Date: 9/13/07 8:30 am
Call to: John Rampe
Phone: 918-629-5108

- Oil Well earthen pit, filled saltwater
  - Indian Land

- Altec
- NW 36 - 28N - 9E Osage Co OK
- Taken Water
- Oily
- Built Pit
- Goes into some tp
- August 13
- Owned by department of Wildlife
- Biologist

Nancy 2:00
2254

John Rampe
918-629-5108

GOVERNMENT EXHIBIT 28

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United States
Environmental Protection
Agency

Office of Water
Regulations and Standards
Criteria and Standards Division
Washington, DC 20460

EPA 440/5-88-001
February 1988

Water

EPA

Ambient Water Quality Criteria for Chloride—1988

AMBIENT AQUATIC LIFE WATER QUALITY CRITERIA FOR

CHLORIDE

U.S. ENVIRONMENTAL PROTECTION AGENCY
OFFICE OF RESEARCH AND DEVELOPMENT
ENVIRONMENTAL RESEARCH LABORATORY
DULUTH, MINNESOTA

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.

William A. Whittington
Director
Office of Water Regulations and Standards

ACKNOWLEDGMENTS

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CONTENTS

TABLES

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, <u>Pimephales promelas</u>, 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.

<u>Toxicity to Aquatic Plants</u>

Data on the toxicity of chloride to aquatic plants show a wide range of sensitivities (Table 4). The alga, <u>Spirogyra setiformis</u>, 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).

Summary

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]	Crankite 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 96 hr	LC50[d]	11,040 10,710	Wallen et al. 1957
Bluegill, *Lepomis macrochirus*	Sodium chloride	412	24 hr 14 days	LC50 (fed)	8,000 8,000	Reed and Evans 1981
Largemouth bass (juvenile), *Micropterus salmoides*	Sodium chloride	412	24 hr 14 days	LC50 (fed)	8,500 8,500	Reed and Evans 1981

[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.

REFERENCES

Academy of Natural Sciences. 1960. The sensitivity of aquatic life to certain chemicals commonly found in industrial wastes. Philadelphia, PA.

Adelman, I.R. and L.L. Smith, Jr. 1976a. Fathead minnows (Pimephales promelas) and goldfish (Carassius auratus) as standard fish in bioassays and their reaction to potential reference toxicants. J. Fish. Res. Board Can. 33:209-214.

Adelman, I.R. and L.L. Smith, Jr. 1976b. Standard test fish development. Part I. Fathead minnows (Pimephales promelas) and goldfish (Carassius auratus) as standard fish in bioassays and their reaction to potential reference toxicants. EPA-600/3-76-061a. National Technical Information Service, Springfield, VA.

Adelman, I.R., L.L. Smith, Jr. and G.D. Siesennop. 1976. Acute toxicity of sodium chloride, pentachlorophenol, Guthion, and hexavalent chromium to fathead minnows (Pimephales promelas) and goldfish (Carassius auratus). J. Fish. Res. Board Can. 33:203-208.

Anderson, B.G. 1944. The toxicity thresholds of various substances found in industrial wastes as determined by the use of Daphnia magna. Sewage Works J. 16:1156-1165.

Anderson, B.G. 1946. The toxicity thresholds of various sodium salts determined by the use of Daphnia magna. Sewage Works J. 18:82-87.

Anderson, B.G. 1948. The apparent thresholds of toxicity to *Daphnia magna* for chlorides of various metals when added to Lake Erie water. Trans. Am. Fish. Soc. 78:96-113.

Anderson, K.B. 1977. *Musculium transversum* in the Illinois River and an acute potassium bioassay method for the species. PB-288088. National Technical Information Service, Springfield, VA.

Arnold, D. 1974. Comparative study of the effects of copper sulfate and sodium chloride upon the growing habits of planktonic algae cultures. J. Tenn. Acad. Sci. 46:14.

Batterton, J.C., Jr. and C. Van Baalen. 1971. Growth responses of blue-green algae to sodium chloride concentration. Arch. Mikrobiol. 76:151-165.

Batterton, J.C., G.M. Boush and F. Matsumura. 1972. DDT: Inhibition of sodium chloride tolerance by the blue-green alga *Anacystis nidulans*. Science 176:1141-1143.

Beeton, A.M. 1965. Eutrophication of the St. Lawrence Great Lakes. Limnol. Oceanogr. 10:240-254.

Biesinger, K.E. and G.M. Christensen. 1972. Effects of various metals on survival, growth, reproduction, and metabolism of *Daphnia magna*. J. Fish. Res. Board Can. 29:1691-1700.

Birge, W.J., J.A. Black, A.G. Westerman, T.M. Short, S.B. Taylor, D.M. Bruser and E.D. Wallingford. 1985. Recommendations on numerical values for regulating iron and chloride concentrations for the purpose of protecting warmwater species of aquatic life in the commonwealth of Kentucky. University of Kentucky, Lexington, KY.

Cairns, J., Jr. and A. Scheier. 1959. The relationship of bluegill sunfish body size to tolerance for some common chemicals. Proc. Ind. Waste Conf. Purdue Univ. 13:243-252.

Carrasquer, G., D. Kissel, W.S. Rehm and M. Schwartz. 1983. Anomalous potential difference responses to changes in sodium concentration in the antrum of frog stomach. Am. J. Physiol. 245:554-561.

Castille, F.L., Jr. and A.L. Lawrence. 1981. The effect of salinity on the osmotic, sodium, and chloride concentrations in the hemolymph of the freshwater shrimps, Macrobrachium ohione Smith and Macrobrachium rosenbergii De Man. Comp. Biochem. Physiol. 70A:47-52.

Christensen, G.M. 1971/72. Effects of metal cations and other chemicals upon the in vitro activity of two enzymes in the blood plasma of the white sucker. Catostomus commersoni (Lacepede). Chem.-Biol. Interact. 4:351-361.

Christensen, G.M. and J.H. Tucker. 1976. Effects of selected water toxicants on the in vitro activity of fish carbonic anhydrase. Chem.-Biol. Interact. 13:181-192.

Coetzee, N. and J. Hattingh. 1977. Effects of sodium chloride on the freshwater fish Labeo capensis during and after transportation. Zool. Afr. 12:244-247.

Cronkite, D.L., A.N. Gustafson and B.F. Bauer. 1985. Role of protein systhesis and ninhydrin-positive substances in acclimation of Paramecium tetraurelia to high NaCl. J. Exp. Zool. 233:21-28.

Das, S. and G.J. Srivastava. 1978. Responses of gill to various changes in salinity in fresh water teleost Colisa fasciatus (Bl. and Schn.). Z. Mikrosk. Anat. Forsch. (Leipz.) 92:770-780.

Davis, K.B., C.P. Schuier and B.A. Simco. 1972. The effect of short and long term exposure to salinity on plasma sodium and chloride concentrations of channel catfish. Am. Soc. Zool. 13:680.

De Jong, L.E.D. 1965. Tolerance of Chlorella vulgaris for metallic and non-metallic ions. Antonie Leeuwenhoek J. Microbiol. 31:301-313.

De Renzis, G. and J. Maetz. 1973. Studies on the mechanism of chloride absorption by the goldfish gill: Relation with acid-base regulation. J. Exp Biol. 59:339-358.

Dickman, M.D. and M.B. Gochnauer. 1978. Impact of sodium chloride on the microbiota of a small stream. Environ. Pollut. 17:109-126.

Dowden, B.F. 1961. Cumulative toxicities of some inorganic salts to Daphnia magna as determined by median tolerance limits. Proc. La. Acad. Sci. 23:77-85.

Dowden, B.F. and H.J. Bennett. 1965. Toxicity of selected chemicals to certain animals. J. Water Pollut. Control Fed. 37:1308-1316.

Edmister, J.O. and J.W. Gray. 1948. The toxicity thresholds for three chlorides and three acids to the fry of whitefish (Coregonus clupeaformis) and yellow pickerel (Stizostedion v. vitreum). Prog. Fish-Cult. 10:105-106.

Ellis, M.M. 1937. Detection and measurement of stream pollution. Bull. Bureau Fish. 48:365-437.

Eyster, C. 1962. Requirements and functions of micronutrients by green plants with respect to photosynthesis. In: Biologistics for space systems symposium. AMRL-TDR-62-116 or AD-292713. National Technical Information Service, Springfield, VA. pp. 199-209.

Ferri, S. and A. Sesso. 1982. Cell response associated to NaCl effect in a freshwater teleost epidermis. Zentralbl. Veterinaermed. Reihe C. 11:307-314.

Frahm, J. 1975. Toxicity tolerance studies utilizing periphyton. Gewasser Abwasser 57/58:59-66.

Greenway, H. and T.L. Setter. 1979a. Accumulation of proline and sucrose during the first hours after transfer of Chlorella emersonii to high NaCl. Aust. J. Plant Physiol. 6:69-79.

Greenway, H. and T.L. Setter. 1979b. Na^+, Cl^- and K^+ concentrations in Chlorella emersonii exposed to 100 and 335 mM NaCl. Aust. J. Plant Physiol. 6:61-67.

Hamilton, R.W., J.K. Buttner and R.G. Brunetti. 1975. Lethal levels of sodium chloride and potassium chloride for an oligochaete, a chironomid midge, and a caddisfly of Lake Michigan. Environ. Entomol. 4:1003-1006.

Hasan, M.R. and D.J. Macintosh. 1986. Effect of chloride concentration on the acute toxicity of nitrite to common carp, Cyprinus carpio L., fry. Aquacult. Fish. Manage. 17:19-30.

Hinkle, M., P. Heller and W. Van Der Kloot. 1971. The influence of potassium and chloride ions on the membrane potential of single muscle fibers of the crayfish. Comp. Biochem. Physiol. 40A:181-201.

