

**AMBIENT AQUATIC LIFE WATER QUALITY CRITERIA FOR
PARATHION**

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NOTICES

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FOREWORD

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

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

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

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Introduction*

Parathion (0,0-diethyl 0-4-nitrophenyl phosphorothioate, sometimes called ethyl parathion or parathion-ethyl) is one of several organophosphorus pesticides developed to replace the more persistent organochlorine pesticides. It is now a restricted-use pesticide that is effective against a wide-range of insect pests on many fruit, nut, vegetable, and field crops. It is usually formulated as an emulsifiable concentrate, but is also available in granules, dusts, aerosols, oil sprays, and wettable powders. These formulations often contain large percentages of unspecified ingredients, which are often considered inert. Although no studies have compared the relative toxicities of technical-grade parathion and its various formulations, other organophosphorus insecticides (e.g., chlorpyrifos) have been shown to differ substantially in this regard. Although some data obtained from studies on formulations are discussed, data from such studies are not used in the derivation of the criteria.

The toxicity of parathion is the result of metabolic conversion to its oxygen analogue, parathion-oxon (paraoxon) and its subsequent binding to and inhibition of various enzyme systems (e.g., cholinesterases, carboxylases, acetylcholinesterases, and mitochondrial oxidative phosphorylases). Its inhibition of acetylcholinesterase (AChE) is generally accepted to be its most critical toxic effect. Inhibition of AChE results in accumulation of the neurotransmitter acetylcholine in synapses, disrupting normal neural transmission. Although even substantial reductions in brain AChE

* An understanding of the "Guidelines for Deriving Numerical National Water Quality Criteria for the Protection of Aquatic Organisms and Their Uses" (Stephan et al. 1985), hereafter referred to as the Guidelines, and the response to public comment (U.S. EPA 1985a) is necessary in order to understand the following text, tables, and calculations.

activity in fish have not always been fatal, the effect of this condition on normal activities (e.g., feeding, reproduction, predator-prey relationships, etc.) in nature is not known. Parathion has also been demonstrated to produce teratogenic effects in fish embryos (Solomon 1977; Solomon and Weis 1979; Tomita and Matsuda 1961).

Parathion is less persistent than organochlorine pesticides and has such a great affinity for organic material that it is quickly sorbed to sediments and suspended particulate matter. Miller et al. (1967) attributed the rapid loss of parathion after application to irrigation water to degradation, although sorption probably contributed greatly to the decrease. The persistence of parathion in water is dependent on chemical hydrolysis and biodegradation (Ahmed and Casida 1958; Eichelberger and Lichtenberg 1971; Faust 1975; Faust and Gomaa 1972; Gomaa and Faust 1972; Ludemann and Herzl 1973; Mackiewicz et al. 1969; Mulla 1963; Sethunathan et al. 1977; Van Middelem 1966; Zuckerman et al. 1970). Graetz et al. (1970) reported that the portion of parathion degradation attributable to abiological processes in natural lake sediments was negligible. The movement and persistence of parathion has been described in a natural pond (Mulla et al. 1966; Nicholson et al. 1962), a model stream (Laplanche et al. 1981), and a model ecosystem (Dortland 1980). Several studies have reported concentrations of parathion in water (Braun and Frank 1980; Dick 1982; Greve et al. 1972; Harris and Miles 1975; Kannan and Job 1979; Sethunathan et al. 1977) and in biota (Chovelon et al. 1984; Haddadin and Alawi 1974; Hesselberg and Johnson 1972; Perry et al. 1983). U.S. EPA (1975) and vom Rumker et al. (1974) reviewed the use, distribution, fate, and effects of parathion.

Unless otherwise noted, all concentrations reported herein are expressed as parathion, not as the material tested. The criteria presented

herein supersede previous aquatic life water quality criteria for parathion (U.S. EPA 1976) because these new criteria were derived using improved procedures and additional information. 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 1985b). The latest comprehensive literature search for information for this document was conducted in July, 1986; some more recent information might have been included.

Acute Toxicity to Aquatic Animals

The results of acute tests that were considered useful for deriving water quality criteria for parathion are listed in Table 1. The most striking disparity of values within a species is for the crayfish, Orconectes nais. An early instar was 375 times more sensitive to parathion than adults. The LC50 of 0.04 µg/L for this early instar of Orconectes nais is the lowest available acute value.

Freshwater Species Mean Acute Values (Table 1) were calculated as geometric means of the available acute values, and then Genus Mean Acute Values (Table 3) were calculated as geometric means of the available freshwater Species Mean Acute Values. Of the 31 genera for which acute values are available, the most sensitive genus, Orconectes, is over 130,000 times more sensitive than the most resistant, Tubifex and Limnodrilus. Although nine of the 31 freshwater genera are fishes, the fifteen most sensitive genera are all invertebrates. However, the two most resistant genera are also invertebrates. Acute values are available

for more than one species in each of five genera, and the range of Species Mean Acute Values within four of the genera is less than a factor of 1.9. In the fifth genus, Gammarus, acute values for mature individuals of the two species are similar, but acute values are available for younger individuals, which are apparently more sensitive, for only one of the species. The freshwater Final Acute Value for parathion was calculated to be 0.1298 µg/L using the procedure described in the Guidelines and the Genus Mean Acute Values in Table 3. The acute value for the crayfish, Oncorhynchus natus, is about one-third the Final Acute Value.

Data on the acute toxicity of parathion are only available for two saltwater species (Table 1). The 96-hr LC50 for the Korean shrimp, Palaemon macrodactylus, was 11.5 µg/L in a static test and 17.8 µg/L in a flow-through test (Earnest 1970). Korn and Earnest (1974) reported that the 96-hr LC50 for the striped bass, Morone saxatilis, was 17.8 µg/L. Acute values are not available for enough species to allow calculation of a saltwater Final Acute Value.

Chronic Toxicity to Aquatic Animals

Chronic tests that are considered useful for deriving water quality criteria have been conducted on parathion with Daphnia magna, the fathead minnow, and the bluegill (Table 2). In the life-cycle test with D. magna, the 21-day LC50 was 0.14 µg/L, and the number of young produced was reduced by 0.12 µg/L, but not by 0.0817 µg/L. Fathead minnows were significantly affected by exposure to parathion at 9.0 µg/L, but not at 4.4 µg/L. In the life-cycle test with bluegills, 0.34 µg/L caused tumors and deformities in the adults, but did not affect survival of any life stage or reproduction. No effects were observed at 0.17 µg/L.

The three Acute-Chronic Ratios available for parathion are 10.10 for Daphnia magna, 79.45 for the fathead minnow, and 2,121 for the bluegill. Of the three species, D. magna is the most acutely sensitive, and produced the lowest chronic value and the lowest acute-chronic ratio. Thus it seems reasonable to use 10.10 as the Final Acute-Chronic Ratio. Division of the freshwater Final Acute Value of 0.1298 µg/L by the Final Acute-Chronic Ratio of 10.10 results in a Final Chronic Value of 0.01285 µg/L (Table 3).

No data are available on the chronic toxicity of parathion to saltwater animals.

Toxicity to Aquatic Plants

Data are available on the toxicity of parathion to two freshwater algae (Table 4). The blue-green alga, Microcystis aeruginosa, was affected at 30 µg/L, whereas the green alga, Scenedesmus quadricauda was not affected by concentrations below 390 µg/L.

No data are available concerning the toxicity of parathion to saltwater plants.

Bioaccumulation

Spacie (1976) and Spacie et al. (1981) reported long-term bioconcentration factors (BCFs) for the brook trout, fathead minnow, and bluegill (Table 5), and short-term BCFs are available for the brown trout, brook trout, and bluegill (Table 6). The BCFs determined with brook trout did not show a consistent relationship with either concentration in water or duration of exposure (Tables 5 and 6); the 260-day BCFs ranged from 31 to 232 for muscle tissue. The 260-day BCFs based on whole-body measurements with fathead minnows ranged from 32.9 to 201.4. The short-term BCFs measured

with bluegills increased steadily with duration of exposure from 80.5 at 12 hr to 462 at 72 hr, but the BCF at 540 days was only 27.

No data that can be used in the derivation of water quality criteria are available on the bioaccumulation of parathion by saltwater species.

