DRAFT AMBIENT AQUATIC LIFE WATER QUALITY CRITERIA

DIAZINON

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DIAZINON

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NOTICES

This document has been reviewed by the Health and Ecological Effects Criteria Division, Office of Science and Technology, U.S. Environmental Protection Agency, and approved for publication.

This document is available to the public through the National Technical Information Service (NTIS), 5285 Port Royal Road, Springfield, VA 22161.

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 which 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 EPA staff and independent peer reviewers. 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. 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 (U.S. EPA 1994). 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 final document is guidance only. It does not establish or affect legal rights or obligations. It does not establish a binding norm and cannot 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.

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Introduction

Diazinon [Chemical Abstract Service registry number 333-41-5; 0,0-diethyl 0-(6-methyl-2-{1-methylethyl}-4-pirimidinyl) phosphorothioate is a broad spectrum insecticide effective against adult and juvenile forms of flying insects, crawling insects, acarians and spiders (WHO 1998). Specific uses include the control of soil insects such as cutworms, wireworms, and maggots (Farm Chemicals Handbook 2000) and ectoparasites on sheep (Virtue and Clayton 1997). It is also effective against many pests of fruits, vegetables, tobacco, forage, field crops, range, pasture, grasslands and ornamentals. Diazinon is routinely applied to the Central, Imperial and San Joaquin Valley agricultural areas of California (Bailey et al. 2000; Domagalski et al. 1997). It is used extensively around households to control cockroaches, and other insects such as flies (Farm Chemicals Handbook 2000) and ectoparasites on pets (Bailey et al. 2000). Additional diazinon uses in urban areas include dormant sprays on fruit trees, professional landscape and maintenance, and structural pest control (Bailey et al. 2000)

Diazinon is an organo-phosphorus compound with the empirical formula of $C_{12}H_{21}N_2O_3PS$, a molecular weight of 304.35 and has an octanol/water partition coefficient (log P_{ow}) of 3.40 (Hunter et al. 1985; WHO 1998). It is a colorless oil in its purest form with a density greater than water (1.116-1.118 g/mL at 20°C) and is soluble in water at 20°C to 0.006 percent (40 mg/L, Farm Chemicals Handbook 2000; 40.5 mg/L, Kanazawa 1983b; 60 mg/L, WHO 1998). The technical product is a pale to dark brown liquid of at least 90 percent purity and has a faint ester-like odor. It decomposes above 120°C (Verschueren 1983, WHO 1998), is susceptible to oxidation above 100°C, is stable in neutral media, but slowly hydrolyses in alkaline media and more rapidly in acidic media (WHO 1998). If stored properly, diazinon has a shelf-life of at least three years (SOLARIS Consumer Affairs for Ortho products, P.O. Box 5008, San Ramos, CA 94583, 1998).

Commercial formulations of diazinon contain the impurity sulfotepp (0,0,0,0-tetraethyl dithiopyrophosphate), which has been found at levels ranging from 0.20 to 0.71 percent of the diazinon concentrations (Meier et al. 1979). Meier et al. (1979) compared the toxicity of sulfotepp and diazinon to four species of freshwater organisms and found sulfotepp 58 times more toxic to fathead minnows (*Pimephales promelas*), 75 times more toxic to bluegill (*Lepomis macrochirus*) and rainbow trout (*Oncorhynchus mykiss*), and 8.7 times more toxic to a cladoceran (*Daphnia magna*). The authors speculated that some of the toxicity attributed to diazinon is likely due to sulfotepp. Sulfotepp is more stable than diazinon and therefore should persist longer in the environment. It should be noted that sulfotepp is also used alone as a pesticide, marketed under the trade names ASP-47 and Bladafun by the Bayer Corporation for fumigation control in greenhouse crops and mushrooms

(Agrochemicals Handbook 1991).

Although diazinon has been detected in freshwater (Bailey et al. 2000; Domagalski et al. 1997; Land and Brown 1996; Lowden et al. 1969; McConnell et al. 1998; Ritter et al. 1974), Goodman et al. (1979) reported that at the time of their paper diazinon had not been detected in the marine environment. However, they stated that the "potential exists for contamination of estuarine areas via agricultural and urban runoff." Organophosphorus pesticides, including diazinon, were found in almost all samples of seawater, but not in net plankton from the harbor of Osaka City, Japan (Kawai et al. 1984). Kawai et al. (1984) reported diazinon was applied from June to August to rice paddy fields resulting in concentrations in the Osaka City harbor reaching greater than 0.1 :g/L.

Diazinon has been detected in point source (wastewater treatment plant effluents) and non-point source (storm water) discharges in recent years, partially due to improved detection procedures (Villarosa et al. 1994). U.S. EPA’s National Effluent Toxicity Assessment Center investigated the occurrence of diazinon in 28 different publicly owned treatment works (POTW) effluents located across the country in 1988 and found detectable levels in samples from 17 of the 28 facilities, primarily those facilities located in southern states (Norberg-King et al. 1989). The authors concluded that the diazinon levels found in several effluents were sufficiently high enough to be a contributing factor to the toxicity observed to *Ceriodaphnia dubia*. The acute and chronic *C. dubia* toxicity observed in other POTW final effluents has also been attributed, in part to diazinon (Amato et al. 1992; Bailey et al. 1997; Burkhard and Jensen 1993; Guinn et al. 1995). This pass through diazinon toxicity present in a POTW’s final effluent could potentially cause an adverse impact on the receiving water community. However, Ku et al. (1998a) achieved nearly complete decomposition of diazinon within one hour in deionized water with ozone treatment under controlled laboratory conditions at a constant pH and temperature.

Diazinon has also been detected in storm water runoff in urban and agricultural areas (Bailey et al. 1997, 2000; Domagalski et al. 1997; Kratzer 1999; McConnell et al. 1998; NCTOC 1993; Waller et al. 1995). Domagalski et al. (1997) observed that in the western valley streams of the San Joaquin River, California, diazinon concentrations peaked within hours of the rainfall’s end, and then decreased thereafter. Diazinon was also detected in air samples over the Mississippi River from New Orleans to St. Paul, most closely related to use on cropland within 40 km of the river (Majewski et al. 1998). Rainfall runoff of pesticides, such as diazinon with a water solubility exceeding 10 mg/L, can cause toxic additions of 1-2 percent to freshwater ecosystems (Wauchope 1978), and field runoff concentrations of diazinon have been measured up to 82 :g/L (Ritter et al. 1974). The widespread occurrence and concern of diazinon in storm water has been addressed by issuance of storm water permits for large municipalities.

The mobility of diazinon in the soil is influenced by the organic matter (OM) and calcium carbonate content of the soil (WHO 1998). Arienzo et al. (1994a,b) found that diazinon is slightly mobile in soils with a low or medium (<2 percent) OM content and immobile in those with high OM content (>2 percent). The sorption of diazinon was enhanced when a sandy loam soil was modified with different exogenous organic materials containing humic-like substances relative to the unmodified sandy loam soil (Iglesias-Jimenez et al. 1997). Martinez-Toledo et al. (1993) found that the presence of 10 to 300 :g/g of diazinon in soil increased the total number of bacteria and the population of denitrifying bacteria. However, aerobic denitrogen fixing bacteria and dinitrogen fixation decreased initially (3 days) at diazinon concentrations of 100 to 300 :g/g before recovering to control levels. Nitrifying bacteria and fungal soil populations were not affected at the 10 to 300 :g/g soil exposure levels.

The fate of diazinon in the aquatic environment is thought to be regulated by two main processes - chemical hydrolysis and microbial degradation. Both processes are influenced by the conditions of pH, temperature and the organic content of the water. Diazinon is stable at pH 7.0 and can persist in the environment for as long as six months. Diazinon is an exception to other organophosphorus insecticides in that it hydrolyzes at both acidic and alkaline pH's (Gomaa et al. 1969). In the laboratory at 20°C, the half-life was determined to be 12, 4436 and 146 hr at the respective pH's of 3.1, 7.4 and 10.4 (Faust and Gomaa 1972). Ku et al. (1998b) found that hydrolytic decomposition occurred only for the diazinon-H+ species present in acidic solutions, and that breakage of the P-O bond was the major decomposition step for the hydrolysis of diazinon. Morgan (1976) measured diazinon half-life due to hydrolysis in well water of pH 7.4 to 7.7 and 16°C at 43.3 days. Hydrolysis of diazinon in laboratory water at 21°C and pH of 7.3 yielded a half-life of 171 days (Mansour et al. 1999). The breakdown of diazinon in soils of flooded rice fields occurs at similar rates as in water and is described in a review of the literature by Sethunathan (1973).

A third, less dominant process influencing the fate of diazinon in aquatic systems is photodegradation. Scheunert et al. (1993) found that when diazinon solutions were irradiated with UV light of different wave lengths, photodegradation was increased when using river or lake water when compared to distilled water. Medina et al. (1999) compared the half-life of diazinon in filtered Limon River samples under light and dark conditions and found a shorter half-life for sunlight exposed samples ($t_{1/2}$ = 31.13 days) when compared to samples held in the dark ($t_{1/2}$ = 37.19 days)

An important factor regulating the rate of microbial decomposition of diazinon is adaptation of microbes to the chemical. Sethunathan and MacRae (1969), Sethunathan and Pathak (1972) and Forrest et al. (1981) found a marked increase in the degrading capacity of microbes when repeatedly exposed to diazinon as compared to a single application. Parkhurst et al. (1981) measured a degradation rate of 2 percent/day and a half-life of 39 days in diazinon treated river water at summer temperatures.

A primary mode of toxic action of organophosphorus insecticides is inhibition of cholinesterases present in the nervous system. The actual toxicant may be the oxygenated homolog of diazinon - diazoxon. Margot and Gysin (1957) have reported that the cholinesterase inhibiting activity of diazoxon is about 4,000 times greater than that of the parent diazinon. Diazoxon has been identified as a metabolite of diazinon in the liver microsomes of channel catfish, *Ictalurus punctatus*, and bluegill (Hogan and Knowles 1972). Insect enzymes efficiently convert the P:S bond to the P:O bond thus producing the toxic oxygen homolog (Albert 1981). Crustacea very likely have a similar ability. Insects and crustacea probably differ from vertebrates by having a less efficient de-esterification process to remove the oxygen homolog from their system, making them more sensitive to diazinon.

Diazinon, on prolonged storage, may became more toxic due to transformation products. An old diazinon formulation was found to have no diazinon, but some sulfotepp and monosulfotepp. The monosulfotepp was shown to be 14,000 times more toxic than diazinon in one test of enzyme inhibition (Singmaster 1990). The use of the old improperly stored diazinon formulation, and accompanying transformation of diazinon to the more toxic products sulfotepp and monothiono-tepp, was cited by Soliman et al. (1982) as the most probable cause of two acute human poisoning cases in Egypt. Allender and Britt (1994) conducted a screening program throughout Australia to determine if a problem existed with toxic levels of breakdown products of diazinon formulations. Of the 169 samples evaluated, only eight contained the breakdown products O,S-TEPP and S,S-TEPP, which was directly correlated with the presence of water in the container.

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), hereafter 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. Whenever adequately justified, a national criterion may be replaced by a site-specific criterion (U.S. EPA 1983a), which may include not only site-specific criterion concentrations (U.S. EPA 1983b), but also site-specific durations of averaging periods and site-specific frequencies of allowed excursions (U.S. EPA 1991).

Results of intermediate calculations such as 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. The latest comprehensive literature search for information for this document was conducted in November, 1999; some of the more recent information was included.

Data in the files of the U.S. EPA's Office of Pesticide Programs concerning the effects of diazinon on aquatic organisms and their uses have also been evaluated for possible use in the derivation of aquatic life criteria.

Acute Toxicity to Aquatic Animals

The acute toxicity of diazinon to freshwater animals has been determined for 12 invertebrate species, 10 fish species and one amphibian (Table 1). Acute values ranged from 0.20 :g/L for an amphipod, *Gammarus fasciatus* (Johnson and Finley 1980; Mayer and Ellersieck 1986), to 11,640 :g/L for planaria, *Dugesia tigrina* (Phipps 1988). The most sensitive organisms tested were invertebrates in the Class Crustacea. The amphipod, *G. fasciatus*, had the lowest Genus Mean Acute Value (GMAV) of 0.2 :g/L. The cladoceran, *Ceriodaphnia dubia*, had the second lowest GMAV which was computed from 14 tests, ten of which were conducted by staff at the U.S. EPA-Duluth laboratory (Norberg-King 1987; Ankley et al. 1991). Results from these 14 tests were relatively consistent (acute values ranged from 0.25 to 0.59 :g/L) considering that different water sources were used and organism age at test initiation ranged from <6 hr-old to 48 hr-old. Data were included in the table when the organisms received food during the exposure, but these data were not used to compute a Species Mean Acute Value (SMAV) for *C. dubia*. Three other cladoceran species (*Daphnia magna*, *D. pulex*, and *Simocephalus serrulatus*) were tested and found to be similarly sensitive to diazinon as *C. dubia* with EC50s ranging from 0.65 to 1.8 :g/L. Two species of amphipods were tested, and the 96-hr LC50s for the two amphipod species differed by a factor of 33. One species, *G. fasciatus*, was the most sensitive organism tested with diazinon and had a 96-hr LC50 of 0.20 :g/L. *Hyalella azteca* was also sensitive to diazinon, with a 96-hr LC50 value of 6.51 :g/L.

