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Ambient Water Quality Criteria for

Pentachlorophenol - 1986

AMBIENT AQUATIC LIFE WATER QUALITY CRITERIA FOR

PENTACHLOROPHENOL

U.S. ENVIRONMENTAL PROTECTION AGENCY
OFFICE OF RESEARCH AND DEVELOPMENT
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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*

Pentachlorophenol (PCP) and its sodium salt, sodium pentachlorophenate (NaPCP), are collectively the second most heavily used pesticide in the United States (Cirelli 1978). The principal uses of PCP and NaPCP are in the treatment of various wood products and as a wide-spectrum fungicide and bactericide. PCP** has been found in fresh and salt water at ng/L to mg/L concentrations (Buhler et al. 1973; Fountaine et al. 1976, Fox and Joshi 1984; Murray et al. 1981; Pierce 1978; Pierce et al. 1977; Renberg et al. 1983) with higher concentrations associated with point discharges. PCP has also been found in tissues of fish (De Vault 1985; Kuehl et al. 1980; Paasivirta et al. 1980,1983; Pierce 1978; Pierce et al. 1977; Veith et al. 1981; Zitko et al. 1974), in plankton, invertebrates, and sediment (DeLaune et al. 1983; Murray et al. 1980, Paasivirta et al. 1980; Pierce 1978; Pierce et al. 1977; Ray et al. 1983), and in humans (Bevenue et al. 1967; Dougherty 1978; Dougherty et al. 1980; Kuehl et al. 1980).

Several impurities are present in commercial-grade PCP, including lower chlorinated phenols (e.g., tetrachlorophenols) and chlorinated dibenzodioxins, dibenzofurans, diphenylethers, and 2-phenoxyphenols (Ahlborg and Thunberg 1980; Nilsson et al. 1978). The highly toxic 2,3,7,8-tetrachlorodibenzo-p-dioxin has not been found in PCP or NaPCP, and due to the methods of synthesis, is not expected to occur (Ahlborg

* 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.

** "PCP" is often used in the text to refer to the total amount of un-ionized pentachlorophenol and the pentachlorophenate ion that occurs in water regardless of whether PCP or NaPCP was initially added to water.

and Thunberg 1980). Cleveland et al. (1982) reported that a composite of three commercial PCP formulations contained much higher concentrations of hepta-, octa- and nonachlorophenoxyphenols, heptachlorodibenzodioxin, octachlorodibenzodioxin, and octachlorodibenzofuran, and was more toxic to fish, than either purified PCP (99% PCP) or Dowicide EC-7 (91% PCP). Dowicide EC-7 contained less of the hepta-, octa- and nonachlorophenoxyphenols than purified PCP, and was less toxic than purified PCP. Although the toxicities of the individual impurities are unknown and their concentrations apparently vary from batch to batch of PCP, Dowicide EC-7 seems to be an acceptable source of PCP for toxicity and bioconcentration tests. A more recent study has shown that ultrapure PCP is considerably less toxic than a mixture of the major impurities in commercial PCP, consisting mainly of octa- and nonachlorophenoxyphenols (Hamilton et al. 1986). Data concerning PCP should be reassessed as more information becomes available regarding the toxicities of various grades of PCP and their impurities to various species and the composition of the PCP that is produced, used, and discharged.

The toxicity of PCP to animals is due to the uncoupling of oxidative phosphorylation in the mitochondria (Ishak et al. 1970; Weinbach 1954,1956) and resultant reduced production of ATP. This is accompanied by an acceleration of metabolic rate and the utilization of tissue energy reserves, causing loss of weight (Cantelmo et al. 1978; Holmberg et al. 1972; Rao et al. 1979). Activities of various enzymes are also affected by PCP (Bostrom and Johansson 1972; Holmberg et al. 1972; Rao et al. 1979).

PCP is a weak acid with a pKa of about 10^{-5} (Blackman et al. 1955; Callahan et al. 1979; Cessna and Grover 1978; Mrak 1974). Consequently, its toxicity and potential for uptake by organisms are pH-dependent (Crandall and Goodnight 1959; Kobayashi and Kishino 1980; Saarikoski and

Viluksela 1981; Spehar et al. 1985). Both bioconcentration and toxicity increase as pH decreases, due to the greater penetration of cell membranes by un-ionized PCP molecules than by the pentachlorophenate ion. Transfer of PCP from water to fish is considered to be mainly by passive diffusion of the un-ionized form across the gill membrane (Kishino and Kobayashi 1980).

Unless otherwise noted, all concentrations reported herein are expressed as pentachlorophenol, not as the material tested. The criteria presented herein supersede previous aquatic life water quality criteria for PCP (U.S. EPA 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

The acute toxicity of PCP to freshwater fish depends on the life stage of the fish and the pH, temperature, and concentration of dissolved oxygen in the water. Van Leeuwen et al. (1985) found that fry of rainbow trout were much more sensitive than embryos. PCP was more toxic to the fathead minnow (Crandall and Goodnight 1959) and to a nonresident fish, *Notopterus notopterus*, (Gupta et al. 1983b) at higher temperatures. Also, Goodnight (1942) observed that fish succumbed more rapidly at higher temperatures (28-30°C) than at cooler temperatures (9-24°C). Acute toxicity to *Notopterus*

notopterus increased with a decrease in the concentration of dissolved oxygen (Gupta et al. 1983a).

Of the variables studied, however, pH is the only one for which quantitative data are available for a variety of freshwater species. The acute value increases and toxicity decreases as pH increases. An analysis of covariance (Dixon and Brown 1979; Neter and Wasserman 1974) was performed using the natural logarithm of the acute value as the dependent variable, species as the treatment or grouping variable, and pH as the covariate or independent variable. This analysis of covariance model was fit to the data in Table 1 for the five freshwater species for which acute values are available over a range of pH. The slopes for all five species are between 0.67 and 1.2 (see end of Table 1). An F-test showed that, under the assumption of equality of slopes, the probability of obtaining five slopes as dissimilar as these is P = 0.28. This was interpreted as indicating that it is not unreasonable to assume that the slopes for the five species are the same.

The pooled slope of 1.005 was used with the data in Table 1 to adjust the acute values to pH = 6.5, where possible. Species Mean Acute Values were calculated as geometric means of the adjusted acute values, and Genus Mean Acute Values at pH = 6.5 (Table 3) were then calculated as geometric means of the available freshwater Species Mean Acute Values. Acute values are available for more than one species in each of three genera and the range of Species Mean Acute Values within each genus is less than a factor of 2.3. Of the 33 genera for which acute values are available, the most sensitive genus, *Cyprinus*, was over 10,000 times more sensitive than the most resistant, *Orconectes*. The freshwater Final Acute Value (FAV) for PCP at pH = 6.5 was calculated to be 10.97 μg/L using the procedure described in the Guidelines and the Genus Mean Acute Values in Table 3. The only Species Mean Acute Value that is lower than the FAV is that for the common carp, Cyprinus carpio. The freshwater Criterion Maximum Concentration (in μg/L) = $e^{[1.005(pH)-4.830]}$.

Tests of the acute toxicity of PCP to resident North American saltwater animals have been performed with 13 species of invertebrates and five species of fish (Table 1). The range of acute values for invertebrates extends from 36.95 μg/L for embryos of the American oyster, Crassostrea virginica (Borthwick and Schimmel 1978) to 18,000 μg/L for the adult stage of the blue mussel, Mytilus edulis (Adema and Vink 1981). The range of acute values for saltwater fish is narrower, extending from 22.63 μg/L for late yolk-sac larvae of the Pacific herring, Clupea harengus pallasi (Vigers et al. 1978) to 442 μg/L for juvenile sheepshead minnow, Cyprinodon variegatus (Parrish et al. 1978). Fish appear to be generally more sensitive than invertebrates to PCP.

Embryos and larvae of the polychaete worm, Ophryotrocha diadema, and the mussel, Mytilus edulis, were more sensitive to PCP than adults of the same species (Adema and Vink 1981; Woelke 1972). Tests with Pacific herring, Clupea harengus pallasi, (Vigers et al. 1978) and the nonresident plaice, Pleuronectes platessa, (Adema and Vink 1981) revealed that sensitivity to PCP increases between the newly hatched yolk-sac larval stage and the late larval premetamorphosis stage. Juveniles and adults are slightly less sensitive than larvae.

Environmental factors, such as temperature, pH, and salinity, might have an effect on the acute toxicity of PCP to some saltwater animals. With the oligochaete worms, Limnodriloides verrucosus and Monophelephorus cuticulatus, sensitivity to PCP increased somewhat between 1°C and 10°C at pH = 7, and between pH = 6 and pH = 8 at a temperature of 10°C (Chapman et al. 1982b). Larvae of the blue mussel, Mytilus edulis, were more sensitive to PCP at a salinity of 24 g/kg than at a salinity of 28 g/kg (Dimick and Breese 1965; Woelke 1972).

With some saltwater crustaceans, the stage of the molt cycle also seems to affect sensitivity to PCP. Late premolt and molting grass shrimp, Palaemonetes pugio, were more than five times as sensitive to PCP as intermolt animals (Conklin and Rao 1978a,b; Rao and Doughtie 1984). This effect was attributed to the greater permeability of the integument of the shrimp during molting.

Of the 17 saltwater genera for which acute values are available, the most sensitive genus, Clupea, is more than 247 times more sensitive than the most resistant, Crepidula (Table 3). The four most sensitive genera include two fish and two invertebrates and the range of the four Genus Mean Acute Values is a factor of 3.5. The saltwater Final Acute Value calculated from the values in Table 3 is 25.05 µg/L, which is very close to the acute value for the most sensitive tested saltwater species.

Chronic Toxicity to Aquatic Animals

Of the freshwater species with which chronic tests have been conducted on PCP, the cladoceran, Ceriodaphnia reticulata, is the most sensitive (Table 2), with a reduction in offspring occurring at 4.1 µg/L, the lowest concentration tested (Hedtke et al. 1986). Production of embryos by the snail, Physa gyrina, was reduced at a PCP concentration of 26 µg/L, the lowest concentration tested (Hedtke et al. 1986). A chronic value of 240 µg/L for Daphnia magna was based upon mortality (Adema 1978). Similarly, survival was the endpoint that determined the chronic values of 177 and 221 µg/L for Simocephalus vetulus (Hedtke et al. 1986).

Significant increases in mortality and decreases in length and weight occurred among rainbow trout at 19 μg/L after a 72-day exposure (Dominguez and Chapman 1984), but the trout were not affected at 11 μg/L. Dominguez and Chapman used a pure form of PCP (99+%) and found that yolk sac edema and cranial malformations were rare as compared to their more common incidences in studies with technical-grade PCP.

Several studies with the fathead minnow in the pH range from 6.5 to 8.5 resulted in chronic values from 24 to 144 μg/L (Table 2). Spehar et al. (1985) studied the relationship between pH and chronic toxicity, and obtained chronic values of 24, 40, 49, and 89 μg/L at pH = 6.5, 7.5, 8.0, and 8.5, respectively. A linear regression of ln(chronic value) on pH resulted in a slope of 0.6174. This slope is similar to the slope of 0.6782 obtained by the same investigators in an acute toxicity study with the fathead minnow. However, because data are available for chronic toxicity versus pH for only one species, the acute pooled slope of 1.005 was also applied to the freshwater chronic data in Table 2, where possible, to adjust the chronic values to pH = 6.5, to allow a comparison of freshwater chronic values at a common pH.

The long-term sublethal toxicity of PCP to fish has been shown to be affected by temperature and concentration of dissolved oxygen (Table 6). Newly hatched rainbow trout were affected more at 6°C than at 10°C, whereas after yolk sac sorption, a greater effect on growth occurred at 20°C than at 12°C (Hodson and Blunt 1981). They concluded that, if these laboratory data were applied in the field to wild trout populations, temperature effects on PCP toxicity would be greatest both during embryo development and subsequent growth of young trout.

Decreased concentrations of dissolved oxygen in the water increased the toxicity of PCP to young rainbow trout (Chapman and Shumway 1978). After a 24-day exposure to 37 µg/L, alevins reared at dissolved oxygen concentrations of 3, 5, and 10 mg/L suffered 76, 20, and 7% mortality, respectively. Also, the time required for trout to attain maximum growth was prolonged at the two lower concentrations of dissolved oxygen.

Usable data, according to the Guidelines, on the chronic toxicity of PCP are available for only two saltwater species, the polychaete worm, Ophryotrocha diadema, (Table 6) and the sheepshead minnow, Cyprinodon variegatus, (Table 2). Test populations of Ophryotrocha diadema were exposed to PCP in a renewal life-cycle test extending from 2 to 3-day-old larvae to two-week-old second generation larvae (Hooftman and Vink 1980). The most sensitive effect was an apparent inhibition of reproduction at 11 µg/L. This value was not used in Table 2 because the authors did not report any statistical analyses of the data. A complete life-cycle test was conducted with the sheepshead minnow, Cyprinodon variegatus (Parrish et al. 1978). The most sensitive effect was decreased long-term survival of the first generation fish at 88 µg/L. At 195 µg/L, survival of second generation embryos and juveniles was reduced.

The seven available Species Mean Acute-Chronic Ratios range from 0.8945 to over 15.79 (Table 3), but the two highest values are both "greater than" values and were obtained with two freshwater species that are much more acutely resistant than the other four freshwater species. Therefore, the Final Acute-Chronic Ratio of 3.166 was calculated as the geometric mean of the five Species Mean Acute-Chronic Ratios ranging from 0.8945 to 6.873. When this ratio is used with the freshwater Final Acute Value and the pooled slope for the pH-toxicity relationship (Table 3), the resulting freshwater Final Chronic Value (in μg/L) = $e^{[1.005(pH)-5.290]}$. Division of the saltwater Final Acute Value by the Final Acute-Chronic Ratio results in a saltwater Final Chronic Value of 7.912 μg/L. This is about a factor of 8 below the only available saltwater chronic value, but no chronic test on PCP has been conducted with any of the 13 acutely most sensitive saltwater species.

Toxicity to Aquatic Plants

Freshwater plants are sensitive to PCP over a range of concentrations from 7.5 to 3,200 μg/L (Tables 4 and 6). Blackman et al. (1955) observed that the degree of chlorosis in a 48-hr exposure of Lemna minor was very sensitive to small changes in PCP concentrations. Only a slight concentration increase was required to induce 50% chlorosis in all of the duckweed fronds as compared to 50 % induction in none of the fronds. In a prolonged exposure of the vascular plant, Elodea canadensis, significant biomass reductions occurred at progressively lower concentrations of PCP as duration of exposure increased (Hedtke et al. 1986). Biomass reductions were detected at 1,440 μg/L after 7 days, 810 μg/L after 14 days, and 380 μg/L after 21 days (Table 6). Biomass was not affected at any time by the next lower concentration of 230 μg/L. In contrast, neither reduced frond production nor chlorosis was observed in Lemna minor at the highest PCP concentration of 1,440 μg/L (Hedtke et al. 1986). The river water used in both of these tests might have had some effect upon the results.

Complete destruction of chlorophyll in Chlorella pyrenoidosa occurred at a PCP concentration of 7.5 μg/L (Huang and Gloyna 1967). In a 7-day study with Selenastrum capricornutum, cell numbers and population growth rates were significantly reduced by 50 μg/L, but were not affected by 10 μg/L (Adams et al. 1985). Concentrations near 300 μg/L resulted in 50% reductions of Selenastrum populations in two separate studies (Crossland and Wolff 1985; Richter 1982). The 4-day EC50 for Scenedesmus subspicatus was 90 μg/L (Geyer et al. 1985).

Usable data on the toxicity of PCP to saltwater plants are available for eight phytoplankters, one macroalgal species, and one vascular plant (Table 4). The 96-hr EC50s, based on reduction of cell population growth, range from 17.40 μg/L for the diatom, Skeletonema costatum (Walsh et al. 1982) to 3,600 μg/L for the green alga, Dunaliella tertiolecta (Adema and Vink 1981). Giant kelp, Macrocystis pyrifera, and seagrass, Thalassia testudinum, are about as sensitive as the phytoplankters. The range of sensitivities of saltwater plants to PCP is similar to that for saltwater animals and, therefore, a criterion that protects saltwater animals will probably also protect saltwater plants.

Bioaccumulation

Bioconcentration of PCP from water, like toxicity, has been shown to be inversely related to pH (Kobayashi and Kishino 1980; Spehar et al. 1985). PCP bioconcentrated in the tissues of fish from 7.3 to 1,066 times (Table 5), with test durations from 16 to 115 days. The gall bladder concentrated the highest levels of PCP (Glickman et al. 1977, Kobayashi and Akitake 1975b, McKim et al., Manuscript), whereas muscle and skin contained the lowest concentrations of PCP in rainbow trout exposed to 0.78 to 1.15 μg/L (McKim et al., Manuscript). The lowest bioconcentration factor (BCF) of 7.3 was obtained in bluegill muscle (Pierce 1978; Pruitt et al. 1977). BCFs of 320 and 378 were estimated from uptake and depuration rates using the rainbow trout (McKim et al., Manuscript) and the non-resident killifish, Oryzias latipes (Sugiura et al. 1984).

Residues of PCP in fish drop quite rapidly upon termination of exposure. Ninety-six percent of whole body ^{14}C-labelled PCP was eliminated by fathead minnows within 3.5 days (Huckins and Petty 1983), whereas about 85 percent of the PCP residues in bluegill muscle were eliminated in 4 days (Pruitt et al. 1977). A first-order simulation model developed from empirical data indicated a half-life of 2.7 days in rainbow trout, with 95% elimination in 11.7 days (McKim et al., Manuscript).

