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

NEW YORK STATE
- AQUATIC FACT SHEET -

Ambient Water Quality Values
for Protection of Aquatic Life

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

TYPE:	**BASIS:**	**AMBIENT WATER QUALITY VALUE (µg/L):**	
		FRESHWATER	**SALTWATER**
Chronic	Propagation	*	8
Acute	Survival	**	204

REMARKS:

* $(CF)\, e^{(1.273[\ln(\text{ppm hardness})] - 4.297)}$

** $(CF)\, e^{(1.273[\ln(\text{ppm hardness})] - 1.052)}$

$CF = 1.46203 - [\ln(\text{ppm hardness})\ (0.145712)]$

SUMMARY OF INFORMATION

The New York State water quality standards for dissolved lead are based primarily upon the national ambient water quality criteria for lead 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).

Elemental lead is a bluish-grey, soft metal. Lead is sparingly soluble in hard basic waters to 30 µg/L, and up to 500 µg/L in soft, acidic waters. In surface waters, lead occurs in three forms: a dissolved labile form such as Pb^{2+}, PbOH, or $PbCO_3$; a dissolved bound form such as colloids or strong complexes; and particulate form (Eisler, 1988). The toxicity of lead to aquatic life is strongly correlated with the concentration of dissolved labile lead (Demayo, 1982). Lead is neither essential nor beneficial to living organisms, and all existing data show that its metabolic effects are adverse (Eisler, 1988). In acute toxicity tests, lead was found to be more toxic to Daphnia magna, rainbow trout, fathead minnow, and bluegill in soft water than hard water (U.S. EPA, 1985). The acute toxicity of lead 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.

Inorganic lead does not biomagnify in aquatic food chains; instead, concentrations in biota appear to be related to surface-to-volume ratios with planktonic organisms having the highest concentrations (Demayo, 1982; Eisler, 1988). Among aquatic biota, Pb concentrations are usually highest in algae and benthic organisms, and lowest in upper trophic level predators. Lead concentrations in aquatic vertebrates tend to increase with increasing age of the organism, and to localize in hard tissues such as bone and teeth (Eisler, 1988). Median bioconcentration factors (BCFs) for aquatic organisms exposed to Pb^{2+} for 14 - 140 days, as reported by Eisler (1988), ranged from 42 in fish to 2,570 in mussels; 536 for oysters; 500 for insects; 725 for algae; and 1,700 for snails.

DERIVATION OF VALUES

In 1985, New York adopted the national water quality criteria for lead (Federal Register, 1985) as the state standard. The water quality standard was applied to the acid-soluble fraction of lead 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 (Davies, 1994). To support that change, the EPA developed conversion factors (CF) for changing criteria and standards derived from total-recoverable metals data to dissolved metals criteria and standards (Federal Register, 1995). The conversion factor for dissolved lead in freshwater is dependent on water hardness, and is determined using the formula:

$$\text{Dissolved Lead CF} = 1.46203-[\ln(\text{ppm hardness})\ (0.145712)]$$

The same conversion factor is applicable to both acute and chronic toxicity data. For hardnesses of 25, 100, 175, and 250 ppm, the dissolved lead conversion factors would be 0.993, 0.791, 0.709, and 0.657 respectively.

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 lead was published in 1985. Only one new study found. Coughlan et al (1986) examined the toxicity of lead to smallmouth bass eggs, sac fry, swim-up fry, and fingerlings. Swim-up fry were the most sensitive stage, with a 96 hour LC_{50} of 2,800 µg/L. This value was integrated into the existing EPA lead water quality database, and lead water quality standards are calculated in accordance with Stephan et al (1985). The resulting freshwater standard for the protection of fish survival **before** application of the dissolved lead conversion factor is $e^{(1.273[\ln(\text{ppm hardness})]-1.052)}$. The numeric calculations for deriving the acute standard are summarized in Appendix 1.

No additional chronic lead toxicity data were found in the EPA AQUIRE database that could be used to revise the chronic standard for lead. This standard was calculated using the acute:chronic ratio methodology of Stephan et al (1985). The inclusion of the Coughlan et al (1986) acute toxicity data effects the calculation of the chronic standard, because the acute:chronic ratio method uses the acute standard to derive the chronic standard. The resulting freshwater chronic standard **before** the application of the dissolved lead conversion factor is $e^{(1.273[\ln(\text{ppm hardness})]-4.297)}$. The numeric calculations for deriving the chronic standard are summarized in Appendix 2. When the dissolved lead correction factor is applied, the resulting freshwater standards for dissolved lead are:

Fish survival (acute):

$$(1.46203-[(\ln \text{ ppm hardness})(0.145712)])\ e^{(1.273[\ln(\text{ppm hardness})]-1.052)}$$