The least sensitive species tested with diazinon was also an invertebrate. The planarian, *D. tigrina* had the highest observed diazinon 96-hr LC50 of 11,640 :g/L. Other invertebrate species exhibiting relatively low sensitivity to diazinon included the snail, *Gillia altilis* (96-hr LC50 of 11,000 :g/L), the oligochaete worm, *Lumbriculus variegatus* (96-hr LC50 values of 9,980 and 6,160 :g/L, or a SMAV of 7,841 :g/L) and the apple snail, *Pomacea paludosa* (96-hr LC50 values of 2,950 and 3,270 and 3,390 :g/L or a SMAV of 3,198 :g/L).

Freshwater fish species that were tested showed moderate sensitivity to diazinon. SMAVs ranged from 425.8 :g/L for the rainbow trout, *Oncorhynchus mykiss*, to 9,000 :g/L for the goldfish, *Carassius auratus* (Table 1). The cutthroat trout, *Oncorhynchus clarki*, was considerably less sensitive (2,166 :g/L) to diazinon than rainbow trout. Rainbow trout were evaluated in five tests with results ranging from 90 :g/L (Cope 1965b; Ciba-Geigy 1976; Johnson and Finley 1980; Mayer and Ellersieck 1986) to 3,200 :g/L (Bathe et al. 1975a). Certain species of warmwater fish, flagfish (*Jordanella floridae*), fathead minnow (*Pimephales promelas*), goldfish, and zebrafish (*Brachydanio rerio*) are less sensitive to diazinon than the coldwater species, rainbow trout, brook trout (*Salvelinus fontinalis*), and lake trout (*Salvelinus namaycush*). Two exceptions include the warmwater bluegill, which is more sensitive to diazinon than the coldwater fish species, and the coldwater cutthroat trout, which is less sensitive than the warmwater flagfish. Genus Mean Acute Values for the four most sensitive genera, all crustaceans, differed by a factor of 7.9 (Table 3 and Figure 1). The Final Acute Value (FAV) for freshwater organisms is 0.1925 :g/L.

The acute toxicity of diazinon to saltwater animals has been determined for seven invertebrate species and two fish species (Table 1). SMAVs ranged from 2.57 :g/L for the copepod, *Acartia tonsa* (Khattat and Farley 1976), to >9,600 :g/L for embryos of the sea urchin, *Arbacia punctulata* (Thursby and Berry 1988), a factor of about 3,735. Acute values for the mysid, *Americamysis bahia* (formerly *Mysidopsis bahia*), from a renewal, unmeasured test (8.5 :g/L) and from a flow-through measured test (4.82 :g/L) were similar. Toxicity tests with copepods, mysids, amphipods (*Ampelisca abdita*), grass shrimp *(Palaemonetes pugio*), pink shrimp (*Penaeus duorarum*) and inland silversides (*Menidia beryllina*) demonstrated an increase in mortalities with duration of exposure. The remaining fish species, the sheepshead minnnow (*Cyprinodon variegatus*), had an LC50 value of 1,400 µg diazinon/L, and is the only saltwater fish with a corresponding chronic value. Acute values for the four most sensitive genera, all invertebrates, differed by only a factor of 2.6 (Table 3 and Figure 2). The saltwater FAV is 1.637 :g/L.

Chronic Toxicity to Aquatic Animals

The chronic toxicity of diazinon was determined for five freshwater species (Table 2). A life-cycle test was conducted with *C. dubia* during a seven-day exposure (Norberg-King 1987). Diluted mineral reconstituted water was used to culture and expose the organisms. All organisms survived in the control and the three lowest exposures (0.063, 0.109, and 0.220 :g/L), but no organisms survived at concentrations $0.520 :g/L. The chronic value determined for *C. dubia* was 0.3382 :g/L. Division of the SMAV (0.3760 :g/L) from ten 48-hr acute tests conducted in the same laboratory with the same dilution water (Norberg-King 1987; Ankley et al. 1991) by the chronic value (0.3382 :g/L) results in an Acute-Chronic Ratio (ACR) of 1.112 for *C. dubia*.

Allison and Hermanutz (1977) exposed brook trout adults to diazinon for six to eight months and then exposed their progeny for an additional 122 days and observed effects. After 173 days of exposure, survival was reduced at 9.6 :g/L and deformities were seen at 4.8 :g/L. However, when these fish spawned there were no differences in the number of eggs produced per female or the viability of these eggs. Continued exposure of the progeny showed measurable effects at 30 days, but at 122 days post-hatch, all exposure concentrations had significantly shorter total lengths and lighter weights. The chronic value was <0.8 :g/L which was the lowest exposure concentration for the progeny. Division of the SMAV (723.0 :g/L) from three 96-hr acute tests (Allison and Hermanutz 1977) by the chronic value (<0.8 :g/L) results in an ACR of >903.8.

Norberg-King (1989) exposed fathead minnow embryos and the resulting larvae to diazinon for 32 days in an early-life stage test. At test termination, wet weight and survival of test fish exposed to only the highest exposure concentration of 285 :g/L were significantly different from that of the control fish. Total length was significantly affected at concentrations $160 :g/L and dry weight was significantly reduced at 37.8 :g/L, but not at 16.5 :g/L. Based upon dry weight, the chronic value for the test was 24.97 :g/L. Division of the 96-hr LC50 (9,350 :g/L) from another group of researchers (University of Wisconsin-Superior 1988) at the same laboratory using the same water supply and the same genetic stock of fish by the chronic value of 24.97 :g/L results in an ACR of 374.4.

Fathead minnow embryos (<24-hr old) and the resulting larvae were exposed to diazinon for a total of 32 days (Jarvinen and Tanner 1982). Results of the early-life stage test were reduced survival at diazinon concentrations $290 :g/L, and reduced weight (10.1 percent reduction) at 90 :g/L, but no weight difference from the control fish at 50 :g/L. The chronic value for fathead minnows in the test was 67.08 :g/L based upon reduced weight. Division of the 96-hr acute value of 6,900 :g/L from a flow-through and measured toxicant concentration test (Jarvinen and Tanner 1982) by the chronic value of 67.08 :g/L results in an ACR of 102.9. The geometric mean of 374.4 and 102.9 is 196.3, which is the species mean acute-chronic ratio for fathead minnows.

Flagfish were exposed to diazinon through one and one-half generations (Allison 1977). The study began with one-day-old larvae and continued through spawning, which occurred at about 60 days, then continued with the fish progeny for 35 days post-hatch. An effect was seen with the parents at 61 days of exposure. The average wet weight of the males was significantly reduced from that of the control fish at diazinon concentrations #88 :g/L. Only two male fish were exposed per treatment and there was a 23.3 percent reduction in wet weight in the 88 :g/L exposure. However, weights of the four female fish from each treatment were not significantly reduced at any exposure concentration even though fish in the highest exposure concentration was reduced in average weight by 21.4 percent. Effects on the progeny were then observed and the only effect seen at hatching was a reduction in the incubation time at all exposure concentrations. At 35 days post-hatch, or a total exposure time of 96 days, significant reductions in average wet weight were measured at all exposure concentrations. Therefore, the flagfish chronic value was <14 µg/L. Division of the SMAV for flagfish of 1,643 :g/L, which is the geometric mean of results from two tests conducted in the same water supply and using fish from the same culture as used in the chronic test (Allison and Hermanutz 1977) by the chronic value of <14 :g/L, results in an ACR of >117.4.

Bresch (1991) evaluated the chronic toxicity of diazinon to zebrafish (early life-stage test). Zebrafish eggs (approximately 2-3 hr after spawning) through juveniles were exposed to diazinon concentration of 8, 40 and 200 :g/L for 42 days under flow-through measured conditions. Survival and growth of the three treatment groups were not statistically different (p<0.05) from the controls. Thus, the zebrafish chronic value was >200 :g/L. An acute-chronic ratio could not be estimated because a suitable acute test value is not available.

The chronic toxicity of diazinon for saltwater organisms has been determined in a life cycle test with the mysid, *A. bahia*, and a partial life-cycle test with the sheepshead minnow (Table 2). The mysid test (Nimmo et al. 1981) was of 22 days duration, and the authors' original data was used to recalculate the chronic limits (Berry 1989). There was no statistical difference in survival observed between the highest concentration tested (4.4 :g/L) and the controls (although there was only 28 percent survival at the highest concentration). Mysid reproduction was not significantly reduced in diazinon concentrations #2.1 :g/L, and only the 4.4 :g/L exposure concentration exhibited significantly reduced reproduction when compared to controls. Based on these observations, the chronic limits were 2.1 and 4.4 :g/L, and the resultant chronic value for the mysid was 3.040 :g/L. A corresponding flow-through measured acute value of 4.82 :g/L (Nimmo et al. 1981) yielded an ACR of 1.586.

Sheepshead minnow reproduction was significantly reduced in all diazinon exposure concentrations observed during a partial life-cycle test (Goodman et al. 1979). The number of eggs spawned per female in the 0.47, 0.98, 1.8, 3.5 and 6.5 :g diazinon/L average measured concentrations were 69, 50, 50, 55 and 45 percent of control fish, respectively. Acetylcholinesterase activity in fish exposed to 0.47 :g/L was consistently less than control fish levels, and levels averaged 71 percent inhibition in the 6.5 :g/L exposure. Neither survival nor growth were affected in #6.5 :g/L exposures to diazinon. The chronic value for sheepshead minnow was <0.47 :g/L, and when coupled with the 96-hr acute value of 1,400 :g/L by the same author, the resultant ACR for this fish was >2,979.

Chronic toxicity tests have been conducted on seven aquatic species and chronic values ranged from 0.34 :g/L for *C. dubia* to >200 :g/L for rainbow trout and zebrafish (Table 2 and Figure 3). The chronic values for sheepshead minnows (<0.47 :g/L) and brook trout (<0.8 :g/L) cannot be determined accurately because all concentrations tested adversely affected reproduction. Alternatively, an effect level on either survival or growth could not be determined for zebrafish (>200 :g/L). Acute-chronic ratios for acutely sensitive crustacean invertebrates were 1.586 for mysids and 1.112 for *C. dubia*. In contrast, ratios are markedly higher for relatively acutely insensitive fishes; >117.4 for flagfish, 102.9 and 374.4 for fathead minnows, >903.8 for brook trout and >2,979 for sheepshead minnows.

Three valid acute-chronic ratios are available for diazinon using the second and seventeenth (Table 3) most sensitive tested species of freshwater animals and the third most sensitive saltwater animal. Two acute-chronic ratios are available for the fathead minnow, which differ by a factor of approximately 3.6 times. The geometric mean of these two values is 196.3. The cladoceran *C. dubia* has an acute-chronic ratio of 1.112 when using the data provided by the U.S. EPA Duluth laboratory (Norberg-King 1987 and Ankley et al. 1991), which was very similar to the mysid acute-chronic ratio of 1.586 (Nimmo et al. 1981). An apparent pattern displayed by the data reviewed shows that a number of invertebrate species (especially crustacea) are acutely sensitive to diazinon, but have a low (<2) acute-chronic ratio. In contrast, most fish species are generally acutely insensitive to diazinon, but have high (>100) acute-chronic ratios. Another pattern observed was that the chronic fish studies conducted with reagent grade diazinon all had relatively high chronic values (>200 µg/L), and those conducted with technical grade diazinon all had lower chronic values (>70 µg/L). Although there are a limited number of chronic fish studies presented, this apparent pattern would suggest that other toxic impurities may be present in the technical material.

Although the three valid acute-chronic ratios vary by more than a factor of ten (by a factor of 177), the Guidelines (Stephen et al. 1985) specify that if the species mean acute-chronic ratio (SMACR) seems to increase or decrease as the SMAV increases, the Final Acute-Chronic Ratio (FACR) should be calculated as the geometric mean of the ACRs for species whose SMAVs are close to the FAV. It does appear that ACR values are lower for species acutely sensitive to diazinon, and higher for acutely insensitive species (Table 2). Therefore, only the acutely sensitive *C. dubia* and *A. bahia* were used to calculate the FACR of 1.328. The Guidelines also stipulate, if the most appropriate SMACRs are less than 2.0, acclimation has probably occurred during the chronic test, and the FACR should be assumed to be 2.0. Thus the FACR for diazinon is 2.0. It appears from available data (Fig. 3) that all tested freshwater species will be protected from adverse effects due to diazinon by the freshwater Chronic Value. Saltwater fish species may not be protected by the established saltwater Chronic Value, and the FCV for salt water species is lowered to 0.40 µg/L to protect the sheepshead minnow.

Toxicity to Aquatic Plants

Acceptable data on the effects of diazinon to freshwater algae are available for one species (Table 4), but no acceptable data are available concerning toxicity to freshwater vascular plants. Hughes (1988) exposed the green alga, *Selenastrum capricornutum*, for seven days in a static, measured toxicant concentration test. An EC50 of 6,400 :g/L was determined based upon reduced cell numbers. No saltwater tests with plants are suitable, according to the Guidelines, for inclusion in this section. Some freshwater and saltwater information is included with "Other Data."

Based upon a single aquatic plant test, the Final Plant Value for diazinon is 6,400 :g/L.

Bioaccumulation

Three freshwater species of fish, rainbow trout, carp (*Cyprinus carpio*) and a guppy (*Poecilia reticulata*), were exposed to diazinon for 14 days and the whole body tissue loadings determined (Seguchi and Asaka 1981; Keizer et al. 1993). Diazinon accumulated rapidly in each study, and reached a plateau approximately in three days. The bioconcentration factor (BCF) for rainbow trout and carp exposed to 15 :g diazinon/L was 62 and 120, respectively (Table 5). The half-life for diazinon in these fish was less than seven days. The guppy was exposed to 350 :g diazinon/L for 14 days, which yielded a BCF value of 188 (Keizer et al. 1993).

