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*CANADIAN ENVIRONMENTAL PROTECTION ACT*

# PRIORITY SUBSTANCES LIST

# SUPPORTING DOCUMENT

# BIS(2-ETHYLHEXYL) PHTHALATE

Government of Canada
Environment Canada

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## 1.0 IDENTITY OF SUBSTANCE

### 1.1 Name of Substance

Bis(2-ethylhexyl) phthalate, a phthalic acid ester, has the CAS (Chemical Abstracts Service) Registry Number 117-81-7, the molecular formula $C_{24}H_{38}O_4$, and a molecular weight of 390.6. Synonyms include: DEHP; 1,2-benzenedicarboxylic acid, bis(2-ethylhexyl) ester; phthalic acid, bis(2-ethylhexyl) ester; and di(2-ethylhexyl) phthalate.

For simplicity, this report will use the term "DEHP" when referring to bis(2-ethylhexyl) phthalate. The structure of DEHP is shown in Figure 1.

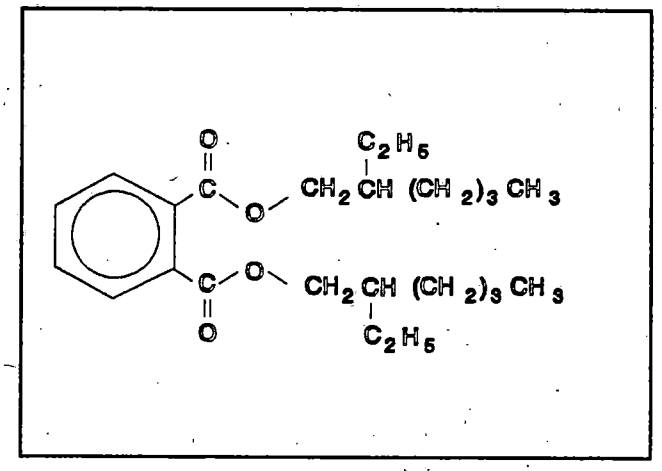


Figure 1. Structure of bis(2-ethylhexyl) phthalate.

### 1.2 Analytical Methodology

The most sensitive and selective analytical method for the determination of phthalic acid esters, including DEHP, in environmental media is gas chromatography with electron capture detection (Kohli *et al.*, 1989). Thin layer chromatography may be used to separate phthalates from other solvent-extracted organic compounds. The U.S. Environmental Protection Agency has standardized the sample preparation and analysis for gas chromatography (GC) (method 606, detection limit 2.0 μg/L) and gas chromatography/mass spectrometry (GC/MS) (method 625, detection limit 2.5 μg/L) (U.S. EPA, 1982b).

Two problems have plagued the chemical analysis and the reporting of concentrations of DEHP. The first problem, which applies to phthalates as a group, is that these chemicals frequently occur as plasticizers in analytical equipment and as

contaminants in laboratory air and solvents. This is believed to result in overestimation of their concentration in environmental samples. For example, Ishida *et al.* (1980) determined DEHP in laboratory solvents at concentrations as high as 1.96 mg/kg (in benzene) and in solid reagents at concentrations up to 4.12 mg/kg (in carboxymethylcellulose), while the heavy-walled tubing they analyzed contained 67.2% DEHP. Therefore, a great deal of care is needed to prevent contamination during the collection, storage and analysis of samples (Hites and Budde, 1991; Kohli *et al.*, 1989; Mathur, 1974; U.S. EPA, 1982b). Many studies conducted prior to 1980 reporting environmental concentrations have not accounted for this problem (Pierce *et al.*, 1980). Steps taken to avoid contamination are rarely described in the published reports and consequently the reliability of the data cannot be assessed. The second problem, specific to DEHP, is that the terminology is not consistent in the technical literature, where the substance is sometimes referred to as "dioctyl phthalate". This has led to confusion with the straight-chain isomer, di-*n*-octyl phthalate (D*n*OP), also sometimes referred to as "dioctyl phthalate" or "DOP". As a consequence, the occurrence of DEHP in the environment may have been slightly overestimated, since reports of environmental concentrations of "dioctyl phthalate" could pertain to D*n*OP, even though DEHP has been used in much higher quantities than D*n*OP.

## 2.0 PHYSICAL AND CHEMICAL PROPERTIES

Bis(2-ethylhexyl) phthalate is a colourless, oily liquid (Montgomery and Welkom, 1990), with reported vapour pressures ranging between 8.3 X $10^{-6}$ (Montgomery and Welkom, 1990) and 8.6 X $10^{-4}$ Pa @ 25°C (Howard *et al.*, 1985), Henry's Law Constant of about 3 X $10^{-2}$ Pa·$m^3$/mol (Volskay and Grady, 1988), reported octanol/water partition coefficient (log $K_{ow}$) values from 5.11 (Geyer *et al.*, 1984) to 9.61 (U.S. EPA, 1982a), and a water solubility of 270 to 400 µg/L @ 25°C (DeFoe *et al.*, 1990; Volskay and Grady, 1988). The determination of the solubility in water and the octanol/water partition coefficient of phthalic acid esters is complicated since these compounds easily form colloidal dispersions in water (Klöpfer *et al.*, 1982) and are subjected to "molecular folding" (Callahan *et al.*, 1979). Bis(2-ethylhexyl) phthalate absorbs infrared radiation, including wavelengths in the 7-13 µm region (Sadtler Research Laboratories, 1982), which is characteristic of trace gases that contribute to warming of the troposphere. Additional chemical and physical properties of DEHP are presented in Table 1.

## 3.0 SOURCES AND RELEASES TO THE ENVIRONMENT

### 3.1 Production and Use

Bis(2-ethylhexyl) phthalate accounts for well over 50% of the total use of phthalate plasticizers, with a worldwide production of about 1,000 kilotonnes DEHP per year (IPCS, 1992).

At present there are two operating DEHP production plants in Canada. The total production capacity for plasticizers in Canada amounted to 21.5 kilotonnes in 1991, down from a high of 51.5 kilotonnes in 1989. The actual production of DEHP was considerably lower, totalling 5 kilotonnes in 1991, compared with 14.8 kilotonnes back in 1984. Approximately 5 kilotonnes of DEHP was imported into Canada in 1991 (virtually all from the United States), down from a high of about 7.5 kilotonnes in 1990 (Camford Information Services Inc., 1992). Bis(2-ethylhexyl) phthalate is also imported into Canada already mixed with polyvinyl chloride (PVC). In 1991, 14.4 kilotonnes of plasticized PVC were imported into Canada. Assuming this material contained a minimum 10% DEHP by weight (see below), then at least an additional 1.4 kilotonnes of DEHP would have entered Canada in 1991. Available information are insufficient to estimate the amount of DEHP imported in finished plastic products. Export sales of DEHP amounted to less than 2 tonnes in each of 1990 and 1991 (Camford Information Services Inc., 1992).

Bis(2-ethylhexyl) phthalate is the most widely used plasticizer for vinyl resins, especially polyvinyl chloride resin (Zenon, 1982). According to Wams (1987), approximately 95% of the world's annual production of DEHP is used as a plasticizer in plastics, and 85% of this plasticizer usage is utilized in PVC resins. The amount of DEHP used in PVC resins is variable, depending on the type of product. Industrial hoses may contain 10 to 15% DEHP by weight, while some types of flexible PVC films may contain more than 40% DEHP (Camford Information Services Inc. 1992). In 1991 about 35% of the total Canadian supply of DEHP was used as a plasticizer in PVC films and sheets, 6% in PVC flooring, 3.5% in plasticized PVC exports, about 51% in other vinyl products (such as coated fibres, etc.), 2.6% in nitrile-butadiene rubber, and 1.8% in miscellaneous applications, including other resin uses (Camford Information Services Inc., 1992).

### 3.2 Releases to the Environment

The occurrence of naturally-produced phthalates in biological and geochemical samples has been suggested, but in most cases the possibility of contamination during sampling or analysis could not be ruled out (Mathur, 1974). However, it is unlikely that the amounts of phthalates produced naturally would

be significant compared with those from anthropogenic sources (IPCS, 1992).

An estimated 2000 tonnes/year, globally, of DEHP is lost during distribution to the plastics producing industry, and a further 32,000 tonnes/year are lost to air and water during the production of polyvinyl chloride (Wams, 1987). An estimated 14,000 tonnes of DEHP/year is lost to the atmosphere during use of plastic products, while about 6000 tonnes/year is believed to be lost to water. Losses of DEHP through percolating waters in landfills may amount to as much as 200,000 tonnes/year globally, while an unknown amount of DEHP would also be released to the atmosphere from incineration of DEHP-containing waste products (Wams, 1987).

According to the U.S. Toxic Chemical Release Inventory (TRI) data base, which contains data submitted to the Environmental Protection Agency (EPA) by industrial facilities in compliance with Section 313 of the Emergency Planning and Community Right-To-Know Act of 1986, manufacturing facilities in the U.S. released about 504,000 kg of DEHP into the environment (TRI89, 1991). Direct releases to air accounted for about 97% (about 490,000 kg), while 2.3% (about 12,000 kg) was released directly to land, 0.26% (about 1,400 kg) was released directly to water, and only 0.05% (about 270 kg) was released by underground injection.

Recent data on releases of phthalates in Canada have not been identified. Leah (1977) estimated that 2 to 4.5% of the total Canadian supply of phthalates is lost to the environment during production and processing, with about 95% of this loss resulting from processing. Peakall (1975) estimated that articles containing phthalate-plasticized material may lose about 1%/year of their phthalate content when in contact with liquids and 0.1%/year when in contact with air.

Phthalates are released in a number of industrial effluents. Bis(2-ethylhexyl) phthalate has been reported in the effluents of Canadian organic chemical plants at concentrations ranging up to 48 μg/L (CCREM, 1987; OME, 1992a). Concentrations of DEHP have been reported within the range of 10 to 100 μg/L in effluents from petrochemical plants along the St. Clair River (Munro *et al.*, 1985). According to data reported by the Ontario Ministry of the Environment under the Municipal/Industrial Strategy for Abatement (MISA) program, loadings of DEHP in liquid effluents from the organic chemical industry in Ontario totalled about 1.6 kg/day (12-month average) (OME, 1992a), while those from the inorganic chemical industry totalled about 0.6 kg/day (12-month average) (OME, 1992b). Bis(2-ethylhexyl) phthalate has also been detected at concentrations up to 40 μg/L in effluents from a Canadian textile mill in a 1985/86 survey (detection frequency = 19/19; detection limit 1 μg/L) (Environment Canada, 1989).

A large amount of phthalic acid esters is often volatilized to the air in processing plants, condenses, and is washed into municipal wastewater systems or is released in effluents from plant mist eliminators (Zenon, 1982). Phthalates also enter municipal wastewater systems from contaminated cooling water from processing plants, from domestic use or disposal of products containing these esters, and from the release of scrubber wastewater from incinerators. Concentrations of DEHP up to 59 µg/L have been reported in municipal waste water from Vancouver, British Columbia, in 1982 (Rogers *et al.*, 1986). Bis(2-ethylhexyl) phthalate was detected in 14 of 15 Canadian municipal sludges sampled between 1980 and 1985, with concentrations ranging from 3 to 215 mg/kg (dw) and a median concentration of 80 mg/kg (Webber and Lesage, 1989).

Bis(2-ethylhexyl) phthalate was detected at concentrations often exceeding 10 µg/L (actual concentration not reported) in samples of waste water collected collected from 1982 to 1984 at Canadian coal mines, coal preparation plants, and coal storage transfer terminals. Concentrations in sediments from these facilities were within the range of 5 to 30 mg/kg dry weight (actual concentration not reported) (Atwater *et al.*, 1990).

Leaching of phthalates from hazardous waste landfills is a possibility. Although no Canadian data were identified, the concentration of DEHP in one U.S. municipal landfill leachate was reported to be 0.20 mg/kg (Ghassemi *et al.*, 1984).

Spills are potential sources of DEHP entry to the environment. Two spills of "dioctyl phthalate" were reported on Environment Canada's National Analysis of Trends in Emergencies System (NATES) database: a discharge of 5 tonnes from a tank truck at Cornwall, Ontario in 1984 and a discharge of 5.6 tonnes at an industrial plant at Brantford, Ontario in 1986 (NATES, 1992).

"Dioctyl phthalate" was reported at a concentration of 15 µg/L in the effluent of a kraft pulp and paper mill at Red Rock, Ontario, on Lake Superior (Brownlee and Strachan, 1977). The analytical method used in this study could not distinguish between DEHP and D*n*OP. Similarly, "dioctyl phthalate" was detected in Norwegian spent pulp chlorination liquors at concentrations of 0.3 to 1 g/tonne of pulp (Carlberg *et al.*, 1986).

"Dioctyl phthalate" (isomer not specified) was detected, but not quantified, in extracts of municipal incinerator fly ash from Ontario, the Netherlands, and Japan (Eiceman *et al.*, 1979).

## 4.0 ENVIRONMENTAL FATE AND CONCENTRATIONS

### 4.1 Environmental Fate

The most important processes affecting the distribution and transformation of DEHP in the environment include atmospheric photooxidation, partitioning to soil, sediment and biota, and aerobic degradation (Al-Omran and Preston, 1987; Howard, 1989; Howard *et al.*, 1991; Sullivan *et al.*, 1982; Wolfe *et al.*, 1980a; Zurmühl *et al.*, 1991).

Giam *et al.* (1980) reported that on the average 57% of DEHP residues in the atmosphere of the Gulf of Mexico was contained in the vapour phase, rather than in association with suspended particulates. Similarly, Cautreels and Van Cauwenberghe (1978) found that 70% of the total airborne DEHP in Antwerp, Belgium was contained in the vapour phase.

Bis(2-ethylhexyl) phthalate has been predicted to react with hydroxyl radicals in air, with an estimated half-life of about 12 hours, although DEHP adsorbed to atmospheric particulates would probably have a longer half-life (U.S. EPA, 1987). Howard *et al.*, (1991) estimated the photooxidation half-life of gaseous DEHP to be from 2.9 to 29 hours (based on scientific judgement). The same authors (Howard *et al.*, 1991) estimated that the photolysis half-life of DEHP in both air and water would be much longer, 144 to 200 days (based on the rate of aqueous photolysis for dimethyl phthalate). Atmospheric DEHP may be transported for long distances in the troposphere, but may be removed from the atmosphere by both wet and dry deposition (Atlas and Giam, 1981; Eisenreich *et al.*, 1981; Ligocki *et al.*, 1985). Atmospheric deposition is a significant source of phthalates in the Great Lakes. Eisenreich *et al.* (1981) calculated a total deposition of 48 tonnes/year of airborne DEHP to the five Great Lakes, with values for each ranging from 3.7 metric tonnes/year (L. Ontario) to 16 metric tonnes/year (L. Superior).

The Niagara River Data Interpretation Group (1990) found that 71% of the DEHP loading was found in the water fraction at Fort Erie and 29% in the solids fraction, while at Niagara-on-the-Lake, 76% was contained in the water fraction and 24% in the suspended solids fraction. Although a significant portion of waterborne DEHP may be associated with the particulate portion, complexation with fulvic acid may increase its solubilization and thus increase its mobility in aquatic systems (Ogner and Schnitzer, 1970).

Bis(2-ethylhexyl) phthalate is considered to be less biodegradable than phthalate esters with shorter alkyl chains (IPCS, 1992). Schouten *et al.* (1979) found that a 50% loss of DEHP from river water sample occurred within five days at a 50 μg DEHP/L level. This loss appeared to be at least partly due to

biodegradation, although the addition of microbial inhibitors was only partially successful in inhibiting this degradation. Bis(2-ethylhexyl) phthalate was about 95% degraded over a 3-week period in the static-flask screening test (Tabak *et al.*, 1981). Primary degradation amounted to 81.5% in 24 hours in the Semi-Continuous Activated Sludge (SCAS) test, while ultimate biodegradation to $CO_2$ amounted to 85.5% ($t\frac{1}{2}$ = 5.25 days) in the Shake Flask test (CMA, 1984). Biodegradation of DEHP in river and lake water has been reported, with a half-life of about 1 month (Saeger and Tucker, 1976). Mineralization of DEHP ranged from 35% to 71% after a 40-day incubation in eutrophic lake water at concentrations from 21 pg DEHP/L to 200 ng DEHP/L, while no mineralization occurred after a 60-day incubation in oligotrophic lake water (Subba-Rao *et al.*, 1982). Biodegradation of DEHP is greatly decreased under anaerobic conditions (Johnson and Lulves, 1975; O'Connor *et al.*, 1989; Shelton *et al.*, 1984). Howard *et al.* (1991) estimated, on the basis of results presented by other authors, a half-life for DEHP ranging between 42 and 389 days in water under anaerobic conditions.

The photolysis half-life of DEHP in water has been estimated to be 144 to 200 days (Howard *et al.*, 1991, based on the rate of aqueous photolysis for dimethyl phthalate). A half-life for DEHP of 10 to 389 days in groundwater was estimated by Howard *et al.* (1991). Volatilization of DEHP from water and soil is thought to be very slow, with an estimated evaporative half-life of about 15 years from a pond 1 metre deep (Branson, 1978). However, Klöpfer *et al.* (1982) determined an evaporative half-life for DEHP of only about 140 days using a vessel with a depth of 21 cm. Chemical hydrolysis of DEHP in water is extremely slow, with an estimated half-life of over 100 years (Wams, 1987; Wolfe *et al.*, 1980a).