Fish propagation (chronic):

$$(1.46203-[(\ln \text{ ppm hardness})(0.145712)])\ e^{(1.273[\ln(\text{ppm hardness})]-4.297)}$$

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

Hardness ppm	**CF**	**Fish Survival**	**Fish Propagation**
25	0.993	20.9 µg/L	0.8 µg/L
50	0.892	45.3 µg/L	1.8 µg/L
100	0.791	97.1 µg/L	3.8 µg/L

In saltwater, lead toxicity is not hardness dependent. The EPA originally promulgated acute and chronic saltwater criteria for lead of 140 and 5.6 µg/L respectively. However, an error was found that the acute toxicity data for the mummichog (Fundulus heteroclitus) (Federal Register, 1992). Fundulus heteroclitus was deleted from the database and 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 lead conversion factor are 214.73 and 8.37 µg/L lead 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 lead conversion factor, 0.951, similarly is not hardness dependent (Federal Register, 1995). When the dissolved lead conversion factor is applied, the revised saltwater standards for dissolved lead are:

Fish survival = (0.951) (214.73) = 204.2 ≈ 204 µg/L

Fish propagation = (0.951) (8.37) = 7.96 ≈ 8 µg/lL

REFERENCES

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Federal Register, 1985.Water quality criteria: availability of documents. Environmental Protection Agency. Federal Register, 50(145):30784-30796, Monday, 29 July 1985.

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Stephan, C.E., 1994. Results of simulation tests concerning the percent dissolved metal in freshwater toxicity tests (Draft - 8/22/94). Environmental Research Laboratory - Duluth, Office of Research and Development, U.S. Environmental Protection Agency, Duluth, Minnesota, 55804.

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

A. Freshwater standard derivation

Table 1-1. Acute toxicity of lead to aquatic and marine organisms. All data are taken from Table 1, U.S. EPA (1985).

SPECIES	Freshwater or Marine	HARDNESS mg/L as $CaCO_3$	LC_{50} µg/L	SMAV[1] µg/L
Amphipod, Gammarus pseudolimnaeus	freshwater	46-48	124-140	142.6
Cladoceran, Daphnia magna	freshwater	54-152	612-1910	447.8
Smallmouth bass Micropterus dolomieui	freshwater	152	2800	680
Snail, Aplexa hypnorum	freshwater	61	1340	1040
Rainbow trout, Salmo gairdneri	freshwater	28 - 353	1170 - 542000	2448
Fathead minnow, Pimephales promelas	freshwater	20 - 360	5580 - 482000	25440
Blue mussel (larvae) Mytilus edulis	marine	-	476	476
Amphipod, Ampelisca abdita	marine	-	547	547
Dungeness crab, Cancer magister	marine	-	575	575
Copepod, Acartia clausi	marine	-	668	668

[1]SMAV = Species Mean Acute Value, see U.S. EPA (1985).

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, rainbow trout, fathead minnows, and bluegill sunfish showed that toxicity was directly related to hardness of the water. The initial step, then, was to determine the pooled slope for these data. 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 normalized slopes for each individual species were all approximately close to 1 except for the rainbow trout, so the rainbow trout data was not included in the calculation of the pooled slope. The data used for determining the pooled slope is summarized in Table 1-2.

Table 1-2. 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	54	612	0.558707	0.590578	-0.582131	-0.526653	
	110	952	1.138106	0.918677	0.129365	-0.084820	1.021
	152	1910	1.572655	1.843145	0.452766	0.611473	
Rainbow trout	290	542000	2.041524	8.106006	0.713696	2.092605	
	353	471000	2.485027	7.044149	0.910284	1.952197	2.475
	28	1171	0.197113	0.052513	-1.623980	-4.044803	
Fathead minnow	20	5580	0.381571	0.206557	-0.963457	-1.577181	
	20	7330	0.381571	0.271337	-0.963457	-1.304394	1.495
	360	482000	6.868285	17.842346	1.926915	2.881575	
Bluegill sunfish	20	23800	0.235702	0.232048	-1.445186	-1.460812	1.011
	360	442000	4.242641	4.309458	1.445186	1.460812	
All data w/rainbow trout							1.608
All data w/o rainbow trout							1.273

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.

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. Once the SMAVs 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 no. of species.

The data used to calculate SMAVs and the ranks and cumulative probabilities are summarized in Table 1-3.

Table 1-3. Summary of data used to calculate species mean acute values (SMAVs).

