

5. POTENTIAL FOR HUMAN EXPOSURE

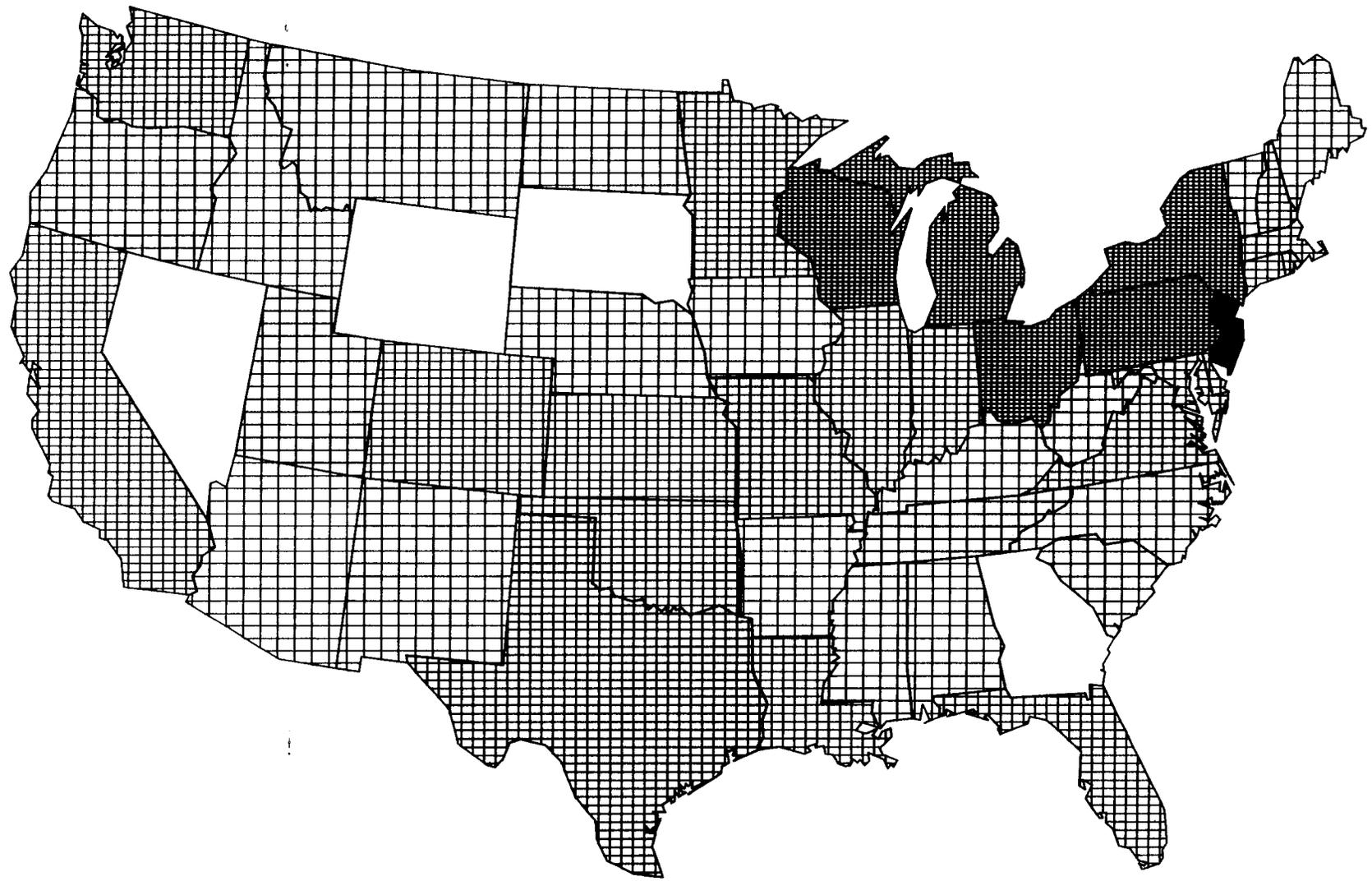
5.1 OVERVIEW

As a result of its use as a plasticizer for cellulose ester films and extruded materials and in a variety of consumer products, human exposure to diethyl phthalate is expected to be significant. Diethyl phthalate may be released to the environment as a result of manufacturing processes, disposal in landfills, incomplete incineration, or by leaching or volatilization from products in which it is used. Releases are expected to be primarily to water or to soil as a result of leaching from landfills. Diethyl phthalate may enter the atmosphere through combustion of plastics and, to a lesser degree, by volatilization. Diethyl phthalate partitions to particulate matter in water or sediments, where it can be biodegraded either aerobically or anaerobically; other degradation processes are not significant. From soils with low organic matter content, diethyl phthalate may enter the underlying groundwater. Diethyl phthalate may bioaccumulate to some degree in aquatic organisms, but it is unlikely to biomagnify up the food chain. Diethyl phthalate has been identified in 248 of the 1,397 NPL hazardous waste sites (HAZDAT 1994). The frequency of these sites within the United States can be seen in Figure 5-1. Of these sites, 241 are located in the United States, and 1 is located in Guam (not shown).

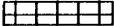
Diethyl phthalate is likely to undergo biodegradation in the environment. Abiotic degradation processes such as hydrolysis, oxidation, and photolysis are unlikely to play significant roles in the environmental fate of diethyl phthalate.

Diethyl phthalate has been detected in ambient indoor air, waste waters from industrial facilities, surface waters and sediments, and marine waters. Fish and other aquatic biota living in contaminated waters have been shown to contain diethyl phthalate in their tissues, although depuration is relatively rapid when the organisms are placed in uncontaminated water.

FIGURE 5-1. FREQUENCY OF NPL SITES WITH DIETHYL PHTHALATE CONTAMINATION *



5. POTENTIAL FOR HUMAN EXPOSURE

FREQUENCY  1 TO 2 SITES  3 TO 10 SITES
  13 TO 20 SITES  28 SITES

*Derived from HazDat 1994

5. POTENTIAL FOR HUMAN EXPOSURE

