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AMBIENT AQUATIC LIFE WATER QUALITY CRITERIA FOR DI-2-ETHYLHEXYL PHTHALATE

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NOTICES

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FOREWORD

Section 304(a)(1) of the Clean Water Act 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. Pursuant to that end, this document proposes water quality criteria for the protection of aquatic life. These criteria do not involve consideration of effects on human health.

This document is a draft, distributed for public review and comment. After considering all public comments and making any needed changes, EPA will issue the criteria in final form, at which time they will replace any previously published EPA aquatic life criteria for the same pollutant.

The term "water quality criteria" is used in two sections of the Clean Water Act, section 304(a)(1) and section 303(c)(2). In section 304, the term represents a non-regulatory, scientific assessment of 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, then they become maximum acceptable pollutant concentrations that can be used to derive enforceable permit limits for discharges to such waters.

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 before incorporation into water quality standards. Guidance is available from EPA to assist States in the modification of section 304(a)(1) criteria, and in the development of water quality standards. It is not until their adoption as part of State water quality standards that the criteria become regulatory.

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Introduction

The chemicals commonly known as phthalates are esters of phthalic acid (1,2-benzenedicarboxylic acid). Phthalates are widely used in the manufacture of plastics. Phthalates are interfused with high molecular weight polymers to increase flexibility, extensibility, and workability of the plastic. It is a major constituent of polyvinyl chloride (PVC) (Daniel 1978; Graham 1973). Di-2-ethylhexyl phthalate (DEHP), also known as bis(2-ethylhexyl) phthalate, is the most produced phthalate (U.S. EPA 1980). The term dioctyl phthalate (DOP) is sometimes used to refer to di-n-octyl phthalate, but is sometimes also used to refer to DEHP; the term DEHP only will be used herein.

DEHP is a component of many products found in homes and automobiles as well as in the medical and packaging industries. Its wide use and distribution, as well as its high volatility and persistence, lead to its common occurrence in fish, water, and sediments (Burns et al. 1981; Corcoran 1973; Glass 1975; Hites 1973; Lindsay 1977; Mayer et al. 1972; Morris 1970; Petersen and Freeman 1982; Ray et al. 1983; Swain 1978; Williams 1973; Zitko 1972,1973). DEHP has been detected in precipitation upon the remote Enewetok Atoll in the North Pacific Ocean (Atlas and Giam 1981). It occurs in sediments of Chesapeake Bay in concentration gradients proportional to the annual production of the compound (Peterson and Freeman 1982).

The reported values of the solubility limit of DEHP range from 50 to 1,300 $\mu g/L$; however, some of the best estimates of solubility are 360 $\mu g/L$ (Biesinger et al., Manuscript) and 400 $\mu g/L$ (Wolfe et al. 1980). The reported values of the log octanol-water partition coefficient range from 4.2 to 8.7 (Callahan et al. 1979; Fishbein and Albro 1972; Leyder and Boulanger 1983; Patty 1967).

Persistence of DEHP has been measured in freshwater hydrosoils (Johnson and Lulves 1975). Under aerobic conditions, the half-life was 14 days, whereas no degradation was observed in 30 days under anaerobic conditions. Wolfe et al. (1980a) found very little transformation and volatilization of DEHP in several computer simulated ecosystems.

A comprehension of the "Guidelines for Deriving Numerical National Water Quality Criteria for the Protection of Aquatic Organisms and Their Uses" (Stephan et al. 1985), hereinafter referred to as the Guidelines, and the response to public comment (U.S. EPA 1985a) is necessary to understand the following text, tables, and calculations. Results of such intermediate calculations as recalculated LC50s and Species Mean Acute Values are given to four significant figures to prevent roundoff error in subsequent calculations, not to reflect the precision of the value. The criteria presented herein supersede previous national aquatic life water quality criteria for DEHP (U.S. EPA 1976,1980) because these new criteria were derived using improved procedures and additional information. The latest comprehensive literature search for information for this document was conducted in February, 1986; some more recent information was included.