Bis(2-ethylhexyl) phthalate released to water tends to adsorb strongly to suspended particulates and sediment (Al-Omran and Preston, 1987; Sullivan *et al.*, 1982; Williams and Hargadine, 1991; Wolfe *et al.*, 1980b), although some may be subsequently desorbed from the sediments back into the water column (Atwater *et al.*, 1990). Optimum degradation of DEHP in sediments occurred at high concentration, warm temperatures, and in a nutrient-rich system under aerobic conditions, although anaerobic biodegradation of DEHP also occurred at a slower rate. Ultimate biodegradation (ring cleavage) of DEHP occurs more quickly in aerobic than in anaerobic sediments, (5.1% versus 1% degradation after 7 days). After 28 days, however, the difference was much less, with 13.8% degradation under aerobic conditions and 9.9% degradation under anaerobic conditions (Johnson *et al.*, 1984).

Howard (1989) cited several studies showing that DEHP has a strong tendency to adsorb to soil, and concluded that it would not be expected to evaporate from soil nor to leach into

groundwater. Bis(2-ethylhexyl) phthalate, however, may form a complex with water-soluble fulvic acid, and this may increase its mobilization and reactivity in soil (Khan, 1980). Biodegradation of DEHP occurs at a slightly slower rate in soil than in water, because adsorption onto soil organic matter reduces its availability for degradation (Wams, 1987). Bis(2-ethylhexyl) phthalate is converted to mono(2-ethylhexyl) phthalate and phthalic acid in soil, and these products are then either mineralized or converted into soil-bound residues (Schmitzer *et al.*, 1988). Howard *et al.* (1991) predicted a half-life of DEHP in soil from 5 to 23 days, based on aerobic biodegradation rates. However, Kirchmann *et al.* (1991) found that 20 and 50% of added DEHP remained in soil after 80 days with initial concentrations of 5 and 250 mg/kg, respectively. Degradation occurred much more quickly during the first 10 days at the lower concentration.

Bioconcentration factors for DEHP for various algal and aquatic invertebrates ranged from 6.9 for the oyster, *Crassostrea virginica* (24-hour exposure period) (Wofford *et al.*, 1981) to 5,400 for the alga, *Chlorella fusca* (24-hour exposure) (Geyer *et al.*, 1984). Bioconcentration factors for fish ranged from 8.9 for rainbow trout, *Oncorhynchus mykiss*, (4-day exposure) (Tarr *et al.*, 1990) to 1,380 for the fathead minnow (*Pimephales promelas*) (28-day exposure) (Mayer and Sanders, 1973). In general, bioconcentration factors appeared to be higher for algae and aquatic invertebrates than for fish. Fish appear to metabolize DEHP quite readily (Callahan *et al.*, 1979; Johnson *et al.*, 1977; Wofford *et al.*, 1981). For example, Mayer (1976) reported that the fathead minnow (*Pimelphales promelas*) metabolized DEHP with a biological half-life averaging 12.2 days. This metabolism limits bioaccumulation in fish, and therefore biomagnification of DEHP through the aquatic food chain is not likely to occur (ATSDR, 1991). In vegetation, uptake of DEHP through plant roots is very low, resulting in negligible bioconcentration (Schmitzer *et al.*, 1988). No information was identified on the bioaccumulation of DEHP in wild mammals.

Bioconcentration factors for a number of organisms are presented in Table 2.

Studies conducted to determine bioaccumulation and distribution of DEHP in birds suggest that birds will accumulate DEHP when fed high levels in their diet. However, the depuration rate is relatively fast (1 week) and the high exposure levels do not reflect environmentally relevant concentrations.

Mallard ducks were fed 10 ppm DEHP for five months (Belisle *et al.*, 1975). Assuming a 1.1 kg duck weight and 0.0619 kg dry-wt/day food consumption (Nagy, 1987), this diet translates to a dose of 0.562 mg DEHP/kg-bird/day. Bis(2-ethylhexyl) phthalate was found in the lung (0.05 to 0.15 mg/kg) and breast (0.1

mg/kg). No DEHP was found in the fat. Detection limits were 0.1 mg/kg in a 2 g sample.

Five of eight captured wild starlings fed 250 mg/kg of DEHP for 30 days had average residue levels of 1.8 ± 0.31 mg/kg (O'Shea and Stafford, 1980). One of eight birds treated with 25 mg/kg of DEHP contained residues (1.6 mg/kg). As the birds weighed approximately 110 g and consumed an average of 21.3 g of food a day, the birds received a dose of 48.5 and 4.85 mg DEHP/kg-bird/day, respectively. Tissue concentrations of DEHP showed a statistically significant decrease after cessation of the treated diet. Detection limits were 1 mg/kg.

Ishida *et al.* (1982) studied the distribution of DEHP in ten-month-old white leghorn fed 0.5 or 1.0 g DEHP/100 g feed (approximately 291 and 582 mg DEHP/kg-bird/day respectively) *ad libitum* for 230 days. Residues were found in the liver, kidney, heart, lung, spleen, ovary, oviduct and muscle at 0.5 to 26.0 ppm. The adipose tissue and feathers contained residues 10- to 100-fold higher. No DEHP residues were found in the brain. Residues accumulated in hens fed 0.2 g/100g feed (an approximate daily intake of 116 mg DEHP/kg-bird) were monitored over 25 days with a 7 day depuration period. After 5 and 25 days livers contained a maximum of 4.8 mg/kg and 5.5 mg/kg respectively with no detection in either control. Feathers contained a maximum of 127.5 mg/kg at day 5 and 397.6 mg/kg at day 25. The corresponding control maximums were 26.5 mg/kg and 13.9 mg/kg. The kidney, adipose tissue and muscle all contained small amounts of DEHP after 25 days. After food had been removed for 7 days trace amounts of DEHP could still be detected in kidney and muscle. Bis(2-ethylhexyl) phthalate levels in the feathers were still 131.4 to 248.2 mg/kg. The yolks of eggs laid by the treated hens were exhibiting trace (<0.5 mg/kg) DEHP residues by the 10th day of treatment. Levels were maintained between 20-24 mg/kg from the 15th to 25th day. One week after the DEHP was removed, DEHP residues in the egg yolk were down to 4.5 mg/kg. This paper suggests that the high accumulation of DEHP in the feathers could be a combination of external contamination from oral feeding and transport of DEHP to the feathers via the skin.

The eggs of chickens fed 1 g of DEHP/100 g of mash per day for 45 days (Ishida *et al.*, 1981) contained average residues of 148.35 mg/kg (9.44-254.88 mg/kg) in the yolks, 1.25 mg/kg (0.72-2.28 mg/kg) in the whites and 4.39 mg/kg (1.05 - 9.21 mg/kg) in the shells. This diet represents a dose of 582 mg DEHP/kg-bird/day assuming an average bird weight of 1 kg and food intake of 0.0582 kg food/day (Nagy, 1987).

## 4.2 Environmental Concentrations

Concentrations of DEHP in various environmental compartments are given in Tables 3a and 3b. The paragraphs below highlight the maximum (and in some cases the "typical") concentrations of these phthalates in the various compartments of the Canadian and Great Lakes and non-Canadian/Great Lakes environment. Much of this data is at least 10 years old and, because of the problem of potential contamination during sampling or analysis, its reliability is questionable.

There are no recent data available pertaining to measured concentrations of DEHP in the atmosphere in Canada. Based on atmospheric concentrations of DEHP at a number of oceanic and inland areas as reported by Giam *et al.* (1978; 1980), Eisenreich *et al.* (1981) estimated that atmospheric concentrations of DEHP in the Great Lakes area ranged from 0.5 to 5 ng/m$^3$. In an early study, several phthalic acid esters were identified in samples of air collected near a municipal incinerator in Hamilton, Ontario (Thomas, 1973). The concentration of DEHP (number of samples not reported) was 300 ng/m$^3$ (detection limit = 10 ng/m$^3$). Outside Canada, Bove *et al.* (1978) reported DEHP concentrations as high as 28.6 ng/m$^3$, at Brooklyn, New York. Weschler (1981) reported DEHP in the Arctic aerosol at Barrow, Alaska, at a concentration of about 20 ng/m$^3$.

Eisenreich *et al.* (1981) calculated that DEHP concentrations in rain water from the Great Lakes area would be from 0.004 to 0.010 µg/L, based on washout ratios and the concentration of DEHP in the atmosphere at other locations. Bis(2-ethylhexyl) phthalate concentrations in rain water from the Enewetak Atoll ranged from 0.0053 to 0.213 µg/L (Atlas and Giam, 1981). "Dioctyl phthalate" was present in small amounts in snow and rain samples from Norway (Lunde *et al.*, 1977). It was unclear if "dioctyl phthalate" referred to D*n*OP or to DEHP.

Information on concentrations of DEHP in surface waters in the NAQUADAT/ENVIRODAT database is limited to approximately 80 records for Alberta and two records for British Columbia dating from 1985 to 1988. Concentrations of DEHP ranged from <1 to 14 µg/L (NAQUADAT, 1993). The Alberta Ministry of the Environment reported that DEHP was detected in 5 of 45 samples analyzed during their monitoring of raw surface water from 16 municipalities; the average concentration was below the detection limit (1 µg/L), while five samples from four municipalities contained measurable levels of DEHP, with a maximum concentration of 8 µg/L (Halina, 1993a). Under the Municipal and Industrial Strategy for Abatement (MISA) program, DEHP was detected in the intake water of two organic chemical manufacturing plants at average concentrations of 6.1 and 7.1 µg/L (both plants located on the St. Clair River) (OME, 1992a). For water samples

collected in 1988 and 1989 using large-volume sampling methods designed to lower the detection limit, the Niagara River Data Interpretation Group (1990) reported mean concentrations of 28.63 ng/L at Fort Erie (51 samples all above the detection limit of 0.16 ng/L; maximum 265.88 ng/L) and 38.48 ng/L at Niagara-on-the-Lake (40 out of 44 samples above detection limit; maximum 136.18 ng/L). Germain and Langlois (1988), also using large-volume sampling techniques, reported a mean concentration of 78 ng/L DEHP in the St. Lawrence River in the Montreal region in 1987. Bis(2-ethylhexyl) phthalate was not detected in 22 samples of raw drinking water supplies from 11 municipalities in the Lac St-Jean and Charlevoix areas of Quebec (detection limit, 1 µg/L) (MENVIQ, 1993). In an older study, concentrations of DEHP as high as 300 µg/L (in water from Black Bay, Ontario, Lake Superior, sampling date not stated) were reported by Mayer *et al.* (1972). In 1979, maximum DEHP concentrations, within the range of 10 to 100 µg/L (actual concentrations not stated), were reported for chemical plant intake water from the St. Clair River (Munro *et al.*, 1985). Other studies indicate DEHP concentrations in Canadian and Great Lakes water to be less than 5 µg/L (OME, 1992b; Schacht, 1974).

Brownlee and Strachan (1977) reported "dioctyl phthalate" at concentrations ranging from 0.1 to 55 µg/L in Lake Superior near a kraft pulp and paper mill at Red Rock, Ontario, on Lake Superior. A concentration of 0.7 mg/kg dry weight was detected in the lake sediments. Only trace amounts were detected in suspended particles in the water column. The analytical method used in this study could not distinguish between DnOP and DEHP.

Bis(2-ethylhexyl) phthalate was detected in 24% of 901 STORET (a U.S. EPA STOrage and RETrieval data base containing water quality data) ambient water stations with a median concentration of 10.0 µg/L (Staples *et al.*, 1985). Sheldon and Hites (1978) reported levels of "dioctyl phthalates" in the Delaware River ranging from 3 to 5 µg/L in early March and from 0.06 to 2 µg/L in August. It is not known which dioctyl isomer(s) this study refers to. Shibuya (1979) reported DEHP concentrations in Japanese river waters as high as 15 µg/L.

No data was found pertaining to concentrations of DEHP in Canadian marine waters. Although several studies showed DEHP concentrations in non-Canadian marine waters to be less than 1 µg/L, Murray *et al.* (1981) found DEHP concentrations in Galveston Bay, Texas, to be as high as 12 µg/L.

Few data have been found pertaining to DEHP concentrations in Canadian ground water. Concentrations of DEHP in Alberta drinking water derived from groundwater were reported as high as 9.0 µg/L (average <2 µg/L) for 1985 and 1986 (Spink, 1986) and as high as 21 µg/L (average <1 µg/L) for 1987 to 1992 (Halina, 1993b). Galceran *et al.* (1989) found DEHP ground water concentrations up to 3.4 µg/L in the Catalonia region of Spain.

Single sediment samples collected in 1983 from the Fraser Estuary, B.C., 0.5 km below a sewage outfall, contained 0.844 mg DEHP/kg dry weight, while the level in sediment from 1.0 km below the outfall was 0.404 mg DEHP/kg dry weight (Rogers and Hall, 1987). Bis(2-ethylhexyl) phthalate concentrations as high as 1.5 mg/kg were reported by Kinkead and Chatterjee (1974) for sediments along the Canadian north shore of Lake Superior.

Bis(2-ethylhexyl) phthalate was detected in 40% of 367 STORET sediment stations at a median concentration of 1.0 mg/kg dry weight (Staples *et al.*, 1985). Thurén (1986) reported DEHP concentrations in sediments from the River Svartan, Sweden, as high as 1,480 mg/kg dry weight, but a number of other studies reported maximum concentrations of DEHP in sediments below 100 mg/kg.

In marine sediments, concentrations of DEHP up to 16 mg/kg were reported (in the Nueces Estuary, Texas (Ray *et al.*, 1983a)). Bis(2-ethylhexyl) phthalate has been detected in sediments from three sites in the Baltic Sea at sediment depths corresponding approximately to the year 1950 (Müller *et al.*, 1980). Concentrations increased progressively in the upper layers of sediment at each site, reaching maximum concentrations (ranging from 0.1 to 0.2 mg/kg) in the surface (i.e. most recent) layers.

In the only study identified where concentrations of DEHP in Canada in soil were reported, levels varied from less than 0.1 to 11 µg DEHP/kg dry weight (n = 30) in samples from Port Credit and Oakville/Burlington, Ontario, (Golder Associates, 1987).

Bis(2-ethylhexyl) phthalate was found at concentrations ranging up to 0.5 mg/kg in soil from the perimeter of an industrial dump in Finland (Persson *et al.*, 1978).

Studies of Canadian/Great Lakes fish showed DEHP concentrations of less than 10 µg/g (Burns *et al.*, 1981; Environment Canada, 1980; GLWQB, 1986; Glass *et al.*, 1977; Mayer *et al.*, 1972; Swain, 1978; Williams, 1973). Williams (1973) reported a concentration of 0.104 µg/g in eel from an unspecified Canadian lake or river. Swain (1978) reported mean DEHP concentrations as high as 1.3 µg/g wet weight (whole fish) in siscowet trout (*Salvelinus namaycush siscowet*) and 0.7 µg/g in whitefish (*Coregonus clupeaformis*) from the vicinity of Isle Royale, Lake Superior, and 0.3 µg/g in lake trout (*Salvelinus namaycush*) from Lake Superior exclusive of the Isle Royale area. A maximum concentration of 2.2 µg DEHP/g was reported for skinless fillets of whitefish from Lake Superior (Glass *et al.*, 1977). Mayer *et al.* (1972) reported DEHP concentrations of up to 0.8 µg/g in walleye (*Stizostedion vitreum*) from Black Bay, Lake Superior. Concentrations of DEHP in commercial fish lipid extracts of up to 7.24 µg/g wet weight were measured in herring (*Clupea harengus harengus*) muscle from the Bay of Fundy (Burns *et*

*al.*, 1981). DEHP concentrations in whole fish from various U.S. Great Lakes harbours and tributary mouths ranged from <0.04 to 32 µg DEHP/g wet weight in 1980 and 1981 (DeVault, 1985).

Bis(2-ethylhexyl) phthalate was detected in 33% of 139 STORET biota stations at a median concentration of 3.0 mg/kg wet weight (Staples *et al.*, 1985). Freshwater biota from the River Ronnebyan, Sweden, contained DEHP ranging from 0.31 to 14.4 mg/kg fresh weight (Thurén, 1986).

Phthalate levels in wild birds and mammals are very sparse. Zitko (1972) detected DEHP in blubber of common seal, *Phoca vitulina*, from Atlantic Canada at a concentration of 10.6 mg/kg lipid. Residue analysis of commercial eggs collected throughout Japan found average levels of 0.182 mg/kg DEHP in egg whites but no DEHP above the detection limit (1.00 mg/kg) in egg yolks (Ishida *et al.*, 1981).

## 5.0 KINETICS AND METABOLISM

Mathur and Rouatt (1975) identified ortho-phthalic acid as a major degradation product of DnOP produced by the bacterium *Serratia marcescens*. Bis(2-ethylhexyl) phthalate is metabolized in fish by enzymatic hydrolysis to mono-2-ethylhexyl phthalate (MEHP), phthalic acid, and glucuronides of these compounds (Stalling *et al.*, 1973). The gill has been found to be the dominant site of DEHP metabolism in rainbow trout, reducing the systemic availability of DEHP by >95% and thereby limiting the accumulation of this substance (Barron *et al.*, 1989).

