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CANADIAN ENVIRONMENTAL PROTECTION ACT

PRIORITY SUBSTANCES LIST

SUPPORTING DOCUMENT

DIBUTYL PHTHALATE

**Government of Canada
Environment Canada**

March 1994

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Unedited supporting documentation pertaining to environmental health aspects of dibutyl phthalate is available from Health Canada at the address cited above.

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1.0 IDENTITY OF SUBSTANCE

1.1 Name of Substance

Dibutyl phthalate, a phthalic acid ester, has the CAS (Chemical Abstracts Service) Registry Number 84-74-2, the molecular formula $C_{16}H_{22}O_4$, and a molecular weight of 278.4. Synonyms include: DBP; 1,2-benzenedicarboxylic acid, dibutyl ester; phthalic acid, dibutyl ester; and di-*n*-butyl phthalate.

For simplicity, this report will use the term "DBP" when referring to dibutyl phthalate. The structure of DBP is shown in Figure 1.

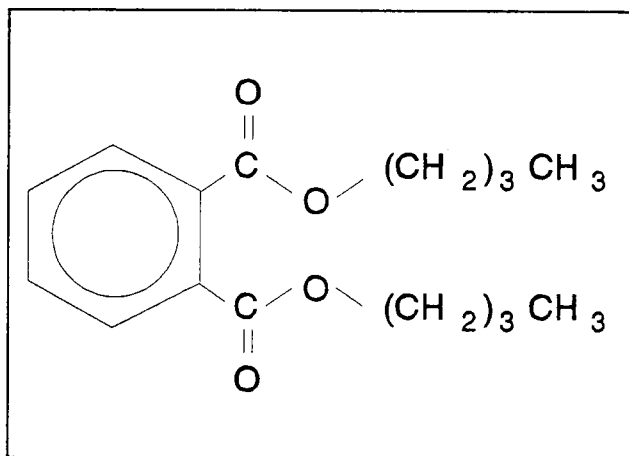


Figure 1. Structure of dibutyl phthalate.

1.2 Analytical Methodology

The most sensitive and selective analytical determinations of phthalic acid esters, including DBP, in environmental media are achieved by 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 $0.36 \mu\text{g/L}$) and gas chromatography/mass spectrometry (GC/MS) (Method 625, detection limit $2.5 \mu\text{g/L}$) (U.S. EPA, 1982a).

Phthalates 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) found DBP in laboratory solvents at concentrations as high as 0.17 mg/kg (in benzene) and in solid reagents at

concentrations up to 9.89 mg/kg (in carboxymethylcellulose), while polyvinyl tubing contained 23.3% DBP. 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, 1982a). 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. ✓

2.0 PHYSICAL AND CHEMICAL PROPERTIES

Dibutyl phthalate is a colourless, oily liquid (Montgomery and Welkom, 1990), with a vapour pressure of about 0.01 Pa @ 25°C (CMA, 1984), Henry's Law Constant of 6.4 Pa·m³/mol or lower (Howard, 1989; McKone and Layton, 1986; Montgomery and Welkom, 1990; U.S. EPA, 1982b), octanol-water partition coefficient (log K_{ow}) between 4.31 and 4.79 (Montgomery and Welkom, 1990), and a solubility in water of about 10 mg/L (McKone and Layton, 1986), although values as high as 4,500 mg/L have been reported (Leyder and Boulanger, 1983). The determination of the water solubility of phthalic acid esters is complicated since these compounds easily form colloidal dispersions in water (Klöpfer et al., 1982) and are subject to "molecular folding" (Callahan et al., 1979). Additional chemical and physical properties of DBP are presented in Table 1.

3.0 SOURCES AND RELEASES TO THE ENVIRONMENT

3.1 Production and Use

At present, there is no manufacture of DBP in Canada (Camford Information Services Inc., 1992). One company had been producing the substance in quantities of less than 1000 tonnes per year, but stopped production in early 1988. About 540 tonnes of DBP were imported into Canada in 1991, down from 860 tonnes in 1988. About 83% of the imported DBP came from the United States in 1991 (Camford Information Services Inc., 1992). Available information is insufficient to estimate the amount of DBP imported in finished plastic products. ✓

Dibutyl phthalate is used mainly as a plasticizer in polyvinyl emulsions. In 1991, approximately 54% of the total Canadian supply of DBP was used as in adhesives, while about 15% was used in coatings (including lacquers), and the rest in miscellaneous applications, including paper coating (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). ✓

Worldwide, the release of phthalates directly to the atmosphere is believed to be the most important mode of entry to the environment. The sources of such releases include emissions during the manufacturing and use of the substances and through the incomplete combustion of plastic material (IPCS, 1992). This is poorly quantified, however, and 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. The concentration of DBP in various waste streams is presented in Table 2. Dibutyl phthalate has been detected at concentrations as high as 158 µg/L in Canadian textile mill effluents in a survey conducted in 1985/86 (detection frequency = 17/19; detection limit 1 µg/L) (Environment Canada, 1989). Dibutyl phthalate has also been detected in the effluents of Canadian chemical plants at concentrations within the range of 1 to 100 µg/L (Munro et al., 1985; OME, 1992a, b). The concentration of DBP in effluents from industrial and municipal plants discharging into the St. Lawrence River at Cornwall, Ontario, ranged from non-detectable to 94 µg/L, with a gross loading of 3.59 kg/day (CCREM, 1987). Loadings in liquid effluents from Ontario's organic chemical industry totalled about 1.7 kg DBP/day (12-month average) (OME, 1992a) while those from the inorganic chemical industry totalled about 0.06 kg DBP/day (12-month average) (OME, 1992b). ✓

A large amount of phthalic acid esters is often volatilized to the air in processing plants, and subsequently condenses on plant equipment or other surfaces in the work area (Zenon, 1982). These esters eventually are washed into municipal wastewater systems or are released as effluents from plant mist eliminators. Phthalates also enter municipal wastewater systems from contaminated cooling water from the processing plants, from domestic use or disposal of products containing these esters, and from the release of scrubber wastewater from incinerators. ✓

Concentrations of DBP have been reported up to 3.0 µg/L in sewage effluents from Ontario municipalities (Beak Consultants, 1991). Dibutyl phthalate was detected in 12 of 15 Canadian municipal sludges sampled between 1980 and 1985, with concentrations ranging from 0.2 to 430 mg/kg (dw) and a median concentration of 10 mg/kg (Webber and Lesage, 1989). ✓

Dibutyl phthalate was detected at concentrations often exceeding 10 µg/L (actual concentrations not reported) in samples of waste water collected in 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 concentrations not reported) (Atwater et al., 1990). ✓

The presence of DBP in leachates from municipal waste landfill sites was documented by Lesage (1991), who reported a concentration of approximately 1 mg/L for a single sample from a landfill site in Guelph, Ontario. ✓

Dibutyl phthalate was detected, but not quantified, in extracts of municipal incinerator fly ash from Ontario, the Netherlands, and Japan (Eiceman et al., 1979). ✓

Dibutyl phthalate was detected in Norwegian spent pulp chlorination liquors at concentrations of 3 to 4 g/tonne of pulp (Carlberg et al., 1986).

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 254,000 kg of DBP into the environment in 1989 (TRI89, 1991). Of this total, 56% (about 140,000 kg) was released by underground injection, 42% (about 106,000 kg) was released directly to air, 2.3% (about 6,000 kg) was released directly to land, and 0.47% (about 1,200 kg) was released directly to water. ✓

4.0 ENVIRONMENTAL FATE AND CONCENTRATIONS

4.1 Environmental Fate

→ In the atmosphere, DBP has been measured in both the vapour and the particulate phases. Giam et al. (1980) reported that on the average, 68% of DBP residues in the atmosphere of the Gulf of Mexico was contained in the vapour phase (as opposed to the suspended particulate phase). Similarly, Cautreels and Van Cauwenberghe (1978) found that in Antwerp, Belgium, 78% of the total airborne DBP was contained in the vapour phase. Hoff and Chan (1987), however, reported that in the Niagara River region, ✓

more than 57% of atmospheric DBP occurred in the suspended particulate phase. Howard et al. (1991), (on the basis of scientific judgement), estimated the photooxidation half-life of DBP in air to range from 7.4 hours to 3.1 days. Washout via rainfall or dry deposition is believed to play a significant role in the removal of DBP from the atmosphere. Eisenreich et al. (1981) predicted that atmospheric deposition is a significant source of DBP in the Great Lakes, with a calculated total deposition of 48 metric tonnes/year to the five Great Lakes, with values for each ranging from 3.7 metric tonnes/year for Lake Ontario to 16 metric tonnes/year for Lake Superior.

In surface water, most of the DBP (>75%) occurs in the water fraction rather than in the suspended solids (Niagara River Data Interpretation Group, 1990). Dibutyl phthalate is biodegradable in natural surface waters, with an estimated half-life in the range of 1 to 14 days (Howard et al., 1991; Johnson et al., 1984; Schouten et al., 1979; Walker et al., 1984). Howard (1989) cited a number of studies showing that DBP is biodegradable in natural surface waters, with degradation >90% occurring in 2 to 17 days under aerobic conditions. Walker et al. (1984) reported half-lives of 1.7 to 13.5 days for DBP in water collected from several freshwater and estuarine sites near the north coast of the Gulf of Mexico. Schouten et al. (1979) found a 90% loss of DBP from water samples occurring within three days at an initial concentration of 50 µg/L. The photolysis half-life of DBP in water has been estimated to be 144 days (Howard, 1989 calculated from Wolfe et al., 1980).