Human exposure to diethyl phthalate can result from breathing contaminated air, eating foods into which diethyl phthalate has leached from packaging materials, eating contaminated seafood, drinking contaminated water, or as a result of medical treatment involving the use of polyvinyl chloride tubing (e.g., dialysis patients). The use of diethyl phthalate in consumer products, however, is likely to be the primary source of human exposure. Diethyl phthalate has been detected in adipose tissue samples taken from people (including children) nationwide. Occupational exposure may occur in industrial facilities where diethyl phthalate is used in the manufacture of plastics or consumer products.

Diethyl phthalate is not included on the Toxics Release Inventory as a reportable chemical.

Releases to the environment occur primarily as a result of production and manufacturing of diethyl phthalate itself and also during use and disposal of products containing diethyl phthalate. Minor releases occur as a result of biosynthesis (Pierce et al. 1980). It has been estimated that 7,600 metric tons of diethyl phthalate are released annually to the environment (EPA 1981b).

5.2 RELEASES TO THE ENVIRONMENT

5.2.1 Air

Approximately 75% of the total environmental release of phthalate plasticizers from dump sites result from low-temperature burning, with subsequent vaporization. Diethyl phthalate may also be released directly to the atmosphere as a result of volatilization/evaporation from consumer items such as cosmetics and toiletries, insect repellents, and insecticides (Peakall 1975).

Based on 1977 production data, EPA (1981a) estimated that 200 metric tons of diethyl phthalate would be released annually to the air as a result of manufacturing, use, or disposal, and another 200 metric tons would be released annually as a result of incineration of diethyl phthalate materials.

5. POTENTIAL FOR HUMAN EXPOSURE

5.2.2 Water

Diethyl phthalate was detected in 4.96% of the groundwater samples and 1.42% of the surface water samples taken at NPL sites included in the Contract Laboratories Program Statistical Database (CLPSD) at mean concentrations of 12.50 and 12.10 $\mu\text{g/L}$, respectively, in the positive samples (CLPSD 1989). Note that the information used from the CLPSD includes data from NPL sites only.

It has been estimated that the phthalate esters released to the environment may be approximately 1% of the phthalate content of plastic materials in direct contact with water or other liquids (Peakall 1975).

