.2 / 17.99 = 8.293\ \mu g/L$$

When the dissolved nickel conversion factor is applied, the dissolved nickel water quality standard for the protection of Fish Propagation in saltwater is:

$$(0.990)\ (8.293) = 8.211 \approx 8.2\ \mu g/L$$

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