Howard et al. (1991) predicted a half-life of DBP from 2 to 23 days in groundwater, based upon aerobic and anaerobic degradation rates.

No information was identified concerning the half-life of DBP in freshwater sediments, however, by analogy with other phthalates such as DEHP, it is expected to be more persistent under anaerobic conditions. Dibutyl phthalate came into solution when 15 g aliquots of air-dried coal mine sediments were added to 1 L of distilled water (Atwater et al., 1990), demonstrating that some of the DBP sorbed onto sediments may subsequently be released back into the water column by desorption.

Howard et al. (1991), (using scientific judgement based on review of data on concentrations in unacclimated aerobic soil grab samples), predicted a half-life for DBP in soil of 2 to 23 days. Inman et al. (1984) found that DBP was almost completely metabolized within 100 days in non-sterile soils of various types (silt loam, sand, mixture of silica sand and peaty muck). Overcash et al. (1982), however, reported half-lives of longer than 26 weeks in loam and sand at application rates of 800 mg DBP/kg and above, while at a lower application rate (200 mg/kg), the half-life of DBP in loam and sand was about 12 weeks.

Dibutyl phthalate is moderately adsorbed to soil (Howard, 1989; Zurmühl et al., 1991), but it forms a complex with water-soluble fulvic acid, and this may increase its mobilization and reactivity in soil to some degree (Matsuda and Schnitzer, 1971). Volatilization of DBP from soil is not expected to be significant because of its low vapour pressure and moderate adsorption to soil (Howard, 1989). ✓

In anaerobic sludge, DBP degradation proceeded through monobutylphthalate to phthalic acid, followed by ring cleavage and mineralization (Shelton et al., 1984). Primary degradation exceeded 95% in 24 hours in the Semi-Continuous Activated Sludge (SCAS) test, while ultimate biodegradation to CO₂ amounted to 57.4% (t_{1/2} 15.4 days) in the shake flask test (CMA, 1984). Sugatt et al. (1984) reported 90% primary degradation of DBP in the 28-day shake flask test using mixed populations of microorganisms from natural sources.

Since DBP is quite readily metabolized in fish (Johnson et al., 1977; Stalling et al., 1973; Wofford et al., 1981), bioaccumulation is likely to be limited in fish species. The limited data that are available fail to confirm this, however, as the reported bioconcentration factors for DBP for various aquatic organisms range from 2.9 for the brown shrimp, *Penaeus aztecus* (Wofford et al., 1981) to 2,125 for the fathead minnow, *Pimephales promelas* (Call et al., 1983).

Birds do not appear to bioaccumulate DBP. Mallard ducks (*Anas platyrhynchos*) were fed 10 mg/kg DBP 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 DBP/kg-bird/day. No phthalates were found in DBP treated birds when fat, heart, lung and breast tissues were analyzed (detection limit = 0.1 mg/kg in a 2 g sample).

No information is available on the biomagnification of DBP in wild mammals. Environmental exposure for the mink (*Mustela vison*) was calculated using aquatic bioconcentration data (see Section 5.2). ✓

Bioconcentration factors for a number of organisms are presented in Table 3.

4.2 Environmental Concentrations

Concentrations of DBP in various environmental compartments are given in Tables 4a and 4b. The paragraphs below highlight the maximum (and in some cases the "typical") concentrations of DBP in the various compartments of the Canadian and Great Lakes and non-Canadian/Great Lakes environment.

Dibutyl phthalate has been detected in samples of air taken in 1982 ($n = 5$) along the Niagara River, with mean concentrations of $1.9 \pm 1.3 \text{ ng/m}^3$ in the gas phase and $4.0 \pm 2.2 \text{ ng/m}^3$ in the particulate phase (Hoff and Chan, 1987). In 1983, mean levels were $4.5 \pm 3.5 \text{ ng/m}^3$ in 15 samples of the gas phase, and $6.2 \pm 2.6 \text{ ng/m}^3$ in 19 samples of the particulate phase. Based on atmospheric concentrations of DBP from a number of oceanic and inland areas as reported by Giam et al. (1978; 1980), Eisenreich et al. (1981) estimated that atmospheric concentrations of DBP in the Great Lakes area ranged from 0.5 to 5 ng/m^3 . In an earlier study, DBP was reported at a concentration of 700 ng DBP/m^3 in air samples collected near a municipal incinerator at Hamilton, Ontario (Thomas, 1973). Outside Canada, Cautreels et al. (1977) reported DBP at concentrations as high as $55\text{--}74 \text{ ng/m}^3$ in the suspended particulates phase of the air at a residential area of Antwerp, Belgium. (Atlas and Giam (1981) reported atmospheric DBP concentrations as high as 18.5 ng/m^3 , at Pigeon Key, Florida. Weschler (1981) reported DBP in the Arctic aerosol at Barrow, Alaska, at a concentration of about 1 ng/m^3 . Other studies show atmospheric DBP concentrations generally below 10 ng/m^3 . X

No data were identified concerning concentrations of DBP in precipitation in Canada; however, Eisenreich et al. (1981) estimated that concentrations of DBP in rain water in the Great Lakes region would range from 0.004 to $0.010 \text{ } \mu\text{g/L}$. Atlas and Giam (1981) reported DBP concentrations in rain water ranging from 0.0026 to $0.0725 \text{ } \mu\text{g/L}$ at the Enewetak Atoll in the north Pacific Ocean. Dibutyl phthalate was present in small amounts in snow and rain samples from Norway (Lunde et al., 1977). X

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 12.2 ng/L at Fort Erie (26 of 26 samples above the detection limit of 0.29 ng/L ; max 26.87 ng/L) and 15.16 ng/L at Niagara-on-the-Lake (25 of 25 samples were above the detection limit of 0.29 ng/L ; max 72.93 ng/L). The calculated mean total loadings were 7.756 kg DBP/day at Fort Erie at the upstream end of the Niagara River and 9.429 kg DBP/day at Niagara-on-the-Lake at the mouth of the river (Niagara River Data Interpretation Group, 1990). Germain and Langlois (1988), also using large-volume sampling techniques, reported a mean concentration of 89 ng/L for DBP in the St. Lawrence River in the Montreal region in 1987. Information on concentrations of DBP in surface waters in the NAQUADAT/ENVIRODAT database is limited to 73 records for Alberta and two records for British Columbia dating from 1985 to 1988. For only 8 records were concentrations above the detection limit, and reported values ranged between <1 to $2 \text{ } \mu\text{g/L}$ (NAQUADAT, 1993). The Alberta Ministry of the Environment detected DBP in 3 of 45 samples of raw surface water; the average concentration was below the detection limit ($1 \text{ } \mu\text{g/L}$) while the maximum ✓

concentration was 4 $\mu\text{g/L}$ (Halina, 1993a). The Ontario Ministry of the Environment, under the Municipal and Industrial Strategy for Abatement (MISA) program, reported that DBP was detected at an average concentration of 1.4 $\mu\text{g/L}$ in the intake water of one organic chemical manufacturing plant located at Sarnia, Ontario (OME, 1992a). In 1979, maximum concentrations of DBP in the range of 10 to 100 $\mu\text{g/L}$ were reported for chemical plant intake water from the St. Clair River (Munro et al., 1985). Pierce et al. (1980) cited concentrations of DBP as high as 14 $\mu\text{g/L}$ (in water from Lake Michigan). Other studies indicate that concentrations of DBP in Canadian and Great Lakes waters are generally below 1 $\mu\text{g/L}$ (Environment Canada, 1980; MENVIQ, 1993). Shibuya (1979) cited DBP concentrations in Japanese fresh waters as high as 36 $\mu\text{g/L}$, but several other studies indicated DBP concentrations of less than 5 $\mu\text{g/L}$ in fresh water outside Canada and the Great Lakes.

No data were found on DBP concentrations in Canadian marine waters, but studies on non-Canadian marine water show DBP concentrations up to 0.4713 $\mu\text{g/L}$ (in water from the Gulf of Mexico (Chan, 1975)).

Few data have been found pertaining to DBP concentrations in Canadian ground water. A concentration of 570 $\mu\text{g DBP/L}$ was detected in a single sample of groundwater beneath a former coke oven plant site at Sidney, Nova Scotia in 1987 (Lesage, 1991). Concentrations of DBP in Alberta drinking water derived from groundwater were reported as <1 $\mu\text{g/L}$ for 1985 and 1986 (Spink, 1986) and from <1 to 2 $\mu\text{g/L}$ (average <1 $\mu\text{g/L}$) for 1987 to 1992 (Halina, 1993b). Outside Canada, Guardiola et al. (1989) reported DBP concentrations up to 80 $\mu\text{g/L}$ in ground water from the Besós River basin in Spain.