McKim et al. (1985) studied the efficiency of chemical uptake by rainbow trout gills using 14 different chemicals including PCP. They found that PCP was in a group of chemicals, all with log n-octanol/water partition coefficients (log P) between 2.84 and 6.18, that were taken up more efficiently by gills than chemicals with either lower or higher partition coefficients. The rate of elimination of the chemicals in this log P range largely determined their BCFs. In this range, the elimination rates decreased as log P increased. PCP, with a log P of 3.32, would be expected to be eliminated quite readily. Indeed, this has been shown, as indicated above.

Several studies have shown that PCP is conjugated with glucuronic acid in fish (Huckins and Petty 1983; Kobayashi 1978,1979; Kobayashi and Nakamura 1979b; Kobayashi et al. 1977; Lech et al. 1978). Reduced glucuronidation occurred in fathead minnows exposed to industrial PCP, as compared to purified PCP, and it was suggested that this might play a role in the elevated toxicity of the impure form (Huckins and Petty 1983). Pentachlorophenylsulfate has been found in goldfish exposed to PCP (Akitake and Kobayashi 1975; Kobayashi 1978,1979; Kobayashi and Nakamura 1979a,b; Kobayashi et al. 1984), but not in rainbow trout (Lech et al. 1978) or fathead minnows (Huckins and Petty 1983).

Probable steady-state BCFs for PCP are available for the eastern oyster, Crassostrea virginica (Schimmel and Garnas 1985; Schimmel et al. 1978), the sheepshead minnow, Cyprinodon variegatus (Parrish et al. 1978) and the longnose killifish, Fundulus similis (Trujillo et al. 1982). In tests with oysters, the steady-state BCF ranged from 34 to 82, and was reached in 14 to 96 hours. In a life-cycle test with the sheepshead minnow, BCFs were 5 to 27 with adult fish, 13 to 22 with embryos, and 16 to 48 with 28-day-old young (Schimmel et al. 1978). A steady-state BCF of 64 was obtained in a 7-day test with the longnose killifish (Trujillo et al. 1982). In four-day acute toxicity tests, Schimmel et al. (1978) found BCFs ranging from 0.26 for brown shrimp to 38.0 for striped mullet, Mugil cephalus. Using radio-labeled PCP, Carr and Neff (1981) reported a 14-day BCF of 280 with the sand worm, Nereis virens.

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

Other Data

Cleveland et al. (1982) and Hamilton et al. (1986) studied the effects of four samples of PCP on the survival and growth of fathead minnows for 90 days. In the range of 60 to 142 µg/L, both a purified PCP and an ultrapure PCP reduced growth by 10 to 25%, whereas Dowicide EC-7 increased growth by 18 to 21%. An industrial composite PCP was much more toxic; 13 µg/L reduced growth by 20%, 27 µg/L reduced growth by 40%, and 67 µg/L killed all the fish. Analyses of the four PCP samples for fourteen polychlorinated impurities and a test on the effects of a mixture of some of the impurities indicated that some of the effects seen in the tests on PCP were probably due to the measured impurities.

Webb and Brett (1973) found that growth and food conversion of sockeye salmon (Oncorhynchus nerka) were affected in a 56-day exposure to PCP concentrations of 1.74 and 1.80 µg/L, respectively, at a pH of 6.8 (Table 6). These are the lowest effect concentrations that have been reported for any species. Growth of salmonids was reduced by 10 to 27% at PCP concentrations ranging from 3.2 to 28 µg/L (Chapman 1969; Chapman and Shumway 1978; Matida et al. 1976). The thresholds for reduction of growth of rainbow trout exposed to PCP through 4-week post swim-up were about 10 and 20 µg/L in warm and cold regimes, respectively (Hodson and Blunt 1981). Reduced growth of largemouth bass, Micropterus salmoides, was observed at 50.4 µg/L after 7 days of exposure (Mathers et al. 1985), of the guppy at 320 µg/L after 28 days of exposure and of the amphibian, Xenopus laevis, at 100 µg/L after 100 days of exposure (Slooff and Canton 1983).

Whitley (1968) and Kobayashi and Kishino (1980) reported that an increase in pH decreased the 24-hr LC50s for both tubificid worms and goldfish. Some reduction in toxicity appeared to result from the presence of sediment in acute toxicity tests conducted with several species of tubificid worms (Chapman et al. 1982a). Similarly, Mississippi River water afforded some protection to various invertebrate species when their LC50s were compared with values obtained in Lake Superior water (Hedtke et al. 1986). The tubificids, Limnodrilus hoffmeisteri and Tubifex tubifex, were more resistant to PCP when tested as mixed species than when each species was tested individually (Chapman et al. 1982a,b). Schauerte et al. (1982) found that 1,000 µg/L decreased daphnids and autotrophic phytoplankton in compartments in a pond, and Yount and Richter

(1986) found that periphyton biomass in experimental streams was inversely related to pentachlorophenol in the range from 48 to 432 µg/L.

A wide variety of acute, chronic, and sublethal effects of PCP have been reported for saltwater organisms (Table 6). Several effects of PCP on polychaete worms have been reported such as reduced feeding activity by *Arenicola cristata* (Rubinstein 1978). depletion of glycogen reserves, increased tissue ascorbic acid concentrations, and disruption of osmoregulation *Nereis virens* (Carr and Neff 1981); and reproductive impairment in *Ophryotrocha diadema* (Hooftman and Vink 1980). PCP induced developmental abnormalities in embryos and larvae of the mussel, *Mytilus edulis*, (Dimick and Breese 1965) and oyster, *Crassostrea virginica*, (Davis and Hidu 1969) and inhibited shell growth of juvenile oysters (Schimmel et al. 1978). Exposure for 18 weeks to 460 µg/L resulted in reduced resistance of the quahog clam, *Mercenaria mercenaria*, to bacterial infection (Anderson et al. 1981).

The grass shrimp, *Palaemonetes pugio*, exhibited a variety of sublethal physiological effects during exposure to PCP concentrations of 400 to 4,600 µg/L (Brannon and Conklin 1978: Cantelmo et al. 1978; Doughtie and Rao 1978; Rao and Doughtie 1984; Rao et al. 1978,1979,1981) such as histological damage to epithelia of the gills, gut, and hepatopancreas, increased metabolic rate, decreased rate of limb regeneration, and increased weight of the molted exoskeleton.

Saltwater fish exposed to 50 to 200 µg/L exhibited elevation of the concentration of acid-soluble thiols in liver of winter flounder (Thomas and Wofford 1984) and elevation of blood cortisol, leading to hyperglycemia, depletion of liver glycogen reserves, and an increase in liver ascorbic acid concentration in mullet (Thomas et al. 1981).

In a series of benthic colonization studies conducted in the laboratory under flow-through conditions, PCP concentrations of 55 to 140 µg/L reduced both species richness and total faunal abundances of benthic macrofauna (Hansen and Tagatz 1980; Tagatz et al. 1977,1980,1981). At a concentration of 15.8 µg/L, PCP, administered as Dowicide G-ST, reduced total faunal abundances, but not species richness. Molluscs were generally most sensitive, but other phyla were also affected.

Unused Data

Some data on the effects of PCP on aquatic organisms were not used because the studies were conducted with species that are not resident in North America (e.g., Adema and Vink 1981; Dalela et al. 1980a,b,c, Dave 1984; Hanumante and Kulkarni 1979; Goel and Prasad 1978; Gupta 1983; Gupta and Dalela 1986; Gupta and Durve 1984a,b, Gupta and Rao 1982; Gupta et al. 1982b,1983a,b; Hattori et al. 1984; Kaila and Saarikoski 1977, Khangarot et al. 1985; Kobayashi et al. 1969, Nagendran and Shakuntala 1979; Rao et al. 1983; Shim and Self 1973; Slooff 1978; Slooff et al. 1983b; Tomiyama et al. 1962; Van Dijk et al. 1977; Verma et al. 1980,1981a,b,1982,1984). Results (e.g., Adema and Vink 1981) of tests conducted with brine shrimp, Artemia sp., were not used because these species are from a unique saltwater environment. Adelman et al. (1976b), Ahlborg and Thurnberg (1980), Alexander et al. (1983), Bevenue and Beckman (1967), Buikema et al. (1979), Conklin and Fox (1978), Hall and Kier (1984a,b), Koch (1982), Kozak et al. (1979), National Research Council of Canada (1982), Rao et al. (1979), von Rumker et al. (1974), and Strufe (1968) only contain data that have been published elsewhere.

Results were not used if either the test procedures or the test material was not adequately described (e.g., Benoit-Guyod et al. 1984a;

Canton and Slooff 1979; Clemens and Sneed 1959; Hashimoto and Nishiuchi 1983: Klein et al. 1984; Knie et al. 1983; Konemann and Musch 1981; Wong 1984), or if PCP was a component of a mixture (Hermens et al. 1985; Statham and Lech 1975). Tests were not used if PCP comprised only eight percent of the formulation (Batte and Swanson 1952; Inglis and Davis 1972). Data were not used if PCP was a component of a sediment (e.g., D'Asaro and Wilkes 1982) or if the organisms were exposed by injection (e.g., Bose and Fujiwara 1978; Tripp et al. 1984) or in food (e.g., Niimi and Cho 1983). Anderson et al. (1984), Bols et al. (1985), Cantelmo and Rao (1978a), Fox and Rao (1978), and Kwasniewska et al. (1979) only exposed enzymes, excised or homogenized tissue, cell cultures, or sewage bacteria.

Tests conducted with too few test organisms (e.g., Coglianese and Neff 1982; McLeese et al. 1979) and tests in which the concentrations fluctuated widely (e.g., Thomas et al. 1981) were not used. The 60-day test reported by Verma et al. (1981c) was not used because there were no replicate test chambers. The early life-stage toxicity data of Johansen et al. (1985) were not used due to high mortality of control fish and an interruption in the exposure. Results were not used if organisms were not cultured and tested in the same dilution water (Berglind and Dave 1984).

Studies with physiological endpoints only were not used (e.g., Bostrom and Johansson 1972; Chowdary et al. 1979; Gupta et al. 1983c,d; Hanke et al. 1983; Holmberg et al. 1972; Huber et al. 1982; Jayaweera et al. 1982; Kaila 1982; Kaila and Saarikoski 1980,1981; LeBlanc and Cochrane 1985. Liu 1981; Oikari and Nittyla 1985: Oikari et al. 1985; Peer et al. 1983: Saarikoski and Kaila 1977: Sarojini et al. 1983; Sloley et al. 1986; Tiedge et al. 1986; Verma 1981b; Verma et al. 1982; Yousri and Hanke 1985). A study of histological effects on bluegills was not used (Owen and Rosso

1981). Toxicity data were not used if they were only qualitative (Palmer and Maloney 1955) or were presented in graphic form (Norup 1972). A study by Anderson and Weber (1975) was not used because acute toxicity results for the guppy were presented only as linear regressions on body size.

A study on the uptake and metabolism of PCP in rice plants (Weiss et al. 1982) was not used, nor were uptake studies in which exposure was via the food (Niimi and Cho 1983) or by gavage (Niimi and Palazzo 1985). Bioconcentration studies were not used if the test was not flow-through or renewal (e.g., Ernst 1979) or if the exposures were of insufficient duration for steady state to have been achieved (Glickman et al. 1977; Kobasyahi and Akitake 1975a,b; Kobayashi et al. 1979; Kuehl et al. 1983; Lech et al. 1978: McKim et al., Manuscript). Reports of the concentrations of PCP in wild aquatic organisms (e.g., Butte et al. 1983; Faas and Moore 1979; Folke et al. 1983: Fox and Joshi 1984; Kuehl and Dougherty 1980; Murray et al. 1980,1981: Ray et al. 1983) were not used if the number of measurements of the concentration in water was too small or if the range of the measured concentrations in water was too great. Studies of the concentration or accumulation of PCP in organisms were not used if the data provided were considered insufficient for determination of a bioconcentration or bioaccumulation factor (Gotham and Rhee 1982; Hallas 1973; Klein et al. 1984; Korte et al. 1978; Oikari 1986; Oikari and Anas 1985; Paasivirta et al. 1981), if the data were being reported secondarily (Branson 1980; Davies and Dobbs 1984), if water and biota samples were not collected at the same times (Metcalfe et al. 1984), or if the measurements were of total radiolabel rather than PCP itself (Fisher and Wadleigh 1986, Freitag et al. 1985; Geyer et al. 1981,1984; Gluth et al. 1985). Bioaccumulation and fate data from model ecosystems or microcosm studies were not used (e.g., Brockway et al. 1984; Knowlton and Huckins 1983; Lu and Metcalf 1975; Robinson-Wilson et al. 1983; Tomizawa and Kazano 1979).

Summary

The acute and chronic toxicity of PCP to freshwater animals increased as pH and dissolved oxygen concentration of the water decreased. Generally, toxicity also increased with increased temperature. The estimated acute sensitivities of 36 species at pH = 6.5 ranged from 4.355 µg/L for larval common carp to >43,920 µg/L for a crayfish. At pH = 6.5, the lowest and highest estimated chronic values of <1.835 and 79.66 µg/L, respectively, were obtained with different cladoceran species. Chronic toxicity to fish was affected by the presence of impurities, with industrial-grade PCP being more toxic than purified samples. Mean acute-chronic ratios for six freshwater species ranged from 0.8945 to >15.79, but the mean ratios for the four most acutely sensitive species only ranged from 0.8945 to 5.035. Freshwater algae were affected by concentrations as low as 7.5 µg/L, whereas vascular plants were affected at 189 µg/L and above. Bioconcentration factors ranged from 7.3 to 1,066 for three species of fish.

Acute acute toxicity values from tests with 18 species of saltwater animals, representing 17 genera, range from 22.63 µg/L for late yolk-sac larvae of the Pacific herring, *Clupea harengus pallasi*, to 18,000 µg/L for adult blue mussels, *Mytilus edulis*. The embryo and larval stages of invertebrates and the late larval premetamorphosis stage of fish appear to be the most sensitive life stages to PCP. With few exceptions, fish are more sensitive than invertebrates to PCP. Salinity, temperature, and pH have a slight effect on the toxicity of PCP to some saltwater animals.

Life-cycle toxicity tests have been conducted with the sheepshead minnow, *Cyprinodon variegatus*, and the polychaete worm, *Ophryotrocha diadema*. The chronic value for the minnow is 64.31 µg/L and the acute-chronic ratio is 6.873. Unfortunately, no statistical analysis of the data from the test with the worm is available.

The EC50s for saltwater plants range from 17.40 µg/L for the diatom, *Skeletonema costatum*, to 3,600 µg/L for the green algae, *Dunaliella tertiolecta*. Apparent steady-state BCFs are available for the eastern oyster, *Crassostrea virginica*, and two saltwater fishes and range from 10 to 82.

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 (in µg/L) of pentachlorophenol does not exceed the numerical value given by $e^{[1.005(pH)-5.290]}$ more than once every three years on the average and if the one-hour average concentration (in µg/L) does not exceed the numerical value given by $e^{[1.005(pH)-4.830]}$ more than once every three years on the average. For example, at pH = 6.5, 7.8, and 9.0 the four-day average concentrations of pentachlorophenol are 3.5, 13, and 43 µg/L, respectively, and the one-hour average concentrations are 5.5, 20, and 68 µg/L. At pH = 6.8, a pentachlorophenol concentration of 1.74 µg/L caused a 50% reduction in the growth of yearling sockeye salmon in a 56-day test.

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 pentachlorophenol does not exceed 7.9 µg/L more than once every three years on the average and if the one-hour average concentration does not exceed 13 µg/L more than once every three years on the average.

