AMBIENT AQUATIC LIFE WATER QUALITY CRITERIA FOR

TOXAPHENE

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NOTICES

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FOREWORD

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

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

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

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Introduction*

Toxaphene first became commercially available in 1948 under the trade name "Hercules 3956" and has been used in various forms, such as emulsifiable concentrates, wettable powders, dusts, and granular baits. Toxaphene is produced by the chlorination of camphene, resulting in a mixture of at least 175 separate components, mostly polychlorinated camphenes and bornanes, with an average chlorine content of 67 to 69% (Casida et al. 1974; Holmstead et al. 1974; Pollock and Kilgore 1978). The technical-grade product is an amber, waxy solid with a vapor pressure of 0.17 to 0.4 mm Hg at 25°C, a melting point range of 65 to 90°C, and a mild terpene odor. Its average empirical formula is $C_{10}H_{10}Cl_8$ (molecular weight = 414) and its reported solubility in water ranges from 37 µg/L (Lee et al. 1968) to over 500 µg/L (Paris et al. 1977). It is slowly dechlorinated photolitically (Callahan et al. 1979) and by heat at about 120°C; breakdown is accelerated by alkaline conditions and by iron catalysis.

Toxaphene was the most heavily used pesticide in the U.S. during the 1960s and 1970s, with annual applications totalling many millions of kilograms (Pollock and Kilgore 1978; Ribick et al. 1982). It was frequently mixed with DDT, methyl parathion, and other pesticides to improve its effectiveness. It has been employed against insect pests of cotton, tobacco, forests, turf, ornamental plants, grains, vegetables, and livestock, most heavily in the southern U.S. and in California. Toxaphene was used as a

* 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.

replacement in many of the former uses of DDT, after it was banned in 1971. In 1976 toxaphene was close behind methyl parathion as the second most heavily used insecticide in the "delta states" of Arkansas, Louisiana, and Mississippi (0.2 million kilograms) and was the sixth most heavily used insecticide in the corn belt (0.2 million kilograms) (Schmitt and Winger 1980). Use in California in the 1970s averaged 1.7 million kilograms per year (Cohen et al. 1982). In addition, 0.7 million kilograms was applied to a wide range of major agricultural crops in 12 north-central states in 1978 (Acie and Parke 1981) and 0.5 million kilograms in 1981 (Zygadlo 1982). Toxaphene's relatively low toxicity to honey bees compared to that of many other insecticides favored its agricultural use (Eckert 1949). Only very small quantities of toxaphene have been used agriculturally in Canada (Department of National Health and Welfare 1977). It was also used in the 1950s and early 1960s by fisheries personnel in several U.S. states and Canadian provinces to remove unwanted fish from lakes and ponds. This use was discontinued or prohibited when an unexpectedly high persistence was discovered in some lakes.

The U.S. EPA cancelled the registration of toxaphene for all uses in November, 1982, except for treatment of cattle and sheep for scabies, of pineapples for mealybug and gummosis moth, of bananas for weevils, and for emergency treatment of cotton, corn, and small grains for armyworms, cutworms, and grasshoppers. Some existing stocks of cancelled products could be sold and used according to label specifications through December 31, 1986, and all other stocks through 1983. Nor-Am Agricultural Products, Inc., the principal North American manufacturer, discontinued production in 1982.

The estimated use of toxaphene in 1982 was 4.1 million kilograms (personal communication from Robert Hitch, U.S. EPA, Washington, DC to Larry Fink, U.S. EPA, Chicago, IL). The reported U.S. stocks totalled about 6 million kilograms in 1983 and Nor-Am reported it still had about 3.6 million kilograms until 1985 (personal communication, Jay Ellenberger, U.S. EPA, Washington, DC). The Canadian registration for all pesticidal uses of toxaphene was revoked in October, 1980, except for a minor use by veterinarians for treatment of hogs for lice.

Capillary gas chromatography, sometimes in combination with mass spectrometry, is the most frequently used analytical method for characterization and quantitation of toxaphene in environmental samples (Ribick et al. 1982). A typical toxaphene gas chromatogram contains many peaks, a few of which are selected to distinguish toxaphene from other possible environmental co-contaminants. The identification and quantification of toxaphene in water and fish tissues is complicated by changes in the numbers and relative sizes of constituent peaks because of their differing rates of degradation, sorption, and volatilization in the environment.

Changes in environmental sample chromatograms as compared to reference standard chromatograms have led some analysts to refer to their values as "toxaphene-like" substances, although the prevailing uncertainty in identification using the latest analysis techniques is small. Durkin et al. (1979) reported a lower limit of detection of about 5 to 10 ng of toxaphene by several GC detection methods, but more recent measurements down to 1 to 2 ng are not uncommon. Concentrations have been quantitatively measured down to 0.1 μg/g in fish tissues (Ribick et al. 1982) and down to 0.01 μg/g in extracted lipid (Wideqvist et al. 1984).

The compositional changes that occur in the field probably also mean that field toxicity differs to some unknown extent from toxicity determined in laboratory tests using technical-grade toxaphene. Using mice, houseflies, and goldfish, Khalifa et al. (1974), Saleh et al. (1977), and Turner et al. (1975,1977) demonstrated that different toxaphene components have substantially different toxicities. Toxaphene that had "weathered" for 10 months in a lake was altered chemically (diminution of late eluting peaks) and was somewhat less toxic to fish than the original formulation (Lee et al. 1977). In contrast, Harder et al. (1983) found that sediment-degraded products of toxaphene were more toxic than the parent material to some saltwater fishes.

Applications of toxaphene to lakes for the purposes of fisheries management have provided substantial amounts of data concerning its aquatic fate and effects. Reports are available on the treatment of water bodies in at least a dozen states and three Canadian provinces. Most of these studies were conducted to determine the persistence of toxaphene in lakes and to determine how soon lakes could be restocked after treatment to eliminate unwanted species of fish. Treatment concentrations were usually between 5 and 200 μg of toxaphene per liter of lake water, with higher concentrations being recommended for warmer, shallower, and more turbid lakes (Rose 1958). Persistence of toxicity to fish was highly variable, ranging from a few weeks (e.g., Mayhew 1959) to greater than five years in Miller Lake, Oregon (Terriere et al. 1966). Concentrations of toxaphene in water typically dropped rapidly within a day or two after application due to sorption to suspended particulates or sediment (Veith and Lee 1971). Concentrations then diminished much more slowly for an indefinite period (Kallman et al. 1962). Toxaphene persisted longest in hypolimnetic areas of the most oligotrophic lakes (Stringer and McMynn 1960; Terriere et al.

1966), although it was detected at 1 to 4 μg/L for up to 10 years after it was applied to shallow eutrophic lakes in Wisconsin (Johnson et al. 1966).

Various studies (e.g., Chandurkar and Matsumura 1979; Chandurkar et al. 1978; Hughes et al. 1970; Isensee et al. 1979; Saleh et al. 1977) have demonstrated that toxaphene can be metabolized or degraded both aerobically and anaerobically. Quantitative data on degradation in water are lacking although it is obviously very slow under some conditions. Smith and Willis (1978) observed a rapid disappearance of toxaphene from Mississippi soil under anaerobic laboratory conditions, but it was not determined whether the disappearance was due to binding to soil particles, biological breakdown, or other factors. Nash and Woolson (1967) estimated the half-life of toxaphene to be 11 years in soil. Toxaphene is not readily desorbed back into water from contaminated sediments (Veith and Lee 1971), although it can be cycled within aquatic ecosystems through the benthos-water column food web connections (Kallman et al. 1962; Rice and Evans 1984). Concentrations approaching 2,000 mg/kg were found in an estuary adjacent to a toxaphene plant discharge, and oysters two miles away had concentrations as high as 6 mg/kg (Durant and Reinold 1972).

In addition to sharply elevated concentrations in air in the immediate vicinity of applications (e.g., Sieber et al. 1979; Stanley et al. 1971), airborne transport of toxaphene over several hundred kilometers has also been observed. Bidleman and Olney (1975) measured concentrations in the air over the northeastern U.S., presumably carried from cotton growing areas of the southern U.S., that were more than 10 times those of other pesticides reported from the same areas. Ohlendorf et al. (1982) detected toxaphene residues in the eggs of 15 of the 19 species of island-nesting Alaskan sea birds they examined. Zell and Ballschmiter (1980) found residues in fish (0.068 to 3.5 mg/kg of extractable lipid) collected from pristine sites in the Tyrolian Alps, Northwest Ireland, Caspian Sea, and the North Atlantic, North Pacific, and Antarctic Oceans. They suggested that such wide distribution of toxaphene residues has created "an overall global pollution larger than that by PCB."

Rice et al. (Manuscript) monitored atmospheric concentrations of toxaphene in the summer and fall of 1981 at four locations between Greenville, Mississippi, and northern Lake Michigan. Several lines of evidence indicated the cotton belt as a source of toxaphene in Lake Michigan: a decrease in number of matching GC chromatogram peaks from south to north; a reduction in concentrations (7.39 ng/m^3 in Greenville, 1.18 ng/m^3 in St. Louis, 0.27 ng/m^3 at Lake Michigan) from south to north; corresponding temporal concentration patterns (all higher in summer); and a net south to north wind flow pattern. The authors estimated a total toxaphene flux to Lake Michigan of 3,360 to 6,720 kg in 1981. Agricultural use of toxaphene in the north central states has been proposed as another possible source. No information could be located on current use of toxaphene in Mexico, or Central or South America; therefore the possibility of long-range transport from there to the U.S. is unfathomable. However, facilities for the production of toxaphene are known to have existed in these areas (personal communication, Office of Pesticide Programs, U.S. EPA).

Because toxaphene is a mixture of many organic chemicals, "pure" toxaphene has many components and is the same as "technical-grade toxaphene." Thus the term "active ingredient" is interpreted to mean "technical-grade toxaphene," that is, "toxaphene." The criteria presented herein supersede previous aquatic life water quality criteria for toxaphene (U.S. EPA 1976,1980) 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

Acute toxicity data that are acceptable for deriving water quality criteria are presented in Table 1. Freshwater data are listed in order of phylogeny, then from lowest to highest temperature within a species, and then from youngest to oldest life stage at each test temperature. For both channel catfish (Table 1) and the leopard frog (Table 6), early exogenously feeding life stages were more sensitive than initial (yolk dependent) or later life stages. Adults of both species appear to be the least sensitive life stage. In most cases where the influence of temperature was examined (e.g., Cope 1964; Hooper and Grzenda 1955; Johnson and Julin 1980; Macek et al. 1969; Mahdi 1966; Workman and Neuhold 1963), toxicity was greater at higher temperatures. The data obtained by Crosby et al. (1966) with *Daphnia magna* constitute a notable contradiction (Table 6), but the tests only lasted for 26 hr.

Where the effects of additional factors (e.g., water quality conditions, source of test organisms) on toxicity were investigated, these are identified in the temperature column of Table 1 and the effect column of Table 6. The most well controlled experiments concerning the effects of water quality were conducted with channel catfish by Johnson and Julin (1980) and indicated little or no influence on toxicity. Henderson et al. (1959)

obtained similar results with the fathead minnow. Data generated using water from different sources (Sanders 1972; Workman and Neuhold 1963) indicate greater differences in toxicity but the causal factors are unclear and the effects might not be attributable to the measured water quality conditions.

Henderson et al. (1960) and Workman and Neuhold (1963) investigated the influence of formulation on toxicity and found essentially no differences, based on active ingredient, between technical-grade toxaphene and commercial formulations with percentages of active ingredient ranging from 10 to 62.6% (Table 1).