Sediments samples collected from the Detroit River in 1982 contained DBP concentrations ranging from <0.1 to 0.65 mg/kg dry weight (Fallon and Horvath, 1985). Concentrations of DBP in sediment samples taken in 1982 from the Fraser Estuary, B.C., ranged from 0.07 to 0.45 mg/kg dry weight (Rogers and Hall, 1987). The concentration of DBP decreased from 0.204 mg/kg dry weight in sediments 0.5 km from a large sewage outfall in the estuary to 0.060 mg/kg in sediments 1.0 km from the outfall (Rogers and Hall, 1987). Concentrations of DBP up to 0.3 mg/kg were reported in samples of sediments collected from Lake Superior and Lake Huron in the 1970s (CCREM, 1987). In their review, Pierce et al. (1980) cited DBP concentrations in various sediments as high as 16 mg/kg (in sediments from the Rhine R., Netherlands). Ray et al. (1983a) reported concentrations of DBP in marine sediments from Portland, Maine, up to 0.28 mg/kg.

Dibutyl phthalate concentrations ranging from <0.1 mg/kg to 1.4 mg DBP/kg were detected in 13 out of 30 samples (detection limit, 0.1 mg/kg) of soils in urban areas of Port Credit and

Oakville/Burlington, Ontario (Golder Associates, 1987). Concentrations of 0.027 to 0.175 mg DBP/kg were identified in an unspecified number of samples of soil from an industrial site in Quebec (MENVIQ, 1989).

The concentrations of DBP in aquatic biota from the Great Lakes and other areas in Canada were less than 10 µg/g (Burns et al., 1981; Glass et al., 1977; Swain, 1978; Williams, 1973). The highest concentrations were reported for skinless fillets from long-nose suckers, *Catostomus catostomus*, (8.1 µg DBP/g) and rainbow trout, *Oncorhynchus mykiss*, (5.4 µg/g) from Lake Superior (Glass et al., 1977). Concentrations of DBP in fish from various U.S. Great Lakes harbours and tributary mouths ranged from <0.02 to 35 µg/g wet weight (DeVault, 1985). Ray et al. (1983a) reported concentrations of DBP in the marine polychaete worm *Neanthes virens* from Portland, Maine, ranging from 0.070 to 0.180 mg/kg.

Data on phthalate levels in wild birds and mammals are very sparse. Zitko (1972) detected DBP in egg yolks of the double-crested cormorant, *Phalacrocorax auritus*, (14.1 µg/g lipid) and herring gull, *Larus argentatus*, (10.9, 17.1 and 19.1 µg/g lipid). Residue analysis of commercial eggs collected throughout Japan found 0.098 µg/g DBP (trace - 0.15 µg/g) in egg whites (Ishida et al., 1981). No phthalate residues above the detection limit (1.00 µg/g) were found in the egg yolks.

5.0 KINETICS AND METABOLISM

5.1 Metabolism

Dibutyl phthalate was metabolized by microsomal preparations from fish liver to mono-*n*-butyl phthalate and three other unidentified metabolites (Stalling et al., 1973).

5.2 Exposure Scenario for Mink

The potential for adverse effects to wildlife from exposure to dibutyl phthalate through air, water and food is evaluated with a "worst case" scenario using mink, (*Mustela vison*), a terrestrial mammal having a diet consisting in part of aquatic prey. A daily exposure of 1318 µg/kg-bw/d was estimated for mink exposed to the highest recent concentration of DBP reported in Canadian waters (Table 5). Reported levels of DBP in the Niagara River area are lower, resulting in a daily exposure for mink of 24 µg/kg bw/d (Table 5). The intake of DBP from air and water in both calculations is negligible when compared to intake from food.

6.0 EFFECTS ON THE ECOSYSTEM

The results of a number of toxicity studies are presented in Tables 6a (acute toxicity) and 6b (chronic toxicity). The results of studies indicating the most toxic effects of DBP in various groups of organisms (i.e. lowest concentrations of DBP having adverse effects) are summarized in the following sections.

6.1 Microorganisms

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 specified exposure period. The 15-minute Apparent Effects Threshold (AET, defined as the concentration above which statistically significant adverse effects are always expected relative to appropriate reference conditions) was estimated as 1,400 μg DBP/kg dry weight for Puget Sound sediment. ✓

For water-borne DBP, both the 5-minute and 30-minute EC50 values were cited as 10,900 $\mu\text{g}/\text{L}$ in the Microtox Test using *Photobacterium phosphoreum* (Tarkpea et al., 1986). Yoshioka et al. (1985) reported a 24-hour EC50 (cell proliferation) of 2,200 μg DBP/L for the protozoan, *Tetrahymena pyriformis*. ✓

Dibutyl phthalate at all concentrations tested, up to 300,000 $\mu\text{g}/\text{L}$, did not inhibit methanogenesis in an anaerobic toxicity assay using secondary sludge as the source of a heterogeneous anaerobic population (O'Connor et al., 1989). ✓

6.2 Algae

Dibutyl phthalate at concentrations of about 7,000 $\mu\text{g}/\text{L}$, 2,800 $\mu\text{g}/\text{L}$ and 2.8 $\mu\text{g}/\text{L}$ reduced the growth rates of monodispersed (i.e. non-aggregated) *Thalassiosira pseudomona* (diatom), *Dunaliella parva* (green algae) and *Synechococcus lividus* (blue-green algae), respectively (Acey et al., 1987). Dibutyl phthalate at a concentration of 2.8 $\mu\text{g}/\text{L}$ increased the percentage of aggregated (as opposed to monodispersed) *Synechococcus lividus* to 95% from 22% in the controls. At each concentration of DBP tested, from 0.28 to 2.8 $\mu\text{g}/\text{L}$, the total number of *S. lividus* organisms was about double that in the control group after 14 to 15 days exposure, thus DBP only caused a decrease in the number of monodispersed organisms in this species. ✓

A 10-day EC50 (decreased cell numbers) of 750 μg DBP/L was reported for the green algae, *Selenastrum capricornutum* (Springborn Bionomics, 1984a). Kühn and Pattard (1990) reported a 48-hour EC50 for DBP of 1,400 $\mu\text{g}/\text{L}$ for *Scenedesmus subspicatus*, based on biomass. The 96-hour EC50 values for the marine

Dinoflagellate, *Gymnodinium breve*, were 3.4-200 μg DBP/L based on growth and 20-600 μg DBP/L based on survival (Wilson et al., 1978).

6.3 Invertebrates

In both laboratory and field studies with estuarine benthic systems, Tagatz et al. (1986) showed that DBP in sediments had statistically significant effects on eight-week colonization only at the highest nominal concentrations tested, 1,000 mg/kg. In the laboratory study, total number of species per box was significantly decreased by the DBP, while in the field study, only the total number of individual mollusks was affected. The actual exposure concentrations would be lower than the nominal concentrations, as only 48% and 19% of the original concentration persisted in the laboratory and field systems, respectively, during the last two weeks of the study. In an earlier study in which DBP was introduced in the water, rather than in the sediment, Tagatz et al. (1983) found that colonization was significantly reduced by DBP concentrations of 3,700 and 3,800 $\mu\text{g/L}$ in laboratory- and field-colonized communities, respectively. Dibutyl phthalate at 340 $\mu\text{g/L}$ did not have a statistically significant effect on the total numbers of species or individuals in the laboratory-colonized community, but did significantly reduce the number of *Corophium acherusicum* (amphipods). Dibutyl phthalate at 450 $\mu\text{g/L}$ did not have a statistically significant effect on the field-colonized community.

Tetra Tech Inc. (1986) reported estimated Apparent Effects Threshold values of $>5,100 \mu\text{g DBP/kg}$ for the amphipod, *Rhepoxynius abronius*, (mortality), 1,400 $\mu\text{g DBP/kg}$ for the oyster *Crassostrea gigas*, (larval abnormalities), and $>5,100 \mu\text{g DBP/kg}$ for total abundance of higher level (Polychaeta, Mollusca, Crustacea) benthic infauna. Subsequent re-evaluation of the Tetra Tech data by Barrick et al. (1988) resulted in a lowering of the amphipod AET for Puget Sound sediments to 1,400 $\mu\text{g DBP/kg}$. This approach involves comparison of data on the composition of sediments collected in contaminated areas to measures of biological effects associated with these sediments. However, as noted by U.S. EPA (1989) the AET approach is not recommended for the development of broadly applicable sediment quality criteria because of its site-specific nature and its inability to describe cause-and-effect relationships.

Using equilibrium partitioning modelling, Tetra Tech Inc. (1986) calculated a sediment quality value of 64 mg DBP/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 DBP 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.