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 Pentachlorophenol to Aquatic Animals

Species	Method*	Chemical**	pH	LC50 or EC50 (µg/L)***	Adjusted LC50 or EC50 (µg/L)****	Species Mean Acute Value (µg/L)*****	Reference
			FRESHWATER SPECIES				
Hydra, *Hydra oligactis*	S, U	PCP (>98%)	-	730	-	-	Slooff et al. 1983a
Tubificid worm, *Branchiura sowerbyi*	R, U	NaPCP	7.0	257.7	155.9	155.9	Chapman et al. 1982a
Tubificid worm, *Limnodrilus hoffmeisteri*	R, U	NaPCP	7.0 (10°C)	303.8	183.8	-	Chapman et al. 1982a,b,c
Tubificid worm, *Limnodrilus hoffmeisteri*	R, U	NaPCP	7.0 (1°C)	478.7†	289.6	-	Chapman et al. 1982b
Tubificid worm, *Limnodrilus hoffmeisteri*	R, U	NaPCP	7.0 (20°C)	451.0†	272.9	-	Chapman et al. 1982b
Tubificid worm, *Limnodrilus hoffmeisteri*	R, U	NaPCP	6.0 (10°C)	303.8†	502.1††	-	Chapman et al. 1982b
Tubificid worm, *Limnodrilus hoffmeisteri*	R, U	NaPCP	8.0 (10°C)	345.2†	76.45	182.5	Chapman et al. 1982b
Tubificid worm, *Quistradrilus multisetosus*	R, U	NaPCP	7.0	524.7	317.5	317.5	Chapman et al. 1982a,b
Tubificid worm, *Rhyacodrilus montana*	R, U	NaPCP	7.0	690.4	417.7	417.7	Chapman et al. 1982a
Tubificid worm, *Spirosperma ferox*	R, U	NaPCP	7.0	395.8	239.5	239.5	Chapman et al. 1982a
Tubificid worm, *Spirosperma nikolskyi*	R, U	NaPCP	7.0	902.1	545.8	545.8	Chapman et al. 1982a
Tubificid worm, *Stylodrilus heringianus*	R, U	NaPCP	7.0	579.9	350.8	-	Chapman et al. 1982a,b
Tubificid worm, *Stylodrilus heringianus*	R, U	NaPCP	7.0 (1°C)	1,638†	991.0	-	Chapman et al. 1982b
Tubificid worm, *Stylodrilus heringianus*	R, U	NaPCP	7.0 (20°C)	681.2†	412.1	-	Chapman et al. 1982b

Table 1. (Continued)

Species	Method*	Chemical**	pH	LC50 or EC50 (µg/L)***	Adjusted LC50 or EC50 (µg/L)****	Species Mean Acute Value (µg/L)*****	Reference
Tubificid worm, *Stylodrilus heringianus*	R, U	NaPCP	6.0 (10°C)	690.4†	1,141††	-	Chapman et al. 1982b
Tubificid worm, *Stylodrilus heringianus*	R, U	NaPCP	8.0 (10°C)	874.5†	193.7	408.2	Chapman et al. 1982b
Tubificid worm, *Tubifex tubifex*	R, U	NaPCP	7.0 (10°C)	349.8	211.6	-	Chapman et al. 1982a,b,c
Tubificid worm, *Tubifex tubifex*	R, U	NaPCP	7.0 (1°C)	607.5†	367.6	-	Chapman et al. 1982b
Tubificid worm, *Tubifex tubifex*	R, U	NaPCP	7.0 (2°C)	405.0†	245.0	-	Chapman et al. 1982b
Tubificid worm, *Tubifex tubifex*	R, U	NaPCP	6.0 (10°C)	340.6†	563.0††	-	Chapman et al. 1982b
Tubificid worm, *Tubifex tubifex*	R, U	NaPCP	8.0 (10°C)	598.3†	132.5	224.2	Chapman et al. 1982b
Tubificid worm, *Varichaeta pacifica*	R, U	NaPCP	7.0	96.65	58.47	58.47	Chapman et al. 1982a
Snail (adult), *Aplexa hypnorum*	F, M	Dowicide EC-7 (88% PCP)	7.1-7.8	157	63.54	-	Phipps and Holcombe 1985
Snail (adult), *Aplexa hypnorum*	F, M	Dowicide EC-7 (88% PCP)	7.1-7.8	142	57.47	60.43	Phipps and Holcombe 1985
Snail, *Physa gyrina*	F, M	Dowicide EC-7 (95.7% PCP)	7.2	267	132.1	132.1	Hedtke et al. 1986
Snail, *Lymnaea stagnalis*	-	PCP	-	240	-	-	Adema and Vink 1981
Snail, *Gillia altilis*	S, U	PCP (99%)	6.7	810	662.5	-	Stuart and Robertson 1985
Snail, *Gillia altilis*	R, U	PCP (99%)	6.7	300	245.4	403.2	Stuart and Robertson 1985

Species	Method*	Chemical**	pH	LC50 or EC50 (µg/L)***	Adjusted LC50 or EC50 (µg/L)****	Species Mean Acute Value (µg/L)*****	Reference
Cladoceran (<4 hr), *Ceriodaphnia reticulata*	S, U	Dowicide EC-7 (93.7% PCP)	7.2-7.4	153.7	68.79	-	Mount and Norberg 1984
Cladoceran (<6 hr), *Ceriodaphnia reticulata*	S, U	NaPCP	7.7	260	77.84	-	Hall et al. 1986
Cladoceran (<6 hr), *Ceriodaphnia reticulata*	S, U	NaPCP	7.7	510	152.7	-	Hall et al. 1986
Cladoceran (<6 hr), *Ceriodaphnia reticulata*	S, U	NaPCP	7.8	290	78.52	-	Hall et al. 1986
Cladoceran (<6 hr), *Ceriodaphnia reticulata*	S, U	NaPCP	7.8	410	111.0	-	Hall et al. 1986
Cladoceran (<24 hr), *Ceriodaphnia reticulata*	S, U	PCP (reagent grade)	8.0	900	199.3	-	Elnabarawy et al. 1986
Cladoceran (<24 hr), *Ceriodaphnia reticulata*	F, M	Dowicide EC-7 (93.7% PCP)	7.3	150	67.13	67.13	Hedtke et al. 1986
Cladoceran (<24 hr), *Daphnia magna*	S, U	-	7.4-9.4	680	100.7	-	LeBlanc 1980
Cladoceran (<24 hr), *Daphnia magna*	S, U	PCP	-	250	-	-	Canton and Adema 1978
Cladoceran (<24 hr), *Daphnia magna*	S, U	PCP	-	400	-	-	Canton and Adema 1978
Cladoceran (<24 hr), *Daphnia magna*	S, U	PCP	-	800	-	-	Canton and Adema 1978
Cladoceran (24 hr), *Daphnia magna*	S, M	PCP	-	600	-	-	Adema 1978
Cladoceran (larva), *Daphnia magna*	-	PCP	-	1,050	-	-	Adema and Vink 1981
Cladoceran (adult), *Daphnia magna*	-	PCP	-	1,400	-	-	Adema and Vink 1981

Table 1. (Continued)

Species	Method*	Chemical**	pH	LC50 or EC50 (µg/L)***	Adjusted LC50 or EC50 (µg/L)****	Species Mean Acute Value (µg/L)*****	Reference
Cladoceran (<24 hr), *Daphnia magna*	S, U	-	-	280	-	-	Hermens et al. 1984
Cladoceran (<24 hr), *Daphnia magna*	S, U	Dowicide EC-7 (93.7% PCP)	7.2-7.4	134.0	59.97	-	Mount and Norberg 1984
Cladoceran (<24 hr), *Daphnia magna*	S, M	PCP (99%)	8.58	145	17.93	-	Thurston et al. 1985
Cladoceran (<24 hr), *Daphnia magna*	S, U	PCP	8.5	300	40.20	-	Lewis and Weber 1985
Cladoceran (<24 hr), *Daphnia magna*	S, U	PCP	8.5	350	46.90	-	Lewis and Weber 1985
Cladoceran (<24 hr), *Daphnia magna*	S, U	PCP	8.5	380	50.92	-	Lewis and Weber 1985
Cladoceran (<24 hr), *Daphnia magna*	S, U	PCP	8.5	300	40.20	-	Lewis and Weber 1985
Cladoceran (<24 hr), *Daphnia magna*	S, U	PCP	8.5	350	46.90	-	Lewis and Weber 1985
Cladoceran (<24 hr), *Daphnia magna*	S, U	PCP	8.5	300	40.20	-	Lewis and Weber 1985
Cladoceran (<24 hr), *Daphnia magna*	S, U	PCP	8.5	280	37.52	-	Lewis and Weber 1985
Cladoceran (<24 hr), *Daphnia magna*	S, U	PCP	8.5	310	41.54	-	Lewis and Weber 1985
Cladoceran (<24 hr), *Daphnia magna*	S, U	PCP	8.5	290	38.86	-	Lewis and Weber 1985
Cladoceran (<24 hr), *Daphnia magna*	S, U	PCP	8.5	370	49.58	-	Lewis and Weber 1985

Table 1. (Continued)

Species	Method*	Chemical**	pH	LC50 or EC50 (µg/L)***	Adjusted LC50 or EC50 (µg/L)****	Species Mean Acute Value (µg/L)*****	Reference
Cladoceran (<24 hr), Daphnia magna	S, U	PCP	8.5	350	46.90	-	Lewis and Weber 1985
Cladoceran (<24 hr), Daphnia magna	S, U	PCP	8.5	370	49.58	-	Lewis and Weber 1985
Cladoceran (<24 hr), Daphnia magna	S, U	PCP	8.5	340	45.56	-	Lewis and Weber 1985
Cladoceran (<24 hr), Daphnia magna	S, U	PCP	8.5	510	68.33	-	Lewis and Weber 1985
Cladoceran (<24 hr), Daphnia magna	S, U	PCP	8.5	840	112.6	-	Lewis and Weber 1985
Cladoceran (<24 hr), Daphnia magna	S, U	PCP	8.5	510	68.33	-	Lewis and Weber 1985
Cladoceran (<24 hr), Daphnia magna	S, U	NaPCP	7.7	450	134.7	-	Hall et al. 1986
Cladoceran (<24 hr), Daphnia magna	S, U	NaPCP	7.7	1,030	308.4	-	Hall et al. 1986
Cladoceran (<24 hr), Daphnia magna	S, U	NaPCP	7.8	960	259.9	-	Hall et al. 1986
Cladoceran (<24 hr), Daphnia magna	S, U	NaPCP	7.8	830	224.7	-	Hall et la. 1986
Cladoceran (<24 hr), Daphnia magna	S, U	PCP (reagent grade)	8.0	1,000	221.5	-	Elnabarawy et al. 1986
Cladoceran (6 d), Daphnia magna	S, M	PCP (99+%)	7.5	183	66.99	55.03	Brooke et al. Manuscript
Cladoceran (<24 hr), Daphnia pulex	S, U	PCP	-	2,000	-	-	Canton and Adema 1978

Table 1. (Continued)

Species	Method*	Chemical**	pH	LC50 or EC50 (µg/L)***	Adjusted LC50 or EC50 (µg/L)****	Species Mean Acute Value (µg/L)*****	Reference
Cladoceran (<24 hr), Daphnia pulex	S, U	PCP	8.2	260	47.10	-	Lewis and Weber 1985
Cladoceran (<24 hr), Daphnia pulex	S, U	PCP	8.2	490	88.76	-	Lewis and Weber 1985
Cladoceran (<24 hr), Daphnia pulex	S, U	PCP	8.2	480	86.95	-	Lewis and Weber 1985
Cladoceran (<24 hr), Daphnia pulex	S, U	PCP	8.2	470	85.13	-	Lewis and Weber 1985
Cladoceran (<24 hr), Daphnia pulex	S, U	PCP	8.2	290	52.53	-	Lewis and Weber 1985
Cladoceran (<24 hr), Daphnia pulex	S, U	PCP	8.2	170	30.79	-	Lewis and Weber 1985
Cladoceran (<24 hr), Daphnia pulex	S, U	PCP	8.2	250	45.28	-	Lewis and Weber 1985
Cladoceran (<24 hr), Daphnia pulex	S, U	PCP	8.2	390	70.64	-	Lewis and Weber 1985
Cladoceran (<24 hr), Daphnia pulex	S, U	PCP	8.2	190	34.42	-	Lewis and Weber 1985
Cladoceran (<24 hr), Daphnia pulex	S, U	PCP	8.2	330	59.78	-	Lewis and Weber 1985
Cladoceran (<24 hr), Daphnia pulex	S, U	PCP	8.2	560	101.4	-	Lewis and Weber 1985
Cladoceran (<24 hr), Daphnia pulex	S, U	PCP	8.2	550	99.63	-	Lewis and Weber 1985
Cladoceran (<24 hr), Daphnia pulex	S, U	PCP	8.2	560	101.4	-	Lewis and Weber 1985
Cladoceran (<24 hr), Daphnia pulex	S, U	PCP	8.2	440	79.70	-	Lewis and Weber 1985

Table 1. (Continued)

Species	Method*	Chemical**	pH	LC50 or EC50 (µg/L)***	Adjusted LC50 or EC50 (µg/L)****	Species Mean Acute Value (µg/L)*****	Reference
Cladoceran (<24 hr), *Daphnia pulex*	S, U	PCP	8.2	590	106.9	-	Lewis and Weber 1985
Cladoceran (<24 hr), *Daphnia pulex*	S, U	PCP	8.2	550	99.63	-	Lewis and Weber 1985
Cladoceran (<24 hr), *Daphnia pulex*	S, U	PCP	8.2	680	123.2	-	Lewis and Weber 1985
Cladoceran (<24 hr), *Daphnia pulex*	S, U	PCP	8.2	350	63.40	-	Lewis and Weber 1985
Cladoceran (<24 hr), *Daphnia pulex*	S, U	NaPCP	7.7	1,000	299.4	-	Hall et al. 1986
Cladoceran (<24 hr), *Daphnia pulex*	S, U	NaPCP	7.8	960	259.9	-	Hall et al. 1986
Cladoceran (<24 hr), *Daphnia pulex*	S, U	NaPCP	7.8	1,050	284.3	-	Hall et al. 1986
Cladoceran (<24 hr), *Daphnia pulex*	S, U	PCP (reagent grade)	8.0	1,100	243.6	90.83	Elnabarawy et al. 1986
Cladoceran (<24 hr), *Simocephalus vetulus*	S, U	Dowicide EC-7 (93.7% EC50)	7.2-7.4	203.3	91.00	-	Mount and Norberg 1984
Cladoceran (<24 hr), *Simocephalus vetulus*	F, M	Dowicide EC-7 (93.7% PCP)	7.3	160	71.61	-	Hedtke et al. 1986
Cladoceran (<24 hr), *Simocephalus vetulus*	F, M	Dowicide EC-7 (93.7% PCP)	7.7	250	74.85	-	Hedtke et al. 1986
Cladoceran (<24 hr), *Simocephalus vetlulus*	F, M	Dowicide EC-7 (93.7% PCP)	8.0	255	56.47	-	Hedtke et al. 1986
Cladoceran (<24 hr), *Simocephalus vetulus*	F, M	Dowicide EC-7 (93.7% PCP)	8.3	364	59.63	-	Hedtke et al. 1986
Cladoceran (<24 hr), *Simocephalus vetulus*	F, M	Dowicide EC-7 (93.7% PCP)	7.9-8.4	196	35.50	57.72	Hedtke et al. 1986
Amphipod (juvenile), *Crangonyx pseudogracilis*	F, M	Dowicide EC-7 (88% PCP)	6.5	139	139.0	-	Spehar et al. 1985

Table 1. (Continued)

Species	Method*	Chemical**	pH	LC50 or EC50 (µg/L)***	Adjusted LC50 or EC50 (µg/L)****	Species Mean Acute Value (µg/L)*****	Reference
Amphipod (juvenile), Crangonyx pseudogracilis	F, M	Dowicide EC-7 (88% PCP)	7.5	465	170.2	-	Spehar et al. 1985
Amphipod (juvenile), Crangonyx pseudogracilis	F, M	Dowicide EC-7 (88% PCP)	8.0	929	205.7	-	Spehar et al. 1985
Amphipod (juvenile), Crangonyx pseudogracilis	F, M	Dowicide EC-7 (88% PCP)	8.5	1,344	180.1	172.1	Spehar et al. 1985
Amphipod (11 mm), Gammarus pseudolimnaeus	S, M	PCP (99+%)	7.5	296	108.35	-	Brooke et al. Manuscript
Amphipod (0.050 g), Gammarus pseudolimnaeus	F, M	PCP (99+%)	7.2	280	138.56	-	Call et al. 1983
Amphipod (juvenile), Gammarus pseudolimnaeus	F, M	Dowicide EC-7 (88% PCP)	6.5	92	92.00	-	Spehar et al. 1985
Amphipod (juvenile), Gammarus pseudolimnaeus	F, M	Dowicide EC-7 (88% PCP)	7.5	121	44.29	-	Spehar et al. 1985
Amphipod (juvenile), Gammarus pseudolimnaeus	F, M	Dowicide EC-7 (88% PCP)	8.0	484	107.19	-	Spehar et al. 1985
Amphipod (juvenile), Gammarus pseudolimnaeus	F, M	Dowicide EC-7 (88% PCP)	8.5	790	105.85	122.1	Spehar et al. 1985
Amphipod, Hyalella azteca	S, M	PCP (99+%)	7.5	239	87.48	87.48	Brooke et al. Manuscript
Crayfish (0.4-2.0 g), Orconectes immunis	F, M	PCP (99%)	7.92	>183,000	>43,920	>43,920	Thurston et al. 1985
Mosquito (3rd instar), Aedes aegypti	S, U	PCP (>98%)	-	7,200	-	-	Slooff et al. 1983a
Mosquito (3rd instar), Culex pipiens	S, U	PCP (>98%)	-	34,000	-	-	Slooff et al. 1983a
Midge (3rd, 4th instar), Tanytarsus dissimilis	S, M	PCP (99%)	8.51	31,300	4,152	-	Thurston et al. 1985
Midge (3rd, 4th instar), Tanytarsus dissimilis	S, M	PCP (99%)	8.55	19,000	2,421	-	Thurston et al. 1985

Table 1. (Continued)