Toxaphene is relatively insoluble in water and tends to sorb onto solid surfaces and particulates, especially those containing organic materials. Actual concentrations of toxaphene in water are almost always lower than amounts introduced into either flow-through or static test systems, but are particularly lower in static tests. For example, Hall and Swineford (1981) measured an average of only 30.5% of the intended water concentrations in a series of static acute tests, whereas in a series of continuous-flow exposures they obtained 55.4% of the amounts intended in their test solutions. Although other flow-through tests probably maintained water concentrations somewhat closer to calculated values, most of the unmeasured acute values are probably higher than the actual concentrations of toxaphene in solution in exposure chambers.

Three stonefly species and eleven fish species have acute values between 0.8 and 8 µg/L (Table 3), whereas all of the tested freshwater species with acute values between 20 and 500 µg/L are amphibians and invertebrates. The few values that are available for freshwater algae are between 100 and 1,000 µg/L (Table 4). These laboratory data appear to correlate well with the substantial body of information from field studies related to fish eradication.

All fish species were found to be similarly sensitive in the field, but older fish were more resistant than young ones (e.g., Henegar 1966). Treatment concentrations recommended for fast, complete eradication of fish (10 to 200 µg/L depending on water quality) correspond well with LC50s obtained with fish in laboratory studies (e.g., Cushing and Olive 1956; Hemphill 1954; Henegar 1966; Kallman et al. 1962; Needham 1966; Rose 1958; Stringer and McMynn 1958; Webb 1980; Woolitz 1962). Field results also agree with one another and with the laboratory data that many invertebrate species are less sensitive than fish; that some midges (especially Chaoborus sp.), amphipods, copepods, cladocerans, protozoans, and odonates are among the most sensitive invertebrates (also Hilsenhoff 1965). Oligochaetes, snails, leeches, and many insects are more resistant, whereas plants and phytoplankton are quite resistant.

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 28 freshwater genera for which acute values are available, the most sensitive genus, Claassenia, is 385 times more sensitive than the most resistant, Pseudacris. Acute values are available for more than one species in each of eight genera, and the range of Species Mean Acute Values within each genus is less than a factor of 4.4. The nine most sensitive genera are all within a factor of 4 and include two stoneflies, the common carp, and several important fish species including the channel catfish, largemouth bass, coho and chinook salmon, rainbow and brown trout, and striped bass. The freshwater Final Acute Value for toxaphene was calculated to be 1.467 µg/L using the procedure described in the Guidelines and the Genus Mean Acute Values in Table 3. This is higher than the Species Mean Acute Value for the important channel catfish, but the value for this species was not based on the results of a flow-through test in which the concentrations of toxaphene were measured.

Acute toxicity values for saltwater animals that are useful for deriving water quality criteria are from tests with nine invertebrate and six fish species. The sensitivities of the tested species range from 0.53 µg/L for for juvenile pinfish, Lagodon rhombiodes (Schimmel et al. 1977) to 460,000 µg/L for adults of the clam, Rangia cuneata (Chaiyarach et al. 1975). Acute values for stage II and III larvae of the drift line crab, Sesarma cinereum, were 0.5542 and 0.5298 µg/L, respectively (Courtenay and Roberts 1973) which are similar to the acute value for the pinfish. Except for resistant species tested at concentrations greater than toxaphene's solubility in water, acute values for most species range from 0.53 to 31.32 µg/L. Fishes and invertebrates are similarly sensitive.

Limited data are available on the effect of water quality on the toxicity of toxaphene. The toxicity of toxaphene to adult blue crabs, Callinectes sapidus, decreased slightly with increase in salinity (Mahood et al. 1970; McKenzie 1970). They report somewhat greater toxicity to this species at 10°C and 21°C than at 15°C at salinities of 8.6, 19.3, and 24.2 g/kg (Table 1). In contrast, the toxicity of toxaphene to adult threespine stickleback, Gasterosteus aculeatus, was similar at salinities of 5 and 25 g/kg. The 96-hr LC50s at these salinities were 8.6 and 7.8 µg/L, respectively (Katz 1961).

Harder et al. (1983) found that the acute toxicities of "parent" toxaphene and "sediment-degraded" toxaphene were similar for the spot, Leiostomus xanthurus, but that "sediment-degraded" toxaphene was about three times more toxic to the white mullet, Mugil curema, (Tables 1 and 6).

Of the fifteen saltwater genera for which acute values are available, the most sensitive, Lagodon, is over 867,000 times more sensitive than the most resistant, Rangia, but the two most resistant genera differ by a factor of 411. The four most sensitive genera include three fishes and an invertebrate, and the range of sensitivities is only a factor of 2.1. The saltwater Final Acute Value was calculated to be 0.4197 µg/L, which is below the acute value for the most sensitive species.

Chronic Toxicity to Aquatic Animals

The freshwater chronic data indicate about one to two orders of magnitude greater sensitivity than the acute data for the same species (Table 2). Effects were observed at the lowest exposure concentration, 0.039 µg/L, in the brook trout partial life-cycle test conducted by Mayer et al. (1975). The chronic value for the fathead minnow is 0.03674 µg/L, whereas that for the channel catfish is 0.1964 µg/L. The one chronic value available for an invertebrate is 0.09165 µg/L for Daphnia magna.

The chronic toxicity tests that have been conducted with saltwater species include an early life-stage test (Goodman et al. 1976) and a life-cycle test (Goodman 1986) with the sheepshead minnow, Cyprinodon variegatus, an early life-stage test with the longnose killifish, Fundulus similis (Schimmel et al. 1977), and a life-cycle test with the mysid, Mysidopsis bahia (Kuhn and Chammos 1986). Survival of sheepshead minnows was significantly reduced in 2.5 µg/L and no effects on survival or growth were detectable in 1.1 µg/L in the 28-day early life-stage toxicity test. In a life-cycle test that lasted 192 days with the same species, 1.0 µg/L reduced survival of both the first and second generations. Average length of fish after 28 days of exposure to 1.0 µg/L was reduced; however, for the remainder of the exposure, growth was not impaired. Effects of toxaphene on survival, growth, or reproduction of the sheepshead minnow were not detected in 0.51 µg/L. Survival of longnose killifish was reduced in all concentrations of toxaphene tested in the early life-stage test; fry survival was reduced in 1.3 µg/L. In the life-cycle test with the mysid, no adverse effects on survival, growth, or reproduction were detected at a toxaphene concentration of 1,585 µg/L, which was the highest concentration tested. The 96-hr LC50 of 2.03 µg/L was used as the upper chronic limit.

Freshwater acute-chronic ratios are available for two fish species and one invertebrate species. The acute sensitivities of these three species only range from 5.5 to 10 µg/L, but the acute-chronic ratios range from 28 to 196. In the chronic test with a third fish species, the brook trout, all tested concentrations of toxaphene caused unacceptable effects. The only acute value available for this species was obtained in a test with yearlings, not juveniles. The available data on freshwater acute-chronic ratios do not allow calculation of a freshwater Final Chronic Value, but if one could be calculated it would have to be less than the 0.039 µg/L that adversely affected brook trout in a partial life-cycle test.

Two acute-chronic ratios are available for the saltwater sheepshead minnow, but because the life-cycle test takes precedence over the early life-stage test, the acute-chronic ratio for this species is 1.540. A ratio of 1.133 was obtained with a mysid. Both of these ratios are much smaller than the two ratios that were obtained with freshwater species. However, according to the Guidelines, the saltwater Final Acute-Chronic Ratio cannot be less than 2. Thus the saltwater Final Chronic Value for coast saltwater fish (Musial and Uthe 1983); birds and several kinds of aquatic organisms from the Apalachicola River in Florida (Elder and Mattraw 1984; Winger et al. 1984) and Louisiana oxbow lakes (Niethammer et al. 1984); and various fish species in Alabama (Grzenda et al. 1964), Texas (Dick 1982), the Colorado River (Johnson and Lew 1970), California (Keith and Hunt 1966), South Dakota (Hannon et al. 1970), and the Mississippi River delta (Crockett et al. 1975: Epps et al. 1967; Hawthorne et al. 1974). Some mortalities of birds have been associated with agricultural applications of toxaphene (e.g., Ginn and Fisher 1974; Keith 1966), although some of these have involved contamination by other pesticides as well (Keith 1966: Plumb and Richburg 1977).

In a summary of data on the concentrations of toxaphene in Great Lakes fish through 1981, Rice and Evans (1984) reported that residues increased through the 1970s and that fish in Lake Michigan contained higher concentrations than those from the other lakes. Like other chlorinated hydrocarbon pesticides, toxaphene is lipophilic and the highest concentrations are usually in the oldest and fattest fish at the top of the food chain, such as lake trout. Concentrations in this species have generally ranged between 1 and 10 mg/kg in the most recently published analyses (Canada Department of Fisheries and Oceans 1982; Rice and Evans 1984; Schmitt et al. 1985). Schmitt et al. (1985) reported that toxaphene residues seemed to have peaked nationally in U.S. freshwater fish collected in 1980 and 1981, even though it was more widely distributed than in previous surveys. Residues in Great Lakes fish, especially those from Lakes Michigan and Superior, generally appeared 2 to 5 mg/kg lower than the 5 to 10 mg/kg commonly observed during the 1970s. Adult lake trout collected from Lake Huron near Rockport, Michigan in 1984 contained 2.2 mg/kg; bloater chubs collected from Lake

Michigan near Saugatuck, Michigan in 1982 contained 1.6 mg/kg, whereas those collected in the same area in the fall of 1984 contained 2.2 mg/kg (personal communication, Robert Hesselberg, U.S. Fish and Wildlife Service, Great Lakes Fishery Laboratory, Ann Arbor, Michigan). All reported values are for concentrations in whole fish, which are probably somewhat higher than concentrations in edible tissue. Clark et al. (1984) reported "apparent toxaphene" residues in coho salmon fillets at below 0.5 mg/kg in Lakes Erie and Superior, and up to nearly 2 mg/kg in Lake Michigan and Lake Huron. "Toxaphene-like" residues have been measured in fillets of lake trout from the mouth of Saginaw Bay in Lake Huron at up to 26 mg/kg (Swain et al. 1986).

The concentration of toxaphene in samples of water collected in 1980 from 5 stations in Lake Huron ranged from 1.2 to 2.1 ng/L and averaged 1.6 ng/L (Swain et al. 1986). Although these are referred to as "toxaphene-like" materials, the analysts feel quite certain that the observed residues were derived from chlorinated camphene (personal communication, Mike Mullin). Swain et al. (1986) also reported "toxaphene-like" residues in Siskiwit Lake on Isle Royale in Lake Superior at 2.2 ng/L. Five composites of lake trout from Siskiwit Lake averaged 4.2 mg/kg and a cross-check of these analyses by the U.S. Fish and Wildlife Service laboratory in Columbia, Missouri measured 3.2 mg/kg. Toxaphene has been measured in the water at several additional sites around Lake Superior since 1982 (personal communication, Steve Eisenrich, University of Minnesota, Minneapolis). Concentrations in water ranged from 1 to 4 ng/L with the higher values being present at the western end of the lake. Measurements of the concentration of toxaphene in water are not known to exist for the other Great Lakes.