Acute Toxicity to Aquatic Animals

Some data that are available on the acute toxicity of DEHP are useable according to the Guidelines in the derivation of Final Acute Values (FAV) for DEHP (Table 1). In only four of twenty-one acute tests with freshwater animal species was enough toxicity observed to permit calculation of an acute value. In a 48-hr exposure of *Daphnia magna* the acute value was 11,000 $\mu g/L$ (LeBlanc 1980). Adams and Heidolph (1985) obtained a 48-hr EC50 of 2,000 $\mu g/L$ with the same species. Cary et al. (Manuscript) reported LC50s of 240,000 $\mu g/L$ for an amphipod and 2,100 $\mu g/L$ for larvae of a midge. In the other seventeen freshwater tests with five invertebrate species and five fish species little or no toxicity was observed at the highest tested concentrations, which ranged from 89 to 1,500,000 μg/L. In addition, DEHP was not lethal to the nonresident amphipod, Gammarus pulex, at concentrations up to 400 μg/L (Stephenson 1983).

The acute toxicity of DEHP has been determined with three species of saltwater animals (Table 1). No effects were detected at 300,000 μg/L with the harpacticoid copepod, Nitocra spinipes (Linden et al. 1979) nor at 550,000 μg/L with the sheepshead minnow, Cyprinodon variegatus (Heitmuller et al. 1981). DEHP concentrations as high as 450 μg/L were not lethal to larvae of the grass shrimp, Palaemonetes pugio (Laughlin et al. 1978).

Because so few quantitative Species Mean Acute Values are available for freshwater and saltwater species, the procedure described in the Guidelines cannot be used to calculate Final Acute Values. However, the data strongly suggest that acute toxicity does not occur at concentrations below the water solubility of DEHP (400 μg/L). The only uncertainties in this assessment are the two species, Hydra oligactis and Lumbriculus variegatus, for which the highest concentration tested was 89 μg/L. However, there is no reason to believe that these two species would have been affected by concentrations up to 400 μg/L. The Criterion Maximum Concentration for both fresh and salt water is set at 400 μg/L, although it is possible that even higher concentrations of DEHP would be acutely toxic to few, if any, species of freshwater or saltwater fish or invertebrates.

Chronic Toxicity to Aquatic Animals

Several tests have been conducted that are useable according to the Guidelines concerning the chronic toxicity of DEHP (Table 2). Four life-cycle tests have been conducted with the cladoceran, Daphnia magna. In the first test, all tested concentrations, including the lowest of 3 μg/L, inhibited reproduction by at least 60% (Mayer and Sanders 1973; Sanders et al. 1973). A comparable acute test was not conducted. Brown and Thompson (1982) found that concentrations up to 107 μg/L did not reduce survival or reproduction of D. magna. Adams and Heidolph (1985) reported that 1,300 μg/L significantly reduced survival and reproduction, whereas 640 μg/L did not. The chronic value was 912.1 μg/L. Because these authors did not conduct an acute test in the dilution water in which their chronic test was conducted, their acute-chronic ratio of 2.20 cannot be used. In the fourth test (Knowles et al. 1987), survival and reproduction were significantly reduced at 811 μg/L, but not at 158 μg/L. The chronic value was 358.0 μg/L.

The early report that DEHP causes chronic toxicity to D. magna at concentrations of 3 μg/L appears to be in error because three other tests found that concentrations above 100 μg/L did not affect survival or reproduction.

Streufert and Sanders (1977) and Streufert et al. (1980) exposed midge larvae to DEHP for 35 days until emergence and then observed the animals until eggs were produced and hatched. The highest concentration tested (360 μg/L) increased emergence by 1%, reduced the total number of eggs by 15%, and reduced hatchability by 2%. At 200 μg/L, emergence was increased by 5%, the total number of eggs was increased by 56%, and hatchability was decreased by 3%. Since the authors found none of these effects to be significant, the chronic value was > 360 μg/L, and an acute-chronic ratio cannot be calculated.

Three early life-stage tests have been conducted on DEHP with fish. Mehrle and Mayer (1976) exposed rainbow trout, Salmo gairdneri, embryos and fry for 100 days. No significant effects occurred in the embryos or in fry older than 24 days. However, fry between hatching and 24 days of age had a significant increase in mortality at a DEHP concentration of 14 μg/L. The calculated chronic value was 8.366 μg/L. However, Spehar (1986) exposed rainbow trout embryos and fry to DEHP for 90 days. The average test concentrations ranged from 49 to 502 μg/L and no significant effects were observed on embryo hatchability, larval or early juvenile survival or growth.

The very low values for both _D. magna_ and rainbow trout were obtained in the same laboratory at about the same time. Subsequently, much higher values have been obtained in this and three other laboratories with these two species.