Species	Method*	Chemical**	pH	LC50 or EC50 (µg/L)***	Adjusted LC50 or EC50 (µg/L)****	Species Mean Acute Value (µg/L)*****	Reference
Midge (3rd, 4th instar), *Tanytarsus dissimilis*	F, M	PCP (99+%)	7.9	46,000	11,260	11,260	Call et al. 1983
Sciomyzid (1st instar), *Sepedon fuscipennis*	S, U	NaPCP (90%)	8	28,000	6,201	-	McCoy and Joy 1977
Sciomyzid (1st instar), *Sepedon fuscipennis*	S, U	NaPCP (90%)	7	30,000	18,150	10,610	McCoy and Joy 1977
Coho salmon (1-3 g), *Oncorhynchus kisutch*	S, U	NaPCP	7.01	89	53.31	-	Davis and Hoos 1975
Coho salmon (1-3 g), *Oncorhynchus kisutch*	S, U	NaPCP	7.01	34	20.36	-	Davis and Hoos 1975
Coho salmon (2.7 g, 6.2 cm), *Oncorhynchus kisutch*	F, U	NaPCP	6.9-7.5	60	29.69	31.82	Iwama and Greer 1980
Sockeye salmon (yearling), *Oncorhynchus nerka*	F, U	NaPCP	6.8	58	42.90	-	Webb and Brett 1973
Sockeye salmon (1-3 g), *Oncorhynchus nerka*	S, U	NaPCP	7.19	46	22.99	-	Davis and Hoos 1975
Sockeye salmon (1-3 g), *Oncorhynchus nerka*	S, U	NaPCP	7.70	120	35.93	32.85	Davis and Hoos 1975
Chinook salmon (1 g), *Oncorhynchus tshawytscha*	S, U	PCP (96%)	7.2-7.5	65.28	27.78	-	Johnson and Finley 1980
Chinook salmon (1 g), *Oncorhynchus tshawytscha*	S, U	NaPCP (90%)	7.2-7.5	56.53	24.06	25.85	Johnson and Finley 1980
Rainbow trout (1-3 g), *Salmo gairdneri*	S, U	NaPCP	6.96	85	53.54	-	Davis and Hoos 1975
Rainbow trout (1-3 g), *Salmo gairdneri*	S, U	NaPCP	7.0	89	53.85	-	Davis and Hoos 1975
Rainbow trout (1-3 g), *Salmo gairdneri*	S, U	NaPCP	7.0	46	27.83	-	Davis and Hoos 1975
Rainbow trout (1-3 g), *Salmo gairdneri*	S, U	NaPCP	7.02	92	54.55	-	Davis and Hoos 1975

Table 1. (Continued)

Species	Method*	Chemical**	pH	LC50 or EC50 (µg/L)***	Adjusted LC50 or EC50 (µg/L)****	Species Mean Acute Value (µg/L)*****	Reference
Rainbow trout (1-3 g), *Salmo gairdneri*	S, U	NaPCP	5.7	44	98.32	-	Davis and Hoos 1975
Rainbow trout (1-3 g), *Salmo gairdneri*	S, U	NaPCP	7.0	69	41.75	-	Davis and Hoos 1975
Rainbow trout (1.0 g), *Salmo gairdneri*	S, U	-	7.0	75	45.38	-	Bentley et al. 1975
Rainbow trout (1.0 g), *Salmo gairdneri*	S, U	-	7.5	92	33.68	-	Bentley et al. 1975
Rainbow trout (0.3-0.4 g), *Salmo gairdneri*	S, U	NaPCP	6.2-6.8	83	83.00	-	Vigers and Maynard 1977
Rainbow trout (1 g), *Salmo gairdneri*	S, U	PCP (96%)	7.2-7.5	49.92	21.25	-	Johnson and Finley 1980
Rainbow trout (1 g), *Salmo gairdneri*	S, U	NaPCP (90%)	7.2-7.5	45.72	19.46	-	Johnson and Finley 1980
Rainbow trout (10 wk), *Salmo gairdneri*	F, U	PCP (99+%)	7.4	66	26.71	-	Dominguez and Chapman 1984
Rainbow trout (embryo; 0 h), *Salmo gairdneri*	R, U	PCP (97%)	7.2	3,000	1,485	-	Van Leeuwen et al. 1985
Rainbow trout (embryo; 24 h), *Salmo gairdneri*	R, U	PCP (97%)	7.2	1,300	643.3	-	Van Leeuwen et al. 1985
Rainbow trout (early eyed embryo; 14 d), *Salmo gairdneri*	R, U	PCP (97%)	7.2	3,000	1,485	-	Van Leeuwen et al. 1985
Rainbow trout (late eyed embryo; 28 d), *Salmo gairdneri*	R, U	PCP (97%)	7.2	480	237.5	-	Van Leeuwen et al. 1985
Rainbow trout (sac fry; 42 d), *Salmo gairdneri*	R, U	PCP (97%)	7.2	32	15.84	-	Van Leeuwen et al. 1985

Table 1. (Continued)

Species	Method*	Chemical**	pH	LC50 or EC50 (µg/L)***	Adjusted LC50 or EC50 (µg/L)****	Species Mean Acute Value (µg/L)*****	Reference
Rainbow trout (early fry; 77 d), Salmo gairdneri	R, U	PCP (97%)	7.2	18	8.907	-	Van Leeuwen et al. 1985
Rainbow trout (0.81 g), Salmo gairdneri	S, M	PCP (99+%)	7.5	47.2	17.28	-	Brook et al. Manuscript
Rainbow trout (1.2-7.9 g), Salmo gairdneri	F, M	NaPCP	8.0-8.3	210	38.04	-	Fogels and Sprague 1977
Rainbow trout (1-4 g), Salmo gairdneri	F, M	PCP	7.6-8.2	160	39.18	-	Hodson et al. 1984; McCarty et al. 1985
Rainbow trout (0.6-8.0 g), Salmo gairdneri	F, M	PCP (99%)	7.85	115	29.61	35.34	Thurston et al. 1985
Brook trout (adult), Salvelinus fontinalis	F, M	PCP (99+%)	7.89	138	34.13	34.13	Cardwell et al. 1976
Goldfish (2.36 g), Carassius auratus	F, M	NaPCP	7.81	210	56.29	-	Adelman and Smith 1976
Goldfish (2.57 g), Carassius auratus	F, M	NaPCP	7.78	220	60.78	-	Adelman and Smith 1976
Goldfish (1.46 g), Carassius auratus	F, M	NaPCP	7.77	230	64.18	-	Adelman and Smith 1976
Goldfish (1.50 g), Carassius auratus	F, M	NaPCP	7.75	210	59.79	-	Adelman and Smith 1976
Goldfish (1.55 g), Carassius auratus	F, M	NaPCP	7.62	170	55.16	-	Adelman and Smith 1976
Goldfish (1.40 g), Carassius auratus	F, M	NaPCP	7.68	170	51.93	-	Adelman and Smith 1976
Goldfish (2.46 g), Carassius auratus	F, M	NaPCP	7.54	220	77.36	-	Adelman and Smith 1976
Goldfish (2.70 g), Carassius auratus	F, M	NaPCP	7.59	230	76.91	-	Adelman and Smith 1976
Goldfish (1.66 g), Carassius auratus	F, M	NaPCP	7.58	240	81.06	-	Adelman and Smith 1976

Table 1. (Continued)

Species	Method*	Chemical**	pH	LC50 or EC50 (µg/L)***	Adjusted LC50 or EC50 (µg/L)****	Species Mean Acute Value (µg/L)*****	Reference
Goldfish (1.74), *Carassius auratus*	F, M	NaPCP	7.59	240	80.25	-	Adelman and Smith 1976
Goldfish (1.69 g), *Carassius auratus*	F, M	NaPCP	7.58	200	67.55	-	Adelman and Smith 1976
Goldfish (1.65 g), *Carassius auratus*	F, M	NaPCP	7.60	190	62.90	-	Adelman and Smith 1976
Goldfish (2.31 g), *Carassius auratus*	F, M	NaPCP	7.83	290	76.19	-	Adelman and Smith 1976
Goldfish (2.31 g), *Carassius auratus*	F, M	NaPCP	7.84	300	78.03	-	Adelman and Smith 1976
Goldfish (1.76 g), *Carassius auratus*	F, M	NaPCP	7.73	200	58.10	-	Adelman and Smith 1976
Goldfish (1.54 g), *Carassius auratus*	F, M	NaPCP	7.76	250	70.47	-	Adelman and Smith 1976
Goldfish (1-2 g), *Carassius auratus*	F, M	NaPCP	-	247†††	-	-	Adelman and Smith 1976; Adelman et al. 1976a
Goldfish (2-4 g), *Carassius auratus*	F, M	NaPCP	-	190†††	-	-	Adelman and Smith 1976; Adelman et al. 1976a
Goldfish (1.9 g), *Carassius auratus*	F, M	Dowicide EC-7 (88% PCP)	7.1-7.8	117	47.36	-	Phipps and Holcombe 1985
Goldfish (1.2 g), *Carassius auratus*	F, M	Dowicide EC-7 (88% PCP)	7.1-7.8	156	63.14	-	Phipps and Holcombe 1985
Goldfish (1.7 g), *Carassius auratus*	F, M	Dowicide EC-7 (88% PCP)	7.1-7.8	191	77.31	-	Phipps and Holcombe 1985
Goldfish (1.0-4.0 g), *Carassius auratus*	F, M	PCP (99%)	7.94	328	77.15	-	Thurston et al. 1985
Goldfish (1.0-4.0 g), *Carassius auratus*	F, M	PCP (99%)	7.84	200	52.02	65.53	Thurston et al. 1985
Common carp (8 mm), *Cyprinus carpio*	R, U	NaPCP	7.2	8.8	4.355	4.355	Verma et al. 1981c

Table 1. (Continued)

Species	Method*	Chemical**	pH	LC50 or EC50 (µg/L)***	Adjusted LC50 or EC50 (µg/L)****	Species Mean Acute Value (µg/L)*****	Reference
Fathead minnow (4-8 wk), *Pimephales promelas*	S, U	PCP	-	600	-	-	Mattson et al. 1976
Fathead minnow (1.1 g), *Pimpehales promelas*	S, U	PCP (96%)	7.2-7.5	196.8	83.76	-	Johnson and Finley 1980
Fathead minnow (40 d), *Pimephales promelas*	F, U	PCP (99%)	7.4	470	190.2	-	Cleveland et al. 1982
Fathead minnow (14-30 d), *Pimephales promelas*	S, U	NaPCP	7.7	18	5.389	-	Hall et al. 1986
Fathead minnow (adult), *Pimephales promelas*	F, M	-	7.92-8.20	194 (15°C)	40.45	-	Ruesink and Smith 1975
Fathead minnow (adult), *Pimephales promelas*	F, M	-	7.81-8.20	314 (25°C)	69.54	-	Ruesink and Smith 1975
Fathead minnow (11 wk), *Pimephales promelas*	F, M	NaPCP	7.82	200	53.08	-	Adelman and Smith 1976
Fathead minnow (11 wk), *Pimephales promelas*	F, M	NaPCP	7.83	180	47.29	-	Adelman and Smith 1976
Fathead minnow (11 wk), *Pimephales promelas*	F, M	NaPCP	7.72	220	64.56	-	Adelman and Smith 1976
Fathead minnow (11 wk), *Pimephales promelas*	F, M	NaPCP	7.72	180	52.82	-	Adelman and Smith 1976
Fathead minnow (11 wk), *Pimephales promelas*	F, M	NaPCP	7.69	190	57.46	-	Adelman and Smith 1976
Fathead minnow (11 wk), *Pimephales promelas*	F, M	NaPCP	7.68	210	64.15	-	Adelman and Smith 1976
Fathead minnow (11 wk), *Pimephales promelas*	F, M	NaPCP	7.86	220	56.08	-	Adelman and Smith 1976
Fathead minnow (11 wk), *Pimephales promelas*	F, M	NaPCP	7.78	180	49.73	-	Adelman and Smith 1976
Fathead minnow (11 wk), *Pimephales promelas*	F, M	NaPCP	7.59	190	63.53	-	Adelman and Smith 1976

Table 1. (Continued)

Species	Method*	Chemical**	pH	LC50 or EC50 (µg/L)***	Adjusted LC50 or EC50 (µg/L)****	Species Mean Acute Value (µg/L)*****	Reference
Fathead minnow (11 wk), *Pimephales promelas*	F, M	NaPCP	7.62	190	61.65	-	Adelman and Smith 1976
Fathead minnow (11 wk), *Pimephales promelas*	F, M	NaPCP	7.65	240	75.56	-	Adelman and Smith 1976
Fathead minnow (11 wk), *Pimephales promelas*	F, M	NaPCP	7.65	200	62.96	-	Adelman and Smith 1976
Fathead minnow (11 wk), *Pimephales promelas*	F, M	NaPCP	7.63	200	64.24	-	Adelman and Smith 1976
Fathead minnow (11 wk), *Pimephales promelas*	F, M	NaPCP	7.58	190	64.18	-	Adelman and Smith 1976
Fathead minnow (11 wk), *Pimephales promelas*	F, M	NaPCP	7.83	270	70.94	-	Adelman and Smith 1976
Fathead minnow (11 wk), *Pimephales promelas*	F, M	NaPCP	7.82	230	61.04	-	Adelman and Smith 1976
Fathead minnow (11 wk), *Pimephales promelas*	F, M	NaPCP	-	227†††	-	-	Adelman and Smith 1976; Adelman et al. 1976a
Fathead minnow (11 wk), *Pimephales promelas*	F, M	NaPCP	-	203†††	-	-	Adelman and Smith 1976; Adelman et al. 1976a
Fathead minnow (4 wk), *Pimephales promelas*	F, M	NaPCP	-	198††††	-	-	Adelman and Smith 1976; Adelman et al. 1976a
Fathead minnow (7 wk), *Pimephales promelas*	F, M	NaPCP	-	230††††	-	-	Adelman and Smith 1976; Adelman et al. 1976a
Fathead minnow (11 wk), *Pimephales promelas*	F, M	NaPCP	-	222††††	-	-	Adelman and Smith 1976; Adelman et al. 1976a
Fathead minnow (14 wk), *Pimephales promelas*	F, M	NaPCP	-	190††††	-	-	Adelman and Smith 1976; Adelman et al. 1976a
Fathead minnow (3 mo), *Pimephales promelas*	F, M	PCP (99+%)	7.83	285	74.88	-	Cardwell et al. 1976
Fathead minnow (30-35 d), *Pimephales promelas*	F, M	-	7.41-8.33	220	55.52	-	Phipps et al. 1981

Table 1. (Continued)

Species	Method*	Chemical**	pH	LC50 or EC50 (µg/L)***	Adjusted LC50 or EC50 (µg/L)****	Species Mean Acute Value (µg/L)*****	Reference
Fathead minnow (30-35 d), _Pimephales promelas_	F, M	-	7.41-8.33	230	58.05	-	Phipps et al. 1981
Fathead minnow (30-35 d), _Pimephales promelas_	F, M	-	7.41-8.33	232	58.55	-	Hall et al. 1984
Fathead minnow (juvenile), _Pimephales promelas_	F, M	Dowicide EC-7 (88% PCP)	6.5	95	95.00	-	Spehar et al. 1985
Fathead minnow (juvenile), _Pimephales promelas_	F, M	Dowicide EC-7 (88% PCP)	7.5	218	79.80	-	Spehar et al. 1985
Fathead minnow (juvenile), _Pimephales promelas_	F, M	Dowicide EC-7 (88% PCP)	8.0	261	57.80	-	Spehar et al. 1985
Fathead minnow (juvenile), _Pimephales promelas_	F, M	Dowicide EC-7 (88% PCP)	8.5	378	50.65	-	Spehar et al. 1985
Fathead minnow (0.5 g), _Pimephales promelas_	F, M	Dowicide EC-7 (88% PCP)	7.1-7.8	223	90.26	-	Phipps and Holcombe 1985
Fathead minnow (0.4 g), _Pimephales promelas_	F, M	Dowicide EC-7 (88% PCP)	7.1-7.8	286	115.76	-	Phipps and Holcombe 1985
Fathead minnow (0.4 g), _Pimephales promelas_	F, M	Dowicide EC-7 (88% PCP)	7.1-7.8	244	98.76	-	Phipps and Holcombe 1985
Fathead minnow (0.2-1.0 g), _Pimephales promelas_	F, M	PCP (99%)	8.01	266	58.32	63.11	Thurston et al. 1985
Channel catfish (0.8 g), _Ictalurus punctatus_	S, U	PCP (96%)	7.2-7.5	65.28	27.78	-	Johnson and Finley 1980
Channel catfish (0.8 g), _Ictalurus punctatus_	S, U	NaPCP (90%)	7.2-7.5	64.01	27.24	-	Johnson and Finley 1980
Channel catfish (1.4 g), _Ictalurus punctatus_	F, M	Dowicide EC-7 (88% PCP)	7.1-7.8	<53	<21.45[††]	-	Phipps and Holcombe 1985
Channel catfish (1.4 g), _Ictalurus punctatus_	F, M	Dowicide EC-7 (88% PCP)	7.1-7.8	54	21.86	-	Phipps and Holcombe 1985
Channel catfish (1.9 g), _Ictalurus punctatus_	F, M	Dowicide EC-7 (88% PCP)	7.1-7.8	54	21.86	-	Phipps and Holcombe 1985

Table 1. (Continued)

