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AMBIENT AQUATIC LIFE WATER QUALITY CRITERIA FOR

ANILINE

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U.S. ENVIRONMENTAL PROTECTION AGENCY

OFFICE OF WATER
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OFFICE OF RESEARCH AND DEVELOPMENT
ENVIRONMENTAL RESEARCH LABORATORIES
DULUTH, MINNESOTA
NARRAGANSETT, RHODE ISLAND

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 represent maximum acceptable pollutant concentrations in ambient waters within that state that are enforced through issuance of discharge limitations in NPDES permits. 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 modify water quality criteria developed under section 304 to reflect local environmental conditions and human exposure patterns. Alternatively, states may use different data and assumptions than EPA in deriving numeric criteria that are scientifically defensible and protective of designated uses. It is not until their adoption as part of state water quality standards that criteria become regulatory. Guidelines to assist the states and Indian tribes in modifying the criteria presented in this document are contained in the Water Quality Standards Handbook (December 1983). This handbook and additional guidance on the development of water quality standards and other water-related programs of this Agency have been developed by the Office of Water.

This document, if finalized, would be guidance only. It would not establish or affect legal rights or obligations. It would not establish a binding norm and would not be finally determinative of the issues addressed. Agency decisions in any particular situation will be made by applying the Clean Water Act and EPA regulations on the basis of specific facts presented and scientific information then available.

Tudor T. Davies
Director
Office of Science and Technology

ACKNOWLEDGMENTS

Larry T. Brooke
(freshwater author)
University of Wisconsin-Superior
Superior, Wisconsin

David J. Hansen
(saltwater author)
Environmental Research Laboratory
Narragansett, Rhode Island

Robert L. Spehar
(document coordinator)
Environmental Research Laboratory
Duluth, Minnesota

Suzanne M. Lussier
(saltwater coordinator)
Environmental Research Laboratory
Narragansett, Rhode Island

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Introduction

Aniline (aminobenzene, benzenamine, phenylamine) is the simplest of the aromatic amines ($C_6H_5NH_2$). It occurs naturally in coal-tars (Shelford 1917) and is manufactured by the catalytic reduction of nitrobenzene, amination of chlorobenzene and ammonolysis of phenol.

The major users of aniline are the polymer, rubber, agricultural and dye industries. Demand for aniline by the dye industry was high prior to the 1970's but decreased markedly in the United States thereafter because of the increased use of synthetic fabrics. Aniline is used today primarily by the polymer industry to manufacture products such as polyurethanes. The rubber industry uses large amounts of aniline to manufacture antioxidants, antidegradants and vulcanization accelerators. The pharmaceutical industry uses aniline in the manufacture of sulfa drugs and other products. Important agricultural uses for aniline derivatives include herbicides, fungicides, insecticides, repellents and defoliants. Aniline has also been used as an antiknock compound in gasolines (Kirk-Othmer 1982).

Aniline is soluble in water up to 34,000,000 µg/L (Verschueren 197[illegible]). The $\log_{10}$ of the octanol-water partition coefficient for aniline is 0.90 (Chiou 1985a). Through direct disposal, such as industrial discharges and non-point sources associated with agricultural uses, it enters the aquatic environment. It is removed from the aquatic environment by several mechanisms. The major pathway of removal from water is by microbial decomposition (Lyons et al. 1984, 1985). Several minor pathways have been identified including evaporation, binding to humic substances and autoxidation.

Additions to the aniline molecule of certain functional groups have been found to increase toxicity (Brooke et al. 1984; Geiger et al. 1986, 19[illegible]). Tests with the fathead minnow (Pimephales promelas) have demonstrated that substitutions with halogens, (chlorine, fluorine, and bromine) increased toxicity. The addition of alkyl groups also increased toxicity; the toxicity increases in proportion to the increase in chain length. Twenty-four substitutions were tested and all except para additions of methyl and nitro groups increased the toxicity to the fathead minnow.

All concentrations reported herein are expressed as aniline. Results of such intermediate calculations as recalculated LC50's and Species Mean Acute Values are given to four significant figures to prevent round-off error in subsequent calculations, not to reflect the precision of the value. Whenever adequately justified, a national criterion may be replaced by a site-specific criterion (U.S. EPA 1983a) that may include not only site-specific concentrations (U.S. EPA 1983b) but also site-specific frequencies of allowed excursion (U.S. EPA 1985).

A comprehension 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 1985), is necessary to understand the following text, tables, and calculations. The latest comprehensive literature search for information for this document was conducted in September 199[illegible]; some more recent information is included.

Acute toxicity to Aquatic Animals

The data that are available according to the Guidelines concer[illegible] the acute toxicity of aniline are presented in Table 1. Cladocera were the most sensitive group of the 19 species tested. Several species of larva[illegible] and embryos and larvae of the clawed toad, Xenopus laevis, were the [illegible] resistant to aniline in acute exposures. Fish tended to be in the [illegible] of sensitivity for aquatic organisms.

Forty-eight-hour EC50s for the cladocerans Ceriodaphnia dubia [illegible] Daphnia magna were 44 μg/L and 530 μg/L, respectively. Several inde[illegible] exposures conducted with both species showed consistency among the [illegible] (Table 1). However, there appears to be a large increase in tolerance [illegible] aniline between cladocerans and other aquatic species. The 96-hr LC[illegible] next most sensitive species, a planarian, Dugesia tigrina, was 31,[illegible]

Ninety-six-hour LC50s for fish ranged from 10,600 to 187,000 [illegible] rainbow trout (Oncorhyncus mykiss) was the most sensitive species of fish tested, with 96-hr LC50s ranging from 10,600 to 41,000 µg/L. The bluegill (Lepomis macrochirus) was slightly more tolerant of aniline with a 96-hr LC50 of 49,000 µg/L. Fathead minnows, Pimephales promelas, and goldfish, Carassius auratus, were the most tolerant of aniline of the fish species tested. Ninety-six-hour LC50s for tests with fathead minnows ranged from 32,000 to 134,000 µg/L. A 96-hr LC50 for the goldfish was 187,000 µg/L.

Franco et al. (1984) exposed four species of midge larvae to aniline and found them to be the most tolerant of aniline of all species tested. The midge, Clinotanypus pinguis, was the most tolerant of the four species tested; a 48-hr LC50 of 477,900 µg/L was calculated for this species. LC50s for other midge species tested by Franco et al. (1984), ranged downward to 272,100 µg/L. Holcombe et al. (1987) tested another species of midge (Tanytarsus dissimilis) and reported a 48-hr LC50 >219,000 µg/L.

The African clawed frog, Xenopus laevis, was relatively tolerant of aniline. In a series of three tests, Davis et al. (1981) found that embryos of African clawed frogs were more tolerant than the larvae. The 96-hr LC50s for embryos and tailbud embryos were 550,000 and 940,000 µg/L, respectively, compared to 150,000 µg/L for the larvae.