Bioconcentration data from laboratory tests with fish indicate that steady-state between concentrations of toxaphene in water and tissue is reached by about 30 days of exposure. Pooling of all fish whole body data in Table 5 provides a geometric mean bioconcentration factor (BCF) of 15,000. Daphnia magna accumulated 4,000 times the water concentration of toxaphene. These values are similar to the bioaccumulation factors (BAFs) observed by Terriere et al. (1966) in several stocked fish species and other aquatic organisms from two Oregon lakes studied over a 3-year period during recovery after a fish eradication treatment. Invertebrate residues ranged between 1,200 and 2 500 times water concentrations, and aquatic plants had BAFs of 500 to 7,000. BAFs for fish ranged from 9,000 to 19,000 for rainbow trout, 4,000 to 8,000 for Atlantic salmon, and averaged 15,000 for brook trout. Residues in caged rainbow trout introduced into one of the lakes indicated that steady-state might have been reached between 38 and 46 days of exposure. The similarity of the laboratory BCFs (direct uptake) and field BAFs -- within a factor of 3 or 4 for fish and invertebrates -- indicates little or no additional contribution from the food chain.

In contrast, factors of 1,250,000 to 25,000,000 would be required to produce residues of 5 to 25 mg/kg in lake trout in the Great Lakes (Rice and Evans 1984; Swain et al. 1986) from toxaphene concentrations of 1 to 4 ng/L in water. Because toxaphene is not known to be used or discharged in substantial quantities near the Great Lakes, and especially near Siskiwit Lake on Isle Royale, it is likely that the toxaphene entered the water from the air and that the high concentrations in fish are not due to localized "hot spots." Possible reasons for the differences between the various data include: a higher percent lipid in lake trout than in other, usually less fatty, fish species; inaccurate measurements of toxaphene; the existence of food-web magnification of residues in Great Lakes fish not evident from other studies (e.g., Oregon lakes); a much longer exposure period in Great Lakes fish: localized concentrations of toxaphene in the Great Lakes that are higher than those that have been measured to date; and differences in the precise composition of the toxaphene being measured. Niimi (1985) discussed the importance of food related bioaccumulation of highly persistent organic chemicals, including toxaphene, and concluded that much higher tissue residues would be expected in adult salmonids in the Great Lakes than in fishes exposed in laboratory tests.

For saltwater organisms, uptake data from tests lasting 28 days or longer are available for the eastern oyster, Crassostrea virginica, and two saltwater fishes, Cyprinodon variegatus and Fundulus similis (Table 5). The bioconcentration factor (BCF) for edible tissue from oysters exposed to 0.7 and 0.8 μg/L for from 84 to 252 days averaged 13,350 (Lowe et al. 1971). After 12 weeks of depuration, no toxaphene could be detected in oyster tissues. BCFs for toxaphene in sheepshead minnows are from an early life-stage and a life-cycle test. A mean BCF of 9,380 was obtained with juvenile fish that survived the early life-stage test (Goodman et al. 1976). In the life-cycle test BCFs averaged 26,550 for first generation and 21,950 for second generation juveniles (Goodman 1986). BCFs in adult females averaged 64,750 and in males 70,140. With longnose killifish, Fundulus similis, BCFs averaged 22,640, 31,550 and 34,440 in 28-day exposures of embryos and fry, fry, and juveniles, respectively.

The BCFs normalized to 1% lipids range from 1,463 to 28,700 (Table 5) and the geometric mean is 6,195. By using the 10 and 11% lipids recommended in the Guidelines for fresh and salt water, respectively, and the FDA action level of 5 mg/kg, the Final Residue Values for toxaphene are 0.07337 μg/L for fresh water and 0.08071 μg/L for salt water. However, these Final Residue Values based on laboratory-derived BCFs will not protect species that accumulate toxaphene like the lake trout does. It is not unusual for lake trout in the Great Lakes to exceed the FDA action level in the whole body, even though the concentration of toxaphene in the water is apparently only 1 to 4 ng/L. Because the percent lipids is so high in the edible portion of lake trout, it is likely that the concentration of toxaphene in the edible portion exceeds the FDA action level whenever the concentration in the whole body exceeds it. Thus the concentration of toxaphene in water apparently should not exceed 1 to 4 ng/L wherever lake trout is a consumed species. Although some of the lake trout that exceeded the FDA action level contained up to 31% lipids, others contained only 10 to 15% lipids (Rice and Evans 1984; Swain et al. 1968), which is in the range of the mean percent lipids reported for freshwater chinook salmon and lake trout, and saltwater Atlantic herring (Sidwell 1981). Therefore, because an average concentration of toxaphene in the Great Lakes of about 2 ng/L causes some lake trout to exceed the FDA action level, there is cause for concern wherever the concentration of toxaphene exceeds 0.0002 μg/L in either fresh or salt water.

Other Data

Other data on the effects of toxaphene are presented in Table 6. Sanders (1980) found that 0.18 μg/L reduced the growth of *Gammarus fasciatus*. The behavior of goldfish was affected by 0.44 μg/L (Warner et al. 1966), and 0.144 μg/L inhibited cytochrome P-450 activity in bluegills (Auwarter 1977).

A biological factor influencing sensitivity to toxaphene is the development of a resistance resulting from exposures killing the more sensitive individuals in field populations. This phenomenon has been demonstrated for several fish and invertebrate species (Table 6) collected in areas of high agricultural use (Albaugh 1972; Burke and Ferguson 1969; Dziuk and Plapp 1973; Ferguson 1968; Ferguson and Bingham 1966; Ferguson et al. 1965a,b; Klassen et al. 1965; Naqvi and Ferguson 1968,1970). Levels of resistance more than two orders of magnitude greater than for individuals from areas uncontaminated with toxaphene have been detected in Mississippi Delta mosquitofish (Ferguson 1968). The degree of resistance appears to correspond to the level of contamination and to be genetically rather than physiologically mediated. Yarbrough and Chambers (1979) concluded that extreme resistance in mosquitofish was due primarily to target site insensitivity, due to a lesser extent to elevated barriers to pesticide penetration, and due very little to increased metabolism of toxaphene.

Schoettger and Olive (1961) found that Daphnia magna exposed to multiple sublethal concentrations of toxaphene could accumulate enough pesticide to be lethal when fed to shiner minnows.

The number and abundance of saltwater arthropods that colonized sand-filled aquaria receiving 11 µg of toxaphene/L for three months were significantly reduced and the abundances of annelids and molluscs were increased (Hansen and Tagatz 1980). No effects on benthic colonization were observed at 0.77 µg/L. The 96-hr EC50s from three oyster-shell deposition tests ranged from 16 to 38 µg/L (Butler 1963; Lowe et al. 1970; Schimmel et al. 1977; U.S. Bureau of Commercial Fisheries 1965). No effects on growth or histopathology were observed in oysters exposed for 9 months to 0.7 µg/L (Lowe et al. 1971). Three species of shrimp were more sensitive to toxaphene. The 48-hr EC50s, based on death plus loss of equilibrium, ranged from 2.7 to 5.2 µg/L (Butler 1963; Lowe et al. 1970; U.S. Bureau of Commercial Fisheries 1965). Histological alterations were observed in 96-hr exposures of blue crab stage II larvae to 0.0072 µg/L, mud crab larvae to 7.16 µg/L, and drift line crab larvae to 0.0215 µg/L. Reproduction of the mysid, Mysidopsis bahia, was reduced 84% following exposure to 0.14 µg/L for 14 days (Nimmo 1977; Nimmo et al. 1981). BCFs after 96-hr exposure averaged 11,000 for eastern oysters, 526.4 for pink shrimp, and 948.6 for grass shrimp (Schimmel et al. 1977).

Concentrations of toxaphene lethal to saltwater fishes decreased as the duration of exposure increased. The 28-day LC50s ranged from 0.9 to 1.4 µg/L for early life stages of the longnose killifish, Fundulus similis (Schimmel et al. 1977). The 48-hr LC50 for this species is 28 µg/L (Lowe et al. 1970). The 48- or 96-hr LC50s range from 1.0 to 3.2 µg/L for the juvenile spot, Leiostomus xanthurus (Butler 1964; Harder et al. 1983; U.S. Bureau of Commercial Fisheries 1965). Exposure of this fish for six days to 0.5 µg/L resulted in 50% mortality; exposure to 0.1 µg/L for five months did not affect growth or survival (Lowe 1964). BCFs after 96-hr exposure averaged 4,284 for sheepshead minnows, 3,850 for pinfish, 2,508 to 3,786 for spot, and 4,807 to 5,020 for white mullet (Harder et al. 1983; Schimmel et al. 1977). BCFs for spot and mullet are from tests with parent and sediment-degraded toxaphene and appear similar.

Blus et al. (1979a,b) reported an apparent linkage between the thickness of shells of eggs of brown pelicans and organochlorine residues in the birds.

Unused Data

Data were not used if the tests were conducted with a species that is not resident in North America. Results (e.g., Nelson and Matsumura 1975a,b) of tests conducted with brine shrimp, Artemia sp., were not used because these species are from a unique saltwater environment. Grahl (1983), Holden

(1981), LeBlanc (1984), Mayer and Mehrle (1978), Pollock and Kilgore (1978), von Rumker (1974), and Whitacre et al. (1972) only contain data that have been published elsewhere.

Schaper and Crowder (1976) used fish from a sewage oxidation pond. Data were not used if the organisms were exposed to toxaphene in food (Haseltine et al. 1980; Loeb and Kelly 1963; Mehrle et al. 1979). Davis et al. (1972), Desaiah and Koch (1977), Hiltibran (1974,1982), Moffett and Yarbrough (1972), and Shea and Berry (1982a,b) only exposed homogenized tissues or cell cultures. Gallagher et al. (1979) studied the fate but not the effects of toxaphene in saline marsh soils.

Results were not used if the test procedures were not adequately described (e.g., Applegate et al. 1957; Boyd 1964; Carter and Graves 1972; Cohen et al. 1960; Davidow and Sabatino 1954; Doudoroff et al. 1953; Lawrence 1950; Mills 1977; Nelson and Matsumura 1975b; Surber 1948) or if toxaphene was a component of a mixture, effluent, or sediment (e.g., Durant and Reimold 1972; Hall et al. 1984; Macek 1975; Rawlings and Samfield 1979; Reimold 1974; Walsh et al. 1982; Weber and Rosenberg 1980). Khattat and Farley (1976) obtained an atypical concentration-effect curve with Acartia tonsa, and Lowe (1964) exposed too few organisms. Some values reported by Courtenay and Roberts (1973) were not used because the test procedures were not adequately described. No value was used for stage I larvae of the drift line crab because two different values were reported and it is not possible to decide which is correct.

Data on the concentrations of toxaphene in wild aquatic organisms were not used to calculate bioaccumulation factors if the concentration of toxaphene in the water was not measured often enough or if the concentration varied too much (e.g., Ballschmiter et al. 1981; Blus et al. 1979a,b; Buhler et al. 1975; Butler 1973; Durant and Reimold 1972; Eisenberg and Topping 1984; Gallagher et al. 1979; Keiser et al. 1973; Klaas and Belisle 1977; Munson 1976; Musial and Uthe 1983; Ohlendorf et al. 1981,1982; Reimold and Durant 1974; Szaro et al. 1979; White et al. 1979,1980; Zell and Ballschmiter 1980). Zaroogian et al. (1985) predicted a BCF for toxaphene based on structure-activity relationships.

Summary

The acute sensitivities of 36 freshwater species in 28 genera ranged from 0.8 µg/L to 500 µg/L. Such important fish species as the channel catfish, largemouth bass, chinook and coho salmon, brook, brown and rainbow trout, striped bass, and bluegill had acute sensitivities ranging from 0.8 µg/L to 10.8 µg/L. Chronic values for four freshwater species range from less than 0.039 µg/L for the brook trout to 0.1964 µg/L for the channel catfish. The growth of algae was affected at 100 to 1,000 µg/L, and bioconcentration factors from laboratory tests ranged from 3,100 to 90,000. Concentrations in lake trout in the Great Lakes have frequently exceeded the U.S. FDA action level of 5 mg/kg, even though the concentrations in the water seem to be only 1 to 4 ng/L. These concentrations in the lake water are thought to have resulted from toxaphene being transported to the Great Lakes from remote sites, the locations of which are not well known.