A 7-day EC50 of 540 μg DBP/L has been reported for the planarian, *Dugesia japonica*, based on reduced head regeneration (Yoshioka et al., 1986). Other sensitive invertebrate species are the scud, *Gammarus pulex*, with a 10-day LOEL of 500 μg DBP/L, based on reduced locomotor activity (Thurén and Woin, 1991), the Mysid shrimp, *Mysidopsis bahia*, with a 96-hour LC50 of 750 μg /L (EG&G Bionomics, 1984a), and the midge, *Chironomus plumosus*, with a 48-hour EC50 of 760 μg DBP/L (Streufert et al., 1980). ✓

Phthalates were found to be the least toxic of the chemical groups tested on the earthworm *Eisenia fetida* (Neuhauser et al., 1985, 1986). LC50 values for DBP was 1360 $\mu\text{g}/\text{cm}^2$ in a 2-day contact test in which the chemical was applied to filter paper, with the toxic units referring to the amount of chemical per cm^2 of paper. Dimethylphthalate was the most toxic phthalate tested, with a LC50 of 550 $\mu\text{g}/\text{m}^2$. By comparison, the most toxic of the 44 chemicals tested, 2,4-dinitrophenol, had a LC50 of 0.6 $\mu\text{g}/\text{m}^2$.

Dibutyl phthalate applied to female house flies topically or by injection at a concentration of 20 $\mu\text{g}/\text{fly}$ (1000 $\mu\text{g}/\text{g}$) 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 DBP 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 DBP 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 DBP may have resulted in an internal concentration of insecticide below the toxicity threshold.

6.4 Fish

Sensitive freshwater fish species include the rainbow trout, *Oncorhynchus mykiss*, with a 99-day LOEL of 190 μg DBP/L (growth reduced by about 27%) and a 99-day NOEL of 100 $\mu\text{g}/\text{L}$ (Ward and Boeri, 1991), the yellow perch, *Perca flavescens*, with a 96-hour LC50 of 350 μg DBP/L (Mayer and Ellersieck), and the channel catfish, *Ictalurus punctatus*, with a 96-hour LC50 of 460 μg DBP/L (Mayer and Ellersieck, 1986). The sheepshead minnow, *Cyprinodon variegatus*, for which a 96-hour LC50 of 600 $\mu\text{g}/\text{L}$ has been reported (CMA, 1984) was the most sensitive marine fish species identified.

Yoshioka et al. (1986) reported a 48-hour LC50 of 630 μg DBP/L for the red killifish, *Oryzias latipes*, while a 96-hour LC50 of 730 μg DBP/L has been reported for the bluegill, *Lepomis macrochirus* (Mayer and Sanders, 1973) and a 96-hour LC50 of 850 μg DBP/L for the fathead minnow, *Pimephales promelas* (DeFoe et al., 1990).

6.5 Amphibians and Reptiles

No information was found pertaining to adverse effects of DBP on amphibians or reptiles.

6.6 Plants

Dibutyl phthalate vapour from flexible plastics (e.g. glazing strips) used in greenhouses has been implicated in development of toxic symptoms in plants. The threshold concentration for visible damage in summer cabbage, *Brassica oleracea* L. cv. Derby Day was determined to be between 0.141 and 0.360 μg DBP/ m^3 , the latter figure determined in a laboratory experiment in which growth restriction, chlorosis and cotyledon death were observed (Hardwick et al., 1984).

Dibutyl phthalate at higher air concentrations has been shown to harm other plant species. In strong light, leaves of radish seedlings (*Raphanus sativus*) faded to pale green due to a disappearance of carotenoid and chlorophyll pigments after 6 days exposure to 41.3 to 62.3 μg DBP/ m^3 air and to white after 9 days exposure to 56.5 to 90.7 μg DBP/ m^3 (Virgin, 1988). Wheat seedlings (*Triticum aestivum*) did not display these symptoms when exposed to DBP vapour alone, but did develop the symptoms when also treated with DBP-saturated water.

Millar and Hannay (1986) showed that DBP inhibited photosynthesis in radish plants (*Raphanus sativus*) exposed to 120 μg DBP/ m^3 at a rate of 0.003 m^3/min for 13 days. Concentrations of DBP as low as 10 $\mu\text{moles}/\text{m}^3$ (approx. 2,800 $\mu\text{g}/\text{m}^3$) reduced uncoupled electron transport in isolated spinach thylakoids by about 13%, while 44 $\mu\text{moles}/\text{m}^3$ (approx. 12,250 $\mu\text{g}/\text{m}^3$) caused a 50% reduction. Basal electron transport rates were reduced by 50% with a DBP concentration of 87 $\mu\text{moles}/\text{m}^3$ (approx. 24,200 $\mu\text{g}/\text{m}^3$).

Løkke and Bro-Rasmussen (1981) found that application of DBP to leaves of white mustard (*Sinapis alba*) at a rate of 1.5 $\mu\text{g}/\text{cm}^2$ caused chlorosis in new leaves as they appeared on the third day after treatment. This effect did not occur with DBP application to nipplewort (*Lapsana communis*) or to milfoil (*Achillea millefolium*).

Plants can also be adversely affected by exposure to DBP in the soil. Dibutyl phthalate at soil concentrations of 200 mg/kg

and above reduced the germination of soybeans, *Glycine max*, by >33% and decreased the growth of corn (*Zea mays*) and soybeans by 29 to 80% (Overcash et al., 1982). Plant height and shoot weight were significantly reduced by 17 and 25%, respectively, when corn seeds were planted in soil containing 2,000 mg DBP/kg and grown for three weeks. Growth was not affected with a soil concentration of 200 mg DBP/kg (Shea et al., 1982).

Dibutyl phthalate at a concentration of 1,000 mg/L (added as a methanol solution) reduced the seed germination by 48% in peas, *Pisum sativum*, and by 58% in spinach, *Spinacia oleracea*, grown in tap water, but had no observable effect on subsequent development of the seeds that did germinate (Herring and Bering, 1988). It should be noted, however, that this concentration is many times higher than saturation concentration of DBP in water of about 10 mg/L.

6.7 Birds

In a study in which ring doves (*Streptopelia risoria*) were fed a diet containing 10 mg DBP/kg (1.1 mg DBP/kg-bw/day) for a period of three weeks prior to mating through completion of a clutch of two eggs, there was a 23% increase in water permeability and a 10% decrease in egg shell thickness (Peakall, 1974). (A 15% decrease in shell thickness is considered significant for reproductive effects). Rapid recovery occurred upon cessation of exposure. ✓

Korhonen et al. (1983) studied the embryo toxicity of DBP to white leghorn chicken eggs. On the third day of incubation, DBP was injected on the inner shell membrane at doses of 13 and 26 μ mol per egg (3.62 and 7.24 mg/egg, respectively). At 26 μ mol per egg, 30 eggs were tested resulting in 6 early deaths (2 days after injection), 4 non-malformed and 1 malformed late deaths (between 3 and 11 days after injection). An approximate ED50 of 33 μ mol (9.19 mg) per egg was calculated for DBP. ✓

6.8 Mammals

No data were identified concerning the potential toxicity of DBP to mammalian wildlife.

7.0 CURRENT REGULATIONS, GUIDELINES AND STANDARDS

Environment Canada has produced a draft interim water quality guideline of 19.0 μ g DBP/L for the protection of freshwater aquatic life (Environment Canada, 1992). The International Joint Commission and the governments of Manitoba and Ontario have published water quality guidelines/objectives of 4.0 μ g DBP/L to protect aquatic life (Environment Canada, 1992).

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Table 1. Chemical and physical properties of DBP.

CAS Name:	1,2-Benzenedicarboxylic acid, dibutyl ester
CAS No.:	84-74-2
Synonyms:	DBP; phthalic acid, dibutyl ester; di-n-butyl phthalate
Empirical Formula:	$C_{16}H_{22}O_4$
Molecular Weight:	278.4
Appearance and Odour:	Colourless oily liquid with a mild aromatic odour ⁽²⁾
Specific Gravity:	1.044-1.048 ⁽¹⁾
Melting Point:	-35 C ⁽¹⁾ -35 to - 71 C ⁽²⁾
Boiling Point:	340 C @ 101,300 Pa ⁽¹⁾
Henry's Law Constant:	6.4 Pa·m ³ /mol ⁽²⁾ 0.05 Pa·m ³ /mol (calculated) ⁽⁵⁾ 0.03 Pa·m ³ /mol ⁽⁹⁾ 1.9 torr·kg/mole ⁽⁶⁾
Vapour Density:	9.61 (air = 1) ⁽²⁾
Vapour Pressure:	0.009 Pa ⁽⁶⁾ 0.01 Pa @ 25 C ⁽¹¹⁾
Water Solubility:	9.2 mg/L ⁽¹³⁾ (fresh water) 1.1 mg/L to 9.6 mg/L ⁽⁴⁾ 11.2 mg/L @ 25 C ⁽¹⁴⁾ 11.2 mg/L @ 25 C ⁽¹¹⁾ 10.0 mg/L ⁽⁶⁾ 13.0 mg/L @ 25 C ⁽⁹⁾ 13.0 mg/L to 4,500 mg/L ⁽⁷⁾ (salt water) 3.25 mg/L ⁽⁸⁾
Solvent Solubility:	Soluble in all common organic solvents and oil ⁽¹⁾
Log K _{oc} :	3.14 ⁽¹³⁾ 5.23 ⁽⁹⁾
Log K _{ow} :	4.13 (estimated) ⁽¹⁰⁾ 4.31-4.79 ⁽²⁾ 4.79 ⁽¹¹⁾ 4.69 ⁽³⁾ 4.72 ⁽⁴⁾ 4.57 ⁽⁶⁾ 4.74 ⁽¹²⁾ 5.56 ⁽⁹⁾

- (1) Data cited in Pierce et al. 1980.
 (2) Data/ranges cited in Montgomery and Welkom 1990.
 (3) Data cited in U.S. EPA 1988.
 (4) DeFoe et al. 1990.
 (5) Data cited in Howard 1989.
 (6) McKone and Layton 1986.
 (7) Leyder and Boulanger 1983.
 (8) Giam et al. 1980.
 (9) U.S. EPA 1982b.