Genus Mean Acute Values (GMAVs) are ranked from most sensitive to most resistant for the nineteen freshwater genera tested (Table 3). The freshwater Final Acute Value (FAV) of 56.97 µg/L was calculated using the GMAVs for the four most sensitive genera, Ceriodaphnia, Daphnia, Dugesia, and Oncorhyncus which differ from one another within a factor of 251. The Final Acute Value is 2.2 times less than the acute value for the most sensitive freshwater species.

The acute toxicity of aniline to resident North American saltwater animals has been determined with five species of invertebrates and three species of fish (Thursby and Berry 1987a, 1987b; Redmond and Scott 1987; Table 1). Grass shrimp, tested as larvae, was the most sensitive species based on an acute value of 610 µg/L. Crustaceans comprised the three most sensitive species tested; acute values ranged from 610 to 16,600 µg/L. Acute values for three fishes, a mollusc and an echinoderm ranged from 17,400 to >333,000 µg/L. Mortalities in acute tests with mysids, grass shrimp, sheepshead minnows and inland silversides increased during 96-hr tests. GMAVs are ranked from the most sensitive to the most resistant (Table 3) for the eight saltwater genera tested. The Final Acute Value for saltwater species is 153.4 µg/L which is four times less than the acute value for the most sensitive saltwater species tested.

Chronic Toxicity to Aquatic Animals

The data that are available according to the Guidelines concerning the chronic toxicity of aniline are presented in Table 2. Four chronic toxicity tests exposing freshwater organisms to aniline have been reported. The cladoceran, *Ceriodaphnia dubia*, was exposed to initial concentrations ranging from 1.07 to 26.5 µg/L for seven days with daily renewed exposures (Spehar 1987). Survival was not significantly affected at any exposure concentration; however, effects on young production were observed at 12.7 µg/L, but not at 8.1 µg/L. The chronic value, based upon reproductive impairment, is 10.1 µg/L. This number may be under-protective since it is based upon initial measured concentrations of aniline and did not take into consideration that the study showed nearly 100% loss of aniline from solution in 24 hr. A companion acute test was conducted with the chronic study and resulted in a 48-hr EC50 of 44 µg/L. Division of this value by the chronic value generates an acute-chronic ratio of 4.356 for *Ceriodaphnia dubia*.

Daphnia magna were exposed to aniline for 21 days in a renewal test (Gersich and Milazzo 1988). Mean concentrations for the exposures ranged from 12.7 to 168.6 µg/L for the five concentrations tested. Mean total young/surviving adult and mean brood size/surviving adult were not significantly different from the control organisms at 24.6 µg/L but were significantly different at 46.7 µg/L. Based upon these two reproduction endpoints, the chronic value is 33.9 µg/L. The companion acute value (48-hr

EC50) used to compute an acute-chronic ratio was 170 µg/L (Gersich and Mayes, 1986). Division of this value by the chronic value of 33.9 µg/L results in an acute-chronic ratio of 5.015.

A 90-day early life-stage test was conducted with rainbow trout (Spehar 1987). The test was started with newly fertilized embryos. After 56 days (swim-up stage), wet weight was significantly reduced at concentrations of 4,000 µg/L and above. After 90 days of exposure, an effect was not seen at 4,000 µg/L but weight was reduced at 7,800 µg/L. Survival was reduced at only the highest exposure concentration (15,900 µg/L). The chronic value for rainbow trout is 5,600 µg/L, based upon growth. Spehar (1987) also conducted a 96-hr acute test which resulted in an acute value of 30,000 µg/L. Division of the acute value by the chronic value generates an acute-chronic ratio of 5.357.

The fathead minnow was exposed to aniline concentrations that ranged from 316 to 2,110 µg/L in 32-day exposures (Russom 1993). Percentage normal fry at hatch and survival at the end of the test did not differ significantly from the control fish at any aniline concentrations. Growth (weight and length) was significantly ($p<0.05$) reduced at aniline concentrations of 735 µg/L and greater, but not at 422 µg/L. Wet weight was reduced by 13.3% and total length by 6.4% compared to control fish wet weight and total length at 735 µg/L. The chronic value for this test, based upon growth, is 557 µg/L. The companion acute test resulted in a 96-hr LC50 of 112,000 µg/L (Geiger et al. 1990). Division of this value by the chronic value results in an acute-chronic ratio of 201.1.

The only chronic toxicity test with aniline and saltwater species was conducted with the mysid, Mysidopsis bahia (Thursby and Berry 1987b). Ninety-five percent of the mysids exposed during a life-cycle test to [illegible] µg/L died and no young were produced by the survivors. Reproduction of mysids in 1,100 µg/L was reduced 94 percent relative to controls. No significant effects were detected on survival, growth, or reproduction in mysids exposed to ≤540 µg/L for 28 days. The chronic value for this species is 770.7 µg/L based upon reproductive impairment. A comparison acute test was conducted with the chronic test which resulted in an acute value of 1,930 µg/L. Division of this value by the chronic value results in an acute-chronic ratio of 2.504.

The Final Acute-Chronic Ratio of 4.137 is the geometric mean of the acute-chronic ratios of 4.356 for the freshwater cladoceran, Ceriodaphnia dubia, 5.015 for the freshwater cladoceran, Daphnia magna, 5.357 for the rainbow trout, Oncorhynchus mykiss, and 2.504 for the saltwater mysid, Mysidopsis bahia (Table 2). The acute-chronic ratio of 201.1 for the fathead minnow was not used in this calculation because, as described in the Guidelines, this species is not acutely sensitive to aniline and its Species Mean Acute Value is not close to the Final Acute Value (Table 3). Division of the freshwater Final Acute Value of 56.97 µg/L by 4.137 results in a freshwater Final Chronic Value of 13.77 µg/L. Division of the saltwater Final Acute Value of 153.4 µg/L by 4.137 results in a saltwater Final Chronic Value of 37.08 µg/L. The freshwater Final Chronic Value is approximately 1.4 times greater than the lowest freshwater chronic value of 10.1 µg/L for Ceriodaphnia dubia. The saltwater Final Chronic Value is a factor of 21 times less than the only saltwater chronic value of 770.7 µg/L.

