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Ambient Water Quality Criteria for Chloride—1988

AMBIENT AQUATIC LIFE WATER QUALITY CRITERIA FOR

CHLORIDE

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NOTICES

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FOREWORD

Section 304(a)(1) of the Clean Water Act of 1977 (P.L. 95-217) requires the Administrator of the Environmental Protection Agency to publish water quality criteria that accurately reflect the latest scientific knowledge on the kind and extent of all identifiable effects on health and welfare that might be expected from the presence of pollutants in any body of water, including ground water. This document is a revision of proposed criteria based upon consideration of comments received from other Federal agencies, State agencies, special interest groups, and individual scientists. Criteria contained in this document replace any previously published EPA aquatic life criteria for the same pollutant(s).

The term "water quality criteria" is used in two sections of the Clean Water Act, section 304(a)(1) and section 303(c)(2). The term has a different program impact in each section. In section 304, the term represents a non-regulatory, scientific assessment of ecological effects. Criteria presented in this document are such scientific assessments. If water quality criteria associated with specific stream uses are adopted by a State as water quality standards under section 303, they become enforceable maximum acceptable pollutant concentrations in ambient waters within that State. Water quality criteria adopted in State water quality standards could have the same numerical values as criteria developed under section 304. However, in many situations States might want to adjust water quality criteria developed under section 304 to reflect local environmental conditions and human exposure patterns before incorporation into water quality standards. It is not until their adoption as part of State water quality standards that criteria become regulatory.

Guidance to assist States in the modification of criteria presented in this document, in the development of water quality standards, and in other water-related programs of this Agency has been developed by EPA.

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Introduction

The major anthropogenic sources of chloride in surface waters are deicing salt, urban and agricultural runoff, and discharges from municipal wastewater plants, industrial plants, and the drilling of oil and gas wells (Birge et al. 1985; Dickman and Gochnauer 1978; Sonzogni et al. 1983). Beeton (1965) reported that concentrations of chloride had been rising in Lake Erie, Lake Ontario, and Lake Michigan since the early 1900s, and in Lake Huron since the 1950s, but Sonzogni et al. (1983) stated that the rate of change of chloride inputs to the Great Lakes had stabilized or decreased.

Chloride has long received special attention from researchers interested in fish. In 1937, Ellis discussed the concept that "fresh-water fish tolerate an osmotic pressure of the external medium equal to that of their own blood if the various salts and substances in the water are balanced against each other so as to exclude the specific toxic effects" and presented supporting data. Chloride has been used as a nutrient and prophylactic for fish (Hinton and Eversole 1979; Phillips 1944). It has also been suggested for use as a reference toxicant (Adelman and Smith 1976a,b; Threader and Houston 1983).

Because anthropogenic sources of chloride are unlikely to pose a threat to saltwater species, this document concerns effects on only freshwater species. Unless otherwise noted, all concentrations of chloride in water reported herein from toxicity and bioconcentration tests are expected to be essentially equivalent to dissolved chloride concentrations. All concentrations are expressed as chloride, not as the chemical tested. An understanding of the "Guidelines for Deriving Numerical National Water Quality Criteria for the Protection of Aquatic Organisms and Their Uses" (Stephan et al. 1985), hereinafter referred to as the Guidelines, and the response to public comment (U.S. EPA 1985a) is necessary in order to understand the following text, tables, and calculations. Results of such intermediate calculations as recalculated LC50s and Species Mean Acute Values are given to four significant figures to prevent roundoff errors in subsequent calculations, not to reflect the precision of the value. The latest comprehensive literature search for information for this document was conducted in August 1985; some more recent information was included.

Acute Toxicity to Aquatic Animals

Data that may be used, according to the Guidelines, in the derivation of a freshwater Final Acute Value for chloride are presented in Table 1. When compared on the basis of mg of chloride/L, the chlorides of potassium, calcium, and magnesium are generally more acutely toxic to aquatic animals than sodium chloride (Biesinger and Christensen 1972; Dowden 1961; Dowden and Bennett 1965; Hamilton et al. 1975; Patrick et al. 1968; Trama 1954). Only for sodium chloride, however, are enough data available to allow derivation of a water quality criterion. In addition, it seems likely that most anthropogenic chloride in ambient water is associated with sodium, rather than potassium, calcium, or magnesium (Dickman and Gochnauer 1978; Sonzogni et al. 1983).

