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Ambient Water Quality Criteria for Parathion - 1986

AMBIENT AQUATIC LIFE WATER QUALITY CRITERIA FOR

PARATHION

U.S. ENVIRONMENTAL PROTECTION AGENCY
OFFICE OF RESEARCH AND DEVELOPMENT
ENVIRONMENTAL RESEARCH LABORATORIES
DULUTH, MINNESOTA
NARRAGANSETT, RHODE ISLAND

NOTICES

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FOREWORD

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

The term "water quality criteria" is used in two sections of the Clean Water Act, section 304(a)(1) and section 303(c)(2). The term has a different program impact in each section. In section 304, the term represents a non-regulatory, scientific assessment of ecological effects. Criteria presented in this document are such scientific assessments. If water quality criteria associated with specific stream uses are adopted by a State as water quality standards under section 303, they 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.

William A. Whittington
Director
Office of Water Regulations and Standards

ACKNOWLEDGMENTS

Loren J. Larson
(freshwater author)
University of Wisconsin-Superior
Superior, Wisconsin

Jeffrey L. Hyland
Sam R. Petrocelli
(saltwater authors)
Battelle New England Laboratory
Duxbury, Massachusetts

Charles E. Stephan
(document coordinator)
Environmental Research Laboratory
Duluth, Minnesota

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

Clerical Support: Shelley A. Heintz
Terry L. Highland
Diane L. Spehar
Nancy J. Jordan
Delcena R. Nisius

CONTENTS

TABLES

Introduction*

Parathion (O,O-diethyl O-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

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* 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 Herzel 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, Orconectes nais, 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 drivation 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 μg/L to 40 μg/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 μg/L. Gutierrez et al. (1977) reported LC50s from 1.8 to 70 μg/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 intoxified 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 artricilla, 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; Hashiomoto 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), Hiltibran (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 Yahalomi 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 Swaninathan 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., Dortland 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

Species	Method*	Chemical**	LC50 or EC50 (µg/L)***	Species Mean Acute Value (µg/L)	Reference
		FRESHWATER SPECIES			
Tubificid worm, *Limnodrilus* sp.	S, U	Analytical (99.6%)	5,230****	5,230	Whitten and Goodnight 1966
Tubificid worm, *Tubifex* sp.	S, U	Analytical (99.6%)	5,230****	5,230	Whitten and Goodnight 1966
Cladoceran, *Daphnia magna*	S, U	-	0.8	-	Boyd 1957
Cladoceran, *Daphnia magna*	S, U	-	1.8	-	Bringmann and Kuhn 1960
Cladoceran (<24 hr), *Daphnia magna*	S, M	Reagent (99%)	1.27	-	Spacie 1976; Spacie et al. 1981
Cladoceran, (<24 hr), *Daphnia magna*	S, U	Analytical (99%)	1.3	-	Dortland 1980
Cladoceran (<24 hr), *Daphnia magna*	F, M	Reagent (99%)	1.0	1.0	Spacie 1976; Spacie et al. 1981
Cladoceran (1st instar), *Daphnia pulex*	S, U	Technical (98.7%)	0.60	0.60	Johnson and Finley 1980
Cladoceran (1st instar), *Simocephalus serrulatus*	S, U	Technical (98.7%)	0.47	0.47	Johnson and Finley 1980
Isopod, *Asellus brevicaudus*	S, U	Technical (98.7%)	600	-	Sanders 1972
Isopoda (mature), *Asellus brevicaudus*	S, U	Technical (98.7%)	2,130	1,130	Johnson and Finley 1980
Amphipod (mature), *Gammarus fasciatus*	S, U	Technical (98.7%)	2.1†	-	Sanders 1972
Amphipod (mature), *Gammarus fasciatus*	F, U	Technical (98.7%)	4.5†	-	Sanders 1972
Amphipod (mature), *Gammarus fasciatus*	S, U	Technical (98.7%)	1.3†	-	Johnson and Finley 1980; Sanders 1972

Table 1. (continued)

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

Table 1. (continued)