No U.S. FDA action level or other maximum acceptable concentration in tissue is available for parathion, and, therefore, no Final Residue Value can be calculated.

Other Data

Additional data on the effects of parathion on aquatic organisms are given in Table 6. The majority of the data are LC50s for durations other than 96 hours. Ahmed (1977) observed a range in 24-hr LC50s from 1.8 $\mu\text{g/L}$ to 40 $\mu\text{g/L}$ with six freshwater coleopteran species. Because of its wide use as a mosquito larvicide, many data are available on acute toxicity to mosquito larva. However, standard methods for testing effectiveness of larvicides prescribe a 24-hr test duration. The 24-hr LC50s for seven species of mosquitos in three genera range from 0.47 to 68 $\mu\text{g/L}$. Gutierrez et al. (1977) reported LC50s from 1.8 to 70 $\mu\text{g/L}$ for larvae of resistant populations of Culex pipiens.

Kynard (1974) observed avoidance of parathion by mosquitofish, and Weiss (1961) found inhibition of AChE in brains of several freshwater fishes. Effects on locomotor behavior of goldfish, bluegills, and largemouth bass were reported by Rand (1977a,b) and Rand et al. (1975). Sun and Taylor (1983) studied effects of parathion on acquisition and retention of a conditioned response by goldfish.

Various studies have examined the effect of a detergent (Solon and Nair 1970; Solon et al. 1969), herbicides (Lichtenstein et al. 1975), and an N-alkyl compound, SKF-525A (Gibson and Ludke 1973) on the toxicity of

parathion. Banas and Sprague (1981) reported that prior exposure of rainbow trout did not affect the LC50.

Several studies evaluated the effectiveness of using trout for detecting parathion and other pollutants (Jung 1973; Morgan 1975,1976,1977; Van Hoof 1980). Mount and Boyle (1969) examined the use of the concentration of parathion in fish blood to diagnose causes of fish kills. Ghetti and Gorbi (1985) studied the effects of a simulated parathion spill on a stream. Albright et al. (1983), Gasith and Perry (1980,1983,1985), Gasith et al. (1983a,b), and Grzenda et al. (1962) reported community effects of parathion on a pond. Warnick et al. (1966) found that increases in the concentrations of organochlorine compounds in water correlated with application of parathion to a pond. They postulated that these compounds were released from decomposing tissues of intoxicated organisms.

At a concentration of 1,000 µg/L, parathion reduced the rate of growth of natural saltwater plankton communities by 9.9% in 4 hr (Butler 1964). Juvenile pink shrimp, Penaeus duorum, had a 48-hr EC50 of 0.24 µg/L, whereas the EC50s for other penaeid and palaemonid shrimp ranged from 1.0 to 5.5 µg/L (Butler 1964; Lowe et al. 1970; U.S. Bureau of Commercial Fisheries 1966,1967). Grass shrimp, Palaemonetes pugio, exposed to 0.1 or 0.5 µg/L were more susceptible to predation by gulf killifish, Fundulus grandis (Farr 1977). Limb regeneration and time to molting of the fiddler crab, Uca pugilator, were apparently unaffected by exposure to parathion for 2 to 3 weeks, but all crabs exposed to 100 µg/L died (Weis and Mantel 1976). The 96-hr EC50 based on shell deposition was 850 µg/L or higher for the eastern oyster, Crassostrea virginica (Butler 1963,1964; Lowe et al. 1970; U.S. Bureau of Commercial Fisheries

1966). Lowe et al. (1971) found that growth of juvenile oysters was not reduced by exposure to 0.8 µg/L for 252 days. Davis and Hidu (1969) reported a 78% reduction in length of oyster larvae after a 12-day exposure to 1,000 µg/L.

The sensitivity of saltwater fishes to parathion did not differ greatly. The 48-hr LC50s were 15 µg/L for longnose killifish, Fundulus similis; 18 µg/L for spot, Leiostomus xanthurus; 36 µg/L for sheepshead minnows, Cyprinodon variegatus; and 100 µg/L for striped mullet, Mugil cephalus (Butler 1964; Lowe et al. 1970; and U.S. Bureau of Commercial Fisheries 1966, 1967). Regeneration of fins by adult mummichogs, Fundulus heteroclitus, was reduced by exposure to 10 µg/L for 10 weeks (Weis and Weis 1975) and this species had a 50% incidence of circulatory failure when exposed to 10,000 µg/L for three days (Weis and Weis 1974).

Inhibition of acetylcholinesterase (AChE) in saltwater fishes is a function of degree and duration of acute exposure and appears associated with death. Regardless of concentration and duration of exposure, when 40 to 60% of the sheepshead minnows, pinfish, and spot died, survivors had AChE reductions of \geq 82.3% (Coppage and Mathews 1974).

White et al. (1979) reported 57 to 90% inhibition of brain cholinesterase activity in dead laughing gulls, Larus atricilla, contaminated with parathion applied to crops. Death of chicks was suspected to be a result of parathion in their food.

Unused Data

Some data on the effects of parathion on aquatic organisms were not used because the studies were conducted with species that are not resident in North American (e.g., Basak and Konar 1976a,b; Bellavere and Gorbi 1984;

Bowman et al. 1981; Butler 1964; Dortland 1980; Fleming 1981; Gregory et al. 1969; Gupta et al. 1979; Hashimoto and Nishiuchi 1981; Hudson et al. 1979; Juhnke and Ludemann (1978); Nishiuchi and Hashimoto 1967; Nishiuchi and Yoshida 1972; Panwar et al. 1976; Price 1976, 1978; Rattner 1982; Shah et al. 1983; Siva Prasada Rao et al. 1983; Weiss 1959) or because the test species was not obtained in North America and was not identified well enough to determine if it is resident in North America (e.g., Lahav and Sarig 1969). Results (e.g., Tarpley 1958) of tests conducted with brine shrimp, Artemia sp., were not used because these species are from a unique saltwater environment. Data were not used if parathion was a component of a mixture (e.g., Macek 1975) or an effluent (e.g., Lewis 1986) or if the test chamber contained sediment (D'Asaro and Wilkes 1982; Farr 1977). Cole and Plapp (1974) did not verify that the parathion was dissolved off the test tubes by the test solution.

Anderson (1960), Chiou et al. (1977), Henderson et al. (1960), LeBlanc (1984), Ramke (1969), Sato and Kubo (1965), Surber (1948), Tarzwell (1959a,b), and Yoshioka et al. (1986) only contain data that have been published elsewhere. Some studies were not used because test procedures or materials were not adequately described (e.g., Gillies et al. 1974; Hart and Womeldorf 1977; Kleerekoper 1974; Konar and Basak 1973; Lahav and Sarig 1969; Lewallen and Wilder 1962; Micks and Rougeau 1977; Moore 1970; Mulla 1980; Wilder and Schaefer 1969; Zboray and Gutierrez 1979).

Data were not used if the organisms were exposed to parathion by injection or gavage or in food (e.g., Benke et al. 1974; Carlson 1973; Hashimoto and Fukami 1969; King et al. 1984; Loeb and Kelly 1963; Murphy et al. 1968).

Bradbury (1973a,b), Chambers (1976), Dortland (1978), Dortland et al. (1976), Estenik and Collins (1979), Goldsmith et al. (1976), Hiltibrand (1974,1982), Hitchcock and Murphy (1971), Huddart (1978), Ludke et al. (1972), McDonald and Fingerman (1979), Murphy et al. (1968), Nollenberger (1982), Nollenberger et al. (1981), Weiss (1959), Weiss and Gakstatter (1964,1965), Whitmore and Hodges (1978), and Yahalom and Perry (1981) only exposed enzymes, excised tissues, or cell cultures or conducted other biochemical or histological studies. Garnas and Crosby (1979) and Lewis et al. (1984) only studied the metabolism of parathion.

Results of some laboratory tests were not used because the tests were
conducted in distilled or deionized water without addition of appropriate salts (e.g., Burchfield and Storrs 1954; Goldsmith 1978; Goldsmith and Carlson 1979; Lewallen 1959,1962; Lichtenstein et al. 1966; Yasuno et al. 1965) or if too few test organisms were exposed (e.g., Carlson 1973; Ludemann and Neumann 1961). Mulla et al. (1967) conducted tests in plastic test chambers.