In a 32-day early-life stage test with the fathead minnow, _Pimephales promelas_, survival was reduced 1% by 23,800 μg/L and was reduced 32% by 42,400 μg/L (Horne et al. 1983). The mean weight of the fish in the control treatment at the end of the test was rather low, but the data indicate that the weight was higher than controls at 23,800 μg/L, but was reduced 16% by 42,400 μg/L. Higher concentrations of DEHP caused even greater reductions in survival and weight. The chronic value was 31,770 μg/L, and the acute-chronic ratio was greater than 34.82.

No acceptable chronic tests have been conducted on DEHP with a saltwater species.

Useful chronic values are available for four freshwater species and no saltwater species. The chronic value for _Daphnia magna_ is in the range of 358.0 to 912.1 μg/L and the midge chronic value was greater than 360 μg/L. The chronic values for the fathead minnow and rainbow trout are much higher, 31,770 and greater than 502 μg/L, respectively. The only information available concerning the acute-chronic ratio for DEHP is greater than 34.82 for the fathead minnow. Acute-chronic ratios are not very useful, because DEHP is not acutely toxic enough to allow determination of a quantitative Final Acute Value. Since DEHP does not ionize in water, it is assumed that it is equally toxic to freshwater and saltwater species. Because the lowest tested reliable chronic value is 358 µg/L and it is with a sensitive species, the freshwater and saltwater Final Chronic Values are identical and set at 358.0 µg/L.

Toxicity to Aquatic Plants

Richter (1982) exposed a green alga, Selenastrum capricornutum, for five days to concentrations up to 410 µg/L, which was assumed to be the solubility limit of DEHP in the dilution water. The highest test concentration did not cause a 50% reduction in growth (Table 3). Davis (1981) conducted seven static tests with the duckweed, Lemna gibba, to study the effect of DEHP on frond production. The EC50s ranged from 408,000 to 7,492,000 µg/L, and the mean EC50 was 2,060,000 µg/L. A test with the saltwater diatom, Gymnodinium breve, resulted in a 96-hr EC50 of 31,000,000 µg/L (Wilson et al. 1978).

A Final Plant Value, as defined in the Guidelines, cannot be obtained because no test in which the concentrations of DEHP were measured resulted in an adverse effect.

Bioaccumulation

Uptake of DEHP directly from water has been studied with a variety of freshwater species. Results of exposures that lasted for at least 28 days and results of tests in which the concentrations in tissue were shown to have reached steady-state are presented in Table 4; other results are presented in Table 5. All exposures were conducted with radiolabeled DEHP and the results are based on measurements of ^{14}C in water and in tissue.

Mayer (1976) determined the percentage composition of DEHP and its metabolites in fathead minnows after 56 days of exposure to several concentrations. DEHP ranged from 33 to 79% and was inversely related to the concentration in water. The principal metabolite was 2-ethylhexyl phthalate. Tests with invertebrates resulted in bioconcentration factors (BCFs) ranging from 14 for an isopod, Asellus brevicaudus, to 3,600 for an amphipod, Gammarus pseudolimnaeus. Fish bioconcentrated ^{14}C-labeled DEHP from 114 to 1,380 times. Fathead minnows showed a wide range of BCFs with a consistent inverse relationship between concentration in water and BCF (Mayer 1976; Mehrle and Mayer 1976).

BCFs for the soft tissues of M. edulis exposed to 4.1 and 42.1 μg/L for 28 days in salt water were 2,366 and 2,627, respectively (Brown and Thompson 1982).

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

Other Data

Additional data concerning the lethal and sublethal effects of DEHP on aquatic species are presented in Table 5. A green alga showed a reduction of chlorophyll fluorescence after a two-hour exposure to 410 μg/L. Cary et al. (Manuscript) reported that 207,000 μg/L did not reduce survival of brook trout exposed for 144 hr. Exposure of the same species to 3,000 μg/L for eight months had no effect on survival, growth rate, or spawning success. Cary et al. (Manuscript) also exposed bluegills to high concentrations of DEHP. A 9-day exposure to 1,175,000 μg/L killed less than 50% of the fish. Exposure of bluegills for 90 days to 2,040 μg/L caused no adverse effects on survival, growth, or spawning success. In the tests conducted by Cary et al. (Manuscript), no effects on brook trout or bluegills were observed even though the fish were exposed to concentrations of Triton X-100 that were to 5 to 8% of the concentrations of DEHP. Mehrle and Mayer (1976) observed no effect on survival or growth of fathead minnows during exposure to 62 μg/L for 56 days.