Species	Method*	Chemical**	LC50 or EC50 (µg/L)***	Species Mean Acute Value (µg/L)	Reference
Mayfly, *Cloeon dipterum*	S, U	Analytical (99%)	2.5	-	Dortland 1980
Mayfly, *Cloeon dipterum*	S, U	Analytical (99%)	2.6	-	Dortland 1980
Mayfly, *Cloeon dipterum*	R, U	Analytical (99%)	1.7	2.227	Dortland 1980
Mayfly (juvenile), *Hexagenia bilineata*	S, U	Technical (98.7%)	15	15	Johnson and Finley 1980
Damselfly (juvenile), *Ischnura venticalis*	S, U	Technical (98.7%)	0.64	0.64	Johnson and Finley 1980
Damselfly, *Lestes congener*	S, U	Technical (>94%)	3.0	3.0	Federle and Collins 1976
Stonefly, *Pteronarcella badia*	S, U	Technical (98.7%)	4.2	4.2	Johnson and Finley 1980; Sanders and Cope 1968
Stonefly (naiad), *Pteronarcys californica*	S, U	Technical (95%)	32[†]	-	Jensen and Gaufin 1964
Stonefly (2nd year class), *Pteronarcys californica*	S, U	Technical (98.7%)	5.4	5.4	Johnson and Finley 1980; Sanders and Cope 1968
Stonefly (naiad), *Acroneuria pacifica*	S, U	Technical (95%)	2.9	2.9	Jensen and Gaufin 1964
Stonefly (2nd year class), *Claassenia sabulosa*	S, U	Technical (98.7%)	1.5	1.5	Johnson and Finley 1980; Sanders and Cope 1968

Table 1. (continued)

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

Table 1. (continued)

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

Table 1. (continued)

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

Table 1. (continued)

Species	Method*	Chemical**	LC50 or EC50 (µg/L)***	Species Mean Acute Value (µg/L)	Reference
			SALTWATER SPECIES		
Korean shrimp (adult), Palaemon macrodactylus	F, U	(99%)	17.8	-	Earnest 1970
Korean shrimp (adult), Palaemon macrodactylus	S, U	(99%)	11.5	14.31	Earnest 1970
Striped bass (juvenile), Morone saxatilis	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%.

**** Limnodrilis 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

Species	Test*	Chemical**	Limits (µg/L)***	Chronic Value (µg/L)	Reference
		FRESHWATER SPECIES			
Cladoceran, *Daphnia magna*	LC	Reagent (99%)	0.0817-0.12	0.0990	Spacie 1976; Spacie et al. 1981
Fathead minnow, *Pimephales promelas*	LC	Reagent (99%)	4.4-9.0	6.293	Spacie 1976; Spacie et al. 1981
Bluegill, *Lepomis macrochirus*	LC	Reagent (99%)	0.17-0.34	0.2404	Spacie 1976; 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

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

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

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

Table 3. (continued)

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

Table 3. (continued)

Rank*	Genus Mean Acute Value (µg/L)	Species	Species Mean Acute Value (µg/L)**	Species Mean Acute-Chronic Ratio***
8	1.697	Midge, *Chironomus riparius*	1.697	-
7	1.5	Stonefly, *Claassenia sabulosa*	1.5	-
6	1.127	Amphipod, *Gammarus fasciatus*	0.3628	-
		Amphipod, *Gammarus lacustris*	3.5	-
5	0.8944	Phantom midge, *Chaoborus* sp.	0.8944	-
4	0.7746	Cladoceran, *Daphnia magna*	1.0	10.10
		Cladoceran, *Daphnia pulex*	0.60	-
3	0.64	Damselfly, *Ischnura venticalis*	0.64	-
2	0.47	Cladoceran, *Simocephalus serrulatus*	0.47	-
1	0.04	Crayfish, *Orconectes nais*	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)

<u>Fresh water</u>

Final Acute Value = 0.1298 µg/L

Criterion Maximum Concentration = (0.1298 µg/L) / 2 = 0.0649 µg/L

Final Acute-Chronic Ratio = 10.10 (see text)