In a 108-day saltwater exposure, uptake of diazinon by the sheepshead minnow was rapid, reaching steady state within 4 days (Goodman, et al. 1979). Whole body (less brain) bioconcentration factors for fish exposed to 1.8, 3.5 and 6.5 :g/L were 147, 147 and 213, respectively (Table 5).

No U.S. FDA action level or other maximum acceptable concentration in tissue, as defined in the Guidelines, is available for diazinon. Therefore, the Final Residue Value cannot be calculated.

Other Data

Additional data on the lethal and sublethal effects of diazinon for freshwater species are presented in Table 6. Sewage microbes (Bauer et al. 1981) and actinomycete bacteria (Sethunathan and MacRae 1969) appear to be unaffected or have growth enhancement at diazinon concentrations near water saturation. Data seem to vary greatly for several species of single celled green plants and diatoms. The green algal species, *Chlorella ellipsoidea* and *Chlamydomonas* sp., were affected only at concentrations of 100,000 :g/L. The green algae *Scenedesmus quadricauda* was not affected at 1,000 :g/L, but a mixture of green alga and diatoms had reduced growth at <10 :g/L (Butler et al. 1975a). From Table 4, the green alga *Selenastrum capricornutum* showed adverse reproduction at 6,400 :g/L. Duckweed (*Wolffia papulifera*) had 100 percent mortality at 100,000 :g/L saturation and developed deformities at

10,000 :g/L in 11-day exposures (Worthley and Schott 1971). Various tested species of protozoans demonstrated low sensitivity to diazinon compared to crustacean and vertebrate species. Adverse affects were reported for protozoans from .3,000 :g/L (Evtugyn et al. 1997) to 29,200 :g/L (Fernandez-Casalderrey et al. 1992b). In contrast, the rotifer *Brachionus calyciflorus*, was investigated by Fernandez-Casalderrey (1992a,b,c,d) and found to be substantially less sensitive than cladocerans and insects to diazinon with respect to survival (24-hr LC50 of 29,220 :g/L), filtration and ingestion rates (50 percent reduction at 14,000 :g/L), reproduction (decreased reproduction at <5,000 :g/L), and median lethal time effects (LT50 values ranged from 2.5 to 4 days for 14,000 and 5,000 :g/L, respectively). Juchelka and Snell (1994) estimated a 48-hr ingestion rate NOEC of 20,000 :g/L for *B. calyciflorus*, and Snell and Moffat (1992) calculated a reproductive NOEC of 8,000 :g/L. Chatterjee and Konar (1984) observed a 96-hr LC50 of 2,220 :g/L for the tubificid worm, *Branchiura sowerbyi*. A snail species (*Physa acuta*) had a 48-hr LC50 of 4,800 :g/L which is near the upper end of the range of fish 96-hr LC50s (Hashimoto and Nishiuchi 1981).

Dortland (1980) conducted a series of tests with the cladoceran, *Daphnia magna*, and found in one exposure that 0.2 :g/L did not affect the organisms during the 21-day exposure, but 0.3 :g/L reduced reproduction and mobility. In four other 21-day tests in which the test organisms were fed, the EC50s ranged from 0.22 to 0.8 :g/L. *D. magna* 21-day unmeasured renewal tests conducted by Fernandez-Casalderrey et al. (1995) yielded survival NOEC and LOEC effect levels of 0.15 :g/L and 0.18 :g diazinon/L, respectively. The mean total young per female and mean brood size were both significantly reduced at the 0.15 :g/L (lowest exposure) concentration when compared to the controls.

Amphipods are usually very sensitive to diazinon. Collyard et al. (1994) compared the sensitivity of different *H. azteca* age groups to diazinon. The eight different age groups (0-2 to 24-26 days old at test initiation) had very similar 96-hr LC50 values that ranged from 3.8 to 6.2 :g/L. One exception to the normally sensitive amphipod was the 96-hr LC50 of 200 :g diazinon/L determined for *Gammarus lacustris* by Sanders (1969).

Mosquito larvae appear to be about as sensitive to diazinon as cladocerans and amphipods. Yasuno and Kerdpibule (1967) exposed mosquito larvae, *Culex pipiens fatigans*, to diazinon in 24-hr exposures and measured LC50s ranging from 1.8 to 5.7 :g/L. Caddisfly larvae have been exposed to diazinon in 6-hr exposures (Fredeen 1972). The results were highly variable with LC50s ranging from 500 to 2,500 :g/L for *Hydropsyche morosa*, and >500 :g/L for *H. recurvata*. It is difficult to predict the LC50 values at exposure durations longer than 6 hr, but it is likely that caddisfly LC50 values would be considerably lower than 500 :g/L if exposed to diazinon for longer time periods. A species of stonefly, *Pteronarcys californicus*, was exposed for 48 hr and had an EC50 of

74 :g/L (Cope 1965a), which again shows insects to be quite sensitive to diazinon. In contrast, the rotifer *Brachionus calyciflorus*, was investigated by Fernandez-Casalderrey (1992a,b,c,d) and found to be substantially less sensitive than cladocerans and insects to diazinon with respect to survival (24-hr LC50 of 29,220 :g/L), filtration and ingestion rates (50 percent reduction at 14,000 :g/L), reproduction (decreased reproduction at <5,000 :g/L), and median lethal time effects (LT50 values ranged from 2.5 to 4 days for 14,000 and 5,000 :g/L, respectively).

Rainbow trout fingerlings were exposed to diazinon concentration of 8, 40 and 200 :g/L under flow-through measured conditions for 28 days (Bresch 1991). Survival and growth of rainbow trout in the three treatment groups after 28 days were not statistically (p>0.05) different from the control group. The resultant chronic value for rainbow trout was >200 :g/L diazinon.

Rainbow trout were also exposed to an insecticidal soap formulation of diazinon for 96 hr and an unspecified form of diazinon for 48 hr, and the resultant LC50s were 20 and 170 :g/L, respectively. Cutthroat trout of two sizes were exposed to diazinon for 96 hr which resulted in LC50s of 3,850 :g/L for the smaller and 2,760 :g/L for the larger fish. The LC50s for rainbow trout and cutthroat trout were consistent with the values used in Table 1 for the same species. Brown trout, *Salmo trutta lacustris*, were also relatively sensitive to diazinon having a 96-hr LC50 value of 602 :g/L for an unspecified formulation of diazinon.

Goldfish and carp are relatively tolerant of diazinon in acute exposures, but newly hatched fathead minnow larvae were found to be sensitive to the technical form of diazinon in seven-day exposures (Norberg-King 1989). Jarvinen and Tanner (1982) exposed fathead minnows to an encapsulated formulation of diazinon in acute and chronic exposures. The encapsulated formulation was less toxic (5,100 and 6,100 :g/L) than the technical grade (2,100 and 4,300 :g/L; Table 1) in 96-hr exposures. They obtained a chronic value of 55.14 :g/L, based upon reduction in weight in embryo-larval 32-day exposures with the encapsulated formulation. The fathead minnow acute-chronic ratio for the encapsulated formulation is 101.6 which is similar to the acute-chronic ratio of 102.9 for the technical grade chemical (Table 2) with this species.

Allison (1977) exposed flagfish, *J. floridae*, in a 21-day pulsed dose exposure with diazinon followed by a period without the chemical to observe effects. Exposure of the parental stock beginning at hatch and lasting 21 days resulted in decreased egg production by the females at concentrations $290 :g/L. Exposure to diazinon for 21 days just prior to spawning resulted in decreased parental survival at concentrations $250 :g/L, but there were no effects upon reproduction at the 250 and 450 :g/L exposure concentrations. Exposure of adults to diazinon for 21 days once spawning had been initiated resulted in decreased survival of the parents at the highest exposure concentration (1,170 :g/L), and reduced survival of larval progeny at 1,170 :g/L.

Chen et al. (1971) exposed the guppy, *P. reticulata*, to diazinon and measured 24-hr LC50s of 3,700 and 3,800 :g/L. These values were in agreement with the work of Ciba-Geigy (1976) which measured a 96-hr LC50 of 3,000 :g/L for the same fish species. Ohayo-Mitoko and Deneer (1993) estimated a lethal body burden of 2,495 :g diazinon/L for the guppy. Relative to some other fish species, the guppy appears to be more tolerant of diazinon than trout species but less tolerant than tested cyprinid species (fathead minnow and goldfish).

Bluegill, *L. macrochirus*, were tested by two research groups with widely different results (Table 6). The results of Cope (1965a) indicate that the bluegill is a relatively sensitive species (48-hr EC50 of 30 :g/L), whereas the work of Li and Chen (1981) indicate intermediate sensitivity (48-hr LC50 of 1,493 :g/L) relative to other fish species.

Bioconcentration factors were determined for various aquatic species with a value of 4.9 for the crayfish, *Procambarus clarkii* (Kanazawa 1978), 17.5 for the guppy (Kanazawa 1978), 28 for oriental weatherfish, *Misgurnus anguillicaudatus* (Seguchi and Asaka 1981), 62 for rainbow trout (Seguchi and Asaka 1981), and for carp 20.9 (Tsuda et al. 1990), 65.1 (Kanazawa 1978) and 120 (Seguchi and Asaka 1981).

Other data on the lethal and sublethal effects of diazinon on saltwater species (Table 6) did not indicate greater sensitivities than indicated previously. Saltwater algae appear to be less sensitive to diazinon than aquatic animals. Photosynthesis of natural phytoplankton was essentially unaffected by a 4-hr exposure to 1,000 :g/L (Butler 1963). There was no effect of diazinon at 1,000 :g/L on sexual reproduction of the red alga, *Champia parvula* (Thursby and Tagliabue 1988). A 24-hr exposure of the red alga, *Chondrus crispus*, to 10,000 :g diazinon/L had no effect on the growth of the alga in a subsequent 18-day grow-out period (Shacklock and Croft 1981). Rotifers, *Brachionis plicatilis*, were also not acutely sensitive to diazinon (Thursby and Berry 1988). Growth of eastern oysters, *Crassostrea virginica*, was not reduced in a diazinon exposure of 1,000 :g/L (Butler 1963). Shacklock and Croft (1981) showed that two days after a 3-hr exposure to 1,000 :g diazinon/L, 100 percent of the amphipod, *Gammarus oceanicus*, and the isopod, *Idotea baltica*, as well as 88 percent of the saltwater snail, *Lacuna vincta*, test organisms were dead. The 48-hr EC50 of diazinon to grass shrimp, *Palaemonetes pugio*, was 28 :g/L (Mayer 1987). The brown shrimp, *Penaeus aztecus*, had a 24-hr EC50 of 44 :g/L (Butler 1963) and a 48-hr EC50 of 28 :g/L (Mayer 1987). The 24- and 48-hr LC50s for the white mullet, *Mugil curema*, were both 250 :g/L.

An aquatic microcosm study was conducted by Giddings et al. (1996) with technical grade diazinon to measure the effects of a range of diazinon exposure regimes to many taxonomic groups under simulated field conditions, and to determine the relationship between the level of diazinon exposure and the magnitude of ecological response. Eighteen fiberglass tanks, each 3.2 m in diameter and 1.5 m in depth, were established with sediment and water (11.2 m^3) from natural ponds and stocked with 40 juvenile bluegill sunfish *(L. macrochirus*). Diazinon was applied in aqueous solution three times at 7-day intervals. Eight loading rates were used, with two microcosms at each level plus two controls. The amounts of diazinon added during each application corresponded to theoretical concentrations from 2.0 :g/L to 500 :g/L. The most sensitive ecological components of the microcosms were Cladocera (zooplankton), and Pentaneurini and Ceratopogonidae (chironomid insects), which were reduced at all treatment levels. Effects on many zooplankton and macroinvertebrate taxa occurred at diazinon concentrations (time-weighted averages) of 9.2 :g/L and higher. Total fish biomass was reduced at 22 :g/L and higher, and fish survival was reduced at 54 :g/L and higher. Odonates, some dipterans, and plants were not adversely affected by diazinon at 443 :g/L, the highest concentration tested. Microcosm results were consistent with laboratory toxicity data for some taxa (e.g., cladocerans, Ephemeroptera, and bluegill sunfish), but differed substantially for others (e.g., rotifers, Chironomini, and odonates). The NOEC (4.3 µg/L) in the microcosms (70-d time-weighted average) was near the 10th percentile of single species LC50 values.

Outdoor experimental channels at EPA’s Monitcello Ecological Research Station (Mississippi River water) were used by Arthur et al. (1983) to evaluate the effects of diazinon on macroinvertebrates. One channel served as a control and two channels as low and high treatments. The low and high treatment channels were continuously dosed at either 0.3 or 3 :g/L nominal diazinon concentrations for 12 weeks, then increased to 6 and 12 :g/L nominal diazinon levels for four weeks, and finally the high treatment was increased to 30 :g/L and the low treatment channel returned to ambient. Only the first 12 week dosing regime achieved nominal diazinon levels (0.3 and 3 :g/L) as indicated by analytical measurements, the latter two dosing regimes did not reach the intended levels. No consistent interchannel differences were observed in total macroinvertebrate abundance or in species diversity indices. *Hyalella* was the most sensitive species encountered, exhibiting substantially higher (5 to 8 times) drift rates in the 0.3 :g diazinon/L dosed channel relative to the control channel, and had sharply reduced population levels at diazinon concentrations as low as 5 :g/L. Macroinvertebrate diazinon tolerance from most tolerant to least tolerant was observed as: flatworms, physid snails, isopods and chironomids most tolerant; leeches and the amphipod *Crangonyx* less tolerant; the amphipod *Hyalella*, mayflies, caddisflies and damselflies sensitive.