EPA (1981b) estimated that 300 metric tons of diethyl phthalate would be released annually to surface water as a result of manufacturing, use, or disposal, based on 1977 production data.

5.2.3 Soil

Based on 1977 production data, EPA (1981b) estimated that 6,800 metric tons of diethyl phthalate would be released annually to the environment as a result of landfilling activities.

Diethyl phthalate has been detected in 4.26% of the soil samples taken from the NPL sites included in the CLPSD at a mean concentration of 39.06 $\mu\text{g/kg}$ in the positive samples (CLPSD 1989). Note that the information used from the CLPSD includes data from NPL sites only.

5.3 ENVIRONMENTAL FATE

5.3.1 Transport and Partitioning

Based on a log octanol water partition coefficient (K_{ow}) ranging from 1.40 (measured, 2.67 estimated; Veith et al. 1980) to 3.3 (Laane et al. 1987), diethyl phthalate is considered to be lipophilic and consequently may be taken up by lipids in aquatic organisms. However, diethyl phthalate may also be degraded by these organisms suggesting that it is unlikely to biomagnify up the food chain (EPA

5. POTENTIAL FOR HUMAN EXPOSURE

1979). The bioconcentration factor (BCF) for diethyl phthalate using the bluegill sunfish (*Lepomis macrochirus*) in a 21-day study was 117 ($\log \text{BCF} = 2.07$; mean water concentration of diethyl phthalate = $9.42 \mu\text{g/L}$), and the half-life in fish tissue was between 1 and 2 days (Barrows et al. 1980; Veith et al. 1980). A study of the uptake of diethyl phthalate through the gills of English sole (*Puophrys vetulus*) indicated that the uptake efficiency was inversely correlated with weight-specific ventilation volume and was not correlated with fish weight or with diethyl phthalate exposure concentration; the mean uptake was only 11.3% (Boese 1984).

Air

No studies were located on the transport and partitioning of diethyl phthalate in the atmosphere. Volatilization of diethyl phthalate is expected to be slow based on its low vapor pressure of 1.65×10^{-3} mmHg at 25°C (Howard et al. 1985). Diethyl phthalate may be removed from the atmosphere by wet or dry deposition (EPA 1989).

Water

A computer simulation of the transport of diethyl phthalate in four aquatic systems using the Exposure Analysis Modeling System (EXAMS) estimated that, based on a sediment/water partition coefficient (K_{oc}) of 4.5×10^2 , >90% of the diethyl phthalate would be distributed to the water column in a river, eutrophic lake, or oligotrophic lake ecosystem, with less than 10% found in bottom sediments. In a pond, 70% of diethyl phthalate would be in the water column with 30% found in the bottom sediment (Wolfe et al. 1980a).

Major transport-mechanisms for diethyl phthalate include sorption onto suspended particulates and biota and possibly the formation of complexes with humic substances in the water (EPA 1979). Based on a Henry's law constant of 7.8×10^{-7} atm m^3/mol , volatilization from water is not expected to be a significant removal process for diethyl phthalate (EPA 1989).

5. POTENTIAL FOR HUMAN EXPOSURE

Studies of phthalate esters in surface sediment samples of the River Mersey in England (Preston and Al-Omran 1989) showed that, in one sample, diethyl phthalate was enriched in the coarser sediment fractions with high lipid content (0.102 $\mu\text{g/g}$ dry weight, background 0.050 $\mu\text{g/g}$); however, in another sample, diethyl phthalate was more concentrated in the finer particle fraction (0.060 $\mu\text{g/g}$, background 0.013 $\mu\text{g/g}$). The greater presence of diethyl phthalate in the sediment with high lipid content suggests that hydrophobic adsorption can occur, although possible mechanisms were not discussed. A study of the presence of diethyl phthalate in waste water and sediments from Canadian coal mines found that diethyl phthalate added to distilled water over mine sediment would remain in the water column rather than partition onto the sediment (Atwater et al. 1990).

Diethyl phthalate adsorbs to suspended particles in marine waters, with the maximum adsorption occurring onto particles of 353-698 μm in size (Al-Omran and Preston 1987).