Toxicity to Aquatic Plants

Results of tests with two species of freshwater green alga exposed to aniline are shown in Table 4. Sensitivity to aniline differed between the two species. Four-day exposures with aniline and Selenastrum capricornutum showed that the EC50s ranged from 1,000 µg/L (Adams et al. 1986) to 19,000 µg/L (Calamari et al. 1980, 1982) with reduced growth as the effect. Slooff [illegible] determined an EC50 of 20,000 µg/L for an unidentified species of Selenastrum with reduced biomass as the effect. The studies by Adams et al. (1986) were conducted both with and without a carrier solvent (acetone). The lowest 96-hr EC50s were obtained from exposures using acetone. However, this relationship was reversed when the exposure duration was increased to five and six days

(Table 4). The green alga, Chlorella vulgaris, is considerably more tolerant to aniline than Selenastrum. In 14-day exposures, growth of C. vulgaris was reduced 58% by 306,000 µg/L and 16% by 184,000 µg/L (Ammann and Terry 1985). The study also demonstrated that aniline had significant effects upon respiration and photosynthesis of the species. There are no acceptable plant data for saltwater species for aniline. A Final Plant Value, as defined in the Guidelines, cannot be obtained for aniline.

Bioaccumulation

Studies to determine the bioconcentration of aniline with three species of organisms have been reported (Table 5). In all these studies, steady-state bioconcentrations were not demonstrated. Daphnia magna bioconcentrated aniline five times in a 24-hr exposure (Dauble et al. 1984, 1986), a green alga 91 times in a 24- to 25-hr exposure (Hardy et al. 1985) and rainbow trout 507 times in a 72-hr exposure (Dauble et al. 1984). Because tests were not of sufficient duration according to the Guidelines, and no U.S. FDA action level or other maximum acceptable concentration in tissue is available for aniline, no Final Residue Value can be calculated.

Other Data

Other data available concerning aniline toxicity are presented in Table 5. Effects on two species of bacteria were seen at aniline concentrations ranging from 30,000 to 130,000 µg/L.

Three genera of algae were exposed to aniline. One species of blue-green algae, Microcystis aeruginosa, (Bringmann and Kuhn 1976, 1978a,b), showed more sensitivity to aniline than other species. Inhibition of cell replication of this species was observed after an 8-day exposure to 160 µg/L. Fitzgerald et al. (1952) reported a 24-hr LC50 of 20,000 µg/L with the same species. A [illegible]% reduction of photosynthesis by the green algae, Selenastrum capricornutum, was reported by Giddings (1979) after a 4-hr exposure to 100,000 µg/L of aniline.

Several species of protozoans were exposed to aniline. A 28-hr aniline exposure with Microregma heterostoma showed that food ingestion was reduced at 20,000 μg/L (Bringmann and Kuhn 1959a). Other species of protozoa were tested and showed less sensitivity to aniline (Table 5).

The hydrazoan, Hydra oligactis, showed sensitivity to aniline in a 48-hr test. The LC50 for this species of 406 μg/L was determined by Slooff (1983) in a static, unmeasured test using river water. Other organisms such as planarians (Dugesia lugubris), tubificid worms (Tubificidae), and snails (Lymnea stagnalis) were also tested and had much higher 48-hr LC50s of 155,000, 450,000 and 800,000 μg/L, respectively.

Cladocera appeared to be the group most sensitive to aniline. Spehar (1987) reported a 48-hr LC50 of 132 μg/L for Ceriodaphnia dubia in an exposure in which the organisms were fed their culturing ration. In the same study, a LC50 of 44 μg/L was determined for unfed Ceriodaphnia dubia. The difference in results could have been due to the complexation of aniline by the food and/or increased hardiness of the fed organisms. Daphnia magna was affected (acoustic reaction and mortality) at aniline concentrations ranging from 400 to 2,000 μg/L (Bringmann and Kuhn 1959a,b, 1960; Lakhnova 1975) for 48-hr exposures. Calamari et al. (1980, 1982) found this species to be more resistant to aniline with a reported 24-hr EC50 of 23,000 μg/L.

Insects showed varying sensitivities to aniline. Puzikova and Markin (1975) exposed the midge, Chironomus dorsalis, to aniline through its complete life cycle and reported 100% survival at 3,000 μg/L and 5% survival at [illegible] μg/L. Slooff (1983) exposed mayfly and mosquito larvae to aniline for 48 hr and reported LC50s of 220,000 and 155,000 μg/L, respectively.

The toxicity values for rainbow trout in Table 5 are in general agreement with those used in Table 1. Rainbow trout were exposed to aniline by several workers using different exposure durations. Shumway and Palensky (1973) found 100% mortality of rainbow trout at 100,000 μg/L in a 48-hr exposure and 100% survival at 10,000 μg/L. Lysak and Marcinek (1972) also reported 100% mortality for a 24-hr exposure at 21,000 μg/L and observed no mortality at 20,000 μg/L. Abram and Sims (1982) determined the 7-day LC50 to be 8,200 µg/L in two separate tests using rainbow trout.

Several tests were run with aniline in dilution waters of different water quality. Water hardness appeared to have little, if any, impact on aniline toxicity (Birge et al. 1979a,b). Young channel catfish, Ictalurus punctatus, were exposed to aniline in waters with a four-fold difference in hardness (53.3 and 197.5 mg/L as $CaCO_3$). The resulting LC50s indicated only a slight decrease in toxicity with increasing hardness. In a similar test they also exposed goldfish and largemouth bass, Micropterus salmoides, and reported the opposite effect on toxicity. pH does not appear to affect toxicity of aniline with aquatic organisms (Table 5).

The African clawed frog demonstrated varied effects over a broad range of concentrations of aniline. Davis et al. (1981) and Dumpert (1987) observed that aniline concentrations of 50 and 70 µg/L resulted in reduced epidermal pigmentation or failure of larvae to develop normal pigmentation. In a 12-week exposure, Dumpert (1987) showed that 1,000 µg/L of aniline slowed metamorphosis and reduced growth. At an exposure concentration of 10,000 µg/L for 96-hr, 6% of the frog larvae developed abnormalities (Dumont et al. 1979; Davis et al. 1981). Frog embryos had 50% teratogeny in 120- and 96-hr exposures at 91,000 and 370,000 µg/L, respectively (Table 5). One hundred percent mortality of immature frogs occurred during a 12-day exposure to 90,000 µg/L (Dumpert 1987) and 50% mortality during a 48-hr exposure to 560,000 µg/L (Slooff 1982; Slooff and Baerselman 1980).

Concentrations of the free amino acids aspartate, glutamate and [illegible] in the sea anemone, Bunodosoma cavernata, increased after seven days of exposure to aniline at 500,000 µg/L (Kasschau et al. 1980; Table 5). The lethal threshold (geometric mean of the highest concentration with no mortality and the next higher concentration) was 29,400 µg/L for sand [illegible] Crangon septemspinosa, and >55,000 for soft-shelled clams, Mya arenaria (McLeese et al. 1979).