Results listed in Table 1 from Dowden and Bennett (1965), Hamilton et al. (1975), and Kostecki and Jones (1983) were obtained from 24- and 48-hr tests, rather than the 96-hr tests specified in the Guidelines. Use of such results is considered acceptable for chloride because the acute values changed little from 24 to 48 or 96 hours, depending on the species, in acute toxicity tests on chloride. For example, ratios of 24-hr and 48-hr LC50s for sodium chloride with a midge and a daphnid were 0.91 and 0.81, respectively (Dowden and Bennett 1965; Thornton and Sauer 1972). Reed and Evans (1981) obtained a ratio of 1.0 for 24-hr and 14-day LC50s determined with the channel catfish, bluegill, and largemouth bass (Table 5). Adelman and Smith (1976a,b) and Adelman et al. (1976) obtained ratios of 24- and 96-hr LC50s of 0.74 and 0.97 with goldfish and fathead minnows, respectively, in tests in which the fish were fed (Table 5).

Adult fingernail clams were more sensitive than juveniles (Anderson 1977), but for the American eel (Hinton and Eversole 1978) and the bluegill (Cairns and Scheier 1959) smaller organisms were slightly more sensitive than larger ones. No pronounced relationships have been observed between the acute toxicity of chloride to freshwater animals and hardness, alkalinity, or pH.

Species Mean Acute Values (Table 1) were calculated as geometric means of the acute values from tests on sodium chloride, and then Genus Mean Acute Values (Table 3) were calculated as geometric means of the Species Mean Acute Values. Of the twelve genera for which acute values are available, the most sensitive genus, Daphnia, was only 6 times more sensitive than the most resistant, Anguilla. Invertebrates were generally more sensitive than vertebrates. The Final Acute Value for chloride was calculated to be 1,720 mg/L using the procedure described in the Guidelines and the Genus Mean Acute Values in Table 3. The acute value for Daphnia pulex is lower than the Final Acute Value.

Chronic Toxicity to Aquatic Animals

The available data that are usable according to the Guidelines concerning the chronic toxicity of chloride are presented in Table 2. In the life-cycle test with Daphnia pulex, survival was as good as in the control treatment at chloride concentrations up to 625 mg/L (Birge et al. 1985). At 314 mg/L, reproduction was as good as in the control, but at 441 and 625 mg/L, reproduction was reduced by 27 and 39%, respectively. Thus, the chronic limits are 314 and 441 mg/L, the chronic value is 372.1 mg/L, and the acute-chronic ratio is 3.951.

In an early life-stage test with rainbow trout, a chloride concentration of 2,740 mg/L killed all the exposed organisms (Spehar 1987). Survival was 54% at 1,324 mg/L, but was 97% or higher at 643 mg/L and at two lower concentrations and in the control treatment. The mean weights of the fish alive at the end of the test at 1,324 mg/L and the lower tested concentrations were within 5% of the mean weight of the fish in the control treatment. The chronic value and the acute-chronic ratio obtained with the rainbow trout were 922.7 mg/L and 7.308, respectively.

In an early life-stage test with the fathead minnow, Pimephales promelas, Birge et al. (1985) found that weight was as good as in the control treatment up to a chloride concentration of 533 mg/L. Survival was reduced 9% by a concentration of 352 mg/L and was reduced 15% by 533 mg/L. The chronic value is 433.1 mg/L, and the acute-chronic ratio is 15.17.

The three acute-chronic ratios available for chloride are 7.308, 15.17, and 3.951 (Table 3). The geometric mean of these three is 7.594, which is used as the Final Acute-Chronic Ratio. Division of the Final Acute Value by the Final Acute-Chronic Ratio results in a Final Chronic Value of 226.5 mg/L, which is substantially lower than all three chronic values in Table 2.

Toxicity to Aquatic Plants

Data on the toxicity of chloride to aquatic plants show a wide range of sensitivities (Table 4). The alga, Spirogyra setiformis, was extremely sensitive to the effects of chloride; inhibition of growth, chlorophyll, and fixation of ^{14}C occurred at 71 mg/L (Shitole and Joshi 1984). Growth of

Netrium digitus was affected at 200 mg/L, but the other sixteen tested species were affected by concentrations ranging from 642 to 36,400 mg/L. A Final Plant Value, as defined in the Guidelines, cannot be obtained because no test in which the concentrations of chloride were measured and the endpoint was biologically important has been conducted with an important aquatic plant species.

Eyster (1962) reported that a concentration of 0.18 mg/L stimulated the growth of many algae, and Sonzogni et al. (1983) discussed the possibility that concentrations above 10 mg/L might shift phytoplankton communities toward nuisance, taste-and-odor-causing blue-green algae. When chloride was added to a small stream at a concentration of 610 mg/L, the algal density decreased whereas the bacterial density increased.