Hinton, M.J. and A.G. Eversole. 1978. Toxicity of ten commonly used chemicals to American eels. Proc. Annu. Conf. Southeast. Assoc. Fish Wildl. Agencies 32:599-604.

Hinton, M.J. and A.G. Eversole. 1979. Toxicity of ten chemicals commonly used in aquaculture to the black eel stage of the American eel. In: Proceedings of the tenth annual meeting of the World Mariculture Society. Avault, J.W., Jr. (Ed). Louisiana State University, Baton Rouge, LA. pp. 554-560.

Hosiaisluoma, V. 1976. Effect of HCl and NaCl on the growth of Netrium digitus (Desmidiales). Ann. Bot. Fenn. 13:107-113.

Hughes, J.S. 1968. Toxicity of some chemicals to striped bass (Roccus saxatilis). Proc. Annu. Conf. Southeast. Assoc. Game Fish Comm. 22:230-234.

Hughes, J.S. 1973. Acute toxicity of thirty chemicals to striped bass (Morone saxatilis). Presented at the Western Association of State Game and Fish Commissioners in Salt Lake City, UT.

Jennings, D.H. 1976. The effects of sodium chloride on higher plants. Biol. Rev. Camb. Philos. Soc. 51:453-486.

Kalinkina, L.G. 1979. Growth and biomass accumulation in marine and freshwater algae of the genus Chlorella as a function of NaCl concentration in the medium. Plant Physiol. (Engl. Transl. Fiziol. Rast.) 26:320-325.

Kalinkina, L.G. and B.P. Strogonov. 1980. Excretion of glycolic acid by marine and freshwater algae under the influence of different NaCl concentrations. Plant Physiol. (Engl. Transl. Fiziol. Rast.) 27:44-50.

Kalinkina, L.G., K.S. Spektorov and V.O. Bogoslovskaya. 1978. Effects of different concentrations of NaCl on growth and development of Chlorella pyrenoidosa. Plant Physiol. (Engl. Transl. Fiziol. Rast.) 25:16-20.

Kardatzke, J.T. 1980. Effect of sodium chloride on larval snow-melt Aedes (Diptera: Culicidae). Mosq. News 40:153-160.

Kardatzke, J.T. 1981. Effect of addition of calcium chloride to larval medium on survival of immature snow-melt Aedes (Diptera: Culicidae). Mosq. News 41:11-12.

Katz, U. and Y. Ben-Sasson. 1984. A possible role of the kidney and urinary bladder in urea conservation of *Bufo viridis* under high salt acclimation. J. Exp. Biol. 109:373-377.

Kessler, E. 1974. Physiological and biochemical contributions to the taxonomy of the genus *Chlorella*. IX. Salt tolerance as a taxonomic character. Arch. Microbiol. 100:51-56.

Konovalov, Y.D. 1984. Binding of dyes by carp embryonic cells under the effect of sulphates and chlorides. Hydrobiol. J. (Engl. Transl. Gidrobiol. Zh). 20(4):47-53.

Kostecki, P.T. and J.J. Jones. 1983. The effect of osmotic and ion-osmotic stresses on the mortality of rainbow trout (*Salmo gairdneri*). Comp. Biochem. Physiol. 74A:773-775.

Kumar, S. and G.J. Srivastava. 1981. The effect of sodium chloride on kidney and corpuscles of stannis of *Channa punctatus* (Bloch). Zool. Beitr. 26:13-16.

Leblanc, G.A. and D.C. Surprenant. 1984. The influence of mineral salts on fecundity of the water flea (*Daphnia magna*) and the implications on toxicity testing of industrial wastewater. Hydrobiologia 108:25-31.

Lee, F.C. 1973. Effect of various sodium chloride concentrations on the development of the mosquito *Culiset a incidens* (Thomson) (Diptera: Culicidae). Mosq. News 33:78-83.

Lewis, S.D. 1971. Effect of selected concentrations of sodium chloride on the growth of channel catfish. Proc. Annu. Conf. Southeast. Assoc. Game Fish Comm. 25:459-466.

Mahajan, C.L., S.D. Sharma and S.P. Sharma. 1979. Tolerance of aquatic organisms to chloride salts. Indian J. Exp. Biol. 17:1244-1245.

McCormick, S.D. and R.J. Naiman. 1984. Osmoregulation in the brook trout, Salvelinus fontinalis - II. Effects of size, age and photoperiod on seawater survival and ionic regulation. Comp. Biochem. Physiol. 79A:17-28.

Meech, R.W. and R.C. Thomas. 1980. Effect of measured calcium chloride injections on the membrane potential and internal pH of snail neurones. J. Physiol. 298:111-129.

Mushak, P.A. 1968. Content and state of nucleic acids in the alga Dunaliella salina Teod. depending upon NaCl concentration. Ukr. Bot. Zh. 25:91-95.

Ooshima, Y. and M. Oguri. 1974. Osmotic pressure, and sodium chloride concentrations in the blood plasma of "Cobalt" variant of rainbow trout. Bull. Jpn. Soc. Sci. Fish. 40:1307.

Palmer, C.M. and T.E. Maloney. 1955. Preliminary screening for potential algicides. Ohio J. Sci. 55:1-8.

Pappas, L.G. and C.D. Pappas. 1983. Laboratory studies on the significance of NaCl as an oviposition deterrent in Culiseta inornata. Mosq. News 43:153-155.

Patrick, R., J. Cairns, Jr. and A. Scheier. 1968. The relative sensitivity of diatoms, snails, and fish to twenty common constituents of industrial wastes. Prog. Fish-Cult. 30:137-140.

Perry, S.F., P. Payan and J.P. Girard. 1984. Effects of perfusate HCO_3 and pCO_2 on chloride uptake in perfused gills of rainbow trout (Salmo gairdneri). Can. J. Fish. Aquat. Sci. 41:1768-1773.

Phillips, A.M., Jr. 1944. The physiological effect of sodium chloride upon brook trout. Trans. Am. Fish. Soc. 74:297-309.

Reed, P. and R. Evans. 1981. Acute toxicity of chlorides, sulfates and total dissolved solids to some fishes in Illinois. Contract Report 283. State Water Survey Division, Peoria, IL.

Reynoso, G.T., B.A. de Gamboa and S.R. Mendoza. 1982. Induction of resistance to salinity in the freshwater alga Chlamydomonas reinhardtii. Environ. Sci. Res. 23:531-534.

Schiewer, U. 1974. Salt tolerance and the influence of increasing NaCl-concentrations on the contents of nitrogen, carbohydrates, pigments and the production of extracellular carbohydrates in some freshwater blue-green algae. Arch. Hydrobiol. Suppl. 46:171-184.

Schiewer, U. 1976. Ash content and ATPase activity of limnic blue green algae under sodium chloride loads. Wiss. Z. Univ. Rostock Math. Naturwiss. Reihe 25:287-294.

Schiewer, U. 1984. The ecophysiology of salt adaptation in freshwater blue-green algae. Limnologica 15:555-558.

Setter, T.L., H. Greenway and J. Kuo. 1982. Inhibition of cell division by high external NaCl concentrations in synchronized cultures of Chlorella emersonii. Aust. J. Plant Physiol. 9:179-196.

Shaw, H.M., R.L. Saunders, H.C. Hall and E.B. Henderson. 1975. Effect of dietary sodium chloride on growth of Atlantic salmon (Salmo salar). J. Fish. Res. Board Can. 32:1813-1819.

Shitole, M.G. and G.V. Joshi. 1984. Effect of sodium chloride on the balance between C_3 and C_4 carbon fixation pathways and growth. Photosynthetica 18:377-384.

Shomer-Ilan, A. and Y. Waisel. 1976. Further comments on the effects of NaCl on photosynthesis in Aeluropus litoralis. Z. Pflanzenphysiol. 77:272-273.

Sonzogni, W.C., W. Richardson, P. Rodgers and T.J. Monteith. 1983. Chloride pollution of the Great Lakes. J. Water Pollut. Control Fed. 55:513-521.

Spehar, R.L. 1987. U.S. EPA, Duluth, MN. (Memorandum to C. Stephan. U.S. EPA, Duluth, MN. June 24).

Sreenivasan, A., R. Ananthanarayanan and N. Kalaimani. 1979. Relationship between high chloride and hardness with rotifers. Indian J. Environ. Health 21:287-288.

Stamper, W.R. 1969. The determination of the optimal combination of sodium, potassium, calcium and magnesium chlorides for the survival of Daphnia pulex. Ph.D. thesis. Pennsylvania State University, University Park, PA. Available from: University Microfilms, Ann Arbor, MI. Order No. 70-19,471.

Stangenberg, M. 1975. The influence of the chemical composition of water on the pike perch (Lucioperca lucioperca L.) fry from the Lake Goplo. Limnologica 9:421-426.

Stanley, R.A. 1974. Toxicity of heavy metals and salts to Eurasian watermilfoil (Myriophyllum spicatum L). Arch. Environ. Contam. Toxicol. 2:331-341.

Stephan, C.E., D.I. Mount, D.J. Hansen, J.H. Gentile, G.A. Chapman and W.A. Brungs. 1985. Guidelines for deriving numerical national water quality criteria for the protection of aquatic organisms and their uses. PB85-227049. National Technical Information Service, Springfield, VA.

Sullivan, L.P., D.J. Welling and L.A. Rome. 1981. Effects of sodium and chloride on potassium transport by the bullfrog kidney. Am. J. Physiol. 240:127-137.

Teeter, J.W. 1965. Effects of sodium chloride on the sago pondweed. J. Wildl. Manage. 29:838-845.