Soil

Diethyl phthalate is fairly mobile in soil, based on tests of the absorption of diethyl phthalate from double-distilled water onto composite soil (1.59% organic carbon); diethyl phthalate moved through the soil at half the rate of water (Russell and McDuffie 1987). In undisturbed soil columns, phthalate ester transport was determined by both physical and chemical nonequilibrium processes (Zurmuhl et al. 1991). In general, the chemical disequilibrium was greater in a soil with greater organic carbon content than in a low organic carbon-content soil. The investigators attributed this finding to the greater sorption capacity of the former soil type. The mobility of diethyl phthalate through the soil columns was greater than the mobility of the more lipophilic dibutyl, butyl benzyl, and di(2-ethylhexyl) phthalate esters.

The presence of diethyl phthalate in groundwater in Phoenix, Arizona, was studied using a rapid infiltration system. Diethyl phthalate, present in the sewage infiltrate at 0.231 $\mu\text{g/L}$, was reduced to 0.017 $\mu\text{g/L}$ or less (detected but too low to be quantified) in groundwater samples taken from a 60-foot well depth (Tomson et al. 1981). Further studies with this system showed that infiltrate basin water containing initial concentrations of diethyl phthalate of 10-20 $\mu\text{g/L}$ decreased by 75-95% after infiltration. Removal was greatest in water taken from deeper sampling wells (30 versus 18 feet). The

5. POTENTIAL FOR HUMAN EXPOSURE

ultimate rate of removal was independent of whether the basin water had been chlorinated or not. However, chlorination appeared to speed the removal of diethyl phthalate in the shallow well (Bouwer et al. 1984). The removal of diethyl phthalate from waste waters using soil as a sorption medium was not confirmed by Hutchins et al. (1983), who found that treatment of secondary effluents containing diethyl phthalate at 0.19 $\mu\text{g/L}$ by a rapid infiltration system in Fort Polk, Louisiana, resulted in the presence of diethyl phthalate in the associated groundwater at 0.26 $\mu\text{g/L}$. It was suggested that this may, in part, be due to the low concentration of diethyl phthalate, which underutilized the biodegradation capacity of the soil column. The removal of diethyl phthalate from waste water by absorption or biodegradation in the soil is dependent on the soil type and, in some cases, on its ability to be transported through soils to underlying groundwaters.

5.3.2 Transformation and Degradation

5.3.2.1 Air

Ultraviolet absorption spectra for diethyl phthalate suggest that, although there is a potential for photodegradation in the atmosphere, this is not a significant removal process (EPA 1989). Diethyl phthalate may exist in the atmosphere in vapor form and adsorb to airborne particulates. Diethyl phthalate reacts photochemically with hydroxyl radicals in the air with an estimated half-life of 22.2 hours (HSDB 1994).

5.3.2.2 Water

The use of a computer-simulated model for aquatic ecosystems (EXAMS) indicated that, compared with biodegradation, abiotic hydrolysis and photolysis are minor degradation processes for diethyl phthalate in most aquatic ecosystems. Only in an oligotrophic lake was photolysis a more significant degradation process than biodegradation for diethyl phthalate. In a river system with a detention time of 1 hour, diethyl phthalate would be virtually unchanged and would be lost only by export (Wolfe et al. 1980a). The hydrolysis half-life for diethyl phthalate in water at pH 7.0 and 30°C is estimated to be greater than 18 years (EPA 1979). The oxidative half-life for alkyl phthalates is estimated to exceed 3 years (EPA 1989). Lewis et al. (1984b) studied the degradation of diethyl phthalate in a