- (10) McDuffie 1981.
- (11) CMA 1984.
- (12) Veith et al. 1984.
- (13) Russell and McDuffie 1986.
- (14) Howard et al. 1985.

Table 2. Concentrations of DBP in waste streams.

<u>Media</u>	<u>Concentration</u> mean (max. or range)	<u>Location</u>	<u>Reference</u>
Industrial waste water	(64 µg/L)	Procter & Gamble final effluent, Alberta	NAQUADAT 1993
" "	(12-mo. ave 10.6 µg/L)	Ontario organic chemical manufacturing plants	OME 1992a
" "	(12-mo. ave. 12.1 µg/L)	Ontario inorganic chemical manufacturing plants	OME 1992b
" "	(within 10-100 µg/L)	Effluents, St. Clair R. petrochemical plants	Munro et al. 1985
" "	0.3 (2.2 µg/L)	Ontario petroleum refining effluents, Dec. 1988 - May 1989	OME 1989
" "	0.135 (1.2 µg/L)	Ontario petroleum refining effluents, June - Nov. 1989	OME 1990
" "	(158 µg/L)	Canadian textile mill effluents	Environment Canada 1989
Municipal waste water	Detected, not quantified	Vancouver, B.C.	Rogers et al. 1986
Sewage effluents	(ND-3.0 µg/L)	Ontario municipalities	Beak Consultants 1991
Sewage sludge	(0.2-161.0 mg/kg dw)	Winnipeg, Manitoba	Webber and Lesage 1989
" "	(14.0-57.0 mg/kg dw)	Hamilton, Ont.	Webber and Leaseg 1989
" "	10.0 mg/kg dw (median)	Other Canadian cities	Webber and Lesage 1989
" "	(0.2-430.0 mg/kg dw)	" " "	Webber and Lesage 1989
Municipal landfill leachate	1,000 µg/L	Guelph, Ont.	Lesage 1991

Table 3. Bioconcentration factors (BCF) for DBP for various aquatic organisms.

Species	Water Concentration	Duration	BCF ^a	Reference
Oyster (<i>Crassostrea virginica</i>)	100 µg/L	1 day	21.1 ^b	Wofford et al. 1981
" "	500 µg/L	1 day	41.6 ^b	Wofford et al. 1981
<i>Daphnia magna</i>	0.08 µg/L	14 days	400	Mayer and Sanders 1973
Scud (<i>Gammarus pseudolimnaeus</i>)	0.10 µg/L	14 days	1,400	Mayer and Sanders 1973
<i>Gammarus pulex</i>	100 µg/L	10 days	140 (accumulated)	Thurén and Woin 1991
" "	100 µg/L	10 days	45 (adsorbed)	Thurén and Woin 1991
" "	500 µg/L	10 days	64 (accumulated)	Thurén and Woin 1991
" "	500 µg/L	10 days	8.4 (adsorbed)	Thurén and Woin 1991
Brown shrimp (<i>Penaeus aztecus</i>)	100 µg/L	1 day	2.9	Wofford et al. 1981
" "	500 µg/L	1 day	30.6	Wofford et al. 1981
Midge (<i>Chironomus plumosus</i>)	0.18 µg/L	7 days	720	Mayer and Sanders 1973
Mayfly (<i>Hexagenia bilineata</i>)	0.008 µg/L	7 days	430	Mayer and Sanders 1973
Fathead minnow (<i>Pimephales promelas</i>)	4.83 µg/L	11 days	2,068	Call et al. 1983
" "	34.8 µg/L	5 days	2,125	Call et al. 1983
Sheepshead minnow (<i>Cyprinodon variegatus</i>)	100 µg/L	1 day	11.7	Wofford et al. 1981

^a BCF's are based on whole-body concentrations unless otherwise indicated.

^b BCF based on concentration in muscle.

Table 4a. Concentrations of DBP in air, water, sediment, soil and biota in the Canadian and Great Lakes environment.

<u>Media</u>	<u>Concentration</u> mean (max. or range)	<u>Location</u>	<u>Reference</u>
Atmosphere	700 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
"	4.0 ng/m ³ (particulate phase)	Niagara R., September	Hoff and Chan 1987
"	6.2 ng/m ³ (particulate phase)	Niagara R., January	Hoff and Chan 1987
"	1.9 ng/m ³ (air phase)	Niagara R., September	Hoff and Chan 1987
"	4.5 ng/m ³ (air phase)	Niagara R., January	Hoff and Chan 1987
Drinking water	<1.0 µg/L (tr-7.2 µg/L)	Alberta, Canada, drinking water derived from surface water	Spink 1986
"	"	<1.0 µg/L (<1.0-8.0 µg/L)	Alberta, Canada, drinking water derived from surface water
"	"	<1.0 µg/L (tr-<1.0 µg/L)	Alberta, Canada, drinking water derived from ground water
"	"	<1.0 µg/L (<1.0-2.0 µg/L)	Alberta, Canada, drinking water derived from ground water
Rain water	0.006 µg/L (0.004-0.010 µg/L)	Great Lakes region	Eisenreich et al. 1981
Surface water	(14 µg/L)	(L. Michigan), highest reported conc. in review	Pierce et al. 1980
"	"	(12-mo. ave. 1.4 µg/L)	Intake water, Ontario organic chemical manufacturing plants

"	"	(within 10-100 µg/L)	St. Clair R.	Munro et al. 1985
"	"	(1 µg/L)	St. Clair R.	Michigan Department of Natural Resources 1974 ⁽¹⁾
"	"	(<1 - 2 µg/L)	Alberta, Canada	NAQUADAT 1993
"	"	<1.0 µg/L (<1.0-4.0 µg/L)	Alberta, Canada	Halina 1993a
"	"	(0.1-1.0 µg/L)	N. Saskatchewan R., Alberta	Alberta Environment 1986 ⁽¹⁾
"	"	0.0122 µg/L (water fraction)	Niagara R. at Fort Erie	Niagara River Data Interpretation Group 1990
"	"	0.003433 µg/L (suspended solids fraction)	Niagara R. at Fort Erie	Niagara River Data Interpretation Group 1990
"	"	0.01516 µg/L (water fraction)	Niagara R. at Niagara- on-the-Lake	Niagara River Data Interpretation Group 1990
"	"	0.003718 µg/L (suspended solids fraction)	Niagara R. at Niagara- on-the-Lake	Niagara River Data Interpretation Group 1990
"	"	(0.070-1.000 mg/kg, suspended sediments)	Niagara R. at Niagara- on-the Lake	Kuntz 1984
"	"	0.0936 µg/L (<0.02- 0.147 µg/L)	Streams tributary to L. Michigan, U.S.A.	Schacht 1974
"	"	Trace	Red R., Manitoba	Environment Canada 1980
"	"	0.103 µg/L (water + suspended solids)	St. Lawrence R.	Germain and Langlois 1988
"	"	0.089 µg/L (water fraction)	St. Lawrence R.	Germain and Langlois 1988
"	"	3.967 mg/kg (suspended solids fraction)	St. Lawrence R.	Germain and Langlois 1988
"	"	(<2 µg/L)	Raw water supplies from Quebec rural areas	MENVIQ 1993
Ground water		570 µg/L	Former Sydney, N.S. coke oven plant site	Lesage 1991

Sediment	(0.100 mg/kg)	(Black Bay, L. Superior), Pierce et al. 1980 highest reported conc. in review	
"	(0.300 mg/kg)	(L. Superior & L. Huron), CCREM 1987 highest reported conc. in review	
"	0.100 mg/kg	Black Bay, L. Superior	Mayer et al. 1972
"	<0.2 mg/kg dw	Lake Michigan	Schacht 1974
"	0.0112 mg/kg dw (<0.2- 0.120 mg/kg dw)	Streams tributary to L. Michigan, U.S.A.	Schacht 1974
"	(0.003-0.006 mg/kg)	Lake Erie/Detroit R.	Michigan Department of Natural Resources 1974 ⁽¹⁾
"	(<0.1-0.65 mg/kg dw)	Detroit R.	Fallon and Horvath 1985
Marine sediment	(0.07-0.45 mg/kg dw)	Fraser Estuary, B.C.	Rogers and Hall 1987
" "	(0.204 mg/kg dw)	Fraser Estuary, B.C. (0.5 km below sewage outfall)	Rogers and Hall 1987
Aquatic biota	(<0.1-0.1 mg/kg ww (chub))	L. Michigan	Schacht 1974
Fish	(<0.02-35.0 mg/kg ww)	Great Lakes harbors and tributary mouths, U.S.A.	DeVault 1985
Fish (unprocessed)	(<0.1-<0.2 mg/kg)	Canadian lakes & rivers	Williams 1973
Rainbow trout (<i>Oncorhynchus mykiss</i>)	5.4 mg/kg	Upper Great Lakes	Glass et al. 1977
Lake trout (<i>Salvelinus namaycush</i>)	3.2 mg/kg ww	Lake Superior exclusive of Isle Royale area	Swain 1978
Lake trout	1.7 mg/kg ww	Lake Superior	Swain 1978
Siscowet trout (<i>Salvelinus namaycush</i> <i>siscowet</i>)	(<0.02 mg/kg ww)	Lake Superior	Swain 1978
Whitefish	0.04 mg/kg ww	Lake Superior, all stations	Swain 1978
"	0.07 mg/kg ww	Lake Superior, Isle Royale area	Swain 1978