The acute toxicity of toxaphene to 15 species of saltwater animals ranges from 0.53 for pinfish, *Lagodon rhomoides*, to 460,000 µg/L for the adults of the clam, *Rangia cuneata*. Except for resistant species tested at concentrations greater than toxaphene's water solubility, acute values for most species were within a factor of 10. The toxicity of toxaphene was found to decrease slightly with increasing salinity for adult blue crabs, Callinectes sapidus, whereas no relationship between toxicity and salinity was observed with the threespine stickleback, Gasterosteus aculeatus. Temperature significantly affected the toxicity of toxaphene to blue crabs.

Early life-stage toxicity tests have been conducted with the sheepshead minnow, Cyprinodon variegatus, and the longnose killifish, Fundulus similis, whereas life-cycle tests have been conducted with the sheepshead minnow and a mysid. For the sheepshead minnow, chronic values of 1.658 µg/L from the early life-stage and 0.7141 µg/L from the life-cycle toxicity test are similar to the 96-hr LC50 of 1.1 µg/L. Killifish are more chronically sensitive with effects noted at 0.3 µg/L. In the life-cycle test with the mysid, no adverse effects were observed at the highest concentration tested, which was only slightly below the 96-hr LC50, resulting in an acute-chronic ratio of 1.132.

Toxaphene is bioconcentrated by an oyster, Crassostrea virginica, and two fishes, C. variegatus and F. similis, to concentrations that range from 9,380 to 70,140 times that in the test solution.

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 toxaphene does not exceed 0.0002 µg/L more than once every three years on the average and if the one-hour average concentration does not exceed 0.73 µg/L more than once every three years on the average. If the concentration of toxaphene does exceed 0.0002 µg/L, the edible portions of consumed species should be analyzed to determine whether the concentration of toxaphene exceeds the FDA action level of 5 mg/kg. If the channel catfish is as acutely sensitive as some data indicate it might be, it will not be protected by this criterion.

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 one-hour average concentration of toxaphene does not exceed 0.21 µg/L more than once every three years on the average and if the four-day average concentration of toxaphene does not exceed 0.0002 µg/L more than once every three years on the average. If the concentration of toxaphene does exceed 0.0002 µg/L, the edible portions of consumed species should be analyzed to determine whether the concentration of toxaphene exceeds the FDA action level of 5 mg/kg.

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 Toxaphene to Aquatic Animals

Species	Method*	Test Material**	Temperature (°C)	LC50 or EC50 (µg/L)***	Species Mean Acute Value (µg/L)	Reference
			FRESHWATER SPECIES			
Cladoceran (1st instar), *Daphnia magna*	S,M	T	18	10	-	Sanders 1980
Cladoceran (1st instar), *Daphnia magna*	S,U	T	21	10	-	Johnson and Finley 1980
Cladoceran (≤24 hr), *Daphnia magna*	S,U	-	23	155†	10	Bringmann and Kuhn 1960
Cladoceran (1st instar), *Daphnia pulex*	S,U	-	15	14.2	-	Johnson and Finley 1980
Cladoceran (1st instar), *Daphnia pulex*	S,U	-	15.6	15	14.59	Sanders and Cope 1966
Cladoceran (1st instar), *Simocephalus serrulatus*	S,U	-	15.6	19	-	Sanders and Cope 1966; Johnson and Finley 1980
Cladoceran (1st instar), *Simocephalus serrulatus*	S,U	-	21.1	10	13.78	Sanders and Cope 1966
Amphipod, *Gammarus fasciatus*	S,U	T	21 (soft water)	35	-	Sanders 1972
Amphipod, *Gammarus fasciatus*	S,U	T	21 (hard water)	6	-	Sanders 1972
Amphipod, *Gammarus fasciatus*	S,U	T	21	26	17.61	Johnson and Finley 1980
Amphipod (2 mo. old), *Gammarus lacustris*	S,U	T	21.1	26	26	Sanders 1969
Amphipod (early instar), *Gammarus pseudolimneaus*	S,M	T	18	24	24	Sanders 1980
Prawn (late instar), *Palaemonetes kadiakensis*	S,U	T	21	28	-	Sanders 1972
Prawn (25-31 mm), *Palaemonetes kadiakensis*	-,U	-	-	36	31.75	Chaiyarach et al. 1975

Table 1. (continued)

Species	Method[a]	Test Material[aa]	Temperature (°C)	LC50 or EC50 (µg/L)[aaa]	Species Mean Acute Value (µg/L)	Reference
Crayfish (60-70 mm), Procambarus simulans	-,U	-	-	210	210	Chaiyarach et al. 1975
Stonefly (15-20 mm), Pteronarcella badia	S,U	T	15.5	3.0	3.0	Sanders and Cope 1968
Stonefly (30-55 mm), Pteronarcys californica	S,U	T	15.5	2.3	2.3	Sanders and Cope 1968; Johnson and Finley 1980
Stonefly (20-25 mm), Claassenia sabulosa	S,U	T	15.5	1.3	1.3	Sanders and Cope 1968; Johnson and Finley 1980
Crane fly (larva), Tipula sp.	S,U	T	15	18	18	Johnson and Finley 1980
Midge (4th instar larva), Chironomus plumosus	S,U	T	15	30	-	Johnson and Finley 1980
Midge (4th instar larva), Chironomus plumosus	S,M	T	22	180	73.48	Sanders 1980
Snipe fly (larva), Atherix variegata	S,U	T	15	40	40	Johnson and Finley 1980
Coho salmon (1 g), Oncorhynchus kisutch	S,U	T	12	8	-	Johnson and Finley 1980
Coho salmon (0.6-1.7 g), Oncorhynchus kisutch	S,U	T	13	4.0	-	Macek and McAllister 1970
Coho salmon (57-76 mm; 2.7-4.1 g), Oncorhynchus kisutch	S,U	T	20	9.4	6.700	Katz 1961
Chinook salmon, Oncorhynchus tshawytscha	S,U	T	14.4	1.54	-	Earnest 1970
Chinook salmon (51-114 mm; 1.45-5 g), Oncorhynchus tshawytscha	S,U	T	20	2.5	1.962	Katz 1961
Rainbow trout (1 g), Salmo gairdneri	S,U	-	7.2	5.4	-	Cope 1964
Rainbow trout, Salmo gairdneri	S,U	CS	11.7	8.4	-	Mahdi 1966

Table 1. (continued)

Species	Method*	Test Material**	Temperature (°C)	LC50 or EC50 (µg/L)***	Species Mean Acute Value (µg/L)	Reference
Rainbow trout (1.4 g), *Salmo gairdneri*	S,U	T	12	10.6	-	Johnson and Finley 1980
Rainbow trout (1 g), *Salmo gairdneri*	S,U	-	12.8	2.7	-	Cope 1964
Rainbow trout (21 g), *Salmo gairdneri*	S,U	Floating (10%)	12.8	28††	-	Workman and Neuhold 1963
Rainbow trout (21 g), *Salmo gairdneri*	S, U	Sinking (62.6%)	12.8	23††	5.782	Workman and Neuhold 1963
Rainbow trout (0.6-1.7 g), *Salmo gairdneri*	S,U	T	13	11	-	Macek and McAllister 1970
Rainbow trout (1 g), *Salmo gairdneri*	S,U	-	18.3	1.8	-	Cope 1964
Rainbow trout (Donaldson trout) (51-79 mm; 3.2 g), *Salmo gairdneri*	S,U	T	20	8.4	-	Katz 1961
Brown trout (1.7 g), *Salmo trutta*	S,U	T	12	3.1	3.1	Johnson and Finley 1980
Brook trout (yearling; 133 g; 231 mm), *Salvelinus fontinalis*	F,M	T	10	10.8	10.8	Mayer et al. 1975
Central stoneroller, *Campostoma anomalum*	S,U	CS	11.7	14	-	Mahdi 1966
Central stoneroller, *Campostoma anomalum*	S,U	CS	11.7	7	-	Mahdi 1966
Central stoneroller, *Campostoma anomalum*	S,U	CS	17.2	32	-	Mahdi 1966
Central stoneroller, *Campostoma anomalum*	S,U	CS	22.7	<5	<11.19	Mahdi 1966
Goldfish (4.2 g), *Carassius auratus*	S,U	Floating (10%)	8.3 (pH 8.3, TDS 166)	26	-	Workman and Neuhold 1963

Table 1. (continued)

Species	Method*	Test Material**	Temperature (°C)	LC50 or EC50 (µg/L)***	Species Mean Acute Value (µg/L)	Reference
Goldfish (4.2 g), *Carassius auratus*	S,U	Sinking (62.6%)	8.3 (pH 8.3, TDS 166)	44	-	Workman and Neuhold 1963
Goldfish, *Carassius auratus*	S,U	CS	11.7	94	-	Mahdi 1966
Goldfish, *Carassius auratus*	S,U	CS	17.2	28	-	Mahdi 1966
Goldfish (1 g), *Carassius auratus*	S,U	T	18	14	-	Johnson and Finley 1980
Goldfish (4.2 g), *Carassius auratus*	S,U	Floating (10%)	20 (pH 8.3, TDS 166)	4	-	Workman and Neuhold 1963
Goldfish (4.2 g), *Carassius auratus*	S,U	Sinking (62.6%)	20 (pH 8.3, TDS 166)	9	-	Workman and Neuhold 1963
Goldfish (4.2 g), *Carassius auratus*	S,U	Floating (10%)	20 (pH 7.8, TDS 238)	28	-	Workman and Neuhold 1963
Goldfish (4.2 g), *Carassius auratus*	S,U	Sinking (62.6%)	20 (pH 7.8, TDS 238)	16	-	Workman and Neuhold 1963
Goldfish (4.2 g), *Carassius auratus*	S,U	Floating (10%)	20 (pH 7.0, TDS 46)	7	-	Workman and Neuhold 1963
Goldfish (4.2 g), *Carassius auratus*	S,U	Sinking (62.6%)	20 (pH 7.0, TDS 46)	9	-	Workman and Neuhold 1963
Goldfish, *Carassius auratus*	S,U	CS	22.7	50	-	Mahdi 1966
Goldfish (6 cm), *Carassius auratus*	F,U	-	25	11	-	Warner et al. 1966
Goldfish (1-2 g), *Carassius auratus*	S,U	-	25	5.6	16.71	Henderson et al. 1959
Common carp (0.6 g), *Cyprinus carpio*	S,U	T	18	3.7	3.7	Johnson and Finley 1980

Table 1. (continued)

Species	Method[*]	Test Material[**]	Temperature (°C)	LC50 or EC50 (µg/L)[***]	Species Mean Acute Value (µg/L)	Reference
Golden shiner, *Notemigonus crysoleucas*	S,U	CS	17.2	<5	-	Mahdi 1966
Golden shiner, *Notemigonus crysoleucas*	S,U	CS	22.7	6	<5.477	Mahdi 1966
Bluntnose minnow, *Pimephales notatus*	S,U	CS	11.7	30	-	Mahdi 1966
Bluntnose minnow, *Pimephales notatus*	S,U	CS	17.2	8.8	-	Mahdi 1966
Bluntnose minnow, *Pimephales notatus*	S,U	CS	22.7	6.3	11.85	Mahdi 1966
Fathead minnow (0.6-1.7 g), *Pimephales promelas*	S,U	T	18	14	-	Macek and McAllister 1970
Fathead minnow (0.5-1.5 g), *Pimephales promelas*	S,U	T	20	20	-	Johnson and Julin 1980
Fathead minnow (1.1 g), *Pimephales promelas*	S,U	T	20	18	-	Johnson and Finley 1980
Fathead minnow (0.5-1.5 g), *Pimephales promelas*	F,U	T	20	7	-	Johnson and Julin 1980
Fathead minnow (0.5-1.5 g), *Pimephales promelas*	F,U	T	25	5	-	Johnson and Julin 1980
Fathead minnow (30 day; 0.32 g; 30 mm), *Pimephales promelas*	F,U	T	25	7.2	-	Mayer et al. 1977
Fathead minnow (0.5-1.5 g), *Pimephales promelas*	S,U	T	25	23	-	Johnson and Julin 1980
Fathead minnow (1-2 g), *Pimephales promelas*	S,U	-	25 (hard water)	5.1	-	Henderson et al. 1959
Fathead minnow (1-2 g), *Pimephales promelas*	S,U	-	25 (soft water)	7.5	10.12	Henderson et al. 1959