Male albino ferrets (*Putorius putorius*) fed DEHP at a dietary concentration of 1% (w/w) for 14 months hydrolysed DEHP to MEHP, which was subsequently excreted in the urine as free or glucuronide conjugated MEHP derivatives (Lake *et al.*, 1976).

## 6.0 MAMMALIAN TOXICOLOGY

Male albino ferrets (*Putorius putorius*) receiving a mean daily intake of 1200 mg DEHP/kg/day as a dietary concentration of 1% (w/w) for 14 months had significantly lower body weights than the controls (about 900 g versus about 1300 g) (Lake *et al.*, 1976). A marked liver enlargement (5.4 g/100 g body weight in treated animals compared to 3.1 g/100 g body weight in controls) was also noted, along with morphological and biochemical changes in the liver, including liver cell enlargement, lysosomal changes, increased smooth endoplasmic reticulum and changes in concentration of a number of liver enzymes. Tissue damage was observed in the testes of some treated animals.

## 7.0 EFFECTS ON THE ENVIRONMENT

The results of a number of toxicity studies are presented in Tables 4a (acute toxicity) and 4b (chronic toxicity). The results of studies indicating the most toxic effects of phthalate esters in various groups of organisms are summarized in the following sections. It should be noted that in some cases adverse effects on aquatic organisms were only reported in studies using nominal DEHP concentrations well above its water solubility of about 300 to 400 µg/L.

### 7.1 Microorganisms

Bis(2-ethylhexyl) phthalate did not inhibit methanogenesis at concentrations up to 100,000 µg/L, but did inhibit production of methane at a concentration of 200,000 µg/L in a 26-day anaerobic toxicity assay using secondary sludge as the source of a heterogeneous anaerobic population (O'Connor *et al.*, 1989).

Volskay and Grady (1988) found that DEHP at its solubility limit of 400 µg/L reduced the oxygen consumption rate of activated sludge microorganisms by only 14% after 30 minutes of exposure.

Bis(2-ethylhexyl) phthalate injected into sediments from a eutrophic lake at concentrations of 25 mg/kg wet weight and above inhibited microbial activity in the sediment, as measured by decrease in oxygen concentration in the overlying water (Larsson *et al.*, 1986).

Tetra Tech Inc. (1986) used the Microtox test in their evaluation of sediment quality in Puget Sound. This toxicity bioassay uses the luminescent marine bacteria *Photobacterium phosphoreum* as the test organism, and response is measured as the reduction in light emitted by the bacteria after a 15 minute exposure. The Apparent Effects Threshold (AET, defined as the concentration above which statistically significant adverse effects are always expected relative to appropriate reference conditions) was estimated to be 1,900 µg DEHP/kg dry weight for Puget Sound sediment.

### 7.2 Algae

A 140h EC50 of >100 µg DEHP/L was reported for *Selenastrum capricornutum* based on numbers of cells (CMA, 1990).

### 7.3 Invertebrates

A 21d LOEL of 3 µg DEHP/L has been reported for *Daphnia magna* based on reduced reproduction (Sanders *et al.*, 1973). This study has, however, been criticized and largely discounted because of a very low rate of reproduction in the control group.

Other studies on the same species have shown adverse effects only at much higher concentrations. CMA (1990) reported a 21-day MATC (maximum acceptable toxicant concentration) of 110 µg DEHP/L for *Daphnia magna* based on survival. Knowles *et al.* (1987) reported a 7-day LOEL of 158 µg DEHP/L based on DNA content, a 7-day LOEL of 811 µg/L based on survival, and a 21-day LOEL of 811 µg/L based on survival, reproduction and glycogen content. Springborn Bionomics (1984) reported a 21-day LOEL of 160 µg DEHP/L (survival reduced by 25%), with a 21-day NOEL of 77 µg/L. This study was carried out under flow-through conditions, with concentrations of DEHP measured weekly. A 48-hour EC50 of 133 µg DEHP/L was reported for *Daphnia pulex* (Passino and Smith, 1987). A 10d LOEL of 500 µg DEHP/L was reported for the scud, *Gammarus pulex*, based on decreased locomotor activity (Thurén and Woin, 1991).

Dragonfly larvae (*Aeshna* sp.) exposed for 3 to 9 weeks to DEHP in aquaria sediments at concentrations of 587 and 623 mg DEHP/kg fresh weight (duplicate experiments) caught significantly fewer prey (*Chaoborus* sp.) per effort than did non-exposed larvae, held in an aquarium with a DEHP sediment concentration of 0.4 mg/kg fw (Woin and Larsson, 1987). Larvae exposed to DEHP successfully caught prey on 53% of the labial strikes, while controls were successful on 66% of their labial strikes.

Tetra Tech Inc. (1986) studied effects of variations in Puget Sound sediment quality on benthic invertebrates. This study used several approaches to evaluate sediment toxicity including the Apparent Effects Threshold. AET were developed for three aquatic invertebrate effects indicators: amphipod (*Rhepoxynius abronius*) mortality, oyster (*Crassostrea gigas*) larvae abnormality, and depressions in total abundance of higher level (Polychaeta, Mollusca, Crustacea) benthic infauna. Estimated AET values for these indicators were >3,100 µg DEHP/kg for the amphipod, 1,900 µg DEHP/kg for the oyster, and 1,900 µg DEHP/kg for the higher level benthic fauna. Subsequent re-evaluation of the Tetra Tech data by Barrick *et al.* (1988) resulted in a lowering of the benthic infaunal community AET to 1,300 µg DEHP/kg for Puget Sound sediments. As Chapman (1989) has noted, one of the criticisms of results of this type is that they can be site-specific. However results for Puget Sound are generally consistent with those of similar studies conducted in San Francisco Bay, California, and Commencement Bay, Washington (Long and Morgan, 1990).

Using equilibrium partitioning modelling, Tetra Tech Inc. (1986) calculated a sediment quality value of 74 mg DEHP/kg (dry weight) for sediment containing 1% organic carbon. Although use of equilibrium partitioning is becoming increasingly common in sediment quality assessment (Di Toro *et al.*, 1991), this method assumes that nonionic organic chemicals such as DEHP are associated with sediment organic carbon and that partitioning of

these chemicals between organic carbon and sediment pore water is at equilibrium (Chapman, 1989). Furthermore, the method has undergone only preliminary field validation (Chapman, 1989; Adams *et al.*, 1992), and thus its use in a regulatory context is controversial.

Phthalates were found to be the least toxic of the chemical groups tested on the earthworm *Eisenia fetida* (Neuhauser *et al.*, 1985, 1986). The LC50 value for DEHP was >25000 $\mu g/cm^2$ in a 2-day contact test in which the chemical was applied to filter paper, with the toxic unit referring to the amount of chemical per $cm^2$ of paper. Dimethylphthalate was the most toxic phthalate tested, with a LC50 of 550 $\mu g/m^2$. By comparison, the most toxic of the 44 chemicals tested, 2,4-dinitrophenol, had a LC50 of 0.6 $\mu g/m^2$.

Bis(2-ethylhexyl) phthalate applied to female house flies topically or by injection at a concentration of 20 $\mu g$/fly (1000 $\mu g/g$) was not toxic, causing a mortality of less than 16% after 24 hours (Al-Badry and Knowles, 1980). Antagonistic interactions were observed when flies were treated simultaneously with DEHP and various organophosphate insecticides, while synergistic interactions were observed when flies were pretreated with the phthalate 30 minutes before exposure to the pesticides. The authors found that DEHP inhibited metabolism of organophosphate pesticides, accounting for the synergistic effects. When the phthalate and insecticides were applied simultaneously, the resulting increase in the total lipophilic pool by the phthalate may have resulted in an internal concentration of insecticide below the toxicity threshold.

## 7.4 Fish

A 102-day LOEL of 14 $\mu g$ DEHP/L, based on sac fry survival, was reported for rainbow trout, *Oncorhynchus mykiss* (Mehrle and Mayer, 1976). This study was not used in the DEHP Assessment Report because after yolk absorption, at 24 days post-hatch, DEHP caused no statistically significant mortality or effects on growth and development for the rest of the exposure period. Furthermore, a later study (DeFoe *et al.*, 1990) found that DEHP had no statistically significant adverse effects on rainbow trout hatchability, survival, or growth during a 90-day exposure period, even at the highest concentration tested, 502 $\mu g$/L. Bis(2-ethylhexyl) phthalate significantly reduced the dry backbone collagen content of rainbow trout (*Oncorhynchus mykiss*, 90-day exposure), brook trout (*Salvelinus fontinalis*, 150-day exposure) and fathead minnow (*Pimephales promelas*, 127-day exposure) at concentrations as low as 14, 3.7 and 11 $\mu g$ DEHP/L, respectively (Mayer *et al.*, 1977). This reduction of vertebral collagen could have a debilitating effect on the fish because the increased mineralization makes their backbones more brittle. In

this study, the highest concentrations of DEHP tested (54, 52 and 100 µg/L for rainbow trout, brook trout and fathead minnow, respectively) did not have a statistically significant effect on the weight of the fish. A 24-day exposure of rainbow trout to DEHP at a concentration of 14 and 54 µg/L caused a significant decrease in protein concentration in whole fish and an increase in the amount of hydroxyproline in relation to protein content, evidence of an increase in catabolism of total body proteins.

A 168-day exposure to 541 µg DEHP/L significantly reduced the growth of the Japanese medaka, *Oryzias latipes* (DeFoe *et al.*, 1990). Freeman *et al.* (1981) found that DEHP administered to Atlantic cod, *Gadus morhua*, at concentrations as high as 10,000 µg/gelatin capsule had little or no effect on steroid metabolism in male fish. In female fish, however, there were a number of alterations in steroid metabolism in the DEHP-treated group that could exert adverse effects on gonadal development.

In acute toxicity studies, CMA (1990) reported 96 hour-$LC_{50}$ values of >320 µg/L and 670 µg/L for the rainbow trout (*Oncorhynchus mykiss*) and the fathead minnow (*Pimephales promelas*), respectively.

## 7.5 Amphibians and Reptiles

Larsson and Thurén (1987) found that DEHP added to sediment decreased hatching success of moorfrogs, *Rana arvalis*. Successful hatchings decreased with increasing sediment DEHP concentrations, with about 50% hatching success at a concentration of about 150 mg/kg fresh weight. The minimum hatching success was about 25% at sediment concentrations of 400 and 800 mg DEHP/kg. Hatching times, percentage of abnormalities, and post-hatch tadpole survival were not affected by exposure to DEHP.

## 7.6 Plants

Bis(2-ethylhexyl) phthalate at a concentration of 1,000,000 µg/L (0.1%) reduced the seed germination by 40% in peas, *Pisum sativum*, and by 52% in spinach, *Spinacia oleracea*, grown in tap water with DEHP added as a methanol solution (Herring and Bering, 1988). Bis(2-ethylhexyl) phthalate had no observable effects on subsequent seedling development of the seeds that did germinate in each treatment.

Løkke and Bro-Rasmussen (1981) found that application of DEHP to leaves of white mustard (*Sinapis alba*), nipplewort (*Lapsana communis*) or milfoil (*Achillea millefolium*) at a rate of 1.5 µg/cm$^2$ had no observable effect on any of the three plant species.

Growth of soybean (*Glycine max*) cell suspension cultures were not affected by a 5-day exposure to DEHP at concentrations as high as $10^{-3}$ moles/L (391,000 µg/L) (Langebartels and Harms, 1986).

A 7-day EC50 value of 2,060,000 µg/L was reported for duckweed, *Lemna gibba*, based on reproduction (Davis, 1981).

## 7.7 Birds

Ten-month-old white leghorn hens fed 0.5 or 1.0 g/100 g feed *ad libitum* for 230 days stopped laying eggs. Their livers and kidneys were hypertrophic and ovaries were abnormal. This diet represents a dose of 291 or 582 mg DEHP/kg-bird/day assuming an average bird weight of 1 kg and food intake of 0.0582 kg food/day (Nagy, 1987). When fed 0.2 g/100 g feed for 25 days, an approximate daily intake of 116 mg DEHP/kg-bird/day, they continued to lay eggs and the livers, kidneys and ovaries did not change visibly (Ishida *et al.*, 1982).

Captured wild starlings were fed 25 or 250 ppm of DEHP for 30 days (O'Shea and Stafford, 1980). As the birds weighed approximately 110 g and consumed an average of 21.3 g of food a day, the birds received a dose of 48.5 and 4.85 mg DEHP/kg-bird/day, respectively. The treated groups had significantly higher percentage of lipid than the control group suggesting that the phthalate diet placed the birds under physiological stress.

Egg production was down 5% from control levels, in white leghorn hens fed a diet of 1% DEHP (582 mg DEHP/kg-bird/day) (Wood and Bitman, 1980). However, egg quality was not affected. Plasma lipid and free cholesterol decreased by approx 20% from control levels over the course of the experiment, with a major drop occurring in the first week. Liver weights also increased although the amount was not statistically significant. When fed 1 or 2% of DEHP or one of 3 metabolites of DEHP for four weeks (582 or 1164 mg DEHP/kg-bird/day), Hubbard broiler breeder hens exhibited decreases in egg production of up to 35%, a 25% decrease in total plasma lipids and a slight but not statistically significant increase in liver weight (Wood and Bitman, 1984). This suggests that the branched aliphatic chain is the biological active component of the DEHP molecule. As similar effect occurs in rodents, the authors suggested that this drop in plasma lipid and free cholesterol could be associated with peroxisome proliferation. This decrease could also be linked to increased $\omega$ and $\omega$-1 oxidation by Cytochrome P-450. The authors gave no indication of where fat was accumulating in the liver. Therefore this paper is only evidence that fat metabolism in hens is affected by DEHP, not that DEHP is hepatocarcinogenic.

Peakall (1974) studied the effects of a 10 ppm diet of DEHP on the egg shell structure of ring doves (*Streptopelia risoria*). Assuming that an a ring dove weighs an average of 150 g and eats 17 g dry-wt of food per day (Nagy, 1987), the daily intake of DEHP is 1.13 mg DEHP/kg-bird. No significant effect was found with DEHP.

Korhonen *et al.* (1983) studied the embryo toxicity of "dioctyl phthalate" (authors did not specify whether DnOP or DEHP) to white leghorn chicken eggs. On the third day of incubation, 5 µL of DOP in acetone were injected onto the inner shell membrane. DOP did not have an embryotoxic effect over the acetone control at the highest dose tested (20 µmol or 7.8 mg). As DOP is a large, hydrophobic molecule, this lack of embryotoxicity is probably due to transport effects from its inability to penetrate the albumin-water layer and the vitelline membrane.

### 7.8 Mammals

No data were identified on toxicity of DEHP in mammalian wildlife.

## 8.0 CURRENT OBJECTIVES, GUIDELINES AND REGULATIONS

Environment Canada has produced a draft interim water quality guideline of 1.0 µg DEHP/L for the protection of freshwater aquatic life (Environment Canada, 1992). Manitoba, Ontario and the International Joint Commission have published water quality guidelines/objectives of 0.6 µg DEHP/L to protect aquatic life (Environment Canada, 1992).

For the protection of freshwater and saltwater aquatic life, the U.S. EPA has suggested a draft Criteria Maximum Concentration (CMC) of 400 µg DEHP/L and a Criteria Continuous Concentration (CCC) of 360 µg DEHP/L. These suggested figures are open to public comment and will serve as guidance to individual States in developing water quality standards which are used as the basis for setting enforceable effluent limitations (Environment Canada, 1992).

## 9.0 REFERENCES


Adams, W.J. and B.B. Heidolph. 1985. Short-cut chronic toxicity estimates using *Daphnia magna*. Aquatic Toxicology and Hazard Assessment: Seventh Symposium, ASTM STP 854, R.D. Cardwell, R Purdy and R.C. Bahner, Eds., American Society for Testing and Materials, Philadelphia, pp. 87-103.

Adams, W.J., R.A. Kimerle and J.W. Barnett. 1992. Sediment quality and aquatic life assessment. Environ. Sci. Technol. 26:1864-1875.

Al-Badry, M.S. and C.O. Knowles. 1980. Phthalate-organophosphate interactions: toxicity, penetration, and metabolism studies with house flies. Arch. Environ. Contam. Toxicol. 9:147-161.

Alberta Environment. 1986. North Saskatchewan River characterization of Water Quality in the vicinity of Edmonton (1982-1983). Water Quality Branch, Edmonton.

Al-Omran, L.A. and M.R. Preston. 1987. The interactions of phthalate esters with suspended particulate material in fresh and marine waters. Environ. Pollut. 46:177-186.

Atlas, E. and C.S. Giam. 1981. Global transport of organic pollutants: ambient concentrations in the remote marine atmosphere. Science 211:163-165.

ATSDR. 1991. Toxicological profile for di(2-ethylhexyl) phthalate. Draft for public comment. Agency for Toxic Substances and Disease Registry, U.S. Dept. of Health & Human Services.

Atwater, J.W., S.E. Jasper, P.D. Parkinson and D.S. Mavinic. 1990. Organic contaminants in Canadian coal wastewaters and associated sediments. Water Pollut. Res. J. Canada 25: 187-200.

Barrick, R., S. Becker, L. Brown, H. Beller and R. Pastrook. 1988. Sediment Quality Values Refinement: 1988 Update and Evaluation of Puget Sound AET. PTI Environmental Services, Bellevue, Washington.

