Draft
11/6/85

AMBIENT AQUATIC LIFE WATER QUALITY CRITERIA FOR PARATHION

NOTE: This draft contains only freshwater data. The saltwater data will be incorporated later. The freshwater CCC is likely to change when the saltwater data are incorporated.

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

NOTICES

This document has been reviewed by the Criteria and Standards Division, Office of Water Regulations and Standards, U.S. Environmental Protection Agency, and approved for publication.

Mention of trade names or commercial products does not constitute endorsement or recommendation for use.

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

ACKNOWLEDGMENTS

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

Jeff Hyland
(saltwater author)
Environmental Research Laboratory
Narragansett, Rhode Island

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

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

Clerical Support: Terry L. Highland
Shelley A. Heintz

CONTENTS

TABLES

Introduction*

Parathion** is one of several organophosphorus compounds developed to replace organochlorine pesticides. Its use is primarily as a domestic and agricultural insecticide. Its direct use in aquatic environments is most often in conjunction with mosquito abatement projects as a larvicide.

The major commercial formulation of parathion is an emulsifiable concentrate, within which the percentage of active ingredient can vary considerably. This results in a large percentage of often unspecified ingredients, many used as carriers, in the commercial formulation. These ingredients are considered inert. Although no studies have compared relative toxicities of technical grade parathion and its emulsifiable concentrate, other organophosphorus insecticides (e.g., chlorpyrifos) have been shown to differ significantly in this regard. For this reason, the effect of the inert ingredients can not be discounted.

Numerical water criteria are derived herein solely for the chemical parathion. Although some data obtained from studies using formulations are discussed, only data derived from toxicity tests utilizing technical grade parathion are used in deriving criteria.

The toxic effect of parathion is the result of metabolic conversion to its oxygen analogue, parathion-oxon, and its subsequent inhibitive interaction with various enzyme systems (e.g., cholinesterases, carboxylases, acetylcholinesterases, mitochondrial oxidative phosphorylation). Its

---

* 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, is necessary in order to understand the following text, tables, and calculations.

** Parathion refers to O,O-diethyl O-p-nitrophenyl phosphorothionate, and is synonymous with ethyl parathion.

activity with acetylcholinesterase (AChE) is generally accepted to be its most critical toxic effect. AChE inhibition results in accumulation of the neurotransmitter, acetylcholine, in synapes, disrupting normal neural transmission. Although in fish even substantial reductions in brain AChE activity have not always been fatal, the effect of this condition on normal activity (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).

Although less persistent than organochlorine compounds, parathion has a great affinity for organic complexes, and is quickly sorbed to sediments and suspended material. Miller et al. (1967) observed a rapid decrease in water concentration after parathion application and attributed it to degradation. It is more likely that sorbtion processes contributed greatly to this observation. Its persistence is dependent on chemical hydrolysis (Faust 1972, 1975; Gomaa and Faust 1971) and biodegradation (Amed and Casida 1958; Mackiewicz et al. 1969; Zuckerman et al. 1970). Working with natural lake sediments, Graetz et al. (1970) reported that the portion of parathion degradation attributable to abiological means was negligible. Movement and persistence of parathion has been described in a natural pond (Mulla et al. 1986; Nicholson et al. 1962) and in a model stream (Laplanche et al. 1981). Several studies report parathion residues in water (Braun and Frank 1980; Dick 1982; Harris and Miles 1975; Greve et al. 1972; 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).

All concentrations herein are expressed as parathion, not as the material tested. 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 exceedences (U.S. EPA 1985). The latest literature search for information for this document was conducted in February, 1985; some newer information was also used.

Acute Toxicity to Aquatic Animals

Data used in calculation of freshwater criteria for parathion are found on Table 1. Thirty-five species are represented, including 13 fish, 10 insects, and 9 crustaceans. Organisms representing a range of ecological and habitat types are included.

Ranked Genus Mean Acute Values (Table 3) for the twenty-eight genera range from 0.47 µg/L for a cladoceran to 5,230 µg/L for two tubifid worm species. Invertebrates are represented by the 15 most sensitive genera. Of the remaining 20 genera, only 4 are invertebrates, and this includes 2 tubifid worms which appear to be greatly more resistant to parathion than any other organism reported on.

The most striking disparity of values within a species on Table 1 is for the crayfish, Orconectes nais. Early instar lifestages are 375 times more susceptible to parathion intoxication than adults (LC50 = 0.04 and 15. µg/L, respectively). Considering only this early instar, Orconectes nais is the most sensitive species reported on. No other values for early instar decapods are available to suggest whether this relationship is valid beyond this species.

Relative toxicity to parathion (Table 3) may be influenced by taxonomic differences, making invertebrates more susceptible. This relationship could also be an artifact of size differences, with smaller organisms, supposedly with higher metabolisms, being more susceptible. There is a general increase in size with increased ranking on Table 3. It appears that centrarchids are more susceptible to parathion than salmonids, although this may be influenced by salmonids being cultured at a lower temperature. Banas and Sprague (1981) report no effect on LC50 in rainbow trout acclimated to low levels of parathion.

Final Acute Value is calculated to be 0.5489 μg/L, resulting in a Criterion Maximum Concentration for parathion of 0.2745 μg/L. With the exception of early instar crayfish, _Orconectes nais_, this value should be adequately protective of all organisms reported on.

Chronic Toxicity to Aquatic Animals

Data used to determine Final Chronic Value for parathion are found on Table 2. Information is available from a single study, reported in two sources (Spacie 1976; Spacie et al. 1981). Although this study reports chronic toxicity in three aquatic invertebrates and three fish because of experimental problems (primarily high control mortality), only chronic values for the fathead minnow and the bluegill are used in calculation of the Final Acute-Chronic Ratio and Final Chronic Value. Much chronic data from this study reports LC50 data only and it is not known whether this is the most sensitive parameter relating to chronic intoxication. Many of these values occur on Table 5. No appropriate data on chronic toxicity to parathion is available for arthropods.

Chronic exposure in bluegill larvae produced no statistically significant effect on growth (in length) at 30, 60, and 90 days. There was also no statistically significant effect on number of eggs spawned, percent hatch, and survival of larvae at 7, 14, 21, and 30 days.

In brook trout embryos LC50 was 75.0 μg/L (duration not stated) after correction for control mortality, when considering percent hatch of 19 day old embryos. This is 4.2% of the 96 hr LC50 for the species. At 10. μg/L, percent hatch was reduced but surviving embryos were normal. At greater than 32 μg/L, developmental abnormalities were common.

Fathead minnows were reported to be significantly affected by chronic exposure to parathion at 9.0 μg/L, with a chronic value of 6.3 μg/L. Acute-Chronic Ratio for fathead minnows is 79.4. Chronic value in bluegills is 0.24 μg/L with an Acute-Chronic Ratio of 2125 (Table 2). Both fish were cultured at approximately equal temperature. Acute toxicity to parathion appeared to be greater in centrarchids (Table 1), therefore, the large Acute-Chronic Ratio in bluegills may be indicative of high sensitivity within this taxon.

Geometric mean of the two Acute-Chronic Ratios results in a Final Acute-Chronic Ratio of 410.8. Division of the Final Acute Value (Table 3) by this factor results in a Final Chronic Value of 0.0013 μg/L. This parathion concentration is below the sensitivity limit of most analytic methods. Chronic toxicity data for a freshater arthropod were not available, therefore were not used in these calculations.

Toxicity to Aquatic Plants

No data is available on the relative toxicity of varying concentrations of parathion to freshwater aquatic plants. A single study (Cole and Plapp 1974) reported the effect of various initial cell concentrations (1 to 1000 μg algae/ml) at a single parathion level (1000 μg/L) in terms of growth and photosynthesis in a green alga, *Chlorella pyrenoidosa* (Table 5).

They reported increased growth inhibition with lower cell concentrations. With a single parathion dose, specific photosynthesis was greater in treated cultures, although with multiple doses photosynthesis was strongly inhibited with greatest effect at lowest cell concentrations.

Bioaccumulation

All available bioaccumulation data comes from a single study, reported in two sources (Spacie 1976, Spacie et al. 1981). Bioaccumulation factors (BAF) are reported in four fishes. Factors for brook trout, fathead minnows and bluegills are found in Table 4. Addition factors, not appropriate for inclusion in Table 4, are available for brown trout, brook trout, and bluegills (Table 5).

In brook trout, average BAF at 180 days is 392, and at 260 days is 105.9. From Table 5, 4.75 day, 5.8 day, and 6.0 day BAFs are reported to be 102.5, 301.5, and 192.5, respectively, indicating rapid uptake of parathion. but unstable residue levels.

At 260 days, BAF for fathead minnows averages 111.4, with a range of 32.9 to 201.4. At 64 hours, BAF in brown trout averaged 69 (Table 5). A single bluegill produced a BAF of 27 in 560 days; at 46, 70, and 72 hrs. factors of 253, 311, and 462 were reported (Table 5).