Although most of the data on toxicity of chloride to freshwater plants has been obtained with sodium chloride, some evidence indicates that a similar cation-anion toxicity relationship exists for both aquatic plants and animals. Patrick et al. (1968) demonstrated that potassium chloride was 2.3 times more toxic to a diatom than sodium chloride (Table 4), although calcium chloride was 1.3 times less toxic than sodium chloride. Tuchman and Stoermer (Manuscript a,b) found that potassium chloride had a greater inhibitory effect on algal population dynamics and nutrient uptake than sodium chloride.

Bioaccumulation

No data that are usable according to the Guidelines are available concerning the accumulation of chloride by freshwater species.

Other Data

Additional data on the lethal and sublethal effects of chloride on freshwater species are presented in Table 5. Anderson (1944,1948) and

Biesinger and Christensen (1972) found the same cation-anion toxicity relationship that is apparent in Table 1. Sreenivasan et al. (1979) reported that the rotifer, Brachionus rubens, tolerates chloride up to at least 1,400 mg/L. Wallen et al. (1957) reported that magnesium chloride was less toxic to the mosquitofish than sodium chloride; however, these tests were conducted in very turbid water and therefore the results might be atypical. A concentration of 13% sodium chloride in the diet of trout caused no ill effects, whereas 25 mg in gelatin capsules caused edema and death of brook trout (Phillips 1944). Food consisting of 12% sodium chloride did not affect growth of Atlantic salmon (Shaw et al. 1975). Hasan and Macintosh (1986) and Tomasso et al. (1980) reported that chloride reduced the acute toxicity of nitrite to fish.

Unused Data

Some data concerning the effects of chloride on aquatic organisms and their uses were not used because the tests were conducted with species that are not resident in North America (e.g., Coetzee and Hattingh 1977; Das and Srivastava 1978; Ferri and Sesso 1982; Katz and Ben-Sasson 1984; Meech and Thomas 1980; Schiewer 1974,1984; Stangenberg 1975; Vaidya and Nagabhushanam 1979). Jennings (1976) compiled data from other sources. Data were not used when chloride was a component of an effluent (Birge et al. 1985). Reports by Batterton et al. (1972), Hosiaisluoma (1976), and Palmer and Maloney (1955) provided no usable data on the toxicity of chloride. Arnold (1974), Davis et al. (1972), and Edmister and Gray (1948) did not adequately describe their test procedures or results or both.

Results of some laboratory tests were not used because the tests were conducted in distilled or deionized water without addition of appropriate salts (e.g., Kardatzke 1980,1981; Lee 1973; Mahajan et al. 1979; Pappas and Pappas 1983; Stamper 1969; Thornton and Wilhm 1974,1975; Zaim and Newson 1979) or were conducted in chlorinated or "tap" water (e.g., Kumar and Srivastava 1981). Christensen (1971/72) and Christensen and Tucker (1976) exposed plasma or enzymes. Length of exposure was not reported by Batterton and Van Baalen (1971). High control mortalities occurred in tests reported by Lewis (1971). Tests conducted without controls (e.g., Vosjan and Siezen 1968) or with too few test organisms (e.g., Leblanc and Surprenant 1984) were also not used. Hughes (1968,1973) did not adequately acclimate the test organisms. Ten-day LC50s (Threader and Houston 1983) were not used because the fish had not been fed during the tests.

Many studies were not used because they addressed the metabolism, regulation, or transport, rather than toxicity, of chloride (e.g., Carrasquer et al. 1983; Castille and Lawrence 1981; De Renzis and Maetz 1973; Greenway and Setter 1979a,b; Hinkle et al. 1971; Konovalov 1984; McCormick and Naiman 1984; Ooshima and Oguri 1974; Perry et al. 1984; Shomer-Ilan and Waisel 1976; Sullivan et al. 1981; Ticku and Olsen 1977). Some references were not used because they were foreign-language reports for which no translation was available and no useful data could be obtained from the English abstracts (e.g., Frahm 1975; Mushak 1968; Schiewer 1976; Turoboyski 1960).

<u>Summary</u>

Although few data are available concerning the toxicity of any chloride salt other than sodium chloride, the data that are available indicate that, when compared on the basis of mg of chloride/L, the chlorides of potassium, calcium, and magnesium are generally more toxic to freshwater species than sodium chloride. Based on tests on sodium chloride, the acute sensitivities of freshwater animals to chloride ranged from 1,470 mg/L for Daphnia pulex to 11,940 mg/L for the American eel. Invertebrate species were generally more sensitive than vertebrates. Results from tests with a variety of species show that if freshwater animals do not die within the first 24 hr of the test, they probably will not die during periods ranging from 48 hr to 11 days. No relationships have been observed between the acute toxicity of chloride to freshwater animals and hardness, alkalinity, pH, or life-stage of the test organisms.