Thornton, K.W. and J.R. Sauer. 1972. Physiological effects of NaCl on Chironomus attenuatus (Diptera: Chironomidae). Ann. Entomol. Soc. Am. 65:872-875.

Thornton, K. and J. Wilhm. 1974. The effects of pH, phenol, and sodium chloride on survival and caloric, lipid, and nitrogen content of a laboratory population of Chironomus attenuatus. Hydrobiologia 45:261-280.

Thornton, K.W. and J.L. Wilhm. 1975. The use of life tables in demonstrating the effects of pH, phenol, and NaCl on Chironomus attenuatus populations. Environ. Entomol. 4:325-328.

Threader, R.W. and A.H. Houston. 1983. Use of NaCl as a reference toxicant for goldfish, Carassius auratus. Can. J. Fish. Aquat. Sci. 40:89-92.

Ticku, M.K. and R.W. Olsen. 1977. Aminobutyric acid-stimulated chloride permeability in crayfish muscle. Biochim. Biophys. Acta 464:519-529.

Tomasso, J.R., M.I. Wright, B.A. Simco and K.B. Davis. 1980. Inhibition of nitrite-induced toxicity in channel catfish by calcium chloride and sodium chloride. Prog. Fish-Cult. 42:144-146.

Trama, F.B. 1954. The acute toxicity of some common salts of sodium, potassium and calcium to the common bluegill (Lepomis macrochirus Rafinesque). Proc. Acad. Nat. Sci. 106:185-205.

Tuchman, M.L. and E.F. Stoermer. Manuscript a. The effects of increased NaCl and KCl concentrations on a natural phytoplankton assemblage from Lake Superior. U.S. EPA, Chicago, IL.

Tuchman, M.L. and E.F. Stoermer. Manuscript b. The effects of NaCl and KCl additions on the competitive interactions between a diatom and a blue-green alga. U.S. EPA, Chicago, IL.

Turoboyski, L. 1960. Influence of high concentrations of some chemical compounds upon carp fry. Rocz. Nauk. Roln. 75B:401-445.

U.S. EPA. 1983a. Water quality standards regulation. Federal Regist. 48:51400-51413. November 8.

U.S. EPA. 1983b. Water quality standards handbook. Office of Water Regulations and Standards, Washington, DC.

U.S. EPA. 1985a. Appendix B - Response to public comments on "Guidelines for deriving numerical national water quality criteria for the protection of aquatic organisms and their uses." Federal Regist. 50:30793-30796. July 29.

U.S. EPA. 1985b. Technical support document for water quality-based toxics control. EPA-440/4-85-032 or PB86-150067. National Technical Information Service, Springfield, VA.

U.S. EPA. 1986. Chapter 1 - Stream design flow for steady-state modeling. In: Book VI - Design conditions. In: Technical guidance manual for performing waste load allocation. Office of Water, Washington, DC. August.

U.S. EPA. 1987. Permit writer's guide to water quality-based permitting for toxic pollutants. EPA-440/4-87-005. Office of Water, Washington, DC.

Vaidya, D.P. and R. Nagabhushanam. 1979. Influence of salt concentrations on survival, body weight and blood chloride of the freshwater snail, Indoplanorbis exustus (Deshyes) Hydrobiologia 63:195-198.

Van Horn, W.M., J.B. Anderson and M. Katz. 1949. The effect of Kraft pulp mill wastes on some aquatic organisms. Trans. Am. Fish. Soc. 79:55-63.

Vosjan, J.H. and R.J. Siezen. 1968. Relation between primary production and salinity of algal cultures. Neth. J. Sea Res. 4:11-20.

Wallen, I.E., W.C. Greer and R. Lasater. 1957. Toxicity to Gambusia affinis of certain pure chemicals in turbid waters. Sewage Ind. Wastes 29:695-711.

Zaim, M. and H.D. Newson. 1979. Larval development and oviposition behavior of Aedes triseriatus (Diptera: Culicidae) as affected by varying concentrations of sodium chloride and calcium nitrate in the water. Environ. Entomol. 8:326-329.

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Animal Health
Fact Sheet

Analysis of Water Quality for Livestock

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Animals are able to ingest a wide variety of different types of water and survive. However, some salts and elements, at high levels, may reduce animal growth and production or may cause illness and death.

The measures used to evaluate water quality include salinity, hardness, pH, sulfate, nitrate and analysis for other specific elements known to be toxic. Waters can be evaluated for these characteristics at university or commercial laboratories. Microbiological agents (bacterial, viral and protozoan) can be spread through water and cause disease. These are not usually evaluated in livestock waters, but samples could be submitted to an animal disease diagnostic laboratory for culture. Only certain laboratories are prepared to test for pesticides and organic toxins.

A. Salinity

Salinity refers to salts dissolved in water. The anions (negatively charged ions) commonly present include: carbonate, bicarbonate, sulfate, nitrate, chloride, phosphate and fluoride. The cations (positively charged ions) include calcium, magnesium, sodium and potassium.

Salinity may be measured as Total Dissolved Solids (TDS) or Total Soluble Salts (TSS) and is expressed as parts per million (ppm) (which is equivalent to mg/l or ug/ml). Salinity may also be measured by electrical conductivity (EC) and is then expressed as reciprocal micro ohms per centimeter (umhos/cm) or decisiemens per meter (dS/m). There is a close correlation of EC and ppm with the values of ppm being about 3/5 of those for EC (@ 300 ppm, EC = 500 umhos/cm and @ 3,000 ppm, EC = 5,000 umhos/cm). The effects seem to be the same whether one or several salts are involved. The conversion factors are listed in Table 6.

An abrupt change from water of low salinity to water of high salinity may cause animals harm while a gradual change would not. Animals can consume water of high salinity (TDS) for a few days, without harm, if they are then given water of low salinity (TDS). Animal tolerance also varies with species, age, water requirement, season of the year, and physiological condition.

As the TDS of water increases, intake also increases, except at very high content where the animals refuse to drink. Depressed water intake is accompanied by depressed feed intake.

The ions of magnesium (Mg), calcium (Ca), sodium (Na) and chloride (Cl) all contribute to the salinity of water, and they may cause toxic effects because of this salinity effect or by interference with other elements. But, these four are not usually considered toxic otherwise.

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30

Salinity by itself tells nothing about which elements are present, but this may be of critical importance. So when the salinity is elevated, the water should be analyzed for the specific anions and cations.

The following tables give guidelines on potential uses of waters of various salinity:

Table 1: TDS and Species Variation(1)

	Total Dissolved Solids (ppm)				
Species	**Excellent**	**Good**	**Fair**	**Poor**	**Limit**
Humans	0-800	800-1600	1600-2500	2500-4000	5000*
Horses, Working	0-1000	1000-2000	2000-3000	3000-5000	6000
Horses, Others	0-1000	1000-2000	2000-4000	4000-6000	10000
Cattle	0-1000	1000-2000	2000-4000	4000-6000	10000
Sheep	0-1000	1000-3000	3000-6000	6000-10000	15000
Chickens & Poultry	0-1000	1000-2000	2000-3000	3000-5000	6000
Swine	(Young pigs and market pigs appear to tolerate less than cattle)				

*The limit for drinking water in Utah is 2,000 ppm.

Table 2. A Guide to the Use of Saline Waters for Livestock and Poultry(2)

Total Soluble Salts Content of Waters (mg/L or ppm)	Comment
Less than 1,000 ppm (1670 umhos/cm)	These waters have a relatively low level of salinity and should present no serious burden to any livestock or poultry.
1,000-2,999 ppm (1670-5008 umhos/cm)	These waters should be satisfactory for all classes of livestock and poultry. They may cause temporary and mild diarrhea in livestock not accustomed to them, or watery droppings in poultry (especially at the higher levels), but should not affect their health or performance.
3,000-4,999 ppm (5010-8348 umhos/cm)	These waters should be satisfactory for livestock, although they may cause temporary diarrhea or be refused at first by animals not accustomed to them. They are poor waters for poultry, often causing watery feces and (at the higher levels of salinity) increased mortality and decreased growth, especially in turkeys.
5,000-6,999 ppm (8350-11688 umhos/cm)	These waters can be used with reasonable safety for dairy and beef cattle, sheep, swine and horses. Avoid the use of those approaching the higher levels for pregnant or lactating animals. They are not acceptable waters for poultry, almost always causing some type of problem, especially near the upper limit, where reduced growth and production or increased mortality will probably occur.

Total Soluble Salts Content of Waters (mg/L or ppm)	Comment
7,000-10,000 ppm (11,690-16,700 umhos/cm)	These waters are unfit for poultry and probably for swine. Con 7,000-10,000 ppm (11,690-16,700 umhos/cm considerable risk may exist in using them for pregnant or lactating cows, horses, sheep, the young of these species, or for any animals subjected to heavy heat stress or water loss. In general, their use should be avoided, although older ruminants, horses, and even poultry and swine may subsist on them for long periods of time under conditions of low stress
More than 10,000 ppm (16,700 umhos/cm)	The risks with these highly saline waters are so great that they cannot be recommended for use under any conditions.
35,000 ppm (58,450 umhos/cm)	Brine

B. HARDNESS

Water containing appreciable amounts of calcium and magnesium are called "hard" because it is hard to make such water lather with soap. The free calcium and magnesium react with soap to form an insoluble curd-like material. If they are removed, the water will lather easily.

Water "hardness" is not necessarily correlated with salinity. Saline waters can be very soft if they contain low levels of calcium and magnesium (the cations which cause hardness). Calcium and magnesium are usually present at less than 1,000 ppm in water. The calcium carbonate content of waters of various hardness is classed as:

Water Hardness	mg/l
Soft	0-60
Moderate	61-120
Hard	121-180
Very Hard	>180

Hardness does not cause urinary calculi

Softening the water through exchange of calcium and magnesium with sodium may cause problems if the water is already high in salinity.