There is considerable variation in BAF data. This most likely is the result of rapid metabolism of parathion in fish or other metabolic factors.

No U.S. FDA action level has been set for parathion, therefore no Final Residue Value is calculated.

Other Data

Other data on the effects of parathion on aquatic organisms are found on Table 5. The majority of entries are LC50 values for durations other than 96 hours.

A 24 hour LC50 for a non-resident snail is the only toxicity data available for the family Mollusca. This species was very resistant, with an LC50 of 8090 μg/L. For a cladoceran, Daphnia magna, 0.34 μg/L resulted in a 50% reproductive impairment (Spacie 1978; Spacie et al 1981). In six coleopteran species, Ahmed (1977) observed a range in 24 hr LC50s from 1.8 μg/L to 40 μg/L.

Because of its wide use as a mosquito larvicide, many studies have tested mosquito larva. Standard methods commonly adhered to using mosquito larvae prescribe a 24 hour test duration, making most mosquito larvae studies inappropriate for consideration in deriving numerical criteria. The three Aedes species in Table 5 have a mean LC50 of 14.8 μg/L, Anopheles species 24 hour LC50s average 5.9 μg/L, and this value for Culex species is 3.1 μg/L.

Several studies have reported associated effects of parathion exposure. Kynard (1974) observed avoidance of parathion by mosquitofish in the laboratory, although the significance of this finding under natural conditions is unknown. Weiss (1961) reports on fish brain AChE as inhibition in several freshwater species. Effects on locomotor behavior in goldfish, bluegills, and largemouth bass are 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 in goldfish.

Interaction of parathion toxicity has to be examined with 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). Ludemann and Herzel (1973) report changes in ambient parathion concentrations under static conditions with and without aeration, and with and without fish. Without fish or aeration, parathion level dropped 22% in 96 hours.

When fish were added, levels dropped 54% in 96 hours. With both fish and aeration, 67% reduction was observed. Other studies on the persistence of parathion in water include Mulla (1963) and Dortland (1980).

Several studies evaluated the effectiveness of biomonitoring of effluents using trout in detecting pollutants including parathion (Jung 1973; Morgan 1976; Van Hoof 1980). Morgan (1977) was able to detect parathion concentrations at 15% of the fishes 48 hour LC50. Mount and Boyle (1969) examined the use of blood parathion residues to diagnose causes of fish kills.

A field study by Ghetti and Gorbi (1985) reported the effects of a simulated parathion spill in a stream. Field studies by Gasith and Perry (1980, 1982) and Grzendz et al. (1962) reported community effects of parathion application to a pond. Warnick et al. (1966) noted increases in water concentrations of organochlorine compounds correlated with parathion application in a natural pond. They postulated the source of these compounds to be the release from decomposing tissues of intoxified organisms.

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., Bellavere and Gorbi 1984; Dortland 1980; Gupta et al. 1979; Hashiomoto and Nishiuchi 1981; Nishiuchi and Hashimoto 1967; Nishiuchi and Yoshida 1972; Panwar et al. 1976; Siva Prasada et al. 1983) 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 1968). Tarpley (1958) conducted tests with brine shrimp, which species are too atypical to be used in deriving national criteria. Data were not used if parathion was a component of a mixture (e.g., Macek 1975).

Anderson (1959), Henderson et al. (1959), LeBlanc (1984), Ramke (1969), Sato and Kubo (1965), Surber (1948), and Tarzwell (1959a, b) only present data that have been published elsewhere. Juhnke and Ludemann (1978) and Gutierrez et al. (1977) present only results. Gaufin et al. (1961) and Ludemann and Neumann (1961) cite no LC50 data. Some studies were not used because of inadequate description of method (e.g., Mulla 1980) or materials (e.g., Gillies et al. 1974; Hart and Womeldorf 1977; Lahav and Sarig 1969; Lewallen and Wilder 1962; Micks and Rougeau 1977; Moore 1970; Wilder 1977; Wilder and Schaefer 1969; and 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. 1973, 1974; Hasimoto and Fukami 1969; Loeb and Kelly 1963 and Murphy et al. 1968).

Chambers (1976); Dortland (1978); Dortland et al. (1976); Estenik and Collins (1979); Goldsmith et al. (1976); Hiltibran (1974, 1982); Huddart (1978); Ludke et al. (1972); McDonald and Fingerman (1979); 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 or cell cultures or conducted other biochemical or histological studies.

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; Carlson 1978; Goldsmith and Carlson 1979; Lewallen 1959, 1962; Lichtenstein et al. 1966; and Yasuno et al. 1965).

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. 1965; Hilsenhoff 1959; Labrecque et al. 1956; Mohamed and Gupta 1984; Pawar et al. 1982; Singh and Singh 1981, Sreenivasen and Swaninathan 1967; Srivastava et al. 1977, Verma et al. 1981). Field studies on parathion which did not measure concentrations were not used (e.g., Ahmed and Washino 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). High pesticide residues were found in field collected worms by Naqvi (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). A bioconcentration study by Schmidt and Weidhaas (1961) was not used because radio-labeled parathion was not adequately identified as the source of residue radioactivity.

Summary

The acute values for thirty-five species in twenty-nine genera range from 0.47 µg/L for a cladoceran to 5230 µg/L for two species of tubifid worm. The early instar of a crayfish, *Orconectes nais* was the most sensitive organism reported with an acute value of 0.04 µg/L. Invertebrates appear to be more sensitive, although this could be related to their smaller size. Centrarchids are more sensitive than salmonids, although differences in culture temperature could effect this relationship.

Chronic toxicity values are available for two fish species, bluegills and fathead minnows, with chronic values of 0.24 µg/L and 6.3 µg/L, respectively. Final Acute-Chronic Ratio was 410.8. Final Chronic Value is calculated to be 0.0013 µg/L, which is below detection limits.

No information is available on the toxicity of parathion to freshwater aquatic plants. Bioconcentration factors are reported in four fish species. Average BCF for the data set is 186.7. Wide variation occurs in BCF data possibly due to metabolism of parathion by fish.

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 0.0013 µg/L more than once every three years on the average or if the one-hour average concentration does not exceed 0.2745 µg/L more than once every three years on the average.

The procedures described in the "Guidelines for Deriving Numerical National Water Quality Criteria for the Protection of Aquatic Organisms and Their Uses" indicate that. except possibly where a locally important species is very sensitive, saltwater aquatic organisms and their uses should not be affected unacceptably if the four-day average concentration of parathion does not exceed AAA µg/L more than once every three years on the average and if the one-hour average concentration does not exceed yyy µg/L more than once every three years on the average.

The allowed excursion frequency of thee years is based on the Agency's best scientific judgment of the average amount of time it will take an aquatic ecosystem to recover from a pollution event in which exposure to parathion exceeds the criterion. The resilience of ecosystems and their ability to recover differ greatly, however, and site-specific criteria may be established if adequate justification is provided.

The use of criteria in designing waste treatment facilities requires selection of an appropriate wasteload allocation model. Dynamic models are preferred for the application of these criteria. Limited data or other factors may make their use impractical, in which case one must rely on a steady-state model. The Agency recommends interim use of 1Q10 for Criterion Maximum Concentration (CMC) design flow and 7Q10 for the Criterion Continuous Concentration (CCC) design flow in steady-state models. These matters are discussed in more detail in the Technical Support Document for Water Quality-Based Toxics Control (U.S. EPA 1985) and the Design Flow Manual (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	5,230†	5,230	Whitten and Goodnight 1966
Tubificid worm, *Tubifex* sp.	S, U	Analytical	5,230†	5,230	Whitten and Goodnight 1966
Cladoceran (<24 hr), *Daphnia magna*	F, M	Reagent	1.00		Spacie 1976; Spacie et al. 1981
Cladoceran, (<24 hr), *Daphnia magna*	S, M	Reagent	1.27		Spacie 1976; Spacie et al. 1981
Cladoceran (<24 hr), *Daphnia magna*	S, U	Analytical	1.3†††	1.3	Dortland 1980
Cladoceran (1st instar), *Daphnia pulex*	S, U	Technical	0.60†††	0.60	Johnson and Finley 1980
Cladoceran (1st instar), *Simocephalus serrulatus*	S, U	Technical	0.47†††	0.47	Johnson and Finley 1980
Isopod, *Asellus brevicaudus*	S, U	Technical	600	-	Sanders 1972
Isopoda (mature), *Asellus brevicaudus*	S, U	Technical	2,130	1,130.5	Johnson and Finley 1980
Amphipod (immature), *Gammarus fasciatus*	F, M	Reagent	0.43		Spacie 1976; Spacie et al. 1981
Amphipod (immature), *Gammarus fasciatus*	F, M	Reagent	0.62		Spacie 1976; Spacie et al. 1981
Amphipod (immature), *Gammarus fasciatus*	F, M	Reagent	0.26		Spacie 1976; Spacie et al. 1981
Amphipod (immature) *Gammarus fasciatus*	F, M	Reagent	0.25		Spacie 1976; Spacie et al. 1981