A life-cycle test with Daphnia pulex and early life-stage tests with the rainbow trout and fathead minnow produced chronic values of 372.1, 922.7, and 433.1 mg/L, respectively. The acute-chronic ratios were calculated to be 3.951 for Daphnia pulex, 7.308 for rainbow trout, and 15.17 for the fathead minnow. Freshwater plants were affected at concentrations of chloride ranging from 71 to 36,400 mg/L. No data are available concerning bioaccumulation of chloride by freshwater organisms.

National Criteria

The procedures described in the "Guidelines for Deriving Numerical National Water Quality Criteria for the Protection of Aquatic Organisms and Their Uses" indicate that, except possibly where a locally important species is very sensitive, freshwater aquatic organisms and their uses should not be affected unacceptably if the four-day average concentration of dissolved chloride, when associated with sodium, does not exceed 230 mg/L more than once every three years on the average and if the one-hour average concentration does not exceed 860 mg/L more than once every three years on the average. This criterion probably will not be adequately protective when the chloride is associated with potassium, calcium, or magnesium, rather than sodium. In addition, because freshwater animals have a narrow range of acute susceptibilities to chloride, excursions above this criterion might affect a substantial number of species.

Implementation

As discussed in the Water Quality Standards Regulation (U.S. EPA 1983a) and the Foreword to this document, a water quality criterion for aquatic life has regulatory impact only after it has been adopted in a State water quality standard. Such a standard specifies a criterion for a pollutant that is consistent with a particular designated use. With the concurrence of the U.S. EPA, States designate one or more uses for each body of water or segment thereof and adopt criteria that are consistent with the use(s) (U.S. EPA 1983b,1987). In each standard a State may adopt the national criterion, if one exists, or, if adequately justified, a site-specific criterion.

Site-specific criteria may include not only site-specific criterion concentrations (U.S. EPA 1983b), but also site-specific, and possibly pollutant-specific, durations of averaging periods and frequencies of allowed excursions (U.S. EPA 1985b). The averaging periods of "one hour" and "four days" were selected by the U.S. EPA on the basis of data concerning how rapidly some aquatic species react to increases in the concentrations of some pollutants, and "three years" is the Agency's best scientific judgment of the average amount of time aquatic ecosystems should be provided between excursions (Stephan et al. 1985; U.S. EPA 1985b). However, various species and ecosystems react and recover at greatly differing rates. Therefore, if adequate justification is provided, site-specific and/or pollutant-specific concentrations, durations, and frequencies may be higher or lower than those given in national water quality criteria for aquatic life.

Use of criteria, which have been adopted in State water quality standards, for developing water quality-based permit limits and for designing waste treatment facilities requires selection of an appropriate wasteload allocation model. Although dynamic models are preferred for the application of these criteria (U.S. EPA 1985b), limited data or other considerations might require the use of a steady-state model (U.S. EPA 1986). Guidance on mixing zones and the design of monitoring programs is also available (U.S. EPA 1985b,1987).

Table 1. Acute Toxicity of Chloride to Aquatic Animals

Species	Method[a]	Chemical	Hardness (mg/L as $CaCO_3$)	LC50 or EC50 (mg/L)[b]	Species Mean Acute Value (mg/L)[c]	Reference
			FRESHWATER SPECIES			
Snail, *Physa gyrina*	F, M	Sodium chloride	100	2,540	2,540	Birge et al. 1985
Snail, *Physa heterostropha*	S, U	Potassium chloride	-	451	-	Academy of Natural Sciences 1960; Patrick et al. 1968
Fingernail clam (adult >5 cm), *Musculium transversum*	S, M	Potassium chloride	263	168	-	Anderson 1977
Fingernail clam (adult >5 cm), *Musculium transversum*	S, M	Potassium chloride	243	254	-	Anderson 1977
Fingernail clam (juvenile <5 cm), *Musculium transversum*	S, M	Potassium chloride	263	472	-	Anderson 1977
Fingernail clam (juvenile <5 cm), *Musculium transversum*	S, M	Potassium chloride	243	907	-	Anderson 1977
Fingernail clam (juvenile <5 cm), *Musculium transversum*	S, M	Potassium chloride	234	1,655[d]	-	Anderson 1977
Cladoceran (1st instar), *Daphnia magna*	S, U	Sodium chloride	-	<2,562[e]	-	Anderson 1946