Unused Data

Some data concerning the effects of diazinon on aquatic organisms and their uses were not used because the tests were conducted with species that are not resident in North America or because the test species was not obtained from a wild population in North America and was not identified well enough to determine whether it is resident in North America (e.g., Alabaster 1969; Alam and Maughan 1993; Alam et al. 1995; Anees 1974, 1976, 1978; Arab et al. 1990; Asaka et al. 1980; Bajpai and Perti 1969; Boumaiza et al. 1979; Ceron et al. 1996a,b; Chu and Lau 1994; El-Elaimy et al. 1990; Ferrando et al. 1991; Hamm et al. 1998; Hidaka et al. 1984; Hirayama and Tamanoi 1980; Hirose and Kawakami 1977; Hirose and Kitsukama 1976; Hirose et al. 1979; Iqbal et al. 1992; Kabir and Ahmed 1979; Kabir and Begum 1978; Kanazawa 1975, 1980, 1981a,b, 1983a; Khalaf-Allah 1999; Kikuchi et al. 1992; Kimura and Keegan 1966; Kobayashi et al. 1993; Miah et al. 1995; Morale et al. 1998; Niforos and Lim 1998; Nishiuchi and Yoshida 1972; Rompas et al. 1989; Sakr and Gabr 1992; Sakr et al. 1991; Sancho et al. 1992a,b, 1993a,b, 1994; Setakana and Tan 1991; Shigehisa and Shiraishi 1998; Sinha et al. 1987; Stevens 1991, 1992; Stevens and Warren 1992; Tsuda et al. 1989, 1992, 1995a,b, 1997a,b; Uno et al. 1997; Van der Geest et al. 1999; Yasutomi and Takahashi 1987). Results (e.g. Kuwabara et al. 1980) of tests conducted with brine shrimp, *Artemia* sp., were not used because these species are from a unique saltwater environment.

Bay et al. 1993; Connolly 1985; Dyer et al. 1997; Eisler 1986; Garten and Trabalka 1983; Kaiser et al. 1997; Kanazawa 1982; Kenaga 1979, 1982; Robinson 1999; Roex et al. 2000; Sanchez et al. 1998; Steen et al. 1999; Van der Geest et al. 1997; Vighi and Calamari 1987; Vittozzi and DeAngelis 1991; Yoshioka et al. 1986; Zaroogian et al. 1985a,b compiled data from other sources. Results were not used when either the test procedures, test material, or dilution water was not adequately described (e.g., Adlung 1957; Ansari et al. 1987; Butler et al. 1975a,b; Chatterjee 1975; Hashimoto and Fukami 1969; Hatakeyama and Sugaya 1989; Kaur and Toor 1980; Murray and Guthrie 1980; Oh et al. 1991; Qadri and Anjum 1982).

Data were not used when diazinon was a component of a drilling mud, effluent, fly ash, mixture, formulation, sediment, or sludge (e.g., Alam and Maughan 1992; Amato et al. 1992; Bailey et al. 1996, 2000; Bathe et al. 1975a, b; Bishop et al. 1999; Burchfield and Storrs 1954; Burkhard and Jenson 1993; Deanovic et al. 1996, 1997; Dennis et al. 1979a,b; DeVlaming et al. 2000; Doggett and Rhodes 1991; Duursma and Hanafi 1975; Foe 1995; Foe et al. 1998; Glass et al. 1995; Gruber and Munn 1998; Hashimoto et al. 1982; Hatakeyama et al. 1997; Hendriks et al. 1998; Hilsenhoff 1959; Kikuchi et al. 1996; Kuivila and Foe 1995; LaBrecque et al. 1956; Larsen et al. 1998; Lehotay et al. 1998; McLeay and Hall 1999; Macek 1975; Malone and Blaylock 1970; Matsuo and Tamura 1970; Mazidji et al. 1990; Mulla et al. 1963; Nishiuchi 1977; Pan and Dutta 1998; Rettich 1979; Singh 1973; Steinberg et al. 1992; Tripathi 1992; Tsuda et al. 1997a,b; Verma et al. 1982; Werner et al. 2000; Wong 1997; Wong and Chang

1988), unless data were available to show that the toxicity was the same as diazinon alone. Anjum and Siddiqui 1990; Ansari and Kumar 1988; Ariyoshi et al. 1990; Burbank and Snell 1994; Christensen and Tucker 1976; Dutta et al. 1992a,b, 1993, 1994, 1997; Dyer et al. 1993; Fujii and Asaka 1982; Garrood et al. 1990; Hiltibran 1974, 1982; Keizer et al. 1995; Kraus 1985; Mitsuhashi et al. 1970; Moore and Waring 1996; Olson and Christensen 1980; Qadri and Dutta 1995; Sastry and Malik 1982a,b; Sastry and Sharma 1980, 1981; Vigfusson et al. 1983; Weiss 1959, 1961; Weiss and Gakstater 1964; Whitmore and Hodges (1978) exposed plasma, enzymes, excised or homogenized tissue, tissue extracts, or cell cultures. Tests conducted without controls or with too few test organisms were not used (e.g., Applegate et al. 1957; Devillers et al. 1985; Federle and Collins 1976). Data of Norland et al. (1974) were not used because it was derived using organisms preconditioned to organophosphorus chemicals.

Results of some laboratory tests were not used because the tests were conducted in distilled or deionized water without addition of appropriate salts or were conducted in chlorinated or "tap" water (e.g., Mulla et al. 1962; Rettich 1977; Yasuno et al. 1965), or the concentration of a water-miscible solvent used to prepare the test solution exceeded 0.5 mL/L (Beauvais et al. 2000). Hirakoso 1968; Lee et al. 1993; Jamnback and Frempong-Boadu 1966; Klassen et al. 1965; Kok 1972; Lilly et al. 1969; Mulla 1963; Nishiuchi and Asano 1979; O'Kelley and Deason 1976; Steinberg et al. 1993 were not used because the results were not adequately described or could not be interpreted.

BCFs and BAFs from laboratory tests were not used when the tests were static or when the concentration of diazinon in the test solution was not adequately measured or varied too much (e.g., Khattat and Farley 1976). Toxicity data were not used if they were generated with a photoluminescence assay utilizing lyophilized marine bacteria that had been rehydrated (e.g., Curtis et al. 1982). Reports of the concentration of diazinon in wild aquatic organisms (e.g., Clark et al. 1984) were not used to calculate BAFs when either the number of measurements of the concentration in water was too small or the range of the measured concentrations in water was too large. BCFs obtained from microcosm or model ecosystem studies were not used when the concentration of diazinon in water decreased with time (e.g., Miller et al. 1966).

Summary

The acute toxicity of diazinon to freshwater organisms was determined for

12 invertebrate species, 10 fish species and one amphibian (Figure 1). Eight of the invertebrate species (two insects and six crustaceans) were the most sensitive organisms tested (0.20 to 25 :g/L) and one invertebrate species (planarian) was the most tolerant species tested (11,640 :g/L). Freshwater fish were intermediate in sensitivity to the two groups of invertebrates. Rainbow trout (*Oncorhynchus mykiss*) was the most sensitive fish (425.8 :g/L), and goldfish (*Carassius auratus*) was the most tolerant fish tested (9,000 :g/L). No relationships have been demonstrated between water quality characteristics such as hardness and toxicity. The freshwater Final Acute Value is 0.1925 :g/L.

Six chronic exposures were conducted with five species of freshwater organisms (Figure 3). Chronic values ranged from 0.3382 to >200 :g/L, and the Acute-Chronic Ratios (ACRs) ranged from 1.112 for *Ceriodaphnia dubia* to >903.8 for brook trout (*Salvelinus fontinalis*). The Final Acute-Chronic Ratio for diazinon was derived using two ACR's for tested species near the FAV because the ACR's decreased with SMAV's. Because the computed FACR was less than 2.0 indicating that the organisms may have become acclimated to diazinon during the study, the value was changed to 2.0. Thus, the freshwater Final Chronic Value (FCV) for diazinon is 0.0963 µg/L (FAV ÷ FACR, or 0.1925 µg/L ÷ 2.0 = 0.0963 µg/L).

The acute toxicity of diazinon to saltwater organisms was determined for nine species, of which seven were invertebrates (Figure 2). Five of the invertebrates were crustaceans and the most sensitive species tested (2.57 to 21 :g/L) and two species (an annelid and an echinoderm) were the most tolerant species tested (>2,880 and >9,600 :g/L, respectively). Two species of saltwater fish were tested and they were intermediate in sensitivity with acute values of 1,170 and 1,470 :g/L. The saltwater Final Acute Value is 1.637 :g/L.

Chronic values were determined for two species of saltwater organisms. The mysid, *Americamysis bahia*, and the sheepshead minnow, *Cyprinodon variegatus*, had chronic values of 3.040 and <0.47 :g/L, respectively (Figure 3). ACRs were 1.586 and >3,128 for the mysid and sheepshead minnow, respectively. The Final Acute-Chronic Ratio for diazinon is 2.0 (see previous text). Thus, the saltwater Final Chronic Value (FCV) for diazinon is 0.8185 µg/L (FAV ÷ FACR, or 1.637 µg/L ÷ 2.0 = 0.8185 µg/L). The FCV for salt water is lowered to 0.4 :g/L to protect the important sheepshead minnow.

Only one acceptable test with a freshwater algal species *(Selenastrum capricornutum*) was conducted, whereas no acceptable toxicity data are available for freshwater vascular plants. No saltwater tests with aquatic plants were suitable for consideration when estimating the Final Plant Value. Therefore, based upon this single test, the Final Plant Value is 6,400 :g/L.

Bioaccumulation of diazinon was measured in three species of freshwater fish and steady-state levels were reached in about three days.

Bioconcentration factors of 62, 120 and 188 were determined for rainbow trout, carp (*Cyprinus carpio*) and guppies (*Poecilia reticulata*), respectively. The tissue half-life was less than seven days. Bioaccumulation of diazinon was determined in one saltwater species. The sheepshead minnow was exposed for 108 days to three concentrations and had a mean bioconcentration factor of 169 times the concentration in water. No U.S. FDA action level or other maximum acceptable concentration in tissue, as defined in the Guidelines, is available for diazinon. Therefore, the Final Residue Value cannot be calculated.

National Criteria

The procedures described in the "Guidelines for Deriving Numerical National Water Quality Criteria for the Protection of Aquatic Organisms and Their Uses" (Stephan et al. 1985) 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 one-hour average concentration does not exceed 0.10 μg/L more than once every three years on the average and if the four-day average concentration of diazinon does not exceed 0.10 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" (Stephan et al. 1985) indicate that, except possibly where a locally important species is very sensitive, saltwater aquatic organisms and their uses should not be affected unacceptably if the one-hour average concentration does not exceed 0.82 μg/L more than once every three years on the average and if the four-day average concentration of diazinon does not exceed 0.40 μg/L more than once every three years on the average. Because sensitive saltwater animals appear to have a narrow range of acute susceptibilities to diazinon, this criterion will probably be as protective as intended only when the magnitude and/or duration of excursions are appropriately small.

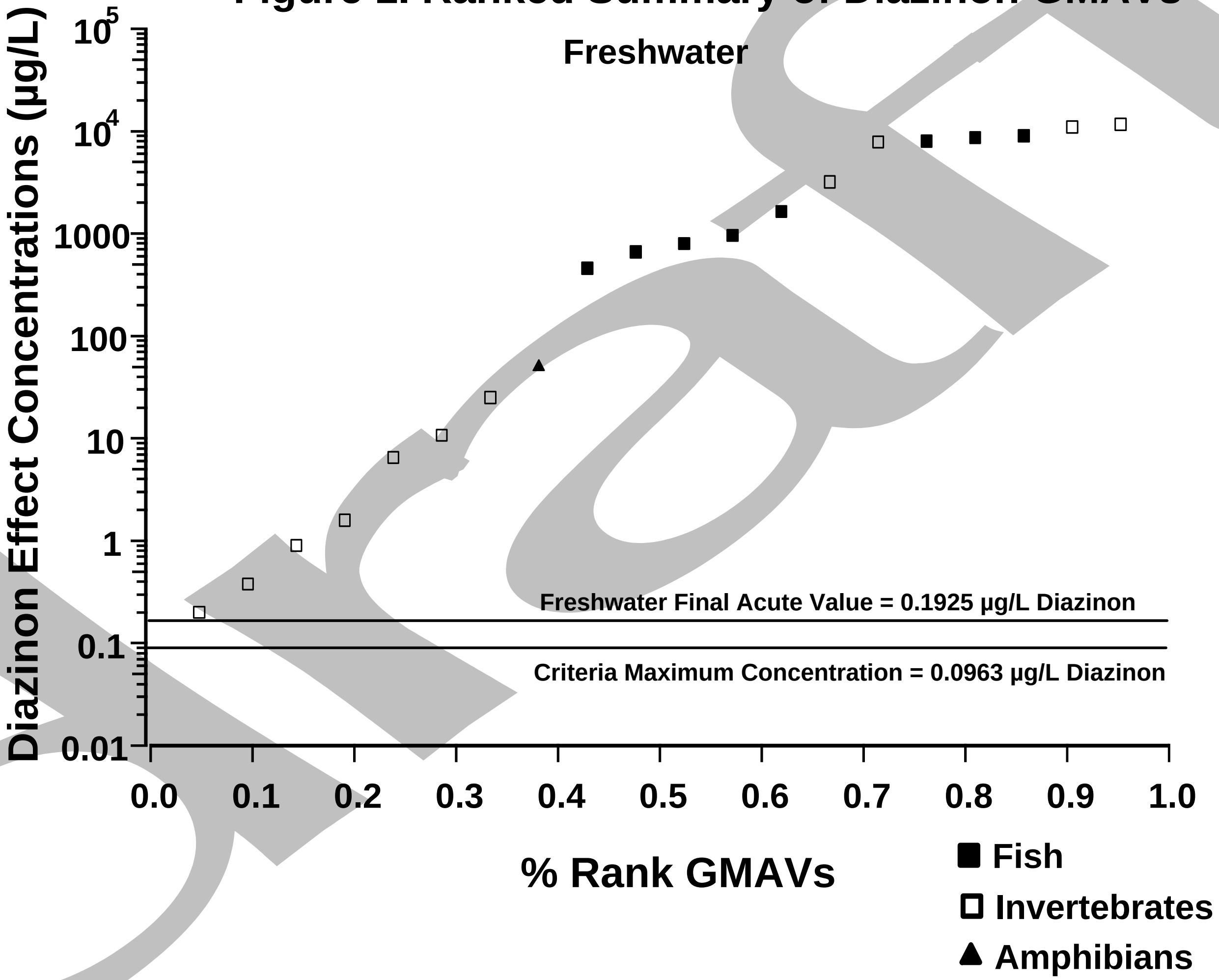
Implementation

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. (If the site is an entire state, the site-specific criterion is also a state-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 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 also available (U.S. EPA 1987, 1991).