Barron, M.G., I.R. Schultz and W.L. Hayton. 1989. Presystemic branchial metabolism limits di-2-ethylhexyl phthalate accumulation in fish. Toxicol. Appl. Pharmacol. 98:49-57.

Barrows, M.E., S.R. Petrocelli, K.J. Macek and J.J. Carroll. 1980. Bioconcentration and elimination of selected water pollutants by bluegill sunfish (*Lepomis macrochirus*). *In* Dynamics, exposure and hazard assessment of toxic chemicals. R. Haque (ed.). Ann Arbor Science Publ. Inc., Ann Arbor, Michigan. pp.370-392.

Beak Consultants. 1991. Evaluation of acute and chronic toxicity of Ontario sewage treatment plant effluents. Report prepared for Ontario Ministry of the Environment by Beak Consultants Limited, March 1991.

Belisle, A.A, W.L Reichel and J. W. Spann. 1975. Analysis of tissues of Mallard Ducks fed two phthalate esters. Bull. Environ. Contam. Toxicol. 13:129-32.

Birge, W.J., J.A. Black and D.M. Bruser. 1979. Toxicity of organic chemicals to embryo-larval stages of fish. EPA-560/11-79-007. NTIS PB80-101637. U.S. Environmental Protection Agency, Washington, DC.

Birge, W.J., J.A. Black and A.G. Westerman. 1978. Effects of polychlorinated biphenyl compounds and proposed PCB-replacement products on embryo-larval stages of fish and amphibians. Water Resources Research Institute, University of Kentucky, Lexington, KY. Research Report No. 118.

Boese, B.L. 1984. Uptake efficiency of the gills of English sole (*Parophrys vetulus*) for four phthalate esters. Can. J. Fish. Aquat. Sci. 41:1713-1718.

Bove, J.L., P. Dalven and V.P. Kukreja. 1978. Airborne di-butyl and di-(2-ethylhexyl)-phthalate at three New York City air sampling stations. Intern. J. Anal. Chem. 5: 189-194.

Branson, D.R. 1978. Predicting the fate of chemicals in the aquatic environment from laboratory data. *In* Estimating the hazard of chemical substances to aquatic life. J. Cairns, Jr., K.L. Dickson and A.W. Maki (eds.) ASTM STP 657. American Society for Testing and Materials, pp. 55-70.

Branson, D.R. 1980. Prioritization of chemicals according to the degree of hazard in the aquatic environment. Environ. Health Perspec. 34:133-138.

Brown, D. and R.S. Thompson. 1982a. Phthalates and the aquatic environment: Part II. The bioconcentration and depuration of di-2-ethylhexyl phthalate (DEHP) and di-isodecyl phthalate (DIDP) in mussels (*Mytilus edulis*). Chemosphere 11:427-435.

Brown, D. and R.S. Thompson. 1982b. Phthalates and the aquatic environment: Part I. The effects of di-2-ethylhexyl phthalate (DEHP) and di-isodecyl phthalate (DIDP) on the reproduction of *Daphnia magna* and observations on their bioaccumulation. Chemosphere 11:417-426.

Brownlee, B. and W.M.J. Strachan. 1977. Distribution of some organic compounds in the receiving waters of a kraft pulp and paper mill. J. Fish. Res. Board Can. 34:830-837.

Buccafusco, R.J., S.J. Ellis and G.A. LeBlanc. 1981. Acute toxicity of priority pollutants to bluegill (*Lepomis macrochirus*). Bull. Environ. Contamin. Toxicol. 26: 446-452.

Burns, B.G., C.J. Musial and J.F. Uthe. 1981. Novel cleanup method for quantitative gas chromatographic determination of trace amounts of di-2-ethylhexyl phthalate in fish lipid. J. Assoc. Off. Anal. Chem. 64:282-286.

Callahan, M.A., M.W. Slimak, N.W. Gabel, I.P. May, C.F. Fowler, J.R. Freed, P. Jennings, R.L. Durfee, F.C. Whitmore, B. Maestri, W.R. Mabey, B.R. Holt and C. Gould. 1979. Water-related environmental fate of 129 priority pollutants. Volume II. Halogenated aliphatic hydrocarbons, halogenated ethers, monocyclic aromatics, phthalate esters, polycyclic aromatic hydrocarbons, nitrosamines, miscellaneous compounds. EPA-440/4-79-029b. U.S. Environmental Protection Agency, Washington, D.C.

Camford Information Services Inc. 1992. CPI product profiles - Dioctyl phthalate. Camford Information Services Inc., Don Mills, Ontario. 4 p.

Carlberg, G.E., H. Drangsholt and N. Gjøs. 1986. Identification of chlorinated compounds in the spent chlorination liquor from differently treated sulphite pulps with special emphasis on mutagenic compounds. Sci. Total Environ. 48: 157-167.

Cautreels, W. and K. Van Cauwenberghe. 1978 Experiments on the distribution of organic pollutants between airborne particulate matter and the corresponding gas phase. Atmospheric Environment 12:1133-1141.

Cautreels, W., K. Van Cauwenberghe and L.A. Guzman. 1977. Comparison between the organic fraction of suspended matter at a background and an urban station. Sci. Total Environ. 8:79-88.

CCREM. 1987. Canadian Water Quality Guidelines. Prepared by the Task Force on Water Quality Guidelines of the Canadian Council of Resource and Environment Ministers.

Chan, H.S. 1975. A study of the transfer processes of phthalate esters to the marine environment. Ph.D. Dissertation submitted to the Graduate College of Texas A&M Univeristy.

Chapman, P. 1989. Current approaches to developing sediment quality criteria. Environ. Toxicol. Chem. 8:589-599.

CMA. 1984. Generation of environmental fate and effects data base on 14 phthalate esters. Summary Report - Environmental Studies - Phase I. Chemical Manufacturers Association, Phthalate Esters Program Panel. Washington, DC.

CMA. 1990. Comments of the Phthalate Esters Panel of the Chemical Manufacturers Association on EPA's proposed ambient water quality criteria for DEHP. Docket OW-FRL-3762-9. Chemical Manufacturers Association, August, 1990.

Davis, J.A. 1981. Comparison of static-replacement and flow-through bioassays using duckweed, *Lemna gibba* G-3. U.S. Environmental Protection Agency, Washington, D.C. EPA 560/6-81-003.

DeFoe, D.L., G.W. Holcombe, D.E. Hammermeister and K.E. Biesinger. 1990. Solubility and toxicity of eight phthalate esters to four aquatic organisms. Environ. Toxicol. Chem. 9:623-636.

DeVault, D.S. 1985. Contaminants in fish from Great Lakes harbors and tributary mouths. Arch. Environ. Contam. Toxicol. 14: 587-594.

Diercxsens, P. and J. Tarradellas. 1987. Soil contamination by some organic micropollutants related to sewage sludge spreading. Intern. J. Environ. Anal. Chem. 28:143-159.

Di Toro, D.M, C.S. Zarba, D.J. Hansen, W.J. Berry, R.C. Swartz, C.E. Cowan, S.P. Pavlou, H.E. Allen, N.A. Thomas and P.R. Paquin. 1991. Technical basis for establishing sediment quality criteria for nonionic organic chemicals using equilibrium partitioning. Environ. Toxicol. Chem. 10:1541-1583.

Eglinton, G., B.R.T. Simoneit and J.A. Zoro. 1975. The recognition of organic pollutants in aquatic sediments. Proc. R. Soc. Lond. B. 189:415-442.

Eiceman, G.A., R.E. Clement and F.W. Karasek. 1979. Analysis of fly ash from municipal incinerators for trace organic compounds. Anal. Chem. 51:2343-2350.

Eisenreich, S.J., B.B. Looney and J.D. Thornton. 1981. Airborne organic contaminants in the Great Lakes ecosystem. Environ. Sci. Technol. 15:30-38.

Environment Canada. 1980. Substances in the list of Priority Chemicals - 1979. Phthalic acid esters. Infonotes CCB-IN-2-80. Environmental Protection Service, Hull, Quebec.

Environment Canada. 1989. Environmental assessment of the Canadian textile industry. Report EPS 5/TX/1. Industrial Programs Branch. June 1989.

Environment Canada. 1992. Water quality guidelines for phthalates. Draft. March 1992. Water Quality Branch, Ottawa, Ontario.

Ewing, B.B., E.S.K. Chian, J.C. Cook, C.A. Evans and P.K. Hopke. 1977. Monitoring to detect previously unrecognized pollutants in surface waters. Appendix 1. Organic Analysis Data. U.S. National Technical Information Service Document No. PB-273-350.

Fallon, M.E. and F.J. Horvath. 1985. Preliminary assessment of contaminants in soft sediments of the Detroit River. J. Great Lakes Res. 11:373-378.

Fatoki, O.S. and F. Vernon. 1990. Phthalate esters in rivers of the Greater Manchester area, U.K. Sci. Total Environ. 95: 227-232.

Freeman, H.C., G.B. Sangalang, B.G. Burns and M McMenemy. 1981. The effects of di-(2-ethylhexyl)-phthalate (DEHP) on steroid metabolism in the Atlantic cod *Gadus morhua*. *In*: Proc. of the Seventh Annual Aquatic Toxicity Workshop. Nov. 5-7, 1980, Montreal, Quebec. N. Bermingham, C. Blaise, P.Couture, B. Hummel, G. Joubert and M. Speyer (Eds.). Can. Tech. Rep. Fish. Aquat. Sci. No. 990, pp.199-226.

Galceran, M.T., R. Rubio and G. Rauret. 1989. Looking for sources of organic pollution in groundwater. Water Supply 7:1-9.

Germain, A. and C. Langlois. 1988. Contamination des eaux et des sédiments en suspension du fleuve Saint-Laurent par les pesticides organochlorés, les biphényles polychlorés et d'autres contaminants organiques prioritaires. Water Pollut. Res. J. Canada 23:602-614.

Geyer, H., G. Politzki and D. Freitag. 1984. Prediction of ecotoxicological behaviour of chemicals: relationship between n-octanol/water partition coefficient and bioaccumulation of organic chemicals by alga Chlorella. Chemosphere 13:269-284.

Ghassemi, M., S. Quinlivan and J. Bachmaier. 1984. Characteristics of leachates from Hazardous Waste Landfills. J. Environ. Sci. Health A19:579-620.

Giam, C.S. and E. Atlas. 1980. Accumulation of phthalate ester plasticizers in Lake Constance sediments. Die Naturwissenschaften 67:508-510.

Giam, C.S., E. Atlas, H. Chan and G. Neff. 1977. Estimation of fluxes of organic pollutants to the marine ernvironment - phthalate plasticizer concentration and fluxes. Rev. Int. Oceanogr. Med. 47:79-84.

Giam, C.S., H.S. Chan, G.S. Neff and E.L. Atlas. 1978. Phthalate ester plasticizers: a new class of marine pollutant. Science 199:419-421.

Giam, C.S., E. Atlas, H.S. Chan and G.S. Neff. 1980. Phthalate esters, PCB and DDT residues in the Gulf of Mexico atmosphere. Atmospheric Environment 14:65-69.

Glass, G.E., W.M.I. Strachan, W.A. Willford, F.A.I. Armstrong, K.L.E. Kaiser and A. Lutz. 1977. Organic contaminants. In: The waters of Lake Huron and Lake Superior. Volume III (Part B). Lake Superior. Report to the International Joint Commission by the Upper Lakes Reference Group. EPA-600/J-77-042. pp. 417-429, 499-502.

GLWQB. 1986. 1985 Annual Report - Committee on the Assessment of Human Health Effects of Great Lakes Water Quality. Great Lakes Water Quality Board/Grealt Lakes Science Advisory Board. Revision of October 1986.

Golder Associates. 1987. Testing of specific organic compounds in soils in background urban areas: Port Credit and Oakville/Burlington, Ontario. Working paper to Shell Canada Ltd. and Texaco Ltd. by Golder Associates, August 1987.

Halina, G.P. 1993a. Letter from G.P. Halina, Environment Alberta to K. Taylor, Environment Canada, April 27, 1993.

Halina, G.P. 1993b. Letter from G.P. Halina, Environment Alberta to K. Taylor, Environment Canada, April 23, 1993.

Heitmuller, P.T., T.A. Hollister and P.R. Parrish. 1981. Acute toxicity of 54 industrial chemicals to sheepshead minnows (*Cyprinodon variegatus*). Bull. Environ. Contam. Toxicol. 27: 596-604.

Herring, R., and C.L. Bering. 1988. Effects of phthalate esters on plant seedlings and reversal by a soil microorganism. Bull. Environ. Contam. Toxicol. 40:626-632.

Hites, R.A. and W.L. Budde. 1991. EPA's analytical methods for water: the next generation. Environ. Sci. Technol. 25: 998-1006.

Howard, P.H. 1989. Handbook of environmental fate and exposure data for organic chemicals. Volume I. Large production and priority pollutants. Lewis Publishers Inc., Chelsea, Michigan.

Howard, P.H., S. Banerjee and K.H. Robillard. 1985. Measurement of water solubilities, octanol/water partition coefficients and vapor pressures of commercial phthalate esters. Environ. Toxicol. Chem. 4:653-661.

Howard, P.H., R.S. Boethling, W.F. Jarvis, W.M. Meylan and E.M. Michalenko. 1991. Handbook of environmental degradation rates. Lewis Publishers Inc., Chelsea, Michigan.

Hrudey, S.E., G.A. Sergy and T. Thackeray. 1976. Toxicity of oil sands plant wastewaters and associated organic contaminants. *In* Water Pollution Research in Canada, Proc. 11th Canadian Symp., pp. 34-45.

IPCS (International Programme on Chemical Safety). 1992. Diethylhexyl Phthalate. Environmental Health Criteria 131. World health Organization, Geneva. 141 pp.

Ishida, M., K. Suyama and S. Adachi. 1980. Background contamination by phthalates commonly encountered in the chromatographic analysis of lipid samples. J. Chromatog. 189:421-424.

Ishida, M., K. Suyama and S. Adachi. 1981. Occurrence of dibutyl and di(2-ethylhexyl) phthalate in chicken eggs. J. Agric. Food Chem. 29:72-74.

Ishida, M., K. Suyama, S. Adachi and T. Hoshino. 1982. Distribution of orally administered di-ethylhexyl phthalate in laying hens. Poult. Sci. 61:262-267.

Jaagumagi, R. 1989. Personal communication, Ontario Ministry of the Environment.

Johnson, B.T., M.A. Heitkamp and J.R. Jones. 1984. Environmental and chemical factors influencing the biodegradation of phthalic acid esters in freshwater sediments. Environ. Pollut. (Ser. B) 8:101-118.

Johnson, B.T. and W. Lulves. 1975. Biodegradation of di-*n*-butyl phthalate and di-2-ethylhexyl phthalate in freshwater hydrosoil. J. Fish. Res. Board Can. 32:333-339.

Johnson, B.T., D.L. Stalling, J.W. Hogan and R.A. Schoettger. 1977. Dynamics of phthalate acid esters in aquatic organisms. *In* Fate of pollutants in the air and water environment. I.H. Suffet (ed.). Part 2, Adv. Environ. Sci. Technol. 8:283-300. Wiley Interscience, New York.

Karara, A.H. and W.L. Hayton. 1989. A pharmacokinetic analysis of the effect of temperature on the accumulation of di-2-ethylhexyl phthalate (DEHP) in sheepshead minnow. Aquatic Toxicol. 15:27-26.

Kenaga, E.E. 1980. Predicted bioconcentration factors and soil sorption coefficients of pesticides and other chemicals. Ecotoxicol. Environ. Safety 4:26-38.

Khan, S.U. 1980. Role of humic substances in predicting fate and transport of pollutants in the environment. *In* Dynamics, exposure and hazard assessment of toxic chemicals. Symposium, Miami Beach, Fla., Sept. 11-13, 1978. R. Haque (ed.). Ann Arbor Science Publishers, Inc., Ann Arbor, Mich. pp. 215-230.

Kinkead, J.D. and R.M. Chatterjee. 1974. A limnological survey of nearshore waters of Lake Superior. Proc. 17th Conf. Great Lakes Res., Internat. Assoc. Great Lakes Res., pp. 549-573.

Kirchmann, H., H. Åström and G. Jönsäll. 1991. Organic pollutants in sewage sludge. 1. Effect of toluene, naphthalene, 2-methylnaphthalene, 4-n-nonylphenol and di-2-ethylhexyl phthalate on soil biological processes and their decomposition in soil. Swedish J. Agric. Res. 21:107-113.

Klöpfer, W., G. Kaufmann, G. Rippen and H.-J. Poremski. 1982. A laboratory method for testing the volatility from aqueous solution: first results and comparison with theory. Ecotoxicol. Environ. Safety 6:545-559.

Knowles, C.O. and M.J. McKee. 1987. Short-term biochemical indicators of chronic insecticide toxicity to *Daphnia magna*. *In*: Pesticide science and biotechnology. Proc. of the Sixth International Congress of Pesticide Chemistry. Aug. 10-15, 1986, Ottawa, Ontario. R. Greenhalgh and T.R. Roberts (Eds.). Blackwell Scientific Publications, pp. 449-452.