Table 1. (continued)

Species	Method[a]	Chemical	Hardness (mg/L as $CaCO_3$)	LC50 or EC50 (mg/L)[b]	Species Mean Acute Value (mg/L)[c]	Reference
Cladoceran, *Daphnia magna*	S, U	Potassium chloride	-	171	-	Dowden 1961
Cladoceran, *Daphnia magna*	S, U	Calcium chloride	-	486	-	Dowden 1961
Cladoceran, *Daphnia magna*	S, U	Sodium chloride	-	2,024	-	Dowden 1961
Cladoceran, *Daphnia magna*	S, U	Calcium chloride	-	1,923	-	Dowden and Bennett 1965
Cladoceran, *Daphnia magna*	S, U	Magnesium chloride	-	2,774	-	Dowden and Bennett 1965
Cladoceran, *Daphnia magna*	S, U	Sodium chloride	-	3,583	-	Dowden and Bennett 1965
Cladoceran, *Daphnia magna*	S, U	Potassium chloride	45	86	-	Biesinger and Christensen 1972
Cladoceran, *Daphnia magna*	S, U	Calcium chloride	45	92	-	Biesinger and Christensen 1972
Cladoceran, *Daphnia magna*	S, U	Magnesium chloride	45	409	-	Biesinger and Christensen 1972
Cladoceran, *Daphnia magna*	S, U	Sodium chloride	45	2,565	2,650	Biesinger and Christensen 1972

Table 1. (continued)

Species	Method[a]	Chemical	Hardness (mg/L as $CaCO_3$)	LC50 or EC50 (mg/L)[b]	Species Mean Acute Value (mg/L)[c]	Reference
Cladoceran, *Daphnia pulex*	R, M	Sodium chloride	93	1,470	1,470	Birge et al. 1985
Isopod, *Lirceus fontinalis*	F, M	Sodium chloride	100	2,950	2,950	Birge et al. 1985
Caddisfly, *Hydroptila angusta*	S, U	Sodium chloride	124	4,039[f]	4,039	Hamilton et al. 1975
Mosquito (larva), *Culex* sp.	S, U	Sodium chloride	-	6,222[f]	6,222	Dowden and Bennett 1965
Midge, *Chironomus attenuatus*	S, U	Sodium chloride	-	4,900	4,900	Thornton and Sauer 1972
Midge, *Cricotopus trifascia*	S, U	Potassium chloride	124	1,434	-	Hamilton et al. 1975
Midge, *Cricotopus trifascia*	S, U	Sodium chloride	124	3,795	3,795	Hamilton et al. 1975
American eel (55 mm), *Anguilla rostrata*	S, U	Sodium chloride	44	10,900	-	Hinton and Eversole 1978
American eel (97.2 mm), *Anguilla rostrata*	S, U	Sodium chloride	44	13,085	11,940	Hinton and Eversole 1979
Rainbow trout, *Salmo gairdneri*	R, U	Sodium chloride	-	3,336[g]	-	Kostecki and Jones 1983
Rainbow trout, *Salmo gairdneri*	F, M	Sodium chloride	46	6,743	6,743	Spehar 1987

Table 1. (continued)

Species	Method[a]	Chemical	Hardness (mg/L as $CaCO_3$)	LC50 or EC50 (mg/L)[b]	Species Mean Acute Value (mg/L)[c]	Reference
Goldfish, *Carassius auratus*	S, U	Sodium chloride	-	8,388[g]	-	Dowden and Bennett 1965
Goldfish, *Carassius auratus*	S, M	Sodium chloride	149	9,455[h]	8,906	Threader and Houston 1983
Fathead minnow, *Pimephales promelas*	F, M	Sodium chloride	100	6,570	6,570	Birge et al. 1985
Bluegill, *Lepomis macrochirus*	S, U	Potassium chloride	39	956	-	Trama 1954
Bluegill, *Lepomis macrochirus*	S, U	Calcium chloride	39	6,804	-	Trama 1954
Bluegill, *Lepomis macrochirus*	S, U	Sodium chloride	39	7,846	-	Trama 1954
Bluegill (3.9 cm), *Lepomis macrochirus*	S, U	Calcium chloride	-	6,080	-	Cairns and Scheier 1959
Bluegill (6.1 cm), *Lepomis macrochirus*	S, U	Calcium chloride	-	6,080	-	Cairns and Scheier 1959
Bluegill (14.2 cm), *Lepomis macrochirus*	S, U	Calcium chloride	-	7,232	-	Cairns and Scheier 1959
Bluegill, *Lepomis macrochirus*	S, U	Potassium chloride	-	965	-	Academy of Natural Sciences 1960; Patrick et al. 1968