Figure 1. Ranked Summary of Diazinon GMAVs



Freshwater

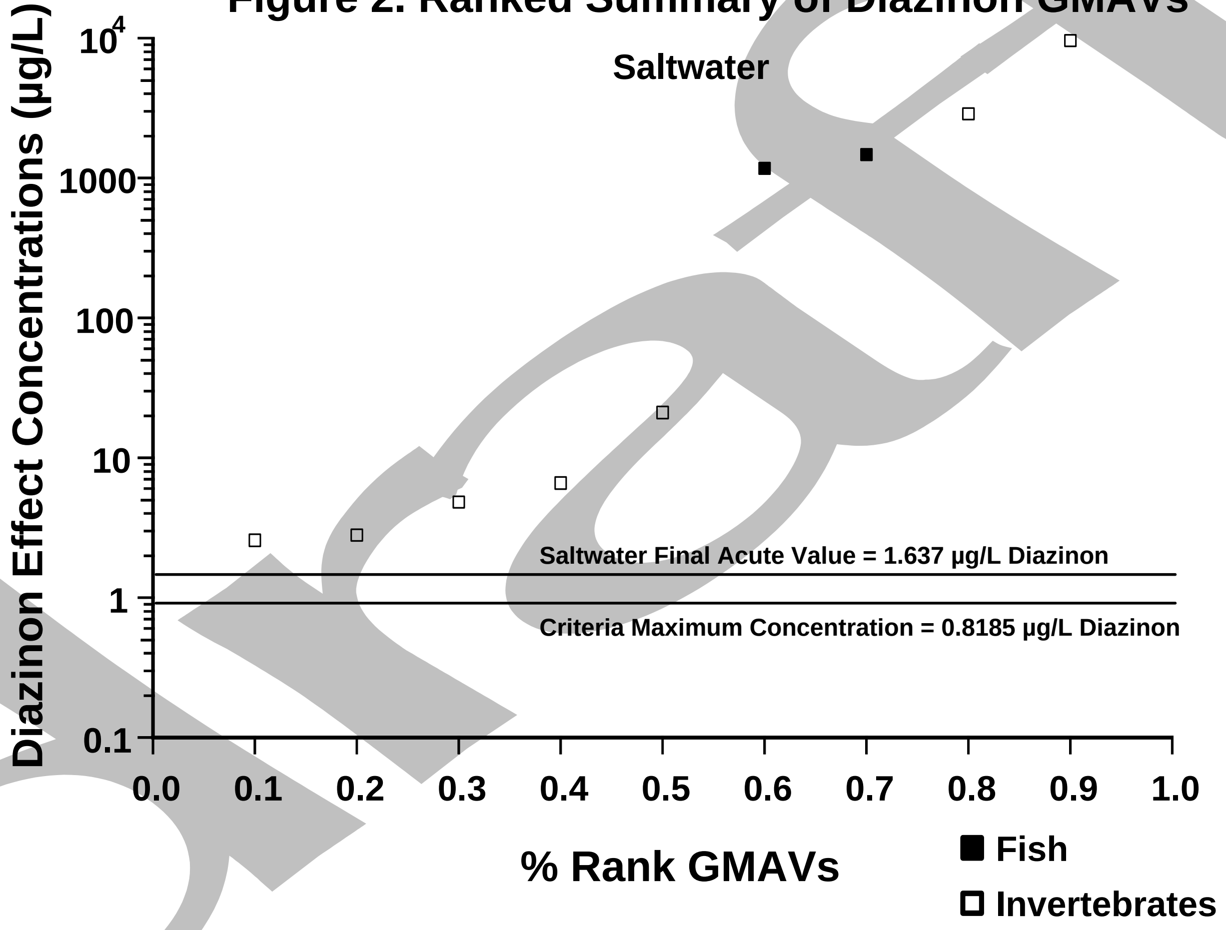


Figure 2. Ranked Summary of Diazinon GMAVs

Figure 3. Chronic Toxicity of Diazinon to Aquatic Animals

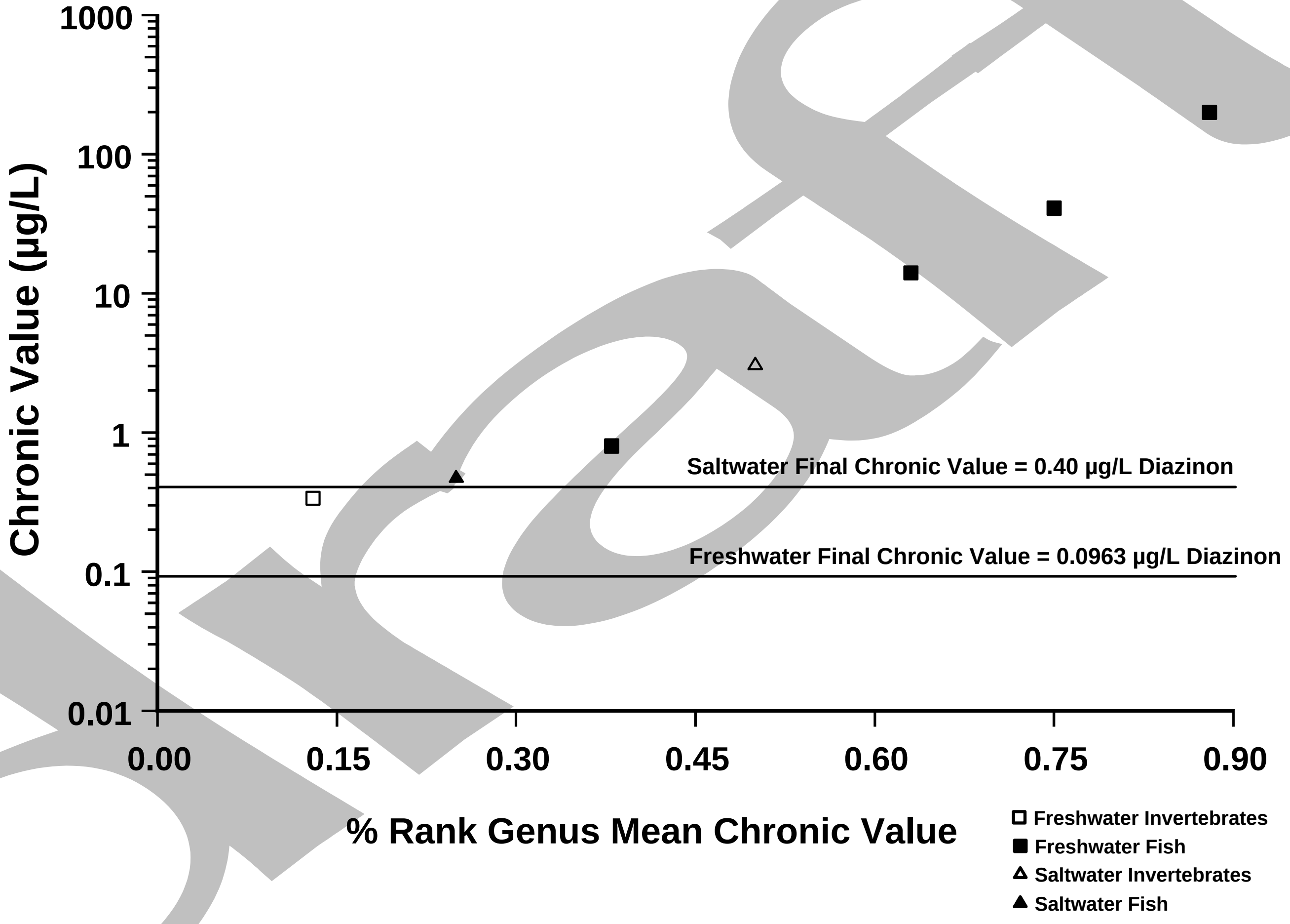


Table 1. Acute Toxicity of Diazinon to Aquatic Animals

Species	Method[a]	Chemical[b]	Hardness (mg/L as $CaCO_3$)	LC50 or EC50 (µg/L)	Species Mean Acute Value (µg/L)	Reference
FRESHWATER SPECIES						
Planaria, *Dugesia tigrina*	S, M	Technical (85%)	46.5-47.5	11,640	11,640	Phipps 1988
Oligochaete worm, *Lumbriculus variegatus*	S, M	Technical (85%)	46-48	9,980	-	Phipps 1988
Oligochaete worm, *Lumbriculus variegatus*	S, U	Technical (95%)	42-47	6,160	7,841	Ankley and Collyard 1995
Snail (2.4 g), *Gillia altilis*	S, U	Technical (89%)	22-35	11,000	11,000	Robertson and Mazzella 1989
Apple snail (1-day), *Pomacea paludosa*	F, M	Technical (87%)	130.5	2,950	-	Call 1993
Apple snail (7-days), *Pomacea paludosa*	F, M	Technical (87%)	219	3,270	-	Call 1993
Apple snail (7-days), *Pomacea paludosa*	F, M	Technical (87%)	173.5	3,390	3,198	Call 1993
Cladoceran (<24 hr), *Ceriodaphnia dubia*	S, U	Technical (85%)	40	0.57[c,d]	-	Norberg-King 1987

Table 1. (continued)

Species	Method[a]	Chemical[b]	Hardness (mg/L as $CaCO_3$)	LC50 or EC50 (µg/L)	Species Mean Acute Value (µg/L)	Reference
Cladoceran (<24 hr), *Ceriodaphnia dubia*	S, U	Technical (85%)	45	0.66[c,d]	-	Norberg-King 1987
Cladoceran (<24 hr), *Ceriodaphnia dubia*	S, U	Technical (85%)	40-48	0.57[c,d]	-	Norberg-King 1987
Cladoceran (<24 hr), *Ceriodaphnia dubia*	S, U	Technical (85%)	-	>1.0[c,d]	-	Norberg-King 1987
Cladoceran (<24 hr), *Ceriodaphnia dubia*	S, U	Technical (85%)	40	>0.6[d]	-	Norberg-King 1987
Cladoceran (<6 hr), *Ceriodaphnia dubia*	S, M	Technical (85%)	40	0.66[c,d]	-	Norberg-King 1987
Cladoceran (<48 hr), *Ceriodaphnia dubia*	S, U	Technical (85%)	-	0.35	-	Norberg-King 1987
Cladoceran (<48 hr), *Ceriodaphnia dubia*	S, U	Technical (85%)	-	0.35	-	Norberg-King 1987
Cladoceran (<6 hr), *Ceriodaphnia dubia*	S, U	Technical (85%)	-	0.25	-	Norberg-King 1987
Cladoceran (<24 hr), *Ceriodaphnia dubia*	S, U	Technical (85%)	-	0.33	-	Norberg-King 1987
Cladoceran (<48 hr), *Ceriodaphnia dubia*	S, U	Technical (85%)	-	0.35	-	Norberg-King 1987

Table 1. (continued)

Species	Method[a]	Chemical[b]	Hardness (mg/L as $CaCO_3$)	LC50 or EC50 (µg/L)	Species Mean Acute Value (µg/L)	Reference
Cladoceran (<48 hr), *Ceriodaphnia dubia*	S, U	Technical (85%)	-	0.59	-	Norberg-King 1987
Cladoceran (<48 hr), *Ceriodaphnia dubia*	S, U	Technical (85%)	-	0.43	-	Norberg-King 1987
Cladoceran (<48 hr), *Ceriodaphnia dubia*	S, U	Technical (85%)	-	0.35	-	Norberg-King 1987
Cladoceran (<48 hr), *Ceriodaphnia dubia*	S, U	Technical (85%)	-	0.36	-	Norberg-King 1987
Cladoceran (<48 hr), *Ceriodaphnia dubia*	S, U	Technical (95%)	40-48	0.5	-	Ankley et al. 1991
Cladoceran (<24 hr), *Ceriodaphnia dubia*	S, M	Analytical (99%)	80-100	0.58	-	Bailey et al. 1997
Cladoceran (<24 hr), *Ceriodaphnia dubia*	S, M	Analytical (99%)	80-100	0.48	-	Bailey et al. 1997
Cladoceran (<24 hr), *Ceriodaphnia dubia*	S, M	Analytical (99%)	80-100	0.26	-	Bailey et al. 1997
Cladoceran (<24 hr), *Ceriodaphnia dubia*	S, M	Analytical (99%)	80-100	0.29	0.3773	Bailey et al. 1997
Cladoceran (<20 hr), *Daphnia magna*	S, U	Technical	50	0.96	-	Vilkas 1976