Table 1. (continued)

Species	Method*	Test Material**	Temperature (°C)	LC50 or EC50 (µg/L)***	Species Mean Acute Value (µg/L)	Reference
Black bullhead, *Ictalurus melas*	S,U	CS	11.7	25††	-	Mahdi 1966
Black bullhead, *Ictalurus melas*	S,U	CS	17.2	2.7	-	Mahdi 1966
Black bullhead (0.6-1.7 g), *Ictalurus melas*	S,U	T	18	5	-	Macek and McAllister 1970
Black bullhead, *Ictalurus melas*	S,U	CS	22.7	1.8	-	Mahdi 1966
Black bullhead (0.9 g), *Ictalurus melas*	S,U	T	24	5.8	3.446	Johnson and Finley 1980
Channel catfish (fingerling; 0.5-1.5 g), *Ictalurus punctatus*	S,U	T	15 (pH 7.4, alk 35, hard 40)	4.7††	-	Johnson and Julin 1980
Channel catfish (1.5 g), *Ictalurus punctatus*	S,U	T	18	13.1††	-	Johnson and Finley 1980
Channel catfish (fingerling; 0.5-1.5 g), *Ictalurus punctatus*	S,U	T	20 (pH 7.4, alk 35, hard 40)	4.2††	-	Johnson and Julin 1980
Channel catfish (fingerling; 0.5-1.5 g), *Ictalurus punctatus*	S,U	T	20 (pH 6.5, alk 35, hard 10)	2.7††	-	Johnson and Julin 1980
Channel catfish (fingerling; 0.5-1.5 g); *Ictalurus punctatus*	S,U	T	20 (pH 7.5, alk 35, hard 40)	3.4††	-	Johnson and Julin 1980
Channel catfish (fingerling; 0.5-1.5 g), *Ictalurus punctatus*	S,U	T	20 (pH 8.3, alk 35, hard 40)	3.0 ††	-	Johnson and Julin 1980
Channel catfish (0.5-1.5 g), *Ictalurus punctatus*	S,U	T	20 (pH 8.2, alk 220, hard 10)	3.9††	-	Johnson and Julin 1980

Table 1. (continued)

Species	Method*	Test Material**	Temperature (°C)	LC50 or EC50 (µg/L)***	Species Mean Acute Value (µg/L)	Reference
Channel catfish (0.5-1.5 g), *Ictalurus punctatus*	S,U	T	20 (pH 8.2, alk 220, hard 40)	3.2††	-	Johnson and Julin 1980
Channel catfish (0.5-1.5 g), *Ictalurus punctatus*	S,U	T	20 (pH 8.2, alk 220, hard 160)	3.9††	-	Johnson and Julin 1980
Channel catfish (0.5-1.5 g), *Ictalurus punctatus*	S,U	T	20 (pH 8.2, alk 220, hard 320)	4.7††	-	Johnson and Julin 1980
Channel catfish (4 g), *Ictalurus punctatus*	F,U	T	20 (pH 7.4, alk 237, hard 272)	5.5††	-	Johnson and Julin 1980
Channel catfish (2.5 yr; 767 g, 394 mm), *Ictalurus punctatus*	F,M	T	20	16.5††	-	Mayer et al. 1977
Channel catfish (yolk sac fry; 1-4 day), *Ictalurus punctatus*	S,U	T	25	8††	-	Johnson and Julin 1980
Channel catfish (swim-up fry; 5-8 days old), *Ictalurus punctatus*	S,U	T	25	0.8	-	Johnson and Julin 1980
Channel catfish (0.15 g), *Ictalurus punctatus*	F,U	T	25 (pH 7.4, alk 237, hard 272)	7.5††	-	Johnson and Julin 1980
Channel catfish (0.5-1.5 g), *Ictalurus punctatus*	S,U	T	25	2.8††	-	Johnson and Julin 1980
Channel catfish (0.5-1.5 g), *Ictalurus punctatus*	S,U	T	25 (pH 7.4, alk 35, hard 40)	3.7††	0.8	Johnson and Julin 1980
Mosquitofish (0.32 g), *Gambusia affinis*	S,U	Floating (10%)	20 (pH 8.3, TDS 166)	24	-	Workman and Neuhold 1963
Mosquitofish (0.32 g), *Gambusia affinis*	S,U	Sinking (62.6%)	20(pH 8.3, TDS 166)	48	-	Workman and Neuhold 1963
Mosquitofish (0.32 g), *Gambusia affinis*	S,U	Floating (10%)	20(pH 7.8, TDS 238)	52	-	Workman and Neuhold 1963
Mosquitofish (0.32 g), *Gambusia affinis*	S,U	Sinking (62.6%)	20 (pH 7.8, TDS 238)	6	-	Workman and Neuhold 1963

Table 1. (continued)

Species	Method*	Test Material**	Temperature (°C)	LC50 or EC50 (µg/L)***	Species Mean Acute Value (µg/L)	Reference
Mosquitofish (0.32 g), *Gambusia affinis*	S,U	Floating (10%)	20 (pH 7.0, TDS 46)	9	-	Workman and Neuhold 1963
Mosquitofish (0.32 g), *Gambusia affinis*	S,U	Sinking (62.6%)	20 (pH 7.0, TDS 46)	9	-	Workman and Neuhold 1963
Mosquitofish (30-40 mm), *Gambusia affinis*	-,U	-	24	8	15.68	Chaiyarach et al. 1975
Guppy (0.1-0.2 g), *Poecilia reticulata*	S,U	-	25	20	20	Henderson et al. 1959
Striped bass (juvenile; 2.3 g), *Morone saxatilis*	F,U	T	17	4.4	-	Korn and Earnest 1974
Striped bass (56 days), *Morone saxatilis*	S,U	T	20	5.4	4.874	Palawski et al. 1985
Green sunfish, *Lepomis cyanellus*	S,U	T	18	13	13	Johnson and Finley 1980
Bluegill (0.6-1.5 g), *Lepomis macrochirus*	S,U	T	12.7	3.2	-	Macek et al. 1969
Bluegill (0.6-1.7 g), *Lepomis macrochirus*	S,U	T	18	18	-	Macek and McAllister 1970
Bluegill (0.6-1.5 g), *Lepomis macrochirus*	S,U	T	18.3	2.6	-	Macek et al. 1969
Bluegill (0.6-1.5 g), *Lepomis macrochirus*	S,U	T	20	2.6	-	Johnson and Julin 1980
Bluegill (0.6-1.5 g), *Lepomis macrochirus*	F,U	T	20	4.7	-	Johnson and Julin 1980
Bluegill (0.6-1.5 g), *Lepomis macrochirus*	S,U	T	23.8	2.4	-	Macek et al. 1969; Johnson and Finley 1980
Bluegill (0.5-1.5 g), *Lepomis macrochirus*	S,U	T	25	2.4	-	Johnson and Julin 1980
Bluegill (0.5-1.5 g), *Lepomis macrochirus*	F,U	T	25	3.4	-	Johnson and Julin 1980

Table 1. (continued)

Species	Method*	Test Material**	Temperature (°C)	LC50 or EC50 (µg/L)***	Species Mean Acute Value (µg/L)	Reference
Bluegill (3.8-6.4 cm, 1.0-2.0 g), *Lepomis macrochirus*	S,U	T	25 (soft water)	3.5	-	Henderson et al. 1960
Bluegill (3.8-6.4 cm, 1.0-2.0 g) *Lepomis macrochirus*	S,U	EC (20%)	25 (hard water)	4.6	-	Henderson et al. 1960
Bluegill (3.8-6.4 cm, 1.0-2.0 g), *Lepomis macrochirus*	S,U	EC (20%)	25 (soft water)	4.4	3.822	Henderson et al. 1960
Redear sunfish (0.6-1.7 g), *Lepomis microlophus*	S,U	T	18	13	13	Macek and McAllister 1970
Largemouth bass (0.9 g), *Micropterus salmoides*	S,U	T	18	2	2	Johnson and Finley 1980
Yellow perch (1.4 g), *Perca flavescens*	S,U	T	18	12	12	Johnson and Finley 1980
Western chorus frog (tadpole, 7 day), *Pseudacris triseriata*	S,U	T	15.5	500	500	Sanders 1970
Fowler's toad (tadpole, 28-35 day), *Bufo fowleri*	S,U	T	15.5	140	140	Sanders 1970

Table 1. (continued)

Species	Method[a]	Test Material[aa]	Salinity (g/kg)	LC50 or EC50 (µg/L)[aaa]	Species Mean Acute Value (µg/L)	Reference
			SALTWATER SPECIES			
Common rangia (adult), *Rangia cuneata*	S, U	-	5	460,000	460,000	Chaiyarach et al. 1975
Quahog clam (embryo), *Mercenaria mercenaria*	R, U	-		1,120	1,120	Davis and Hidu 1969
Mysid (juvenile), *Mysidopsis bahia*	F, M	T	20-26	6.32	-	Nimmo 1977
Mysid (adult), *Mysidopsis bahia*	F, M	T	20-26	3.19	-	Nimmo 1977
Mysid (juvenile), *Mysidopsis bahia*	F, M	T	-	2.67	-	Nimmo et al. 1981
Mysid (juvenile), *Mysidopsis bahia*	F, M	T	30	2.03	3.222	Kuhn and Chammas 1986
Pink shrimp (nauplius), *Penaeus duorarum*	S, U	(71.6%)	-	1.575	-	Courtenay and Roberts 1973
Pink shrimp (protozoea), *Penaeus duorarum*	S, U	(71.6%)	-	1.288	-	Courtenay and Roberts 1973
Pink shrimp (mysis), *Penaeus duorarum*	S, U	(71.6%)	-	1.002	-	Courtenay and Roberts 1973
Pink shrip (adult), *Penaeus duorarum*	F, M	T	23.9	1.4	1.4	Schimmel et al. 1977
Korean shrimp (adult), *Palaemon macrodactylus*	S, U	T	27	20.3	-	Earnest 1970
Korean shrimp (adult), *Palaemon macrodactylus*	F, U	T	26	20.8	20.55	Earnest 1970
Grass shrimp (adult), *Palaemonetes pugio*	F, M	T	21.3	4.4	4.4	Schimmel et al. 1977
Blue crab (adult), *Callinectes sapidus*	S, U	-	8.6 (10°C)	580	-	Mahood et al. 1970; McKenzie 1970

Table 1. (continued)