C. PH

The pH is a measure of acidity or alkalinity. A pH of 7 is neutral, under 7 is acidic and over 7 is alkaline. Most waters in the western states are slightly alkaline. The preferred pH is 6.0 to 8.0 for dairy animals and from 5.5 to 8.3 for other livestock. Highly alkaline waters may cause digestive upsets, diarrhea, poor feed conversion and reduced water/feed intake.

D. SULFATE

Sulfate imparts a bitter taste to the water, but animals can acclimate to it. Consider diluting high sulfate water for weanling pigs and for animals who are not accustomed to it. The maximum recommended levels are:

Table 3. Maximum Recommended Levels of Sulfate

Animals	ppm Sulfate (SO4) ppm	Sulfate as Sulfur (SO4-S)
Calves	< 500	< 167
Adult Cattle	< 1,000	< 333

Magnesium sulfate (Epsom salt) and sodium sulfate (Glauber salt) tend to make water taste objectionable. Sulfate levels up to 1500 ppm produce slight effects on livestock and levels of 1500 to 2500 produce temporary diarrhea. When the sulfate level reaches 3500 ppm, it is unfit for sows. Water with levels above 4500 ppm should not be used.(3)

E. NITRATE

Nitrate toxicity is seldom caused by a water source alone, but it may contribute to a problem feed source. The nitrate ion (NO3-) itself is not especially toxic. However, nitrite (NO2-) is readily absorbed and is quite toxic (10 times more than nitrate). The bacteria present in the digestive tract of ruminants and herbivores can readily convert nitrate to nitrite. The clinical signs of nitrate poisoning in animals include lack of coordination, labored breathing, blue discoloration of mucous membranes, vomiting and abortions. Dairy cows can have reduced milk production without showing any clinical signs. If animals show signs of nitrate poisoning or a problem is suspected, a veterinarian should be consulted to determine if nitrate is the problem, and administer an antidote if needed.

The following table can be used as a guide for nitrate in water, but must be considered along with the forage level.

Table 4. Nitrate Content (ppm)(1)

	Nitrate-N (NO3-N	Nitrate (NO3)	Potassium Nitrate (KNO3)	Interpretation
A. Water: (ppm)	0-100 100-300 Over 300	0-440 440-1300 Over 1300	0-720 720-2100 Over 2100	Considered safe. Exercise caution. Consider additive effect of nitrate in feed. Potentially toxic.
B. Forages: (%)	0-.15% 0.15-0.45% Over .45%	0-0.65% 0.65-2% Over 2%	0-1% 1-3% Over 3%	Considered safe. Exercise caution. May need to dilute or limit feed forages Potentially toxic.
C: Other elements	Several other elements can contaminate water under special circumstances. These will require special tests and are usually not performed unless there are indications of a problem. Questions of cost, accuracy and range of detection must be evaluated. Then a request should be made for the specific elements desired.			

Table 5. Recommended Limits of Concentration of Some Potentially Toxic Substances in Drinking Water for Livestock Safe Upper Limit of Concentration (mg/L)

Element	U.S. EPA (for humans)	U.S. EPA (for livestock)	NAS (for livestock
Aluminum	—		—
Arsenic (b)	0.05	5.0	0.2
Barium (c)	1.0	0.2	NE*
Berylium (c)	—	—	—
Boron	—	NE*	—
Cadmium	0.01	5.0	0.05
Chromium	0.05	0.05	1.0
Cobalt	—	1.0	1.0
Copper (c)	1.0	1.0	0.05
Fluoride	4.0/2.0 (e)	0.5	2.0
Iron (e)	0.3	2.0	NE*
Lead (a) (b)	.005	No limit	0.1
Manganese (e)	0.05	No limit	NE*
Mercury (c)	0.002	0.001	0.01
Molybdenum	—	No limit	NE*
Nickel	—	—	1.0
Nitrate (d)	10	100	100
Nitrite (c)	—	33	33
Selenium (a)	0.01	0.05	—
Vanadium (a)	—	0.1	0.1
Zinc (e)	5.0	25.0	25.0

*Not established. Experimental data available are not sufficient to make definite recommendations.
(a) Lead is cumulative and problems may begin at threshold value (0.05 mg/L).
(b) The safe limit is below the lowest detectable level.
(c) Analyses available only at certain laboratories.
(d) As Nitrate-N (NO3-N).
(e) Secondary standard. Drinking water limits for humans are classed as primary and secondary. Primary limits are health related and are enforced by law. Secondary limits are for aesthetics and are recommendations.

G. CONVERSION FACTORS AND TABLES

Table 6. Conversion Factors for Salinity Measures

ppm to umhos = ppm x 5/3 = ____________ umhos/cm
umhos to ppm = umhos/cm x 3/5 = ____________ ppm
(umhos/cm) to dS/m = (umhos/cm) x (0.001) = ____________ dS/m (or mmhos/cm)
dS/m (or mmhos/cm) to (umhos/cm) = dS/m / 0.001 = ____________ umhos/cm
ppm to dS/m = ppm x 0.0017 = ____________ dS/m
dS/m to ppm = dS/m / 0.0017 = ____________ ppm

Table 7: Nitrate and Nitrite Expressions and Conversion Factors for Converting from One Form of Expression to Another

	FORM A		FORM B		
	Nitrogen (N)	Nitrite (NO2)	Nitrate (NO3)	Potassium Nitrate (KNO3)	Sodium Nitrate (NaNO3)
Nitrate-Nitrogen (N)	1.0	3.3	4.4	7.2	6.1
Nitrate (NO3)	0.23	0.74	1.0	1.63	1.37
Nitrite (NO2)	0.3	1.0	1.34	2.2	1.85
Potassium Nitrate(KNO3)	0.14	0.64	0.61	1.0	.84
Sodium Nitrate (NaNO3)	0.16	0.54	0.72	1.2	1.0

To convert Form A to the equivalent amount of Form B, multiply A by the appropriate conversion factor. (Form A X Conversion Factor = Form B)

Examples:
1. 1.0% nitrate-nitrogen (N) X 4.4 = 4.4% nitrate (NO3)
2. 1.0% nitrate (NO3) X 0.23 = 0.23% nitrate-nitrogen (N)
3. 1.0% KNO3 X 0.61 = 0.61% nitrate (NO3)
4. 1.0% KNO3 X 0.14 = 0.14% nitrate-nitrogen (N)

Table 8. Conversions, Equivalents and Abbreviations

To convert Ca to CaCO3 multiply by 2.50
To convert SO4 to S multiply by 0.333
One U.S. gallon of water weighs 8.345 lbs.
One cubic foot of water weighs 62.43 lbs.
One U.S. gallon equals .13368 cubic foot
One kilogram equals 2.2 pounds
One pound equals 454 grams
One ounce equals 28.35 grams
ppm is parts per million
ppb is parts per billion
One part per million is equal to 1 mg/l
One part per million is equal to 1 mg/kg
One part per million is 0.0001 percent
One percent is 10000 parts per million

H. REFERENCES

1. Boyles, S. et al. Livestock and water. North Dakota State University, Extension Service Bulletin #AS-954. June 1988.

2. National Academy of Sciences. Nutrients and toxic substances in water for livestock and poultry. 1974.

3. Kober, J.A. Water: The most limiting nutrient. Agri-Practice 14:39-42. February 1993.

4. Carson, T.L. Water quality for livestock. In Current Veterinary Therapy, Food Animal Practice 3. W.B. Saunders and Co., 1993, pg. 375-377.

5. Water Quality Criteria, 1972. National Academy of Science - National Academy of Engineering, Environmental Study Board, ad hoc Committee on Water Quality Criteria, U.S. Gov't. Printing Office.

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Measuring salinity

Salinity is the accumulation of salt in soil and water. High salt levels can adversely affect plant growth, soil structure, water quality and infrastructure.

High salt levels occur naturally in many parts of the Australian landscape but in many cases have been exacerbated where human activities accelerate the mobilisation and accumulation of salt.

Methods for measuring salinity

It is important to identify saline areas so they can be appropriately managed. There are a range of methods for measuring salinity. Two common ways are by using an electrical conductivity (EC) meter or by measuring how much salt is in a solution of soil or water.

An EC meter measures how much electricity moves through a solution—the saltier the solution, the more electricity moves through it, and the higher the conductivity reading. EC can be easily measured in the field or in a laboratory. A wide range of EC meters are available, ranging in price and size.

Electrical conductivity can be expressed in different units—for soil, EC is measured in dS/m (deci-Siemens/metre), while water is measured in µS/cm (micro-Siemens/centimetre). It is important to always calibrate the EC meter before use.

Another way to detect salinity is by measuring how much salt is in a solution—this measurement is called total dissolved solids (TDS) or total dissolved ions (TDI). It is measured in units of mg/l (milligrams/litre) or ppm (parts per million). Higher readings mean more salt is present in the solution.

Measuring salinity in water

Salinity in surface water and groundwater can be easily measured in the field by collecting a water sample, inserting an EC probe into the sample and reading the value shown on the meter.

Alternatively, a water sample can be collected and forwarded to a laboratory for testing of salinity and chemical composition. The container should be entirely filled with the water sample to exclude air. Samples for laboratory analysis should be forwarded as quickly as possible. Delays and high temperatures will change the composition of salts in the sample, affecting the results. Typical salinity values for water are given in Table 1.