Species	Method*	Chemical**	pH	LC50 or EC50 (µg/L)***	Adjusted LC50 or EC50 (µg/L)****	Species Mean Acute Value (µg/L)*****	Reference
Channel catfish (0.3-4.0 g), *Ictalurus punctatus*	F, M	PCP (99%)	7.71	132	39.12	26.54	Thurston et al. 1985
Flagfish (0.1-0.3 g), *Jordanella floridae*	F, M	NaPCP (79%)	8.0-8.3	1,610	291.6	291.6	Fogels and Sprague 1977
Mosquitofish (0.1-1.0 g), *Gambusia affinis*	F, M	PCP (99%)	8.05	288	60.62	-	Thurston et al. 1985
Mosquitofish (0.1-1.0 g), *Gambusia affinis*	F, M	PCP (99%)	8.02	278	60.34	60.50	Thurston et al. 1985
Guppy (young), *Poecilia reticulata*	-	PCP	-	720	-	-	Adema and Vink 1981
Guppy (young), *Poecilia reticulata*	-	PCP	-	880	-	-	Adema and Vink 1981
Guppy (adult), *Poecilia reticulata*	-	PCP	-	450	-	-	Adema and Vink 1981
Guppy, *Poecilia reticulata*	R, M	-	7.0	400	242.0	-	Salkinoja-Salonen et al. 1981
Guppy (0.04-0.06 g), *Poecilia reticulata*	R, U	PCP	5	42.6	192.4	-	Saarikoski and Viluksela 1981,1982
Guppy (0.04-0.06 g), *Poecilia reticulata*	R, U	PCP	6	117	193.4	-	Saarikoski and Viluksela 1981,1982
Guppy (0.04-0.06 g), *Poecilia reticulata*	R, U	PCP	7	442	267.4	-	Saarikoski and Viluksela 1981,1982
Guppy (0.04-0.06 g), *Poecilia reticulata*	R, U	PCP	8	911	201.8	-	Saarikoski and Viluksela 1981, 1982
Guppy (0.0875 g), *Poecilia reticulata*	R, U	PCP	8.1	970	194.3	-	Gupta et al. 1982a
Guppy (0.0875 g), *Poecilia reticulata*	R, U	NaPCP	8.1	711	142.4	-	Gupta et al. 1982a
Guppy, *Poecilia reticulata*	R, U	PCP	7.7	204	61.08	-	Khangarot 1983

Table 1. (Continued)

Species	Method*	Chemical**	pH	LC50 or EC50 (µg/L)***	Adjusted LC50 or EC50 (µg/L)****	Species Mean Acute Value (µg/L)*****	Reference
Guppy (juvenile), <u>Poecilia reticulata</u>	R, U	PCP	7.2	1,020	504.7	195.4	Brown et al. 1985
Bluegill (1.1 g), <u>Lepomis macrochirus</u>	S, U	-	7.0	60	36.30	-	Bentley et al. 1975
Bluegill (1.1 g), <u>Lepomis macrochirus</u>	S, U	-	7.5	77	28.19	-	Bentley et al. 1975
Bluegill (6 mo), <u>Lepomis macrochirus</u>	R, U	PCP	7.2-7.7	260	105.23	-	Pruitt et al. 1977; Pierce 1978
Bluegill (6 mo), <u>Lepomis macrochirus</u>	R, U	PCP	7.2-7.7	305	123.5	-	Pruitt et al. 1977; Pierce 1978
Bluegill (0.4 g), <u>Lepomis macrochirus</u>	S, U	PCP (96%)	7.2-7.5	30.72	13.07	-	Johnson and Finley 1980
Bluegill (0.4 g), <u>Lepomis macrochirus</u>	S, U	NaPCP (90%)	7.2-7.5	36.58	15.57	-	Johnson and Finley 1980
Bluegill (0.2 g), <u>Lepomis macrochirus</u>	F, M	Dowicide EC-7 (88% PCP)	7.1-7.8	150	60.71	-	Phipps and Holcombe 1985
Bluegill (0.3 g), <u>Lepomis macrochirus</u>	F, M	Dowicide EC-7 (88% PCP)	7.1-7.8	152	61.52	-	Phipps and Holcombe 1985
Bluegill (0.4 g), <u>Lepomis macrochirus</u>	F, M	Dowicide EC-7 (88% PCP)	7.1-7.8	115	46.55	-	Phipps and Holcombe 1985
Bluegill (0.3-2.0 g), <u>Lepomis macrochirus</u>	F, M	PCP (99%)	8.03	202	43.41	56.41	Thurston et al. 1985
Largemouth bass (14 d), <u>Micropterus salmoides</u>	R, U	PCP (99%)	7.2	287	142.0	-	Johansen et al. 1985
Largemouth bass (28 d), <u>Micropterus salmoides</u>	R, U	PCP (99%)	7.2	275	136.1	-	Johansen et al. 1985
Largemouth bass (49 d), <u>Micropterus salmoides</u>	R, U	PCP (99%)	7.2	136	67.30	-	Johansen et al. 1985
Largemouth bass (84 d), <u>Micropterus salmoides</u>	R, U	PCP (99%)	7.2	189	93.53	105.0	Johansen et al. 1985
Bullfrog (tadpole), <u>Rana catesbeiana</u>	F, M	PCP (99%)	8.3	207	44.48	44.48	Thurston et al. 1985

Table 1. (Continued)

Species	Method*	Chemical**	Salinity (g/kg)	LC50 or EC50 (µg/L)***	Species Mean Acute Value (µg/L)	Reference
			SALTWATER SPECIES			
Polychaete worm (adult), Nereis arenaceodentata	S, U	PCP (98%)	28	435	435	Rubenstein 1981
Polychaete worm (3-d larva), Ophryotrocha diadema	R, M	PCP	33	620	-	Adema and Vink 1981; Hooftman and Vink 1980
Polychaete worm (adult), Ophryotrocha diadema	R, M	PCP	33	1,200	862.6	Adema and Vink 1981; Hooftman and Vink 1980
Oligochaete worm (adult), Limnodriloides verrucosus	R, U	NaPCP	20 (10°C, pH 6)	64.43[†,††]	-	Chapman et al. 1982b
Oligochaete worm (adult), Limnodriloides verrucosus	R, U	NaPCP	20 (10°C, pH 7)	230.1	397.2	Chapman et al. 1982a,b
Oligochaete worm (adult), Limnodriloides verrucosus	R, U	NaPCP	20 (10°C, pH 8)	441.8[†]	-	Chapman et al. 1982b
Oligochaete worm (adult), Limnodriloides verrucosus	R, U	NaPCP	20 (1°C, pH 7)	644.4[†]	-	Chapman et al. 1982b
Oligochaete worm, Monopheleophorus cuticulatus	R, U	NaPCP	20 (1°C, pH 7)	1,473[†]	-	Chapman et al. 1982b
Oligochaete worm, Monopheleophorus cuticulatus	R, U	NaPCP	20 (10°C, pH 7)	487.9	-	Chapman et al. 1982a,b
Oligochaete worm, Monopheleophorus cuticulatus	R, U	NaPCP	20 (20°C, pH 7)	492.5[†]	-	Chapman et al. 1982b
Oligochaete worm, Monopheleophorus cuticulatus	R, U	NaPCP	20 (10°C, pH 6)	423.4[†,††]	-	Chapman et al. 1982b
Oligochaete worm, Monopheleophorus cuticulatus	R, U	NaPCP	20 (10°C, pH 8)	635.6[†]	-	Chapman et al. 1982b
Oligochaete worm, Monopheleophorus cuticulatus	R, U	NaPCP	10 (10°C, pH 7)	340.6[†]	598.2	Chapman et al. 1982b

Table 1. (Continued)

Species	Method*	Chemical**	Salinity (g/kg)	LC50 or EC50 (µg/L)***	Species Mean Acute Value (µg/L)	Reference
Oligochaete worm, *Tubificoides gabriellae*	R, U	NaPCP	20 (10°C, pH 7)	423.4	423.4	Chapman et al. 1982a
Common Atlantic slippershell (larva), *Crepidula fornicata*	Averaged results from S, R, F; M	PCP	-	1,200	1,200	Adema and Vink 1981
Blue mussel (adult), *Mytilus edulis*	Averaged results from S, R, F; M	PCP	-	18,000††	-	Adema and Vink 1981
Blue mussel (embryo), *Mytilus edulis*	S, U	NaPCP	24	328.8†††††	328.8	Woelke 1972
Pacific oyster (embryo), *Crassostrea gigas*	S, U	NaPCP	-	40.83†††††	40.83	Woelke 1972
Eastern oyster (embryo), *Crassostrea virginica*	S, U	NaPCP	17	36.95	-	Borthwick and Schimmel 1978
Eastern oyster (embryo), *Crassostrea virginica*	S, U	PCP (98%)	30	430	-	Zaroogian 1981
Eastern oyster (embryo), *Crassostrea virginica*	S, U	PCP (98%)	30	49	-	Zaroogian 1981
Eastern oyster (embryo), *Crassostrea virginica*	S, U	PCP (98%)	30	>180	-	Zaroogian 1981
Eastern oyster (embryo), *Crassostrea virginica*	S, U	PCP (98%)	30	640	††††††	Zaroogian 1981
Copepod (adult), *Pseudodiaptomus coronatus*	S, U	NaPCP	18	62.81	62.81	Hauch et al. 1980
Copepod (adult), *Temora longicornus*	Averaged results from S, R, F; M	PCP	-	170	170	Adema and Vink 1981
Brown shrimp (adult), *Penaeus aztecus*	F, M	NaPCP	26.5	>195	>195	Schimmel et al. 1978

Table 1. (Continued)

Species	Method*	Chemical**	Salinity (g/kg)	LC50 or EC50 (µg/L)***	Species Mean Acute Value (µg/L)	Reference
Pink shrimp (adult), *Penaeus duorarum*	S, U	PCP	25	5,600	5,600	Bentley et al. 1975
Grass shrimp (adult intermolt), *Palaemonetes pugio*	R, U	NaPCP	10	2,431[††]	-	Conklin and Rao 1978a
Grass shrimp (adult early premolt), *Palaemonetes pugio*	R, U	NaPCP	10	2,534[††]	-	Conklin and Rao 1978a
Grass shrimp (adult late premolt), *Palaemonetes pugio*	R, U	NaPCP	10	402.7	-	Conklin and Rao 1978a,b
Grass shrimp (24-hr larva), *Palaemonetes pugio*	S, U	NaPCP	24	599.5	-	Borthwick and Schimmel 1978
Grass shrimp (juvenile), *Palaemonetes pugio*	F, M	NaPCP	24.3	>515.0[††]	491.3	Schimmel et al. 1978
Pacific herring (day 1 yolk sac larva), *Clupea harengus pallasi*	S, U	NaPCP	24-27	147.8[†,††]	-	Vigers et al. 1978
Pacific herring (day 12 larva), *Clupea harengus pallasi*	S, U	NaPCP	24-27	63.74[†,††]	-	Vigers et al. 1978
Pacific herring (day 52 larva), *Clupea harengus pallasi*	S, U	NaPCP	24-27	23.09[†]	-	Vigers et al. 1978
Pacific herring (day 180 juvenile), *Clupea harengus pallasi*	S, U	NaPCP	24-27	27.71[†]	25.29	Vigers et al. 1978
Sheepshead minnow (1-day juvenile), *Cyprinodon variegatus*	S, U	PCP	10	329	-	Borthwick and Schimmel 1978

Table 1. (Continued)

Species	Method*	Chemical**	Salinity (g/kg)	LC50 or EC50 (µg/L)***	Species Mean Acute Value (µg/L)	Reference
Sheepshead minnow (2-week juvenile), *Cyprinodon variegatus*	S, U	PCP	10	392	-	Borthwick and Schimmel 1978
Sheepshead minnow (4-week juvenile), *Cyprinodon variegatus*	S, U	PCP	10	240	-	Borthwick and Schimmel 1978
Sheepshead minnow (6-week juvenile), *Cyprinodon variegatus*	S, U	PCP	10	223	-	Borthwick and Schimmel 1978
Sheepshead minnow (2-week juvenile) *Cyprinodon variegatus*	S, U	Dowicide (79% NaPCP)	24	376.5	-	Borthwick and Schimmel 1978
Sheepshead minnow (juvenile), *Cyprinodon variegatus*	F, M	PCP	24	442	442	Parrish et al. 1978
Longnose killifish (juvenile), *Fundulus similis*	F, M	NaPCP	22.9	>306	>306	Schimmel et al. 1978
Pinfish (larva), *Lagodon rhomboides*	S, U	NaPCP	26	35.10	-	Borthwick and Schimmel 1978
Pinfish (larva), *Lagodon rhomboides*	S, U	Dowicide (79% NaPCP)	26	48.16	-	Borthwick and Schimmel 1978
Pinfish (adult), *Lagodon rhomboides*	F, M	NaPCP	20.8	53.2	53.2	Schimmel et al. 1978
Striped mullet (juvenile), *Mugil cephalus*	F, M	NaPCP	25.5	112.1	112.1	Schimmel et al. 1978

Table 1. (Continued)

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

** PCP = pentachlorophenol; NaPCP = sodium pentachlorophenate. Percent purity is given in parentheses when available.

*** Results are expressed as pentachlorophenol. 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%.

**** Freshwater LC50s and EC50s were adjusted to pH = 6.5 using the pooled slope of 1.005 (see text).

***** Freshwater Species Mean Acute Values are at pH = 6.5.

† Interpolated from graph.

†† Not used in calculation of Species Mean Acute Value.

††† Mean of three LC50s.

†††† Mean of four LC50s.

††††† Calculated using moving average method and author's raw data.

†††††† No Species Mean Acute Value calculated because acute values are too divergent for this species.

Results of Covariance Analysis of Freshwater Acute Toxicity versus pH

Species	n	Slope	95% Confidence Limits		Degrees of Freedom
Simocephalus vetulus	4	0.760	0.128,	1.393	2
Crangonyx pseudogracilis	4	1.164	0.844,	1.484	2
Gammarus pseudolimnaeus	4	1.129	-0.319,	2.578	2
Fathead minnow	4	0.678	0.413,	0.943	2
Guppy	4	1.052	0.710,	1.394	2
All of above	20	1.005*	0.841,	1.169	14

* P = 0.28 for equality of slopes.

Table 2. Chronic Toxicity of Pentachlorophenol to Aquatic Animals

Species	Test*	Chemical**	pH	Limits (µg/L)***	Chronic Value (µg/L)	Adjusted Chronic Value (µg/L)****	Reference
			FRESHWATER SPECIES				
Snail, *Physa gyrina*	LC	Dowicide EC-7 (93.7% PCP)	7.4-7.7	<26[†]	<26	<8.607	Hedtke et al. 1986
Cladoceran, *Ceriodaphnia reticulata*	LC	Dowicide EC-7 (93.7% PCP)	7.3	<22[†]	<22	<9.846	Hedtke et al. 1986
Cladoceran, *Ceriodaphnia reticulata*	LC	Dowicide EC-7 (93.7% PCP)	7.3	<4.1[†]	<4.1	<1.835	Hedtke et al. 1986
Cladoceran, *Daphnia magna*	LC	PCP	-	180-320	240	-	Adema 1978
Cladoceran, *Simocephalus vetulus*	LC	Dowicide EC-7 (93.7% PCP)	7.3	119-264	177.2	79.66	Hedtke et al. 1986
Cladoceran, *Simocephalus vetulus*	LC	Dowicide EC-7 (93.7% PCP)	7.9-8.4[††]	137-357	221.2	40.03	Hedtke et al. 1986
Rainbow trout, *Salmo gairdneri*	ELS	PCP (99+%)	7.4	11-19	14.46	5.666	Dominguez and Chapman 1984
Fathead minnow, *Pimephales promelas*	ELS	PCP (Reagent grade)	7.2-7.9	44.9-73.0	57.25	18.94	Holcombe et al. 1982
Fathead minnow, *Pimephales promelas*	ELS	Dowicide EC-7 (88% PCP)	6.5	16.5-34.6	23.89	23.89	Spehar et al. 1985

Table 2. (Continued)

Species	Test*	Chemical**	pH	Limits (µg/L)***	Chronic Value (µg/L)	Adjusted Chronic Value (µg/L)****	Reference
Fathead minnow, *Pimephales promelas*	ELS	Dowicide EC-7 (88% PCP)	7.5	27.6-58.2	40.08	14.64	Spehar et al. 1985
Fathead minnow, *Pimephales promelas*	ELS	Dowicide EC-7 (88% PCP)	8.0	32.0-75.0	48.99	10.85	Spehar et al. 1985
Fathead minnow, *Pimephales promelas*	ELS	Dowicide EC-7 (88% PCP)	8.5	63.7-125.0	89.23	11.92	Spehar et al. 1985
				SALTWATER SPECIES			
Sheepshead minnow, *Cyprinodon variegatus*	LC	PCP	-	47-88	64.31	-	Parrish et al. 1978

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

** PCP = pentachlorophenol. Percent purity is given in parentheses when available.

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

****Freshwater chronic values were adjusted to pH = 6.5 using the pooled slope of 1.005 (see text).

† Unacceptable effects occurred at all concentrations tested.

†† Controlled daily pH fluctuation consisting of 16 hours at 8.4 and 8 hours at 7.9.

Table 2. (Continued)

Acute-Chronic Ratio

Species	pH	Acute Value (µg/L)	Chronic Value (µg/L)	Ratio
Snail, *Physa gyrina*	7.2-7.7	267	<26	>10.27
Cladoceran, *Ceriodaphnia reticulata*	7.3	150	<22	>6.818
Cladoceran, *Ceriodaphnia reticulata*	7.3	150	<4.1	>36.59
Cladoceran, *Daphnia magna*	-	600	240	2.500
Cladoceran, *Simocephalus vetulus*	7.3	160	177.2	0.9029
Cladoceran, *Simocephalus vetulus*	7.9-8.4	196	221.2	0.8861
Rainbow trout, *Salmo gairdneri*	7.4	66	14.46	4.564
Fathead minnow, *Pimephales promelas*	7.1-8.3	224.9*	57.25	3.928
Fathead minnow, *Pimephales promelas*	6.5	95	23.89	3.977
Fathead minnow, *Pimephales promelas*	7.5	218	40.08	5.439
Fathead minnow, *Pimephales promelas*	8.0	261	48.99	5.328
Fathead minnow, *Pimephales promelas*	8.5	378	89.23	4.236
Sheepshead minnow, *Cyprinodon variegatus*	-	442	64.31	6.873

* Geometric mean of 2 acute values obtained by Phipps et al. (1981) (see Table 1).