Longnose sucker	8.1 mg/kg	Upper Great Lakes	Glass et al. 1977
(<i>Catostomus catostomus</i>)			
Pickereel	Trace	L. Ontario	Environment Canada 1980
"	<0.020 mg/kg	L. Ontario	Williams 1973
"	<0.010 mg/kg	L. Huron	Williams 1973
Eel	<0.010 mg/kg	Canadian lakes & rivers	Williams 1973
Catfish	<0.010 mg/kg	L. St. Pierre, Canada	Williams 1973
Herring (<i>Clupea</i>	0.16 mg/kg ww	Gulf of St. Lawrence	Burns et al. 1981
<i>harengus harengus</i>)			
fillets			
Mackerel (<i>Scomber</i>	0.02 mg/kg ww	Gulf of St. Lawrence	Burns et al. 1981
<i>scombrus</i>) fillets			
Plaice	0.01 mg/kg ww	Gulf of St. Lawrence	Burns et al. 1981
(<i>Hippoglossoides</i>			
<i>platessoides</i>) fillets			
Burbot	(0.010-0.100 mg/kg)	L. Huron	Environment Canada 1980
Egg yolk, double-	14.1 mg/kg lipid	Location not stated	Zitko 1972
crested cormorant			
(<i>Phalacrocorax auritus</i>)			
Egg yolk, herring	(10.9-19.1 mg/kg lipid)	Location not stated	Zitko 1972
gull (<i>Larus argentatus</i>)			

⁽¹⁾ Cited in Environment Canada 1992.

Table 4b. Concentrations of DBP in air, water, sediment, soil and biota in the non-Canadian, non-Great Lakes environment.

<u>Media</u>	<u>Concentration</u> mean (max. or range)	<u>Location</u>	<u>Reference</u>
Urban runoff	(<3.0-<6.0 µg/L)	Pima Co., Arizona	Wilson et al. 1990
Dry-well sediment	(ND-37 mg/kg)	Pima Co., Arizona	Wilson et al. 1990
Sewage treatment plant effluent	6.0 µg/L	Manchester, U.K.	Fatoki and Vernon 1990
Sewage treatment plant effluent	0.110 µg/L (0.055-0.250 µg/L)	Illinois, U.S.A.	Schacht 1974
Phthalate ester plant discharge	0.2 mg/kg	Maryland, U.S.A.	Peterson and Freeman 1984
pond sediment			
Sewage sludge	13 mg/kg	Oslo, Norway	Kveseth 1980
" "	(<1.0-3,210 mg/kg dw)	Non-Canadian sludges	Webber and Lesage 1989
Atmosphere	3.73 ng/m ³ (ND-4.90 ng/m ³)	Queens, New York	Bove et al. 1978
"	5.69 ng/m ³ (1.99-10.99 ng/m ³)	Brooklyn, New York	Bove et al. 1978
"	3.28 ng/m ³ (ND-7.38 ng/m ³)	Staten Island, New York	Bove et al. 1978
"	means 0.36-1.72 ng/m ³	Sterling Forest, New York	Bove et al. 1978
"	1.0 ng/m ³	North Atlantic	Atlas and Giam 1981
"	1.0 ng/m ³ (0.4-2.3 ng/m ³)	North Atlantic	Giam et al. 1978
"	(0.1-1.0 ng/m ³)	Barrow, Alaska	Weschler 1981
"	1.3 ng/m ³ (0.65-3.71 ng/m ³)	Gulf of Mexico	Giam et al. 1980
"	0.3 ng/m ³ (0.08-0.7 ng/m ³)	Gulf of Mexico	Giam et al. 1978
"	0.3 ng/m ³ (0.08-1.5 ng/m ³)	Gulf of Mexico	Chan 1975
"	0.87 ng/m ³ (0.40-1.80 ng/m ³)	Enewetak Atoll, north Pacific Ocean	Atlas and Giam 1981
"	3.8 ng/m ³	College Station, Texas	Atlas and Giam 1981
"	18.5 ng/m ³	Pigeon Key, Florida	Atlas and Giam 1981

"	(19-36 ng/m ³) (suspended particulates phase)	near La Paz, Bolivia	Cautreels et al. 1977
"	(55-74 ng/m ³) (suspended particulates phase)	Antwerp, Belgium	Cautreels et al. 1977
"	(24-47 ng/m ³) (suspended particulates phase)	Antwerp, Belgium	Cautreels et al. 1977
Rain water	0.031 µg/L (0.0026-0.0725 µg/L)	Enewetak Atoll, north Pacific Ocean	Atlas and Giam 1981
Surface water	(5.6 µg/L)	(Tama R., Japan), highest reported conc. in review	Pierce et al. 1980
"	"	(0.1-0.6 µg/L)	Delaware R., U.S.A. Sheldon and Hites 1979
"	"	(0.2-0.6 µg/L)	Delaware R., U.S.A., March Sheldon and Hites 1978
"	"	(0.1-0.4 µg/L)	Delaware R., U.S.A., August Sheldon and Hites 1978
"	"	0.014 µg/L	Mississippi R., U.S.A. Chan 1975
"	"	(12.1 - 33.5 µg/L)	Rivers, Manchester, U.K. Fatoki and Vernon 1990
"	"	(<0.1-2.8 µg/L)	Rhine R., Netherlands Schouten et al. 1979
"	"	(1.1-2.8 µg/L)	IJssel R., Netherlands Schouten et al. 1979
"	"	(<0.1-1.0 µg/L)	Meuse R., Netherlands Schouten et al. 1979
"	"	4.1 µg/L	Tamagawa R., Japan Ogura et al. 1975
"	"	1.39 µg/L (<0.1-4.3 µg/L)	River water, Shizuoka Prefecture, Japan Shibuya 1979
"	"	0.96 µg/L (<0.1-36 µg/L)	Japanese river water Shibuya 1979
Sea water	Non-detectable	North Atlantic	Giam et al. 1978
"	"	(0.070-0.230 ⁽¹⁾ µg/L)	Nueces Estuary, Texas Ray et al. 1983b
"	"	0.095 µg/L (0.0065-0.471 µg/L)	Mississippi delta, U.S.A. Giam et al. 1978
"	"	0.074 µg/L (0.0034-0.265 µg/L)	Gulf of Mexico, coast Giam et al. 1978
"	"	0.093 µg/L (0.003-0.133 µg/L)	Gulf of Mexico, open gulf Giam et al. 1978
"	"	0.087 µg/L (0.003-0.4713 µg/L)	Gulf of Mexico Chan 1975

"	"	(0.0588-0.203 $\mu\text{g/L}$)	Kiel Bight, Baltic Sea	Ehrhardt and Derenbach 1980
"	"	(3.8-24.1 $\mu\text{g/L}$)	Surface microlayer, Germany	Westernhagen et al. 1987
"	"	(0.0242-0.0582 $\mu\text{g/L}$)	Crouch Estuary, U.K.	Waldock 1983
"	"	(0.012-4.800 $\mu\text{g/L}$)	U.K. estuaries, etc.	Law et al. 1991
Ground water		(ND-80 $\mu\text{g/L}$)	Besós R. basin, Spain	Guardiola et al. 1989
"	"	<10 $\mu\text{g/L}$	Pima Co., Arizona	Wilson et al. 1990
Sediment		(16 mg/kg)	(Rhine R., Netherlands), highest reported conc. in review	Pierce et al. 1980
"		(0.028-0.900 mg/kg)	Chester R. system, Maryland, U.S.A.	Peterson and Freeman 1984
"		8 mg/kg	Usk R., U.K.	Eglinton et al. 1975
"		(0.073-0.210 mg/kg)	Rhine R., Germany	Malisch et al. 1981
"		(<0.5-15.5 mg/kg dw)	Rhine R., Netherlands	Schwartz et al. 1979
"		(0.090-0.300 mg/kg)	Neckar R., Germany	Malisch et al. 1981
"		(<0.5-7.5 mg/kg dw)	IJssel R., Netherlands	Schwartz et al. 1979
"		(<0.5-1.5 mg/kg dw)	Meuse R., Netherlands	Schwartz et al. 1979
"		(0.1-0.3 mg/kg dw)	Lake Constance	Giam and Atlas 1980
"		0.170 mg/kg dw (<0.01-0.96 mg/kg dw)	River sediments, Shizuoka Prefecture, Japan	Shibuya 1979
"		<0.01 mg/kg dw	Tagonoura, Japan	Shibuya 1979
"		0.08 mg/kg dw (<0.05-2.3 mg/kg dw)	Japanese river sediments	Shibuya 1979
Marine sediment		0.160 mg/kg (0.040-0.280 mg/kg)	Portland, Maine	Ray et al. 1983a
"	"	(0.0042-0.036 ⁽²⁾ mg/kg dw)	Nueces Estuary, Texas	Ray et al. 1983b
"	"	0.013 mg/kg (<0.0001-0.0521 mg/kg)	Mississippi delta, U.S.A.	Giam et al. 1978
"	"	0.016 mg/kg (0.0018-0.052 mg/kg)	Mississippi delta, U.S.A.	Chan 1975
"	"	0.0076 mg/kg (<0.0001-0.0153 mg/kg)	Gulf of Mexico, coast	Giam et al. 1978