Unused Data

Some data on the effects of aniline on aquatic organisms were not used because the studies were conducted with species that are not resident in North America or Hawaii (Freitag et al. 1984; Hattori et al. 1984; Inel and Atalay 1981; Juhnke and Ludemann 1978; Lallier 1971; Slooff and Baerselman 1980; Tonogai et al. 1982; Yoshioka et al. 1986a). Chiou (1985b); Hermens et al. (1985); Hodson (1985); Koch (1986); Newsome et al. (1984); Persson (1984); Schultz and Moulton (1984); Slooff et al. (1983); Vighi and Calamari (1987) compiled data from other sources. Results were not used where the test procedures or test material were not adequately described (Buzzell et al. 1968; Canton and Adema 1978; Carlson and Caple 1977; Clayberg 1917; Demay and Menzies 1982; Kuhn and Canton 1979; Kwasniewska and Kaiser 1984; Pawlaczyk-Szpilowa et al. 1972; Sayk and Schmidt 1986; Shelford 1917; Wellens 1982). Data were not used when aniline was part of a mixture (Giddings and Franco 1985; Lee et al. 1985; Winters et al. 1977) or when the organisms were exposed to aniline in food (Lee et al. 1985; Loeb and Kelly 1963).

Babich and Borenfreund (1988), Batterton et al. (1978), Bols et al. (1985); Buhler and Rasmusson (1968), Carter et al. (1984), Elmamlouk et al. (1974), Elmamlouk and Gessner (1976), Fabacher (1982), Lindstrom-Seppa et al. (1983), Maemura and Omura (1983), Pedersen et al. (1976), Sakai et al. and Schwen and Mannering (1982) exposed only enzymes, excised or homogenized tissue, or cell cultures. Anderson (1944), and Bringmann and Kuhn (19[illegible]) cultured organisms in one water and conducted tests in another. Batterton et al. (1978) conducted a study in which organisms were not tested in water but were tested on agar in the "algal lawn" test.

Results of one laboratory test were not used because the test was conducted in distilled or deionized water without addition of appropriate salts (Mukai 1977). Results of laboratory bioconcentration tests were not used when the test was not flow-through or renewal (Freitag et al. 198[illegible] [illegible] et al. 1981; Geyer et al. 1984) and BCFs obtained from microcosm or model ecosystem studies were not used where the concentration of aniline in [illegible] decreased with time (Lu and Metcalf 1975; Yount and Shannon 1987). Douglas et al. (1986) had insufficient mortalities to calculate an LC50 and Sollmann (1949) conducted studies without control exposures.

Summary

Data on the acute toxicity of aniline are available for nineteen species of freshwater animals. Cladocera were the most acutely sensitive group tested. Mean 48-hr EC50s ranged from 125.8 μg/L for Ceriodaphnia dubia to 250 μg/L for Daphnia magna. The planarian, Dugesia tigrina, was the fourth most sensitive species to aniline with a 96-hr LC50 of 31,600 μg/L.

Freshwater fish 96-hr LC50s ranged from 10,600 to 187,000 μg/L. Rainbow trout, Oncorhynchus mykiss, were the most sensitive fish tested, with species mean acute values of 26,130 μg/L. The bluegill, Lepomis macrochirus, was nearly as sensitive to aniline as rainbow trout, with a 96-hr LC50 of 49,000 μg/L reported for this species. The fathead minnow, Pimephales promelas, and goldfish, Carassius auratus, were the most tolerant fish species exposed to aniline, with species mean acute values of 106,000 μg/L and 187,000 μg/L, respectively.

The most tolerant freshwater species tested with aniline was a midge, Clinotanypus pinguis, with a 48-hr LC50 of 477,000 μg/L. Developmental stages of an amphibian, Xenopus laevis, had differing sensitivities to aniline. The embryos were the most tolerant with a 96-hr LC50 of 550,000 μg/L and the larvae had a 96-hr LC50 of 150,000 μg/L.

Data on the acute toxicity of aniline are available for eight spe[illegible] saltwater animals. Species Mean Acute Values ranged from >333,000 μg/L [illegible] larval winter flounder, Pseudopleuronectes americanus, to 610 μg/L for [illegible] grass shrimp, Palaemonetes pugio. Arthropods appear particularly sens[illegible] aniline. There are no data to support the derivation of a salinity- or temperature-dependent Final Acute Equation.

Chronic tests have been conducted with four species of freshwater organisms. A chronic value of 10.1 μg/L for the cladoceran, Ceriodaphnia dubia, was based upon reproductive impairment. A chronic value of 33.9 µg/L for another cladoceran, Daphnia magna, was also based on reproductive impairment. Rainbow trout were exposed for 90 days to aniline and the results showed that survival was reduced at 15,900 µg/L and growth (wet weight) at 7,800 µg/L. The chronic value for trout of 5,600 µg/L was based upon growth. The fathead minnow was exposed for 32 days in an early life-stage test. The chronic value of 557 µg/L was also based upon growth.

One saltwater chronic value was found. A chronic value of 770.7 µg/L for the mysid, Mysidopsis bahia, was based upon reproductive impairment.

Effects due to aniline have been demonstrated with two freshwater plant species. The green alga, Selenastrum capricornutum, had EC50s ranging from 1,000 to 19,000 µg/L in 4-day exposures. Another green alga, Chlorella vulgaris, was considerably more resistant to aniline, showing a growth reduction of 58% by 306,000 µg/L in a 14-day exposure. No acceptable saltwater plant data have been found. Final Plant Values, as defined in the Guidelines, could not be obtained for aniline.

No suitable data have been found for determining the bioconcentration of aniline in freshwater or saltwater organisms.

Acute-chronic ratio data that are acceptable for deriving numerical water quality criteria are available for three species of freshwater animals and one species of saltwater animal. The acute-chronic ratios range from 2.504 to 5.357 with a geometric mean of 4.137.

The freshwater Final Acute Value for aniline is 56.97 µg/L and [illegible] Chronic Value is 13.77 µg/L. The Freshwater Final Chronic Value is [illegible] greater than the lowest chronic value observed for one species of Cla[illegible] indicating that sensitive species of this group may not be adequately protected if ambient water concentrations exceed this value. The sa[illegible] Final Acute Value for aniline is 153.4 µg/L and the Final Chronic Va[illegible] 37.08 µg/L. Chronic adverse effects to the only saltwater species ex[illegible] aniline occurred at concentrations that are higher than the saltwater [illegible] Chronic Value which should be protective of saltwater 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 for certain sensitive species of Cladocera, freshwater organisms and their uses should not be affected unacceptably if the four-day average concentration of aniline does not exceed 14 µg/L more than once every three years on the average and if the one-hour average concentration does not exceed 28 µg/L more than once every three years on the average.

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, saltwater organisms and their uses should not be affected unacceptably if the four-day average concentration of aniline does not exceed 37 µg/L more than once every three years on the average and if the one-hour average concentration does not exceed 77 µg/L more than once every three years on the average.