Measuring salinity in soil

EC is usually measured in the field using a 1:5 soil:water suspension ($EC_{1:5}$), or in a laboratory using a soil saturation extract EC (EC_{se}) or a 1:5 solution.

To measure $EC_{1:5}$ in the field, put approximately 10ml of distilled water, rainwater or tank water into a jar, container or tube. Add small soil particles until the contents of the container increase by 5ml to bring the volume to 15ml. Add additional water to bring the total volume to 30ml. Shake intermittently for five minutes and allow it to settle for five minutes. Dip an EC probe into the solution and take a reading. Remember to wash the EC probe after using it.

The interpretation of EC values to determine soil salinity levels depends on the texture of the soil. Salts are readily dissolved out of sandy soils whereas salts are more tightly held by clay soils. This means that the same amount of salt will have a greater impact on sandy soils then it will on clay soils. As a guide, sandy or loamy soils are moderately saline if $EC_{1:5}$ is above 0.3 dS/m, and clay soils are moderately saline if $EC_{1:5}$ is above 0.6 dS/m.

As the $EC_{1:5}$ is measured on a diluted sample, a more realistic measurement of the actual salt levels that a plant will encounter can be measured on a saturated extract (EC_{se}). This can be done by some laboratories. As a guide, soils are generally considered saline if their EC_{se} is greater than 2–4 dS/m.

Salinity tolerance ratings for soils are usually based on EC_{se} values, rather than $EC_{1:5}$. To convert $EC_{1:5}$ to EC_{se}, identify the texture of the soil, and use the following guide:

Soil type	Multiply $EC_{1:5}$ by
Sand	23
Sandy loam	14
Loam	10
Clay loam	9
Light clay	7.5
Heavy clay	6

For example, sand with an $EC_{1:5}$ of 0.3 dS/m is equivalent to an EC_{se} of 6.9 dS/m, while a heavy clay with an $EC_{1:5}$ of 0.3 dS/m is equivalent to an EC_{se} of 1.8 dS/m. Soil salinity classes are shown in Table 2.

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Table 1. Guide to typical salinity limits for waters. It is important to also check other water quality parameters (e.g. chemical composition, sodium absorption ratio, metals etc) before use.

		Electrical Conductivity (EC) (µS/cm)	(dS/m)	TDS (mg/l or ppm)
Distilled water		1	0.001	0.67
Rainfall		30	0.03	20
Sewage effluent		840	0.84	565
Freshwater		0–1500	0–1.5	0–1000
Great Artesian Basin water		700–1000	0.7–1.0	470–670
Brackish water		1500–15 000	1.5–15	1000–10 050
Upper limit recommended for drinking		1600	1.6	1070
Tolerances of livestock to salinity in drinking water (at these values, animals may have an initial reluctance to drink, but stock should adapt without loss of production)	Beef cattle	5970–7460	5.9–7.5	4000–5000
	Dairy cattle	3730–5970	3.7–5.9	2500–4000
	Sheep	7460–14 925	7.5–14.9	5000–10 000
	Horses	5970–8955	5.9–8.9	4000–6000
	Pigs	5970–8955	5.9–8.9	4000–6000
	Poultry	2985–4475	2.9–4.4	2000–3000
General limits for irrigation	Salt sensitive crops	650	0.65	435
	Moderately salt sensitive crops	1300	1.3	870
	Salt tolerant crops	5200	5.2	3485
	Generally too saline for crops	8100	8.1	5430
Salt water swimming pool		5970–8955	5.9–8.9	4000–6000
Seawater		55 000	55	36 850
Dead Sea		110 000	110	73 700

Note: To convert from µS/cm to dS/m, divide by 1000. To approximately convert from µS/cm to mg/l, multiply by 0.67.

Table 2. Approximate soil salinity classes.

Salinity Rating	EC_{se} (dS/m)	
Slightly saline	1.5–2	Salinity effects usually minimal
Moderately saline	2–6	Yield of salt sensitive plants restricted
Highly saline	6–15	Only salt tolerant plants yield satisfactorily
Extremely saline	>15	Few salt tolerant plants yield satisfactorily

Salinity tolerance of crops

As a general guide, salt tolerant crops include barley, canola, cotton, beetroot, soybean, wheat, olives and sorghum. Moderately salt tolerant crops include lucerne, tomato, cabbage, potato and carrots. Low salt tolerant crops include maize, sugar cane, celery, lettuce and pumpkin.

References

The information in this fact sheet came from the following references:

- ANZECC (2000). Australian and New Zealand Guidelines for Fresh and Marine Water Quality. ANZECC and ARMCANZ.
- Charman PEV and Murphy BW (2007). Soils: Their Properties and Management, 3rd Edition. Oxford University Press, South Melbourne.
- Foth HD (1990). Fundamentals of Soil Science, 8th Edition. John Wiley & Sons, New York, USA.
- Price G (ed) (2006). Australian Soil Fertility Manual, 3rd Edition. CSIRO Publishing and Fertilizer Industry Federation of Australia, Collingwood.
- Salcon (1997). Salinity Management Handbook. Department of Natural Resources, Indooroopilly.

Further information

For more information on salinity, refer to the *Salinity Management Handbook*—available from the NRW Service Centre – phone 07 3896 3216—or visit the NRW website <www.nrw.qld.gov.au>.

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Issue Paper – Total Dissolved Solids (TDS)

I. Background

The TDS is a measure of all constituents dissolved in water. The principal inorganic anions dissolved in water include carbonates, chlorides, sulfates and nitrates. The principal cations are sodium, potassium, calcium and magnesium.

The current Iowa water quality standard for Total Dissolved Solid (TSD) was developed in the 70's and is stated in IAC [567] Chapter 61.3(2)g *General water quality criteria* as follows:

"Total dissolved solids shall not exceed 750 mg/l in any lake or impoundment or in any stream with a flow rate equal to or greater than three times the flow rate of upstream point source discharges."

Several NPDES permittees have noted that Iowa's long standing Total Dissolved Solids (TDS) numerical criteria of 750 mg/l is inconsistent with current toxicity information. This criterion is listed as one of the General Water Quality Criteria that are applicable to all waters. Data that provided by a Permittee indicates that warm water aquatic species are tolerant of a more relaxed TDS level.

The triennial review of the TDS criteria would address the issue and also include the implementation methodology for wasteload allocations.

II. Site-Specific Toxicity Data for TDS

IPSCO Steel Inc. provided the toxicity testing for Fathead minnow (*Pimephales promelas)* and Ceriodaphnia (*Ceriodaphnia dubia)* to IDNR on March 14, 1996. The facility was planning to collect the treated process wastewater and storm water in a detention pond and then discharge into Comrie Creek, a tributary of the Mississippi River. In order to determine the maximum level of effluent TDS that would potentially be acceptable from an aquatic acute toxicity standpoint, acute toxicity tests were conducted. Since the facility was under construction during that time and no wastewater was being generated, a simulated effluent from the process wastewater systems in conformance with the guidelines established by the IDNR standard Operating Procedure for Effluent Toxicity Testing was used. A 48-hour toxicity testing on the indicator species were conducted. The acute toxicity testing indicated that the LC50 response level to the TDS for Fathead minnow is between 5000 mg/l and 7000 mg/l. The LC50 response level to the TDS for Ceriodaphnia was between 2500 mg/l and 3000 mg/l.

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III. TDS Information from Different Sources

All species of fish and other aquatic life must tolerate a range of dissolved solids concentrations in order to survive under natural conditions. According to the redbook of EPA (Quality Criteria for Water, 1976), studies have shown that lakes with dissolved solids in excess of 15,000 mg/l were unsuitable for most freshwater fishes.

It has also been reported that for livestock, 3000 mg/l of TDS should be satisfactory for animal consumption under most circumstances.

The report that IPSCO Steel Inc. submitted to IDNR included some TDS testing information on different freshwater fishes and other organisms. Table 1 presents the information on certain species that also present in Iowa streams.

Table 1. Toxicity Test Data on Certain Species based on Literature

Organisms	**Concentration (mg/L)**	**Reported Effect**
Daphnia magna	9,500-11,500	96-hr LC50
Hyalella azteca	11,500	96-hr LC50
Bigmouth buffalo Emerging fry	9,000	Upper tolerance limit
Black buffalo Emerging fry	9,000	Upper tolerance limit
Channel catfish	14,000	Upper tolerance limit
Black bullhead	8,000 10,000	Median toxicity threshold in NaCl Probable lethal limit
Yellow perch	11,500	No adverse effects
Fathead minnow	6,000-7,000 5,300-5,900	Acutely lethal 96-hr LC50
Green Sunfish	10,700 20,000	Median toxicity threshold in NaCl Lethal
Bluegill	11,900	Lethal limit
Golden Shiner	5,600	Upper tolerance limit
Common Carp	12,000 18,500-19,000	No observed effect Upper tolerance limit
Beef cattle	10,000	Safe upper limit
Dairy cattle	7,150	Safe upper limit
Poultry	2,860	Safe upper limit

IV. TDS Criteria in Other States

1. Kansas

(1) Domestic Water Supply:

Chloride – 250 mg/l
Sulfate – 250 mg/l

(2) Aquatic Life Use:

Chloride – 860 mg/l (Acute)

(3) Agricultural Livestock Use:
Sulfate – 1000 mg/l

2. Missouri

(1) Drinking Water Use:

Chloride – 250 mg/l
Sulfate – 250 mg/l

(2) Protection of Aquatic Life:

Chloride – 860 mg/l (Acute), 230 mg/l (Chronic)

3. Nebraska

(1) Drinking Water Use

Chloride: 250 mg/l
Sulfate: 250 mg/l
TDS: 500 mg/l

(2) Agricultural Use

Conductivity: 2,000 μmho/cm between April 1 and September 30 (equivalent to TDS of 1280 – 1400 mg/l).
NO3 and NO2 as Nitrogen: not to exceed 100 mg/l
Selenium: not to exceed 0.02 mg/l

3. Illinois

(1) General Water Quality Standards:

Chloride – 500 mg/l
Sulfate – 500 mg/l
TDS – 1000 mg/l

(2) Public and Food Processing Water Supply Standards

Chloride – 250 mg/l
Sulfate – 250 mg/l
TDS – 500 mg/l

(3) Secondary Contact and Indigenous Aquatic Life Standards:

TDS – 1500 mg/l.