Collagen synthesis was reduced in the vertebrae of brook trout exposed to 3.7 μg/L for 150 days (Mayer et al. 1977). They found the same effect in rainbow trout exposed for 90 days to 14 μg/L and fathead minnows exposed for 127 days to 11 μg/L. The heart-beat rate of goldfish was reduced when the fish were exposed to 200,000 μg/L for 10 minutes (Pfuderer and Francis 1975; Pfuderer et al. 1975). Geyer et al. (1981,1984) reported a 24-hour BCF of 5,400 for a green alga (Table 5). Cladocerans exposed for 7 days had BCFs of 1,040 (Sanders et al. 1973) and 420 (Mayer and Sanders 1973). Mayflies had BCFs of 460 and 575 in 7-day tests (Table 5).

The fate and effects of ^{14}C-labeled DEHP were studied in a saltwater microcosm during 30-day experiments in the winter and summer (Perez et al. 1983). Ammonia flux from the benthic subsystem was reduced during the summer at a average temperature of 18°C in microcosms in which the DEHP concentration averaged 15.5 μg/L. A similar effect was not observed at 58.9 μg/L in the winter at an average temperature of 1°C. Average concentrations of DEHP in the molluscs, Pitar morrhuana and Mulinia lateralus, from the sediment compartment were 1,767 times the concentration in the overlying water and BCFs for the zooplankter Acartia sp. averaged 2,659 (Perez et al. 1983). Values for these three species differed little between tests run in the winter and summer. In contrast, BCFs for two infaunal polychaetes, Nucula annulata and Nepthys incisa, averaged 89.2 and 1,420 in the winter and summer experiments, respectively.

A steady-state BCF of 637 was predicted from uptake and depuration kinetics of DEHP in sheepshead minnows, Cyprinodon variegatus (Karara and Hayton 1984). In contrast, DEHP was not detected at 2 mg/kg in the tissues of post-larval grass shrimp exposed for 25 to 28 days to mean measured concentrations of 62 to 450 µg/L (Laughlin et al. 1978).

Unused Data

Some data concerning the effects of DEHP on aquatic organisms and their uses were not used because the tests were conducted with species that are not resident in North America (e.g., Stephenson 1983). Results (e.g., Sugawara 1974) of tests conducted with brine shrimp, Artemia sp., were not used because these species are from a unique saltwater environment. Biddinger and Gloss (1984), Davies and Dobbs (1984), Environment Canada (1983), Johnson et al. (1977), Neely (1979), Peakall (1975), Thomas and Northrup (1982), Thomas and Thomas (1984), Thomas et al. 1978; and Veith et al. (1979) compiled data from other sources.

Results were not used when the test procedures or results were not adequately described (Group 1986; Parker 1984; Streufert and Sanders 1977). Tests conducted without controls were not used (Heitmuller et al. 1981). Data were not used when DEHP was a component of an effluent or sediment (Horning et al. 1984; Larsson and Thuren 1987; Pickering 1983; Woin and Larsson 1987). The concentration of dissolved oxygen was too low in the test chambers in a test conducted by Silvo (1974). Studies were not used when the test chemical was reported as dioctylphthalate (Birge et al. 1978,1979; Black and Birge 1980; McCarthy et al. 1985; McCarthy and Whitmore 1985). Results of tests (e.g., Cary, Manuscript; Dumpert and Zietz 1984; Zitko 1972), in which the concentration of surfactant or organic solvent was too high were not used.

Reports of the concentrations of DEHP in wild aquatic organisms (DeVault 1985; Glass 1975; Kaiser 1977; Lindsay 1977; Murray et al. 1981; Musial et al. 1981; Ray and Giam 1984; Ray et al. 1983; Swain 1978; Williams 1973; Zitko 1973) were not used to calculate BCFs if the number of measurements of DEHP in water was too low or if the range of the concentration in water was too high. Studies of the metabolism of DEHP in aquatic organisms were not used (Henderson and Sargent 1983; Lech and Melancon 1980; Melancon and Lech 1976,1977,1979; Melancon et al. 1977; Stalling et al. 1973). Results of laboratory bioconcentration tests were not used when the test was not flow-through or renewal (e.g., Karara et al. 1984; Wofford et al. 1981). BCFs obtained from microcosm or model ecosystem studies were not used when the concentration of DEHP in water decreased with time (Metcalf 1975; Metcalf et al. 1973; Sodergren 1982).