Table 1. (continued)

Species	Method*	Chemical	LC50 or EC50 (µg/L)	Species Mean Acute Value (µg/L)	Reference
Amphipod (mature), *Gammarus fasciatus*	S, U F, U	Technical	2.1 4.5	- -	Sanders 1972
Amphipod (mature), *Gammarus fasciatus*	S, U	Technical	1.3	2.3	Johnson and Finley 1980; Sanders 1972
Amphipod (mature), *Gammarus lacustris*	S, U	Technical	3.5	3.5	Johnson and Finley 1980; Sanders 1969
Prawn, *Palaemonetes kadiakensis*	F, U	Technical	5.0	-	Sanders 1972
Prawn (mature), *Palaemonetes kadiakensis*	S, U	Technical	1.5	2.7	Johnson and Finley 1980; Sanders 1972
Crayfish (early instar), *Orconectes nais*	S, U	Technical	0.04	-	Johnson and Finley 1980; Sanders 1972
Crayfish (mature), *Orconectes nais*	S, U	Technical	15	0.77	Sanders 1972
Crayfish (mature), *Procambarus* sp.	S, U	Technical	<250	<250	Johnson and Finley 1980
Mayfly, *Cloeon dipterum*	S, U S, U R, U	Analytical	2.5 2.6 1.7	- - 2.2	Dortland 1980
Mayfly (juvenile), *Hexagenia bilineata*	S, U	Technical	15	15	Johnson and Finley 1980
Damselfly (juvenile), *Ischnura venticalis*	S, U	Technical	0.64	0.64	Johnson and Finley 1980
Damselfly, *Lestes congener*	S, U	Technical	3	3	Federle and Collins 1976
Stonefly, *Pteronarcella badia*	S, U	Technical	4.2	4.2	Johnson and Finley 1980; Sanders and Cope 1969
Stonefly (naiad), *Pteronarcys californica*	S, U	Technical	32	-	Jensen and Gaufin 1964

Table 1. (continued)

Species	Method*	Chemical	LC50 or EC50 (µg/L)	Species Mean Acute Value (µg/L)	Reference
Stonefly (2nd year class), *Pteronarcys californica*	S, U	Technical	5.4	13.1	Johnson and Finley 1980; Sanders and Cope 1969
Stonefly (naiad), *Acroneuria pacifica*	S, U	Technical	2.9	2.9	Jensen and Gaufin 1964
Stonefly (2nd year class), *Claassenia sabulosa*	S, U	Technical	1.5	1.5	Johnson and Finley 1980; Sanders and Cope 1969
Crawling water beetle (adult), *Peltodytes* spp.	S, U	Technical	7	7	Federle and Collins 1976
Chironomid (4th instar), *Chironomus tentans*	F, M	Reagent	31.0		Spacie 1976; Spacie et al. 1981
Cutthroat trout (0.3 g), *Salmo clarki*	S, U	Technical	1,560	1,560	Johnson and Finley 1980
Rainbow trout (1.0 g), *Salmo gairdneri*	S, U	Technical	1,430	1,430	Johnson and Finley 1980
Brown trout (16-19 cm), *Salmo trutta*	F, M	Reagent	1,510	1,510	Spacie 1976; Spacie et al. 1981
Brook trout (juvenile), *Salvelinus fontinalis*	F, M	Reagent	1,760**		Spacie 1976; Spacie et al. 1981
Lake trout (0.7 g), *Salvelinus namaycush*	S, U	Technical	1,920	1,920	Johnson and Finley 1980
Goldfish (juvenile), *Carassius auratus*	S, U	Technical	2,700	-	Pickering et al. 1962
Goldfish (0.9 g), *Carassius auratus*	S, U	Technical	1,830	2,223	Johnson and Finley 1980
Fathead minnow (adult), *Pimephales promelas*	S, M	Reagent	1,600		Spacie 1976; Spacie et al. 1981
Fathead minnow (adult), *Pimephales promelas*	F, M	Reagent	500		Spacie 1976; Spacie et al. 1981

Table 1. (continued)

Species	Method[a]	Chemical	LC50 or EC50 (µg/L)	Species Mean Acute Value (µg/L)	Reference
Fathead minnow (1.8-4.0 cm), *Pimephales promelas*	F, M	Analytical	1,410	-	Solon et al. 1969
Fathead minnow, *Pimephales promelas*	F, M	Technical	1,410	-	Solon and Nair 1970
Fathead minnow (1-1.5 g), *Pimephales promelas*	S, U	Technical	1,400	-	Henderson and Pickering 1958
Fathead minnow (1-1.5 g), *Pimephales promelas*	S, U	Technical	1,600	-	Henderson and Pickering 1958
Fathead minnow (1-1.5 g), *Pimephales promelas*	S, U	Technical	2,800	-	Henderson and Pickering 1958
Fathead minnow (1-1.5 g), *Pimephales promelas*	S, U	Technical	3,700	-	Henderson and Pickering 1958
Fathead minnow (juvenile), *Pimephales promelas*	S, U	Technical	1,300		Pickering et al. 1962
Fathead minnow (0.8 g), *Pimephales promelas*	S, U	Technical	2,350	1,410	Johnson and Finley 1980
Channel catfish (1.4 g), *Ictalurus punctatus*	S, U	Technical	2,650	2,650	Johnson and Finley 1980
Mosquitofish (1.1 g), *Gambusia affinis*	S, U	Technical	320	320	Johnson and Finley 1980
Guppy (~6 mo), *Poecilia reticulata*	S, U	Technical	56	56	Pickering et al. 1962
Green sunfish (1.1 g), *Lepomis cyanellus*	S, U	Technical	930	930	Johnson and Finley 1980
Bluegill (juvenile), *Lepomis macrochirus*	F, M	Reagent	510		Spacie 1976; Spacie et al. 1981
Bluegill (juvenile), *Lepomis macrochirus*	S, U	Technical	95	-	Pickering et al. 1962

Table 1. (continued)

Species	Method*	Chemical	LC50 or EC50 (µg/L)	Species Mean Acute Value (µg/L)	Reference
Bluegill (1.0 g), *Lepomis macrochirus*	S, U	Technical	400	-	Finley and Johnson 1980
Bluegill (1.5 g), *Lepomis macrochirus*	S, U	Technical	710	-	Henderson and Pickering 1958
Bluegill (1.5 g), *Lepomis macrochirus*	S, U	Technical	710	372	Henderson and Pickering 1958
Largemouth bass (0.7 g), *Micropterus salmoides*	S, U	Technical	620	620	Johnson and Finley 1980
Western chorus frog (1 wk), *Pseudacris triseriata*	S, U	Technical	1,000	1,000	Sanders 1970

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

** Normalized by author for 5% mortality in the control.

† Average LC50 when cultured with *Tubifex* sp.

†† Average LC50 when cultured with *Limnodrilus* sp.

††† 48 hr EC50.

Table 2. Chronic Toxicity of Parathion to Aquatic Animals

Species	Test*	Chemical	Limits (µg/L)	Chronic Value (µg/L)	Reference
		FRESHWATER SPECIES			
Fathead minnow, *Pimephales promelas*	LC	Reagent	4.4-9.0	6.3	Spacie 1976; Spacie et al. 1981
Bluegill, *Lepomis macrochirus*	LC	Reagent	0.17-0.34	0.24	Spacie 1976; Spacie et al. 1981

* LC = life-cycle or partial life-cycle

Acute-Chronic Ratio

Species	Acute Value (µg/L)	Chronic Value (µg/L)	Ratio
Fathead minnow, *Pimephales promelas*	500	6.3	79.4
Bluegill, *Lepomis macrochirus*	510	0.24	2,125

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		
29	5,230	Tubificid worm, *Tubifex* sp.	5,230	-
28	5,230	Tubificid worm, *Limnodrilus* sp.	5,230	-
27	2,650	Channel catfish, *Ictalurus punctatus*	2,650	-
26	2,223	Goldfish, *Carassius auratus*	2,223	-
25	1,838	Lake trout, *Salvelinus namaycush*	1,920	-
		Brook trout, *Salvelinus fontinalis*	1,760	-
24	1,499	Cutthroat trout, *Salmo clarki*	1,560	-
		Brown trout, *Salmo trutta*	1,510	-
		Rainbow trout, *Salmo gairdneri*	1,430	-
23	1,131	Isopod, *Asellus brevicaudus*	1,131	-
22	1,000	Western chorus frog, *Pseudacris triseriata*	1,000	-
21	998	Fathead minnow, *Pimephales promelas*	998	79.4
20	689	Green sunfish, *Lepomis cyanellus*	930	-
		Bluegill, *Lepomis macrochirus*	510	2,125

Table 3. (continued)