Species	Method[a]	Test Material[**]	Salinity (g/kg)	LC50 or EC50 (µg/L)[***]	Species Mean Acute Value (µg/L)	Reference
Blue crab (adult), *Callinectes sapidus*	S, U	-	8.6 (15°C)	900	-	Mahood et al. 1970; McKenzie 1970
Blue crab (adult), *Callinectes sapidus*	S, U	-	8.6 (21°C)	370	-	Mahood et al. 1970; McKenzie 1970
Blue crab (adult), *Callinectes sapidus*	S, U	-	19.3 (10°C)	960	-	Mahood et al. 1970; McKenzie 1970
Blue crab (adult), *Callinectes sapidus*	S, U	-	19.3 (15°C)	3,800	-	Mahood et al. 1970; McKenzie 1970
Blue crab (adult), *Callinectes sapidus*	S, U	-	19.3 (21°C)	770	-	Mahood et al. 1970; McKenzie 1970
Blue crab (adult), *Callinectes sapidus*	S, U	-	24.2 (10°C)	1,200	-	Mahood et al. 1970; McKenzie 1970
Blue crab (adult), *Callinectes sapidus*	S, U	-	24.2 (15°C)	2,700	-	Mahood et al. 1970; McKenzie 1970
Blue crab (adult), *Callinectes sapidus*	S, U	-	24.2 (21°C)	1,000	1,065	Mahood et al. 1970; McKenzie 1970
Mud crab (stage I larva), *Rhithropanopeus harrisii*	S, U	(71.6%)	-	31.32	31.32	Courtenay and Roberts 1973
Drift line crab (stage II larva), *Sesarma cinereum*	S, U	(71.6%)	-	0.5442	-	Courtenay and Roberts 1973
Drift line crab (stage III larva), *Sesarma cinereum*	S, U	(71.6%)	-	0.5298	-	Courtenay and Roberts 1973
Drift line crab (stage IV larva), *Sesarma cinereum*	S, U	(71.6%)	-	4.869[††]	-	Courtenay and Roberts 1973
Drift line crab (megalopa), *Sesarma cinereum*	S, U	(71.6%)	-	6.014[††]	0.5370	Courtenay and Roberts 1973

Table 1. (continued)

Species	Method*	Test Material**	Salinity (g/kg)	LC50 or EC50 (µg/L)***	Species Mean Acute Value (µg/L)	Reference
Sheepshead minnow (juvenile), *Cyprinodon variegatus*	F, M	T	23.2	1.1	1.1	Schimmel et al. 1977
Threespine stickleback (adult), *Gasterosteus aculeatus*	S, U	-	5	8.6	-	Katz 1961
Threespine stickleback (adult), *Gasterosteus aculeatus*	S, U	-	25	7.8	8.190	Katz 1961
Striped bass (juvenile), *Morone saxatilis*	F, U	T	30	4.4	-	Korn and Earnest 1974
Striped bass (56 days), *Morone saxatilis*	S, U	T	1	7.6	5.783	Palawski et al. 1985
Pinfish (juvenile), *Lagodon rhomboides*	F, M	T	22.5	0.53	0.53	Schimmel et al. 1977
Spot (juvenile), *Leiostomus xanthurus*	F, M	-	32-35	0.92	0.92	Harder et al. 1983
White mullet (juvenile), *Mugil curema*	F, M	-	32-35	2.88	2.88	Harder et al. 1983

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

** EC = emulsifiable concentrate; CS = commercial stock, probably an emulsifiable concentrate; T = technical grade. Percent purity is given in parentheses when available. By definition, the purity of technical-grade toxaphene is 100%.

*** 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%.

† Value is inordinately different from others for this species and therefore not used in calculation of Species Mean Acute Value.

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

Table 2. Chronic Toxicity of Toxaphene to Aquatic Animals

Species	Test*	Test Material**	Temperature (°C)	Limits (µg/L)***	Chronic Value (µg/L)	Reference
			FRESHWATER SPECIES			
Cladoceran, *Daphnia magna*	LC	T	18	0.07-0.12	0.09165	Sanders 1980
Brook trout, *Salvelinus fontinalis*	LC	T	9	<0.039****	<0.039	Mayer and Mehrle 1978
Fathead minnow, *Pimephales promelas*	LC	T	25	0.025-0.054	0.03674	Mayer et al. 1977
Channel catfish, *Ictalurus punctatus*	LC	T	26	0.129-0.299	0.1964	Mayer et al. 1977
			SALTWATER SPECIES			
Mysid, *Mysidopsis bahia*	LC	T	-	1.585-2.03	1.794	Kuhn and Chammas 1986
Sheepshead minnow, *Cyprinodon variegatus*	ELS	T	12.9† (7-23.5)	1.1-2.5	1.658	Goodman et al. 1976
Sheepshead minnow, *Cyprinodon variegatus*	LC	T	7.5-32†	0.51-1.0	0.7141	Goodman 1986
Longnose killifish, *Fundulus similis*	ELS	T	10.5-30†	<0.3****	<0.3	Schimmel et al. 1977

* LC = life-cycle or partial life-cycle; ELS = early life-stage.

** T = technical grade. Percent purity is given in parentheses when available. By definition, the purity of technical-grade toxaphene is 100%.

*** Results are based on measured concentrations of toxaphene.

**** Unacceptable effects occurred at all concentrations tested.

† Salinity (g/kg), not temperature.

Table 2. (continued)

Acute-Chronic Ratio

Species	Acute Value (µg/L	Chronic Value (µg/L)	Ratio
Cladoceran, *Daphnia magna*	10	0.09165	109.1
Fathead minnow, *Pimephales promelas*	7.2	0.03674	196.0
Channel catfish, *Ictalurus punctatus*	5.5*	0.1964	28.00
Mysid, *Mysidopsis bahia*	2.03	1.794	1.132
Sheepshead minnow, *Cyprinodon variegatus*	1.1	1.658	0.6634
Sheepshead minnow, *Cyprinodon variegatus*	1.1	0.7141	1.540**

* This acute value was measured with juveniles in the same water that was used in the chronic test with this species.

** This value takes precedence for this species because it is based on a life-cycle test, rather than an early life-stage test.

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

Rank[a]	Genus Mean Acute Value (µg/L)	Species	Species Mean Acute Value (µg/L)**	Species Mean Acute-Chronic Ratio***
		FRESHWATER SPECIES		
28	500	Western chorus frog, *Pseudacris triseriata*	500	-
27	210	Crayfish, *Procambarus simulans*	210	-
26	140	Fowler's toad, *Bufo fowleri*	140	-
25	73.48	Midge, *Chironomus simulans*	73.48	-
24	40	Snipefly, *Atherix variegata*	40	-
23	31.75	Prawn, *Palaemonetes kadiakensis*	31.75	-
22	21.40	Amphipod, *Gammarus fasciatus*	17.61	-
		Amphipod, *Gammarus lacustris*	26	-
		Amphipod, *Gammarus pseudolimnaeus*	24	-
21	20	Guppy, *Poecilia reticulata*	20	-
20	18	Crane fly, *Tipula* sp.	18	-
19	16.71	Goldfish, *Carassius auratus*	16.71	-
18	15.68	Mosquitofish, *Gambusia affinis*	15.68	-

Table 3. (continued)

Rank[a]	Genus Mean Acute Value (µg/L)	Species	Species Mean Acute Value (µg/L)[**]	Species Mean Acute-Chronic Ratio[***]
17	13.78	Cladoceran, *Simocephalus serrulatus*	13.78	-
16	12.08	Cladoceran, *Daphnia magna*	10	109.1
		Cladoceran, *Daphnia pulex*	14.59	-
15	12	Yellow perch, *Perca flavescens*	12	-
14	<11.19	Central stoneroller, *Campostoma anomalum*	<11.19	-
13	10.95	Bluntnose minnow, *Pimephales notatus*	11.85	-
		Fathead minnow, *Pimephales promelas*	10.12	196.0
12	10.8	Brook trout, *Salvelinus fontinalis*	10.8	-
11	8.644	Green sunfish, *Lepomis cyanellus*	13	-
		Bluegill, *Lepomis macrochirus*	3.822	-
		Redear sunfish, *Lepomis microlophus*	13	-
10	<5.477	Golden shiner, *Notemigonus crysoleucas*	<5.477	-
9	4.874	Striped bass, *Morone saxatilis*	4.874	-

Table 3. (continued)

Rank*	Genus Mean Acute Value (µg/L)	Species	Species Mean Acute Value (µg/L)**	Species Mean Acute-Chronic Ratio***
8	4.234	Rainbow trout, *Salmo gairdneri*	5.782	-
		Brown trout, *Salmo trutta*	3.1	-
7	3.7	Common carp, *Cyprinus carpio*	3.7	-
6	3.626	Coho salmon, *Oncorhynchus kisutch*	6.7	-
		Chinook salmon, *Oncorhynchus tshawytscha*	1.962	-
5	3.0	Stonefly, *Pteronarcella badia*	3.0	-
4	2.3	Stonefly, *Pteronarcys californica*	2.3	-
3	2	Largemouth bass, *Micropterus salmoides*	2	-
2	1.660	Black bullhead, *Ictalurus melas*	3.446	-
		Channel catfish, *Ictalurus punctatus*	0.8	28.00
1	1.3	Stonefly, *Claassenia sabulosa*	1.3	-
		SALTWATER SPECIES		
15	460,000	Common rangia, *Rangia cuneata*	460,000	-
14	1,120	Quahog clam, *Mercenaria mercenaria*	1,120	-

Table 3. (continued)

Rank[a]	Genus Mean Acute Value (µg/L)	Species	Species Mean Acute Value (µg/L)[aa]	Species Mean Acute-Chronic Ratio[aaa]
13	1,065	Blue crab, *Callinectes sapidus*	1,065	-
12	31.32	Mud crab, *Rhithropanopeus harrisii*	31.32	-
11	20.55	Korean shrimp, *Palaemon macrodactylus*	20.55	-
10	8.190	Threespine stickleback, *Gasterosteus aculeatus*	8.190	-
9	5.783	Striped bass, *Morone saxatilis*	5.783	-
8	4.4	Grass shrimp, *Palaemonetes pugio*	4.4	-
7	3.222	Mysid, *Mysidopsis bahia*	3.222	1.132
6	2.88	White mullet, *Mugil curema*	2.88	-
5	1.4	Pink shrimp, *Penaeus duorarum*	1.4	-
4	1.1	Sheepshead minnow, *Cyprinodon variegatus*	1.1	1.540
3	0.92	Spot, *Leiostomus xanthurus*	0.92	-

Table 3. (continued)

Rank*	Genus Mean Acute Value (µg/L)	Species	Species Mean Acute Value (µg/L)**	Species Mean Acute-Chronic Ratio***
2	0.5370	Drift line crab, *Sesarma cinereum*	0.5370	-
1	0.53	Pinfish, *Lagodon rhomboides*	0.53	-

* Ranked from most resistant to most sensitive based on Genus Mean Acute Value. Inclusion of "less 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.

Fresh water

Final Acute Value = 1.467 µg/L

Criterion Maximum Concentration = (1.467 µg/L) / 2 = 0.7335 µg/L

Final Chronic Value = <0.039 µg/L (to protect brook trout; see text)

Salt water

Final Acute Value = 0.4197 µg/L

Criterion Maximum Concentration = (0.4197 µg/L) / 2 = 0.2098 µg/L

Final Acute-Chronic Ratio = 2 (see text)

Final Chronic Value = (0.4197 µg/L) / 2 = 0.2098

Table 4. Toxicity of Toxaphene to Aquatic Plants

Species	Test Material*	Temperature (°C)	Duration (days)	Effect	Concentration (µg/L)**	Reference
			FRESHWATER SPECIES			
Green alga, *Scenedesmus quadricauda*	-	21	10	Significant decrease in cell numbers	100-1,000	Stadnyk et al. 1971
Green alga, *Selenastrum capricornutum*	T	24	4	EC50 (reduced growth)	380	Call et al. 1983

* T = technical grade. Percent purity is given in parentheses when available. By definition, the purity of technical-grade toxaphene is 100%.