4. State of Pennsylvania

For Public Water Supply use, the TDS, chloride and sulfate water quality standards are:

Parameters	Monthly Average	Daily Maximum
TDS	500	750
Chloride	-	250
Sulfate	-	250

These standards **<u>only</u>** apply to public water supply uses.

Most States have a TDS criterion of 500 mg/l for domestic drinking water supply, and chloride and sulfate range from 200 to 250 mg/l for domestic water supply. For aquatic life, the values range from 250 mg/l to 2500 mg/l. Some states limit the TDS concentration not exceeding 133% of ambient stream concentration. Some States do not have any specific numeric criteria for TDS.

V. Discussion of TDS as a Water Quality Parameter

Some studies (Mount et al., 1997) indicated that aquatic organisms respond differently to different TDS compositions. Mount et al. (1997) also demonstrated that relative ion toxicity was in the order of $K^+ > HCO_3^- \approx Mg^{2+} > Cl^- > SO_4^{2-}$. EPA's chloride criteria document (1988) indicated that when compared on the basis of chloride, the chlorides of potassium, calcium, and magnesium are generally more acutely toxic to aquatic animals than sodium chloride. Thus, the toxicity of TDS may vary depending on the specific constituent compositions of the TDS in the effluent. The same problems would relate to the effects of TDS on livestock. However, there is still a lack of sufficient research data required to quantify the potential effects of all the different constituents of TDS.

VI. Agricultural Uses: TDS and Individual Ions

A. Livestock Watering

Both the US and Canada have developed "Guides to the Use of Saline Waters for Livestock Watering." The Canadian Task Force on Water Quality (1987) published both a Summary – Guidelines for Livestock Drinking Water Quality and a Guide to Use of Saline Water for Livestock Watering. They are listed as follows:

Table 2. Summary – Guidelines for Livestock Drinking Water Quality

Parameter	Guidelines (mg/l)
Major Ions and Nutrients	
Calcium	1000
Nitrate plus nitrite	100
Nitrite alone	10
Sulfate	1000
TDS	3000

The National Academy of Sciences (1974) published a Guide to the Use of Saline Waters for Livestock and Poultry. It states that "if the TDS is between 1000 – 2999 mg/l, the waters should be satisfactory for all classes of livestock and poultry. They may cause temporary and mild diarrhea in livestock not accustomed to them or watery droppings in poultry, but should not affect their health or performance."

The web site of "Manitoba Agriculture and Food" pointed out an upper limit of 300 – 400 mg/l of magnesium has been suggested for dairy cows. For sodium, water with over 800 mg sodium/l can cause diarrhea and a drop in milk production in dairy cows.

The EPA's "Quality Criteria for Water" (1976) stated that chickens, swine, cattle, and sheep can survive on saline waters up to 15,000 mg/l salts of sodium and calcium combined with bicarbonates, chlorides, and sulfates but only 10,000 mg/l of corresponding salts of potassium and magnesium. The approximate limit for highly alkaline waters containing sodium and calcium carbonates is 5,000 mg/l.

Rodenburg (1989) indicated that routine water analysis for livestock use should include TDS, sodium, magnesium, calcium, sulfate, nitrate, iron and pH. Rodenburg (1989) also pointed out that studies demonstrate that magnesium, sodium, and sulfate are toxic at lower levels than calcium, chloride or bicarbonate, and that there will be highly variable response to water of 1000 to 5000 mg/l TDS, depending on which ions dominate. He provided the water quality criteria for dairy cattle. The following table lists the major ion criteria for dairy cattle based on Rodenburg (1989).

Table 3. Water Quality Criteria for Dairy Cattle

Ions	Max. Recommended Concentration (mg/l)
Sulfate	1000
Magnesium	800
Sodium	800
Calcium (dry cows & growing bulls)	1000
Calcium (milking cows & heifers)	2000
Nitrate-N	100

Most of the studies on TDS are based on sodium chloride constituent. Different studies recommended different safe values of sodium chloride for livestock uses. The National Academy of Sciences (1974) reported the safe sodium chloride value for cattle as 10,000 mg/l. And Jaster et al (1978) reported that the safe sodium chloride value for dairy cows were 2500 – 3500 mg/l. Some studies indicated that for poultry the safe sodium chloride value was 3000 mg/l.

To summarize the status of the current studies of TDS toxicity on aquatic life and livestock, it is recognized that the toxicity of TDS may vary depending on the specific constituent compositions of the TDS in the effluent. However, there are a lot of uncertainties about the potential effects of all the different constituents of TDS. Based on limited studies on TDS and the individual ions, the following water quality criteria should meet the livestock uses.

Table 4. Recommended Water Quality Criteria for Livestock Uses

Ions	Recommended Criteria for Livestock Uses (mg/l)
Calcium	1000
Magnesium	800
Sodium	800
Sulfate	1000
Nitrate+Nitrite-N	100

B. Irrigation Water Uses

Peterson (1999) pointed out that TDS levels below 700 mg/l are considered safe; TDS between 700 mg/l and 1,750 mg/l are considered possibly safe, while levels above these levels are considered hazardous to any crop. Peterson (1999) also listed the tolerance of selected crops to TDS in irrigation water, for example, corn as *slightly tolerant* (TDS < 800 mg/l) and soybean as *very tolerant* (TDS < 3500 mg/l). However, as long as the TDS concentration is less than 2,800 mg/l, no reduction in crop yield for moderately sensitive crops including corns and soybeans (Peterson, 1999). Generally forage crops are the most resistant to salinity, followed by field crops, vegetable crops, and fruit crops which are generally the most sensitive.

Irrigation water containing large amounts of sodium is of special concern due to sodium's effects on the soil structure. Crops grown on soil having an imbalance of calcium and magnesium may also exhibit toxic symptoms. Sulfate salts affect sensitive crops by limiting the uptake of calcium and increasing the adsorption of sodium and potassium, resulting in a disturbance in the cationic balance within the plant. The bicarbonate ion in soil solution harms the mineral nutrition of the plant through its effects on the uptake and metabolism of nutrients. High concentrations of potassium may introduce a magnesium deficiency and iron chlorosis. An imbalance of magnesium may be toxic, but the effects of both can be reduced by high calcium levels. The Surface Water Quality Objectives published by Saskatchewan Environment and Resource Management in August 1997 listed corn as one of the *moderately tolerant* plant to sodium and chloride. The tolerance concentration to chloride and sodium in irrigation water for corns are Chloride (335 – 710mg/l) and Sodium (230 – 460mg/l). Also, Mills (2001) provided the following toxicity values for chloride, iron and NO3 to plants.

Table 5. Toxicity Data for Chloride, Iron and NO3 in Irrigation water

Chloride Ion Conc.	Suitability for Irrigation
< 350 mg/l	Suitable all crops
350 – 700 mg/l	Suitable for high, medium and low salt tolerant crops
700 – 900 mg/l	Suitable for high and medium salt tolerance crops
900 – 1300 mg/l	Suitable for high salt tolerant crops only.
Greater than 1300 mg/l	Too saline for irrigation of any crops
Iron	< 1 mg/l
NO3	<133 mg/l

Since corn is *moderately tolerant* to chloride, it should be able to tolerate 700 – 900 mg/l of chloride concentration. Some studies have shown that for surface irrigation, most tree crops and woody plants are sensitive to sodium and chloride, while most annual crops are not sensitive ("Water Quality and Crop Production").

To summarize the water quality requirement for irrigation uses, the following criteria should apply:

Table 6. Water Quality Criteria for Irrigation Uses

Ions	Criteria for Irrigation Uses (mg/l)
Chloride	900
NO3	<133 mg/l

However, at the Technical Advisory Committee meeting on March 21, 2003, the committee members agreed to drop the chloride value of 900 mg/l for irrigation uses at this time because of lack of sufficient information. The IDNR and the committee could visit the issue later when new information becomes available.

VI. Proposed Ion Criteria for Iowa

Based on the literature review and the recommendations by WQS Technical Advisory Committee, the Department proposes the following ion criteria and approach for the protection of both the agricultural use and the aquatic life use.

1. Protection of Agricultural Uses

(1) Ion Criteria Values

Table 7. Recommended Water Quality Criteria for Agricultural Uses

Ions	Recommended Criteria for Livestock Uses (mg/l)
Calcium	1000
Magnesium	800
Sodium	800
Sulfate	1000
Nitrate+Nitrite-N	100

On March 21, 2003, the TAC members agreed that the above ion criteria values should be included in the Support Document for implementation since these numbers are based on guidelines for livestock uses not criteria-based toxicity tests.

(2) Implementation

The ion criteria values shown in Table 7 should be applied at the end-of-pipe in general use waters, and at the end of the mixing zone in designated waters.

2. Protection of Aquatic Life Uses

The Technical Advisory Committee on the March 21th meeting agreed that in order to protect the aquatic life uses, Whole Effluent Toxicity (WET) test of TDS is required **whenever the facility requests for a permit renewal every five years**. The facility also needs to measure the ion constituents in the effluent at the same time. The following table lists the parameters need to be included in the specific ion constituent test.