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		
33	>43,920	Crayfish, *Orconectes immunis*	>43,920	-
32	11,260	Midge, *Tanytarsus dissimilis*	11,260	-
31	10,610	Sciomyzid, *Sepedon fuscipennis*	10,610	-
30	417.7	Tubificid worm, *Rhyacodrilus montana*	417.7	-
29	408.2	Tubificid worm, *Stylodrilus heringianus*	408.2	-
28	403.2	Snail, *Gillia altilis*	403.2	-
27	361.6	Tubificid worm, *Spirosperma ferox*	239.5	-
		Tubificid worm, *Spirosperma nikolskyi*	545.8	-
26	317.5	Tubificid worm, *Quistradrilus multisetosus*	317.5	-
25	291.6	Flagfish, *Jordanella floridae*	291.6	-
24	224.2	Tubificid worm, *Tubifex tubifex*	224.2	-
23	182.5	Tubificid worm, *Limnodrilus hoffmeisteri*	182.5	-
22	172.1	Amphipod, *Crangonyx pseudogracilis*	172.1	-
21	195.4	Guppy, *Lebistes reticulata*	195.4	-

Table 3. (Continued)

Rank*	Genus Mean Acute Value (µg/L)	Species	Species Mean Acute Value (µg/L)**	Species Mean Acute-Chronic Ratio***
20	155.9	Tubificid worm, *Branchiura sowerbyi*	155.9	-
19	132.1	Snail, *Physa gyrina*	132.1	>10.27
18	121.1	Amphipod, *Gammarus pseudolimnaeus*	122.1	-
17	105.0	Largemouth bass, *Micropterus salmoides*	105.0	-
16	87.48	Amphipod, *Hyalella azteca*	87.48	-
15	78.10	Cladoceran, *Daphnia pulex*	90.83	-
		Cladoceran, *Daphnia magna*	67.15	2.500
14	67.13	Cladoceran, *Ceriodaphnia reticulata*	67.13	>15.79[†]
13	65.53	Goldfish, *Carassius auratus*	65.53	-
12	63.11	Fathead minnow, *Pimephales promelas*	63.11	4.535[††]
11	60.50	Mosquitofish, *Gambusia affinis*	60.50	-
10	60.43	Snail, *Aplexa hypnorum*	60.43	-
9	58.47	Tubificid worm, *Varichaeta pacifica*	58.47	-
8	57.72	Cladoceran, *Simocephalus vetulus*	57.72	0.8945[†]

Table 3. (Continued)

Rank*	Genus Mean Acute Value (µg/L)	Species	Species Mean Acute Value (µg/L)**	Species Mean Acute-Chronic Ratio***
7	56.41	Bluegill, <u>Lepomis macrochirus</u>	56.41	-
6	44.48	Bullfrog, <u>Rana catesbiana</u>	44.48	-
5	35.34	Rainbow trout, <u>Salmo gairdneri</u>	35.34	4.564
4	34.13	Brook trout, <u>Salvelinus fontinalis</u>	34.13	-
3	30.01	Coho salmon, <u>Oncorhynchus kisutch</u>	31.82	-
		Sockeye salmon, <u>Oncorhynchus nerka</u>	32.85	-
		Chinook salmon, <u>Oncorhynchus tshawytscha</u>	25.85	-
2	26.54	Channel catfish, <u>Ictalurus punctatus</u>	26.54	-
1	4.355	Common carp, <u>Cyprinus carpio</u>	4.355	-
		SALTWATER SPECIES		
17	1,200	Common Atlantic slippershell, <u>Crepidula fornicata</u>	1,200	-
16	>1,045	Brown shrimp, <u>Penaeus aztecus</u>	>195	-
		Pink shrimp, <u>Penaeus duorarum</u>	5,600	-
15	862.6	Polychaete worm, <u>Ophryotrocha diadema</u>	862.6	-

Table 3. (Continued)

Rank*	Genus Mean Acute Value (µg/L)	Species	Species Mean Acute Value (µg/L)**	Species Mean Acute-Chronic Ratio***
14	598.2	Oligochaete worm, *Monopylephorus cuticulatus*	598.2	-
13	491.3	Grass shrimp, *Palaemonetes pugio*	491.3	-
12	442	Sheepshead minnow, *Cyprinodon variegatus*	442	6.873
11	435	Polychaete worm, *Nereis arenaceodentata*	435	-
10	423.4	Oligochaete worm, *Tubificoides gabriellae*	423.4	-
9	397.2	Oligochaete worm, *Limnodriloides verrucosus*	397.2	-
8	328.8	Blue mussel, *Mytilus edulis*	328.8	-
7	>306	Longnose killifish, *Fundulus similis*	>306	-
6	170	Copepod, *Temora longicornis*	170	-
5	112.1	Striped mullet, *Mugil cephalus*	112.1	-
4	62.81	Copepod, *Pseudodiaptomus coronatus*	62.81	-
3	53.2	Pinfish, *Lagodon rhomboides*	53.2	-
2	40.83	Pacific oyster, *Crassostrea gigas*	40.83	-

Table 3. (Continued)

Rank*	Genus Mean Acute Value (µg/L)	Species	Species Mean Acute Value (µg/L)**	Species Mean Acute-Chronic Ratio***
1	25.29	Pacific herring, <u>Clupea harengus pallasi</u>	25.29	-

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

** From Table 1.

*** From Table 2.

† Geometric mean of two values in Table 2.

†† Geometric mean of five values in Table 2.

Table 3. (Continued)

Fresh water

Final Acute Value = 10.97 µg/L (at pH = 6.5)

Criterion Maximum Concentration = (10.97 µg/L) / 2 = 5.485 µg/L (at pH = 6.5)

Pooled Slope = 1.005 (see Table 1)

ln(Criterion Maximum Intercept) = ln(5.485) - [slope x 6.5]

= 1.702 - (1.005 x 6.5) = -4.830

Criterion Maximum Concentration = $e^{[1.005(pH)-4.830]}$

Final Acute-Chronic Ratio = 3.166 (see text)

Final Chronic Value = (10.97 µg/L) / 3.166 = 3.465 µg/L (at pH = 6.5)

ln(Final Chronic Intercept) = ln(3.465) - [slope x 6.5]

= 1.243 - (1.005 x 6.5) = -5.290

Final Chronic Value = $e^{[1.005(pH)-5.290]}$

Salt water

Final Acute Value = 25.05 µg/L

Criterion Maximum Concentration = (25.05 µg/L) / 2 = 12.52 µg/L

Final Acute-Chronic Ratio = 3.166 (see text)

Final Chronic Value = (25.05 µg/L) / 3.166 = 7.912 µg/L

Table 4. Toxicity of Pentachlorophenol to Aquatic Plants

Species	Chemical*	pH	Duration (days)	Effect	Concentration (µg/L)**	Reference
			FRESHWATER SPECIES			
Alga, *Chlorella vulgaris*	NaPCP (98%)	-	11	EC50	600	Burrell et al. 1985
Alga, *Chlorella pyrenoidosa*	-	7.0	3	EC100 (chlorosis)	7.5	Huang and Gloyna 1967
Alga, *Chlorella pyrenoidosa*	PCP	-	4	EC50 (growth)	7,000	Adema and Vink 1981
Alga, *Scenedesmus quadricauda*	PCP	-	4	EC50 (growth)	80	Adema and Vink 1981
Alga, *Scenedesmus subspicatus*	PCP (99%)	7.0	4	EC50	90	Geyer et al. 1985
Alga, *Selenastrum capricornutum*	NaPCP	-	7	Reduced growth	50	Adams et al. 1985
Alga, *Selenastrum capricornutum*	PCP	-	4	EC50 (growth)	290	Crossland and Wolff 1985
Alga, *Selenastrum capricornutum*	PCP	-	4	EC50 (growth)	312	Richter 1982
Alga, *Ankistrodesmus braunii*	NaPCP (98%)	-	11	EC50	830	Burrell et al. 1985
Duckweed, *Lemna minor*	-	5.1	2	EC50 (chlorosis)	189.1	Blackman et al. 1955
			SALTWATER SPECIES			
Green alga, *Chlamydomonas* sp.	PCP	-	4	EC50 (population growth)	1,400	Adema and Vink 1981
Green alga, *Dunaliella tertiolecta*	PCP	30***	4	EC50 (population growth)	206	Walsh et al. 1982
Green alga, *Dunaliella tertiolecta*	PCP	30***	4	EC50 (population growth)	170	Walsh et al. 1982
Green alga, *Dunaliella* sp.	PCP	-	4	EC50 (population growth)	3,600	Adema and Vink 1981

Table 4. (Continued)

Species	Chemical*	pH	Duration (days)	Effect	Concentration (µg/L)**	Reference
Golden brown alga, *Monochrysis* sp.	PCP	-	4	EC50 (population growth)	200	Adema and Vink 1981
Diatom, *Skeletonoma costatum*	PCP	30***	4	EC50 (population growth)	20.30	Walsh et al. 1982
Diatom, *Skeletonema costatum*	PCP	30***	4	EC50 (population growth)	17.40	Walsh et al. 1982
Diatom, *Skeletonema costatum*	PCP	30***	4	EC50 (population growth)	17.80	Walsh et al. 1982
Diatom, *Thalassiosira pseudonana*	PCP	30***	4	EC50 (population growth)	205	Walsh et al. 1982
Diatom, *Thalassiosira pseudonana*	PCP	30***	4	EC50 (population growth)	189	Walsh et al. 1982
Diatom, *Thalassiosira pseudonana*	PCP	30***	4	EC50 (population growth)	179	Walsh et al. 1982
Diatom, *Phaeodactylum tricornutum*	PCP	-	4	EC50 (population growth)	3,000	Adema and Vink 1981
Giant kelp (young fronds), *Macrocystis pyrifera*	NaPCP (Santobrite)	-	4	EC50 (photosynthetic activity)	277.1	Clendenning and North 1959

* PCP = pentachlorophenol; NaPCP = sodium pentachlorophenate. Percent purity is given in parentheses when available.

** Results are expressed as pentachlorophenol. 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%.

*** Salinity (g/kg), not pH.

Table 5. Bioaccumulation of Pentachlorophenol by Aquatic Organisms

Species	Chemical*	Concentration in Water (µg/L)**	pH	Duration (days)	Tissue	BCF or BAF***	Reference
FRESHWATER SPECIES							
Rainbow trout (400 g), *Salmo gairdneri*	PCP (Reagent grade)	0.035	-	115	****	406	Niimi and McFadden 1982
Rainbow trout (400 g), *Salmo gairdneri*	PCP (Reagent grade)	0.660	-	115	****	168	Niimi and McFadden 1982
Fathead minnow (6 mo), *Pimephales promelas*	-	-	7.49	32	Whole body	770	Veith et al. 1979
Fathead minnow (0.5-1.5 g), *Pimephales promelas*	PCP (99%)	50	-	31	Whole body	163	Huckins and Petty 1983
Fathead minnow (0.5-1.5 g), *Pimephales promelas*	PCP (88%)	50	-	31	Whole body	211	Huckins and Petty 1983
Fathead minnow (juvenile), *Pimephales promelas*	Dowicide EC-7 (88% PCP)	3.1-34.6	6.5	32	Whole body	1,066	Spehar et al. 1985
Fathead minnow (juvenile), *Pimephales promelas*	Dowicide EC-7 (88% PCP)	5.6-58.2	7.5	32	Whole body	434	Spehar et al. 1985
Fathead minnow (juvenile), *Pimephales promelas*	Dowicide EC-7 (88% PCP)	12.7-161.0	8.0	32	Whole body	426	Spehar et al. 1985
Fathead minnow (juvenile), *Pimephales promelas*	Dowicide EC-7 (88% PCP)	29.3-125.0	8.5	32	Whole body	281	Spehar et al. 1985
Bluegill (6 mo), *Lepomis macrochirus*	PCP	100	7.2-7.7	16	Muscle	7.3	Pruitt et al. 1977; Pierce 1978
SALTWATER SPECIES							
Eastern oyster (adult), *Crassostrea virginica*	NaPCP	25	-	28	Soft tissue	41	Schimmel et al. 1978
Eastern oyster (adult), *Crassostrea virginica*	NaPCP	2.5	-	28	Soft tissue	78	Schimmel et al. 1978

Table 5. (Continued)

Species	Chemical*	Concentration in Water (µg/L)**	pH	Duration (days)	Tissue	BCF or BAF***	Reference
Eastern oyster (adult), *Crassostrea virginica*	NaPCP	3.7±1.4	-	Steady state	Soft tissue	82	Schimmel and Garnas 1985
Eastern oyster (adult), *Crassostrea virginica*	NaPCP	9.5±3.4	-	Steady state	Soft tissue	34	Schimmel and Garnas 1985
Eastern oyster (adult), *Crassostrea virginica*	NaPCP	11.3±1.7	-	Steady state	Soft tissue	76	Schimmel and Garnas 1985
Sheepshead minnow (embryo), *Cyprinodon variegatus*	PCP	18-195	-	Parents exposed 133-142 days	Whole body	19.39†	Parrish et al. 1978
Sheepshead minnow (juvenile), *Cyprinodon variegatus*	PCP	18-195	-	28	Whole body	31.56†	Parrish et al. 1978
Sheepshead minnow (adult), *Cyprinodon variegatus*	PCP	18-195	-	151	Whole body	10.75†	Parrish et al. 1978
Longnose killifish, *Fundulus similis*	PCP	57-120	-	7 (Steady state)	Whole body	64	Trujillo et al. 1982

* PCP = pentachlorophenol; NaPCP = sodium pentachlorophenate. Percent purity is given in parentheses when available.

** Measured concentration of pentachlorophenol.

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

**** Whole body minus intestines, liver, and gall bladder.

† Geometric mean of values from four test concentrations.

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

Species	Chemical*	pH	Duration	Effect	Concentration (µg/L)**	Reference
FRESHWATER SPECIES						
Alga, *Scenedesmus pannonicus*	PCP	-	4 days	Reduced biomass	100-320	Slooff and Canton 1983
Pond phytoplankton community	PCP	-	10 days	Community structural change	1,000	Boyle et al. 1984
Vascular plant, *Elodea canadensis*	Dowicide EC-7 (93.7% PCP)	7.7-8.2	21 days	Reduced growth (river water)	380	Hedtke et al. 1986
Duckweed, *Lemna minor*	PCP	-	7 days	Reduced specific growth rate	1,000-3,200	Slooff and Canton 1983
Duckweed, *Lemna minor*	Dowicide EC-7 (93.7% PCP)	7.7-8.2	21 days	Reduced growth (river water)	>1,440	Hedtke et al. 1986
Bacterium, *Pseudomonas fluorescens*	PCP	-	0.3 days	Reduced specific growth rate	1,000-3,200	Slooff and Canton 1983
Cyanobacterium, *Microcystis aeruginosa*	PCP	-	4 days	Reduced specific growth rate	1,000-3,200	Slooff and Canton 1983
Detritus mixed microbial community	Dowicide EC-7 (88% PCP)	-	56 days	Reduction in biomass and activity	8,131	Fairchild et al. 1984
Amoeba, *Amoeba proteus*	-	4.5	30 min	Reduced survival	1,332	Smith and Ord 1979
Ciliate protozoan, *Colpidium campylum*	-	-	43 hr	Minimal active dose	600	Dive et al. 1980
Hydra, *Hydra oligactis*	PCP (>98%)	-	48 hr	LC50	730	Slooff 1983
Hydra, *Hydra oligactis*	PCP	-	21 days	Reduced specific growth rate	32-100	Slooff and Canton 1983
Planarian, *Dugesia lugubris*	PCP (>98%)	-	48 hr	LC50	130	Slooff 1983

Table 6. (Continued)

Species	Chemical*	pH	Duration	Effect	Concentration (µg/L)**	Reference
Rotifer, *Brachionus rubens*	-	-	24 hr	LC50	160	Halbach et al. 1983
Rotifer, *Brachionus rubens*	PCP	-	5 days	LC100	200	Halbach 1984
Rotifer, *Brachionus rubens*	PCP	-	23 days	Reduced population density	50	Halbach 1984
Tubificid worm, *Branchiura sowerbyi*	NaPCP	7.0	96 hr	LC50 (with sediment)	515.5	Chapman et al. 1982a
Tubificid worm, *Limnodrilus hoffmeisteri*	NaPCP	7.0	96 hr	LC50 (with sediment)	1,150	Chapman et al. 1982a
Tubificid worm, *Quistradrilus multisetosus*	NaPCP	7.0	96 hr	LC50 (with sediment)	846.9	Chapman et al. 1982a
Tubificid worm, *Spirosperma nikolskyi*	NaPCP	7.0	96 hr	LC50 (with sediment)	3,314	Chapman et al. 1982a
Tubificid worm, *Stylodrilus heringianus*	NaPCP	7.0	96 hr	LC50 (with sediment)	1,243	Chapman et al. 1982a
Tubificid worm, *Tubifex tubifex*	NaPCP	7.0	96 hr	LC50 (with sediment)	754.8	Chapman et al. 1982a
Mixed tubificid worms, *Tubifex tubifex* and *Limnodrilus hoffmeisteri*	NaPCP	7.0	96 hr	LC50	533.9	Chapman et al. 1982c
Mixed tubificid worms, *Tubifex tubifex* and *Limnodrilus hoffmeisteri*	NaPCP	7.5	24 hr	LC50	290	Whitley 1968
Mixed tubificid worms, *Tubifex tubifex* and *Limnodrilus hoffmeisteri*	NaPCP	8.5	24 hr	LC50	620	Whitley 1968
Mixed tubificid worms, *Tubifex tubifex* and *Limnodrilus hoffmeisteri*	NaPCP	9.5	24 hr	LC50	1,290	Whitley 1968