Summary

Data on the acute toxicity of DEHP are available for twelve species of freshwater animals. The lowest reported acute value of 2,100 μg/L was obtained with a midge. Higher concentrations were not acutely toxic to most species, but the high tested concentration was only 89 μg/L in tests with two species. Chronic toxicity tests have been conducted with four species of freshwater animals, and conflicting results have been obtained with two of the species. The chronic value for *Daphnia magna* is in the range of 358.0 to 912.1 μg/L and the midge chronic value is greater than 360 μg/L. The chronic values for the rainbow trout and fathead minnow seem to be higher.

The green alga, *Selenastrum capricornutum*, was not affected by 410 μg/L. The EC50s determined with duckweed ranged from 408,000 to 7,492,000 μg/L. Bioaccumulation has been determined with a variety of freshwater species using ^{14}C-labeled DEHP. Invertebrate studies resulted in BCFs ranging from 14 for an isopod to 3,600 for an amphipod. Fish bioconcentrated DEHP from 114 to 1,380 times. Fathead minnows showed a wide range of BCFs with a inverse relationship between concentration in water and BCF.

The only data available on the acute toxicity of DEHP to saltwater animals shows that it was not acutely lethal to the harpacticoid copepod, Nitocra spinipes, at 300,000 µg/L nor to larval grass shrimp, Palaemonetes pugio, at 450 µg/L. Survival and development of P. pugio were not affected after 25 to 28 days in DEHP concentrations ≤ 450 µg/L. Ammonia flux from sediments in microcosms was reduced after 30 days at 15.5 µg/L in the summer but not at 58.9 µg/L in the winter. BCFs averaged 89.2 in the winter and 1,420 in the summer for the polychaetes Nucula annulata and Nepthys incisa, 2,659 for the zooplankter Acartia sp., and for molluscs averaged 2,496 for Mytilus edulis, 881 for Pitar morrhuana and 2,560 for Mulinia lateralus. For the fish, Cyprinodon variegatus, the predicted BCF was 637.

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 and saltwater aquatic organisms and their uses should not be affected unacceptably if the four-day average concentration of di-2-ethylhexyl phthalate does not exceed 360 µg/L more than once every three years on the average and if the one-hour average concentration does not exceed 400 µg/L more than once every three years on the average.

Implementation

As discussed in the Water Quality Standards Regulation (U.S. EPA 1983a) and the Foreword to this document, a water quality criterion for aquatic life has regulatory impact only after it has been adopted in a state water quality standard. Such a standard specifies a criterion for a pollutant that is consistent with a particular designated use. With the concurrence of the U.S. EPA, states designate one or more uses for each body of water or segment thereof and adopt criteria that are consistent with the use(s) (U.S. EPA 1983b,1987). In each standard a state may adopt the national criterion, if one exists, or, if adequately justified, a site-specific criterion.

Site-specific criteria may include not only site-specific criterion concentrations (U.S. EPA 1983b), but also site-specific, and possibly pollutant-specific, durations of averaging periods and frequencies of allowed excursions (U.S. EPA 1985b). The averaging periods of "one hour" and "four days" were selected by the U.S. EPA on the basis of data concerning how rapidly some aquatic species react to increases in the concentrations of some aquatic pollutants, and "three years" is the Agency's best scientific judgment of the average amount of time aquatic ecosystems should be provided between excursions (Stephan et al. 1985; U.S. EPA 1985b). However, various species and ecosystems react and recover at greatly differing rates. Therefore, if adequate justification is provided, site-specific and/or pollutant-specific concentrations, durations, and frequencies may be higher or lower than those given in national water quality criteria for aquatic life.

Use of criteria, which have been adopted in state water quality standards, for developing water quality-based permit limits and for designing waste treatment facilities requires selection of an appropriate wasteload allocation model. Although dynamic models are preferred for the application of these criteria (U.S. EPA 1985b), limited data or other considerations might require the use of a steady-state model (U.S. EPA 1986). Guidance on mixing zones and the design of monitoring programs is also available (U.S. EPA 1985b,1987).