Table 8. Ion Constituents Tested in the WET Test

Ions
TDS
Calcium
Potassium
Magnesium
Sodium
Sulfate
Ion
Nitrate+Nitrite-N

If the effluent discharges into a general use stream, 100% of the effluent should be used in the WET test. If the effluent discharges directly into a designated stream, a 2.5% of the stream 7Q10 flow is allowed for dilution in the WET test. The WET test should follow the EPA published manual of "*Methods for Measuring the Acute Toxicity of Effluents and Receiving Waters to Freshwater and Marine Organisms*" adopted as final rule on November 19, 2002. And the WET test should be performed for two freshwater organisms: *fathead minnows* and *Ceriodaphnia dubia.*

In conclusion, all Waters of the State should meet the above requirements to protect both the agricultural and aquatic life uses.

VIII. Proposed Rule Changes: reserved for future.

References

Birge, W. J., J.A. Black, A.G. Westerman, T.M. Short, S.B. Taylor, D.M. Bruser, and E.D. Wallingford. 1985. Recommendations on numerical values for regulating iron and chloride concentrations for the purpose of protecting warmwater species of aquatic life in the commonwealth of Kentucky. University of Kentucky, Lexington, K.Y.

Jaster, E.H., J.D. Schuh, and T.N. Wegner. 1978. Physiological Effects of Saline Drinking Water on High Producing Dairy Cows. Journal of Dairy Science. Vol. 61:66.

Mills, B. Interpreting Water Analysis for Crop and Pasture. March 2001. Farming Systems Institute, Toowoomba.

Mount, David R., et al. 1997. Statistical models to predict the toxicity of major ions to Ceriodaphnia Dubia, Daphnia Magna and Pimephales Promelas (Fathead Minnows). Environmental Toxicology and Chemistry. Vol. 16:10, pp. 2009-2019.

Peterson, H.G. Irrigation and Salinity. 1999. WateResearch Corp. and Agriculture and Agri-Food Canada-Prairie Farm Rehabilitation Administration.

Rodenburg, J. Practical Water Evaluation for Dairy Cattle. Ontario Ministry of Agriculture & Food, Woodstock, Ontario, Canada.

The Task Force on Water Quality Guidelines of the Canadian Council of Resource and Environmental Ministers. March 1987. Canadian water quality guidelines.

U.S. EPA. Quality Criteria for Water. July 1976. Office of Water and Hazardous Materials, Washington, D.C. 20460.

U.S. EPA. 1988. Ambient water quality criteria for Chloride. Office of Water Regulations and Standards, Washington, D.C. 20460.

Appendix A: Ion Concentration Comparison
(surface water vs. groundwater vs. industrial discharge)

Table A1. Surface and Groundwater Ion Concentrations

	Groundwater (70 stations-2000 water year)	Des Moines R. at Des Moines	Missouri R. @ Omaha	Mississippi River@ Clinton	WAPSIPINICON River@ TRIPOLI	IOWA River@Rc
TDS	555	422	522.9	230.6	249	411.8
Hardness as CaCo3	356		270	163.	--	--
Ca	89	77.2	66.3	38.9	51.0	83.6
Mg	29	27.8	25.4	15.7	11.7	26.5
K	4	2.8	7.0	2.61	2.0	2.6
Na	32	17.8	55.7	9.15	9.7	9.5
CO3 as CaCo3	--	--	1.0	1.00	0	0.6
HCO3 as CaCo3	--	--	199.3	170.	155	282
Chloride	22	33.2	14.8	13.98	21.4	19.9
Sulfate	106	77.5	197.6	25.92	21.5	42.3
NO3	5	7.5	1.5	1.80	5.3	7.1

The following shows a few sample industrial discharge characteristics:

Table A2. ADM – Des Moines Discharge Characteristics

Parameter	Month	Effluent Concentration (mg/l)	Des Moines River Concentration (mg/l)
TDS	9/02	443	400
	8/02	544	380
	7/02	645	380
	6/02	593	400
	5/02	322	390
	4/02	418	480
	3/02	705	470
	2/02	716	540
	1/02	640	550
	12/01	464	380
	11/01	420	340
	10/01	334	350

Table A3. Siouxland Ethanol Facility, Sioux Center, Sioux County, IA

Parameters	Raw Groundwater	RO Reject Water	Surface Water (Tributary)
TDS	2113	7288	703 (Big Sioux data)
Ca	305	1033	129
Mg	138	458	58
K	0	0	1.5
Na	148	485	20

Cl	23	131	35
SO4	1420	4716	107
NO3	10	30	128
HCO3	155	412	NA

Table A4. Midwest Grain Processors in Kossuth County

Parameters	Groundwater Source (mg/l)	Tower Blowdown Effluent
TDS	878	3020
Ca		136
Mg		194
K		0
Na		222
Iron		0.588
Cl		14.6
SO4		1510

Table A5. Little Sioux Ethanol: Simulated Blowdown

Parameters	Tower Blowdown Effluent
TDS	3240 as CaCO3
Ca	637.5
Mg	184.8
K	32.5
Na	297
Iron	1.3
Cl	26.9
SO4	2265

UNITED STATES
ENVIRONMENTAL PROTECTION AGENCY
REGION 6
DALLAS, TEXAS

08 JUN [illegible]
REGIONAL HEARING CLERK
EPA REGION VI

In the Matter of:	)	
	)	
Altec Petroleum Group, Inc.,	)	Docket No. CWA-06-2008-1832
	)	
Respondent.	)	

SCHEDULING ORDER

This action, initiated by the Complainant, the Director of the Compliance Assurance and Enforcement Division, United States Environmental Protection Agency Region 6 ("EPA"), seeks to assess a Class I administrative penalty under Section 309(g) of the Clean Water Act, 33 U.S.C. § 1319(g). Class I penalty actions are governed by procedures set forth in the revised rules for non-Administrative Procedures Act (non-APA) cases. *See* 40 C.F.R. Part 22, Subpart I. I have been assigned to act as Presiding Officer in this case.

Complainant filed the Administrative Complaint ("Complaint") in this action on May 20, 2008. A request by Respondent Altec Petroleum Group, Inc., for a hearing in this matter was filed with the Regional Hearing Clerk on June 26, 2008.

THEREFORE, IT IS ORDERED:

1. If the parties have not discussed the possibility of settlement of this matter prior to the date of this Order, the parties shall confer regarding the possibility of settlement of this matter on or before **<u>July 23, 2008</u>**. This conference may be in person or by telephone.

2. On or before **<u>July 30, 2008</u>**, the parties shall file a report on the status of settlement negotiations in this matter (without disclosing the substance of settlement negotiations), including, at a minimum, the date and outcome of the settlement conference ordered in paragraph 1 above, a summary of other contacts between the parties regarding this case, an assessment of whether settlement of this matter is likely or if negotiations are at an impasse, a statement of whether a settlement in principle has been reached, and, if applicable, a projected date for the filing of a consent agreement and final order. If the parties cannot agree on a joint status report, they shall file separate reports.

3. On or before **<u>July 30, 2008</u>**, Respondent shall file an answer to the Complaint, as described in 40 C.F.R. § 22.15, which responds paragraph by paragraph to the Complaint, clearly and directly admitting, denying, or explaining each of the

GOVERNMENT EXHIBIT 33

factual allegations in the Complaint with regard to which the Respondent has any knowledge. Where Respondent has no knowledge of a particular factual allegation and so states, the allegation will be deemed to be denied. The answer shall also set out the circumstances or arguments which are alleged to constitute the grounds of any defense. Failure of Respondent to admit, deny, or explain any material factual allegation contained in the Complaint will be deemed an admission of the allegation.

4. Both Complainant and Respondent shall submit a prehearing exchange, as provided for in 40 C.F.R. §§ 22.52 and 22.19(a), for use at the hearing to be held in this matter. The prehearing exchange shall be **filed** no later than **August 26, 2008**. This submission, at a minimum, shall include:

a.) The name of each witness, including experts, each party intends to present at the hearing, as well as a brief description of the witness' connection to the case, the witness' qualifications (in the case of an expert witness), and a narrative of the witness' expected testimony. If the Respondent does not plan to call any witnesses (and thus rely solely on cross-examination of the Complainant's witnesses), Respondent must affirmatively state that it does not plan to call any witnesses at the hearing.

b.) A statement as to whether any witness will need an interpreter in order to testify, and, if so, what language.

c.) A statement as to whether any special accommodations under the Americans with Disabilities Act are needed for counsel or any witness or party representative.

d.) Copies of exhibits (including an index of the exhibits) intended for introduction into evidence at the hearing. The documents shall be submitted as part of the prehearing exchange even if they previously have been filed with the Regional Hearing Clerk. The exhibits shall include a resume or curriculum vitae for each proposed expert witness. If the Respondent does not plan to introduce any exhibits into evidence, Respondent must affirmatively state that it does not plan to introduce any exhibits into evidence at the hearing.

The exhibits shall be identified as "Complainant's" or "Respondent's" exhibit, as appropriate, and numbered with Arabic numerals (e.g., "Complainant's Ex. 1").

Documents used solely for purposes of impeachment do not have to by included.

e.) A statement of the party's estimate of how long it will take to put on its case.

f.) A statement of the party's position regarding the location of the hearing, keeping in mind that the rules provide that the hearing shall be held in the county where the Respondent resides or conducts the business which the hearing concerns, in the city in which the relevant Environmental Protection Agency Regional Office is located, or in Washington, D.C., unless the Presiding Officer determines that there is good cause to hold it in another location. 40 C.F.R. §§ 22.21(d) and 22.19(d).

g.) The Complainant shall provide an explanation of how its proposed penalty was calculated in accordance with the criteria set forth in the Clean Water Act.

h.) The Respondent shall provide an explanation of why the proposed penalty should be mitigated or eliminated.