Hughes (1970,1973) did not acclimate the test organisms to the dilution water for a long enough period of time. Laboratory studies using formulations of parathion were not used (e.g., Alexander et al. 1982; Basak and Konar 1976a,b; Chang and Lange 1967; Davey et al. 1976; Gaufin et al. 1961,1965; Hilsenhoff 1959; Labrecque et al. 1956; Mohamed and Gupta 1984; Panwar et al. 1982; Singh and Singh 1981, Sreenivasan and Swaminathan 1967; Srivastava et al. 1977; Verma et al. 1981). Field studies in which the concentration of parathion was not measured were not used (e.g., Ahmed 1977; Benge and Fronk 1970; Chang and Lange 1967; Davey and Meisch 1977; Davey et al. 1976; Gahan 1957; Grigarick and Way 1982;

Labrecque 1956; Mulla and Isaak 1961; Mulla et al. 1963, 1964, 1978; Myers et al. 1969; Stewart 1977).

High control mortalities occurred in tests reported by Fleming et al. (1982) and in tests with Gammarus fasciatus reported by Spacie et al. (1976). High pesticide residues were found in field collected worms by Naqvi (1973), and the concentration of solvent was too high in studies by Poorman (1973).

Microcosm studies were not used (e.g., Dordtland 1980; Francis et al. 1980; Miller et al. 1966; Yu and Sanborn 1975).

Results of laboratory bioconcentration tests were not used if the test was not flow-through or renewal (e.g., Verma and Gupta 1976) or the concentration in water was not measured (e.g., Kortus et al. 1971). A bioconcentration study by Schmidt and Weidaas (1961) was not used because radio-labeled parathion was not adequately identified as the radioactive compound in the organisms. Reports of concentrations of parathion in wild aquatic organisms (e.g., Bradbury 1973a,b; Butler and Schutzmann 1978) were not used to calculate bioaccumulation factors if the number of measurements of the concentration was too small or if the range of the measured concentrations was too great.

Summary

The acute values for thirty-seven freshwater species in thirty-one genera range from 0.04 µg/L for an early instar of a crayfish, Orconectes nais, to 5,230 µg/L for two species of tubifid worms. For Daphnia magna, the chronic value and acute-chronic ratio are 0.0990 µg/L and 10.10 µg/L, respectively. Chronic toxicity values are available for two freshwater fish species, the bluegill and the fathead minnow, with chronic values of

0.24 µg/L and 6.3 µg/L, and acute-chronic ratios of 2,121 and 79.45, respectively. Two freshwater algae were affected by toxaphene concentrations of 30 and 390 µg/L, respectively. Bioconcentration factors determined with three fish species ranged from 27 to 573.

The acute values that are available for saltwater species are 11.5 and 17.8 µg/L for the Korean shrimp, Palaemon macrodactylus, and 17.8 µg/L for the striped bass, Morone saxatilis. No data are available concerning the chronic toxicity of parathion to saltwater species, toxicity to saltwater plants, or bioaccumulation by saltwater species. Some data indicate that parathion is acutely lethal to commercially important saltwater shrimp at concentrations as low as 0.24 µg/L. Measurement of AChE might be useful for diagnosing fish kills caused by parathion.

National Criteria

The procedures described in the "Guidelines for Deriving Numerical National Water Quality Criteria for the Protection of Aquatic Organisms and Their Uses" indicate that, except possibly where a locally important species is very sensitive, freshwater aquatic organisms and their uses should not be affected unacceptably if the four-day average concentration of parathion does not exceed 0.013 µg/L more than once every three years on the average and if the one-hour average concentration does not exceed 0.065 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" require the availability of specified data for the derivation of a criterion. A saltwater criterion for parathion cannot be derived because very few of the required data are available.

Three years is the Agency's best scientific judgment of the average amount of time aquatic ecosystems should be provided between excursions (U.S. EPA 1985b). The resiliencies of ecosystems and their abilities to recover differ greatly, however, and site-specific allowed excursion frequencies may be established if adequate justification is provided.

Use of criteria for developing water quality-based permit limits and for designing waste treatment facilities requires selection of an appropriate wasteload allocation model. Dynamic models are preferred for the application of these criteria (U.S. EPA 1985b). Limited data or other considerations might make their use impractical, in which case one must rely on a steady-state model (U.S. EPA 1986).

Table 1. Acute Toxicity of Parathion to Aquatic Animals

| <u>Species</u> | <u>Method^a</u> | <u>Chemical^b</u> | <u>LC50 or EC50 (µg/L) uses</u> | <u>Species Mean Acute Value (µg/L)</u> | <u>Reference</u> |
|--|---------------------------|-----------------------------|---|--|--|
| <u>FRESHWATER SPECIES</u> | | | | | |
| Tubifield worm, <u>Limnodrilus</u> sp. | S, U | Analytical (99.6%) | 5,230 | 5,230 | Whitten and Goodlight 1966 |
| Tubifield worm, <u>Tubifex</u> sp. | S, U | Analytical (99.6%) | 5,230 | 5,230 | Whitten and Goodlight 1966 |
| Cladoceran, <u>Daphnia magna</u> | S, U | - | 0.8 | - | Boyd 1957 |
| Cladoceran, <u>Daphnia magna</u> | S, U | - | 1.8 | - | Briegmann and Kuhn 1960 |
| Cladoceran (<24 hr), <u>Daphnia magna</u> | S, M | Reagent (99%) | 1.27 | - | Spacie 1976; Spacie et al. 1981 |
| Cladoceran (<24 hr), <u>Daphnia magna</u> | S, U | Analytical (99%) | 1.3 | - | Dorti and 1980 |
| Cladoceran (<24 hr), <u>Daphnia magna</u> | F, M | Reagent (99%) | 1.0 | 1.0 | Spacie 1976; Spacie et al. 1981 |
| Cladoceran (1st Instar), <u>Daphnia pulex</u> | S, U | Technocal (98.7%) | 0.60 | 0.60 | Johnson and Finley 1980 |
| Cladoceran (1st Instar), <u>Simocephalus serrulatus</u> | S, U | Technocal (98.7%) | 0.47 | 0.47 | Johnson and Finley 1980 |
| Isopod, <u>Aesillus brevicaudus</u> | S, U | Technocal (98.7%) | 600 | - | Sanders 1972 |
| Isopoda (mature), <u>Aesillus brevicaudus</u> | S, U | Technocal (98.7%) | 2,130 | 1,130 | Johnson and Finley 1980 |
| Amphipod (mature), <u>Gammarus fasciatus</u> | S, U | Technocal (98.7%) | 2.1 [†] | - | Sanders 1972 |
| Amphipod (mature), <u>Gammarus fasciatus</u> | F, U | Technocal (98.7%) | 4.5 [†] | - | Sanders 1972 |
| Amphipod (mature), <u>Gammarus fasciatus</u> | S, U | Technocal (98.7%) | 1.3 [†] | - | Johnson and Finley 1980; Sanders 1972 |