Table 1. Acute Toxicity of Di-2-ethylhexyl Phthalate to Aquatic Animals

Species	Method[a]	Hardness (mg/L as $CaCO_3$)	LC50 or EC50 (µg/L)	Species Mean Acute Value (µg/L)	Reference
		FRESHWATER SPECIES			
Hydra, *Hydra oligactis*	F, M	-	> 89	> 89	Sabourin 1986
Worm, *Lumbriculus variegatus*	F, M	-	> 89	> 89	Sabourin 1986
Cladoceran (< 24 hr), *Daphnia magna*	S, U	173	11,000	-	LeBlanc 1980
Cladoceran (< 24 hr), *Daphnia magna*	S, M	180	> 304	-	Brown and Thompson 1982
Cladoceran, *Daphnia magna*	S, M	120-250	2,000	4,690	Adams and Heidolph 1985
Amphipod, *Gammarus fasciatus*	S, M	297	240,000	240,000	Cary et al., Manuscript
Amphipod, *Gammarus pseudolimnaeus*	S, U	-	> 32,000	> 32,000	Sanders et al. 1973; Johnson and Finley 1980; Mayer and Ellersieck 1986
Midge (3rd and 4th instar), *Chironomus plumosus*	S, U	270	> 18,000	> 18,000	Mayer and Ellersieck 1986; Streufert et al. 1980
Midge (2nd instar), *Chironomus tentans*	S, M	297	2,100	2,100	Cary et al., Manuscript
Coho salmon (fingerling), *Oncorhynchus kisutch*	S, U	44	> 100,000	> 100,000	Johnson and Finley 1980, Mayer and Ellersieck 1986

Table 1. (continued)

Species	Method[a]	Hardness (mg/L as $CaCO_3$)	LC50 or EC50 (µg/L)	Species Mean Acute Value (µg/L)	Reference
Rainbow trout (fingerling), *Salmo gairdneri*	S, U	44	> 100,000	-	Johnson and Finley 1980; Mayer and Ellersieck 1986
Rainbow trout (fingerling), *Salmo gairdneri*	F, M	46.4	> 19,508	> 19,508	Spehar 1986
Fathead minnow (adult), *Pimephales promelas*	S, M	45.0	> 1,500,000	-	Horne et al. 1983
Fathead minnow (fingerling), *Pimephales promelas*	F, U	272	> 1,000	-	Mayer and Ellersieck 1986
Fathead minnow (adult), *Pimephales promelas*	F, M	44.0	> 1,106,200	> 1,106,200	Horne et al. 1983
Fathead minnow (30 days), *Pimephales promelas*	F, M	44	> 327	-	Biesinger et al., Manuscript
Channel catfish (fingerling), *Ictalurus punctatus*	S, U	44	> 100,000	-	Johnson and Finley 1980; Mayer and Ellersieck 1986
Channel catfish (fingerling), *Ictalurus punctatus*	F, U	272	> 200	> 100,000	Mayer and Ellersieck 1986
Bluegill (fingerling), *Lepomis macrochirus*	S, U	44	> 100,000	-	Johnson and Finley 1980; Mayer and Ellersieck 1986
Bluegill (young-of-year), *Lepomis macrochirus*	S, U	28-44	> 770,000	-	Buccafusco et al. 1981
Bluegill (fingerling), *Lepomis macrochirus*	F, U	272	> 200	> 770,000	Mayer and Ellersieck 1986

Table 1. (continued)

Species	Method[a]	Salinity (g/kg)	LC50 or EC50 (µg/L)	Species Mean Acute Value (µg/L)	Reference
		SALTWATER SPECIES			
Harpacticoid copepod (adult), *Nitocra spinipes*	S, U	7	> 300,000	> 300,000	Linden et al. 1979
Grass shrimp (larva), *Palaemonetes pugio*	R, M	17	> 450	> 450	Laughlin et al. 1978
Sheepshead minnow (juvenile), *Cyprinodon variegatus*	S, U	-	> 550,000	> 550,000	Heitmuller et al. 1981; U.S. EPA 1978

[a] S = static; R = renewal; F = flow-through; M = measured; U = unmeasured.