Rank*	Genus Mean Acute Value (µg/L)	Species	Species Mean Acute Value (µg/L)**	Species Mean Acute-Chronic Ratio***
19	620	Largemouth bass, *Micropterus salmoides*	620	-
18	320	Mosquitofish, *Gambusia affinis*	320	-
17	<250	Crayfish, *Procambarus* sp.	<250	-
16	56	Guppy, *Poecilia reticulata*	56	-
15	31.0	Midge, *Chironomus tentans*	31.1	-
14	15	Mayfly, *Hexagenia bilineata*	15	-
13	13.1	Stonefly, *Pteronarcys californica*	13.1	-
12	7.0	Beetle, *Peltodytes* spp.	7.0	-
11	4.2	Stonefly, *Pteronarcella badia*	4.2	-
10	3.0	Damselfly, *Lestes congener*	3.0	-
9	2.9	Stonefly, *Acroneuria pacifica*	2.9	-
8	2.8	Amphipod, *Gammarus lacustris*	3.5	-
		Amphipod, *Gammarus fasciatus*	2.3	-
7	2.7	Prawn, *Palaemonetes kadiakensis*	2.7	-

Table 3. (continued)

Rank*	Genus Mean Acute Value (µg/L)	Species	Species Mean Acute Value (µg/L)**	Species Mean Acute-Chronic Ratio***
6	2.2	Mayfly, *Cloeon dipterum*	2.2	-
5	1.5	Stonefly, *Claassenia sabulosa*	1.5	-
4	0.77	Cladoceran, *Daphnia magna*	1.0	-
		Cladoceran, *Daphnia pulex*	0.60	-
3	0.77	Crayfish, *Orconectes nais*	0.77	-
2	0.64	Damselfly, *Ischnura venticalis*	0.64	-
1	0.47	Cladoceran, *Simocephalus serrulatus*	0.47	-

* Ranked from most resistant to most sensitive based on Genus Mean Acute Value.

** From Table 1.

*** From Table 2.

Fresh water

Final Acute Value = 0.5489 µg/L

Criterion Maximum Concentration = (0.5489 µg/L) / 2 = 0.2745 µg/L

Final Acute-Chronic Ratio = 410.8

Final Chronic Value = (0.5489 µg/L) / 410.8 = 0.0013 µg/L

Table 4. 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	0.44	260	Muscle	124	Spacie 1976; Spacie et al. 1981
		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	
		0.6	180		258	
		0.6			312	
		1.4			299	
		2.6			439	
		4.0			471	
		6.7			573	
Fathead minnow, *Pimephales promelas*	Reagent	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	4.00	540	Muscle	27	Spacie 1976; Spacie et al. 1981

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

Species	Chemical	Duration	Effect	Result (mg/L)	Reference
Alga, *Chlorella pyrenoidosa*	Technical	7 hr	Change in growth		
			1,000•μg algae/ml*	91%	Cole and Plapp 1974
			100•μg algae/ml*	84%	
			10•μg algae/ml*	74%	
			1•μg algae/ml*	47%	
Alga, *Chlorella pyrenoidosa*	Technical	7 hr	Change in photosynthesis		
			1,000•μg algae/ml*	156%	Cole and Plapp 1974
			100•μg algae/ml*	118%	
			10•μg algae/ml*	147%	
			1•μg algae/ml*	181%	
Ciliate *Colpidium campylum*	-	43 hr	MAD**	10,000	Dive et al. 1980
Worm, *Tubifex tubifex*	-	18 hr	Onset of symptoms	10,000	Ludemann and Neumann 1960c
		18-36 hr	Onset of death	100,000	
Snail, *Biomphalaria glabrata*	-	24 hr	LC50	8,090	Ghetti and Gorbi 1985
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	7 days	EC50	0.39	Spacie 1976; Spacie et al. 1981
		14 days		0.31	
		21 days		0.16	
		21 days	RI50	0.34	
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
Isopod, *Asellus aquaticus*	-	24 hr (exp.) 72 hr (rec.)	LC50	55***	Ludemann and Neumann 1960c

Table 5. (continued)

Species	Chemical	Duration	Effect	Result (mg/L)	Reference
Prawn, *Palaemonetes kadiakensis*	Technical	24 hr	LC50	7.1[†] 11.8[†] 7.4[†] 6.6[†]	Naqvi and Ferguson 1970
Mayfly (larva), *Baetis rhodani*	-	65 min	LT50	1,000	Ghetti and Gorbi 1985
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 basillaris*	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* spp.	Technical	24 hr	LC50	60	Ahmed 1977
Caddisfly (larva), *Hydropsyche pellucidula*	-	110 min	LT50	1,000	Ghetti and Gorbi 1985
Mosquito (4th instar), *Aedes aegypti*	32-P labeled	24 hr	LC50	4.8	Schmidt and Weidhaas 1961
Mosquito (larva), *Aedes nigromaculis*	Technical	24 hr	LC50	40 35 3.5	Mulla et al. 1970
Mosquito (4th instar), *Aedes nigromaculis*	Technical	24 hr	LC50	27 68	Mulla et al. 1978

Table 5. (continued)

Species	Chemical	Duration	Effect	Result (mg/L)	Reference
Mosquito (4th instar), *Aedes taeniorhynchus*	32-P labeled	24 hr	LC50	3.6	Schmidt and Weidhaas 1961
Mosquito (4th instar), *Anopheles freeborni*	Technical	24 hr	LC50	9.7 4.5 3.7 6.3 6.2 7.2 7.6 5.7 6.1 2.9 2.6 2.4 9.7 8.6 4.9 15.0 8.0 11.0 6.0 4.0 10.0 11.0 2.2 2.6	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 Weidhaas 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

Table 5. (continued)

Species	Chemical	Duration	Effect	Result (mg/L)	Reference
Mosquito (larva), *Culex tarsalis*	Technical	24 hr	LC50	5.8	Ahmed 1977
Midge (larva), *Chironomus plumosus*	-	24 hr	LC50	39	Ludemann and Neumann 1960b
Midge (4th instar), *Chironomus riparius*	Technical	24 hr	LC50	2.5	Estenik and Collins 1979
Midge (2nd and 4th instar), *Chironomus tentans*	Reagent	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
Brown trout, *Salmo trutta*	Reagent	64 hr	BAF	61 77	Spacie 1976; Spacie et al. 1981
Brook trout, *Salvelinus fontinalis*	Reagent	8 hr 114 hr 140 hr 144 hr	BAF	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
Carp (3.9 g), *Cyprinus carpio*	-	48 hr	LC50	3,500	Ludemann and Neumann 1960a
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 5. (continued)

Species	Chemical	Duration	Effect	Result (mg/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 and Washino 1977
Mosquitofish (15-30 mg), *Gambusia affinis*	Analytical	24 hr	LC50	1,400	Krieger and Lee 1973
Mosquitofish (adult) (DDT-resistant), *Gambusia affinis*	Analytical	48 hr	LC50	390 950	Chambers and Yarbough 1974
Mosquitofish (adult) (DDT-susceptible), *Gambusia affinis*	Analytical	48 hr	LC50	350 610	Chambers and Yarbough 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*	-	24 hr	LC50	141	Gibson 1971

Table 5. (continued)

Species	Chemical	Duration	Effect	Result (mg/L)	Reference
Bluegill, *Lepomis macrochirus*	Reagent	12 hr	BAF	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
Toad (larva), *Bufo bufo*	-	48 hr	LC50	311***	Ludemann and Neumann 1960c

** Minimum active dose to elicit 3% change in growth rate.

*** Calculated from table.

† Collected at potentially pesticide contaminated sites.

REFERENCES

Ahmed, M.K. and J.E. Casida. 1958. Metabolism of some organophosphorus insecticides by microorganisms. J. Econ. Entomol. 51:59-63.

Ahmed, W. 1977. A laboratory and field study on the toxicity of mosquito larvicides to non-target insects found in California rice fields. Ph.D. Thesis, University of California-Davis.

Ahmed, W. and R.K. Washino. 1977. Toxicity of pesticides used in rice culture in California on Gambusia affinis. Ph.D. Thesis, University of California-Davis.

Alexander, T.C., M.V. Meisch, W.B. Kottkamp and A.L. Anderson. 1982. Effect of notonectids on mosquito larvae and preliminary observations of insecticide toxicity. Ark. Farm Res. 31:5.

Anderson, B.G. 1959. The toxicity of organic insecticides to Daphnia. Trans. 2nd Sem. Biol. Probl. Water Pollut. 94-95.

Banas, W.P. and J.P. Sprague. 1981. Absence of acclimation to parathion by rainbow trout. IN: Proceedings of the Eighth Annual Aquatic Toxicity Workshop. Canadian Technical Report of Fisheries and Aquatic Sciences No. 1151. Kaushik, N.K. and K.R. Solomon (eds.). p. 170.

Basak, P.K. and S.K. Konar. 1976a. Toxicity of six insecticides to fish. Geobios 3:209-210.