Table 1. (continued)

| <u>Species</u> | <u>Method^a</u> | <u>Chemicals</u> | <u>LC50 or EC50 (µg/L)***</u> | <u>Species Mean Acute Value (µg/L)</u> | <u>Reference</u> |
|--|---------------------------|-------------------|---------------------------------------|--|---------------------------------------|
| <u>Amphipod (immature), <i>Gammarus fasciatus</i></u> | F, M | Reagent (99%) | 0.43 | - | Spacie 1976; Spacie et al. 1981 |
| <u>Amphipod (immature), <i>Gammarus fasciatus</i></u> | F, M | Reagent (99%) | 0.62 | - | Spacie 1976; Spacie et al. 1981 |
| <u>Amphipod (immature), <i>Gammarus fasciatus</i></u> | F, M | Reagent (99%) | 0.26 | - | Spacie 1976; Spacie et al. 1981 |
| <u>Amphipod (immature), <i>Gammarus fasciatus</i></u> | F, M | Reagent (99%) | 0.25 | 0.3628 | Spacie 1976; Spacie et al. 1981 |
| <u>Amphipod (mature), <i>Gammarus lacustris</i></u> | S, U | Technical (98.7%) | 3.5 | 3.5 | Johnson and Finley 1980; Sanders 1969 |
| <u>Prawn, <i>Palaeomonetes kadiakensis</i></u> | F, U | Technical (98.7%) | 5.0 | - | Sanders 1972 |
| <u>Prawn (mature), <i>Palaeomonetes kadiakensis</i></u> | S, U | Technical (98.7%) | 1.5 | 2.739 | Johnson and Finley 1980; Sanders 1972 |
| <u>Crayfish (mature), <i>Oncorhynchus mykiss</i></u> | S, U | Technical (98.7%) | 15† | - | Sanders 1972 |
| <u>Crayfish (early instar), <i>Oncorhynchus mykiss</i></u> | S, U | Technical (98.7%) | 0.04 | 0.04 | Sanders 1972; Johnson and Finley 1980 |
| <u>Crayfish (mature), <i>Procambarus sp.</i></u> | S, U | Technical (98.7%) | <250 | <250 | Johnson and Finley 1980 |
| <u>Phantom midge, <i>Chaoborus sp.</i></u> | S, U | - | 48†† | - | Collins and Shank 1983 |
| <u>Phantom midge, <i>Chaoborus sp.</i></u> | S, U | - | 0.8††† | - | Collins and Shank 1983 |
| <u>Phantom midge, <i>Chaoborus sp.</i></u> | S, U | - | 1.0††† | 0.8944 | Collins and Shank 1983 |

Table 1. (continued)

| <u>Species</u> | <u>Method^a</u> | <u>Chemical</u> | <u>LC50 or EC50 (µg/L) ^b</u> | <u>Species Name Acute Value (µg/L)</u> | <u>Reference</u> |
|--|---------------------------|----------------------|---|--|--|
| Mayfly, <u>Cloeon dipteron</u> | S, U | Analytical (95%) | 2.5 | - | Dortland 1980 |
| Mayfly, <u>Cloeon dipteron</u> | S, U | Analytical (95%) | 2.6 | - | Dortland 1980 |
| Mayfly, <u>Cloeon dipteron</u> | R, U | Analytical (95%) | 1.7 | 2.227 | Dortland 1980 |
| Mayfly (Juvenile), <u>Hexagenia bilineata</u> | S, U | Technical (98.7%) | 15 | 15 | Johnson and Flinley 1980 |
| Damsel fly (Juvenile), <u>Ischnura verticalis</u> | S, U | Technical (98.7%) | 0.64 | 0.64 | Johnson and Flinley 1980 |
| Damsel fly, <u>Lestes congener</u> | S, U | Technical (>94%) | 3.0 | 3.0 | Federle and Collins 1976 |
| Stonefly, <u>Pteronarcys badia</u> | S, U | Technical (98.7%) | 4.2 | 4.2 | Johnson and Flinley 1980; Sanders and Cope 1968 |
| Stonefly (naiad), <u>Pteronarcys californica</u> | S, U | Technical (95%) | 32 ^t | - | Jensen and Gauthin 1964 |
| Stonefly (2nd year class), <u>Pteronarcys californica</u> | S, U | Technical (98.7%) | 5.4 | 5.4 | Johnson and Flinley 1980; Sanders and Cope 1968 |
| Stonefly (naiad), <u>Acroneuria pacifica</u> | S, U | Technical (95%) | 2.9 | 2.9 | Jensen and Gauthin 1964 |
| Stonefly (2nd year class), <u>Classenaria sabulosa</u> | S, U | Technical (98.7%) | 1.5 | 1.5 | Johnson and Flinley 1980; Sanders and Cope 1968 |

Table 1. (continued)

| <u>Species</u> | <u>Method^a</u> | <u>Chemicals</u> | <u>LC50 or EC50 (μg/L)^b</u> | <u>Species Mean Acute Value (μg/L)</u> | <u>Reference</u> |
|--|---------------------------|----------------------|---|---|------------------------------------|
| Crawling water beetle (adult), <u>Peltodytes</u> sp. | S, U | Technical (>94%) | 7.0 | 7.0 | Federle and Collins 1976 |
| Midge, <u>Chironomus riparius</u> | S, U | - | 8.4†† | - | Collins and Shank 1983 |
| Midge, <u>Chironomus riparius</u> | S, U | - | 1.6††† | - | Collins and Shank 1983 |
| Midge, <u>Chironomus riparius</u> | S, U | - | 1.8††† | 1.697 | Collins and Shank 1983 |
| Chironomid (4th instar), <u>Chironomus tentans</u> | F, M | Reagent (99%) | 31.0 | 31.0 | Spacie 1976; Spacie et al. 1981 |
| Cutthroat trout (0.3 g), <u>Salmo clarki</u> | S, U | Technical (98.7%) | 1,560 | 1,560 | Johnson and Finley 1980 |
| Rainbow trout (1.0 g), <u>Salmo gairdneri</u> | S, U | Technical (98.7%) | 1,430 | - | Johnson and Finley 1980 |
| Rainbow trout (embryo, 0 hr), <u>Salmo gairdneri</u> | R, U | (99%) | 10,000† | - | Van Leeuwen et al. 1985 |
| Rainbow trout (embryo, 24 hr), <u>Salmo gairdneri</u> | R, U | (99%) | 10,000† | - | Van Leeuwen et al. 1985 |
| Rainbow trout (embryo, 14 day), <u>Salmo gairdneri</u> | R, U | (99%) | 10,000† | - | Van Leeuwen et al. 1985 |
| Rainbow trout (embryo, 28 day), <u>Salmo gairdneri</u> | R, U | (99%) | 10,000† | - | Van Leeuwen et al. 1985 |
| Rainbow trout (fry, 42 day), <u>Salmo gairdneri</u> | R, U | (99%) | 10,000† | - | Van Leeuwen et al. 1985 |

Table 1. (continued)

| <u>Species</u> | <u>Method^a</u> | <u>Chemicals</u> | <u>LC50 or EC50 (µg/L) ^{b,c}</u> | <u>Species Mean Acute Value (µg/L)</u> | <u>Reference</u> |
|---|---------------------------|----------------------|---|--|---------------------------------|
| Rainbow trout (fry, 77 day), <u>Salmo gairdneri</u> | R, U | (99%) | 1,400 | 1,415 | Van Leeuwen et al. 1985 |
| Brown trout (16-19 cm), <u>Salmo trutta</u> | F, M | Reagent† (99%) | 1,510 | 1,510 | Spacie et al. 1981 |
| Brook trout (juvenile), <u>Salvelinus fontinalis</u> | F, M | Reagent (99%) | 1,760 | 1,760 | Spacie 1976; Spacie et al. 1981 |
| Lake trout (0.7 g), <u>Salvelinus namaycush</u> | S, U | Technocal (98.7%) | 1,920 | 1,920 | Johnson and Finley 1980 |
| Goldfish (juvenile), <u>Carassius auratus</u> | S, U | Technocal (99%) | 2,700 | - | Pickering et al. 1962 |
| Goldfish (0.9 g), <u>Carassius auratus</u> | S, U | Technocal (98.7%) | 1,830 | 2,223 | Johnson and Finley 1980 |
| Fathead minnow (1-1.5 g), <u>Pimephales promelas</u> | S, U | Technocal (96.5%) | 1,400 | - | Henderson and Pickering 1958 |
| Fathead minnow (1-1.5 g), <u>Pimephales promelas</u> | S, U | Technocal (96.5%) | 1,600 | - | Henderson and Pickering 1958 |
| Fathead minnow (1-1.5 g), <u>Pimephales promelas</u> | S, U | Technocal (96.5%) | 2,800 | - | Henderson and Pickering 1958 |
| Fathead minnow (1-1.5 g), <u>Pimephales promelas</u> | S, U | Technocal (96.5%) | 3,700 | - | Henderson and Pickering 1958 |
| Fathead minnow (juvenile), <u>Pimephales promelas</u> | S, U | Technocal (99%) | 1,300 | - | Pickering et al. 1962 |
| Fathead minnow (adult), <u>Pimephales promelas</u> | S, M | Reagent (99%) | 1,600 | - | Spacie 1976; Spacie et al. 1981 |