Table 1. (continued)

Species	Method[a]	Chemical[b]	Hardness (mg/L as $CaCO_3$)	LC50 or EC50 (µg/L)	Species Mean Acute Value (µg/L)	Reference
Cladoceran (<24 hr), *Daphnia magna*	S, U	Analytical	200	1.5	-	Dortland 1980
Cladoceran (<48 hr), *Daphnia magna*	S, U	Technical (95%)	40-48	0.8	1.048	Ankley et al. 1991
Cladoceran (first instar), *Daphnia pulex*	S, U	Technical (89%)	47	0.90	-	Cope 1965a; Sanders and Cope 1966
Cladoceran (first instar), *Daphnia pulex*	S, U	Technical (89%)	47	0.8	-	Johnson and Finley 1980; Mayer and Ellersieck 1986
Cladoceran (<48 hr), *Daphnia pulex*	S, U	Technical (95%)	40-48	0.65	0.7764	Ankley et al. 1991
Cladoceran (first instar), *Simocephalus serrulatus*	S, U	Technical (89%)	47	1.8	-	Cope 1965a; Sanders and Cope 1966; Mayer and Ellersieck 1986
Cladoceran (first instar), *Simocephalus serrulatus*	S, U	Technical (89%)	47	1.4	1.587	Sanders and Cope 1966; Johnson and Finley 1980; Mayer and Ellersieck 1986

Table 1. (continued)

Species	Method[a]	Chemical[b]	Hardness (mg/L as $CaCO_3$)	LC50 or EC50 (µg/L)	Species Mean Acute Value (µg/L)	Reference
Amphipod (mature), *Gammarus fasciatus*	S, U	Technical (89%)	44	0.20	0.20	Johnson and Finley 1980; Mayer and Ellersieck 1986
Amphipod (7-14 days), *Hyalella azteca*	S, U	Technical (95%)	42-47	6.51	6.51	Ankley and Collyard 1995
Stonefly (larva 30-35 mm), *Pteronarcys californica*	S, U	Technical (89%)	47	25	25	Cope 1965a; Sanders and Cope 1968; Johnson and Finley 1980; Mayer and Ellersieck 1986
Midge (third instar), *Chironomus tentans*	S, U	Technical (95%)	42-47	10.7	10.7	Ankley and Collyard 1995
Cutthroat trout (2.0 g), *Oncorhynchus clarki*	S, U	Technical (92%)	162	1,700	-	Johnson and Finley 1980; Mayer and Ellersieck 1986
Cutthroat trout (2.0 g), *Oncorhynchus clarki*	S, U	Technical (92%)	44	2,760	2,166	Mayer and Ellersieck 1986
Rainbow trout (3.7 cm), *Oncorhynchus mykiss*	S, U	Technical	-	400	-	Beliles 1965

Table 1. (continued)

Species	Method[a]	Chemical[b]	Hardness (mg/L as $CaCO_3$)	LC50 or EC50 (µg/L)	Species Mean Acute Value (µg/L)	Reference
Rainbow trout (1.20 g), *Oncorhynchus mykiss*	S, U	Technical (89%)	44	90	-	Cope 1965a; Johnson and Finley 1980; Mayer and Ellersieck 1986
Rainbow trout (25-50 g), *Oncorhynchus mykiss*	S, U	Technical	-	3,200	-	Bathe et al. 1975a
Rainbow trout, *Oncorhynchus mykiss*	S, U	Technical	-	90	-	Ciba-Giegy 1976
Rainbow trout, *Oncorhynchus mykiss*	S, U	Reagent	192	1,350	425.8	Meier et al. 1979; Dennis et al. 1980
Brook trout (1 yr), *Salvelinus fontinalis*	F, M	Technical (92.5%)	45	800	-	Allison and Hermanutz 1977
Brook trout (1 yr), *Salvelinus fontinalis*	F, M	Technical (92.5%)	45	450	-	Allison and Hermanutz 1977
Brook trout (1 yr), *Salvelinus fontinalis*	F, M	Technical (92.5%)	45	1,050	723.0	Allison and Hermanutz 1977
Lake trout (3.20 g), *Salvelinus namaycush*	S, U	Technical (92%)	162	602	602	Johnson and Finley 1980; Mayer and Ellerseick 1986
Zebrafish (0.4 g), *Brachydanio rerio*	R, M	Technical (98%)	-	8,000	8,000	Keizer et al. 1991

Table 1. (continued)

Species	Method[a]	Chemical[b]	Hardness (mg/L as $CaCO_3$)	LC50 or EC50 (µg/L)	Species Mean Acute Value (µg/L)	Reference
Fathead minnow, *Pimephales promelas*	S, U	Reagent	192	10,300[d]	-	Meier et al. 1979; Dennis et al. 1980
Fathead minnow (newly hatched larva), *Pimephales promelas*	S, M	Technical (87.1%) (fresh stock solution)	45.8	4,300[d]	-	Jarvinen and Tanner 1982
Fathead minnow (newly hatched larva), *Pimephales promelas*	S, M	Technical (87.1%) (aged stock solution)	45.8	2,100[d]	-	Jarvinen and Tanner 1982
Fathead minnow (juvenile), *Pimephales promelas*	F, M	Technical (92.5%)	45	10,000	-	Allison and Hermanutz 1977
Fathead minnow (newly hatched larva), *Pimephales promelas*	F, M	Technical (87.1%)	45	6,900	-	Jarvinen and Tanner 1982
Fathead minnow (juvenile), *Pimephales promelas*	F, M	Technical (87.1%)	43.6	9,350	8,641	University of Wisconsin-Superior 1988

Table 1. (continued)

Species	Method[a]	Chemical[b]	Hardness (mg/L as $CaCO_3$)	LC50 or EC50 (µg/L)	Species Mean Acute Value (µg/L)	Reference
Goldfish (2.5-6.0 cm), *Carassius auratus*	S, U	Technical (91%)	-	9,000	9,000	Beliles 1965
Flagfish (6 wk), *Jordanella floridae*	F, M	Technical (92.5%)	45	1,500	-	Allison and Hermanutz 1977
Flagfish (7 wk), *Jordanella floridae*	F, M	Technical (92.5%)	45	1,800	1,643	Allison and Hermanutz 1977
Guppy (0.6 g), *Poecilia reticulata*	R, M	Technical (98%)	-	800	800	Keizer et al. 1991
Bluegill (2.5-5.0 cm), *Lepomis macrochirus*	S, U	Technical	-	136[d]	-	Beliles 1965
Bluegill (0.87 g), *Lepomis macrochirus*	S, U	Technical	-	22[d]	-	Cope 1965b
Bluegill, *Lepomis macrochirus*	S, U	Technical	-	22[d]	-	Ciba-Geigy 1976
Bluegill (0.8 g), *Lepomis macrochirus*	S, U	Reagent	192	120[d]	-	Meier et al. 1979; Dennis et al. 1980
Bluegill (1.00 g), *Lepomis macrochirus*	S, U	Technical (92%)	44	168.0[d]	-	Johnson and Finley 1980; Mayer and Ellersieck 1986

Table 1. (continued)

Species	Method[a]	Chemical[b]	Hardness (mg/L as $CaCO_3$)	LC50 or EC50 (µg/L)	Species Mean Acute Value (µg/L)	Reference
Bluegill (1 yr.), *Lepomis macrochirus*	F, M	Technical (92.5%)	45	480	-	Allison and Hermanutz 1977
Bluegill (1 yr.), *Lepomis macrochirus*	F, M	Technical (92.5%)	45	440	459.6	Allison and Hermanutz 1977
Green frog (stage 8), *Rana clamitans*	R, U	Technical	-	>50	>50	Harris et al. 1998

Table 1. (continued)

Species	Method[a]	Chemical[b]	Salinity (g/kg)	LC50 or EC50 (µg/L)	Species Mean Acute Value (µg/L)	Reference
			SALTWATER SPECIES			
Annelid worm (juvenile), *Neanthes arenaceodentata*	R, U	(96%)	30	>2,880	>2,880	Thursby & Berry 1988
Copepod (adult), *Acartia tonsa*	S, M	Technical (97.6%)	20	2.57	2.57	Khattat & Farley 1976
Mysid (juvenile), *Americamysis bahia*	R, U	(96%)	29	8.5[d]	-	Thursby & Berry 1988
Mysid (juvenile), *Americamysis bahia*	S, U	Technical	25	8.5[d]	-	Cripe 1994
Mysid (juvenile), *Americamysis bahia*	F, M	Diazinon	17	4.82	4.82	Nimmo et al. 1981
Amphipod (juvenile), *Ampelisca abdita*	R, U	(96%)	30	6.6	6.6	Thursby & Berry 1988
Pink shrimp (larval), *Penaeus duorarum*	S, U	Technical	25	21	21	Cripe 1994
Grass shrimp (larval), *Palaemonetes pugio*	R, U	(96%)	30	2.8	2.8	Thursby & Berry 1988

Table 1. (continued)

Species	Method[a]	Chemical[b]	Salinity (g/kg)	LC50 or EC50 (µg/L)	Species Mean Acute Value (µg/L)	Reference
Sea urchin (embryo/larval), *Arbacia punctulata*	S, U	(96%)	31	>9,600	>9,600	Thursby & Berry 1988
Sheepshead minnow (juvenile), *Cyprinodon variegatus*	F, M	(92.6%)	23	1,400	1,400	Goodman et al. 1979; Mayer 1987
Inland silverside (juvenile), *Menidia beryllina*	R, U	(96%)	30	1,170	1,170	Thursby & Berry 1988

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

[b] Percent purity is given in parenthesis when available

[c] Animals were fed during the exposure

[d] Results were not used in the calculation of the Species Mean Acute Value due to availability of data from more sensitive test conditions.

Table 2. Chronic Toxicity of Diazinon to Aquatic Animals

Species	Test[a]	Chemical[b]	Hardness (mg/L as $CaCO_3$)	Chronic Limits (µg/L)	Chronic Value (µg/L)	Reference
			FRESHWATER SPECIES			
Cladoceran (<6-hr. old), *Ceriodaphnia dubia*	LC (7-day)	Technical (85%)	40	0.220-0.520	0.3382	Norberg-King 1987
Brook trout (yearling), *Salvelinus fontinalis*	PLC	Technical (92.5%)	45	0-0.8	<0.8	Allison and Hermanutz 1977
Zebrafish, *Brachydanio rerio*	ELS	Analytical	360	200->200	>200	Bresch 1991
Fathead minnow (embryo-larva), *Pimephales promelas*	ELS	Technical (87.1%)	45.8	50-90	67.08	Jarvinen and Tanner 1982
Fathead minnow (embryo-larva), *Pimephales promelas*	ELS	Technical (88.2%)	44-49	16.5-37.8	24.97	Norberg-King 1989
Flagfish (1-day old), *Jordanella floridae*	LC	-	-	0-14	<14	Allison 1977
			SALTWATER SPECIES			

Table 2. (continued)

Mysid (juvenile), *Americamysis bahia*	LC	-	30-31[c]	2.1-4.4	3.040	Nimmo et al. 1981
Sheepshead minnow (juvenile), *Cyprinodon variegatus*	PLC	Technical (92.6%)	16.5[c]	0-0.47	<0.47	Goodman et al. 1979

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

[b] Percent purity is listed in parentheses when available.

[c] Salinity g/kg.

Acute-Chronic Ratio

Species	Hardness (mg/L as $CaCO_3$)	Acute Value (µg/L)	Chronic Value (µg/L)	Ratio	Mean Ratio
Cladoceran, *Ceriodaphnia dubia*	40	0.3760	0.3382	1.112	1.112
Mysid, *Americamysis bahia*	17[c]	4.82	3.040	1.586	1.586
Flagfish, *Jordanella floridae*	45	1,643	<14	>117.4	>117.4

Table 2. (continued)

Fathead minnow, *Pimephales promelas*	45.8	6,900	67.08	102.9	-
Fathead minnow, *Pimephales promelas*	44-49	9,350	24.97	374.4	196.3
Brook trout, *Salvelinus fontinalis*	45	723.0	<0.8	>903.8	>903.8
Sheepshead minnow, *Cyprinodon variegatus*	16.5[c]	1,400	<0.47	>2,979	>2,979

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[c] Salinity (g/kg).