5. POTENTIAL FOR HUMAN EXPOSURE

simulated aquatic ecosystem consisting of microbial growth attached to submerged surfaces or suspended as mats or streamers in the water (*aufwuchs*). Diethyl phthalate did not adsorb to any aquatic surfaces (including autoclaved *aufwuchs*, sediment, and equipment surfaces). It was virtually untransformed by photolysis (<1%), and only 10 µg/L of 191 µg/L diethyl phthalate was lost by hydrolysis in 12 hours at a pH of 10. Degradation occurred as a result of bacterial transformation (95-99% of loss), which was dependent on the surface area colonized by the bacteria and unaffected by dissolved organic carbon, nitrogen, and phosphorus. However, as bacterial densities increased in the *aufwuchs*, the rate of transformation decreased, possibly as a result of the increased growth of bacteria that were unable to degrade diethyl phthalate (Lewis and Holm 1981). Further studies using laboratory microcosms and field-collected microbiota found that while diethyl phthalate was degraded in all of the laboratory studies, degradation occurred at only 2 of 10 field sites. The degradation rates were similar, however, for both ecosystems (Lewis et al. 1985). Diethyl phthalate was degraded in 3 hours by *Brevibacterium sp.* isolated from several lakes and rivers in Georgia. The rate of degradation was increased by the addition of spent fungal culture medium to the bacterial culture (Lewis et al. 1984a).

A phthalate ester-hydrolyzing enzyme purified from *Nocardia erythropolis*, a bacterium found in soils and waste waters, had relative enzyme activity using diethyl phthalate of 76.3% (relative to 100% enzyme activity for di-[2-ethylhexyl] phthalate). Diethyl phthalate was hydrolyzed to the free phthalic acid and alcohol. The phthalic acid would be metabolized by intradiol fission via protocatechuic acid to β-ketoadipic acid (Kurane 1986). The soil and waste-water bacterium *Pseudomonas acidovorans* was found to degrade diethyl phthalate with a half-life of 10.5 days at 30°C (initial concentration of 3,000 mg/kg) (Kurane et al. 1977). Karegoudar and Pujar (1984b, 1985) isolated two types of bacteria, *Micrococcus varians* and *Bacillus sphaericus*, from industrial waste water and sewage ponds. These bacteria were able to grow aerobically using diethyl phthalate as the sole carbon source. Diethyl phthalate is hydrolyzed by the bacterial enzymes to free phthalic acid via the intermediate monoester (Karegoudar and Pujar 1984a). Other bacteria found in sewage treatment facilities are also able to degrade diethyl phthalate (Gibbons and Alexander 1989).

5. POTENTIAL FOR HUMAN EXPOSURE

Aerobic degradation of diethyl phthalate by acclimated soil and activated sewage sludge microbes was studied by using carbon dioxide (CO₂) evolution. Primary biodegradation (loss of parent ester) of diethyl phthalate was greater than 99% with a lag phase of 2.3 days, and ultimate biodegradation (CO₂ evolution) was 95%. The half-life for the compound under these conditions was 2.21 days (Sugatt et al. 1984). Complete bacterial acclimation to graded concentrations (50 to 410 mg/L) of diethyl phthalate was found in an aerobic, activated sludge system (Tokuz 1991). More than 94% of diethyl phthalate, however, was biodegraded within 1.1 days using semicontinuous activated sludge treatment (O'Grady et al. 1985). Other studies of the aerobic biodegradation of diethyl phthalate indicated that using settled domestic waste water as the microbial inoculum in the static culture flask test and 5 or 10 mg/L of diethyl phthalate, degradation was complete within 1 week of incubation in the dark (Tabak et al. 1981). Diethyl phthalate was degraded by activated sludge with an estimated half-life of 10.5 minutes (Urushigawa and Yonezawa 1979). Investigators found virtually complete primary and ultimate biodegradation of diethyl phthalate using semi-continuous sludge and shake flask procedures, respectively (Monsanto Corporation 1983).

The degradation of diethyl phthalate by sewage sludge bacteria indicated that aerobic degradation is more rapid than anaerobic degradation; however, aerobic degradation is significantly reduced by low dissolved oxygen levels and low temperature. Under less-than-optimal aerobic conditions and anaerobic conditions, facultative bacteria will outcompete aerobic bacteria in degrading diethyl phthalate (Zhang and Reardon 1990).

All of the diethyl phthalate added to river water at 25 mg/L was degraded within 6 days, while after 14 days in relatively clean ocean water the degradation rate was between 14% and 20%, and in polluted ocean water the degradation rate was 68% (Hattori et al. 1975). Primary degradation using river die-away procedures was virtually complete (Monsanto Corporation 1983).

Diethyl phthalate was aerobically degraded by two of three marine bacteria isolated from waters near the Mississippi River delta region (Taylor et al. 1981).