** 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 Toxaphene by Aquatic Organisms

Species	Test Material*	Concentration in Water (µg/L)**	Duration (days)	Tissue	Percent Lipids	BCF or BAF***	Normalized BCF or BAF†	Reference
			FRESHWATER SPECIES					
Cladoceran, *Daphnia magna*	T	0.06-0.12	7	Whole body	-	4,000	-	Sanders 1980
Brook trout, *Salvelinus fontinalis*	T	0.039-0.139	60	Whole body	-	12,000	-	Mayer et al. 1975
Brook trout, *Salvelinus fontinalis*	T	0.068-0.502	60	Whole body	-	4,200	-	Mayer et al. 1975
Brook trout, *Salvelinus fontinalis*	T	0.039-0.139	90	Whole body	-	18,000	-	Mayer et al. 1975
Brook trout, *Salvelinus fontinalis*	T	0.039-0.502	140	Whole body	-	9,400	-	Mayer et al. 1975
Brook trout, *Salvelinus fontinalis*	T	0.039-0.502	161	Whole body	-	6,400	-	Mayer et al. 1975
Brook trout, *Salvelinus fontinalis*	T	0.068-0.502	161	Fillet	-	3,100	-	Mayer et al. 1975
Fathead minnow, *Pimephales promelas*	T	0.013-0.173	30	Whole body	5.2	16,000	3,077	Mayer et al. 1977
Fathead minnow, *Pimephales promelas*	T	0.013-0.173	30	Whole body	5.7	22,000	3,860	Mayer et al. 1977
Fathead minnow, *Pimephales promelas*	T	0.013-0.173	98	Whole body	9.3	51,000	5,484	Mayer et al. 1977
Fathead minnow, *Pimephales promelas*	T	0.055-0.621	150	Whole body	-	90,000	-	Mehrle and Mayer 1975
Fathead minnow, *Pimephales promelas*	T	0.013-0.173	295	Whole body	2.7	7,900	2,926	Mayer et al. 1977
Channel catfish, *Ictalurus punctatus*	T	0.049-0.630	30	Whole body	1.8	11,000	6,111	Mayer et al. 1977
Channel catfish, *Ictalurus punctatus*	T	0.049-0.630	30	Whole body	8.8	13,000	1,477	Mayer et al. 1977

Table 5. (continued)

Species	Test Material*	Concentration in Water (µg/L)**	Duration (days)	Tissue	Percent Lipids	BCF or BAF***	Normalized BCF or BAF†	Reference
Channel catfish, *Ictalurus punctatus*	T	0.049-0.630	50	Whole body	8.2	12,000	1,463	Mayer et al. 1977
Channel catfish, *Ictalurus punctatus*	T	0.049-0.630	60	Whole body	2.7	24,000	8,889	Mayer et al. 1977
Channel catfish, *Ictalurus punctatus*	T	0.049-0.630	75	Whole body	7.1	18,000	2,535	Mayer et al. 1977
Channel catfish, *Ictalurus punctatus*	T	0.049-0.630	90	Whole body	4.7	39,000	8,298	Mayer et al. 1977
Channel catfish, *Ictalurus punctatus*	T	0.049-0.630	100	Whole body	7.6	22,000	2,895	Mayer et al. 1977
			SALTWATER SPECIES					
Eastern oyster (juvenile to adult), *Crassostrea virginica*	T	0.7-0.8	84, 168, 252	Edible tissue	-	13,350 (2)	-	Lowe et al. 1971
Sheepshead minnow (juvenile), *Cyprinodon variegatus*	T	0.20-2.5	28	Whole body	3.2††	9,380 (5)	2,931	Goodman et al. 1976
Sheepshead minnow (juvenile, first generation), *Cyprinodon variegatus*	T	0.28-0.51	35	Whole body	3.2††	26,550 (2)	8,297	Goodman et al. 1976
Sheepshead minnow (juvenile, second generation), *Cyprinodon variegatus*	T	0.28-1.0	35	Whole body	3.2††	21,950 (6)	6,859	Goodman 1986
Sheepshead minnow (adult female), *Cyprinodon variegatus*	T	0.28-1.0	155, 183	Whole body	4.1†††	64,750 (6)	15,790	Goodman 1986
Sheepshead minnow (adult male), *Cyprinodon variegatus*	T	0.28-1.0	155, 183	Whole body	3.2†††	70,140 (6)	21,920	Goodman 1986

Table 5. (continued)

Species	Test Material[a]	Concentration in Water (µg/L)[aa]	Duration (days)	Tissue	Percent Lipids	BCF or BAF[aaa]	Normalized BCF or BAF[†]	Reference
Longnose killifish (embryo, fry), *Fundulus similis*	T	0.3-1.3	28	Whole body	1.2[†††]	22,640 (3)	18,870	Schimmel et al. 1977
Longnose killifish (fry), *Fundulus similis*	T	0.3-1.4	28	Whole body	1.2[†††]	31,550 (3)	26,290	Schimmel et al. 1977
Longnose killifish (juvenile), *Fundulus similis*	T	0.3-1.7	28	Whole body	1.2[†††]	34,440 (4)	26,290	Schimmel et al. 1977
Longnose killifish (ovum), *Fundulus similis*	T	0.2-0.9	32	Ova	-	3,408 (3)	-	Schimmel et al. 1977

a T = technical grade. Percent purity is given in parentheses when available. By definition, the purity of technical-grade toxaphene is 100%.

aa Measured concentration of toxaphene.

aaa Bioconcentration factors (BCFs) and bioaccumulation factors (BAFs) are based on measured concentrations of toxaphene in water and tissue. Number of exposure concentrations from which the geometric mean factor was calculated is given in parentheses when it is greater than 1.

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

†† From Moore (1981).

††† From Hansen (1980).

Maximum Permissible Tissue Concentration

Consumer	Action Level or Effect	Concentration (mg/kg)	Reference
Man	Action level for edible fish or shellfish	5	U.S. FDA 1985

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

Species	Test Material[a]	Temperature (°C)	Duration	Effect	Concentration (µg/L)[aa]	Reference
			FRESHWATER SPECIES			
Cladoceran, *Daphnia magna*	EC	12.7	24 hr	LC50	1,500	Hooper and Grzenda 1955
Cladoceran (1st instar, <24 hr), *Daphnia magna*	-	19	26 hr	LC50	94	Frear and Boyd 1967
Cladoceran, *Daphnia magna*	R	21.1	26 hr	EC50 (immobilization)	260	Crosby et al. 1966
Cladoceran, *Daphnia magna*	R	25	26 hr	EC50 (immobilization)	1,900	Crosby et al. 1966
Isopod, *Asellus intermedius*	EC	12.7	24 hr	LC50	100	Hooper and Grzenda 1955
Amphipod, *Gammarus fasciatus*	EC	12.7	24 hr	LC50	60	Hooper and Grzenda 1955
Amphipod (15-20 mm), *Gammarus fasciatus*	T	-	7.67 hr	LT50	50	McDonald 1962
Amphipod (5-10 day old), *Gammarus fasciatus*	T	18	30 day	Reduced growth	0.18	Sanders 1980
Prawn, *Palaemonetes kadiakensis*	T	24	24 hr	LC50 (Site 1)	44	Naqvi and Ferguson 1970
Prawn, *Palaemonetes kadiakensis*	T	24	24 hr	LC50 (Site 2)	229	Naqvi and Ferguson 1970
Prawn, *Palaemonetes kadiakensis*	T	24	24 hr	LC50 (Site 3)	20.9	Naqvi and Ferguson 1970
Prawn, *Palaemonetes kadiakensis*	T	24	24 hr	LC50 (Site 4)	80.9	Naqvi and Ferguson 1970
Prawn, *Palaemonetes kadiakensis*	T	20	36 hr	LC50 (Site 1)	170	Ferguson et al. 1965a
Prawn, *Palaemonetes kadiakensis*	T	20	36 hr	LC50 (Site 2)	57.5	Ferguson et al. 1965a

Table 6. (continued)

Species	Test Material[a]	Temperature (°C)	Duration	Effect	Concentration (µg/L)[aa]	Reference
Goldfish (6 cm), *Carassius auratus*	-	25	96 hr	Affected behavior	0.44	Warner et al. 1966
Golden shiner, *Notemigonus crysoleucas*	CS	11.7	24 hr	LC50	12.5	Mahdi 1966
Golden shiner, *Notemigonus crysoleucas*	T	20	36 hr	LC50 (Site 1)	30	Ferguson et al. 1964
Golden shiner, *Notemigonus crysoleucas*	T	20	36 hr	LC50 (Site 2)	1200	Ferguson et al. 1964
Golden shiner, *Notemigonus crysoleucas*	CS	17.2	72 hr	LC50	6.2	Mahdi 1966
Fathead minnow, *Pimephales promelas*	EC	10	24 hr	LC50	36	Hooper and Grzenda 1955
Fathead minnow, *Pimephales promelas*	EC	23.8	24 hr	LC50	5.7	Hooper and Grzenda 1955
Fathead minnow (3-3.5 cm), *Pimephales promelas*	-	-	48 hr	LC50	77.55	Chandurkar et al. 1978
Fathead minnow (30 day; 0.32 g; 30 mm), *Pimephales promelas*	T	25	10 day	LC50	4.8	Mayer et al. 1977
Fathead minnow (0.5-1.5 g), *Pimephales promelas*	T	25	16 day	LC50	1.5	Johnson and Julin 1980
Fathead minnow (10 day old), *Pimephales promelas*	T	25	150 day	Impaired bone quality	0.054	Mehrle and Mayer 1975b
Fathead minnow (0.5-1.5 g), *Pimephales promelas*	T	20	24 day	LC50	2.6	Johnson and Julin 1980
Black bullhead (fingerling), *Ictalurus melas*	T	20	36 hr	LC50 (Site 1)	12.5	Ferguson et al. 1965b
Black bullhead (fingerling), *Ictalurus melas*	T	20	36 hr	LC50 (Site 2)	50	Ferguson et al. 1965b

Table 6. (continued)

Species	Test Material[a]	Temperature (°C)	Duration	Effect	Concentration (µg/L)[aa]	Reference
Black bullhead (fingerling), *Ictalurus melas*	T	20	36 hr	LC50 (Site 3)	3.75	Ferguson et al. 1965b
Black bullhead (fingerling), *Ictalurus melas*	T	20	36 hr	LC50 (Site 4)	22.5	Ferguson et al. 1965b
Channel catfish (fingerling, 0.5-1.5 g), *Ictalurus punctatus*	T	15	24 hr	LC50	12.5	Johnson and Julin 1980
Channel catfish (0.15 g), *Ictalurus punctatus*	T	25	12 day	LC50	3.7	Johnson and Julin 1980
Channel catfish (4 g), *Ictalurus punctatus*	T	20	29 day	LC50	1.9	Johnson and Julin 1980
Channel catfish (2.5 yr; 767 g, 394 mm), *Ictalurus punctatus*	T	20	9 day	LC50	15	Mayer et al. 1977
Channel catfish, *Ictalurus punctatus*	T	20	90 day	Impaired bone quality	0.072	Mayer et al. 1977
Mosquitofish, *Gambusia affinis*	-	20	36 hr	LC50 (Site 1)	10	Ferguson et al. 1965b
Mosquitofish, *Gambusia affinis*	-	20	36 hr	LC50 (Site 2)	30	Ferguson et al. 1965b
Mosquitofish, *Gambusia affinis*	-	20	36 hr	LC50 (Site 3)	25	Ferugson et al. 1965b
Mosquitofish, *Gambusia affinis*	-	20	36 hr	LC50 (Site 4)	<10	Ferguson et al. 1965b
Mosquitofish, *Gambusia affinis*	-	20	36 hr	LC50 (Site 5)	20	Ferugson et al. 1965b
Mosquitofish, *Gambusia affinis*	-	20	36 hr	LC50 (Site 6)	15	Ferguson et al. 1965b
Mosquitofish, *Gambusia affinis*	-	20	36 hr	LC50 (Site 7)	>200	Ferguson et al. 1965b