Knowles, C.O., M.J. Mckee and D.U. Palawski. 1987. Chronic effects of di-2-ethylhexyl phthalate on biochemical composition, survival and reproduction of *Daphnia magna*. Environ. Toxicol. Chem. 6:201-208.

Kohli, J., J.F. Ryan and B.K. Afghan. 1989. Phthalate esters in the aquatic environment. *In* Analysis of trace organics in the aquatic environment. B.K. Chau and A.S.Y. Chau (eds.). CRC Press, Inc, Boca Raton, Fla. P.243-281.

Korhonen, A., K. Hemminki and H. Vanio. 1983. Embryo toxic effects of phthalic-acid derivatives, phosphates and aromatic oils used in the manufacturing of rubber on three day chicken embryos. Drug Chem. Toxicol. 6:191-208.

Kuntz, K.W. 1984. Toxic contaminants in the Niagara River, 1975-1982. Technical Bulletin No. 134. Environment Canada, Inland Waters Directorate, Ontario Region, Burlington, Ontario.

Kveseth, N.J. 1980. Chlorinated hydrocarbons in sewage sludge from a plant in Oslo. Nord. Vet.- Med. 32:341-347.

Lake, B.G., P.G. Brantom, S.D. Gangolli, K.R. Butterworth and P. Grasso. 1976. Studies on the effects of orally administered di-(2-ethylhexyl) phthalate in the ferret. Toxicology 6:341-356.

Langebartels, C. and H. Harms. 1986. Plant cell suspension cultures as test systems for an ecotoxicologic evaluation of chemicals. Growth inhibition effects and comparison with the metabolic fate in intact plants. Angew. Botanik 60:113-123.

Larsson, P. and A. Thurén. 1987. Di-2-ethylhexylphthalate inhibits the hatching of frog eggs and is bioaccumulated by tadpoles. Environ. Toxicol. Chem. 6:417-422.

Larsson, P., A. Thurén and G. Gahnström. 1986. Phthalate esters inhibit microbial activity in aquatic sediments. Environ. Pollut. 42:223-231.

Laughlin, R.B., Jr., J.M. Neff, Y.C. Hrung, T.C. Goodwin and C.S. Giam. 1978. The effects of three phthalate esters on the larval development of the grass shrimp *Palaemonetes pugio* (Holthuis). Water Air Soil Pollut. 9:323-336.

Law, R.J., T.W. Fileman and P. Matthiessen. 1991. Phthalate esters and other industrial organic chemicals in the North and Irish Seas. Water Sci. Tech. 24:127-134.

Leah, T.D. 1977. Environmental contaminants inventory study No. 4. The production, use and distribution of phthalic acid esters in Canada. Inland Waters Directorate. Report Series 47. Fisheries and Environment Canada. 67 pp.

LeBlanc, G.A. 1980. Acute toxicity of priority pollutants to water flea (*Daphnia magna*). Bull. Environ. Contam. Toxicol. 24:684-691.

Ligocki, M.P., C. Leuenberger and J.F. Pankow. 1985. Trace organic compounds in rain - II. Gas scavenging of neutral organic compounds. Atmos. Environ. 19:1609-1617.

Lindén, E., B.-E. Bengtsson, O. Svanberg and G. Sundström. 1979. The acute toxicity of 78 chemicals and pesticide formulations against two brackish water organisms, the bleak (*Alburnus alburnus*) and the harpticoid (*Nitocra spinipes*). Chemosphere 8:843-851.

Løkke, H. and F. Bro-Rasmussen. 1981. Studies of mobility of di-iso-butyl phthalate (DiBP), Di-n-butyl phthalate (DBP), and di-(2-ethyl hexyl) phthalate (DEHP) by plant foliage treatment in a closed terrestrial simulation chamber. Chemosphere 10:1223-1235.

Long, E.R. and L.G. Morgan. 1990. The Potential for Biological Effects of Sediment-Sorbed Contaminants Tested in the National Status and Trends Program. NOAA Tech. Memo. NOS OMA 52. Seattle, Washington. National Ocean and Atmospheric Administration. 175 pp.

Lunde, G., J. Gether, N. Gjøs and M.-B. Støbet Lande. 1977. Organic micropollutants in precipitation in Norway. Atmospheric Environment 11:1007-1014.

Macek, K.J., S.R. Petrocelli and B.H. Sleight, III. 1979. Considerations in assessing the potential for, and significance of chemical residues in aquatic food chains. *In* Aquatic toxicology, ASTM STP 667. L.L. Marking and R.A. Kimerle (eds.). American Society for Testing and Materials. pp. 251-268.

Malisch, R., E. Schulte and L. Acker. 1981. Chlororganische Pestizide, polychlorierte Biphenyle und Phthalate in Sedimenten aus Rhein und Neckar. Chemiker-Zeitung 105: 187-194.

Mathur, S.P. 1974. Phthalate esters in the environment: pollutants or natural products? J. Environ. Qual. 3: 189-197.

Mathur, S.P. and J.W. Rouatt. 1975. Utilization of the pollutant di-2-ethylhexyl phthalate by a bacterium J. Environ. Qual. 4:273-275.

Mayer, F.L. 1976. Residue dynamics of di-2-ethylhexyl phthalate in fathead minnows (*Pimephales promelas*). J. Fish. Res. Board Can. 33:2610-2613.

Mayer, F.L., Jr. and M.R. Ellersieck. 1986. Manual of acute toxicity: interpretation and data base for 410 chemicals and 66 species of freshwater animals. Resource Publication 160, U.S. Department of the Interior, Fish and Wildlife Service, Washington, D.C.

Mayer, F.L., Jr., M. Mehrle and R.A. Schoettger. 1977. Collagen metabolism in fish exposed to organic chemicals. *In*: Recent advances in fish toxicology. A symposium held in Corvallis, Oregon, January 13-14, 1977. pp. 31-54.

Mayer, F.L., Jr. and H.O. Sanders. 1973. Toxicology of phthalic acid esters in aquatic organisms. Environ. Health Perspect. 3:153-157.

Mayer, F.L., Jr., D.L.Stalling and J.L. Johnson. 1972. Phthalate esters as environmental contaminants. Nature 238:411-413.

Mehrle, P.M. and F.L. Mayer. 1976. Di-2-ethylhexyl phthalate: residue dynamics and biological effects in rainbow trout and fathead minnows. *In* Trace Substances in Environmental Health - X. Proc. Universtity of Missouri's 10th Annual Conf. D.D. Hemphill (ed.). pp. 519-524.

MENVIQ. 1993. Ministère de l'Environnement de Québec. Unpublished data.

Michael, P.R., W.J. Adams, A.F. Werner and O. Hicks. 1984. Surveillance of phthalate esters in surface waters and sediments in the United States. Environ. Toxicol. Chem. 3: 377-389.

Michigan Department of Natural Resources. 1974. Studies of water, sediments and biota in Lake St. Clair.

Monsanto Co. 1981. Acute toxicity of di-(2-ethylhexyl) phthalate (DEHP) to the midge Paratanytarsus parthenogenetica. U.S. Environmental Protection Agency, Office of Toxic Substances, ES-81-SS-35.

Monsanto Co. 1982. Acute toxicity of di(2-ethylhexyl) phthalate to Chironomus tentans. U.S. Environmental Protection Agency, Office of Toxic Substances, ES-82-SS-80.

Montgomery, J.H. and L.M. Welkom. 1990. Groundwater chemicals desk reference. Lewis Publishers Inc., Chelsea, Michigan.

Müller, G., J. Dominik, R. Reuther, R. Malisch, E. Schulte, L. Acker and G. Irion. 1980. Sedimentary record of environmental pollution in the Western Baltic Sea. Naturwissenschaften 67:595-600.

Munro, J.R., M.G. Foster, T. Pawson, A. Stelzig, T. Tseng and L. King. 1985. St. Clair River point source survey 1979 - 1980. Ontario Ministry of the Environment and Environment Canada. September 1985.

Murray, H.E., L.E. Ray and C.S. Giam. 1981. Phthalic acid esters, total DDTs, and polychlorinated biphenyls in marine samples from Galveston Bay, Texas. Bull. Environ. Contam. Toxicol. 26:769-774.

Nagy, K.A. 1987. Field metabolic rate and food requirement scaling in mammals and birds. Ecol. Mono. 57:111-128.

NAQUADAT. 1993. National Water Quality Data Bank. Water Quality Branch, Inland Waters Directorate, Environment Canada.

NATES. 1992. National Analysis of Trends in Emergencies System database. Environmental Emergencies Branch, Environment Canada.

Neuhauser, E.F., R.C. Loehr and M.R. Malecki. 1986. Contact and artificial soil tests using earthworms to evaluate the impact of wastes in soil. Hazardous and Industrial Solid Waste Testing: Fourth Symposium. ASTM STP 886. J.K. Petros, Jr., W.J. Lacy and R.A. Conway, Eds. American Society for Testing and Materials, Philadelphia, pp. 192-203.

Neuhauser, E.F., R.C. Loehr, M.R. Malecki, D.L. Milligan and P.R. Durkin. 1985. The toxicity of selected organic chemicals to the earthworm *Eisenia fetida*. J. Environ. Qual. 14:383-388.

Niagara River Data Interpretation Group. 1990. Joint evaluation of upstream/downstream Niagara River monitoring data, 1988-1989. Prepared by Data Interpretation Group, River Monitoring Committee. A joint publication of Environment Canada, U.S. Environmental Protection Agency, Ontario Ministry of the Environment, and New York State Dept. of Environmental Conservation.

O'Connor, O.A., M.D. Rivera and L.Y. Young. 1989. Toxicity and biodegradation of phthalic acid esters under methanogenic conditions. Environ. Toxicol. Chem. 8:569-574.

Ogner, G. and M. Schnitzer. 1970. Humic substances: fluvic acid-dialkyl phthalate complexes and their role in pollution. Science 170:317-318.

Ogura, N., Y. Ambe, K. Ogura, R. Ishiwatari, T. Mizutani, Y. Satoh, H. Matsushima, T. Katase, M. Ochiai, K. Tadokoro, T. Takada, K. Sugihara, G. Matsumoto, N. Nakamoto, M. Funakoshi and T. Hanya. 1975. Chemical composition of organic compounds present in water of the Tamagawa River. Jap. J. Limnol. 36:23-30.

OME (Ontario Ministry of the Environment). 1992a. Municipal-Industrial Strategy for Abatement (MISA). Twelve month monitoring data report. Organic Chemical Manufacturing Sector (Oct.1, 1989 to September 30, 1990. Water Resources Branch.

OME (Ontario Ministry of the Environment). 1992b. Municipal-Industrial Strategy for Abatement (MISA). Draft. Twelve month monitoring data report - inorganic chemical sector. Periods covered: December 1, 1989 to November 30, 1990, February 1, 1990 to January 31, 1991. Water Resources Branch. March 1992.

O'Shea, T.J. and C.J. Stafford. 1980. Phthalate plasticizers accumulation and effects on weight and food consumption in captive starlings. Bull. Environ. Contam. Toxicol. 25:345-352.

Passino, D.R.M. and S.B. Smith. 1987. Acute bioassays and hazard evaluation of representative contaminants detected in Great Lakes fish. Environ. Toxicol. Chem. 6:901-907.

Peakall, D.B. 1974. Effects of di-n-butyl and di-2-ethylhexyl phthalate on the eggs of ring doves. Bull. Environ. Contam. Toxicol. 12:698-702.

Peakall, D.B. 1975. Phthalate esters: occurrence and biological effects. Residue Rev. 54: 1-41.

Perez, K.T., E.W. Davey, N.F. Lackie, G.E. Morrison, P.G. Murphy, A.E. Sopper and D.L. Winslow. 1983. Environmental assessment of a phthalate ester, di(2-ethylhexyl) phthalate (DEHP), derived from a marine microcosm. *In* Aquatic Toxicology and Hazard Assessment: Sixth Symposium. ASTM STP 802. W.E. Bishop, R.D. Cardwell and B.B. Heidolph (eds.). American Society for Testing and Materials. Philadelphia. pp. 180-191.

Persson, P.-E, H. Penttinen and P. Nuorteva. 1978. DEHP in the vicinity of an industrial area in Finland. Environ. Pollut. 16:163-166.

Peterson, J.C. and D.H. Freeman. 1984. Variations of phthalate ester concentrations in sediments from the Chester River, Maryland. Intern. J. Environ. Anal. Chem. 18:237-252.

Pierce, R.C., S.P. Mathur, D.T. Williams and M.J. Boddington. 1980. Phthalate esters in the aquatic environment. National Research Council of Canada, Associate Committee on Scientific Criteria for Environmental Quality. NRCC No. 17583. Ottawa, Ontario.

Ray, L.E., H.E. Murray and C.S. Giam. 1983a. Analysis of water and sediment from the Nueces Estuary/Corpus Christi Bay (Texas) for selected organic pollutants. Chemosphere 12: 1039-1045.

Ray, L.E., H.E. Murray and C.S. Giam. 1983b. Organic pollutants in marine samples from Portland, Maine. Chemosphere 12: 1031-1038.

Rogers, I.H., I.K. Birtwell and G.M. Kruzynski. 1986. Organic extractables in municipal wastewater, Vancouver, British Columbia. Water Pollut. Res. J. Canada 21:187-204.

Rogers, I.H. and K. J. Hall. 1987. Chlorophenols and chlorinated hydrocarbons in starry flounder (*Platichthys stellatus*) and contaminants in estuarine sediments near a large municipal outfall. Water Pollut. Res. J. Canada 22:197-210.

Sadtler Research Laboratories. 1982. Infrared spectra of priority pollutants and toxic chemicals. Sadtler Research Laboratories, Philadelphia, PA.

Saeger, V.W. and E.S. Tucker. 1976. Biodegradation of phthalic acid esters in river water and activated sludge. Appl. Environ. Microbiol. 31:29-34.

Sanders, H.O., F.L. Mayer and D.F. Walsh. 1973. Toxicity, residue dynamics, and reproductive effects of phthalate esters in aquatic invertebrates. Environ. Res. 6:84-90.

Schacht, R.A. 1974. Pesticides in the Illinois waters of Lake Michigan. U.S. EPA. EPA 660/3-74-002.

Schmitzer, J.L., I. Scheunert and F. Korte. 1988. Fate of bis(2-ethylhexyl) [$^{14}$C]phthalate in laboratory and outdoor soil-plant systems. J. Agric. Food Chem. 36:210-215.

Schouten, M.J., J.W. Copius Peereboom and U.A.Th. Brinkman. 1979. Liquid chromatographic analysis of phthalate esters in Dutch river water. Int. J. Environ. Anal. Chem. 7:13-23.

Schwartz, H.E., C.J.M. Anzion, H.P.M. Van Vleit, J.W. Copius Peerbooms and U.A. Th. Brinkman. 1979. Intern. J. Anal. Chem. 6:133-144.

Sheldon, L.S. and R.A. Hites. 1978. Organic compounds in the Delaware River. Environ. Sci. Technol. 12:1188-1194.

Sheldon, L.S. and R.A. Hites. 1979. Sources and movement of organic chemicals in the Delaware River. Environ. Sci. Technol. 13:574-579.

Shelton, D.R., S.A. Boyd and J.M. Tiedje. 1984. Anaerobic biodegradation of phthalic acid esters in sludge. Environ. Sci. Technol. 18:93-97.

Shibuya, S. 1979. Phthalic acid esters as one of the marker environmental pollutants - occurrence in the water and aquatic environment in Shizuoka Prefecture. Numazu Kogyo Kota Semmon Gakko Kenkyu Hokoku 14:63-72.

Spink, D. 1986. Letter from D. Spink, Environment Alberta to P. Toft, Health and Welfare Canada, August 8, 1986.

Springborn Bionomics. 1984. Chronic toxicity of fourteen phthalate esters to *Daphnia magna*. Toxicity test report submitted to Chemical Manufacturers Association, Washington, D.C. Report No. BW-84-5-1567.

Stalling, D.L., J.W. Hogan and J.L. Johnson. 1973. Phthalate ester residues - their metabolism and analysis in fish. Environ. Health Perspec. 30:159-173.

Staples, C.A., A.F. Wernerand T.J. Hooghem. 1985. Assessment of priority pollutant concentrations in the United States using STORET database. Environ. Toxicol. Chem. 4:131-142.

Streufert, J.M., J.R. Jones and H.O. Sanders. 1980. Toxicity and biological effects of phthalate esters on midges (*Chironomus plumosus*). Trans. Missouri Acad. Sci. 14:33-40.

Subba-Rao, R.V., H.E. Rubin and M. Alexander. 1982. Kinetics and extent of mineralization of organic chemicals at trace levels in freshwater and sewage. Appl. Environ. Microbiol. 43:1139-1150.

Sullivan, K.F., E.L. Atlas and C.S. Giam. 1982. Adsorption of phthalic acid esters from seawater. Environ. Sci. Technol. 16:428-432.

Swain, W.R. 1978. Chlorinated organic residues in fish, water, and precipitation from the vicinity of Isle Royale, Lake Superior. J. Great Lakes Res. 4:398-407.

Swartz, R.C., D.W. Schults, G.R. Ditsworth, W.A. DeBen and F.A. Cole. 1985. Sediment toxicity, contamination, and macrobenthic communities near a large sewage outfall. Validation and Predictabolity of Laboratory Methods for Assessing the Fate and Effects of Contaminants in Aquatic Ecosystems. ASTM STP 865. T.P. Boyle, Ed. American Society for Testing and Materials, Philadelphia, pp. 152-175.