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). Water quality criteria adopted in state water quality standards could have the same numerical values as criteria developed under Section 304 of the Clean Water Act. 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. Alternatively, states may use different data and assumptions than EPA in deriving numeric criteria that are scientifically defensible and protective of designated uses. State water quality standards include both numeric and narrative criteria. A state may adopt a numeric criterion within its water quality standards and apply it either state-wide to all waters designated for the use the criterion is designed to protect or to a specific site. A state may use an indicator parameter or the national criterion, supplemented with other relevant information, to interpret its narrative criteria within its water quality standards when developing NPDES effluent limitations under 40 CFR 122.44(d)(1)(vi).2

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 1991). 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 1991). 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 1991), 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 available (U.S. EPA 1987, 1991).

Table 1. Acute Toxicity of Aniline to Aquatic Animals

Species	Method[a]	Chemical[b]	pH	LC50 or EC50 (µg/L)	Species Mean Acute Value µg/L	Reference
FRESHWATER SPECIES						
Planarian, <u>Dugesia</u> <u>tigrina</u>	S,U	Reagent Grade	6.5-8.5	31,600	31,600	Ewell et al. 1986
Annelid, <u>Lumbriculus</u> <u>variegatus</u>	S,U	Reagent Grade	6.5-8.5	>100,000	>100,000	Ewell et al. 1986
Snail (adult), <u>Aplexa</u> <u>hypnorum</u>	F,M	-	7.4	>219,000	>219,000	Holcombe et al. 1987
Snail, <u>Helisoma</u> <u>trivolvis</u>	S,U	Reagent Grade	6.5-8.5	100,000	100,000	Ewell et al. 1986
Cladoceran (<24-hr), <u>Ceriodaphnia</u> <u>dubia</u>	S,U	99.5%	7.4-7.9	119	-	Norberg-King 1987
Cladoceran (<24 hr), <u>Ceriodaphnia</u> <u>dubia</u>	S,U	99.5%	7.4-7.7	193	-	Norberg-King 1987
Cladoceran (<24 hr), <u>Ceriodaphnia</u> <u>dubia</u>	S,U	99.5%	7.4-7.9	146	-	Norberg-King 1987
Cladoceran (<24 hr), <u>Ceriodaphnia</u> <u>dubia</u>	S,U	99.5%	7.4-7.7	184	-	Norberg-King 1987
Cladoceran (<24-hr), <u>Ceriodaphnia</u> <u>dubia</u>	S,U	99.5%	7.5-8.0	146	-	Norberg-King 1987
Cladoceran (<24-hr), <u>Ceriodaphnia</u> <u>dubia</u>	S,M	99.5%	7.8	44	125.8	Spehar 1987
Cladoceran (<24-hr), <u>Daphnia</u> <u>magna</u>	S,M	-	-	150	-	Biesinger 1987
Cladoceran (<24-hr), <u>Daphnia</u> <u>magna</u>	S,M	-	-	530	-	Biesinger 1987
Cladoceran (juvenile), <u>Daphnia</u> <u>magna</u>	S,U	Reagent Grade	6.5-8.5	210	-	Ewell et al. 1986
[illegible]	[illegible]	99%	7.7-7.9	170		Gersich and Mayes 1986

Table 1. (continued)

Species	Method[a]	Chemical[b]	pH	LC50 or EC50 (µg/L)	Species Mean Acute Value µg/L	Reference
Cladoceran (<24-hr), Daphnia magna	F,M	-	7.4	250	250.0	Holcombe et al. 1987
Isopod, Asellus intermedius	S,U	Reagent Grade	6.5-8.5	>100,000	>100,000	Ewell et al. 1986
Amphipod, Gammarus fasciatus	S,U	Reagent Grade	6.5-8.5	>100,000	>100,000	Franco et al. 1986
Midge (larva), Chironomus tentans	S,U	Reagent Grade	7.8	399,900	399,900	Franco et al. 1984
Midge (larva), Clinotanypus pinguis	S,U	Reagent Grade	7.8	477,900	477,900	Franco et al. 1984
Midge (larva), Lenziella natchitocheae	S,U	Reagent Grade	7.8	427,900	427,900	Franco et al. 1984
Midge (larva), Tanypus neopunctipennis	S,U	Reagent Grade	7.8	272,100	272,100	Franco et al. 1984
Midge (3rd-4th instar), Tanytarsus dissimilis	F,M	-	7.4	>219,000	>219,000	Holcombe et al. 1987
Rainbow trout (juvenile), Oncorhynchus mykiss	F,M	-	7.1-7.7	10,600	-	Abram and Sims 1982
Rainbow trout, Oncorhynchus mykiss	S,M	Analytical Grade	-	41,000	-	Calamari et al. 1980, 1982
Rainbow trout, Oncorhynchus mykiss	S,M	Analytical Grade	-	20,000	-	Calamari et al. 1980, 1982
Rainbow trout, Oncorhynchus mykiss	F,M	-	7.6-8.2	36,220	-	Hodson et al. 1984
Rainbow trout (juvenile), Oncorhynchus mykiss	F,M		7.4	40,500		Holcombe et al. 1987
Rainbow trout, Oncorhynchus mykiss	F,M	[illegible]	7.8	30,000	26,130	Spehar 1987

Table 1. (continued)

Species	Method[a]	Chemical[b]	pH	LC50 or EC50 (µg/L)	Species Mean Acute Value µg/L	Reference
Fathead minnow (juvenile), Pimephales promelas	F,M	99%	7.6	134,000	-	Brooke et al. 1984
Fathead minnow (juvenile), Pimephales promelas	S,U	Reagent Grade	6.5-8.5	32,000	-	Ewell et al. 1986
Fathead minnow (juvenile), Pimephales promelas	F,M	-	7.4	77,900	-	Holcombe et al. 1987; Geiger et al. 1990
Fathead minnow (juvenile), Pimephales promelas	F,M	99%	7.5	114,000	106,000	Geiger et al. 1990
Goldfish (juvenile), Carassius auratus	F,M	-	7.4	187,000	187,000	Holcombe et al. 1987
Bluegill (juvenile), Lepomis macrochirus	F,M	-	7.4	49,000	49,000	Holcombe et al. 1987
White sucker (juvenile), Catostomus commersoni	F,M	-	7.4	78,400	78,400	Holcombe et al. 1987
African clawed frog (embryo), Xenopus laevis	S,U	-	-	550,000[c]	-	Davis et al. 1981
African clawed frog (tailbud embryo), Xenopus laevis	S,U	-	-	940,000[c]	-	Davis et al. 1981
African clawed frog (larva), Xenopus laevis	S,U	-	-	150,000	150,000	Davis et al. 1981
			SALTWATER SPECIES			
Eastern oyster (embryos), Crassostrea virginica	S,U	100%	7.9-8.0	>30,000	>30,000	Thursby and Berry 1987a
Mysid (juvenile), Mysidopsis bahia	[illegible]	[illegible]	7.4-7.5	1,090		Thursby and Berry 1987a