Basak, P.K. and S.K. Konar. 1976b. Pollution of water by pesticides and protection of fishes: Parathion. Proc. Nat. Acad. Sci., India. 46(B):382-392.

Benge, M.K. and L.E. Fronk. 1970. Effects of pesticides on non-target aquatic organisms on the Ogden Bay Waterfowl Management Area, Utah. Proc. Ann. Meet. Utah Mosq. Abat. Assoc. 23:34-40.

Benke, G.M., K.L. Cheever and S.D. Murphy. 1973. Comparative toxicity, anticholinesterase action and metabolism of methyl parathion, parathion and guthion in sunfish and mice. Proc. 12th Ann. Meet. Soc. Toxicol. pp. 473-474.

Benke, G.M., K.L. Cheever, F.E. Mirer and S.D. Murphy. 1974. Comparative toxicity, anticholinesterase action and metabolism of methyl parathion and parathion in sunfish and mice. Toxicol. Appl. Pharmacol. 28:97-109.

Braun, H.E. and R. Frank. 1980. Organochlorine and organophosphorus insecticides: Their use in eleven agricultural watersheds and their loss to stream waters in southern Ontario, Canada, 1975-1977. Sci. Total. Environ. 15:169-192.

Bringmann, V.G. and R. Kuhn. 1977. Limiting values for the damaging action of water pollutants to bacteria (Pseudomonus putida) and green algae (Scenedesmus quadricauda) in the cell multiplication inhibition test. Z. Wasser Abwasser Forsch. 10:3-4.

Bringmann, G. and R. Kuhn. 1978a. Testing of substances for their toxicity threshold: Model organisms Microcystis (Diplocystis) aeruginosa and Scenedesmus quadricauda. Mitt. Int. Ver. Theor. Angew. Limnol. 21:275-284.

Bringmann, G. and R. Kuhn. 1978b. Grenzwerte der schadwirkung wassergefahrdender stoffe gegen blaualgen (Microcystis aeruginosa) und grunalgen (Scenedesmus quadricauda) im zellvermehrungshemmtest. Vom Wasser 50:45-60.

Burchfield, H.P. and E.E. Storrs. 1954. Kinetics of insecticidal action based on the photomigration of larvae of Aedes aegypti. Contributions of the Boyce Thompson Institute 17:439-452.

Chambers, J.E. 1976. The relationship of esterases to organophosphorus insecticide tolerance to mosquitofish. Pestic. Biochem. Physiol. 6:517-522.

Chambers J.E. and J.D. Yarbrough. 1974. Parathion and methyl parathion toxicity to insecticide-resistant and susceptible mosquitofish (Gambusia affinis). Bull. Environ. Contam. Toxicol. 11:315-320.

Chang, V.C. and W.H. Lange. 1967. Laboratory and field evaluation of selected pesticides for control of the red crayfish in California rice fields. J. Econ. Entomol. 60:473-477.

Chen, P.S., Y.N. Lin and C.L. Chung. 1971. Laboratory studies on the susceptibility of mosquito-eating fish, Lebistes reticulatus and the larvae of Culex pipiens fatigans to insecticides. Tai-Wan I Hsueh Hui Tsa Chih 70:28-35.

Chovelon. A., L. George, C. Gulayets, Y. Hoyano, E. McGuinness, J. Moore, S. Ramamoorthy, P. Singer, K. Smiley and A. Wheatley. 1984. Pesticide and PCB levels in fish from Alberta. Chemosphere 13:19-32.

Cole, D.R. and F.W. Plapp. 1974. Inhibition of growth and photosynthesis in Chlorella pyrenoidosa by a polychlorinated biphenyl and several insecticides. Environ. Entomol. 3:217-220.

Culley, D.D., Jr. and D.E. Ferguson. 1969. Patterns of insecticide resistance in the mosquitofish, Gambusia affinis. J. Fish Res. Bd. Canada 26:2395-2401.

Davey, R.B. and M.V. Meisch. 1977. Dispersal of mosquitofish, *Gambusia affinis*, in Arkansas rice field. Mosq. News 37:777-778.

Davey, R.B., M.V. Meisch and F.L. Carter. 1976. Toxicity of five rice field pesticides to mosquitofish, *Gambusia affinis*, and green sunfish, *Lepomis cyanellus*, under laboratory and field conditions in Arkansas. Environ. Entomol. 5:1053-1056.

Dick, M. 1982. Pesticide and PCB concentrations in Texas water, sediment and fish tissue. Report 264, Texas Department of Water Resources, Austin, TX.

Dive, D., H. Leclerc and G. Perscone. 1980. Pesticide toxicity on the ciliate protozoan *Colpidium campylum*: Possible consequences of the effect of pesticides in the aquatic environment. Ecotoxicol. Environ. Safety 4:129-133.

Dortland, R.J. 1978. Aliesterase-(ALI-E) activity in *Daphnia magna* as a parameter for exposure to parathion. Hydrobiologia 59:141-144.

Dortland, R.J. 1980. Toxicological evaluation of parathion and azinphosmethyl in freshwater model ecosystems. Versl. Landbouwkd. Onderz 898:1-112.

Dortland, R.J., H.R. Smissaert, J. Hamoen and M. Scholte. 1976. In vitro and in vivo inhibition of ali-esterases and cholinesterases by paraoxon and parathion in *Daphnia magna*. Meded. Fac Landbouw. Rijks Univ. Gent. 41:1477-1482.

Estenik, J.F. and W.J. Collins. 1979. In vivo and in vitro studies of mixed-function oxidase in an aquatic insect. *Chironomus riparius*. Am. Chem. Soc. Symp. Ser. 99:349-370.

Federle, P.F. and W.J. Collins. 1976. Insecticide toxicity to three insects from Ohio ponds. Ohio J. Sci. 76(1):19-24.

Fleming, W.J., H. deChacin, O.H. Pattee and T.G. Lamont. 1982. Parathion accumulation in cricket frogs and its effect on American kestrels. J. Toxicol. Environ. Health 10:921-927.

Francis, B.M., L.G. Hansen, T.R. Fukuto, P. Lu and R.L. Metcalf. 1980. Ecotoxicology of phenylphosphonothioates. Environ. Health Perspect. 36:187-196.

Frear, D.E. and J.E. Boyd. 1967. Use of Daphnia magna for the microbioassay of pesticides. I. Development of standardized techniques for rearing Daphnia and preparation of dosage-mortality curves for pesticides. J. Econ. Entomol. 60:1228-1236.

Gahan, J.B. 1957. Further studies with water-soluble insecticides for the control of mosquito larvae in irrigation water. Mosq. News 17:198-201.

Gasith, A. and A.S. Perry. 1980. Fate of parathion in a fish pond ecosystem and its impact on food chain organisms. Proc. Rep. Agrochem. Residue-Biota interaction in soil and aquatic ecosystems. IAEA. pp. 125-151.

Gasith, A. and A.S. Perry. 1983. Effect of containment, presence of fish and repetitive exposure to parathion on the composition and dynamics of the natural fish pond zooplankton community. Isr. J. Zool. 32:165-166.

Gasith, A. and A.S. Perry. 1985. Use of limnocorrals for pesticide toxicity studies: Effect on zooplankton composition and dynamics. Verh. Internat. Verein. Limnol. 22:2432-2436.

Gasith, A., A.S. Perry and A. Halevy. 1983. The effect of repeated exposures to sublethal levels of parathion on the survival, growth, reproduction, and biomass production of three species of fish in a eutrophic fish pond ecosystem. IN: Environmental Quality and Ecology, Vol. 2.

Gaufin, A.R., L. Jensen and T. Nelson. 1961. Bioassays determine pesticide toxicity to aquatic invertebrates. Water Sewage Works 108:355-359.

Gaufin, A.R., L.D. Jensen, A.V. Nebeker, T. Nelson and R.W. Teel. 1965. The toxicity of ten organic insecticides to various aquatic invertebrates. Water Sewage Works. 12:276-279.

Ghetti, P.F. and G. Gorbi. 1985. Effects of acute parathion pollution on macroinvertebrates in a stream. Verh. Internat. Verein. Limnol. 22:2426-2431.

Gibson, J.R. 1971. Comparative biochemistry of parathion metabolism in three species of fishes. Ph.D. Dissertation, Mississippi State University; Diss. Abstr. Int. (B) 32:2365. Order No. 71-27,040.

Gibson, J.R. and J.L. Ludke. 1973. Effect of SKF-525A on brain acetylcholinesterase inhibition by parathion in fishes. Bull. Environ. Contam. Toxicol. 9:140-142.

Gillies, P.A., D.J. Womeldorf, E.P. Zboray and K.E. White. 1974. Insecticide susceptibility of mosquitoes in California: Status of organophosphorus resistance in larval _Aedes nigromaculis_ and _Culex tarsalis_ through 1973. Proc. Pap. Ann. Conf. Calif. Mosq. Control Assoc. 42:107-112.