Table 1. (continued)

Species	Method[a]	Chemical	Hardness (mg/L as $CaCO_3$)	LC50 or EC50 (mg/L)[b]	Species Mean Acute Value (mg/L)[c]	Reference
Bluegill, *Lepomis macrochirus*	S, U	Calcium chloride	-	6,816	-	Academy of Natural Sciences 1960; Patrick et al. 1968
Bluegill, *Lepomis macrochirus*	S, U	Sodium chloride	-	7,897	-	Academy of Natural Sciences 1960; Patrick et al. 1968
Bluegill, *Lepomis macrochirus*	S, U	Potassium chloride	-	2,640[g]	-	Dowden and Bennett 1965
Bluegill, *Lepomis macrochirus*	S, U	Calcium chloride	-	5,344[g]	-	Dowden and Bennett 1965
Bluegill, *Lepomis macrochirus*	S, U	Sodium chloride	-	8,616[g]	-	Dowden and Bennett 1965
Bluegill, *Lepomis macrochirus*	F, M	Sodium chloride	100	5,870	5,870	Birge et al. 1985

[a] S = static; R = renewal; F = flow-through; U = unmeasured; M = measured.

[b] Concentration of chloride, not the chemical.

[c] Only data obtained with sodium chloride were used in calculation of Species Mean Acute Values. Data for other salts are presented for comparison purposes only.

[d] Test temperature = 7°C; the other tests with this species were at 17°C.

[e] Not used in calculations because quantitative values are available for this species.

[f] This value is from a 48-hr test (see text).

[g] This value is from a 24-hr test (see text).

[h] This value was derived from the published graph.

Table 2. Chronic Toxicity of Chloride to Aquatic Animals

Species	Test[a]	Chemical	Hardness (mg/L as $CaCO_3$)	Limits (mg/L)[b]	Chronic Value (mg/L)	Reference
			FRESHWATER SPECIES			
Cladoceran, *Daphnia pulex*	LC	Sodium chloride	100	314-441	372.1	Birge et al. 1985
Rainbow trout, *Salmo gairdneri*	ELS	Sodium chloride	46	643-1,324	922.7	Spehar 1987
Fathead minnow, *Pimephales promelas*	ELS	Sodium chloride	100	352-533	433.1	Birge et al. 1985

[a] LC = life-cycle or partial life-cycle; ELS = early life-stage.

[b] Measured concentrations of chloride.

Acute-Chronic Ratio

Species	Hardness (mg/L as $CaCO_3$)	Acute Value (mg/L)	Chronic Value (mg/L)	Ratio
Cladoceran, *Daphnia pulex*	100	1,470	372.1	3.951
Rainbow trout, *Salmo gairdneri*	46	6,743	922.7	7.308
Fathead minnow, *Pimephales promelas*	100	6,570	433.1	15.17

Table 3. Ranked Genus Mean Acute Values with Species Mean Acute-Chronic Ratios

Rank[a]	Genus Mean Acute Value (mg/L)	Species	Species Mean Acute Value (mg/L)[b]	Species Mean Acute-Chronic Ratio[c]
		FRESHWATER SPECIES		
12	11,940	American eel, *Anguilla rostrata*	11,940	-
11	8,906	Goldfish, *Carassius auratus*	8,906	-
10	6,743	Rainbow trout, *Salmo gairdneri*	6,743	7.308
9	6,570	Fathead minnow, *Pimephales promelas*	6,570	15.17
8	6,222	Mosquito, *Culex* sp.	6,222	-
7	5,870	Bluegill, *Lepomis macrochirus*	5,870	-
6	4,900	Midge, *Chironomus attenuatus*	4,900	-
5	4,039	Caddisfly, *Hydroptila angusta*	4,039	-
4	3,795	Midge, *Cricotopus trifascia*	3,795	-
3	2,950	Isopod, *Lireus fontinalis*	2,950	-
2	2,540	Snail, *Physa gyrina*	2,540	-

Table 3. (continued)

Rank[a]	Genus Mean Acute Value (mg/L)	Species	Species Mean Acute Value (mg/L)[b]	Species Mean Acute-Chronic Ratio[c]
1	1,974	Cladoceran, *Daphnia magna*	2,650	-
		Cladoceran, *Daphnia pulex*	1,470	3.951

[a] Ranked from most resistant to most sensitive based on Genus Mean Acute Value.

[b] From Table 1.

[c] From Table 2.