Table 1. (continued)

Species	Method[a]	Chemical[b]	pH	LC50 or EC50 (µg/L)	Species Mean Acute Value µg/L	Reference
Mysid (juvenile), Mysidopsis bahia	F,M	100%	7.5-7.6	1,930	1,930	Thursby and Berry 1987b
Amphipod (juvenile), Ampelisca abdita	R,U	100%	7.5-7.6	16,600	16,600	Redmond and Scott 1987
Grass shrimp (larva), Palaemonetes pugio	R,U	100%	7.9-8.0	610	610	Thursby and Berry 1987a
Sea urchin (embryo-larva), Arbacia punctulata	S,U	100%	7.6-7.7	>200,000	>200,000	Thursby and Berry 1987a
Sheepshead minnow (juvenile), Cyprinodon variegatus	R,U	100%	7.8-8.2	120,000	120,000	Thursby and Berry 1987a
Inland silverside (juvenile), Menidia beryllina	R,U	100%	8.0-8.2	17,400	17,400	Thursby and Berry 1987a
Winter flounder (larva), Pseudopleuronectes americanus	S,U	100%	7.9-8.1	>330,000	>330,000	Thursby and Berry 1987a

[a] S = Static; R = Renewal; F = Flow-through; M = Measured; U = Unmeasured.
[b] Purity of the test chemical.
[c] Results from less sensitive life stages are not used in the calculation of the Species Mean Acute Value.

Table 2. Chronic Toxicity of Aniline to Aquatic Animals

Species	Test[a]	Chemical[b]	pH	Chronic Limits (µg/L)[c]	Chronic Value (µg/L)	Reference
			FRESHWATER SPECIES			
Cladoceran, *Ceriodaphnia dubia*	LC	99.5%	7.8	8.1-12.7	10.14	Spehar 1987
Cladoceran, *Daphnia magna*	LC	99%	7.8-8.1	24.6-46.7	33.89	Gersich and Milazzo 1988
Rainbow trout, *Oncorhynchus mykiss*	ELS	99.5%	7.8	4,000-7,800	5,600	Spehar 1987
Fathead minnow, *Pimephales promelas*	ELS	99.5%	7.93	422-735	557	Russom 1993
			SALTWATER SPECIES			
Mysid *Mysidopsis bahia*	LC	100%	7.4-7.6	540-1,100	770.7	Thursby and Berry 1987b

[a] LC = life cycle or partial life cycle; ELS = early life-stage.
[b] Purity of the test chemical.
[c] Results are based on measured concentrations of aniline.

Table 2. (continued)

		Acute-Chronic Ratio		
Species	pH	Acute Value (µg/L)	Chronic Value (µg/L)	Ratio
Rainbow trout, *Oncorhynchus mykiss*	7.8	30,000	5,600	5.357
Cladoceran, *Daphnia magna*	7.7-8.1	170	33.9	5.015
Cladoceran, *Ceriodaphnia dubia*	7.8	44	10.1	4.356
		SALTWATER SPECIES		
Mysid, *Mysidopsis bahia*	7.4-7.6	1,930	770.7	2.504

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

Rank[a]	Genus Mean Acute Value (µg/L)	Species	Species Mean Acute Value (µg/L)[b]	Species Mean Acute-Chronic Ratio[c]
		FRESHWATER SPECIES		
19	477,900	Midge, <u>Clinotanypus</u> <u>pinguis</u>	477,900	-
18	427,900	Midge, <u>Einfeldia</u> <u>natchitocheae</u>	427,900	-
17	399,900	Midge, <u>Chironomus</u> <u>tentans</u>	399,900	-
16	272,100	Midge, <u>Tanypus</u> <u>neopunctipennis</u>	272,100	-
15	>219,000	Midge, <u>Tanytarsus</u> <u>dissimillis</u>	>219,000	-
14	>219,000	Snail, <u>Aplexa</u> <u>hypnorum</u>	>219,000	-
13	187,000	Goldfish, <u>Carassius</u> <u>auratus</u>	187,000	-
12	150,00	African clawed frog, <u>Xenopus</u> <u>laevis</u>	150,000	-
11	106,000	Fathead minnow, <u>Pimephales</u> <u>promelas</u>	106,000	-
10	>100,000	Annelid, <u>Lumbriculus</u> <u>variegatus</u>	>100,000	-
9	>100,000	Amphipod, <u>Gammarus</u> <u>fasciatus</u>	>100,000	-
8	>100,000	Isopod, <u>Asellus</u> <u>intermedius</u>	>100,000	-
7	100 000	Snail, <u>Helisoma</u> <u>trivolvis</u>	100,000	-
[illegible]	[illegible]	White sucker, <u>Catostomus</u> <u>commersoni</u>	78,400	

Table 3. (continued)

Rank[a]	Genus Mean Acute Value (µg/L)	Species	Species Mean Acute Value (µg/L)[b]	Species Mean Acute-Chronic Ratio[c]
5	49,000	Bluegill, *Lepomis macrochirus*	49,000	-
4	31,600	Planarian, *Dugesia tigrina*	31,600	-
3	26,130	Rainbow trout, *Oncorhynchus mykiss*	26,130	5.357
2	250	Cladoceran, *Daphnia magna*	250.0	5.015
1	125.8	Cladoceran, *Ceriodaphnia dubia*	125.8	4.356
		SALTWATER SPECIES		
8	>333,000	Winter flounder, *Pseudopleuronectes americanus*	>333,000	-
7	>200,000	Sea urchin, *Arbacia punctulata*	>200,000	-
6	120,000	Sheepshead minnow, *Cyprinodon variegauts*	120,000	-
5	>30,000	Eastern oyster, *Crassostrea virginica*	>30,000	-
4	17,400	Inland silverside, *Menidia beryllina*	17,400	-
3	16,600	Amphipod, *Ampelisca abdita*	16,600	-

Table 3. (continued)

Rank[a]	Genus Mean Acute Value (µg/L)	Species	Species Mean Acute Value (µg/L)[b]	Species Mean Acute-Chronic Ratio[c]
2	1,930	Mysid, *Mysidopsis bahia*	1,930	2.504
1	610	Grass shrimp, *Palaemonetes pugio*	610	-

[a] Ranked from most resistant to most sensitive based on Genus Mean Acute Value.
[b] From Table 1.
[c] From Table 2.