Table 6. (continued)

Species	Test Material[a]	Temperature (°C)	Duration	Effect	Concentration (µg/L)[aa]	Reference
Mosquitofish (adult), *Gambusia affinis*	T	21.1	36 hr	LC50 (Site 1)	10	Boyd and Ferguson 1964
Mosquitofish (adult), *Gambusia affinis*	T	21.1	36 hr	LC50 (Site 2)	160	Boyd and Ferguson 1964
Mosquitofish (adult), *Gambusia affinis*	T	21.1	36 hr	LC50 (Site 3)	60	Boyd and Ferguson 1964
Mosquitofish (adult), *Gambusia affinis*	T	21.1	36 hr	LC50 (Site 4)	480	Boyd and Ferguson 1964
Mosquitofish, *Gambusia affinis*	-	-	48 hr	LC50 (Site 1)	31	Dziuk and Plapp 1973
Mosquitofish, *Gambusia affinis*	-	-	48 hr	LC50 (Site 2)	212	Dziuk and Plapp 1973
Mosquitofish, *Gambusia affinis*	-	-	48 hr	LC50 (Site 3)	301	Dziuk and Plapp 1973
Mosquitofish, *Gambusia affinis*	T	-	15 min	Avoidance	250	Kynard 1974
Bluegill, *Lepomis macrochirus*	T	20.5	72 hr	LC50	1.5	Auwarter 1977
Bluegill (6-10 cm), *Lepomis macrochirus*	T	19.2-20.5	21 and 42 day	Reduced cytochrome P-450 activity levels	0.144	Auwarter 1977
Bluegill (0.5-1.5 g), *Lepomis macrochirus*	T	20	34 day	LC50	0.7	Johnson and Julin 1980
Bullfrog (larva), *Rana catesbeiana*	T	-	96 hr	LC50 (after 8 days)	99	Hall and Swineford 1981
Leopard frog (embryo), *Rana sphenocephala*	T	20	96 hr	LC50 (after 24 days)	46	Hall and Swineford 1980
Leopard frog (young larva), *Rana sphenocephala*	T	20	96 hr	LC50 (after 30 days)	32	Hall and Swineford 1980

Table 6. (continued)

Species	Test Material*	Temperature (°C)	Duration	Effect	Concentration (µg/L)**	Reference
Leopard frog (sub-adult), *Rana sphenocephala*	T	20	96 hr	LC50 (after 8 days)	378	Hall and Swineford 1980
Wood frog (larva), *Rana sylvatica*	T	-	96 hr	LC50 (after 8 days)	195	Hall and Swineford 1980
American toad (larva), *Bufo americanus*	T	-	96 hr	LC50 (after 8 days)	34	Hall and Swineford 1981
Northern cricket frog, (larva), *Acris crepitans*	T	-	96 hr	LC50 (after 8 days)	76	Hall and Swineford 1981
Spotted salamander (larva), *Ambystoma maculatum*	T	-	96 hr	LC50 (after 8 days)	34	Hall and Swineford 1981
Marbled salamander (larva), *Ambystoma opacum*	T	-	96 hr	LC50 (after 8 days)	342	Hall and Swineford 1981
			SALTWATER SPECIES			
Natural phytoplankton communities	-	-	4 hr	90.8% decrease in ^{14}C	1,000	Butler 1963
Green alga, *Protococcus* sp.	EC (60%)	-	10 days	23% reduction in growth	40	Ukeles 1962
Green alga, *Dunaliella euchlora*	EC (60%)	-	10 days	45% reduction in growth	40	Ukeles 1962
Green alga, *Chlorella* sp.	EC (60%)	-	10 days	30% reduction in growth	10-40	Ukeles 1962
Golden-brown alga, *Monocrysis lutheri*	EC (60%)	-	10 days	22% reduction in growth	0.015	Ukeles 1962
Diatom, *Phaeodactylum tricornutum*	EC (60%)	-	10 days	46% reduction in growth	10	Ukeles 1962
Protozoan, *Euplotes* sp.	-	-	24 hr	EC50 (reduced growth)	1,250***	Weber et al. 1982

Table 6. (continued)

Species	Test Material[a]	Temperature (°C)	Duration	Effect	Concentration (µg/L)[aa]	Reference
Benthic macrofauna	-	-	3 mo	Significant reduction in abundance and number of species of arthropods; significant increase in abundance of annelids and molluscs	11	Hansen and Tagatz 1980
Benthic macrofauna	-	-	3 mo	No significant effects on faunal numbers or diversity	0.77	Hansen and Tagatz 1980
Eastern oyster (juvenile), *Crassostrea virginica*	T	-	96 hr	EC50 (shell deposition)	34	Butler 1963; U.S. Bureau of Commercial Fisheries 1965
Eastern oyster (juvenile), *Crassostrea virginica*	T	-	96 hr	EC50 (shell deposition)	38	Butler 1963; Lowe et al. 1970; U.S. Bureau of Commercial Fisheries 1965
Eastern oyster (juvenile), *Crassostrea virginica*	T	-	96 hr	EC50 (shell deposition)	16	Schimmel et al. 1977
Eastern oyster (juvenile), *Crassostrea virginica*	T	-	9 mo	No significant effect on growth or histology	0.7	Lowe et al. 1971
Eastern oyster (juvenile), *Crassostrea virginica*	T	-	96 hr	BCF = 11,000 (4)[†]	-	Schimmel et al. 1977
Quahog clam (larva), *Mercenaria mercenaria*	-	-	12 days	LC50	<250	Davis and Hidu 1969

Table 6. (continued)

Species	Test Material*	Temperature (°C)	Duration	Effect	Concentration (µg/L)**	Reference
Mysid, *Mysidopsis bahia*	T	-	14 days	84% decrease in number of young produced	0.14	Nimmo et al. 1981; Nimmo 1977
Brown shrimp (juvenile), *Penaeus aztecus*	T	-	28 hr	EC50 (mortality and loss of equilibrium)	2.7	U.S. Bureau of Commercial Fisheries 1965; Lowe et al. 1970; Butler 1963
Pink shrimp (juvenile), *Penaeus duorarum*	T	-	48 hr	EC50 (mortality and loss of equilibrium)	4.2	U.S. Bureau of Commercial Fisheries 1967; Lowe et al. 1970
Pink shrimp (adult), *Penaeus duorarum*	T	-	96 hr	BCF = 526.4 (4)†	-	Schimmel et al. 1977
Grass shrimp (juvenile), *Palaemonetes pugio*	T	-	48 hr	EC50 (mortality and loss of equilibrium)	5.2	U.S. Bureau of Commercial Fisheries 1967
Grass shrimp (adult), *Palaemonetes pugio*	T	-	96 hr	BCF = 948.6 (5)†	-	Schimmel et al. 1977
Crab (juvenile), *Callinectes ornatus*	T	-	48 hr	EC50 (mortality and loss of equilibrium)	180	U.S. Bureau of Commercial Fisheries 1965; Butler 1963
Blue crab (stage I larva), *Callinectes sapidus*	71.6%	-	96 hr	Histological changes	0.0072††	Courtenay and Roberts 1973
Blue crab (stage II larva), *Callinectes sapidus*	71.6%	-	96 hr	No histological changes	0.0004††	Courtenay and Roberts 1973
Mud crab (larva), *Rhithropanopeus harrisii*	71.6%	-	96 hr	Histological changes	7.160-143.2††	Courtenay and Roberts 1973
Drift line crab (larva), *Sesarma cinereum*	71.6%	-	96 hr	Histological changes	0.0215-0.0286	Courtenay and Roberts 1973
Sand dollar (embryo), *Echinarachnius parma*	-	-	3 days	Arrested development (at prism stage)	10,000	Crawford and Guarina 1976

Table 6. (continued)

Species	Test Material[a]	Temperature (°C)	Duration	Effect	Concentration (µg/L)[aa]	Reference
Sheepshead minnow (juvenile), *Cyprinodon variegatus*	T	-	96 hr	BCF = 4,284 (4)†	-	Schimmel et al. 1977
Longnose killifish, *Fundulus similis*	T	-	24 hr	LC50	28	U.S. Bureau of Commercial Fisheries 1965
Longnose killifish (juvenile), *Fundulus similis*	-	-	48 hr	LC50	28	Lowe et al. 1970
Longnose killifish (fry), *Fundulus similis*	T	-	28 days	LC50	1.3	Schimmel et al. 1977
Longnose killifish (juvenile), *Fundulus similis*	T	-	28 days	LC50	0.9	Schimmel et al. 1977
Longnose killifish (gamete), *Fundulus similis*	T	-	2 hr	No effect on fertilization	0.32-10.0	Schimmel et al. 1977
Longnose killifish (adult), *Fundulus similis*	T	-	14 days	BCF = 5,329 (3)†	-	Schimmel et al. 1977
Pinfish (juvenile), *Lagodon rhomboides*	T	-	96 hr	BCF = 3,850 (2)†	-	Schimmel et al. 1977
Spot (juvenile), *Leiostomus xanthurus*	-	-	48 hr	LC50	1.0	Butler 1964
Spot (juvenile), *Leiostomus xanthurus*	T	-	144 hr	50% mortality	0.5	Lowe 1964
Spot (juvenile), *Leiostomus xanthurus*	T	-	5 mo	No effect on growth or survival	0.01-0.1	Lowe 1964
Spot (juvenile), *Leiostomus xanthurus*	T	-	48 hr	LC50	3.2	U.S. Bureau of Commercial Fisheries 1965
Spot (juvenile), *Leiostomus xanthurus*	"Parent toxaphene"	-	96 hr	BCF = 2,508 (3)†	-	Harder et al. 1983

Table 6. (continued)

Species	Test Material*	Temperature (°C)	Duration	Effect	Concentration (µg/L)**	Reference
Spot (juvenile), *Leiostomus xanthurus*	"Sediment-degraded toxaphene"	-	96 hr	BCF = 3,786 (3)†	-	Harder et al. 1983
Spot (juvenile), *Leiostomus xanthurus*	"Sediment-degraded toxaphene"	-	96 hr	LC50	1.10	Harder et al. 1983
Striped mullet (juvenile), *Mugil cephalus*	T	-	48 hr	LC50	3.2	Butler 1963; U.S. Bureau of Commercial Fisheries 1965
White mullet (juvenile), *Mugil curema*	"Parent toxaphene"	-	96 hr	BCF = 4,807 (4)†	-	Harder et al. 1983
White mullet (juvenile), *Mugil curema*	"Sediment-degraded toxaphene"	-	96 hr	BCF = 5,020 (2)†	-	Harder et al. 1983
White mullet (juvenile), *Mugil curema*	"Sediment-degraded toxaphene"	-	96 hr	LC50	1.02	Harder et al. 1983

* T = technical grade; EC = emulsifiable concentrate; R = refined commercial grade; WP = wettable powder; CS = commercial stock, probably an emulsifiable concentrate. Percent purity is given in parentheses when available. By definition, the purity of technical-grade toxaphene is 100%.

** 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 tan 97%.

*** Value was obtained graphically.

† Number of exposure concentrations from which the geometric mean factor was calculated.

†† Concentration adjusted to µg toxaphene/L.

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