Tabak, H.H., S.A. Quave, C.I. Mashni and E.F. Barth. 1981. Biodegradability studies with organic priority pollutant compounds. J. Water Pollut. Contr. Fed. 53:1503-1518.

Tarr, B.D., M.G. Barron and W.L. Hayton. 1990. Effect of body size on the uptake and bioconcentration of di-2-ethylhexyl phthalate in rainbow trout. Environ. Toxicol. Chem. 9: 989-995.

Tetra Tech Inc. 1986. Development of Sediment Quality Values for Puget Sound. Vol. 1. Bellevue, Washington, 128 pp.

Thomas, G.H. 1973. Quantitative determination and confirmation of identity of trace amounts of dialkyl phthalates in environmental samples. Environ. Health Perspect. 3:23-28.

Thurén, A. 1986. Determination of phthalates in aquatic environments. Bull. Environ. Contam. Toxicol. 36:33-40.

Thurén, A. and P. Woin. 1991. Effects of phthalate esters on the locomotor activity of the freshwater amphipod *Gammarus pulex*. Bull. Environ. Contam. Toxicol. 46:159-166.

TRI89. 1991. Toxic Chemical Release Inventory. National Library of Medicine, National Toxicology Information Program, Behtesda, MD.

Turney, G.L. and D.F. Goerlitz. 1990. Organic contamination of ground water aat Gas Works Park, Seattle, Washington. Ground Water Monit. Rev. 10:187-198.

U.S. EPA. 1982a. Aquatic fate process data for organic priority pollutants. EPA-440/4-81-014. NTIS PB87-169090. U.S. Environmental Protection Agency, Washington, D.C.

U.S. EPA. 1982b. Methods for organic chemical analysis of municipal and industrial wastewater. U.S. Environmental Protection Agency, Environmental Monitoring and Support Laboratory, Cincinnati, Ohio. EPA 600/4-82-057. NTIS PB83-201798. July 1982.

U.S. EPA. 1987. Health effects assessment for selected phthalic acid esters. EPA-600/8-88-053. NTIS PB88-178934. U.S. Environmental Protection Agency, Washington, D.C.

Veith, G.D., D. DeFoe and M. Knuth. 1984. Structure-activity relationships for screening organic chemicals for potential ecotoxicity effects. Drug Metab. Rev. 15:1295-1303.

Volskay, V.T., Jr. and C.P.L. Grady, Jr. 1988. Toxicity of selected RCRA compounds to activated sludge microorganisms. J. Water Pollut. Contr. Fed. 60:1850-1856.

Waldock, M.J. 1983. Determination of phthalate esters in samples from the marine environment using gas chromatography mass spectrometry. Chemistry in Ecology 1:261-277.

Wams, T.J. 1987. Diethylhexylphthalate as an environmental contaminant - a review. Sci. Total Environ. 66:1-16.

Webber, M.D. and S. Lesage. 1989. Organic contaminants in Canadian municipal sludges. Waste Manage. Res. 7:63-82.

Weschler, C. 1981. Identification of selected organics in the Arctic aerosol. Atmospheric Environment 15:1365-1369.

Westernhagen, H. von, M. Landolt, R. Kocan, G. Fürstenberg, D. Janssen and K. Kremling. 1987. Toxicity of sea-surface microlayer: effects on herring and turbot embryos. Marine Environ. Res. 23:273-290.

Williams, D.T. 1973. Dibutyl- and di-(2-ethylhexyl)phthalate in fish. J. Agric. Food Chem. 21:1128-1129.

Williams, M.D. and S. Hargadine. 1991. Sediment adsorption isotherm of $^{14}C$-di(2-ethylhexyl) phthalate. Study completed for the Chemical Manufacturers Association by Analytical Bio-Chemistry Laboratories, Inc., Columbia, Missouri.

Wilson, L.G., M.D. Osborn, K.L. Olson, S.M. Maida and L.T. Katz. 1990. The ground water recharge and pollution potential of dry wells in Pima County, Arizona. Ground Water Monit. Rev. 10:114-121.

Wofford, H.W., C.D. Wilsey, G.S. Neff, C.S. Giam and J.M. Neff. 1981. Bioaccumulation and metabolism of phthalate esters by oysters, brown shrimp, and sheepshead minnows. Ecotoxicol. Environ. Safety 5:202-210.

Woin, P. and P. Larsson. 1987. Phthalate esters reduce predation efficiency of dragonfly larvae, Odonata; *Aeshna*. Bull. Environ. Contam. Toxicol. 38:220-225.

Wolfe, N.L., W.C. Steen and L.A. Burns. 1980a. Phthalate ester hydrolysis: linear free energy relationships. Chemosphere 9:403-408.

Wolfe, N.L. L.A. Burns and W.C. Steen. 1980b. Use of linear free energy relationships and an evaluative model to assess the fate and transport of phthalate esters in the aquatic environment. Chemosphere 9:393-402.

Wood, D.L. and J. Bitman. 1980. The effect of feeding di-2-ethylhexyl phthalate on the lipid metabolism of laying hens. Lipids 15:151-156.

Wood, D.L. and J. Bitman. 1984. The effect of feeding di-2-ethylhexyl phthalate and related compounds on lipids in the laying hen. Poult. Sci. 63:467-477.

Zenon. 1982. Sources of persistent organic substances in municipal wastewater. Report prepared for Environmental Protection Service, Environment Canada. Zenon Environmental Enterprises Ltd., Hamilton, Ontario.

Zitko, V. 1972. Determination of phthalates in biological samples, Int. J. Environ. Anal. Chem 2:241-252.

Zurmühl, T., W. Durner and R. Herrmann. 1991. Transport of phthalate-esters in undisturbed and unsaturated soil columns. J. Contaminant Hydrol. 8:111-133.

Table 1. Chemical and physical properties of DEHP.

CAS Name: 1,2-Benzenedicarboxylic acid, bis(2-ethylhexyl) ester
CAS No.: 117-81-7
Synonyms: DEHP; phthalic acid, bis(2-ethylhexyl) ester; di(2-ethylhexyl) phthalate; di-*sec*-octyl phthalate
Empirical Formula: $C_{24}H_{38}O_4$
Appearance and Odour: Colourless oily liquid with a very faint odour[2]
Molecular Weight: 390.6
Specific Gravity: 0.980-0.985 @ 25 C[1]
0.985-0.9861 @ 20 C[2]
Melting Point: -50 C[1]
-46 to -55 C[2]
Boiling Point: 236 C @ mm Hg, 387 C @ 5 mm Hg[1]
230 C @ 5 mm Hg[4]
Henry's Law Constant: $3.0 \times 10^{-2}$ Pa·m$^3$/mol[5]
Vapour Density: 13.48 (air = 1)[2]
Vapour Pressure: $2.1 \times 10^{-5}$ Pa[1]
$8.3 \times 10^{-6}$ Pa @ 25 C to $2.7 \times 10^{-5}$ Pa @ 20 C[2]
$8.6 \times 10^{-4}$ @ 25 C[8]
$8.6 \times 10^{-4}$ Pa @ 25 C[11]
Water Solubility: < 50.0 mg/L @ 25 C[1]
(fresh water) 0.041 mg/L (@ 20 C) to 0.4 mg/L (@ 25 C)[2]
0.27 mg/L; 0.36 mg/L[3]
0.34 mg/L @ 25 C[8]
0.34 mg/L @ 25 C[11]
0.4 mg/L[5]
(salt water) 0.0006 mg/L @ 25 C[7]
0.16 mg/L @ 25 C[8]
1.16 mg/L[9]
Solvent Solubility: Miscible with most common solvents[1]
Log $K_{oc}$: 3.76 (calculated)[6]
5.0 [2]
5.41-5.95[12]
9.3[10]
Log $K_{ow}$: 5.11[13]
5.24 (calculated)[11]
7.06[14]
8.66[3]
9.61[10]

(1) Data/ranges cited in Pierce *et al.* 1980.
(2) Data/ranges cited in Montgomery and Welkom 1990.
(3) DeFoe *et al.* 1990.
(4) Howard 1989.
(5) Volskay and Grady 1988.
(6) Kenaga 1980.
(7) Boese 1984.
(8) Howard *et al.* 1985.
(9) Giam *et al.* 1980.

(10) U.S. EPA 1982a.
(11) CMA 1984.
(12) Williams and Hargadine 1991.
(13) Geyer *et al*. 1984.
(14) Veith *et al*. 1984.

Table 2. Bioconcentration factors (BCF) for DEHP for various aquatic organisms.

| Species | Water Concentration | Duration | BCF[a] | Reference |
|---|---|---|---|---|
| Alga (*Chlorella fusca*) | 50 µg/L | 1 day | 5,400 | Geyer *et al.* 1984 |
| Oyster (*Crassostrea virginica*) | 100 µg/L | 1 day | 11.2[b] | Wofford *et al.* 1981 |
| " " | 500 µg/L | 1 day | 6.9[b] | Wofford *et al.* 1981 |
| Mussel (*Mytilus edulis*) | 4.1 µg/L | 28 days | 2,366[c] | Brown and Thompson 1982a |
| " " | 42.1 µg/L | 28 days | 2,627[c] | Brown and Thompson 1982a |
| Bivalve (*Mulinia lateralis*) | 0.6-58.9 µg/L | 30 days | 2,436-3,891 @ 1°C | Perez *et al.* 1983 |
| " " | 0.2-15.5 µg/L | 30 days | 916-3,311 @ 18°C | Perez *et al.* 1983 |
| *Acartia* sp. | 0.6-58.9 µg/L | 30 days | 158-2,550 @ 1°C | Perez *et al.* 1983 |
| " " | 0.2-15.5 µg/L | 30 days | 1,995-5,263 @ 18°C | Perez *et al.* 1983 |
| *Daphnia magna* | 0.3 µg/L | 7 days | 420 | Sanders *et al.* 1973; Mayer and Sanders 1973 |
| " " | 5.4 µg/L | 1 day | 518 | Macek *et al.* 1979 |
| " " | 3.2 µg/L | 21 days | 166 | Brown and Thompson 1982b |
| " " | 100 µg/L | 21 days | 268 | Brown and Thompson 1982b |
| Scud (*Gammarus pseudolimnaeus*) | 0.1 µg/L | 14 days | 3,600 | Sanders *et al.* 1973; Mayer and Sanders 1973 |
| *Gammarus pulex* | 100 µg/L | 10 days | 870 (accumulated) | Thurén and Woin 1991 |
| " " | 100 µg/L | 10 days | 620 (adsorbed) | Thurén and Woin 1991 |
| " " | 500 µg/L | 10 days | 4000 (accumulated) | Thurén and Woin 1991 |

| | | | | |
|---|---|---|---|---|
| " " | 500 µg/L | 10 days | 4600 (adsorbed) | Thurén and Woin 1991 |
| Brown shrimp (*Penaeus aztecus*) | 100 µg/L | 1 day | 10.2 | Wofford *et al.* 1981 |
| " " | 500 µg/L | 1 day | 16.6 | Wofford *et al.* 1981 |
| Sowbug (*Asellus brevicaudus*) | 1.9 µg/L | 21 days | 70 | Sanders *et al.* 1973 |
| " " | 62.3 µg/L | 21 days | 250 | Sanders *et al.* 1973 |
| Midge (*Chironomus plumosus*) | 0.3 µg/L | 7 days | 350 | Sanders *et al.* 1973; Mayer and Sanders 1973 |
| " " | 0.2 µg/L | 7 days | 408 | Streufert *et al.* 1980 |
| Mayfly (*Hexagenia bilineata*) | 0.1 µg/L | 7 days | 575 | Sanders *et al.* 1973; Mayer and Sanders 1973 |
| Polychaete (*Nepthys incisa*) | 0.6-58.9 µg/L | 30 days | 30-59 @ 1°C | Perez *et al.* 1983 |
| " " | 0.2-15.5 µg/L | 30 days | 549-1,100 @ 18°C | Perez *et al.* 1983 |
| Fathead minnow (*Pimephales promelas*) | 1.9 µg/L | 14 days | 458 | Mayer and Sanders 1973 |
| " " | 1.9 µg/L | 28 days | 1,380 | Mayer and Sanders 1973 |
| " " | 62 µg/L | 56 days | 155 | Mayer 1976 |
| " " | 2.5 µg/L | 56 days | 886 | Mayer 1976 |
| Rainbow trout (*Oncorhynchus mykiss*) (eggs + fry) | 5 µg/L | 100 days | 78 | Mehrle and Mayer 1976 |
| " " | 14 µg/L | 100 days | 113 | Mehrle and Mayer 1976 |
| " " | 54 µg/L | 100 days | 42 | Mehrle and Mayer 1976 |
| " " (2.9 g) | 20 µg/L | 4 days | 51.5 | Tarr *et al.* 1990 |
| " " (61 g) | 20 µg/L | 4 days | 8.9 | Tarr *et al.* 1990 |
| " " (441 g) | 30 µg/L | 2 days | 1.6[d] | Tarr *et al.* 1990 |
| Channel catfish (*Ictalurus punctatus*) | 1 µg/L | 1 day | 2,600 | Stalling *et al.* 1973 |
| Bluegill (*Lepomis macrochirus*) | 5.82 µg/L | 42 days | 114 | Barrows *et al.* 1980 |
| " " | 5.7 µg/L | 35 days | 112 | Macek *et al.* 1979 |

| | | | | |
|---|---|---|---|---|
| Sheepshead minnow (*Cyprinodon variegatus*) | 60 µg/L | 4 days | 45 @ 10°C | Karara and Hayton 1989 |
| " " | 60 µg/L | 4 days | 131 @ 16°C | Karara and Hayton 1989 |
| " " | 60 µg/L | 4 days | 637 @ 23°C | Karara and Hayton 1989 |
| " " | 60 µg/L | 4 days | 962 @ 29°C | Karara and Hayton 1989 |
| " " | 60 µg/L | 4 days | 6,510 @ 35°C | Karara and Hayton 1989 |
| " " | 100 µg/L | 1 day | 10.7 | Wofford *et al.* 1981 |
| " " | 500 µg/L | 1 day | 13.5 | Wofford *et al.* 1981 |

[a] BCF's are based on whole-body concentrations unless otherwise indicated.
[b] BCF based on concentration in muscle.
[c] BCF based on concentration in soft tissue.
[d] BCF calculated from concentration in blood plasma.

Table 3a. Concentrations of DEHP in air, water, sediment, soil and biota in the Canadian and Great Lakes environment.

| Media | Concentration mean (max. or range) | Location | Reference |
|---|---|---|---|
| Waste streams | (within 10-100 µg/L) | Effluents, St. Clair R. petrochemical plants | Munro *et al.* 1985 |
| " " | (24 µg/L) | Procter & Gamble final effluent, Alberta | NAQUADAT 1993 |
| " " | (12-mo. ave. 19 µg/L) | Ontario Organic chemical manufacturing plants | OME 1992a |
| " " | (12-mo. ave. 65.1 µg/L) | Ontario Inorganic chemical manufacturing plants | OME 1992b |
| " " | (40 µg/L) | Canadian textile mill effluents | Environment Canada 1989 |
| Municipal waste water | (ND-59 µg/L) | Vancouver, B.C. | Rogers *et al.* 1986 |
| Sewage effluents | (ND-10 µg/L) | Ontario municipalities | Beak Consultants 1991 |
| Sewage sludge | (3.0-176.0 mg/kg dw) | Winnipeg, Manitoba | Webber and Lesage 1989 |
| " " | (26.0-137.0 mg/kg dw) | Hamilton, Ont. | Webber and Lesage 1989 |
| " " | 80.0 mg/kg dw (median) | Other Canadian cities | Webber and Lesage 1989 |
| " " | (3.0-215.0 mg/kg dw) | " " " | Webber and Lesage 1989 |
| Atmosphere | 300 ng/m$^3$ | Hamilton, Ontario | Thomas 1973 |
| " | 2 ng/m$^3$ (0.5-5.0 ng/m$^3$) | Great Lakes region | Eisenreich *et al.* 1981 |

| | | | |
|---|---|---|---|
| Drinking water | 3.0 µg/L (trace-110 µg/L) | Alberta, Canada, drinking water derived from surface water | Spink 1986 |
| " " | <1.0 µg/L (<1.0-54 µg/L) | Alberta, Canada, drinking water derived from surface water | Halina 1993b |
| " " | 2.0 µg/L (trace-9.0 µg/L) | Alberta, Canada, drinking water derived from ground water | Spink 1986 |
| " " | <1.0 µg/L (<1.0-21 µg/L) | Alberta, Canada, drinking water derived from ground water | Halina 1993b |
| Rain water | 0.006 µg/L (0.004-0.010 µg/L) | Great Lakes region | Eisenreich *et al.* 1981 |
| Surface water | (within 10-100 µg/L) | St. Clair R. | Munro *et al.* 1985 |
| " " | (1.6-4.6 µg/L) | St. Clair R. | Michigan DNR 1974[1] |
| " " | (300 µg/L) | (Black Bay, Ont., Lake Superior) highest reported conc. in review | Pierce *et al.* 1980 |
| " " | (12-mo. ave. 7.1 µg/L) | Intake water, Ontario organic chemical manufacturing plants | OME 1992a |
| " " | (12-mo. ave. 2.61 µg/L) | Intake water, Ontario inorganic chemical manufacturing plants | OME 1992b |
| " " | 0.02863 µg/L (water fraction) | Niagara R. at Fort Erie | Niagara River Data Interpretation Group 1990 |
| " " | 0.01192 µg/L (suspended solids fraction) | Niagara R. at Fort Erie | Niagara River Data Interpretation Group 1990 |
| " " | 0.03848 µg/L (Water fraction) | Niagara R. at Niagara-on-the-Lake | Niagara River Data Interpretation Group 1990 |