5. Any response by a party to the prehearing exchange filed by the other party shall be filed not later than **September 12, 2008**.

6. The parties shall participate in a prehearing conference with the Presiding Officer on **September 23, 2008, beginning at 2:00 p.m. central time**. The parties should be prepared to address the matters identified in 40 C.F.R. § 22.19(b) during the conference. The conference will be conducted by telephone. Each party shall join the call by calling the following **dial-in number: 866-299-3188**. At the prompt, enter **conference code 214-665-2143, followed by the # sign**. If a party encounters problems connecting to the call, the customer service number for the conference call is: 888-876-3081.

Failure by the Complainant or the Respondent to comply with the prehearing exchange requirements or to appear for the prehearing conference may result in that party being found in default. 40 C.F.R. § 22.17(a). Failure by a party to list witnesses or submit documents as part of the information exchange may result in exclusion of those witnesses from testifying or the documents not being admitted into evidence. 40 C.F.R. §§ 22.19(a) and 22.22(a).

The Complainant's or the Respondent's failure to comply with any part of this Order may result in any sanction authorized by 40 C.F.R. Part 22.

SO ORDERED, this 30th day of June 2008.

MICHAEL C. BARRA
REGIONAL JUDICIAL OFFICER

CERTIFICATE OF SERVICE

I, Lorena S. Vaughn, the Regional Hearing Clerk for the Region 6 office of the Environmental Protection Agency, do hereby certify that a TRUE AND CORRECT copy of the Scheduling Order CWA 06-2008-1832 as served upon the parties on the date and in the manner set forth below:

Patrick S. Adams
President
Altec Testing & Engineering, Inc.
6035 Fremont Street
Riverside, CA 92504

U.S. First Class Mail
Return Receipt Requested

Lorraine Dixon
Assistant Regional Counsel
Environmental Protection Agency
1445 Ross Avenue
Dallas, Texas 75202

HAND-DELIVERED

DATE: 6-30-08

Lorena S. Vaughn
Regional Hearing Clerk

08 JUL 23 AM 10:27
REGIONAL HEARING CLERK
EPA REGION VI

UNITED STATES

ENVIRONMENTAL PROTECTION AGENCY
REGION 6
DALLAS, TEXAS

In the Matter of:	)	
	)	
Altec Petroleum Group, Inc.	)	**Docket No. CWA-06-2008-1832**
	)	
	)	

JOINT STATUS REPORT

COMES NOW COMPLAIANT, Director of the Compliance Assurance and Enforcement Division, the United States Environmental Protection Agency, Region 6, by and through its attorney, Lorraine Dixon and Respondent, Altec Petroleum Group and files this Joint Status Report pursuant to the Court's June 30, 2008 Order.

Complainant and Respondent met on June 17, 2008, via telephone conference to discuss the above referenced case and options for resolution. Although a settlement was not reached Complainant and Respondent believe that the meeting was productive and that a settlement in this matter is highly likely. Thus, Complainant and Respondent request a thirty day extension of time to file their pre-hearing exchange so that settlement discussions may continue.

Respectfully submitted,

Lorraine Dixon

cc: Patrick S. Adams
President
Altec Testing & Engineering, Inc.
6035 Fremont Street
Riverside, CA 92504

GOVERNMENT EXHIBIT 34

CERTIFICATE OF SERVICE

I hereby certify that the original and one copy of the foregoing JOINT STATUS REPORT was filed with the Regional Hearing Clerk, EPA Region 6, 1445 Ross Avenue, Dallas, Texas 75202, and that a true copy of the same was sent by Certified Mail, Return Receipt Requested to:

Mr. Patrick Adams
President
Altec Testing & Engineering
6035 Fremont Street
Riverside, CA 92504

7-23-06
Date

Lorraine Dixon

UNITED STATES
ENVIRONMENTAL PROTECTION AGENCY
REGION 6
DALLAS, TEXAS

08 JUL 31 PM 3:12
REGIONAL HEARING CLERK
EPA REGION VI

In the Matter of:	)	
	)	
Altec Petroleum Group, Inc.,	)	Docket No. CWA-06-2008-1832
	)	
Respondent.	)	

FIRST AMENDED SCHEDULING ORDER

This action, initiated by the Complainant, the Director of the Compliance Assurance and Enforcement Division, United States Environmental Protection Agency Region 6 ("EPA"), seeks to assess a Class I administrative penalty under Section 309(g) of the Clean Water Act, 33 U.S.C. § 1319(g). Class I penalty actions are governed by procedures set forth in the revised rules for non-Administrative Procedures Act (non-APA) cases. *See* 40 C.F.R. Part 22, Subpart I. I have been assigned to act as Presiding Officer in this case.

Complainant filed the Administrative Complaint ("Complaint") in this action on May 20, 2008. A request by Respondent Altec Petroleum Group, Inc., for a hearing in this matter was filed with the Regional Hearing Clerk on June 26, 2008. A Scheduling Order for this case was filed on June 30, 2008, which, among other things required the parties to confer regarding the possibility of settlement and to report on the status of their settlement negotiation. As required by the Scheduling Order, the parties filed a Joint Status Report on July 23, 2008. In their report, they stated that they had conferred regarding settlement, that settlement had not been reached, but the parties believe that settlement of the matter is likely. Based on their assessment of the prospects for settlement, the parties requested an extension of the deadline for filing prehearing exchanges.

THEREFORE, FOR GOOD CAUSE SHOWN, IT IS ORDERED:

1. Both Complainant and Respondent shall submit a prehearing exchange, as provided for in 40 C.F.R. §§ 22.52 and 22.19(a), for use at the hearing to be held in this matter. The prehearing exchange shall be **filed** no later than **September 26, 2008**. This submission, at a minimum, shall include:

   a.) The name of each witness, including experts, each party intends to present at the hearing, as well as a brief description of the witness' connection to the case, the witness' qualifications (in the case of an expert witness), and a narrative of the witness' expected testimony. If the Respondent does not plan to call any witnesses (and thus rely solely on cross-examination of the Complainant's witnesses), Respondent must affirmatively state that it does not plan to call any witnesses at the hearing.

b.) A statement as to whether any witness will need an interpreter in order to testify, and, if so, what language.

c.) A statement as to whether any special accommodations under the Americans with Disabilities Act are needed for counsel or any witness or party representative.

d.) Copies of exhibits (including an index of the exhibits) intended for introduction into evidence at the hearing. The documents shall be submitted as part of the prehearing exchange even if they previously have been filed with the Regional Hearing Clerk. The exhibits shall include a resume or curriculum vitae for each proposed expert witness. If the Respondent does not plan to introduce any exhibits into evidence, Respondent must affirmatively state that it does not plan to introduce any exhibits into evidence at the hearing.

The exhibits shall be identified as "Complainant's" or "Respondent's" exhibit, as appropriate, and numbered with Arabic numerals (e.g., "Complainant's Ex. 1").

Documents used solely for purposes of impeachment do not have to by included.

e.) A statement of the party's estimate of how long it will take to put on its case.

f.) A statement of the party's position regarding the location of the hearing, keeping in mind that the rules provide that the hearing shall be held in the county where the Respondent resides or conducts the business which the hearing concerns, in the city in which the relevant Environmental Protection Agency Regional Office is located, or in Washington, D.C., unless the Presiding Officer determines that there is good cause to hold it in another location. 40 C.F.R. §§ 22.21(d) and 22.19(d).

g.) The Complainant shall provide an explanation of how its proposed penalty was calculated in accordance with the criteria set forth in the Clean Water Act.

h.) The Respondent shall provide an explanation of why the proposed penalty should be mitigated or eliminated.

2. Any response by a party to the prehearing exchange filed by the other party shall be filed not later than **October 17, 2008**.

3. The parties shall participate in a prehearing conference with the Presiding Officer on **October 28, 2008, beginning at 2:00 p.m. central time**. The parties should be prepared to address the matters identified in 40 C.F.R. § 22.19(b) during the

conference. The conference will be conducted by telephone. Each party shall join the call by calling the following **dial-in number: 866-299-3188**. At the prompt, enter **conference code 214-665-2143, followed by the # sign**. If a party encounters problems connecting to the call, the customer service number for the conference call is: 888-876-3081.

Failure by the Complainant or the Respondent to comply with the prehearing exchange requirements or to appear for the prehearing conference may result in that party being found in default. 40 C.F.R. § 22.17(a). Failure by a party to list witnesses or submit documents as part of the information exchange may result in exclusion of those witnesses from testifying or the documents not being admitted into evidence. 40 C.F.R. §§ 22.19(a) and 22.22(a).

The Complainant's or the Respondent's failure to comply with any part of this Order may result in any sanction authorized by 40 C.F.R. Part 22.

SO ORDERED, this 31st day of July 2008.

MICHAEL C. BARRA
REGIONAL JUDICIAL OFFICER

CERTIFICATE OF SERVICE

I, Lorena S. Vaughn, the Regional Hearing Clerk for the Region 6 office of the Environmental Protection Agency, do hereby certify that a TRUE AND CORRECT copy of the First Amended Scheduling Order for CWA 06-2008-1832 as served upon the parties on the date and in the manner set forth below:

Patrick Adams President Altec Testing & Engineering 6035 Fremont Street Riverside, CA 92504	U.S. First Class Mail Return Receipt Requested
Lorraine Dixon Assistant Regional Counsel Environmental Protection Agency 1445 Ross Avenue Dallas, Texas 75202	HAND-DELIVERED

DATE: ______________

____
Lorena S. Vaughn
Regional Hearing Clerk