Fresh water

Final Acute Value = 56.97 µg/L

Criterion Maximum Concentration = 56.97 µg/L / 2 = 28.49 µg/L

Final Acute-Chronic Ratio = 4.137 (see text)

Final Chronic Value = (56.97 µg/L) / 4.137 = 13.77 µg/L

Salt water

Final Acute Value = 153.4 µg/L

Criterion Maximum Concentration = (153.4 µg/L) / 2 = 76.7 µg/L

Final Acute-Chronic Ratio = 4.137 (see text)

Final Chronic Value = (153.4 µg/L) / 4.137 = 37.08 µg/L

Table 4. Toxicity of Aniline to Aquatic Plants

Species	Chemical[a]	pH	Duration	Effect	Result (µg/L)	Reference
			FRESHWATER SPECIES			
Green algae, Selenastrum capricornutum	Analytical Grade	-	4 days	EC50 (growth)	19,000	Clamari et al. 1980, 1982
Green algae, Selenastrum capricornutum	-	-	7 days	No effect (cell number)	<5,000	Adams et al. 1986
Green algae, Selenastrum capricornutum	-	-	7 days	No effect (growth rate)	10,000	Adams et al. 1986
Green algae, Selenastrum capricornutum	-	-	4 days	Incipient effect (growth)	3,000	Adams et al. 1986
Green algae, Selenastrum capricornutum			4 days	Incipient effect (growth)	1,000[b]	Adams et al. 1986
Green algae, Selenastrum capricornutum		-	5 days	Incipient effect (growth)	3,000	Adams et al. 1986
Green algae, Selenastrum capricornutum	-	-	5 days	Incipient effect (growth)	5,000[b]	Adams et al. 1986
Green algae, Selenastrum capricornutum	-	-	6 days	Incipient effect (growth)	3,000	Adams et al. 1986
Green algae, Selenastrum capricornutum	-	-	6 days	Incipient effect (growth)	5,000[b]	Adams et al. 1986
Green algae, Selenastrum sp.	-	-	4 days	EC50 (biomass)	20,000	Sloof 1982
Green alga Chlorella vulgaris			14 days	16% reduction in growth	184,000	Ammann and Terry 1985

Table 4. (continued)

Species	Chemical[a]	pH	Duration	Effect	Result (µg/L)	Reference
Green alga, *Chlorella vulgaris*	-	-	14 days	58% reduction in growth	306,000	Ammann and Terry 1985
Green alga, *Chlorella vulgaris*	-	-	14 days	66% reduction in growth	613,200	Ammann and Terry 1985
Green alga, *Chlorella vulgaris*	-	-	14 days	75% reduction in growth	817,000	Ammann and Terry 1985

SALTWATER SPECIES

No acceptable toxicity data for saltwater plants

[a] Purity of the test chemical.

[b] Acetone carrier used.

Table 5. Other Data on the Effects of Aniline on Aquatic Organisms

Species	Chemical*	pH	Duration	Effect	Concentration (µg/L)	Reference
			FRESHWATER SPECIES			
Bacterium, *Pseudomonas putida*	-	7.0	16 hr	Incipient inhibition	130,000	Bringmann 1973; Bringmann and Kuhn 1976, 1977b, 1980b
Bacterium, *Spirillum volutans*	-	6.8	1 hr	Inhibition of motility	30,000	Bowdre and Krieg 1974
Blue-green alga, *Microcystis aeruginosa*	-	-	24 hr	50% mortality	20,000	Fitzgerald et al. 1952
Blue-green alga, *Microcystis aeruginosa*	-	-	8 days	Incipient inhibition	160	Bringmann and Kuhn 1976, 1978a,b
Green algae, *Scenedesmus quadricauda*	-	7.5	4 days	Incipient inhibition	10,000	Bringmann and Kuhn 1959a,b
Green algae, *Scenedesmus quadricauda*	-	-	8 days	Incipient inhibition	8,300	Bringmann and Kuhn 1977b, 1978a,b, 1980b
Green alga, *Scenedesmus quadricauda*	-	-	24-25 hr	BCF = 91	-	Hardy et al. 1985
Green algae, *Selenastrum capricornutum*	Reagent Grade	-	4 hr	66% reduction in photosynthesis	100,000	Giddings 1979
Protozoan, *Chilomonas paramaecium*	-	-	48 hr	Incipient inhibition	250,000	Bringmann et al. 1980; Bringmann and Kuhn 1981
Protozoan [illegible]		6.9	72 hr	Incipient inhibition	24,000	Bringmann 1978; Bringmann and Kuhn 1980b, 1981

Table 5. (continued)

Species	Chemical[a]	pH	Duration	Effect	Concentration (µg/L)	Reference
Protozoan, <u>Microregma heterostoma</u>	-	7.5-7.8	28 hr	Incipient inhibition	20,000	Bringmann and Kuhn 1959a
Protozoan, <u>Tetrahymena pyriformis</u>	-	6.3	72 hr	EC50 (growth)	154,270	Schultz and Allison 1979
Protozoan, <u>Uronema parduczi</u>	-	6.9	20 hr	Incipient inhibition	91,000	Bringmann and Kuhn 1980a, 1981
Hydrozoan, <u>Hydra oligactis</u>	>98%	-	48 hr	LC50	406,000	Slooff 1983
Planarian, <u>Dugesia lugubris</u>	>98%		48 hr	LC50	155,000	Slooff 1983
Tubificid worm, Tubificidae	>98%		48 hr	LC50	450,000	Slooff 1983
Snail, <u>Lymnaea stagnalis</u>	>98%	-	48 hr	LC50	800,000	Slooff 1982, 1983
Cladoceran, <u>Ceriodaphnia dubia</u>	99.5%	7.8	48 hr	EC50 (fed)	132	Spehar 1987
Cladoceran, <u>Daphnia magna</u>	-	7.5	48 hr	EC50 (acoustic reaction)	400	Bringmann and Kuhn 1959a,b 1960
Cladoceran, <u>Daphnia magna</u>	-	7.6-7.7	24 hr	EC50 (immobility)	500	Bringmann and Kuhn 1977a
Cladoceran, <u>Daphnia magna</u>	Pure Analytical Grade	7.4	24 hr	EC50	23,000	Clamari et al. 1980, 1982
Cladoceran, <u>Daphnia magna</u>	-	-	24 hr	BCF = 5.0	-	Dauble et al. 1984, 1986
[illegible]			10 hr	LT50	10,000	Lakhnova 1975
[illegible]			12 hr	LT50	8,000	Lakhnova 1975

Table 5. (continued)