SPECIES	VALUES FOR X		VALUES FOR W		RANK	P	SMAV µg/L
	HARDNESS ppm	GM HARDNESS ppm	LC50 µg/L	GM LC50 µg/L			
Amphipod		46.99		131.76	1	0.08	142.6
Daphnia magna		96.7		1036.3	2	0.17	447.8
Smallmouth bass	152		2800		3	0.25	680
Snail	61		1340		4	0.33	1040
Rainbow trout	28		1170		5	0.42	2448
Brook trout	44		4100		6	0.50	4824
Fathead minnow		52.4		27014.8	7	0.58	25439
Bluegill sunfish		84.9		102565	8	0.67	52310
Guppy		20	20600		9	0.75	66152
Goldfish	20		31500		10	0.83	101129
Midge	48		22400		11	0.92	235941

Stephan et al (1985) uses genus mean acute values (GMAVs). The GMAV is the geometric mean of SMAVs for species within the same genus. Since none of the species in the lead data set are from the same genus, the SMAV can be used instead of GMAVs. The procedure then uses the four lowest SMAVs to calculate the final acute value 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 lead FAV = 101.5669. The FAV is then divided by 2. The final acute equation can then be written as:

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

Using the data above:

$$e^{(1.273 [\ln (ppm\ hardness)] + (\ln 101.5669) /2 - 1.273 (\ln 50))} =$$

$$e^{(1.273 [\ln (ppm\ hardness)] + 3.9276 - 1.273 (3.912))} =$$

$$e^{(1.273 [\ln (ppm\ hardness)] - 1.052)}$$

The saltwater acute standard is calculated in the same manner. However, the data show that lead 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. Because all of the test species were from different genera, acute toxicity values could be converted to species mean acute values (SMAVs) and genus mean acute values (GMAVs) did not have to be calculated. The EPA database for saltwater lead toxicity contained 10 records. However the data for the mummichog was deleted because of an error (US EPA, 1992), so the total number of records is 9. The ranks and cumulative probabilities are listed in Table 1-4.

Table 1-4. Acute toxicity data used to calculate the saltwater lead water quality standard.

SPECIES	**SMAV µg/L**	**RANK**	**P**
Blue mussel larvae	476	1	0.1
Ampelisca abdita (amphipod)	547	2	0.2
Dungeness crab	575	3	0.3
Acartia clausi	668	4	0.4
Pacific oyster larvae	758	5	0.5
Quahog clam larvae	780	6	0.6
Eastern oyster larvae	2450	7	0.7
Mysid shrimp	3130	8	0.8
Soft-shell clam (adult)	27000	9	0.9

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 429.4666. This value is divided by two in order to obtain the Fish Survival Standard before application of the dissolved lead conversion factor of 214.7333. The EPA determined criterion maximum concentration (CMC), which is the EPA name for the Fish Survival standard, to be 217.16 (U.S. EPA, 1995). This value is in error. When the EPA deleted the mummichog data from the database, they failed to change the total number of records. In their calculation, they set N = 10 instead of 9, which resulted in the slightly higher value.

When the dissolved lead correction factor is applied, the final dissolved lead saltwater standard for the protection of Fish Survival is:

$$(0.951)\ (214.7333) = 204.2 \approx 204\ \mu g/L$$

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

Table 2-1. Chronic toxicity of lead to aquatic and marine organisms. All entries taken from Tables 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**
Brook trout, Salvelinus fontinalis	freshwater	4100	58 - 119	83.08	49.35
Rainbow trout, Salmo gairdneri	freshwater	1170	13.2 - 27	18.88	61.97
Cladoceran, Daphnia magna	freshwater	612 952 1910	9 - 16.7; 78 - 181; 85 - 193	12.26; 118.8; 128.1	49.92 8.01 14.91 GM = 18.13
Mysid, Mysidopsis bahia	marine	3130	17 - 37	25.08	124.8

The Fish Propagation, or "chronic" standard, can be computed in the same manner as the acute standard if enough adequate data is available. With lead, 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 lead toxicity were identified by the US EPA (US EPA, 1985). 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.

The final acute:chronic ratio is the geometric mean of all acute:chronic ratios for both freshwater and saltwater alike:

$$(49.35)\ (61.97)\ (18.13)\ (124.8) = 6{,}919{,}600.838$$

$$(6{,}919{,}600.838)^{0.25} = 51.29$$

Since lead 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 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, the Final Chronic Value (FCV), to the formula:

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

$$\ln\ (\text{Final Chronic Intercept}) = \ln\ (101.5669/51.29) - (1.273)\ (3.912)$$

$$\ln\ (\text{Final Chronic Intercept}) = \ln\ (1.9802) - 4.98$$

$$\ln\ (\text{Final Chronic Intercept}) = 0.6832 - 4.98 = -\ 4.297$$

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

$$e^{(1.273\ [\ln\ (\text{ppm hardness})\ ]\ -\ 4.297)}$$

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

$$(1.46203 - [\ln(\text{ppm hardness})(0.145712)])\ e^{(1.273\ [\ln\ (\text{ppm hardness})]\ -\ 4.297)}\ \mu\text{g/L}$$

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

$$429.4666 \div 51.29 = 8.37$$

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

$$(0.951)\ (8.37) = 7.96 \approx 8\ \mu\text{g/L}$$

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