More than 98% of diethyl phthalate was degraded (original concentration of 4 mg/L) in less than 8 days by anaerobic sewage sludge (Ziogou et al. 1989). Under anaerobic conditions, diethyl phthalate

5. POTENTIAL FOR HUMAN EXPOSURE

was degraded to CO₂ and methane (CH₄) (greater than 75% of theoretical CH₄ production) by a 10% sludge solution from a primary digester and partially degraded (30-75% of theoretical CH₄ production) by a 10% sludge solution from a secondary digester (Shelton and Tiedje 1984). Diethyl phthalate removal was greater than 90% within 1 week with undiluted sludge (Shelton et al. 1984).

In other studies of the anaerobic degradation of diethyl phthalate, municipal sewage sludge mixed with 20 mg/L of diethyl phthalate yielded between 33% and 55% of the theoretical methane production after 6 days of incubation. Higher concentrations of diethyl phthalate (100 and 200 mg/L) strongly inhibited methane production regardless of the length of the incubation period (O'Conner et al. 1989). The degradation of diethyl phthalate under anaerobic conditions appears to be, in part, dependent on the type of sewage sludge used. A comparison of anaerobic degradation using two municipal sludges showed that one did not mineralize diethyl phthalate after 8 weeks of incubation, whereas a second sludge showed 32% of theoretical methane production in 4 weeks (Horowitz et al. 1982).

5.3.2.3 Soil

Degradation of diethyl phthalate applied to soil at an initial concentration of 1 mg/kg was 4% at 24 hours, 11% at 48 hours, 40% at 72 hours, and 86% at 120 hours. Addition of landfill leachate to the soil significantly increased the degradation rate with all of the diethyl phthalate being degraded within 72 hours (Russell et al. 1985). The biodegradation rate of an aerobic microbial strain in batch fermentation and sandy soil column experiments was facilitated at 25°C (relative to 5°C or 15°C) and at dissolved oxygen concentrations of 0.85 to 8.5 mg/L (Reardon and Zhang 1992). The degradation kinetics of a facultative strain were inhibited by anaerobic conditions, unaffected by the dissolved oxygen level, and greater at 15°C than at 25°C under aerobic conditions. Differences in biodegradation kinetics were related to the tighter adsorption of the facultative strain.

A 2-year study of slow-rate land treatment using waste waters containing diethyl phthalate found that diethyl phthalate was relatively nonvolatile during spray application. Applied at a rate of 56 µg/L to sandy loam and silty loam soils, diethyl phthalate accumulated in the top 5 cm of sandy loam soils to concentrations of 1,000-6,700 ng/g and on the surface of the silty soil from below the detection limit (1 ng/g) to 2,200 ng/g dry soil. Diethyl phthalate was present in greater concentrations at greater

5. POTENTIAL FOR HUMAN EXPOSURE

depths in the sandy soil. Although diethyl phthalate was detectable in each soil type down to a depth of 150 cm, it was not detected to any significant degree in the percolate from either soil. Diethyl phthalate did not appear to volatilize from the soil during spray application of the waste water to the soil or thereafter (Parker and Jenkins 1986).

The soil fungus *Fusarium 2P3* was able to use diethyl phthalate as a growth substrate with growth being constant after 4 days of incubation (Klausmeier and Jones 1960).

5.4 LEVELS MONITORED OR ESTIMATED IN THE ENVIRONMENT

Analytical data regarding diethyl phthalate concentrations in environmental media must be interpreted with caution, because of the extensive contamination of laboratory glassware with these chemical agents (Lopez-Avila et al. 1990).

5.4.1 Air

Diethyl phthalate has been measured in the indoor air of a telephone switching office and in outdoor air in Newark, New Jersey, at concentrations ranging from 1.60 to 2.03 $\mu\text{g}/\text{m}^3$ and from 0.40 to 0.52 $\mu\text{g}/\text{m}^3$, respectively, during a 43-day sampling period (Shields and Weschler 1987).