Species	Chemical*	pH	Duration	Effect	Concentration (µg/L)	Reference
Cladoceran, Daphnia magna	-	-	1.0 day	LT50	6,000	Lakhnova 1975
Cladoceran, Daphnia magna	-	-	1.5 days	LT50	4,000	Lakhnova 1975
Cladoceran, Daphnia magna	-	-	2.0 days	LT50	2,000	Lakhnova 1975
Cladoceran, Daphnia magna	-	-	3.5 days	LT50	1,000	Lakhnova 1975
Cladoceran, Daphnia magna	99%	-	14 days	MATC	29.9	Gersich and Milazzo 1990
Cladoceran, Daphnia magna	99%		14 days	MATC	14.9	Gersich and Milazzo 1990
Cladoceran (adult), Moina macrocopa	Analytical Grade		3 hr	LC50	1,000,000	Yoshioka et al. 1986b
Midge, Chironomus dorsalis	-	-	20-21 days	95% Mortality	7,800	Puzikova and Markin 1975
Midge, Chironomus dorsalis	-	-	20-21 days	30% Mortality	7,000	Puzikova and Markin 1975
Midge, Chironomus dorsalis	-	-	20-21 days	0% Mortality	3,000	Puzikova and Markin 1975
Mayfly (larva), Cloeon dipterum	>98%	-	48 hr	LC50	220,000	Slooff 1983
Mosquito (3rd instar), Aedes aegypti	>98%	-	48 hr	LC50	155,000	Slooff 1982
Rainbow trout (juvenile), Oncorhynchus mykiss	-	7.4	7 days	LC50	8,200	Abram and Sims 1982

Table 5. (continued)

Species	Chemical[a]	pH	Duration	Effect	Concentration (µg/L)	Reference
Rainbow trout (juvenile), Oncorhynchus mykiss	-	7.4	7 days	LC50	8,200	Abram and Sims 1982
Rainbow trout (juvenile), Oncorhynchus mykiss	-	7.4	72 hr	BCF = 507	-	Dauble et al. 1984
Rainbow trout (2 yr), Oncorhynchus mykiss	-	-	24 hr	No mortality	10,000-20,000	Lysak and Marcinek 1972
Rainbow trout (2 yr), Oncorhynchus mykiss			24 hr	LC100	21,000	Lysak and Marcinek 1972
Rainbow trout, Oncorhynchus mykiss	-	7.0-8.0	48 hr	No impairment of flavor	10,000	Shumway and Palensky 1973
Rainbow trout, Oncorhynchus mykiss	-	7.0-8.0	48 hr	100% mortality	100,000	Shumway and Palensky 1973
Guppy, Poecilia reticulata	99%	-	14 days	LC50	125,629	Hermens et al. 1984
Fathead minnow (3-4 wk), Pimephales promelas	>98%	-	48 hr	LC50	65,000	Slooff 1982
Channel catfish (embryo, larva), Ictalurus punctatus	-	7.7	To hatch (4.5 days)	LC50	5,600 (5,500)[b]	Birge et al. 1979b
[illegible]		-	8.5 days (4 days post hatch)	LC50	5,000 (5,000)[b]	Birge et al. 1979b

Table 5. (continued)

Species	Chemical*	pH	Duration	Effect	Concentration (µg/L)	Reference
Channel catfish (embryo, larva), Ictalurus punctatus	-	7.7	To hatch (4.5 days)	LC50	7,400 (6,300)[b]	Birge et al. 1979b
Channel catfish (embryo, larva), Ictalurus punctatus	-	7.7	8.5 days (4 days post-hatch)	LC50	7,000 (6,200)[b]	Birge et al. 1979b
Goldfish (embryo, larva), Carassius auratus	-	7.7	To hatch (3.5 days)	LC50	10,200 (9,300)[b]	Birge et al. 1979b
Goldfish (embryo, larva), Carassius auratus		7.7	7.5 days (4 days post-hatch)	LC50	5,600 (5,500)[b]	Birge et al. 1979b
Goldfish (embryo, larva), Carassius auratus		7.7	11.5 days (4 days post-hatch)	LC50	5,500	Birge et al. 1979b
Goldfish (embryo, larva), Carassius auratus	-	7.7	To hatch (3.5 days)	LC50	10,000 (7,600)[b]	Birge et al. 1979b
Goldfish (embryo, larva), Carassius auratus	-	7.7	7.5 days (4 days post-hatch)	LC50	4,800 (4,600)[b]	Birge et al. 1979b
Goldfish (embryo, larva), Carassius auratus	-	7.7	11.5 days (8 days post-hatch)	LC50	4,700	Birge et al. 1979b
Largemouth bass (embryo, larva), Micropterus salmoides	-	7.7	To hatch (2.5-3.5 days)	LC50	47,300 (32,700)[b]	Birge et al. 1979b
Largemouth bass [illegible]		7.7	6.5-7.5 days (4 days post-hatch)	LC50	10,500 (7,100)[b]	Birge et al. 1979b

Table 5. (continued)

Species	Chemical[a]	pH	Duration	Effect	Concentration (µg/L)	Reference
Largemouth bass (embryo, larva), Micropterus salmoides	-	7.7	10.5-11.5 days (8 days post-hatch)	LC50	5,200	Birge et al. 1979b
Largemouth bass (embryo, larva), Micropterus salmoides	-	7.7	To hatch (2.5-3.5 days)	LC50	43,200 (29,900)[b]	Birge et al. 1979b
Largemouth bass (embryo, larva), Micropterus salmoides	-	7.7	6.5-7.5 days (4 day post-hatch)	LC50	8,400 (7,100)[b]	Birge et al. 1979b
Largemouth bass (embryo, larva), Micropterus salmoides		7.7	10.5-11.5 days (8 days post-hatch)	LC50	4,400	Birge et al. 1979b
African clawed frog (embryo), Xenopus laevis	-	-	96 hr	EC50 (teratogeny)	370,000	Davis et al. 1981
African clawed frog (embryo), Xenopus laevis	-	-	120 hr	EC50 (teratogeny)	91,000	Davis et al. 1981
African clawed frog (larva), Xenopus laevis	-	-	96 hr	6% abnormalities	10,000	Dumont et al. 1979; Davis et al. 1981
African clawed frog (tadpole), Xenopus laevis	-	-	12 days	100% mortality	90,000	Dumpert 1987
African clawed frog (embryo), Xenopus laevis	-	-	12 weeks	Slowed metamorphosis, reduced growth	1,000	Dumpert 1987
[illegible]	[illegible]		LC50	560,000		Slooff 1982; Slooff and Baerselman 1980

Table 5. (continued)

Species	Chemical[a]	pH	Duration	Effect	Concentration (µg/L)	Reference
			SALTWATER SPECIES			
Sea anemone, Bunodosoma cavernata	-	-	7 days	Significant increase in concentration of free aspartate, glutamate, alanine	500,000	Kasschau et al. 1980
Sand shrimp (adult), Crangon septemspinosa	-	-	96 hr	Lethal threshold	29,400	McLeese et al. 1979

[a] Purity of the test chemical.

[b] Data in parenthesis are from Birge et al. 1979a.

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