| | | | | |
|---|---|---|---|---|
| " | " | 0.01233 µg/L (suspended solids fraction) | Niagara R. at Niagara-on-the-Lake | Niagara River Data Interpretation Group 1990 |
| " | " | (1.700-107.000 mg/kg, suspended sediments) | Niagara R. at Niagara-on-the Lake | Kuntz 1984 |
| " | " | 300 µg/L | Black Bay, Ont., Lake Superior | Mayer *et al.* 1972 |
| " | " | 5.0 µg/L | Lake Huron | Mayer *et al.* 1972 |
| " | " | (1-137 µg/L) | Lake Michigan | Ewing *et al.* 1977[1] |
| " | " | <0.1 µg/L | Streams tributary to Lake Michigan, U.S.A. | Schacht 1974 |
| " | " | 0.166 µg/L (water + suspended solids) | St. Lawrence R. | Germain and Langlois 1988 |
| " | " | 0.078 µg/L (water fraction) | St. Lawrence R. | Germain and Langlois 1988 |
| " | " | 30.600 mg/kg (suspended solids fraction) | St. Lawrence R. | Germain and Langlois 1988 |
| " | " | (<1 µg/L) | Raw water supplies from Quebec rural areas | MENVIQ 1993 |
| " | " | (<1 - 14 µg/L) | Alberta, Canada | NAQUADAT 1993 |
| " | " | <1.0 µg/L (<1.0-8.0 µg/L) | Alberta, Canada | Halina 1993a |
| " | " | (0.5-1.0 µg/L) | N. Saskatchewan R., Alberta | Alberta Environment 1986[1] |
| Sediment | | (0.300 mg/kg) | (Lake Superior & Lake Huron) highest reported conc. in review | CCREM 1987 |
| " | | (0.200 mg/kg) | (Black Bay, Ont., Lake Superior) highest reported conc. in review | Pierce *et al.* 1980 |
| " | | (0-1.5 mg/kg) | Lake Superior | Kinkead and Chatterjee 1974. |
| " | | 0.200 mg/kg | Black Bay, Ont., Lake Superior | Mayer *et al.* 1972 |
| " | | 0.00052 mg/kg dw (<0.001-0.00718 mg/kg dw) | Lake Michigan | Schacht 1974 |

| | | | |
|---|---|---|---|
| " | 0.0306 mg/kg dw (<0.001-0.218 mg/kg dw) | Streams tributary to Lake Michigan | Schacht 1974 |
| " | (0.0038-0.0053 mg/kg) | Lake St. Clair | Michigan DNR 1974[1] |
| " | (<0.1-1.18 mg/kg dw) | Detroit R. | Fallon and Horvath 1985 |
| " | (0.001-0.005 mg/kg) | Detroit R./Lake Erie | Michigan DNR 1974[1] |
| " | (0.00583 mg/kg) | Cornwall, Ont. | Jaagumagi 1989 |
| Marine sediment | (0.02-0.60 mg/kg dw) | Fraser Estuary, B.C. | Rogers and Hall 1987 |
| " " | (0.844 mg/kg dw) | Fraser Estuary, B.C. (0.5 km below sewage outfall) | Rogers and Hall 1987 |
| Soil | (<0.0001-0.011 mg/kg) | Port Credit & Oakville/ Burlington, Ont. | Golder Associates 1987 |
| Aquatic biota | (<0.01-1.3 mg/kg ww (chub)) | Lake Michigan | Schacht 1974 |
| Fish | (<0.04-32.10 mg/kg ww) | Great Lakes harbors and tributary mouths | DeVault 1985 |
| " | (1.3 mg/kg) | Great Lakes | GLWQB 1986 |
| Fish liver/muscle | (ND-3.83 mg/kg) | Lower Fraser R., B.C. | GLWQB 1986? |
| Fish (unprocessed) | (<0.015-0.104 mg/kg) | Canadian lakes & rivers | Williams 1973 |
| Atlantic salmon | (1.300-1.600 mg/kg) | Hatchery, St. John R., N.B. | Environment Canada 1980 |
| Lake trout (*Salvelinus namaycush*) | 0.3 mg/kg ww | Lake Superior exclusive of Isle Royale area | Swain 1978 |
| Lake trout | 0.15 mg/kg ww | Lake Superior | Swain 1978 |
| Siscowet trout (*Salvelinus namaycush siscowet*) | (ND-1.3 mg/kg ww) | Lake Superior | Swain 1978 |
| Whitefish (skinless fillets) | 2.2 mg/kg | Upper Great Lakes | Glass *et al.* 1977 |
| Whitefish | 0.44 mg/kg ww | Lake Superior, all stations | Swain 1978 |
| " | 0.7 mg/kg ww | Lake Superior, Isle Royale area | Swain 1978 |

| | | | |
|---|---|---|---|
| Burbot | 0.010-0.100 mg/kg | Lake Huron | Environment Canada 1980 |
| Catfish | Trace | Lake St. Pierre, Ontario | Environment Canada 1980 |
| Walleye (*Stizostedion vitreum*) | 0.800 mg/kg | Black Bay, Ont., Lake Superior | Mayer *et al.* 1972 |
| Pickerel | Trace | Lake Ontario | Environment Canada 1980 |
| " | <0.030 mg/kg | Lake Ontario | Williams 1973 |
| " | <0.030 mg/kg | Lake Huron | Williams 1973 |
| Eel muscle | (0.22-0.37 mg/kg ww) | Freshwater lakes | Burns *et al.* 1981 |
| " " | (1.1-6.7 mg/kg fat wt) | Freshwater lakes | Burns *et al.* 1981 |
| " | 0.104 mg/kg | Canadian lakes & rivers | Williams 1973 |
| Catfish | <0.030 mg/kg | Lake St. Pierre, Canada | Williams 1973 |
| Herring (*Clupea harengus harengus*) fillets | 7.24 mg/kg ww<br>47.1 mg/kg fat wt | Bay of Fundy, N.B. | Burns *et al.* 1981 |
| " | 4.71 mg/kg ww | Gulf of St. Lawrence | Burns *et al.* 1981 |
| " | 29.1 mg/kg fat wt | Gulf of St. Lawrence | Burns *et al.* 1981 |
| Mackerel (*Scomber scombrus*) fillets | 6.50 mg/kg ww<br>51.3 mg/kg fat wt | Gulf of St. Lawrence | Burns *et al.* 1981 |
| Cod (*Gadus morhua*) liver | 5.19 mg/kg ww<br>10.4 mg/kg fat wt | Gulf of St. Lawrence | Burns *et al.* 1981 |
| Plaice (*Hippoglossoides platessoides*) fillets | <0.001 mg/kg ww<br><0.001 mg/kg fat wt | Gulf of St. Lawrence | Burns *et al.* 1981 |
| Redfish (*Sebastes marinus*) fillets | <0.001 mg/kg ww<br><0.001 mg/kg fat wt | Gulf of St. Lawrence | Burns *et al.* 1981 |
| Seal (*Phoca vitulina*) | 10.6 mg/kg lipid | Location not stated | Zitko 1972 |

[1] Cited in Environment Canada 1992.

Table 3b. Concentrations of DEHP in air, water, sediment, soil and biota in the non-Canadian, non-Great Lakes environment.

| Media | Concentration mean (max. or range) | Location | Reference |
|---|---|---|---|
| Phthalate ester plant discharge pond water | 110.0 µg/L | Maryland, U.S.A. | Peterson and Freeman 1984 |
| Urban runoff | <9.0 µg/L | Pima Co., Arizona | Wilson *et al.* 1990 |
| Dry-well sediment | (<1.7-7.3 mg/kg) | Pima Co., Arizona | Wilson *et al.* 1990 |
| Industrial effluent | 10.0 µg/L (median) | United States STORET stations | Staples *et al.* 1985 |
| Sewage treatment plant effluent | 1.9 µg/L | Manchester, U.K. | Fatoki and Vernon 1990 |
| Sewage treatment plant effluents | 0.292 µg/L (<0.1-0.760 µg/L) | Illinois, U.S.A. | Schacht 1974 |
| Phthalate ester plant discharge pond sediment | 1,200 mg/kg | Chester R. system, Maryland, U.S.A. | Peterson and Freeman 1984 |
| Sewage sludge | 16,610 mg/kg | Switzerland | Diercxsens and Terradellas 1987 |
| " " | 27 mg/kg | Oslo, Norway | Kveseth 1980 |
| " " | (<1.0-58,300 mg/kg dw) | Non-Canadian sludges | Webber and Lesage 1989 |
| Leachate | 0.20 mg/kg | U.S.A. Hazardous waste landfill | Ghassemi *et al.* 1984 |
| Atmosphere | 10.2 ng/m$^3$ (ND-13.52 ng/m$^3$) | Queens, New York | Bove *et al.* 1978 |
| " | 16.79 ng/m$^3$ (10.06-28.6 ng/m$^3$) | Brooklyn, New York | Bove *et al.* 1978 |
| " | 14.2 ng/m$^3$ (ND-22.15 ng/m$^3$) | Staten Island, New York | Bove *et al.* 1978 |
| " | means 2.10-4.14 ng/m$^3$ | Sterling Forest, New York | Bove *et al.* 1978 |
| " | 2.9 ng/m$^3$ (1.4-4.1 ng/m$^3$) | North Atlantic | Giam *et al.* 1978 |

| | | | |
|---|---|---|---|
| " | 1.4 ng/m$^3$ (0.32-2.68 ng/m$^3$) | Enewetak Atoll, north Pacific Ocean | Atlas and Giam 1981 |
| " | 2.9 ng/m$^3$ | North Atlantic | Atlas and Giam 1981 |
| " | 1.16 ng/m$^3$ (0.72-1.92 ng/m$^3$) | Gulf of Mexico | Giam *et al.* 1980 |
| " | 0.61 ng/m$^3$ (particulate phase) | Gulf of Mexico | Giam *et al.* 1977 |
| " | 0.57 ng/m$^3$ (vapour phase) | Gulf of Mexico | Giam *et al.* 1977 |
| " | 0.4 ng/m$^3$ (<0.4-2.3 ng/m$^3$) | Gulf of Mexico | Giam *et al.* 1978 |
| " | 2.4 ng/m$^3$ | College Station, Texas | Atlas and Giam 1981 |
| " | 16.6 ng/m$^3$ | Pigeon Key, Florida | Atlas and Giam 1981 |
| " | (0.5-20.0 ng/m$^3$) | Barrow, Alaska | Weschler 1981 |
| " | (17-20 ng/m$^3$) (suspended particulates phase) | near La Paz, Bolivia | Cautreels *et al.* 1977 |
| " | (26-29 ng/m$^3$) (suspended particulates phase) | Antwerp, Belgium residential area, Winter | Cautreels *et al.* 1977 |
| " | (91-132 ng/m$^3$) (suspended particulates phase) | Antwerp, Belgium residential area, Spring | Cautreels *et al.* 1977 |
| Rain water | 0.055 µg/L (0.0053-0.213 µg/L) | Enewetak Atoll, north Pacific Ocean | Atlas and Giam 1981 |
| Surface water | (4.9 µg/L) | (Missouri R.), highest reported conc. in review | Pierce *et al.* 1980 |
| " " | 2.5 µg/L | U.S.A. waters | Branson 1980 |
| " " | (<0.3-0.9 µg/L) | U.S.A. waters | Michael *et al.* 1984 |
| " " | (0.5-1.0 µg/L) | Delaware R., U.S.A. | Sheldon and Hites 1979 |
| " " | 0.063 µg/L | Mississippi R., U.S.A. | Chan 1975 |
| " " | (ND-1.6 µg/L) | Rivers, Manchester, U.K. | Fatoki and Vernon 1990 |
| " " | (0.32-1.78 µg/L) | River Ronnebyan, Sweden | Thurén 1986 |
| " " | ((0.66-3.10 µg/L) | River Ronnebyan, Sweden[1] | Thurén 1986 |
| " " | (0.39-0.52 µg/L) | River Svartan, Sweden | Thurén 1986 |
| " " | 1.98 µg/L | River Svartan, Sweden[1] | Thurén 1986 |
| " " | (0.3-1.7 µg/L) | Rhine R., Netherlands | Schouten *et al.* 1979 |
| " " | (0.6-2.6 µg/L) | IJssel R., Netherlands | Schouten *et al.* 1979 |

| | | | |
|---|---|---|---|
| " " | (0.2-4.2 μg/L) | Meuse R., Netherlands | Schouten *et al.* 1979 |
| " " | 10.0 μg/L (median) | United States STORET stations | Staples *et al.* 1985 |
| " " | 0.3 & 14.2 μg/L | Tamagawa R., Japan | Ogura *et al.* 1975 |
| " " | 1.25 μg/L (0.3-6.1 μg/L) | River water, Shizuoka Prefecture, Japan | Shibuya 1979 |
| " " | 0.68 μg/L (<0.1-15 μg/L) | Japanese river water | Shibuya 1979 |
| Sea water | 0.0049 μg/L (0.0001-0.0063 μg/L) | North Atlantic | Giam *et al.* 1978 |
| " " | 0.600 μg/L (<0.002-12.000 μg/L) | Galveston Bay, Texas | Murray *et al.* 1981 |
| " " | (0.210-0.770[2] μg/L) | Nueces Estuary, Texas | Ray *et al.* 1983a |
| " " | 0.070 μg/L (0.023-0.225 μg/L) | Mississippi delta, U.S.A. | Giam *et al.* 1978 |
| " " | 0.130 μg/L (0.006-0.316 μg/L) | Gulf of Mexico, coast | Giam *et al.* 1978 |
| " " | 0.080 μg/L (0.006-0.097 μg/L) | Gulf of Mexico, open gulf | Giam *et al.* 1978 |
| " " | 0.112 μg/L (0.006-0.500 μg/L) | Gulf of Mexico | Chan 1975 |
| " " | (0.0585-0.0783 μg/L) | Crouch Estuary, U.K. | Waldock 1983 |
| " " | (<0.050-8.400 μg/L) | U.K. estuaries, etc. | Law *et al.* 1991 |
| " " | (2.7-17.2 μg/L) | Surface microlayer, Germany | Westernhagen *et al.* 1987 |
| Ground Water | (ND-3.4 μg/L) | Catalonia, Spain | Galceran *et al.* 1989 |
| " " | <10 μg/L | Pima Co., Arizona | Wilson *et al.* 1990 |
| Sediment | (71 mg/kg) | (Rhine R., Netherlands), highest reported conc. in review | Pierce *et al.* 1980 |
| " | 1.0 mg/kg dw (median) | United States STORET stations | Staples *et al.* 1985 |
| " | (0.020-4.800[3] mg/kg) | Chester R. system, Maryland, U.S.A. | Peterson and Freeman 1984 |
| " | 30 mg/kg | Usk R., U.K. | Eglinton *et al.* 1975 |
| " | (1.20-8.03 mg/kg dw) | River Ronnebyan, Sweden | Thurén 1986 |
| " | (79.20-628.00 mg/kg dw) | River Ronnebyan, Sweden[1] | Thurén 1986 |

| | | | |
|---|---|---|---|
| " | (0.15-3.52 mg/kg dw) | River Svartan, Sweden | Thurén 1986 |
| " | 1,480.00 mg/kg dw | River Svartan, Sweden[1] | Thurén 1986 |
| " | (0.050-14.600 mg/kg) | Rhine R., Germany | Malisch *et al.* 1981 |
| " | (6.5-70.5 mg/kg dw) | Rhine R., Netherlands | Schwartz *et al.* 1979 |
| " | (5.100-8.400 mg/kg) | Neckar R., Germany | Malisch *et al.* 1981 |
| " | (2.5-52.5 mg/kg dw) | IJssel R., Netherlands | Schwartz *et al.* 1979 |
| " | (1.0-17.0 mg/kg dw) | Meuse R., Netherlands | Schwartz *et al.* 1979 |
| " | (<0.5-34 mg/kg dw) | Polder Kortenhoef nature reserve, Netherlands | Schwartz *et al.* 1979 |
| " | (0.2-0.7 mg/kg dw) | Lake Constance | Giam and Atlas 1980 |
| " | 1.558 mg/kg dw (0.02-12.24 mg/kg dw) | River sediments, Shizuoka Prefecture, Japan | Shibuya 1979 |
| " | (1.42-46.29 mg/kg dw) | Tagonoura, Japan | Shibuya 1979 |
| " | 0.48 mg/kg dw (<0.05-17 mg/kg dw) | Japanese river sediments | Shibuya 1979 |
| Marine sediment | 0.022 mg/kg (<0.001-0.110 mg/kg) | Galveston Bay, Texas | Murray *et al.* 1981 |
| " " | (0.040-16.000[4] mg/kg) | Nueces Estuary, Texas | Ray *et al.* 1983a |
| " " | 0.069 mg/kg (<0.0001-0.248 mg/kg) | Mississippi delta, U.S.A. | Giam *et al.* 1978 |
| " " | 0.116 mg/kg (0.002-0.2483 mg/kg) | Mississippi delta, U.S.A. | Chan 1975 |
| " " | 0.0066 mg/kg (0.0034-0.0142 mg/kg) | Gulf of Mexico, coast | Giam *et al.* 1978 |
| " " | 0.002 mg/kg | Gulf of Mexico, open gulf | Giam *et al.* 1978 |
| " " | 0.009 mg/kg | Gulf of Mexico, open gulf | Chan 1975 |
| " " | 1.500 mg/kg (0.060-7.800 mg/kg) | Portland, Maine | Ray *et al.* 1983b |
| " " | (0.138-25.380 mg/kg dw) | Los Angeles, California | Swartz *et al.* 1985 |
| " " | (0.0112-0.0262 mg/kg) | Crouch Estuary, U.K. | Waldock 1983 |
| " " | (0.100-.200 mg/kg) | Baltic Sea | Müller *et al.* 1980 |