Goldsmith, L.A. 1978. The toxicity of parathion to _Orconectes rusticus_ and _Viviparus malleatus_. Ph.D. Dissertation, University of Rhode Island, Kingston, R.I. Available from University Microfilms, Ann Arbor, MI. Order No. 7915457.

Goldsmith, L.A. and G.P. Carlson. 1979. Divergent toxicity of parathion in two freshwater invertebrates, Orconectes rusticus and Viviparus malleatus. J. Environ. Sci. Health. B14:579-588.

Goldsmith, L.A., G.P. Carlson and G.C. Fuller. 1976. Toxicity and identification of parathion metabolites in freshwater crayfish (Cambarus) and snail (Viviparus). Pharmacologist 18: 170.

Gomaa, H.M. and S.D. Faust. 1971. Chemical hydrolysis and oxidation of parathion and paraoxon in aquatic environments. IN: Fate of Organic Pesticides in the Aquatic Environment. Faust, S.D. (ed.). American Chemical Society, Washington, D.C. pp. 189-201.

Graetz, D.A., G. Chesters, T.C. Daniel, L.W. Newland and G.B. Lee. 1970. Parathion degradation in lake sediments. J. Water Pollut. Control Fed. 42:R76-R94.

Greve, P.A., J. Freudenthal and S.L. Wit. 1972. Potentially hazardous substances in surface waters. II. Cholinesterase inhibitors in Dutch surface waters. Sci. Total. Environ. 1:253-265.

Grigarick, A.A. and M.O. May. 1982. Role of crayfish (Decapoda: Astacidae) as pests of rice in California and their control. Entomol. Soc. Am. 75: 633-636.

Grzenda, A.R., G.J. Lauer and H.P. Nicholson. 1962. Insecticide contamination in a farm pond. Part II. Biological effects. Trans. Am. Fish Soc. 91:213-222.

Gutierrez, M.C., E.P. Zboray and K.E. White. 1977. Insecticide susceptibility of mosquitoes in California: Status of organophosphorus resistance in larval Culex pipiens subspp., 1976. Proc. Pap. Ann. Conf. Calif. Mosq. Vector Control Assoc. 45:124-131.

Haddadin, M.J. and A.A. Alawi. 1974. Dead populations of fish in the rivers Jordan and Zarga. Biol. Conserv. 6:215-216.

Hall, R.J. and E. Kolbe. 1980. Bioconcentration of organophosphorus pesticides to hazardous levels by amphibians. J. Toxicol. Environ. Health 6:853-860.

Hart, N.R. and D.J. Womeldorf. 1977. Insecticide susceptibility of mosquitoes in Utah. Status of organophosphorus larvicide resistance through 1976. Proc. Ann. Meet. Utah Mosq. Abat. Assoc. 29:23-28.

Hashimoto, Y. and J. Fukami. 1969. Toxicity of orally and topically applied pesticide ingredients to carp, Cyprinus carpio. Botyukagaku 34:63-66.

Hashimoto, Y. and Y. Nishiuchi. 1981. Establishment of bioassay methods for the evaluation of acute toxicity of pesticides to aquatic organisms. J. Pest. Sci. 6:257-264.

Henderson, C. and Q.H. Pickering. 1958. Toxicity of organic phosphorus insecticides to fish. Trans. Am. Fish Soc. 87:39-51.

Henderson, C., Q.H. Pickering and C.M. Tarzell. 1959. The toxicity of organic phosphorus and chlorinated hydrocarbon insecticides to fish. Trans. 2nd Sem. Biol. Probl. Water Pollut., U.S. Public Health Service, Robert A. Taft Sanitary Engineering Center, Cincinnati, OH.

Hesselberg, R.J. and J.L. Johnson. 1972. Column extraction of pesticides from fish, fish food and mud. Bull. Envir. Contam. Toxicol. 7:115-120.

Hilsenhoff, W.L. 1959. The evaluation of insecticides for the control of Tendipes plumosus. J. Econ. Entomol. 52: 331-332.

Hiltibran, R.C. 1974. Oxygen and phosphate metabolism of bluegill liver mitochondria in the presence of some insecticides. Trans. Ill. State Acad. Sci. 67:228-237.

Hiltibran, R.C. 1982. Effects of insecticides on the metal-activated hydrolysis of adenosine triphosphate by bluegill liver mitochondria. Arch. Environ. Contam. Toxicol. 11:709-717.

Huddart, H. 1978. Parathion- and DDT-induced effects on tension and calcium transport in molluscan visceral muscle. Comp. Biochem. Physiol. 61C:1-6.

Hughes, J.S. 1970. Tolerance of striped bass, Morone saxatilis, larvae and fingerlings to nine chemicals used in pond culture. Proc. Ann. Conf. S.E. Assoc. Game Fish Comm. 24:431-438.

Hughes, J.S. 1973. Acute toxicity of thirty chemicals to striped bass (Morone saxatilis). Louisiana Dept. of Wildlife and Fisheries, Fish and Game Div., P.O. Box 4004, Monroe, LA. 71203.

Jensen, L.D. and A.R. Gaufin. 1964. Effects of ten organic insecticides on two species of stonefly naiads. Trans. Am. Fish Soc. 93:27-34.

Juhnke, V.I. and D. Ludemann. 1978. Ergebnisse der undersuchung von 200 chemischen verbindungen auf akute fischtoxizitat mit dem goldorfentest. Z. Wass. Abwass. Forsch. 11:161-164.

Jung, K.D. 1973. Substances extremely toxic to fish and their importance for a fish test warning system. G.W.F.-Wass. Abwass. 114:232-233.

Kannan, V. and S.V. Job. 1979. Studies on the residual levels of pesticide pollution in the Sathiar reservoir, J. Radio. Anal. Chem. 53:247-253.

Kortus, J., P. Macuch, J. Mayer, K. Durcek and V. Krcmery. 1971. Uptake of 32-P parathion and 32-P imidam by Euglena gracilis. J. Hyg. Epidemiol. Microbiol. Immunol. (Prague). 15:101-103.

Krieger, R.I. and P.W. Lee. 1973. Inhibition of in vivo and in vitro epoxidation of aldrin and potentiation of toxicity of various insecticide chemicals by diquat in two species of fish. Arch. Environ. Contam. Toxicol. 1:112-121.

Kynard, B. 1974. Avoidance behavior of insecticide susceptible and resistant populations of mosquitofish to four insecticides. Trans. Am. Fish Soc. 103:557-561.

Labrecque, G.C., J.R. Noe and J.B. Gahan. 1956. Effectiveness of insecticides on granular clay carriers against mosquito larvae. Mosq. News 16:1-3.

Lahav, M. and S. Sarig. 1969. Sensitivity of pond fish to cotnian (azinphosmethyl) and parathion. Bamidgeh. Bull. Fish Cult. Israel. 21:67-74.

Laplanche, A., M. Bouvet, F. Venien, G. Martin and A. Chabrolles. 1981. Modeling parathion changes in the natural environment laboratory experiment. Water Res. 15:599-607.

LeBlanc, G.A. 1984. Interspecies relationships in acute toxicity of chemicals to aquatic organisms. Environ. Toxicol. Chem. 3:47-60.

Lewallen, L.L. 1959. Toxicity of several organophosphorus insecticides to *Gambusia affinis* in laboratory tests. Mosq. News 19:1-2.

Lewallen, L.L. 1962. Toxicity of certain insecticides to hydrophilid larvae. Mosq. News 22:112-113.

Lewallen, L.L. and W.H. Wilder. 1962. Toxicity of certain organophosphorus and carbamate insecticides to rainbow trout. Mosq. News 22:369-372.

Lichtenstein, E.P., T.T. Liang and B.N. Anderegg. 1975. Synergism of insecticides by herbicides under various environmental conditions. Environ. Conserv. 2:148

Lichtenstein, E.P., K.R. Schulz, R.F. Skrentny and Y. Tsukano. 1966. Toxicity and fate of insecticide residues in water. Arch. Environ. Health 12:199-212.

Loeb, H.A. and W.H. Kelly. 1963. Acute oral toxicity of 1,496 chemicals force-fed to carp. U.S. Fisheries and Wildlife Service Special Report No. 471. Washington, D.C.

Ludemann, V.D. and F. Herzel. 1973. Toxicity and concentration changes with time of the insecticide parathion in water. Z. Angew. Zool. 60:177-181.

Ludemann, V.D. and H. Neumann. 1960a. Versuche uber die akute toxische wirkung neuzeilieher kontaktinsektizide auf einsommerige karpfen (*Cyprinus carpio*). Z. Angew. Zool. 47:11-33.

Ludemann. V.D. and H. Neumann. 1960b. Studies on the acute toxicity of modern contact insecticides in freshwater. III. Chironomid larvae. Z. Angew. Zool. 32: 493-505.

Ludemann, V.D. and H. Neumann. 1960c. Studies on the acute toxicity of modern contact insecticides in freshwater. Z. Angew. Zool. 20:303-321.