"	"	0.0034 mg/kg (<0.0016- 0.0056 mg/kg)	Gulf of Mexico, open gulf	Giam et al. 1978
"	"	(0.018-0.355 mg/kg dw)	Los Angeles, California	Swartz et al. 1985
"	"	(0.0039-0.0145 mg/kg)	Crouch Estuary, U.K.	Waldock 1983
Marine biota		<0.0001 mg/kg	Gulf of Mexico	Giam et al. 1978
<i>Neanthes virens</i>		(0.070-0.180 mg/kg)	Portland, Maine	Ray et al. 1983a
Clams		(0.040-0.100 mg/kg)	Portland, Maine	Ray et al. 1983a
Molluscs		(0.0092 mg/kg, digestive gland of <i>Scrobicularia</i> <i>plana</i>)	Crouch Estuary, U.K.	Waldock 1983
Fish		(0.023 mg/kg, liver of <i>Limanda limanda</i>)	Crouch Estuary, U.K.	Waldock 1983

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- (1) Highest concentration in a sample taken from a tidal marsh.
(2) Highest concentration in a sample taken from near a residential area.

Table 5. Estimated Total Daily Exposure of a Piscivorous Mammal in Canadian Waters.

Exposure Route	Environmental Levels ^a	Mink Daily Requirements (per kg-bw) ^b	Daily Intake (µg/kg-bw/d)
Air	4.5 ng/m ³	0.55 m ³ /d	0.002
Surface water	4 µg/L ¹ 73 ng/L ²	0.1 L/d	0.4 ¹ 0.0073 ²
Biota (Fish)	8.5 µg/g ¹ 155 ng/g ²	155 g/d	1318 ¹ 24 ²
Total	-----	-----	1318 ¹ 24 ²

- a The level in air is the maximum level measured in the Great Lakes (Hoff and Chan 1987); the levels in surface water are ¹the maximum DBP level in Canadian waters (NAQUADAT, 1993) and ²the maximum concentration of DBP in water samples from Niagara-on-the-Lake, 1988-89 (Niagara River Data Interpretation Group, 1990); the level in fish is the level predicted in fish based on the maximum measured BCF of 2125 for the fathead minnow and the above water concentrations.
- b Inhalation rate from Stahl (1967); drinking rate from Calder and Braun (1983); and ingestion rate from Nagy (1987), assuming a diet of 75% fish.

Table 6a. Summary of Acute Toxicity Values of DBP.

Species	Study Type	End Point	Value	Reference
<u>Microorganisms</u>				
<i>Photobacterium</i>	AET, Puget Sound	15 min. (reduced luminescence)	1,400 µg/kg dw sediment	Tetra Tech Inc. 1986
<i>Photobacterium phosphoreum</i>	Microtox	5m EC50	10,900 µg/L	Tarkpea et al. 1986
<i>Photobacterium phosphoreum</i>	Microtox	15m EC50	11,100 µg/L	Tarkpea et al. 1986
<i>Photobacterium phosphoreum</i>	Microtox	30m EC50	10,900 µg/L	Tarkpea et al. 1986
<i>Tetrahymena pyriformis</i> (protozoa)	Acute, static	24h EC50 (cell proliferation)	2,200 µg/L	Yoshioka et al. 1985
<u>Algae/Plants</u>				
<i>Scenedesmus subspicatus</i>	Acute, static	48h EC10 (biomass)	1,400 µg/L	Kühn and Pattard 1990
<i>Scenedesmus subspicatus</i>	Acute, static	48h EC50 (biomass)	3,500 µg/L	Kühn and Pattard 1990
<i>Scenedesmus subspicatus</i>	Acute, static	48h EC10 (growth rate)	2,600 µg/L	Kühn and Pattard 1990
<i>Scenedesmus subspicatus</i>	Acute, static	48h EC50 (growth rate)	9,000 µg/L	Kühn and Pattard 1990
Algae	Acute, static	96h EC50	750 µg/L	CMA 1984
Dinoflagellate (<i>Gymnodinium breve</i>)	Acute, static	96h EC50 (TLM)	20-600 µg/L	Wilson et al. 1978
" "	Acute, static	96h EC50 (growth)	3.4-200 µg/L	Wilson et al. 1978

Invertebrates

<i>Daphnia magna</i>	Acute, static	48h LC50	5,200 µg/L	McCarthy and Whitmore 1985
" "	Acute, static	48h EC50	3,400 µg/L	CMA 1984
" "	Acute, static renewal	48h LC50	3,700 µg/L	Call et al. 1983
" "	Acute, static	24h EC50	17,000 µg/L	Kühn et al. 1989
" "	Acute, static	24h EC0	8,900 µg/L	Kühn et al. 1989
<i>Palaemonetes pugio</i>	Acute, static	96h LC0	1,000 µg/L	Clark et al. 1987
" "	Acute, static	96h LC50	>1,000 µg/L	Clark et al. 1987
" "	Acute, static	96h LC0	10 mg/kg	Clark et al. 1987
" "	Acute, static	96h LC50	>10 mg/kg	Clark et al. 1987
" "	Acute, static	10d LC0	10 mg/kg	Clark et al. 1987
" "	Acute, static	10d LC50	>10 mg/kg	Clark et al. 1987
Mysid shrimp (<i>Mysidopsis bahia</i>)	Acute, static	96h LC50	750 µg/L	EG&G Bionomics 1984a
Scud (<i>Gammarus pseudolimnaeus</i>)	Acute, static	24h LC50	7,000 µg/L	Mayer and Sanders 1973
Scud	Acute, static	96h LC50	2,100 µg/L	Mayer and Sanders 1973
Brine shrimp (<i>Artemia salina</i>)	Sublethal, static	72h NOEL	<10,000 µg/L	Sugawara 1974a, 1974b
" "	Acute, static	24h LC50	8,000 µg/L	Hudson et al. 1981
" "	Acute, static	24h LC50	5,600 µg/L	Hudson and Bagshaw 1978
Crayfish (<i>Orconectes nais</i>)	Acute, static	24h LC50	>10,000 µg/L	Mayer and Ellersieck 1986
" "	Acute, static	96h LC50	>10,000 µg/L	Mayer and Sanders 1973

Harpacticoid (<i>Nitocra spinipes</i>)	Acute, static	96h LC50	1,700 µg/L	Lindén et al. 1979
Midge larvae (<i>Chironomus plumosus</i>)	Acute, static	48h LC50	5,400 µg/L	Mayer and Ellersieck 1986
" "	Acute, static	48h LC50	4,000 µg/L	Mayer and Ellersieck 1986
" "	Acute, static	48h EC50 (immobilization)	760 µg/L	Streufert et al. 1980
Midge (<i>Paratanytarsus parthenogenica</i>)	Acute, static	48h EC50	5,800 µg/L	EG&G Bionomics 1984b ⁽¹⁾

Fish

Fathead minnow (<i>Pimephales promelas</i>)	Acute, static	24h LC50	3,300 µg/L	Mayer and Ellersieck 1986
" "	Acute, static	24h LC50	3,000 µg/L	EG&G Bionomics 1983a ⁽¹⁾
" "	Acute, flow-through	24h LC50	4,800 µg/L	Mayer and Ellersieck 1986
" "	Acute, flow-through	24h LC50	1,600 µg/L	EG&G Bionomics 1983b ⁽¹⁾
" "	Acute	48h LC50	1,490 µg/L	Mayer and Sanders 1973
" "	Acute, static	48h LC50	3,000 µg/L	EG&G Bionomics 1983a ⁽¹⁾
" "	Acute, flow-through	48h LC50	1,200 µg/L	EG&G Bionomics 1983b ⁽¹⁾
" "	Acute	96h LC50	1,300 µg/L	Mayer and Sanders 1973
" "	Acute, static	96h LC50	2,020 µg/L	McCarthy and Whitmore 1985
" "	Acute, static	96h LC50	1,300 µg/L	Mayer and Ellersieck 1986