Final Chronic Value = (0.1298 µg/L) / 10.10 = 0.01285 µg/L

Table 4. Toxicity of Parathion to Aquatic Plants

Species	Chemical*	Duration (days)	Effect	Concentration (µg/L)**	Reference
			FRESHWATER SPECIES		
Blue-green alga, *Microcystis aeruginosa*	-	8	Incipient inhibition	30 (34)	Bringmann and Kuhn 1978a,b
Green alga, *Scenedesmus quadricauda*	-	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

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

Species	Chemical*	Duration	Effect	Concentration (µg/L)**	Reference
			FRESHWATER SPECIES		
Bacterium, *Pseudomonas putida*	-	16 hr	Incipient inhibition	>1	Bringmann and Kuhn 1977
Ciliate, *Colpidium campylum*	-	43 hr	Change in growth rate	10,000	Dive et al. 1980
Worm, *Tubifex tubifex*	-	18 hr 18-36 hr	Onset of symptoms Onset of death	10,000 100,000	Ludemann and Neumann 1960b
Cladoceran, *Daphnia magna*	-	24 hr	LC50	4	Ghetti and Gorbi 1985
Cladoceran (<24 hr old), *Daphnia magna*	-	26 hr	LC50	0.8	Frear and Boyd 1967
Cladoceran, *Daphnia magna*	Reagent (99%)	7 days 14 days 21 days	EC50	0.39 0.31 0.16	Spacie 1976; Spacie et al. 1981
Cladoceran (adult), *Daphnia pulex*	Technical	3 hr	LC50	0.8	Nishiuchi and Hashimoto 1967,1969
Cladoceran (adult), *Moina macrocopa*	Technical	3 hr	LC50	8.1	Nishiuchi and Hashimoto 1967,1969
Prawn, *Palaemonetes kadiakensis*	Technical	24 hr	LC50	7.1 11.8† 7.4† 6.6†	Naqvi and Ferguson 1970
Mayfly, *Stenonema femoratum*	-	48 hr	EC50 (4°C) (22°C)	 30.0 1.7	Collins and Shank 1983
Mayfly, *Stenonema vicarium*	-	48 hr	EC50	29.0	Collins and Shank 1983
Mayfly, (larva), *Baetis rhodani*	-	65 min	LT50	1,000	Ghetti and Gorbi 1985

Table 6. (continued)

Species	Chemical*	Duration	Effect	Concentration (µg/L)**	Reference
Stonefly, *Allocapnia* sp.	-	48 hr	EC50	2.2	Collins and Shank 1983
Beetle (larva), *Hydrophilus triangularis*	Technical	24 hr	LC50	17	Ahmed 1977
Beetle (adult), *Hygrotus* sp.	Technical	24 hr	LC50	28	Ahmed 1977
Beetle (adult), *Laccophilis decipiens*	Technical	24 hr	LC50	12	Ahmed 1977
Beetle (adult), *Thermonectus basiliaris*	Technical	24 hr	LC50	1.8	Ahmed 1977
Beetle (adult), *Tropisternus lateralis*	Technical	24 hr	LC50	32	Ahmed 1977
Beetle (larva), *Tropisternus lateralis*	Technical	24 hr	LC50	40	Ahmed 1977
Water bug (adult), *Belostoma* sp.	Technical	24 hr	LC50	60	Ahmed 1977
Caddisfly, *Cheumatopsyche* sp.	-	48 hr	EC50 (4°C) (22°C)	 21.0 2.5	Collins and Shank 1983
Caddisfly (larva), *Hydropsyche pellucidula*	-	110 min	LT50	1,000	Ghetti and Gorbi 1985
Caddisfly, *Hydropsyche* sp.	-	48 hr	EC50 (4°C) (22°C)	 36.0 1.3	Collins and Shank 1983
Mosquito (4th instar)· *Aedes aegypti*	32-P labeled	24 hr	LC50	4.8	Schmidt and Weidaas 1961
Mosquito (larva), *Aedes nigromaculis*	Technical	24 hr	LC50	40 35 3.5	Mulla et al. 1970

Table 6. (continued)

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

Table 6. (continued)

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

Table 6. (continued)

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

Table 6. (continued)

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

Table 6. (continued)

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

Table 6. (continued)

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