Table 1. (continued)

| Species | Method ^a | Chemicals ^b | LC50 or EC50 (µg/L) ^{c,d} | Species Mean Acute Value (µg/L) | Reference |
|---|---------------------|------------------------|------------------------------------|---------------------------------|---|
| Fathead minnow (0.8 g), <i>Pimephales promelas</i> | S, U | Technical (98.7%) | 2,350 | - | Johnson and Flinley 1980 |
| Fathead minnow (1.8-4.0 cm), <i>Pimephales promelas</i> | F, M | Analytical (98.7%) | 1,410 | - | Solon et al. 1969; Solon and Nair 1970 |
| Fathead minnow (adult), <i>Pimephales promelas</i> | F, M | Reagent (99%) | 500 | 839.6 | Spacie 1976; Spacie et al. 1981 |
| Channel catfish (1.4 g), <i>Ictalurus punctatus</i> | S, U | Technical (98.7%) | 2,650 | 2,650 | Johnson and Flinley 1980 |
| Mosquitofish (1.1 g), <i>Gambusia affinis</i> | S, U | Technical (98.7%) | 320 | 320 | Johnson and Flinley 1980 |
| Guppy (6 mo), <i>Poecilia reticulata</i> | S, U | Technical (99%) | 56 | 56 | Pickerling et al. 1962 |
| Green sunfish (1.1 g), <i>Lepomis cyanellus</i> | S, U | Technical (98.7%) | 930 | 930 | Johnson and Flinley 1980 |
| Bluegill (1.5 g), <i>Lepomis macrochirus</i> | S, U | Technical (96.5%) | 710 | - | Henderson and Pickerling 1958 |
| Bluegill (Juvenile), <i>Lepomis macrochirus</i> | S, U | Technical (99%) | 95 | - | Pickerling et al. 1962 |
| Bluegill (1.0 g), <i>Lepomis macrochirus</i> | S, U | Technical (98.7%) | 400 | - | Johnson and Flinley 1980 |
| Bluegill (Juvenile), <i>Lepomis macrochirus</i> | F, M | Reagent (99%) | 510 | 510 | Spacie 1976; Spacie et al. 1981 |
| Largemouth bass (0.7 g), <i>Micropterus salmoides</i> | S, U | Technical (98.7%) | 620 | 620 | Johnson and Flinley 1980 |
| Western chorus frog (1 wk), <i>Pseudacris triseriata</i> | S, U | Technical (98.7%) | 1,000 | 1,000 | Sanders 1970 |

Table 1. (continued)

| <u>Species</u> | <u>Method^a</u> | <u>Chemical^b</u> | <u>LC50 or EC50 (sp/L)</u> | <u>Species Mean Acute Value (sp/L)</u> | <u>Reference</u> |
|--|---------------------------|-----------------------------|------------------------------------|--|-----------------------|
| <u>SALTWATER SPECIES</u> | | | | | |
| Korean shr imp (adult), <u>Palaemon macrodactylus</u> | F, U | (99%) | 17.8 | - | Earnest 1970 |
| Korean shr imp (adult), <u>Palaemon macrodactylus</u> | S, U | (99%) | 11.5 | 14.31 | Earnest 1970 |
| Striped bass (juvenile), <u>Morone saxatilis</u> | F, U | (99%) | 17.8 | 17.8 | Korn and Earnest 1974 |

* S = static; R = renewal; F = flow-through; U = unmeasured; M = measured.

** Percent purity is given in parentheses when available.

*** If the concentrations were not measured and the published results were not reported to be adjusted for purity, the published results were multiplied by the purity if it was reported to be less than 97%.

**** Limnodrillus sp. and Tubifex sp. were tested together, but appeared to be equally resistant.

† Not used in calculation of Species Mean Acute Value because data are available for a more sensitive life stage.

†† 4°C; not used in calculations.

††† 22°C.

Table 2. Chronic Toxicity of Parathion to Aquatic Animals

| <u>Species</u> | <u>Test*</u> | <u>Chemicals</u> | <u>LC₅₀ (µg/L)†</u> | <u>Chronic Value (µg/L)</u> | <u>Reference</u> |
|---|------------------------|------------------|--------------------------------|-----------------------------|-----------------------|
| FRESHWATER SPECIES | | | | | |
| <u>Cladoceran, <i>Daphnia magna</i></u> | LC Reagent (99%) | 0.0017-0.12 | 0.0990 | | Spacie et al. 1981 |
| <u>Fathead minnow, <i>Pimephales promelas</i></u> | LC Reagent (99%) | 4.4-9.0 | 6.293 | | Spacie et al. 1981 |
| <u>Bluegill, <i>Lepomis macrochirus</i></u> | LC Reagent (99%) | 0.17-0.34 | 0.2404 | | Spacie et al. 1981 |

* LC = life-cycle or partial life-cycle.

†# Percent purity is given in parentheses when available.

Results are based on measured concentrations of parathion.

Acute-Chronic Ratio

| <u>Species</u> | <u>Acute Value (µg/L)</u> | <u>Chronic Value (µg/L)</u> | <u>Ratio</u> |
|---|---------------------------|-----------------------------|--------------|
| <u>Cladoceran, <i>Daphnia magna</i></u> | 1.00 | 0.0990 | 10.10 |
| <u>Fathead minnow, <i>Pimephales promelas</i></u> | 500 | 6.293 | 79.45 |
| <u>Bluegill, <i>Lepomis macrochirus</i></u> | 510 | 0.2404 | 2,121 |

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

| Rank ^a | Genus Mean Acute Value (µg/L) | Species Species | Species Mean Acute Value (µg/L) | Species Mean Acute-Chronic Ratios |
|---------------------------|-------------------------------|--|---------------------------------|-----------------------------------|
| <u>FRESHWATER SPECIES</u> | | | | |
| 31 | 5,230 | Tubificid worm, <u>Tubifex</u> sp. | 5,230 | - |
| 30 | 5,230 | Tubificid worm, <u>Limnodrilus</u> sp. | 5,230 | - |
| 29 | 2,650 | Channel catfish, <u>Ictalurus punctatus</u> | 2,650 | - |
| 28 | 2,223 | Goldfish, <u>Carassius auratus</u> | 2,223 | - |
| 27 | 1,838 | Brook trout, <u>Salvelinus fontinalis</u> | 1,760 | - |
| | | Lake trout, <u>Salvelinus namaycush</u> | 1,920 | - |
| 26 | 1,494 | Cutthroat trout, <u>Salmo clarki</u> | 1,560 | - |
| | | Brown trout, <u>Salmo trutta</u> | 1,510 | - |
| | | Rainbow trout, <u>Salmo gairdneri</u> | 1,415 | - |
| 25 | 1,130 | Isopod, <u>Asellus brevicaudus</u> | 1,130 | - |
| 24 | 1,000 | Western chorus frog, <u>Pseudacris triseriata</u> | 1,000 | - |
| 23 | 859.6 | Fathead minnow, <u>Pimephales promelas</u> | 839.6 | 79.45 |
| 22 | 688.7 | Green sunfish, <u>Lepomis cyanellus</u> | 930 | - |
| | | Bluegill, <u>Lepomis macrochirus</u> | 510 | 2,121 |

Table 3. (continued)

| <u>Rank</u> | <u>Genus Mean Acute Value (µg/L)</u> | <u>Species</u> | <u>Species Mean Acute Value (µg/L)es</u> | <u>Acute-Chronic Ratios</u> | <u>Species Mean Acute Value (µg/L)es</u> |
|-------------|--------------------------------------|--|--|-----------------------------|--|
| 21 | 620 | Largemouth bass, <u>Micropterus salmoides</u> | 620 | - | - |
| 20 | 320 | Mosquitofish, <u>Gambusia affinis</u> | 320 | - | - |
| 19 | <250 | Crayfish, <u>Procambarus</u> sp. | <250 | - | - |
| 18 | 56 | Guppy, <u>Poecilia reticulata</u> | 56 | - | - |
| 17 | 31.0 | Widgeon, <u>Chironomus tentans</u> | 31.0 | - | - |
| 16 | 15 | Mayfly, <u>Hexagenia bilineata</u> | 15 | - | - |
| 15 | 7.0 | Beetle, <u>Peltodytes</u> spp. | 7.0 | - | - |
| 14 | 5.4 | Stonefly, <u>Pteronarcys californica</u> | 5.4 | - | - |
| 13 | 4.2 | Stonefly, <u>Pteronarcilla badia</u> | 4.2 | - | - |
| 12 | 3.0 | Damsel fly, <u>Lestes congener</u> | 3.0 | - | - |
| 11 | 2.9 | Stonefly, <u>Acronemura pacifica</u> | 2.9 | - | - |
| 10 | 2.739 | Prawn, <u>Palaeomonetes kadiakensis</u> | 2.739 | - | - |
| 9 | 2.227 | Mayfly, <u>Cloeon dipterum</u> | 2.227 | - | - |