Table 6. (Continued)

Species	Chemical*	pH	Duration	Effect	Concentration (µg/L)**	Reference
Snail, *Lymnaea stagnalis*	PCP (>98%)	-	48 hr	LC50	560	Slooff 1983
Snail, *Lymnaea stagnalis*	PCP	-	40 days	Reduced hatching	3.2-10	Slooff and Canton 1983
Snail, *Physa gyrina*	Dowicide EC-7 (93.7% PCP)	7.7-7.9	96 hr	LC50 (river water)	1,380	Hedtke et al. 1986
Snail, *Physa gyrina*	Dowicide EC-7 (93.7% PCP)	7.8-8.5	12 wk	Reduced population density	365	Zischke et al.1985
Snail, *Physa gyrina*	Dowicide EC-7 (93.7% PCP)	7.6-8.0	96 hr	LC50 (river water)	1,250	Hedtke et al. 1986
Snail, *Physa gyrina*	Dowicide EC-7 (93.7% PCP)	7.7-8.1	96 hr	LC50 (river water)	730	Hedtke and Arthur 1985; Hedtke et al. 1986
Snail, *Physa gyrina*	Dowicide EC-7 (93.7% PCP)	8.2-8.4	96 hr	LC50 (river water)	620	Hedtke et al. 1986
Snail, *Physa gyrina*	Dowicide EC-7 (93.7% PCP)	8.0-8.2	96 hr	LC50 (river water)	220	Hedtke et al. 1986
Snail, *Physa gyrina*	Dowicide EC-7 (93.7% PCP)	7.9-8.1	96 hr	LC50 (river water)	260	Hedtke et al. 1986
Snail, *Physa gyrina*	Dowicide EC-7 (93.7% PCP)	7.8-7.9	96 hr	LC50 (river water)	580	Hedtke et al. 1986
Snail, *Physa gyrina*	Dowicide EC-7 (93.7% PCP)	7.7-7.9	96 hr	LC50 (river water)	810	Hedtke et al. 1986
Cladoceran, *Ceriodaphnia affinis/dubia*	Dowicide EC-7 (93.7% PCP)	7.9-8.0	7 days	MATC (river water)	110	Hedtke et al. 1986
Cladoceran, *Ceriodaphnia affinis/dubia*	Dowicide EC-7 (93.7% PCP)	8.0	48 hr	LC50 (river water)	307	Hedtke et al. 1986
Cladoceran, *Ceriodaphnia affinis/dubia*	Dowicide EC-7 (93.7% PCP)	7.9-8.0	48 hr	LC50 (river water)	347	Hedtke et al. 1986

Table 6. (Continued)

Species	Chemical*	pH	Duration	Effect	Concentration (µg/L)**	Reference
Cladoceran, *Ceriodaphnia reticulata*	Dowicide EC-7 (93.7% PCP)	7.8-7.9	48 hr	LC50 (river) water)	240	Hedtke et al. 1986
Cladoceran, *Ceriodaphnia reticulata*	Dowicide EC-7 (93.7% PCP)	7.8-8.0	48 hr	LC50 (river water)	700	Hedtke et al. 1986
Cladoceran, *Daphnia magna*	PCP	-	21 days	LC50	480	Adema 1978
Cladoceran, *Daphnia magna*	PCP	-	21 days	LC50	510	Adema 1978
Cladoceran, *Daphnia magna*	PCP	-	21 days	LC50	400	Adema 1978
Cladoceran, *Daphnia magna*	PCP	-	21 days	LC50	470	Adema 1978
Cladoceran, *Daphnia magna*	PCP	-	21 days	LC50	430	Adema 1978
Cladoceran, *Daphnia magna*	PCP	-	21 days	LC50	490	Adema 1978
Cladoceran, *Daphnia magna*	PCP	-	21 days	LC50	170	Adema 1978
Cladoceran, *Daphnia magna*	PCP	-	21 days	LC50	190	Adema 1978
Cladoceran, *Daphnia magna*	PCP	-	14 days	LC50	440	Adema 1978
Cladoceran, *Daphnia magna*	PCP	-	14 days	LC50	460	Adema 1978
Cladoceran, *Daphnia magna*	PCP	-	21 days	No effect on reproduction	340	Adema and Vink 1981
Cladoceran, *Daphnia magna*	PCP	-	21 days	Reduced survival and reproduction	100-320	Slooff and Canton 1983

Table 6. (Continued)

Species	Chemical*	pH	Duration	Effect	Concentration (µg/L)**	Reference
Cladoceran (<24 hr), *Daphnia magna*	-	-	16 days	EC50 (reproduction)	150	Hermens et al. 1984
Cladoceran (6 d), *Daphnia magna*	PCP (99+%)	7.9	48 hr	EC50 (river water)	254	Brooke et al. Manuscript
Cladoceran (6 d), *Daphnia magna*	PCP (99+%)	7.6	48 hr	EC50 (river water)	599	Brooke et al. Manuscript
Cladoceran, *Simocephalus vetulus*	Dowicide EC-7 (93.7% PCP)	7.8-7.9	48 hr	LC50 (river water)	670	Hedtke and Arthur 1985; Hedtke et al. 1986
Cladoceran, *Simocephalus vetulus*	Dowicide EC-7 (93.7% PCP)	8.0	48 hr	LC50 (river water)	204	Hedtke et al. 1986
Isopod, *Asellus racovitzai*	Dowicide EC-7 (93.7% PCP)	7.7-7.9	96 hr	LC50 (river water)	>7,770	Hedtke et al. 1986
Isopod, *Asellus racovitzai*	Dowicide EC-7 (93.7% PCP)	7.6-8.0	96 hr	LC50 (river water)	4,320	Hedtke et al. 1986
Isopod, *Asellus racovitzai*	Dowicide EC-7 (93.7% PCP)	7.7-8.1	96 hr	LC50 (river water)	2,370	Hedtke and Arthur 1985; Hedtke et al. 1986
Isopod, *Asellus racovitzai*	Dowicide EC-7 (93.7% PCP)	7.8-7.9	96 hr	LC50 (river water)	3,400	Hedtke et al. 1986
Amphipod, *Crangonyx pseudogracilis*	Dowicide EC-7 (93.7% PCP)	7.7-7.9	96 hr	LC50 (river water)	3,120	Hedtke et al. 1986
Amphipod, *Crangonyx pseudogracilis*	Dowicide EC-7 (93.7% PCP)	7.7-8.1	96 hr	LC50 (river water)	2,770	Hedtke et al. 1986
Amphipod, *Crangonyx pseudogracilis*	Dowicide EC-7 (93.7% PCP)	7.7-8.1	96 hr	LC50 (river water)	1,890	Hedtke and Arthur 1985; Hedtke et al. 1986
Amphipod, *Crangonyx pseudogracilis*	Dowicide EC-7 (93.7% PCP)	8.2-8.4	96 hr	LC50 (river water)	500	Hedtke et al. 1986
Amphipod, *Crangonyx pseudogracilis*	Dowicide EC-7 (93.7% PCP)	8.0-8.1	96 hr	LC50 (river water)	320	Hedtke et al. 1986

Table 6. (Continued)

Species	Chemical*	pH	Duration	Effect	Concentration (µg/L)**	Reference
Amphipod, *Crangonyx pseudogracilis*	Dowicide EC-7 (93.7% PCP)	8.0-8.1	96 hr	LC50 (river water)	220	Hedtke et al. 1986
Amphipod, *Crangonyx psedogracilis*	Dowicide EC-7 (93.7% PCP)	7.8-7.9	96 hr	LC50 (river water)	1,550	Hedtke et al. 1985
Amphipod, *Crangonyx pseudogracilis*	Dowicide EC-7 (93.7% PCP)	7.7-7.9	96 hr	LC50 (rver water)	2,000	Hedtke et al. 1986
Amphipod (11 mm), *Gammarus pseudolimnaeus*	PCP (99+%)	7.9	96 hr	LC50 (river water)	451	Brooke et al. Manuscript
Amphipod (11 mm), *Gammarus pseudolimnaeus*	PCP (99+%)	7.6	96 hr	LC50 (river water)	450	Brooke et al. Manuscript
Amphipod, *Hyalella azteca*	PCP (99+%)	7.9	96 hr	LC50 (river water)	286	Brooke et al. Manuscript
Amphipod, *Hyalella azteca*	PCP (99+%)	7.6	96 hr	LC50 (river water)	353	Brooke et al. Manuscript
Mayfly, *Callibaetis skokianus*	Dowicide EC-7 (93.7% PCP)	7.5-7.7	96 hr	LC50 (river water)	1,780	Hedtke and Arthur 1985; Hedtke et al. 1986
Mayfly, *Callibaetis skokianus*	Dowicide EC-7 (93.7% PCP)	7.8-7.9	96 hr	LC50 (river water)	1,300	Hedtke et al. 1986
Mayfly (larvae), *Cloeon dipterum*	PCP (>98%)	-	48 hr	LC50	5,900	Slooff 1983
Caddisfly, *Philarctus quaeris*	Dowicide EC-7 (93.7% PCP)	7.5-7.7	96 hr	LC50 (river water)	1,260	Hedtke and Arthur 1985; Hedtke et al. 1986
Sciomyzid fly (1st instar), *Sepedon fuscipennis*	NaPCP (90%)	-	96 hr	LC50 (fed)	2,200	McCoy and Joy 1977
Mosquito (1st instar), *Culex pipiens*	PCP	-	25 days	Reduced survival and development	3,200-10,000	Slooff and Canton 1983

Table 6. (Continued)

Species	Chemical*	pH	Duration	Effect	Concentration (µg/L)**	Reference
Midge (4th instar), *Chironomus riparius*	PCP (97%)	7.0	24 hr (15°C) (25°C) (35°C)	LC50	1,176 1,556 631	Fisher 1986
Midge (4th instar), *Chironomus riparius*	PCP (reagent grade)	4.0 6.0 9.0	24 hr	LC50	384 465 1,948	Fisher and Wadleigh 1986
Sockeye salmon (<1 yr), *Oncorhynchus nerka*	NaPCP	6.8	21 days	LC50	57	Webb and Brett 1973
Sockeye salmon (<1 yr), *Oncorhynchus nerka*	NaPCP	6.8	42 days	10% growth inhibition	3.2	Webb and Brett 1973
Sockeye salmon (<1 yr), *Oncorhynchus nerka*	NaPCP	6.8	56 days	EC50 (growth)	1.74	Webb and Brett 1973
Sockeye salmon (<1 yr), *Oncorhynchus nerka*	NaPCP	6.8	56 days	EC50 (food conversion)	1.80	Webb and Brett 1973
Chinook salmon (juvenile), *Oncorhynchus tschawytscha*	NaPCP	7.0-7.1	96 hr	LC50 (high loading)	72	Iwama and Greer 1979
Chinook salmon (juvenile), *Oncorhynchus tschawytscha*	-	6.5-6.9	8 days	LC100 (with bacterial disease injection)	36	Iwama and Greer 1982
Rainbow trout (alevin), *Salmo gairdneri*	Santobrite (>90% NaPCP)	-	20 days	11% growth inhibition	28	Chapman 1969
Rainbow trout (alevin), *Salmo gairdneri*	Santobrite (>90% NaPCP)	-	20 days	18% growth inhibition	28	Chapman 1969
Rainbow trout (alevin), *Salmo gairdneri*	Santobrite (>90% NaPCP)	-	21 days	18% growth inhibition	28	Chapman 1969

Table 6. (Continued)

Species	Chemical*	pH	Duration	Effect	Concentration (µg/L)**	Reference
Rainbow trout (alevin), *Salmo gairdneri*	Santobrite (>90% NaPCP)	-	28 days	12% growth inhibition	28	Chapman 1969
Rainbow trout (embryo and alevin), *Salmo gairdneri*	Santobrite (>90% NaPCP)	-	41 days	LC100	46	Chapman 1969
Rainbow trout, *Salmo gairdneri*	Santobrite (>90% NaPCP)	7.8	Fertilization and yolk sac resorption	25% mortality	18	Chapman and Shumway 1978
Rainbow trout (alevin), *Salmo gairdneri*	Santobrite (>90% NaPCP)	7.8	71 days	9.1% growth reduction	18	Chapman and Shumway 1978
Rainbow trout, *Salmo gairdneri*	-	-	28 days	27% growth inhibition	7.4	Matida et al. 1976
Rainbow trout (2.1-11.4 g), Nisqually strain, *Salmo gairdneri*	-	7.4-7.7	8.8 hr	Median survival time	250	Alexander and Clarke 1978
Rainbow trout (2.1-11.4 g), Idaho strain, *Salmo gairdneri*	-	7.4-7.7	7.1 hr	Median survival time	250	Alexander and Clarke 1978
Rainbow trout, *Salmo gairdneri*	-	8.0	24 hr	Increased respiration	70	Slooff 1979
Rainbow trout, *Salmo gairdneri*	NaPCP	7.78-7.89	4 wk post swim-up	Biomass reduction (lower temperature)	20-80	Hodson and Blunt 1981
Rainbow trout, *Salmo gairdneri*	NaPCP	7.96-8.08	4 wk post swim-up	Biomass reduction (higher temperature)	>16	Hodson and Blunt 1981
Rainbow trout (0.81 g), *Salmo gairdneri*	PCP	7.9	96 hr	LC50 (river water)	70.1	Brooke et al. Manuscript

Table 6. (Continued)

Species	Chemical*	pH	Duration	Effect	Concentration (µg/L)**	Reference
Rainbow trout (0.81 g), *Salmo gairdneri*	PCP (99+%)	7.6	96 hr	LC50 (river water)	85.6	Brooke et al. Manuscript
Atlantic salmon, *Salmo salar*	NaPCP	-	24 hr	Altered temperature preference	46	Peterson 1976
Brown trout (4.5 g), *Salmo trutta*	PCP (99%)	-	24 hr	LC50	200	Hattula et al. 1981
Central stoneroller (10 g), *Campostoma anomalum*	NaPCP	7.6	4.3 hr	LC100	400	Goodnight 1942
Goldfish (1.5 g), *Carassius auratus*	PCP	-	24 hr	LC90	1,600	Lemma and Yau 1974
Goldfish (108.0 g), *Carassius auratus*	PCP	-	24 hr	LC90	1,600	Lemma and Yau 1974
Goldfish (adult), *Carassius auratus*	PCP (99+%)	7.59	46 hr	LC50	270	Cardwell et al. 1976
Goldfish (juvenile), *Carassius auratus*	NaPCP	7.59	21 hr	LC50	369	Cardwell et al. 1976
Goldfish (juvenile), *Carassius auratus*	NaPCP	7.59	120 hr	LC50	253	Cardwell et al. 1976
Goldfish (juvenile), *Carassius auratus*	NaPCP	7.59	336 hr	LC50	189	Cardwell et al. 1976
Goldfish (2 g), *Carassius auratus*	-	-	24 hr	LC50	270	Kobayashi et al. 1979
Goldfish (1.3 g), *Carassius auratus*	-	5.5	24 hr	LC50	52	Kobayashi and Kishino 1980
Goldfish (1.3 g), *Carassius auratus*	-	6	24 hr	LC50	60	Kobayashi and Kishino 1980
Goldfish (1.3 g), *Carassius auratus*	-	7	24 hr	LC50	82	Kobayashi and Kishino 1980

Table 6. (Continued)

Species	Chemical*	pH	Duration	Effect	Concentration (µg/L)**	Reference
Goldfish (1.3 g), *Carassius auratus*	-	8	24 hr	LC50	250	Kobayashi and Kishino 1980
Goldfish (1.3 g), *Carassius auratus*	-	9	24 hr	LC50	2,200	Kobayashi and Kishino 1980
Goldfish (1.3 g), *Carassius auratus*	-	10	24 hr	LC50	16,000	Kobayashi and Kishino 1980
Common carp (eyed embryo), *Cyprinus carpio*	PCP	-	24 hr	LC50	180	Hashimoto et al. 1982
Common carp (1-3 days), *Cyprinus carpio*	PCP	-	24 hr	LC50	140	Hashimoto et al. 1982
Common carp (5-6 days), *Cyprinus carpio*	PCP	-	24 hr	LC50	150	Hashimoto et al. 1982
Common carp (9-10 days), *Cyprinus carpio*	PCP	-	24 hr	LC50	130	Hashimoto et al. 1982
Common carp (17-19 days), *Cyprinus carpio*	PCP	-	24 hr	LC50	110	Hashimoto et al. 1982
Common carp (25-33 days), *Cyprinus carpio*	PCP	-	24 hr	LC50	100	Hashimoto et al. 1982
Common carp (50-60 days), *Cyprinus carpio*	PCP	-	24 hr	LC50	110	Hashimoto et al. 1982
Common carp (70-80 days), *Cyprinus carpio*	PCP	-	24 hr	LC50	110	Hashimoto et al. 1982
Common carp (15.1-28.8 g), *Cyprinus carpio*	PCP	-	50 min	LT50	3,000	Peer et al. 1983
Silverjaw minnow (2 g), *Ericymba buccata*	NaPCP	7.6	6.25 hr	LC100	400	Goodnight 1942
Redfin shiner (2 g), *Notropis umbratilis*	NaPCP	7.6	2.67 hr	LC100	600	Goodnight 1942