| | | | |
|---|---|---|---|
| Soil | (ND-0.5 mg/kg) | Industrial dump, factory perimeter, Finland | Persson *et al.* 1978 |
| " | (ND-0.27 mg/kg) | Site of former coal/oil gasification plant, Seattle, Washington | Turney and Goerlitz 1990 |
| Soil arthropods | 2.8 mg/kg | Industrial dump, factory perimeter, Finland | Persson *et al.* 1978 |
| Freshwater biota | (ND-2.3 mg/kg (*Esox lucius* liver)) | Finland | Persson *et al.* 1978 |
| " " | (0.31-14.40 mg/kg fw) | River Ronnebyan, Sweden | Thurén 1986 |
| " " | (0.11-1.81 mg/kg fw) | River Svartan, Sweden | Thurén 1986 |
| " " | 5.31 mg/kg fw | River Svartan, Sweden[1] | Thurén 1986 |
| " " | 3.0 mg/kg ww | United States STORET stations | Staples *et al.* 1985 |
| Marine biota | 0.0045 mg/kg (<0.001-0.135 mg/kg (starfish) *Luidia clathrata*) | Gulf of Mexico | Giam *et al.* 1978 |
| *Neanthes virens* | (0.380-0.490 mg/kg) | Portland, Maine | Ray *et al.* 1983b |
| Clams | (0.110-0.170 mg/kg) | Portland, Maine | Ray *et al.* 1983b |
| Molluscs | (0.2137 mg/kg, digestive gland of *Scrobicularia plana*) | Crouch Estuary, U.K. | Waldock 1983 |
| Fish | 10 mg/kg | U.S.A. waters | Branson 1980 |
| " | (0.0859 mg/kg, liver of *Pleuronectes platessa*) | Tees Bay, U.K. | Waldock 1983 |

(1) Sampled at point of industrial effluent discharge to river.
(2) Highest concentration in a sample taken from near a refinery.
(3) Site located approximately 3 km below phthalate ester plant discharge pond.
(4) Highest concentration in a sample taken from near an industrial area.

Table 4a. Summary of Acute Toxicity Values of DEHP.

| Species | Study Type | End Point | Value | Reference |
|---|---|---|---|---|
| | | **Microorganisms** | | |
| Activated sludge microorganisms | Static | 30 min EC50 (decreased oxygen consumption) | >400 µg/L | Volskay and Grady 1988 |
| Freshwater sediment microorganisms | Static | 60h (inhibition of community respiration) | 25,000 µg/kg | Larsson *et al.* 1986 |
| *Photobacterium phosphoreum* | AET, Puget Sound | 15 min. (reduced luminescence) | 1,900 µg/kg dw sediment | Tetra Tech Inc. 1986 |
| | | **Algae/Plants** | | |
| *Selenastrum capricornutum* | Static | 140h EC50 (cell numbers) | >100 µg/L | CMA 1990 |
| | | **Invertebrates** | | |
| *Daphnia magna* | Static | 24h LC50 | >68,000 µg/L | LeBlanc 1980 |
| " " | Static | 24h LC50 | 9,500 µg/L | Adams and Heidolph 1985 |
| " " | Static | 48h LC50 | >320 µg/L | CMA 1990 |
| " " | Static | 48h LC50 | 11,000 µg/L | LeBlanc 1980 |
| " " | Static | 48h LC50 | 2,000 µg/L | Adams and Heidolph 1985 |
| *Daphnia pulex* | Static | 48h LC50 | 133 µg/L | Passino and Smith 1987 |
| *Mysidopsis bahia* | Static | 96h LC50 | >440 µg/L | CMA 1990 |
| *Paratanytarsus parthenogenica* | Static | 48h LC50 | >240 µg/L | CMA 1990 |
| " " | Static | 48h LC50 | >10,000 µg/L | Monsanto Co. 1981 |

| | | | | |
|---|---|---|---|---|
| Scud (*Gammarus pseudolimnaeus*) | Static | 24h LC50 | >32,000 µg/L | Mayer and Ellersieck 1986 |
| " " | Static | 96h LC50 | >32,000 µg/L | Mayer and Ellersieck 1986 |
| " " | | 96h LC50 | >10,000 µg/L | Mayer and Sanders 1973 |
| Midge (*Chironomus tentans* | Static | 48h LC50 | >10,000 µg/L | Monsanto Co. 1982 |
| Midge (*Chironomus plumosus*) | Static | 48h LC50 | >18,000 µg/L | Mayer and Ellersieck 1986 |
| " " | Static | 48h LC50 | >72,000 µg/L | Mayer and Ellersieck 1986 |
| " " | Static | 48h LC50 | >18,000 µg/L | Streufert *et al.* 1980 |
| Crayfish (*Orconectes nais*) | | 96h LC50 | >10,000 µg/L | Mayer and Sanders 1973 |
| Harpacticoid (*Nitocra spinipes*) | Static | 96h LC50 | >300,000 µg/L | Lindén *et al.* 1979 |
| | | **Fish** | | |
| Rainbow trout (*Oncorhynchus mykiss*) | Static | 24h LC50 | >100,000 µg/L | Mayer and Ellersieck 1986 |
| " " | | 96h LC50 | >10,000 µg/L | Mayer and Sanders 1973 |
| " " | Static | 96h LC50 | 540,000 µg/L | Hrudey *et al.* 1976 |
| " " | Static | 96h LC50 | >100,000 µg/L | Mayer and Ellersieck 1986 |
| " " | Flow-through | 96h LC50 | >320 µg/L | CMA 1990 |
| Coho salmon (*Oncorhynchus kisutch*) | Static | 24h LC50 | >100,000 µg/L | Mayer and Ellersieck 1986 |
| " " | Static | 96h LC50 | >100,000 µg/L | Mayer and Ellersieck 1986 |
| Fathead minnow (*Pimephales promelas*) | Static | 96h NOEL | 670 µg/L | CMA 1990 |
| " " | Static | 96h LC50 | >240 µg/L | CMA 1984 |
| " " | Flow-through | 96h LC50 | >670 µg/L | CMA 1990 |

| | | | | |
|---|---|---|---|---|
| " " | | 96h LC50 | >10,000 µg/L | Mayer and Sanders 1973 |
| " " | | 96h LC50 | >327 µg/L | DeFoe *et al.* 1990 |
| " " | Static | 96h LC50 | >1,000 µg/L | Mayer and Ellersieck 1986 |
| Bluegill (*Lepomis macrochirus*) | Static | 24h LC50 | >770,000 µg/L | Buccafusco *et al.* 1981 |
| " " | Static | 24h LC50 | >100,000 µg/L | Mayer and Ellersieck 1986 |
| " " | Static | 96h LC50 | >320 µg/L | CMA 1990 |
| " " | | 96h LC50 | >10,000 µg/L | Mayer and Sanders 1973 |
| " " | Static | 96h LC50 | >770,000 µg/L | Buccafusco *et al.* 1981 |
| " " | Static | 96h LC50 | >100,000 µg/L | Mayer and Ellersieck 1986 |
| " " | Flow-through | 96h LC50 | >200 µg/L | Mayer and Ellersieck 1986 |
| Redear sunfish (*Lepomis microlophus*) (eggs) | Static renewal | 72h LC50 | 77,200 µg/L | Birge *et al.* 1978 |
| Largemouth bass (*Micropterus salmoides*) (eggs) | Flow-through | 84h LC50 | 65,500 µg/L (soft water) | Birge *et al.* 1979 |
| " " (eggs) | Flow-through | 84h LC50 | 32,100 µg/L (hard water) | Birge *et al.* 1979 |
| Sheepshead minnow (*Cyprinodon variegatus*) | Flow-through | 96h LC50 | >170 µg/L | CMA 1990 |
| " " | Static | 24h LC50 | >550,000 µg/L | Heitmuller *et al.* 1981 |
| " " | Static | 96h LC50 | >550,000 µg/L | Heitmuller *et al.* 1981 |

| | | | | |
|---|---|---|---|---|
| Channel catfish (*Ictalurus punctatus*) | Static | 24h LC50 | >100,000 µg/L | Mayer and Ellersieck 1986 |
| " " | Static | 96h LC50 | >100,000 µg/L | Mayer and Ellersieck 1986 |
| " " | | 96h LC50 | >10,000 µg/L | Mayer and Sanders 1973 |
| " " | Flow-through | 96h LC50 | >200 µg/L | Mayer and Ellersieck 1986 |
| " " (eggs) | Static renewal | 72h LC50 | 2,210 µg/L | Birge *et al.* 1978 |
| Goldfish (*Carassius auratus*) (eggs) | Flow-through | 96h LC50 | >186,000 µg/L (soft water) | Birge *et al.* 1979 |
| " " (eggs) | Flow-through | 96h LC50 | >191,000 µg/L (hard water) | Birge *et al.* 1979 |
| | | <u>Amphibians</u> | | |
| Leopard frog (*Rana pipiens*) (eggs) | Static renewal | 72h LC50 | 5,520 µg/L | Birge *et al.* 1978 |
| Fowlers toad (*Bufo fowleri*) (eggs) | Static renewal | 72h LC50 | 44,140 µg/L | Birge *et al.* 1978 |

Table 4b. Summary of Chronic Toxicity Values of DEHP.

| Species | Study Type | End Point | Value | Reference |
|---|---|---|---|---|
| | | **Algae/Plants** | | |
| Duckweed (*Lemna gibba*) | Static renewal | 7d EC50 (reproduction) | 2,060,000 µg/L | Davis 1981 |
| | | **Invertebrates** | | |
| Oyster (*Crassostrea gigas*) | AET, Puget Sound | (increased abnormalities) | 1,900 µg/kg dw sediment | Tetra Tech Inc. 1986 |
| *Daphnia magna* | Static renewal | 21d NOEL (reproduction) | 77 µg/L | CMA 1984 |
| " " | Static renewal | 21d LOEL (reproduction) | 160 µg/L | CMA 1984 |
| " " | Static renewal | 21d EC50 (growth, survival & reprod.) | >1,300 µg/L | Adams and Heidolph 1985 |
| " " | Static renewal | 21d NOEL (survival & reprod.) | 640 µg/L | Adams and Heidolph 1985 |
| " " | Static renewal | 21d LOEL (survival & reprod.) | >100 µg/L | Brown and Thompson 1982b |
| " " | Static renewal | 21d NOEL (survival & reprod.) | 77 µg/L | Springborn Bionomics 1984 |
| " " | Static renewal | 21d LOEL (survival & reprod.) | 160 µg/L | Springborn Bionomics 1984 |
| " " | Static renewal | 21d MATC (survival) | 110 µg/L | CMA 1990 |
| " " | Flow-through | 21d NOEL (reproduction & survival) | 600 µg/L | Knowles and McKee 1987 |
| " " | Flow-through | 21d LOEL (reproduction & survival) | 1,200 µg/L | Knowles and McKee 1987 |

| | | | | |
|---|---|---|---|---|
| " " | Flow-through | 21d LOEL (reproduction) | 3 µg/L[1] | Sanders *et al.* 1973 |
| " " | Flow-through | 21d NOEL (survival, reproduction & glycogen content) | 158 µg/L | Knowles *et al.* 1987 |
| " " | Flow-through | 21d LOEL (survival, reproduction & glycogen content) | 811 µg/L | Knowles *et al.* 1987 |
| *Palaemonetes pugio* | Semi-static | 28d LOEL (survival and development) | >1,000 µg/L | Laughlin *et al.* 1978 |
| *Gammarus pulex* | Flow-through | 10d LOEL (survival) | >500 µg/L | Thurén and Woin 1991 |
| " " | Flow-through | 10d NOEL (dec. locomotor activity) | 100 µg/L | Thurén and Woin 1991 |
| " " | Flow-through | 10d LOEL (dec. locomotor activity) | 500 µg/L | Thurén and Woin 1991 |
| Amphipod *Rhepoxynius abronius* | AET, Puget Sound | (increased mortality) | >3,100 µg/kg dw sediment | Tetra Tech Inc. 1986 |
| Midge (*Chironomus plumosus*) | Flow-through | 35d LOEL (growth and development) | >360 µg/L | Streufert *et al.* 1980 |
| | | <u>Fish</u> | | |
| Rainbow trout (*Oncorhynchus mykiss*) | Static renewal | 90d NOEL (dec. backbone collagen) | 5 µg/L | Mayer *et al.* 1977 |
| " " | Static renewal | 90d LOEL (dec. backbone collagen) | 14 µg/L | Mayer *et al.* 1977 |
| " " | Static renewal | 90d LOEL (growth) | >54 µg/L | Mayer *et al.* 1977 |

| | | | | |
|---|---|---|---|---|
| " " | Flow-through | 90d LOEL (hatchability, survival and growth) | >508 µg/L | DeFoe *et al.* 1990 |
| " " | Flow-through | 102d NOEL (sac fry survival) | 5 µg/L | Mehrle and Mayer 1976 |
| " " | Flow-through | 102d LOEL (sac fry survival) | 14 µg/L | Mehrle and Mayer 1976 |
| " " | Flow-through | LC50, 27d (4d post-hatch) | 139,500 µg/L (soft water) | Birge *et al.* 1979 |
| " " | Flow-through | LC50, 27d (4d post hatch) | 149,200 µg/L (hard water) | Birge *et al.* 1979 |
| " " (eggs) | Flow-through | LC50, 23d | 139,100 µg/L (soft water) | Birge *et al.* 1979 |
| " " (eggs) | Flow-through | LC50, 23d | 154,000 µg/L (hard water) | Birge *et al.* 1979 |
| Brook trout (*Salvelinus fontinalis*) | Static renewal | 150d LOEL (dec. backbone collagen) | 3.7 µg/L[2] | Mayer *et al.* 1977 |
| " " | Static renewal | 150d LOEL (growth) | >52 µg/L | Mayer *et al.* 1977 |
| Fathead minnow (*Pimephales promelas*) | Flow-through | 56d LOEL (growth & survival) | >62 µg/L | Mehrle and Mayer 1976 |
| " " | Static renewal | 127d LOEL (dec. backbone collagen) | 11 µg/L[2] | Mayer *et al.* 1977 |
| " " | Static renewal | 127d LOEL (growth) | >100 µg/L | Mayer *et al.* 1977 |
| Redear sunfish (*Lepomis microlophus*) | Static renewal | LC50, 7d (4d post-hatch) | 6,180 µg/L | Birge *et al.* 1978 |
| Largemouth bass (*Micropterus salmoides*) | Flow-through | LC50, 7.5d (4d post-hatch) | 55,700 µg/L (soft water) | Birge *et al.* 1979 |
| " " | Flow-through | LC50, 7.5d (4d post-hatch) | 45,500 µg/L (hard water) | Birge *et al.* 1979 |
| Channel catfish | Static renewal | LC50, 7d (4d post-hatch) | 690 µg/L | Birge *et al.* 1978 |

| | | | | |
|---|---|---|---|---|
| Goldfish (*Carassius auratus*) | Flow-through | LC50, 8d (4d post-hatch) | >186,000 µg/L (soft water) | Birge *et al.* 1979 |
| " " | Flow-through | LC50, 8d (4d post-hatch) | >191,000 µg/L (hard water) | Birge *et al.* 1979 |
| Zebra fish (*Brachydanio rerio*) | | 90d NOEL (fry survival) | <50 mg/kg (in diet) | Mayer and Sanders 1973 |
| Japanese medaka (*Oryzias latipes*) | Flow-through | 168d NOEL (growth) | <541 µg/L | DeFoe *et al.* 1990 |
| | | <u>Amphibians</u> | | |
| Leopard frog (*Rana pipiens*) | Static renewal | LC50, 7d (4d post-hatch) | 4,440 µg/L | Birge *et al.* 1978 |
| Moorfrog (*Rana arvalis*) | Static | 60d EC50 (% hatch) | 150 mg/kg ww (sediment) | Larsson and Thurén 1987 |
| Fowlers toad (*Bufo fowleri*) | Static renewal | LC507, d (4d post-hatch) | 3,880 µg/L | Birge *et al.* 1978 |

(1) This study has been criticized and largely discounted because of an abnormally low rate of reproduction in the control group.
(2) Lowest toxicant concentration tested.