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		
20	11,640	Planaria, *Dugesia tigrina*	11,640	-
19	11,000	Snail, *Gillia altilis*	11,000	-
18	9,000	Goldfish, *Carassius auratus*	9,000	-
17	8,641	Fathead minnow, *Pimephales promelas*	8,641	196.3
16	8,000	Zebrafish, *Brachydanio rerio*	8,000	-
15	7,841	Oligachaete worm, *Lumbricus variegatus*	7,841	-
14	3,198	Snail, *Pomacea paludosa*	3,198	-
13	1,643	Flagfish, *Jordanella floridae*	1,643	>117.4
12	960.4	Cutthroat trout, *Oncorhynchus clarki*	2,166	-
		Rainbow trout, *Oncorhynchus mykiss*	425.8	-
11	800	Guppy, *Poecilia reticulata*	800	-
10	660	Brook trout, *Salvelinus fontinalis*	723	>903.8

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]
		Lake trout, *Salvelinus namaycush*	602	-
9	459.6	Bluegill, *Lepomis macrochirus*	459.6	-
8	>50	Green frog *Rana clamitans*	>50	-
7	25	Stonefly, *Pteronarcys californica*	25	-
6	10.7	Midge, *Chironomus tentans*	10.7	-
5	6.51	Amphipod, *Hyalella azteca*	6.51	-
4	1.587	Cladoceran, *Simocephalus serrulatus*	1.587	-
3	0.9020	Cladoceran, *Daphnia magna*	1.048	-
		Cladoceran, *Daphnia pulex*	0.7764	-
2	0.3773	Cladoceran, *Ceriodaphnia dubia*	0.3773	1.112
1	0.20	Amphipod, *Gammarus fasciatus*	0.20	-

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]
		SALTWATER SPECIES		
9	>9,600	Sea urchin, *Arbacia punctulata*	>9,600	-
8	>2,880	Annelid worm, *Neanthes arenaceodentata*	>2,880	-
7	1,400	Sheepshead minnow, *Cyprinodon variegatus*	1,400	>2,979
6	1,170	Inland silverside, *Menidia beryllina*	1,170	-
5	21	Pink shrimp, *Penaeus duorarum*	21	-
4	6.6	Amphipod, *Ampelisca abdita*	6.6	-
3	4.82	Mysid, *Americamysis bahia*	4.82	1.586
2	2.8	Grass shrimp *Palaemonetes pugio*	2.8	-
1	2.57	Copepod, *Acartia tonsa*	2.57	-

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

Table 3. (continued)

<u>Fresh Water</u>

Final Acute Value = 0.1925 µg/L

Criterion Maximum Concentration = (0.1925 µg/L)/2 = 0.0963 µg/L

Final Acute-Chronic Ratio = 2.0 (see text)

Final Chronic Value = (0.1925 µg/L)/2.0 = 0.0963 µg/L

<u>Salt Water</u>

Final Acute Value = 1.637 µg/L

Criterion Maximum Concentration = (1.637 µg/L)/2 = 0.8185 :g/L

Final Acute-Chronic Ratio = 2.0 (see text)

Final Chronic Value = (1.637 µg/L)/2.0 = 0.8185 µg/L

Table 4. Toxicity of Diazinon to Aquatic Plants

Species	Hardness (mg/L as $CaCO_3$)	Duration (days)	Effect	Concentration (µg/L)	Reference
FRESHWATER SPECIES					
Green algae, *Selenastrum capricornutum*	-	7	EC50 (cell numbers)	6,400	Hughes 1988

Table 5. Bioaccumulation of Diazinon by Aquatic Organisms

Species	Concentration in Water (µg/L)[a]	Duration (days)	Tissue	Percent Lipids	BCF or BAF[b]	Normalized BCF or BAF[c]	Reference
FRESHWATER SPECIES							
Rainbow trout (16 g), *Oncorhynchus mykiss*	15	14	Whole body	-	62	-	Seguchi and Asaka 1981
Carp (8 g), *Cyprinus carpio*	15	14	Whole body	-	120	-	Seguchi and Asaka 1981
Guppy, *Poecilia reticulata*	350	14	Whole body	-	188	-	Keizer et al. 1993
SALTWATER SPECIES							
Sheepshead minnow, *Cyprinodon variegatus*	1.8	108	Whole body (less brain)	-	147	-	Goodman et al. 1979
Sheepshead minnow, *Cyprinodon variegatus*	3.5	108	Whole body (less brain)	-	147	-	Goodman et al. 1979
Sheepshead minnow, *Cyprinodon variegatus*	6.5	108	Whole body (less brain)	-	213	-	Goodman et al. 1979

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[a] Measured concentration of diazinon.

[b] Bioconcentration factors (BCFs) and bioaccumulation factors (BAFs) are based on measured concentrations of diazinon in water and in tissue.

[c] When possible, the factors were normalized to 1% lipids by dividing the BCFs and BAFs by the percent lipids.

Table 6. Other Data on Effects of Diazinon on Aquatic Organisms

Species	Chemical[a]	Hardness (mg/L as $CaCO_3$)	Duration	Effect	Concentration (µg/L)	Reference
			FRESHWATER SPECIES			
Sewage microbes	Regent	-	22 hr	No reduction of oxygen consumption	40,000	Bauer et al. 1981
Actinomycete bacteria	Technical	-	20 days	Stimulated growth	40,000	Sethunathan and MacRae 1969
Green alga, *Chlorella ellipsoidea*	-	-	72 hr	Decreased ATP content	100,000	Clegg and Koevenig 1974
Green alga, *Chlamydomonas* sp.	-	-	72 hr	Decreased ATP content	100,000	Clegg and Koevenig 1974
Green alga, *Scenedesmus quadricauda*	-	-	10 days	No decrease in cell number, biomass, or photosynthesis	1,000	Stadnyk and Campbell 1971
Mixture of green alga and diatoms	(99.9%)	-	14 days	Decreased growth	<10	Butler et al. 1975a
Euglenoid, *Euglena elastica*	-	-	72 hr	Decreased ATP content	100,000	Clegg and Koevenig 1974
Duckweed, *Wolffia papulifera*	(97%)	-	11 days	Lethal	100,000	Worthley and Schott 1971
Duckweed, *Wolffia papulifera*	(97%)	-	11 days	Teratogenic effects	10,000	Worthley and Schott 1971
Protozan, *Paramecium caudatum*	-	-	1 hr	LC50	.3,000	Evtugyn et al. 1997

Table 6. (continued)

Species	Chemical[a]	Hardness (mg/L as $CaCO_3$)	Duration	Effect	Concentration (µg/L)	Reference
Rotifer, *Brachionus calyciflorus*	Technical (92%)	80-100	24 hr	LC50	29,220	Fernandez-Casalderrey et al. 1992a
Rotifer (16-18 hr), *Brachionus calyciflorus*	Technical (92%)	80-100	5 hr	Reduced (50%) filtration and ingestion ratios	14,000	Fernandez-Casalderrey et al. 1992b
Rotifer (<2 hr), *Brachionus calyciflorus*	Technical (92%)	80-100	10 days	Decreased reproduction	<5,000	Fernandez-Casalderrey et al. 1992c
Rotifer (<2 hr), *Brachionus calyciflorus*	Technical (99%)	80-100	4.04 days	LT50	5,000	Fernandez-Casalderry et al. 1992d
Rotifer (<2 hr), *Brachionus calyciflorus*	Technical (99%)	80-100	4.66 days	LT50	7,000	Fernandez-Casalderrey et al. 1992d
Rotifer (<2 hr), *Brachionus calyciflorus*	Technical (99%)	80-100	2.49 days	LT50	14,000	Fernandez-Casalderry et al. 1992d
Rotifer (<2 hr), *Brachionus calyciflorus*	-	80-100	48 hr	NOEC Reproduction	8,000	Snell and Moffat 1992
Rotifer (<2 hr), *Brachionus calyciflorus*	-	80-100	48 hr	NOEC Ingestion	20,000	Juchelka and Snell 1994
Oligochaete worm, *Lumbriculus variegatus*	-	-	4 hr	Lethal	20,000	Rogge and Drewes 1993
Tubificid worm, *Branchiura sowerbyi*	-	-	96 hr	LC50	2,220	Chatterjee and Konar 1984
Snail, *(Physa acuta)*	-	-	48 hr	LC50	4,800	Hashimoto and Nishiuchi 1981

Table 6. (continued)

Species	Chemical[a]	Hardness (mg/L as $CaCO_3$)	Duration	Effect	Concentration (µg/L)	Reference
Cladoceran (<6 hr), *Ceriodaphnia dubia*	Technical (85%)	40	7 days	No effect on survival or reproduction	0.220	Norberg-King 1987
Cladoceran (<6 hr), *Ceriodaphnia dubia*	Technical (85%)	40	7 days	Lethal	0.520	Norberg-King 1987
Cladoceran *Daphnia magna*	-	202	50 hr	EC50	4.3	Anderson 1959
Cladoceran (adult), *Daphnia magna*	-	-	24 hr	Adhesion of algal particles on 2nd antennae and immobilization	1	Stratton and Corke 1981
Cladoceran (<24 hr), *Daphnia magna*	Analytical (95%)	200	21 days	Reduced reproduction and mobility	0.3	Dortland 1980
Cladoceran (<24 hr), *Daphnia magna*	Analytical (99%)	200	21 days	No reduction in reproduction or mobility	0.2	Dortland 1980
Cladoceran (<24 hr), *Daphnia magna*	Analytical (99%)	200	21 days	EC50 (immobilization)	0.22	Dortland 1980
Cladoceran (<24 hr), *Daphnia magna*	Analytical (99%)	200	21 days	EC50 (immobilization)	0.24	Dortland 1980
Cladoceran (<24 hr), *Daphnia magna*	Analytical (99%)	200	21 days	EC50 (immobilization)	0.7	Dortland 1980
Cladoceran (<24 hr), *Daphnia magna*	Analytical (99%)	200	21 days	EC50 (immobilization)	0.8	Dortland 1980

Table 6. (continued)

Species	Chemical[a]	Hardness (mg/L as $CaCO_3$)	Duration	Effect	Concentration (µg/L)	Reference
Cladoceran (<24 hr), *Daphnia magna*	Insecticidal soap	-	48 hr	LC50	0.74	Mitchell 1985
Cladoceran (<24 hr), *Daphnia magna*	Insecticidal soap	-	96 hr	LC50	0.21	Mitchell 1985
Cladoceran (adult), *Daphnia magna*	Technical	-	3 hr	LC50	7.8	Nishiuchi and Hashimoto 1967
Cladoceran, *Daphnia magna*	Technical	-	3 hr	LC50	80	Hashimoto and Nishiuchi 1981
Cladoceran, *Daphnia magna*	Technical (92%)	-	5 hr	Reduced (50%) filtration rate	0.47	Fernandez-Casalderrey et al. 1994
Cladoceran (<24 hr), *Daphnia magna*	Technical (92%)	250	21 days	NOEC survival	0.15	Fernandez-Casalderrey et al. 1995
Cladoceran (<24 hr), *Daphnia magna*	Technical (92%)	250	21 days	LOEC survival	0.18	Fernandez-Casalderrey et al. 1995
Cladoceran (<24 hr), *Daphnia magna*	Technical (92%)	250	21 days	LOEC reproduction	0.15	Fernandez-Casalderrey et al. 1995
Cladoceran, *Daphnia magna*	Optimum	160-180	30 min	IC50	0.45	Fort et al. 1996
Cladoceran, *(Daphnia pulex)*	-	-	3 hr	LC50	80	Hashimoto and Nishiuchi 1981
Cladoceran, *(Daphnia pulex)*	-	-	3 hr	LC50	7.8	Nishiuchi and Hashimoto 1967

Table 6. (continued)

Species	Chemical[a]	Hardness (mg/L as $CaCO_3$)	Duration	Effect	Concentration (µg/L)	Reference
Cladoceran (adult), *Moina macrocopa*	Technical	-	3 hr	LC50	26	Nishiuchi and Hashimoto 1967
Cladoceran, *Moina macrocopa*	Technical	-	3 hr	LC50	50	Hashimoto and Nishiuchi 1981
Copepod, *Cyclops vividis*	-	-	96 hr	LC50	2,600	Chatterjee and Konar 1984
Amphipod (adult), *Hyalella azteca*	Technical	160-180	48 hr	LC50	19 (measured)	Werner and Nagel 1997
Amphipod (0-2 days), *Hyalella azteca*	Technical	40	96 hr	LC50	6.2	Collyard et al. 1994
Amphipod (2-4 days), *Hyalella azteca*	Technical	40	96 hr	LC50	4.2	Collyard et al. 1994
Amphipod (6-8 days), *Hyalella azteca*	Technical	40	96 hr	LC50	4.3	Collyard et al. 1994
Amphipod (8-10 days), *Hyalella azteca*	Technical	40	96 hr	LC50	4.4	Collyard et al. 1994
Amphipod (12-14 days), *Hyalella azteca*	Technical	40	96 hr	LC50	3.8	Collyard et al. 1994
Amphipod (16-18 days), *Hyalella azteca*	Technical	40	96 hr	LC50	4.4	Collyard et al. 1994
Amphipod (20-22 days), *Hyalella azteca*	Technical	40	96 hr	LC50	4.6	Collyard et al. 1994
Amphipod (24-26 days), *Hyalella azteca*	Technical	40	96 hr	LC50	4.6	Collyard et al. 1994
Amphipod (2 mo.), *Gammarus lacustris*	-	-	96 hr	LC50	200	Sanders 1969

Table 6. (continued)

Species	Chemical[a]	Hardness (mg/L as $CaCO_3$)	Duration	Effect	Concentration (µg/L)	Reference
Crayfish, *Procambarus clarkii*	-	-	7 days	BCF = 4.9	10	Kanazawa 1978
Stonefly (nymph), *Pteronarcys californicus*	-	-	48 hr	EC50	74	Cope 1965a
Caddisfly (larva), *Hydropsyche morosa*	-	-	6 hr	LC50	2,500	Fredeen 1972
Caddisfly (larva), *Hydropsyche morosa*	-	-	6 hr	LC50	500	Fredeen 1972
Caddisfly (larva), *Hydropsyche recurvata*	-	-	6 hr	LC50	>500	Freeden 1972
Caddisfly (larva), *Hydropsyche recurvata*	-	-	6 hr	LC50	>500	Freeden 1972
Mosquito (4th instar), *Aedes aegypti*	Technical	-	24 hr	LC50	350	Klassen et al. 1965
Mosquito (3rd-4th instar), *Culex pipiens fatigans*	Technical	-	24 hr	LC50	61	Chen et al. 1971
Mosquito (3rd-4th instar), *Culex pipiens fatigans*	Technical	-	24 hr	LC50	80	Chen et al. 1971
Mosquito (4th instar), *Culex pipiens fatigans*	Technical	-	24 hr	LC50	3.5	Yasuno and Kerdpibule 1967
Mosquito (4th instar), *Culex pipiens fatigans*	Technical	-	24 hr	LC50	5.7	Yasuno and Kerdpibule 1967