Ludemann, V.D. and H. Neumann. 1961. Study of the acute toxicity of modern contact insecticides for freshwater animals. Z. Angew. Zool. 48: 87-96.

Ludke, J.L., J.R. Gibson and C.I. Lusk. 1972. Mixed function oxidase activity in freshwater fishes. Aldrin epoxidation and parathion activation. Toxicol. Appl. Pharmacol. 21:89-97.

Macek, K.J. 1975. Acute toxicity of pesticide mixtures to bluegills. Bull. Environ. Contam. Toxicol. 14:648-652.

Mackiewicz, M., K.H. Deubert, H.B. Gunner and B.M. Zuckerman. 1969. Study of parathion biodegradation using gnotobiotic techniques. J. Agric. Food Chem. 17:129-130.

McDonald, T.O. and M. Fingerman. 1979. Effects of DDT and parathion on goldfish retina/pigment epithelium/choroid concentrations of serotonin, dopamine, and norepinephrine. Toxicol. Appl. Pharmacol. 48: A199.

Micks, D.W. and D. Rougeau. 1977. Organophosphorus tolerance in Culex quinquefasciatus in Texas. Mosq. News 37:233-239.

Miller, C.W., W.E. Tomlinson and R.L. Norgen. 1967. Persistence and movement of parathion in irrigation waters. Pestic. Monitor. J. 1:47-48.

Miller, C.W., B.M. Zuckerman and A.J. Charig. 1966. Water translocation of diazinon-14C and parathion-35S off a model cranberry bog and subsequent occurrence in fish and mussels. Trans. Am. Fish Soc. 95:345-349.

Minchew, C.D. and D.E. Ferguson. 1970. Toxicities of six insecticides to resistant and susceptible green sunfish and golden shiners in static bioassays. Miss. Acad. Sci. J. 15:29-32.

Mohamed, M.P. and R.A. Gupta. 1984. Effects of sublethal concentration of ethyl parathion on oxygen consumption and random swimming activity of _Cirrhinus mrigala_. India. J. Exper. Biol. 22:42-44.

Morgan, W.S. 1975. Monitoring pesticides by means of changes in electric potential caused by fish opercular rhythms. Prog. Water Technol. 7.33-40.

Morgan, W.S. 1976. Fishing for toxicity: Biological automonitor for continuous water quality control. Effluent Water Treat. J. 16:471-472, 474-475.

Morgan, W.S. 1977. Biomonitoring with fish: An aid to industrial effluent and surface water quality control. Prog. Water Technol. 9:703-711.

Moore, R.B. 1970. Effects of pesticides on growth and survival of _Euglena gracilis Z_. Bull. Environ. Contam. Toxicol. 5:226-230.

Mount, D.I. and H.W. Boyle. 1969. Parathion-use of blood concentration to diagnose mortality of fish. Environ. Sci. Technol. 3:1183-1185.

Mulla, M.S. 1963. Persistence of mosquito larvicides in water. Mosq. News 23:234-237.

Mulla, M.S. 1980. New synthetic pyrethroids - effective mosquito larvicides. Proc. Pap. Ann. Conf. Calif. Mosq. Vector Control Assoc. 48:92-93.

Mulla, M.S., H.A. Darwazeh and P.A. Gillies. 1970. Evaluation of aliphatic amines against larvae and pupae of mosquitoes. J. Econ. Entomol. 63:1472-1475.

Mulla. M.S. and L.W. Isaak. 1961. Field studies on the toxicity of insecticides to the mosquitofish, Gambusia affinis. J. Econ. Entomol 54:1237-1242.

Mulla, M.S., L.W. Isaak and H. Axelrod. 1963. Field studies on the effects of insecticides on some aquatic wildlife species. J. Econ. Entomol. 56:184-188.

Mulla, M.S., J.O. Keith and F.A. Gunther. 1966. Persistence and biological effects of parathion residues in waterfowl habitats. J. Econ. Entomol. 59:1085-1090.

Mulla, M.S., R.L. Metcalf and L.W. Isaak. 1962. Some new and highly effective mosquito larvicides. Mosq. News 22: 231-238.

Mulla, M.S., R.L. Metcalf and G. Kats. 1964. Evaluation of new mosquito larvicides with notes on resistant stains. Mosq. News 24:312-319.

Mulla, M.S., H. Navvab-Gojrati and H.A. Darwazeh. 1978. Biological activity and longevity of new synthetic pyrethroids against mosquitoes and some non-target insects. Mosq. News 38:90-96.

Mulla, M.S., J. St. Amant and L.D. Anderson. 1967. Evaluation of organic pesticides for possible use as fish toxicants. Prog. Fish Cult. 29:36-42.

Murphy, S.D., R.R. Lauwerys and K.L. Cheever. 1968. Comparative anticholinesterase action of organophosphorus insecticides in vertebrates. Toxicol. Appl. Pharmacol. 12:22-35.

Myers, C.M., P.A. Gillies and R.F. Frolli. 1969. Field test of Abate and parathion granules in catch basins. Proc. Pap. Ann. Conf. Calif. Mosq. Control Assoc. 37:61-63.

Nagasawa, K., E. Koshimura and H. Fukuda. 1968. LD50 and ED50 of parathion and potassium cyanide and their bioassay using guppies (Lebistes reticulatus). Bull. Natl. Inst. Hyg. Sci. (Tokyo). 86:32-36.

Naqvi, S.M. 1973. Toxicity of twenty-three insecticides to a tubificid worm Branchiura sowerbyi from the Mississippi delta. J. Econ. Entomol. 66:70-74.

Naqvi, S.M. and D.E. Ferguson. 1970. Levels of insecticide resistance in freshwater shrimp, Palaemonetes kadiakensis. Trans. Am. Fish Soc. 99:696-699.

Nicholson, H.P., H.J. Webb, G.J. Lauer, R.E. O'Brien, A.R. Grzenda and D.W. Shanklin. 1962. Insecticide contamination in a farm pond. Part I. Origin and duration. Trans. Am. Fish Soc. 91:213-222.

Nishiuchi, Y. and Y. Hashimoto. 1967. Toxicity of pesticide ingredients to some freshwater organisms. Botyu-Kagaku (Sci. Pest. Control) 32:5-11.

Nishiuchi, Y. and Y. Hashimoto. 1969. Toxicity of pesticides to some freshwater organisms. Rev. Plant. Protec. Res. 2:137-139.

Nishiuchi, Y. and K. Yoshida. 1972. Toxicities of pesticides to some freshwater snails. Bull. Agr. Chem. Inspect. Stn. 12:86-92.

Nollenberger, E.L. 1982. Toxicant-induced changes in brain, gill, liver and kidney of brook trout exposed to carbaryl, atrazine, 2,4-D, and parathion: A cytochemical study. Diss. Abstr. Int. B. 42:3922.

Nollenberger, E.L., W. Neff and A. Anthony. 1981. Cytochemical analysis of brain nucleic acid changes in brook trout (Salvelinus fontinalis) exposed to carbaryl and parathion toxication. Proc. Pa. Acad. Sci. 55:97.

Panwar, R.S., R.A. Gupta, H.C. Joshi and D. Kapoor. 1982. Toxicity of some chlorinated hydrocarbon and organophosphorus insecticides to gastropod, Viviparus bengalensis. J. Environ. Biol. 3:31-36.

Panwar, R.S., D. Kapoor, H.C. Joshi and R.A. Gupta. 1976. Toxicity of some insecticides to the weed fish, Trichogaster fasciatus. J. Inl. Fish Soc. India. 8:129-130.

Perry, A.S., A. Gasith and Y. Mozel. 1983. Pesticide residues in fish and aquatic invertebrates. Arch. Toxicol. Suppl. 6:199-204.

Pickering, Q.H., C. Henderson and A.E. Lemke. 1962. The toxicity of organic phosphorus insecticides to different species of warmwater fishes. Trans. Am. Fish Soc. 91:175-184.

Poorman, A.E. 1973. Effects of pesticides on Euglena gracilis. I. Growth studies. Bull. Environ. Contam. Toxicol. 10:25-28.

Ramke, D. 1969. Development of organophosphorus resistant Aedes nigromaculis in the Tulane Mosquito Abatement District. Proc. Pap. Ann. Conf. Calif. Mosq. Control Assoc. 37:63.

Rand, G.M. 1977a. The effect of subacute parathion exposure on the locomotor behavior of the bluegill sunfish and largemouth bass. IN: Aquatic Toxicology and Hazard Evaluation. ASTM STP 634, Mayer, F.L. and J.L. Hamelink (eds.). American Society for Testing and Materials.

Rand, G.M. 1977b. The effect of exposure to a subacute concentration of parathion on the general locomotor behavior of the goldfish. Bull. Environ. Contam. Toxicol. 18:259-266.

Rand, G., H. Kleerekoper and J. Matis. 1975. Interaction of odor and flow perception and the effects of parathion in the locomotor orientation of the goldfish *Carassius auratus*. J. Fish Biol. 7:497-504.