Final Acute Value = 1,720 mg/L

Criterion Maximum Concentration = (1,720 mg/L) / 2 = 860.0 mg/L

Final Acute-Chronic Ratio = 7.594 (see text)

Final Chronic Value = (1,720 mg/L) / 7.594 = 226.5 mg/L

Table 4. Toxicity of Chloride to Aquatic Plants

Species	Chemical	Duration (days)	Effect	Concentration (mg/L)[a]	Reference
			FRESHWATER SPECIES		
Alga, *Anacystis nidulans*	Sodium chloride	4	Growth inhibition	>24,300	Schiewer 1974
Alga, *Anabaena variabilis*	Sodium chloride	4	Growth inhibition	14,300	Schiewer 1974
Alga, *Chlamydomonas reinhardtii*	Sodium chloride	3-6	Growth inhibition	3,014	Reynoso et al. 1982
Alga, *Chlorella emersonii*	Sodium chloride	8-14	Growth inhibition	7,000	Setter et al. 1982
Alga, *Chlorella fusca fusca*	Sodium chloride	28	Growth inhibition	18,200	Kessler 1974
Alga, *Chlorella fusca rubescens*	Sodium chloride	28	Growth inhibition	24,300	Kessler 1974
Alga, *Chlorella fusca vacuolata*	Sodium chloride	28	Growth inhibition	24,300	Kessler 1974
Alga, *Chlorella kessleri*	Sodium chloride	28	Growth inhibition	18,200	Kessler 1974
Alga, *Chlorella luteoviridis*	Sodium chloride	28	Growth inhibition	36,400	Kessler 1974

Table 4. (continued)

Species	Chemical	Duration (days)	Effect	Concentration (mg/L)[a]	Reference
Alga, *Chlorella minutissima*	Sodium chloride	28	Growth inhibition	12,100	Kessler 1974
Alga, *Chlorella protothecoides*	Sodium chloride	28	Growth inhibition	30,300	Kessler 1974
Alga, *Chlorella saccharophilia*	Sodium chloride	28	Growth inhibition	30,300	Kessler 1974
Alga, *Chlorella vulgaris*	Potassium chloride	90-120	Growth inhibition	23,800	De Jong 1965
Alga, *Chlorella vulgaris*	Sodium chloride	90-120	Growth inhibition	24,100	De Jong 1965
Alga, *Chlorella vulgaris tertia*	Sodium chloride	28	Growth inhibition	18,200	Kessler 1974
Alga, *Chlorella vulgaris vulgaris*	Sodium chloride	28	Growth inhibition	24,300	Kessler 1974
Alga, *Chlorella zofingiensis*	Sodium chloride	28	Growth inhibition	12,100	Kessler 1974
Alga, *Pithophora oedogonia*	Sodium chloride	10	Inhibition of growth, chlorophyll, and ^{14}C fixation	886	Shitole and Joshi 1984
Alga, *Spirogyra setiformis*	Sodium chloride	10	Inhibition of growth, chlorophyll, and ^{14}C fixation	71	Shitole and Joshi 1984
Desmid, *Netrium digitus*	Sodium chloride	21	Growth inhibition	200	Hosiaisluoma 1976

Table 4. (continued)

Species	Chemical	Duration (days)	Effect	Concentration (mg/L)[a]	Reference
Desmid, *Netrium digitus*	Sodium chloride	21	Growth inhibition	250	Hosiaisluoma 1976
Diatom, *Nitzschia linearis*	Potassium chloride	5	EC50	642	Academy of Natural Sciences 1960; Patrick et al. 1968
Diatom, *Nitzschia linearis*	Calcium chloride	5	EC50	2,003	Academy of Natural Sciences 1960; Patrick et al. 1968
Diatom, *Nitzschia linearis*	Sodium chloride	5	EC50	1,482	Academy of Natural Sciences 1960; Patrick et al. 1968
Eurasian watermilfoil, *Myriophyllum spicatum*	Sodium chloride	32	50% reduction in dry weight	3,617	Stanley 1974
Eurasian watermilfoil, *Myriophyllum spicatum*	Sodium chloride	32	50% reduction in dry weight	4,964	Stanley 1974
Angiosperm (seed), *Potamogeton pectinatus*	Sodium chloride	28	Reduced germination	1,820	Teeter 1965
Angiosperm (9-wk old plants), *Potamogeton pectinatus*	Sodium chloride	35	Reduced dry weight	1,820	Teeter 1965
Angiosperm (13-wk old plants), *Potamogeton pectinatus*	Sodium chloride	35	Reduced shoots and dry weight	1,820	Teeter 1965

[a] Concentration of chloride, not the chemical.