Table 3. (continued)

| <u>Rank*</u> | <u>Genus Mean Acute Value (µg/L)</u> | <u>Species</u> | <u>Species Mean Acute Value (µg/L)</u> | <u>Species Mean Acute-Chronic Ratios</u> |
|--------------|--------------------------------------|---|--|--|
| 8 | 1.697 | Midge, <u>Chironamus riparius</u> | - | 1.697 |
| 7 | 1.5 | Stonefly, <u>Claassenia sabulosa</u> | - | 1.5 |
| 6 | 1.127 | Amphipod, <u>Gammarus fasciatus</u> | - | 0.3628 |
| | | Amphipod, <u>Gammarus lacustris</u> | - | 3.5 |
| 5 | 0.8944 | Phantom midge, <u>Chaoborus</u> sp. | 0.8944 | - |
| 4 | 0.7746 | Cladoceran, <u>Daphnia magna</u> | 1.0 | 10.10 |
| | | Cladoceran, <u>Daphnia pulex</u> | - | 0.60 |
| 3 | 0.64 | Damsel fly, <u>Ischnura verticalis</u> | 0.64 | - |
| 2 | 0.47 | Cladoceran, <u>Simocephalus serrulatus</u> | 0.47 | - |
| 1 | 0.04 | Crayfish, <u>Oncorhynchus nelsoni</u> | 0.04 | - |

* Ranked from most resistant to most sensitive based on Genus Mean Acute Value. Inclusion of "greater than" values does not necessarily imply a true ranking, but does allow use of all genera for which data are available so that the Final Acute Value is not unnecessarily lowered.

** From Table 1.

*** From Table 2.

Table 3. (continued)

Fresh water

Final Acute Value = 0.1298 $\mu\text{g/L}$

Criterion Maximum Concentration = (0.1298 $\mu\text{g/L}$) / 2 = 0.0649 $\mu\text{g/L}$

Final Acute-Chronic Ratio = 10.10 (see text)

Final Chronic Value = (0.1298 $\mu\text{g/L}$) / 10.10 = 0.01285 $\mu\text{g/L}$

Table 4. Toxicity of Pesticides to Aquatic Plants

| <u>Species</u> | <u>Chemical*</u> | <u>Duration (days)</u> | <u>Effect</u> | <u>Concentration (µg/L)†</u> | <u>Reference</u> |
|---|------------------|----------------------------|-------------------------|----------------------------------|-------------------------------------|
| <u>FRESHWATER SPECIES</u> | | | | | |
| Blue-green alga, <i>Microcystis aeruginosa</i> | - | 8 | Incipient inhibition | 30 (34) | Bringmann and Kuhn 1978a,b |
| Green alga, <i>Scenedesmus quadrivalvis</i> | - | 8 | Incipient inhibition | 390 | Bringmann and Kuhn 1977; 1978a,b |
| | | | | | |

* Percent purity is given in parentheses when available.

** If the concentrations were not measured and the published results were not reported to be adjusted for purity, the published results were multiplied by the purity if it was reported to be less than 97%.

Table 5. Bioaccumulation of Parathion by Aquatic Organisms

| <u>Species</u> | <u>Chemical*</u> | <u>Concentration In Water (ppm) **</u> | <u>Duration (days)</u> | <u>Tissue</u> | <u>BCF or BAF***</u> | <u>Reference</u> | |
|---|------------------|---|----------------------------|---------------|---|--|--|
| <u>FRESHWATER SPECIES</u> | | | | | | | |
| Brook trout, <i>Salvelinus fontinalis</i> | Reagent (99%) | 0.6 0.6 1.4 2.6 4.0 6.7 6.7 0.44 0.53 1.26 1.45 1.45 2.76 2.86 4.24 5.53 8.30 8.72 | 180 260 | Muscle | 258 312 299 439 471 573 124 86 31 43 99 91 86 88 232 179 | Spacie et al., 1981 | Spacie 1976; Spacie et al., 1981 |
| Fathead minnow, <i>Pimephales promelas</i> | Reagent (99%) | 0.15 4.2 9.0 15.5 21.7 49.0 | 260 | Whole body | 93.3 169.4 104.6 32.9 66.8 201.4 | Spacie 1976; Spacie et al., 1981 | |
| Bluegill, <i>Lepomis macrochirus</i> | Reagent (99%) | 4.00 | 540 | Muscle | 27 | Spacie 1976; Spacie et al., 1981 | |

* Percent purity is given in parentheses when available.

** Measured concentration of parathion.

*** Bioconcentration factors (BCFs) and bioaccumulation factors (BAFs) are based on measured concentrations of parathion in water and in tissue.

Table 6. Other Data on the Effects of Permethrin on Aquatic Organisms

| <u>Species</u> | <u>Chemical*</u> | <u>Duration</u> | <u>Effect</u> | <u>Concentration (μg/L)†</u> | <u>Reference</u> |
|---|-------------------|------------------------------|-------------------------------------|---|--|
| <u>Bacterium, <i>Pseudomonas putida</i></u> | - | 16 hr | Incipient inhibition | >1 | Briegmann and Kuhn 1977 |
| <u>Ciliate, <i>Colpidium campylum</i></u> | - | 43 hr | Change in growth rate | 10,000 | Dive et al. 1980 |
| <u>Worm, <i>Tubifex tubifex</i></u> | - | 18 hr 18-36 hr | Onset of symptoms Onset of death | 10,000 100,000 | Ludemann and Neumann 1960b |
| <u>Cladoceran, <i>Daphnia magna</i></u> | - | 24 hr | LC50 | 4 | Ghetti and Gorbi 1985 |
| <u>Cladoceran (<24 hr old), <i>Daphnia magna</i></u> | - | 26 hr | LC50 | 0.8 | Frear and Boyd 1967 |
| <u>Cladoceran, <i>Daphnia magna</i></u> | Reagent† (99%) | 7 days 14 days 21 days | EC50 | 0.39 0.31 0.16 | Spacie 1976; Spacie et al. 1981 |
| <u>Cladoceran, <i>Daphnia magna</i></u> | Technical | 3 hr | LC50 | 0.8 | Nishizuchi and Hashimoto 1967, 1969 |
| <u>Cladoceran (adult), <i>Daphnia pulex</i></u> | Technical | 3 hr | LC50 | 0.1 | Nishizuchi and Hashimoto 1967, 1969 |
| <u>Cladoceran (adult), <i>Molna macrocopa</i></u> | Technical | 24 hr | LC50 | 7.1 11.8† 7.4† 6.6† | Naqvi and Ferguson 1970 |
| <u>Prawn, <i>Palamonaetes kadiakensis</i></u> | - | 48 hr | EC50 (4°C) (22°C) | 30.0 1.7 | Collins and Shank 1983 |
| <u>Mayfly, <i>Stenonema femoratum</i></u> | - | 48 hr | EC50 | 29.0 | Collins and Shank 1983 |
| <u>Mayfly, <i>Stenonema vicarium</i></u> | - | 65 min | LT50 | 1,000 | Ghetti and Gorbi 1985 |
| <u>Mayfly, <i>Baetis rhodani</i></u> | - | | | | |