Sanders, H.O. 1969. Toxicity of pesticides to the crustacean *Gammarus lacustris*. Tech. Paper No. 25, Bur. Sports Fish Wildl., Fish Wildl. Serv.

Sanders, H.O. 1970. Pesticide toxicities to tadpoles of the western chorus frog, *Pseudaeris triseriata* and Fowler's toad *Bufo woodhousii fowleri*. Copeia 2:246-251.

Sanders, H.O. 1972. Toxicity of some insecticides to four species of malacostracan crustaceans. Technical Paper No. 66. Bureau of Sport Fisheries and Wildlife, U.S. Fish and Wildlife Service, Washington, D.C.

Sanders, H.O. and O.B. Cope. 1968. The relative toxicities of several pesticides to naiads of three species of stoneflies. Limnol. and Oceanogr. 13(1):112-117.

Sato, R. and H. Kubo. 1965. The water pollution caused by organophosphorus insecticides in Japan. IN: Advances in Water Pollution Research. Jaag, O. (ed.), Pergamon Press, London. pp. 95-99.

Schmidt, C.H. and D.E. Weidaas. 1961. The toxicological action of three organophosphorus insecticides with three species of mosquito larvae. J. Econ. Entomol. 54:583-586.

Sethunathan, N., R. Siddaramappa, K.P. Rajaram, S. Barik and P.A. Wahid. 1977. Parathion: Residues in soil and water. Resid. Rev. 68:92-122.

Singh, H. and T.P. Singh. 1981. Effect of parathion and aldrin on survival, ovarian 32-P uptake and gonadotrophic potency in a freshwater catfish, *Heteropneustes fossilis*. Endokrinologie 77:173-178.

Siva-Prasada, K., K.R. Sambasiva and K.V. Ramana. 1983. Effect of parathion on tissue ionic changes in fish, *Channa punctatus*. Geobios 10:60-62.

Solomon, H.M. 1977. The teratogenic effects of the insecticides DDT, carbaryl, malathion, and parathion on developing medaka eggs (*Oryzias latipes*). Diss. Abst. Int. B. 39:2176-2177.

Solomon, H.M. and J.S. Weis. 1979. Abnormal circulatory development in medaka caused by the insecticides carbaryl, malathion and parathion. Teratology 19:51-61.

Solon, J.M. and J.H. Nair, III. 1970. The effect of a sublethal concentration of LAS on the acute toxicity of various phosphate pesticides to the fathead minnow (*Pimephales promelas* Rafinesque). Bull. Environ. Contam. Toxicol. 5:408-413.

Solon, J.M., J.L. Lincer and J.H. Nair. 1969. The effect of sublethal concentrations of LAS on the acute toxicity of various insecticides to the fathead minnow (*Pimephales promelas*). Water Res. 3:767-775.

Spacie, A. 1976. Acute and chronic parathion toxicity to fish and invertebrates. PB-257800. Available from National Technical Information Service, Springfield, VA.

Spacie, A., A.G. Vilkas, G.F. Doebbler, W.J. Kuc and G.R. Iwan. 1981. Acute and chronic parathion toxicity to fish and invertebrates. EPA-600/3-81-047. U.S. EPA, Washington, D.C.

Sreenivasan, A. and G.K. Swaminathan. 1967. Toxicity of six organophosphorus insecticides to fish. Curr. Sci. 36:397-398.

Srivastava, G.N., R.A. Gupta, M.P. Mohamed and D. Nath. 1977. Effect of sub-lethal ethyl parathion on the metabolism and activity of *Colisa fasciata*. India. J. Environ. Health 19:63-66.

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

Stewart, D.K., D. Chisholm and M.T. Ragab. 1971. Long-term persistence of parathion in soil. Nature 229:47.

Stewart, J.P. 1977. Synergism of chlorpyrifos by DEF in the control of organophosphorus resistant *Culex pipiens quinquefasciatus* larvae, with notes on synergism of parathion and fenthion. Proc. Pap. Ann. Conf. Calif. Mosq. Vect. Control Assoc. 45:132-133.

Sunm, T.J. and D.H. Taylor. 1983. The effects of parathion on acquisition and retention of shuttlebox avoidance - conditioning in the goldfish *Carassius auratus*. Environ. Pollut. (Series A) 31:119-131.

Surber, E.W. 1948. Chemical control agents and their effects on fish. Prog. Fish-Cult. 10:125-131.

Tarpley, W.A. 1958. Studies on the use of the brine shrimp, *Artemia salina*, as a test organism for bioassay. J. Econ. Entomol. 51:780-783.

Tarzwell, C.M. 1959a. Some effects of mosquito larviciding and the new pesticides on fishes. Proceedings of the Symposium on Coordination of Mosquito Control and Wildlife Management, Washington, D.C. April 1-2, 1959.

Tarzwell, C.M. 1959b. Pollutional effects of organic insecticides. Transactions of the 24th North American Wildlife Conference. Wildlife Management Institute, Washington, D.C. pp. 132-142.

Tomita, H. and N. Matsuda. 1961. Deformity of vertebrae induced by lathyrogenic agents and phenyl-thiourea in medaka (Oryzias latipes). Embryologia 5:413-422.

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

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

U.S. EPA. 1985. Technical support document for water-quality based toxic controls. Office of Water, Washington, D.C. September.

Van Hoof, F. 1980. Evaluation of an automatic system for detection of toxic substances in surface water using trout. Bull. Environ. Contam. Toxicol. 25:221-225.

Van Middelem. C.H. 1966. Fate and persistence of organic pesticides in the environment. IN: Organic Pesticides in the Environment. Rosen, A.A. and H.F. Kraybill (eds.). American Chemical Society, Washington, D.C. pp. 228-242.

Verma, S.R. and S.P. Gupta. 1976. Pesticides in relation to water pollution. Accumulation of aldrin and ethyl parathion in the tissues of Colisa fasciatus and Notopterus notopterus. India. J. Environ. Health 18:10-14.

Verma, S.R., V. Kumar and R.C. Dalela. 1981. Studies on the accumulation and elimination of three pesticides in the gonads of Notopterus notopterus and Colisa fasciatus. India. J. Environ. Health 23:275-281.

Warnick, S.L., R.F. Gaufin and A.R. Gaufin. 1966. Concentrations and effects of pesticides in aquatic environments. J. Amer. Water Works Assoc. 58:601-608.

Weiss, C.M. 1959. Stream pollution: Response of fish to sub-lethal exposures of organic phosphorus insecticides. Sewage Ind. Wastes 31:580-593.

Weiss, C.M. 1961. Physiological effect of organic phosphorus insecticides on several species of fish. Trans. Am. Fish Soc. 90:143-152.

Weiss, C.M. and J.H. Gakstatter. 1964. Detection of pesticides in water by biochemical assay. J. Water Pollut. Control Fed. 36:240-253.

Weiss, C.M. and J.H. Gakstatter. 1965. The decay of anticholinesterase activity of organic phosphorus insecticides on storage in waters of different pH. IN: Advances in Water Pollution Research. Jaag, O. (ed.), Pergamon Press, London. pp. 83-95.

Whitmore, D.H. and D.H. Hodges. 1978. In vitro pesticide inhibition of muscle esterases of the mosquitofish, Gambusia affinis. Comp. Biochem. Physiol. C. 59:145-149.

Whitten, B.K. and C.J. Goodnight. 1966. Toxicity of some common insecticides to tubificids. J. Water Pollut. Control Fed. 38:227-235.

Wilder, W.H. and C.S. Schaefer. 1969. Organophosphorus resistance levels in adults and larvae of the pasture mosquito, Aedes nigromaculis, in the San Joaquin Valley of California. Proc. Pap. Ann. Conf. Calif. Mosq. Control Assoc. 37:64-67.

Yahalomi, Z. and A.S. Perry. 1981. Microsomal mixed-function oxidases in fish in relation to environmental contamination by organochlorine insecticides. Comp. Biochem. Physiol. 70C:97-102.

Yasuno, M., S. Hirakoso, M. Sasa and M. Uchida. 1965. Inactiviation of some organophosphorus insecticides by bacteria in polluted water. Japan. J. Exp. Med. 35:545-563.

Yu, C.C. and J.R. Sanborn. 1975. The fate of parathion in a model ecosystem. Bull. Environ. Contam. Toxicol. 13:543-550.

Zboray, E.P. and M.C. Gutierrez. 1974. Insecticide susceptibility of mosquitoes in California: Status of organophosphorus resistance in larval Culex tarsalis through 1978, with notes on mitigating the problem. Proc. Pap. Ann. Conf. Calif. Mosq. Vect. Control Assoc. 47:26-28.

Zuckerman, B.M., K. Deubert, M. Mackiewicz and H. Gunner. 1970. Studies on the biodegradation of parathion. Plant and Soil 33:273-281.