Table 6. (Continued)

Species	Chemical*	pH	Duration	Effect	Concentration (µg/L)**	Reference
Steelcolor shiner (2 g), <u>Notropis whipplei</u>	NaPCP	7.6	5.25 hr	LC100	400	Goodnight 1942
Bluntnose minnow (3 g), <u>Pimephales notatus</u>	NaPCP	7.6	7.45 hr	LC100	400	Goodnight 1942
Fathead minnow (2 inches), <u>Pimephales promelas</u>	NaPCP	7.4-7.5	24 hr	LC50	300-320	Crandall and Goodnight 1959
Fathead minnow (juvenile), <u>Pimephales promelas</u>	NaPCP	7.83	336 hr	LC50	153	Cardwell et al. 1976
Fathead minnow, <u>Pimephales promelas</u>	PCP	-	48 hr	LC50	210	Slooff 1982
Fathead minnow, <u>Pimephales promelas</u>	Dowicide EC-7 (93.7% PCP)	7.7-8.4	12 wk	Reduced growth and larval drift	111	Zischke et al. 1985
Fathead minnow (adult), <u>Pimephales promelas</u>	Dowicide EC-7 (93.7% PCP)	8.0-8.1	96 hr	LC50 (river water)	300	Hedtke et al. 1986
Fathead minnow (adult), <u>Pimephales promelas</u>	Dowicide EC-7 (93.7% PCP)	7.9-8.2	96 hr	LC50 (river water)	190	Hedtke et al. 1986
Fathead minnow (adult), <u>Pimephales promelas</u>	Dowicide EC-7 (93.7% PCP)	7.9-8.1	96 hr	LC50 (river water)	170	Hedtke et al. 1986
Fathead minnow (adult), <u>Pimephales promelas</u>	Dowicide EC-7 (93.7% PCP)	8.0-8.2	96 hr	LC50 (river water)	160	Hedtke et al. 1986
Fathead minnow (adult), <u>Pimephales promelas</u>	Dowicide EC-7 (93.7% PCP)	7.7-8.1	96 hr	LC50 (river water)	120	Hedtke et al. 1986
Fathead minnow (adult), <u>Pimephales promelas</u>	Dowicide EC-7 (93.7% PCP)	7.9-8.1	96 hr	LC50 (river water)	208	Hedtke and Arthur 1985; Hedtke et al. 1986
Fathead minnow (adult), <u>Pimephales promelas</u>	Dowicide EC-7 (93.7% PCP)	7.4-7.9	96 hr	LC50 (river water)	120	Hedtke et al. 1986
Fathead minnow (juvenile), <u>Pimephales promelas</u>	Dowicide EC-7 (93.7% PCP)	7.8-8.2	96 hr	LC50 (river) water)	396	Hedtke et al. 1986

Table 6. (Continued)

Species	Chemical*	pH	Duration	Effect	Concentration (µg/L)**	Reference
Fathead minnow (juvenile), *Pimephales promelas*	Dowicide EC-7 (93.7% PCP)	7.8-8.1	96 hr	LC50 (river water)	510	Hedtke et al. 1986
Fathead minnow (fry), *Pimephales promelas*	Dowicide EC-7 (93.7% PCP)	7.9-8.2	96 hr	LC50 (river water)	314	Hedtke et al. 1986
Fathead minnow (embryo), *Pimephales promelas*	Dowicide EC-7 (93.7% PCP)	7.8-8.1	96 hr	LC50 (river water)	465	Hedtke et al. 1986
Fathead minnow (embryo), *Pimephales promelas*	Dowicide EC-7 (93.7% PCP)	8.0-8.1	96 hr	LC50 (river water)	480	Hedtke et al. 1986
Fathead minnow (embryo, fry), *Pimephales promelas*	Dowicide EC-7 (93.7% PCP)	7.8-8.1	32 days	Reduced survival or growth (river water)	118-176	Hedtke et al. 1986
Fathead minnow (<2 wk), *Pimephales promelas*	PCP (purified; 99%)	7.4	90 days	Decreased growth 24%	85	Cleveland et al. 1982
				Decreased growth 18%	142	
Fathead minnow (<2 wk), *Pimephales promelas*	Dowicide EC-7 (91%)	7.4	90 days	Increased growth 18%	60	Cleveland et al. 1982
				Increased growth 21%	139	
Fathead minnow (<2 wk), *Pimephales promelas*	PCP (industrial composite)	7.4	90 days	Decreased growth 20%	13	Cleveland et al. 1982
				Decreased growth 40%	27	
				100% mortality	67	
Fathead minnow (7 day), *Pimephales promelas*	PCP (ultrapure)	7.4	90 days	Reduced growth 10%	66	Hamilton et al. 1986
				Reduced growth 17%	130	
Creek chub (12 g), *Semotilus atromaculatus*	NaPCP	7.6	3.92 hr	LC100	600	Goodnight 1942
White sucker, *Catostomus commersoni*	Dowicide EC-7 (93.7% PCP)	7.7-8.2	96 hr	LC50 (river water)	85	Hedtke et al. 1986

Table 6. (Continued)

Species	Chemical[a]	pH	Duration	Effect	Concentration (µg/L)[a]	Reference
Blackstripe topminnow (3 g), *Fundulus notatus*	NaPCP	7.6	9.75 hr	LC100	800	Goodnight 1942
Guppy, *Poecilia reticulata*	NaPCP	8.4-8.6	180 days	Damaged liver and kidney	462	Crandall and Goodnight 1962,1963
Guppy, *Poecilia reticulata*	PCP	-	60 days	No effect on growth	180	Adema and Vink 1981
Guppy, *Poecilia reticulata*	PCP	-	28 days	Reduced growth	100-320	Slooff and Canton 1983
Guppy (2-3 mo), *Poecilia reticulata*	-	7.7	24 hr	LC50	40	Benoit-Guyod et al. 1984a
Threespine stickleback (0.6 g), *Gasterosteus aculeatus*	PCP	-	24 hr	LC90	370	Lemma and Yau 1974
Orangespotted sunfish (2 g), *Lepomis humilis*	NaPCP	7.6	6.75 hr	LC100	400	Goodnight 1942
Bluegill (juvenile), *Lepomis macrochirus*	PCP (99+%)	7.94	30 hr	LC50	303	Cardwell et al. 1976
Bluegill (juvenile), *Lepomis macrochirus*	PCP (99+%)	7.94	336 hr	LC50	215	Cardwell et al. 1976
Bluegill, *Lepomis macrochirus*	Dowicide EC-7 (93.7% PCP)	7.7-7.9	96 hr	LC50 (river water)	200	Hedtke and Arthur 1985; Hedtke et al. 1986
Bluegill, *Lepomis macrochirus*	Dowicide EC-7 (93.7% PCP)	7.8-7.9	96 hr	LC50 (river water)	270	Hedtke et al. 1986
Bluegill, *Lepomis macrochirus*	Dowicide EC-7 (93.7% PCP)	7.6-8.6	12 wk	Reduced growth and larval drift	40	Zischke et al. 1985

Table 6. (Continued)

Species	Chemical*	pH	Duration	Effect	Concentration (µg/L)**	Reference
Largemouth bass, *Micropterus salmoides*	-	7.0	<4 hr	Threshold opercular rhythm response	47 50	Morgan 1976, 1977
Largemouth bass (4.1 g), *Micropterus salmoides*	PCP (99%)	7.2	7 days	Reduced growth rate and food conversion efficiency	50.4	Mathers et al. 1985
Mozambique tilapia (2.0 g), *Tilapia mossambica*	PCP	-	24 hr	LC90	800	Lemma and Yau 1974
Leopard frog (tadpole), *Rana pipiens*	NaPCP	7.6	9.5 hr	LC100	800	Goodnight 1942
African clawed toad (3-4 wk), *Xenopus laevis*	-	-	48 hr	LC50	260	Slooff 1982; Slooff and Baerselman 1980
African clawed toad (<2 d), *Xenopus laevis*	PCP	-	100 days	Reduced survival and growth	32-100	Slooff and Canton 1983
			SALTWATER SPECIES			
Photoluminescent bacterium, *Photobacterium phosphoreum*	PCP	-	5 min	50 % reduction in light output	80	Curtis et al. 1982
Photoluminescent bacterium, *Photobacterium phosphoreum*	PCP	-	5 min	50 % reduction in light output	924	Ribo and Kaiser 1983
Microfungal populations in microcosms	PCP	10-17***	8 wk	Successional change in microfungal species composition	140	Cook et al. 1980
Golden brown alga, *Monochrysis lutheri*	NaPCP	28.9***	12-15 days	Decreased cell numbers	270.6	Woelke 1965
Diatom, *Skeletonema costatum*	PCP	25***	7 days	EC50 (cell division)	2,000	Erickson and Freeman 1978

Table 6. (Continued)

Species	Chemical*	Salinity (g/kg)	Duration	Effect	Concentration (µg/L)**	Reference
Diatom, *Thalassiosira pseudonana*	PCP	25	7 days	EC50 (cell division)	500	Erickson and Freeman 1978
Diatom, *Thalassiosira pseudonana*	PCP	26-29	24 hr	EC50 (cell division)	250	Erickson 1981
Diatom, *Thalassiosira pseudonana*	PCP	26-29	48 hr	EC50 (cell division)	300	Erickson 1981
Dinoflagellate, *Glenodinium halli*	PCP	25	7 days	EC50 (cell division)	1,000	Erickson and Freeman 1978
Microflagellate, *Isochrysis galbana*	PCP	25	7 days	EC50 (cell division)	250	Erickson and Freeman 1978
Sea grass, *Thalassia testudinum*	PCP	30	40 hr	EC50 (reduced oxygen evolution)	740	Walsh et al. 1982
Giant kelp, *Macrocystis pyrifera*	PCP	-	4 days	Photosynthesis inhibition	2,660	Lammering and Burbank 1960; reported in Buikema et al. 1979
Giant kelp, *Macrocystis pyrifera*	PCP	-	2 days	Photosynthesis inhibition	1,000	Lammering and Burbank 1960; reported in Buikema et al. 1979
Nematodes, (Meiobenthic communities)	Dowicide G-ST	-	9-13 wk	Decrease in biomass and density; shift in species composition	≥161	Cantelmo and Rao 1978b,c
Polychaete worm, *Nereis virens*	PCP	32-35	48 hr	Significant decrease in coelomic fluid osmolality, coupled with mortality	720	Carr and Neff 1981
Polychaete worm, *Nereis virens*	PCP	32-35	14 days	BCF = 280	-	Carr and Neff 1981

Table 6. (Continued)

Species	Chemical*	Salinity (g/kg)	Duration	Effect	Concentration (µg/L)**	Reference
Polychaete worm, *Nereis virens*	PCP	32-35	2 mo	Significant increase in ascorbic acid levels and significant decrease in glycogen reserves	100	Carr and Neff 1981
Polychaete worm, *Ophryotrocha diadema*	PCP	33	37 days	Apparent reduction in reproduction	≥98	Hooftman and Vink 1980
Polychaete worm, *Ophryotrocha diadema*	PCP	-	41 days	EC50 (reproduction)	23	Adema and Vink 1981
Polychaete worm, *Ophryotrocha diadema*	PCP	-	48 days	Apparent reduction in reproduction	≥11	Adema and Vink 1981
Polychaete worm (adult), *Arenicola cristata*	Dowicide G-ST	22-24	6 days	Reduced feeding activity	≥80	Rubinstein 1978
Japanese littleneck, *Tapes philippinarum*	PCP	-	120 days	Lethal	100	Tomiyama et al. 1962
Japanese littleneck, *Tapes philippinarum*	PCP	-	24 hr	BCF = 6 to 189 depending on tissue	-	Kobayashi et al. 1969
Common Atlantic slippershell (larva), *Crepidula fornicata*	PCP	-	7 days	LC50	460	Adema and Vink 1981
Blue mussel (larva), *Mytilus edulis*	NaPCP	28	48 hr	22.1% abnormal larvae	369.5	Dimick and Breese 1965; Woelke 1972
Blue mussel (larva), *Mytilus edulis*	NaPCP	24	48 hr	69.1% abnormal larvae	369.5	Dimick and Breese 1965; Woelke 1972

Table 6. (Continued)

Species	Chemical*	Salinity (g/kg)	Duration	Effect	Concentration (µg/L)**	Reference
Blue mussel, *Mytilus edulis*	PCP	-	14 days	LC50	750	Adema and Vink 1981
Eastern oyster (embryo), *Crassostrea virginica*	PCP	-	48 hr	100% abnormal larvae	250-5,000	Davis and Hidu 1969
Eastern oyster (larva), *Crassostrea virginica*	PCP	-	14 days	100% mortality	100-500	Davis and Hidu 1969
Eastern oyster (adult), *Crassostrea virginica*	NaPCP	20.3	192 hr	EC50 (growth)	76.50	Schimmel et al. 1978
Quahog clam, *Mercenaria mercenaria*	NaPCP	28-30	18 wk	Reduced resistance to bacterial infection	459.9	Anderson et al. 1981
Quahog clam, *Mercenaria mercenaria*	NaPCP	28-30	8 wk	BCF = 100	-	Anderson et al. 1981
Quahog clam, *Mercenaria mercenaria*	NaPCP	28-30	18 wk	BCF = 54	-	Anderson et al. 1981
Copepod, *Pseudodiaptomus coronatus*	NaPCP	18	96 hr	Significant increase in feeding rate	74.82	Hauch et al. 1980
Brown shrimp (adult), *Penaeus aztecus*	NaPCP	26.5	96 hr	BCF = 0.2165 (geometric mean of 4 values)	-	Schimmel et al. 1978
Grass shrimp (adult), *Palaemonetes pugio*	NaPCP	10	12 days	Histological changes (gill necrosis; loss of microvilli and epithelial rupture of midgut and hepatopancreas; and mitochondria compartmentalization)	923.7	Doughtie and Rao 1978; Rao and Doughtie 1984

Table 6. (Continued)

Species	Chemical*	Salinity (g/kg)	Duration	Effect	Concentration (µg/L)**	Reference
Grass shrimp (adult), Palaemonetes pugio	NaPCP	24.3	96 hr	BCF = 1.506 (geometric mean of 4 values)	-	Schimmel et al. 1978
Grass shrimp (post molt), Palaemonetes pugio	NaPCP	-	13 hr	100% mortality, 3 hrs after molt	4,618	Cantelmo et al. 1978
Grass shrimp (adult), Palaemonetes pugio	NaPCP	10	9 days	50% reduction in limb regeneration	436.9 521.9	Rao et al. 1978,1979, 1981
Grass shrimp (adult), Palaemonetes pugio	NaPCP	10	96 hr	Significant increase in exuvial dry weight	923	Brannon and Conklin 1978
Grass shrimp (adult), Palaemonetes pugio	NaPCP	-	24-36 hr	Significant increase or decrease in oxygen consumption followed by death	≥9.237	Cantelmo et al. 1978
Grass shrimp (adult, new molt), Palaemonetes pugio	PCP	10	1 hr	BCF = 150	-	Rao et al. 1981
Grass shrimp (adult, intermolt), Palaemonetes pugio	PCP	10	1 hr	BCF = 30	-	Rao et al. 1981
Longnose killifish, (juvenile), Fundulus similis	NaPCP	22.9	96 hr	BCF = 27.03 (geometric mean of 4 values)	-	Schimmel et al. 1978
Striped mullet, Mugil cephalus	NaPCP	25.5	96 hr	BCF = 7.446 (geometric mean of lowest two values)	-	Schimmel et al. 1978

Table 6. (Continued)

Species	Chemical*	Salinity (g/kg)	Duration	Effect	Concentration (µg/L)**	Reference
Striped mullet, *Mugil cephalus*	PCP	33	1-120 hr	Elevation of plasma cortisol concentration, hyperglycemia, depletion of liver glycogen, increase in liver ascorbate concentration	100-200	Thomas et al. 1981
Winter flounder, *Pseudopleuronectes americanus*	PCP	-	15 days	Elevated levels of acid-soluble thiol in liver	50	Thomas and Wofford 1984
Benthic macrofauna	PCP	27	5 wk	Significant reduction in species richness and faunal numbers	55	Tagatz et al. 1983
Benthic macrofauna	PCP	16.7	9 wk	Significant reduction in species richness and faunal numbers	76	Hansen and Tagatz 1980; Tagatz et al. 1977,1980
Benthic macrofauna	PCP	16.7	9 wk	No significant effects on colonization	7	Tagatz et al. 1977,1980
Benthic macrofauna	PCP	18	1 wk	Significant reduction in species richness and total faunal numbers	140 141	Tagatz et al. 1981
Benthic macrofauna	Dowicide G-ST	22	13 wk	Significant reduction in total faunal numbers	15.8	Hansen and Tagatz 1980; Tagatz et al. 1978,1980

Table 6. (Continued)

Species	Chemical*	Salinity (g/kg)	Duration	Effect	Concentration (µg/L)**	Reference
Benthic macrofauna	Dowicide G-ST	22	13 wk	No significant effect on colonization	1.8	Hansen and Tagatz 1980; Tagatz et al. 1978, 1980

* PCP = pentachlorophenol; NaPCP = sodium pentachlorophenate. Percent purity is given in parentheses when available.

** Results are expressed as pentachlorophenol. 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%.

** Salinity (g/kg), not pH.

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