Table 6. (continued)

| <u>Species</u> | <u>Chemical^a</u> | <u>Duration</u> | <u>Effect</u> | <u>Concentration (µg/L)^b</u> | <u>Reference</u> |
|--|-----------------------------|-----------------|-------------------------|---|--------------------------|
| Stonefly, <u>Allocapnia</u> sp. | - | 48 hr | EC50 | 2.2 | Collins and Shank 1983 |
| Beetle (larva), <u>Hydrophilus triangularis</u> | Technic al | 24 hr | LC50 | 17 | Ahmed 1977 |
| Beetle (adult), <u>Hygrotes</u> sp. | Technic al | 24 hr | LC50 | 28 | Ahmed 1977 |
| Beetle (adult), <u>Laccophilus decipiens</u> | Technic al | 24 hr | LC50 | 12 | Ahmed 1977 |
| Beetle (adult), <u>Thermonectus basillaris</u> | Technic al | 24 hr | LC50 | 1.8 | Ahmed 1977 |
| Beetle (adult), <u>Tropisternus lateralis</u> | Technic al | 24 hr | LC50 | 32 | Ahmed 1977 |
| Beetle (larva), <u>Tropisternus lateralis</u> | Technic al | 24 hr | LC50 | 40 | Ahmed 1977 |
| Water bug (adult), <u>Belostoma</u> sp. | Technic al | 24 hr | LC50 | 60 | Ahmed 1977 |
| Caddisfly, <u>Chaumatopsyche</u> sp. | - | 48 hr | EC50 (4°C) (22°C) | 21.0 2.5 | Collins and Shank 1983 |
| Caddisfly (larva), <u>Hydropsyche pellucida</u> | - | 110 min | LT50 | 1,000 | Ghetti and Gorbi 1985 |
| Caddisfly, <u>Hydropsyche sp.</u> | - | 48 hr | EC50 (4°C) (22°C) | 36.0 1.3 | Collins and Shank 1983 |
| Mosquito (4th Instar) <u>Aedes aegypti</u> | 32-P labeled | 24 hr | LC50 | 4.8 | Schmidt and Woldaas 1961 |
| Mosquito (larva), <u>Aedes nigromaculatus</u> | Technic al | 24 hr | LC50 | 40 35 3.5 | Mulla et al. 1970 |

Table 6. (continued)

| <u>Species</u> | <u>Chemical*</u> | <u>Duration</u> | <u>Effect</u> | <u>Concentration (μg/L)ss</u> | <u>Reference</u> |
|--|------------------|--|---------------|--|------------------------------------|
| Mosquito (4th Instar), <u>Aedes nigromaculis</u> | Technic al | 24 hr | LC50 | 27 68 | Mulla et al. 1978 |
| Mosquito (4th Instar), <u>Aedes taeniorhynchus</u> | 32-P labeled | 24 hr | LC50 | 3.6 | Schmidt and Heldas 1961 |
| Mosquito (4th Instar), <u>Anopheles freeborni</u> | Technic al | 24 hr | LC50 | 2-2-15.0 (24 values) | Wohndorf et al. 1970 |
| Mosquito (larva), <u>Anopheles freeborni</u> | Technic al | 24 hr | LC50 | 0.7 | Ahmed 1977 |
| Mosquito (4th Instar), <u>Anopheles quadrimaculatus</u> | 32-P labeled | 24 hr | LC50 | 6.0 | Schmidt and Heldas 1961 |
| Mosquito (4th Instar), <u>Culex pipiens</u> | Technic al | 24 hr | LC50 | 4.5 | Mulla et al. 1962 |
| Mosquito (4th Instar), <u>Culex pipiens</u> | Technic al | 24 hr | LC50 | 4.5 | Mulla et al. 1964 |
| Mosquito (3rd-4th Instar), <u>Culex pipiens</u> | Technic al | 24 hr | LC50 | 0.45 5.0 | Chen et al. 1971 |
| Mosquito (larva), <u>Culex tarsalis</u> | Technic al | 24 hr | LC50 | 5.8 | Ahmed 1977 |
| Midge (larva), <u>Chironomus plumosus</u> | - | 24 hr | LC50 | 39 | Ludemann and Neumann 1960c |
| Midge (4th Instar), <u>Chironomus riparius</u> | Technic al | 24 hr | LC50 | 2.5 | Estenik and Collins 1979 |
| Midge (2nd and 4th Instar), <u>Chironomus tentans</u> | Reagent (99%) | 1 day 2 day 5 day 8 day 14 day | LC50 | 660 135 7.3 2.2 2.6 | Spacle 1976; Spacle et al. 1981 |

Table 6. (continued)

| <u>Species</u> | <u>Chemical*</u> | <u>Duration</u> | <u>Effect</u> | <u>Concentration ($\mu\text{g/L}$)^{**}</u> | <u>Reference</u> |
|---|------------------|-----------------|--------------------------|--|--|
| Rainbow trout, <u><i>Salmo gairdneri</i></u> | - | 72 hr | LC50 | 920 | Leland 1968 |
| Brown trout, <u><i>Salmo trutta</i></u> | Reagent (99%) | 64 hr | BCF = 61 71 | - | Spacie 1976; Spacie et al. 1981 |
| Brook trout, <u><i>Salvelinus fontinalis</i></u> | Reagent (99%) | - | LC50 | 75 | Spacie 1976; Spacie et al. 1981 |
| Brook trout, <u><i>Salvelinus fontinalis</i></u> | Reagent (99%) | - | Reduced percent hatch | 10 | Spacie 1976; Spacie et al. 1981 |
| Brook trout, <u><i>Salvelinus fontinalis</i></u> | Reagent (99%) | 8 hr | BCF = 88.5 | - | Spacie 1976; Spacie et al. 1981 |
| | | 114 hr | 102.5 | - | |
| | | 140 hr | 301.5 | - | |
| | | 144 hr | 192.5 | - | |
| Goldfish (1.0 g), <u><i>Cyprinus auratus</i></u> | Technic al | 48 hr | LC50 | 1,700 | Nishizuchi and Hashimoto 1967, 1969 |
| Common carp (3.9 g), <u><i>Cyprinus carpio</i></u> | - | 48 hr | LC50 | 3,500 | Ludemann and Neumann 1960a |
| Common carp (1.1 g), <u><i>Cyprinus carpio</i></u> | Technic al | 48 hr | LC50 | 3,200 | Nishizuchi and Hashimoto 1967, 1969 |
| Golden shiner, (DDT-susceptible), <u><i>Notemigonus crysoleucas</i></u> | Technic al | 48 hr | LC50 | 1,895 | Minchew and Ferguson 1970 |
| Golden shiner, (DDT-resistant), <u><i>Notemigonus crysoleucas</i></u> | Technic al | 48 hr | LC50 | 2,800 | Minchew and Ferguson 1970 |
| Golden shiner, <u><i>Notemigonus crysoleucas</i></u> | - | 24 hr | LC50 | 931 | Gibson 1971 |

Table 6. (continued)

| <u>Species</u> | <u>Chemical*</u> | <u>Duration</u> | <u>Effect</u> | <u>Concentration (µg/L)†</u> | <u>Reference</u> |
|---|---------------------|-----------------|---------------|----------------------------------|-----------------------------|
| Fathead minnow (DDT-susceptible), <u>Pimephales promelas</u> | Technical | 48 hr | LC50 | 48 | Culley and Ferguson 1969 |
| Fathead minnow (DDT-resistant), <u>Pimephales promelas</u> | Technical | 48 hr | LC50 | 199 | Culley and Ferguson 1969 |
| Mosquitofish, <u>Gambusia affinis</u> | Technical | 24 hr | LC50 | 140 | Ahmed 1977 |
| Mosquitofish (15-30 mg), <u>Gambusia affinis</u> | Analytical | 24 hr | LC50 | 1,400 | Kreiger and Lee 1973 |
| Mosquitofish (adult), (DDT-resistant), <u>Gambusia affinis</u> | Analytical (99%) | 48 hr | LC50 | 390 | Chambers and Yarbrough 1974 |
| Mosquitofish (adult) (DDT-susceptible), <u>Gambusia affinis</u> | Analytical (99%) | 48 hr | LC50 | 950 | Chambers and Yarbrough 1974 |
| Guppy, <u>Poecilia reticulata</u> | - | 72 hr | LC50 | 350 | Chambers and Yarbrough 1974 |
| Guppy (7 wk old), <u>Poecilia reticulata</u> | Technical | 24 hr | LC50 | 610 | Chambers and Yarbrough 1974 |
| Green sunfish (DDT-susceptible), <u>Lepomis cyanellus</u> | Technical | 48 hr | LC50 | 29 | Nagasawa et al. 1968 |
| Green sunfish (DDT-resistant), <u>Lepomis cyanellus</u> | Technical | 48 hr | LC50 | 80 | Chen et al. 1971 |
| Bluegill, <u>Lepomis cyanellus</u> | - | 48 hr | LC50 | 45 | Minchew and Ferguson 1970 |
| Bluegill, <u>Lepomis macrochirus</u> | - | 24 hr | LC50 | 207 | Minchew and Ferguson 1970 |
| Bluegill, <u>Lepomis macrochirus</u> | - | 24 hr | LC50 | 275 | Minchew and Ferguson 1970 |
| Bluegill, <u>Lepomis macrochirus</u> | - | 24 hr | LC50 | 155 | Gibson 1971 |
| Bluegill, <u>Lepomis macrochirus</u> | - | 48 hr | LC50 | 90 | Leland 1968 |
| Bluegill, <u>Lepomis macrochirus</u> | - | 24 hr | LC50 | 141 | Gibson 1971 |