"	"	Acute, static	96h LC50	3,000 µg/L	EG&G Bionomics 1983a ⁽¹⁾
"	"	Acute, flow-through	96h LC50	850 µg/L	DeFoe et al. 1990
"	"	Acute, flow-through	96h LC50	1,100 µg/L	DeFoe et al. 1990
"	"	Acute, flow-through	96h LC50	3,950 µg/L	Mayer and Ellersieck 1986
"	"	Acute, flow-through	96h LC50	920 µg/L	EG&G Bionomics 1983b ⁽¹⁾
"	"	Acute, flow-through	96h LOEL (embryo survival)	1,800 µg/L	McCarthy and Whitmore 1985
"	"	Acute, flow-through	96h NOEL (embryo survival)	1,000 µg/L	McCarthy and Whitmore 1985
Yellow perch (<i>Perca flavescens</i>)		Acute, flow-through	24h LC50	>1,240 µg/L	Mayer and Ellersieck 1986
"	"	Acute, flow-through	96h LC50	350 µg/L	Mayer and Ellersieck 1986
Bluegill (<i>Lepomis macrochirus</i>)		Acute, static	24h LC50	1,230 µg/L	Mayer and Sanders 1973
"	"	Acute, static	24h LC50	2,100 µg/L	Buccafusco et al. 1981
"	"	Acute, static	24h LC50	>3,000 µg/L	Mayer and Ellersieck 1986
"	"	Acute, static	24h LC50	1,000 µg/L	EG&G Bionomics 1983c ⁽¹⁾
"	"	Acute, static	48h LC50	1,200 µg/L	EG&G Bionomics 1983c ⁽¹⁾
"	"	Acute, static	96h LC50	1,200 µg/L	Buccafusco et al. 1981
"	"	Acute, static	96h LC50	730 µg/L	Mayer and Sanders 1973
"	"	Acute, static	96h LC50	2,100 µg/L @ pH 6.5	Mayer and Ellersieck 1986
"	"	Acute, static	96h LC50	1,580 µg/L @ pH 7.5	Mayer and Ellersieck 1986
"	"	Acute, static	96h LC50	2,050 µg/L @ pH 9.0	Mayer and Ellersieck 1986

"	"	Acute, static	96h LC50	850 µg/L	EG&G Bionomics 1983c ⁽¹⁾
"	"	Acute, flow-through	96h LC50	1,550 µg/L	Mayer and Ellersieck 1986
Channel catfish (<i>Ictalurus punctatus</i>)		Acute	24h LC50	3,720 µg/L	Mayer and Sanders 1973
"	"	Acute	96h LC50	2,910 µg/L	Mayer and Sanders 1973
"	"	Acute, flow-through	96h LC50	460 µg/L	Mayer and Ellersieck 1986
Rainbow trout (<i>Oncorhynchus mykiss</i>)		Acute, static	24h LC50	>16,000 µg/L	Mayer and Ellersieck 1986
"	"	Acute, static	24h LC50	2,800 µg/L	Mayer and Ellersieck 1986
"	"	Acute, flow-through	24h LC50	1,600 µg/L	EG&G Bionomics 1983d ⁽¹⁾
"	"	Acute, flow-through	24h LC50	4,200 µg/L	Mayer and Ellersieck 1986
"	"	Acute, flow-through	48h LC50	1,600 µg/L	EG&G Bionomics 1983d ⁽¹⁾
"	"	Acute, static	96h LC50	2,560 µg/L	Mayer and Ellersieck 1986
"	"	Acute, static	96h LC50	1,200 µg/L	Hrudey et al. 1976
"	"	Acute, static	96h LC50	6,470 µg/L	Mayer and Sanders 1973
"	"	Acute, flow-through	96h LC50	1,480 µg/L	Mayer and Ellersieck 1986
"	"	Acute, flow-through	96h LC50	1,600 µg/L	EG&G Bionomics 1983d ⁽¹⁾
"	"	Acute, flow-through	24h LC50 (yolk-sac fry)	>1,240 µg/L	Mayer and Ellersieck 1986
"	"	Acute, flow-through	96h LC50 (yolk-sac fry)	>1,240 µg/L	Mayer and Ellersieck 1986

Red killifish (<i>Orizias latipes</i>)	Acute, static	48h LC50	630 µg/L	Yoshioka et al. 1986
Sheepshead minnow (<i>Cyprinodon</i> <i>variegatus</i>)	Acute, flow- through	96h LC50	600 µg/L	CMA 1984

(1) Cited in Environment Canada 1992.

Table 6b. Summary of Chronic Toxicity Values of DBP.

Species	Study Type	End Point	Value	Reference
<u>Algae/Plants</u>				
<i>Selenastrum capricornutum</i>	Chronic, static	10d EC50 (dec. cell numbers)	750 µg/L	Springborn Bionomics 1984a ⁽¹⁾
" "	Chronic, static	7d NOEL (dec. biomass)	2,800 µg/L	Melin and Egnéus 1983
" "	Chronic, static	7d LOEL (dec. biomass)	28,000 µg/L	Melin and Egnéus 1983
<i>Synechococcus lividus</i>	Chronic	14d LOEL (inc. cell aggregation)	2.8 µg/L	Acey et al. 1987
<u>Invertebrates</u>				
Benthic community composition	Chronic, flow-through	14d LOEL (dec. no. amphipods)	340 µg/L	Tagatz et al. 1983
Planarian (<i>Dugesia japonica</i>)	Acute, static	7d EC50 (head regeneration)	540 µg/L	Yoshioka et al. 1986
<i>Dugesia japonica</i>	Acute, static	7d LC50	840 µg/L	Yoshioka et al. 1986
Oyster (<i>Crassostrea gigas</i>)	AET, Puget Sound	(increased abnormalities)	1,400 µg/kg dw sediment	Tetra Tech Inc. 1986
<i>Daphnia magna</i>	Chronic	NOEL	>960 µg/L	CMA 1984
" "	Chronic	LOEL	<2,500 µg/L	CMA 1984
" "	Chronic, static renewal	16d LOEL (survival and reproduction)	1,800 µg/L	McCarthy and Whitmore 1985
" "	Chronic, static renewal	16d NOEL (survival and reproduction)	560 µg/L	McCarthy and Whitmore 1985
" "	Chronic, static renewal	21d LC50	1,920 µg/L	DeFoe et al. 1990

"	"	Chronic, static	21d EC50	1,640 µg/L	DeFoe et al. 1990
		renewal	(reproduction)		
"	"	Chronic, static	21d NOEL	1,050 µg/L	DeFoe et al. 1990
		renewal	(reproduction)		
"	"	Chronic, static	21d NOEL	500 µg/L	Kühn et al. 1989
		renewal	(parent survival)		
"	"	Chronic, static	21d LOEL	2,500 µg/L	Springborn Bionomics
		renewal	(survival & reprod.)		1984b
<i>Palaemonetes pugio</i>		Chronic, static	10d LC0	10 mg/kg	Clark et al. 1987
			(sediment exposure)		
"	"	Chronic, static	10d LC50	>10 mg/kg	Clark et al. 1987
			(sediment exposure)		
"	"	Chronic, semi-static	28d LOEL	1,000 µg/L	Laughlin et al. 1978
			(survival)		
"	"	Chronic, semi-static	28d NOEL	500 µg/L	Laughlin et al. 1978
			(survival)		
Scud (<i>Gammarus pulex</i>)		Chronic, flow-through	10d LOEL	>500 µg/L	Thurén and Woin 1991
"	"	Chronic, flow-through	10d LOEL	500 µg/L	Thurén and Woin 1991
			(dec. locomotor activity)		
"	"	Chronic, flow-through	10d NOEL	100 µg/L	Thurén and Woin 1991
			(dec. locomotor activity)		
Midge (<i>Chironomus plumosus</i>)		Chronic, flow-through	30d LOEL	>560 µg/L	Streufert and Sanders 1977
Amphipod (<i>Rhepoxynius abronius</i>)		AET, Puget Sound	(increased mortality)	>5,100 µg/kg sediment	Tetra Tech Inc. 1986
<i>Rhepoxynius abronius</i>		AET, Puget Sound	(increased mortality)	1,400 µg/kg sediment	Barrick et al. 1988

Fish

Fathead minnow (<i>Pimephales promelas</i>)	Chronic, flow-through	20d EC100	1,800 µg/L	McCarthy and Whitmore 1985
		(embryo mortality)		

"	"	Chronic, flow-through	20d LOEL (hatching rate and larval survival)	1,000 µg/L	McCarthy and Whitmore 1985
"	"	Chronic, flow-through	20d NOEL (hatching rate and larval survival)	560 µg/L	McCarthy and Whitmore 1985
Rainbow trout (<i>Oncorhynchus mykiss</i>)		Chronic, flow-through	99d NOEL (growth)	100 µg/L	Ward and Boeri 1991
"	"	Chronic, flow-through	99d LOEL (growth)	190 µg/L	Ward and Boeri 1991
Cyprinodontiform fish (<i>Rivulus marmoratus</i>)		Chronic, static	147d 13% red. embryonic viability	2,000 µg/L	Davis 1988
"	"	Chronic, static	147d 155% inc. skeletal abnormal. progeny of exposed fish	1,000 µg/L	Davis 1988
"	"	Post-exposure	63d NOEL (reproduction)	1,000 µg/L	Davis 1988
"	"	Post-exposure	63d LOEL (reproduction)	2,000 µg/L	Davis 1988

(1) Cited in Environment Canada 1992.