Table 2. Chronic Toxicity of Di-2-ethylhexyl Phthalate to Aquatic Animals

Species	Test[a]	Hardness (mg/L as $CaCO_3$)	Chronic Limits (µg/L)[b]	Chronic Value (µg/L)	Reference
			FRESHWATER SPECIES		
Cladoceran, *Daphnia magna*	LC	270	< 3[c]	< 3	Mayer and Sanders 1973; Sanders et al. 1973
Cladoceran (< 24 hr), *Daphnia magna*	LC	180	> 85.6[d]	> 85.6	Brown and Thompson 1982
Cladoceran, *Daphnia magna*	LC	240-310	640-1,300	912.1	Adams and Heidolph 1985
Cladoceran, *Daphnia magna*	LC	300	158-811	358.0	Knowles et al. 1987
Midge (3rd and 4th instar), *Chironomus plumosus*	LC	270	> 360[d]	> 360	Streufert et al. 1980
Rainbow trout (embryo, fry), *Salmo gairdneri*	ELS	270	5-14	8.366	Mehrle and Mayer 1976
Rainbow trout (embryo, fry), *Salmo gairdneri*	ELS	45.5	> 502[d]	> 502	Spehar 1986
Fathead minnow, *Pimephales promelas*	ELS	43.7	23,800-42,400	31,770	Horne et al 1983

Table 2. (continued)

Acute-Chronic Ratio

Species	Hardness (mg/L as $CaCO_3$)	Acute Value (µg/L)	Chronic Value (µg/L)	Ratio
Cladoceran, *Daphnia magna*	180	> 304	> 85 6	-
Midge, *Chironomus plumosus*	270	> 18,000	> 360	-
Rainbow trout, *Salmo gairdneri*	45 5	> 19,508	> 502	-
Fathead minnow, *Pimephales promelas*	44-45	>1,106,200	31,770	> 34 82

[a] LC = life-cycle or partial life-cycle; ELS = early life-stage.

[b] Measured concentrations of DEHP.

[c] Unacceptable effects occurred at all concentrations tested.

[d] The highest concentration tested did not cause an unacceptable effect.

Table 3. Toxicity of Di-2-ethylhexyl Phthalate to Aquatic Plants

Species	Hardness (mg/L as $CaCO_3$)	Duration (days)	Effect	Concentration (µg/L)	Reference
FRESHWATER SPECIES					
Green alga, *Selenastrum capricornutum*	-	5	EC50	> 410	Richter 1982
Duckweed, *Lemna gibba*	331.9	7	EC50	2,060,000	Davis 1981
SALTWATER SPECIES					
Diatom, *Gymnodinium breve*	-	4	EC50	31,000,000	Wilson et al. 1978

Table 4. Bioaccumulation of Di-2-ethylhexyl Phthalate by Aquatic Organisms

Species	Concentration in Water (µg/L)[a]	Duration (days)	Tissue	Percent Lipids	BCF or BAF[b]	Normalized BCF or BAF[c]	Reference
			FRESHWATER SPECIES				
Cladoceran (< 24 hr), *Daphnia magna*	2.20	21	Whole body	-	241	-	Brown and Thompson 1982
Cladoceran (< 24 hr), *Daphnia magna*	7.35	21	Whole body	-	190	-	Brown and Thompson 1982
Cladoceran (< 24 hr), *Daphnia magna*	25.3	21	Whole body	-	330	-	Brown and Thompson 1982
Cladoceran (< 24 hr), *Daphnia magna*	85.6	21	Whole body	-	313	-	Brown and Thompson 1982
Isopod, *Asellus brevicaudus*	1.9	21	Whole body	-	14[d]	-	Sanders et al. 1973
Isopod, *Asellus brevicaudus*	62.3	21	Whole body	-	50[d]	-	Sanders et al. 1973
Amphipod, *Gammarus pseudolimnaeus*	0.1	14	Whole body	-	3,600 (2,680[d])	-	Mayer and Sanders 1973; Mayer et al. 1972; Sanders et al. 1973
Amphipod, *Gammarus pseudolimnaeus*	62 8	21	Whole body	-	52[d]	-	Sanders et al. 1973
Midge (3rd and 4th instar), *Chironomus plumosus*	0 2	7	Whole body	-	408	-	Streufert et al. 1980

Table 4. (continued)

Species	Concentration in Water (µg/L)[a]	Duration (days)	Tissue	Percent Lipids	BCF or BAF[b]	Normalized BCF or BAF[c]	Reference
Fathead minnow, *Pimephales promelas*	1.9	28	Whole body	-	1,380	-	Mayer and Sanders 1973
Fathead minnow (7.5 mo), *Pimephales promelas*	1.9-62	56	Whole body	-	155-886	-	Mayer 1976; Mehrle and Mayer 1976
Bluegill (juvenile), *Lepomis macrochirus*	5.82	42	Whole body	-	114	-	Barrows et al. 1980
			SALTWATER SPECIES				
Blue mussel (adult), *Mytilus edulis*	4.1	28	Soft tissues	-	2,366	-	Brown and Thompson 1982
Blue mussel (adult), *Mytilus edulis*	42 1	28	Soft tissues	-	2,627	-	Brown and Thompson 1982

[a] Based on measured concentration of ^{14}C-labeled DEHP.