Table 5. Other Data on Effects of Chloride on Aquatic Organisms

Species	Chemical	Hardness (mg/L as $CaCO_3$)	Duration	Effect	Concentration (mg/L)[a]	Reference
				FRESHWATER SPECIES		
Alga, *Chlorella pyrenoidosa*	Sodium chloride	-	24 hr	Inhibited growth	301	Kalinkina 1979; Kalinkina and Strogonov 1980; Kalinkina et al. 1978
Protozoan, *Paramecium tetraurelia*	Sodium chloride	-	5 days	17% reduction in cell division	350[b]	Cronkite et al. 1985
Cladoceran (1st instar), *Daphnia magna*	Potassium chloride	-	16 hr	LC50	179	Anderson 1944
Cladoceran (1st instar), *Daphnia magna*	Calcium chloride	-	16 hr	LC50	853	Anderson 1944
Cladoceran (1st instar), *Daphnia magna*	Sodium chloride	-	16 hr	LC50	3,747	Anderson 1944
Cladoceran, *Daphnia magna*	Potassium chloride	-	64 hr	Incipient inhibition	207	Anderson 1948
Cladoceran, *Daphnia magna*	Calcium chloride	-	64 hr	Incipient inhibition	589	Anderson 1948
Cladoceran, *Daphnia magna*	Magnesium chloride	-	64 hr	Incipient inhibition	555	Anderson 1948
Cladoceran, *Daphnia magna*	Sodium chloride	-	64 hr	Incipient inhibition	2,245	Anderson 1948
Cladoceran, *Daphnia magna*	Potassium chloride	45	21 days	Reproductive impairment	44[c]	Biesinger and Christensen 1972

Table 5. (continued)

Species	Chemical	Hardness (mg/L as $CaCO_3$)	Duration	Effect	Concentration (mg/L)[a]	Reference
Cladoceran, *Daphnia magna*	Calcium chloride	45	21 days	Reproductive impairment	206[c]	Biesinger and Christensen 1972
Cladoceran, *Daphnia magna*	Magnesium chloride	45	21 days	Reproductive impairment	239[c]	Biesinger and Christensen 1972
Cladoceran, *Daphnia magna*	Sodium chloride	45	21 days	Reproductive impairment	1,062[c]	Biesinger and Christensen 1972
Caddisfly, *Hydroptila angusta*	Potassium chloride	124	48 hr	LC50	2,119	Hamilton et al. 1975
Goldfish, *Carassius auratus*	Sodium chloride	-	24 hr 96 hr -	LC50 (fed) LC50 (fed) Threshold LC50	6,037 4,453 4,442	Adelman and Smith 1976a,b; Adelman et al. 1976
Shiners, *Notropis* sp.	Sodium chloride	-	5 days	Reduced survival	1,525	Van Horn et al. 1949
Fathead minnow (11 wk), *Pimephales promelas*	Sodium chloride	-	24 hr 96 hr -	LC50 (fed) LC50 (fed) Threshold LC50	4,798 4,640 4.640	Adelman and Smith 1976a,b; Adelman et al. 1976
Channel catfish, *Ictalurus punctatus*	Sodium chloride	412	24 hr 14 days	LC50 (fed)	8,000 8,000	Reed and Evans 1981
Mosquitofish, *Gambusia affinis*	Potassium chloride	-	24 hr 96 hr	LC50[d]	4,800 442	Wallen et al. 1957
Mosquitofish, *Gambusia affinis*	Calcium chloride	-	24 hr 96 hr	LC50[d]	8,576 8,576	Wallen et al. 1957
Mosquitofish, *Gambusia affinis*	Magnesium chloride	-	24 hr 96 hr	LC50[d]	14,060 12,370	Wallen et al. 1957

Table 5. (continued)

Species	Chemical	Hardness (mg/L as $CaCO_3$)	Duration	Effect	Concentration (mg/L)[a]	Reference
Mosquitofish, *Gambusia affinis*	Sodium chloride	-	24 hr	LC50[d]	11,040	Wallen et al. 1957
			96 hr		10,710	
Bluegill, *Lepomis macrochirus*	Sodium chloride	412	24 hr	LC50 (fed)	8,000	Reed and Evans 1981
			14 days		8,000	
Largemouth bass (juvenile), *Micropterus salmoides*	Sodium chloride	412	24 hr	LC50 (fed)	8,500	Reed and Evans 1981
			14 days		8,500	

[a] Concentration of chloride, not the chemical.

[b] This value was derived from the published graph.

[c] Concentrations not measured in test solutions.

[d] Turbidity = <25 to 320 mg/L.

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