Table 6. (continued)

Species	Chemical[a]	Hardness (mg/L as $CaCO_3$)	Duration	Effect	Concentration (µg/L)	Reference
Mosquito (4th instar), *Culex pipiens fatigans*	Technical	-	24 hr	LC50	2.2	Yasuno and Kerdpibule 1967
Mosquito (4th instar), *Culex pipiens fatigans*	Technical	-	24 hr	LC50	3.2	Yasuno and Kerdpibule 1967
Mosquito (4th instar), *Culex pipiens fatigans*	Technical	-	24 hr	LC50	4.6	Yasuno and Kerdpibule 1967
Mosquito (4th instar), *Culex pipiens fatigans*	Technical	-	24 hr	LC50	4.5	Yasuno and Kerdpibule 1967
Mosquito (4th instar), *Culex pipiens fatigans*	Technical	-	24 hr	LC50	1.9	Yasuno and Kerdpibule 1967
Mosquito (4th instar), *Culex pipiens fatigans*	Technical	-	24 hr	LC50	1.8	Yasuno and Kerdpibule 1967
Mosquito (4th instar), *Culex pipiens fatigans*	Technical	-	24 hr	LC50	5.4	Yasuno and Kerdpibule 1967
Mosquito (4th instar), *Culex pipiens fatigans*	Technical	-	24 hr	LC50	3.5	Yasuno and Kerdpibule 1967
Midge (1st instar), *Chironomus riparius*	Analytical (99.7%)	-	96 hr	LC50 (fed)	23	Stuijfzand et al. 2000
Midge (4th instar), *Chironomus riparius*	Analytical (99.7%)	-	96 hr	LC50 (fed)	167	Stuijfzand et al. 2000
Salmonidae	Emulsible concentrate (60%)	-	96 hr	LC50	8,000	Ciba-Geigy 1976
Brown Trout (3.22 g), *Salma trutta lacustris*	-	-	96 hr	LC50	602	Swedberg 1973

Table 6. (continued)

Species	Chemical[a]	Hardness (mg/L as $CaCO_3$)	Duration	Effect	Concentration (µg/L)	Reference
Cutthroat trout (0.52 g), *Oncorhynchus clarki*	-	-	96 hr	LC50	3,850	Swedberg 1973
Cutthroat trout (2.02 g), *Oncorhynchus clarki*	-	-	96 hr	LC50	2,760	Swedberg 1973
Rainbow trout (fry), *Oncorhynchus mykiss*	Insecticidal soap	-	96 hr	LC50	20	Mitchell 1985
Rainbow trout, *Oncorhynchus mykiss*	-	-	48 hr	EC50	170	Cope 1965a
Rainbow trout (16 g), *Oncorhynchus mykiss*	Synthesized	-	14 days	BCF = 62	15	Seguchi and Asaka 1981
Rainbow trout, *Oncorhynchus mykiss*	Analytical	360	28 days	NOEC	200	Bresch 1991
Goldfish (4.01 cm), *Carassius auratus*	Technical	-	48 hr	LC50	5,100	Nishiuchi and Hashimoto 1967; Hashimoto and Nishiuchi 1981
Carp, *Cyprinus carpio*	-	-	7 days	BCF = 65.1	10	Kanazawa 1978
Carp (4.2 cm), *Cyprinus carpio*	Technical	-	72 hr	LC50	2,000	Nishiuchi and Asano 1981

Table 6. (continued)

Species	Chemical[a]	Hardness (mg/L as $CaCO_3$)	Duration	Effect	Concentration (µg/L)	Reference
Carp (6.0 cm), *Cyprinus carpio*	Technical	-	48 hr	LC50	3,200	Nishiuchi and Hashimoto 1967; Hashimoto and Nishiuchi 1981; Nishiuchi and Asano 1981
Carp (8 g), *Cyprinus carpio*	Synthesized	-	14 days	BCF = 120	18	Seguchi and Asaka 1981
Carp (1.1-1.4 g), *Cyprinus carpio*	-	-	72 hr	LC50	1,420	Dutt and Guha 1988
Carp (24-35 g), *Cyprinus carpio*	Reagent (98%)	-	7 days	BCF = 20.9	2.4	Tsuda et al. 1990
Fathead minnow (larva), *Pimephales promelas*	Technical (88.2%)	44-49	7 days	No reduction in growth or survival	277	Norberg-King 1989
Fathead minnow (embryo-larva), *Pimephales promelas*	Technical (88.2%)	44-49	12 days	No reduction in growth or survival	285	Norberg-King 1989
Fathead minnow (larva), *Pimephales promelas*	Technical (88.2%)	44-49	7 days	Reduction in dry weight	347	Norberg-King 1989
Fathead minnow (larva), *Pimephales promelas*	Technical (88.2%)	44-49	7 days	Reduction in dry weight	277	Norberg-King 1989
Fathead minnow (newly hatched larvae), *Pimephales promelas*	Encapsulated formulation (fresh stock)	45.8	96 hr	LC50	6,100	Jarvinen and Tanner 1982

Table 6. (continued)

Species	Chemical[a]	Hardness (mg/L as $CaCO_3$)	Duration	Effect	Concentration (µg/L)	Reference
Fathead minnow (newly hatched larvae), *Pimephales promelas*	Encapsulated formulation (11 week-old stock)	45.8	96 hr	LC50	5,100	Jarvinen and Tanner 1982
Fathead minnow (embryo-larva), *Pimephales promelas*	Encapsulated formulation	45.8	32 days	No effect on weight	40	Jarvinen and Tanner 1982
Fathead minnow (embryo-larva), *Pimephales promelas*	Encapsulated formulation	45.8	32 days	Significant reduction in weight	76	Jarvinen and Tanner 1982
Ide *Leucisuc idus*	Emulsifiable concentrate (60%)	-	96 hr	LC50	150	Ciba-Geigy 1976
Catfish *Ictalurus* sp.	Emulsifiable concentrate (60%)	-	96 hr	LC50	8,000	Ciba-Geigy 1976
Flagfish (larva-juvenile), *Jordanella floridae*	-	-	21-day pulsed dose + recovery	Decreased egg production	290	Allison 1977
Flagfish (juvenile-adult), *Jordanella floridae*	-	-	21-day pulsed dose + recovery	Decreased parental survival	250	Allison 1977
Flagfish (adult-spawning), *Jordanella floridae*	-	-	21-day pulsed dose + recovery	Decreased survival of parents and larvae	1,170	Allison 1977

Table 6. (continued)

Species	Chemical[a]	Hardness (mg/L as $CaCO_3$)	Duration	Effect	Concentration (µg/L)	Reference
Oriental weatherfish, *Misqurnus anguillicaudatus*	Technical	-	48 hr	LC50	500	Hashimoto and Nishiuchi 1981
Oriental weatherfish (2.6 g), *Misgurnus anguillicaudatus*	Synthesized	-	14 days	BCF = 28	14	Seguchi and Asaka 1981
Guppy (7 wk), *Poecilia reticulata*	Technical	-	24 hr	LC50	3,700	Chen et al. 1971
Guppy (7 wk), *Poecilia reticulata*	Technical	-	24 hr	LC50	3,800	Chen et al. 1971
Guppy (7 wk), *Poecilia reticulata*	Technical	-	30 min	Loss of equilibrium	7,000	Chen et al. 1971
Guppy, *Poecilia reticulata*	Emulsifiable concentrate (60%)	-	96 hr	LC50	3,000	Ciba-Geigy 1976
Guppy, *Poecilia reticulata*	-	-	7 days	BCF = 17.5	10	Kanazawa 1978
Guppy (2-3 mon), *Poecilia reticulata*	Technical (99%)	100	3 days	Lethal body burden	2,495	Ohayo-Mitoko and Deneer 1993
Guppy (2-3 mon), *Poecilia reticulata*	-	75	24 hr	Lethal body burden (@ 4,330 µg/l exposure)	2.1 (µmol/g)	Deneer et al. 1999
Guppy (2-3 mon), *Poecilia reticulata*	-	75	7 days	Lethal body burden (@ 2,420 µg/L exposure)	1.8 (µmol/g)	Deneer et al. 1999

Table 6. (continued)

Species	Chemical[a]	Hardness (mg/L as $CaCO_3$)	Duration	Effect	Concentration (µg/L)	Reference
Tilapia, *Tilapia* sp.	-	-	48 hr	LC50	1,492	Li and Chen 1981
Mozambique tilapia (5-9 g), *Tilapia mossambica*	Technical	-	-	LC100	15,850	Mustafa et al. 1982
Mozambique tilapia (3.56 g), *Tilapia mossambica*	-	-	96 hr	LC50	2,280	Chatterjee and Konar 1984
Mozambique tilapia (1.4 g), *Tilapia mossambica*	-	-	72 hr	LC50	2,880	Dutt and Guha 1988
Bluegill, *Lepomis macrochirus*	-	-	48 hr	EC50	30	Cope 1965a
Bluegill, *Lepomis macrochirus*	Basudin (93%)	-	48 hr	LC50	1,493	Li and Chen 1981
Experimental stream community	Technical (92.5%)	170-195	84 days	Increased drift rates for *Hyalella*	0.3	Arthur et al. 1983
Experimental stream community	Technical (92.5%)	170-195	112 days	Reduced *Hyalella* populations	5	Arthur et al. 1983
Experimental pond community	Technical (88%)	70-150	70 days	NOEC for phytoplankton and periphyton chlorophyll, and macrophyte biomass	443	Giddings et al. 1996

Table 6. (continued)

Species	Chemical[a]	Hardness (mg/L as $CaCO_3$)	Duration	Effect	Concentration (µg/L)	Reference
Experimental pond community	Technical (88%)	70-150	70 days	LOEC for Cladocera, Pentaneurcini, and Ceratopogonidae abundance	2.4	Giddings et al. 1996
Experimental pond community	Technical (88%)	70-150	70 days	LOEC for zooplankton and macroinvertebrate taxonomic richness	9.2	Giddings et al. 1996
Experimental pond community	Technical (88%)	70-150	70 days	Reduced bluegill sunfish biomass	22	Giddings et al. 1996
Experimental pond community	Technical (88%)	70-150	70 days	Reduced bluegill sunfish survival	54	Giddings et al. 1996

Species	Chemical[a]	Salinity (g/kg)	Duration	Effect	Concentration (ug/L)	Reference
			SALTWATER SPECIES			
Natural photoplankton	-	-	4 hr	6.8% decrease in photosynthesis	1,000	Butler 1963

Table 6. (continued)

Species	Chemical[a]	Salinity (g/kg)	Duration	Effect	Concentration (ug/L)	Reference
Red alga, *Chondrus crispus*	(12.5%)	-	24 hr exposure 18 day holding	No effect on growth	10,000	Shacklock & Croft 1981
Red alga, *Champia parvula*	(96%)	-	48 hr exposure	No effect on sexual reproduction	1,000	Thursby & Tagliabue 1988
Rotifer, *Brachionus plicatilis*	(96%)	-	24 hr	LC50	55,100	Thursby & Berry 1988
Rotifer, *Brachionus plicatilis*	Standard ($95%)	-	24 hr	EC50	28,000	Guzzella et al. 1997
Snail, *Lacuna vincta*	(12.5%)	-	3 hr exposure, 48 hr holding	88% mortality	1,000	Shacklock & Croft 1981
Snail, *Lacuna vincta*	(12.5%)	-	3 hr exposure, 48 hr holding	75% mortality	10,000	Shacklock & Croft 1981
Eastern oyster, *Crassostrea virginica*	-	-	96 hr	No decrease in shell growth	1,000	Butler 1963; Mayer 1987
Eastern oyster (5-10 cm height), *Crassostrea virginica*	Technical and 14C- labeled	-	96 hr	LC50 shell growth	1,115	Williams 1989
Eastern oyster (6-10 cm height), *Crassostrea virginica*	Technical and 14C-labeled	-	5 days	BFC = 56	100	Williams 1989
Amphipod (adult), *Ampelisea aldita*	Technical	25	48 hr	LC50	10	Werner & Nagel 1997
Amphipod, *Gammarus oceanicus*	(12.5%)	-	3 hr exposure	100% mortality	1,000	Shacklock & Croft 1981

Table 6. (continued)

Species	Chemical[a]	Salinity (g/kg)	Duration	Effect	Concentration (ug/L)	Reference
Amphipod (adult), *Rhepoxynius abronius*	Technical	31	24 hr	LC50	9.2	Werner & Nagel 1997
Isopod, *Idotea baltica*	(12.5%)	-	3 hr exposure	100% mortality	1,000	Shacklock & Croft 1981
Brown shrimp, *Penaeus aztecus*	-	-	24 hr	EC50	44	Butler 1963
Brown shrimp, *Penaeus aztecus*	Technical 95.1% pure	-	48 hr	EC50	28	Mayer 1987
Grass shrimp, *Palaemonetes pugio*	Technical 95.1% pure	-	48 hr	EC50	28	Mayer 1987
White mullet, *Mugil curema*	-	-	24 & 48 hr	LC50	250	Butler 1963
Striped mullet, *Mugil cephalus*	Technical 95.1% pure	-	48 hr	LC50	150	Mayer 1987
Sheepshead minnow, *Cyprinodon variegatus*	92.6% pure	-	108 days	Decrease in acetylcholinesterase activity	0.47	Goodman et al. 1979; Mayer 1987

[a] Percent purity is listed in parentheses when available.

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