[b] Bioconcentration factors (BCFs) and bioaccumulation factors (BAFs) are based on measured concentrations of ^{14}C in water and in tissue (see text)

[c] When possible, the factor was normalized to 1% lipids by dividing the BCF or BAF by the percent lipids.

[d] Converted to wet weight basis

Table 5. Other Data on Effects of Di-2-ethylhexyl Phthalate on Aquatic Organisms

Species	Hardness (mg/L as $CaCO_3$)	Duration	Effect	Concentration (µg/L)	Reference
		FRESHWATER SPECIES			
Green alga, *Chlorella fusca*	-	24 hr	BCF=5,400	50	Geyer et al. 1981,1984
Green alga, *Selenastrum capricornutum*	-	2 hr	Reduced fluorescence	410	Richter 1982
Cladoceran, *Daphnia magna*	270	7 days	BCF=420 (BCF=1,040[a])	0.3	Mayer and Sanders 1973; Sanders et al. 1973
Cladoceran, *Moina macrocarpa*	-	3 hr	No effect	Water solubility	Yoshioka et al. 1986
Mayfly (nymph), *Hexagenia bilineata*	270	7 days	BCF=575 (BCF=460[a])	0.1	Mayer and Sanders 1973; Sanders et al. 1973
Midge (larva), *Chironomus plumosus*	270	7 days	BCF=350 (BCF=620[a])	0.3	Mayer and Sanders 1973; Sanders et al. 1973
Rainbow trout (eyed embryo, fingerling), *Salmo gairdneri*	-	90 days	Reduced collagen in backbone	14	Mayer et al. 1977
Brook trout (adult), *Salvelinus fontinalis*	-	150 days	Reduced collagen in backbone	3.7	Mayer et al. 1977

Table 5. (continued)

Species	Hardness (mg/L as $CaCO_3$)	Duration	Effect	Concentration (µg/L)	Reference
Goldfish, *Carassius auratus*	-	10 min	Decreased heart rate	200,000	Pfuderer and Francis 1975; Pfuderer et al. 1975
Fathead minnow (7.5 mo), *Pimephales promelas*	270	56 days	Did not reduce survival or growth	62	Mehrle and Mayer 1976
Fathead minnow (fingerling, adult), *Pimephales promelas*	-	127 days	Reduced collagen in backbone	11	Mayer et al. 1977

Table 5. (continued)

Species	Salinity (g/kg)	Duration	Effect	Concentration (µg/L)	Reference
		SALTWATER SPECIES			
Benthic nitrifiers	-	30 days	Reduced ammonia flux from sediments in summer	15.5	Perez et al. 1983
Benthic nitrifiers	-	30 days	No effect on ammonia flux in winter	58.9	Perez et al. 1983
Polychaete, *Nucula annulata*	-	30 days	BCF = 133 (winter)	0.575 to 58.9	Perez et al. 1983
Polychaete, *Nucula annulata*	-	30 days	BCF = 2,000 (summer)	0.186 to 15.5	Perez et al. 1983
Polychaete, *Nephthys incisa*	-	30 days	BCF = 45 (winter)	0.575 to 58.9	Perez et al. 1983
Polychaete, *Nephthys incisa*	-	30 days	BCF = 835 (summer)	0.186 to 15.5	Perez et al. 1983
Morrhur venus, *Pitar morrhuana*	-	30 days	BCF = 881	0.186 to 58.9	Perez et al. 1983
Clam, *Mulinia lateralis*	-	30 days	BCF = 2,506	0.186 to 58.9	Perez et al. 1983
Grass shrimp (zoea to post-larva), *Palaemonetes pugio*	17	25 to 28 days	No effect on survival or development	450	Laughlin et al 1978

Table 5. (continued)

Species	Salinity (g/kg)	Duration	Effect	Concentration (µg/L)	Reference
Grass shrimp (zoea to post-larva), *Palaemonetes pugio*	17	25 to 28 days	DEHP not detected in tissues $\leq$ 2 mg/kg	62 to 450	Loughlin et al. 1978
Sheepshead minnow, *Cyprinodon variegatus*	10	4 days	Predicted steady-state BCF = 637	Variable	Karara and Hayton 1984

[a] Converted to wet weight basis.

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