Table 6. (continued)

| <u>Species</u> | <u>Chemical*</u> | <u>Duration</u> | <u>Effect</u> | <u>Concentration (mg/L)±</u> | <u>Reference</u> |
|---|------------------|---|---|------------------------------|--|
| <u>Bluegill, <i>Lepomis macrochirus</i></u> | Reagent (99%) | 12 hr 18 hr 24 hr 29 hr 46 hr 70 hr 72 hr | BCF = 80.5 145 173 175.3 253.0 311 462 | - - - - - | Spacie 1976; Spacie et al. 1981 |
| <u>Largemouth bass, <i>Micropterus salmoides</i></u> | - | 24 hr | Change in opercular rhythm | 160 | Morgan 1976 |
| <u>Frog (tadpole), <i>Rana catesbeiana</i></u> | - | 96 hr | BCF = 50.1 | - | Hall and Kolbe 1980 |
| <u>SALTWATER SPECIES</u> | | | | | |
| <u>Natural phytoplankton communities</u> | (99.6%) | 4 hr | 9.9% decrease in population growth | 1,000 | Butler 1964 |
| <u>Eastern oyster (juvenile), <i>Crassostrea virginica</i></u> | - | 96 hr | EC50 (shell deposition) | 850 | Butler 1963 |
| <u>Eastern oyster (juvenile), <i>Crassostrea virginica</i></u> | (99.6%) | 96 hr | 22% reduction in shell deposition | 1,000 | Butler 1964; Lone et al. 1970; U.S. Bureau of Commercial Fisheries 1966 |
| <u>Eastern oyster (juvenile to adult), <i>Crassostrea virginica</i></u> | (99.6%) | 336 days | No significant effects on growth | 0.8 | Lone et al. 1971 |
| <u>Eastern oyster (larva), <i>Crassostrea virginica</i></u> | - | 12 days | 78% reduction in average length | 1,000 | Davis and Hildu 1969 |
| <u>Grass shrimp (juvenile), <i>Palamonaetes pugio</i></u> | (99.6%) | 48 hr | EC50 (mortality and loss of equilibrium) | 2.8 | U.S. Bureau of Commercial Fisheries 1967 |
| <u>Grass shrimp, <i>Palamonaetes pugio</i></u> | (99.6%) | 24-72 hr | Increased predation by gulf killifish, <i>Fundulus grandis</i> | 0.1-0.5 | Farr 1977 |

Table 6. (continued)

| <u>Species</u> | <u>Chemical*</u> | <u>Duration</u> | <u>Effect</u> | <u>Concentration (µg/L)†</u> | <u>Reference</u> |
|---|------------------|-----------------|--|----------------------------------|--|
| Brown shr imp (adult), <i>Penaeus aztecus</i> | (99.6%) | 48 hr | BC50 (mortality and loss of equilibrium) | 1 | Butler 1964; U.S. Bureau of Commercial Fisheries 1966 |
| Pink shr imp (juvenile), <i>Penaeus duorarum</i> | (99.6%) | 48 hr | EC50 (mortality and loss of equilibrium) | 0.24 | Lore et al. 1970; U.S. Bureau of Commercial Fisheries 1967 |
| Fiddler crab, <i>Uca pugillator</i> | (95%) | 2-3 wk | No effect on limb regeneration or time to molt | 10 | Wels and Mantel 1976 |
| Fiddler crab, <i>Uca pugillator</i> | (95%) | 2-3 wk | 100% mortality | 100 | Wels and Mantel 1976 |
| Sheepshead minnow (juvenile), <i>Cyprinodon variegatus</i> | (99.6%) | 48 hr | LC50 | 60 | Butler 1964 |
| Sheepshead minnow (juvenile), <i>Cyprinodon variegatus</i> | (99.6%) | 48 hr | LC50* | 36 | U.S. Bureau of Commercial Fisheries 1966 |
| Sheepshead minnow (adult), <i>Cyprinodon variegatus</i> | - | 2 hr | 40-60% mortality; brain AChE activity reduced $\geq 82\%$ | 5,000 | Coppage 1972 |
| Sheepshead minnow (adult), <i>Cyprinodon variegatus</i> | - | 24 hr | 40-60% mortality; brain AChE activity reduced $\geq 82\%$ | 2,000 | Coppage 1972 |
| Sheepshead minnow (adult), <i>Cyprinodon variegatus</i> | - | 48 hr | 40-60% mortality; brain AChE activity reduced $\geq 82\%$ | 100 | Coppage 1972 |
| Sheepshead minnow (adult), <i>Cyprinodon variegatus</i> | - | 72 hr | 40-60% mortality; brain AChE activity reduced $\geq 82\%$ | 10 | Coppage 1972 |
| Sheepshead minnow (adult), <i>Cyprinodon variegatus</i> | - | 120 hr | Greatest reduction (78-82%) in normal brain AChE activity obtained without causing death | 5 | Coppage 1972 |

Table 6. (continued)

| <u>Species</u> | <u>Chemical*</u> | <u>Duration</u> | <u>Effect</u> | <u>Concentration (µg/l)**</u> | <u>Reference</u> |
|---|------------------|-------------------|--|-------------------------------|--|
| Mummichog (adult), <i>Fundulus heteroclitus</i> | (91%) | 2 wk | Significant reduction in fin regeneration | 10 | Weis and Weis 1975 |
| Mummichog (embryo), <i>Fundulus heteroclitus</i> | (95%) | 3 days | 50% incidence of circulatory failure | 10,000 | Weis and Weis 1974 |
| Longnose killifish (juvenile), <i>Fundulus similis</i> | (99.6%) | 48 hr | LC50 | 15 | Lowe et al. 1970 |
| Plntfish (65-125 mm), <i>Lagodon rhomboides</i> | Technocal | 24 hr | 40-60% mortality; brain AChE activity reduced 90% | 10 | Coppedge and Matthews 1974 |
| Spot (juvenile), <i>Leiostomus xanthurus</i> | (99.6%) | 48 hr | LC50 | 18 | U.S. Bureau of Commercial Fisherries 1966 |
| Spot (65-150 mm), <i>Leiostomus xanthurus</i> | Technocal | 24 hr | 40-60% mortality; brain AChE activity reduced 88% | 10 | Coppedge and Matthews 1974 |
| Striped mullet (juvenile) <i>Mugil cephalus</i> | (99.6%) | 48 hr | LC50 | 100 | U.S. Bureau of Commercial Fisherries 1967 |
| Laughing gull (chick), <i>Larus atricilla</i> | - | Field collections | 75-90% inhibition of brain ChE in dead chicks contaminated with parathion | - | White et al. 1979 |
| Laughing gull (adult), <i>Larus atricilla</i> | - | Field collections | 57-89% inhibition of brain ChE in dead adults contaminated with parathion | - | White et al. 1979 |

* Percent purity is given in parentheses when available.

** If the concentrations were not measured and the published results were not reported to be adjusted for purity, the published results were multiplied by the purity if it was reported to be less than 97%.

† Organisms collected at sites potentially contaminated by pesticides.

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