5.4.2 Water

Diethyl phthalate was found in the finished drinking water of 6 of 10 U.S. cities at concentrations of 0.01 $\mu\text{g}/\text{L}$ (Seattle, Washington; Philadelphia, Pennsylvania; New York, New York), 0.04 $\mu\text{g}/\text{L}$ (Lawrence, Kansas), 0.1 $\mu\text{g}/\text{L}$ (Cincinnati, Ohio), and 1.0 $\mu\text{g}/\text{L}$ (Miami, Florida) (Keith et al. 1976). Diethyl phthalate was identified but not quantified in the Cincinnati drinking water by reverse osmosis (Kopfler et al. 1977). A survey of 39 public water wells identified diethyl phthalate at a maximum concentration of 4.6 $\mu\text{g}/\text{L}$ (EPA 1989).

5. POTENTIAL FOR HUMAN EXPOSURE

The Storage and Retrieval (STORET) database maintained by EPA contains over 80 million data points on water quality. Diethyl phthalate has been found at a median concentration of less than 10 µg/L in 9.9% of the industrial effluent samples and in 3.0% of the ambient water samples. It has also been detected in 10.0% of all sediment samples at a median concentration of less than 500 µg/kg dry weight and in 6.0% of aquatic biota samples at a median concentration of less than 2.500 mg/kg wet weight (Staples et al. 1985).

Water samples taken from Galveston Bay, Texas, contained diethyl phthalate, as well as other phthalate esters, at unspecified levels; they were among the most abundant pollutants found in the samples (Ray and Giam 1984). Surface water samples collected along the length of the Mississippi River contained diethyl phthalate in significant concentrations: 190 ng/L at Lake Itasca, Minnesota (the source of the Mississippi River); 84 ng/L 25 miles below the inflow of the Ohio River at Cairo, Illinois; 350 ng/L 20 miles below Memphis, Tennessee; and 63 ng/L in the industrial corridor in New Orleans, Louisiana (DeLeon et al. 1986). Diethyl phthalate concentrations ranged from less than 1 ng/L to 430 ng/L in subsurface water samples from North Sea estuaries that had been polluted by industrial waste (Law et al. 1991). Diethyl phthalate was also detected at 0.7 µg/L in ebb tide water of the Inner Harbor Navigation Canal of Lake Pontchartrain, Louisiana (McFall et al. 1985b).

Diethyl phthalate has been detected in the treated waste waters from various manufacturing facilities: textile manufacturing plants at 3.2 µg/L diethyl phthalate (Walsh et al, 1980); a tire manufacturing plant at 60 µg/L (Jungclaus et al. 1976); and pulp and paper manufacturers at 50 µg/L (Brownlee and Strachan 1977; Voss 1984). River water samples from the lower Tennessee River taken below the Calvert City, Kentucky, chemical complex were found to have 11.2 µg/L diethyl phthalate (Goodley and Gordon 1976). Diethyl phthalate was detected at 21 ng/L in tap water from the Kitakyushu area of Japan. Sources were considered to be domestic sewage and industrial waste (Akiyama et al. 1980). River water samples and sewage effluent collected in 1984 from the Rivers Irwell and Etherow near Manchester, England, contained 0.4-0.6 µg/L of diethyl phthalate (Fatoki and Vernon 1990). Cooling water discharges from electric generating plants along the California coast contained diethyl phthalate in both chlorinated effluents (0.10 µg/L) and unchlorinated effluents (0.01 µg/L). Ocean samples taken 1 km from the discharge site contained 0.06 µg/L of diethyl phthalate (Grove et al. 1985). The

5. POTENTIAL FOR HUMAN EXPOSURE

Nationwide Urban Runoff Program, conducted in 1982, detected diethyl phthalate in 4% (3 locations) of 86 samples at concentrations of 0.5-1.0 $\mu\text{g/L}$ (Cole et al. 1984).

Diethyl phthalate was found in 28 of 47 waste-water samples taken from a Canadian coal mine with 6 of the positive samples having concentrations exceeding 10 $\mu\text{g/L}$. Diethyl phthalate was also found in sediments associated with the mine at concentrations of between 5 and 30 $\mu\text{g/g}$ (Atwater et al. 1990).

Diethyl phthalate has been detected in sediment samples taken from the Chesapeake Bay at concentrations ranging from 11 to 42 $\mu\text{g/kg}$. A sediment sample taken from the Chester River (which flows into the Chesapeake Bay) contained 26 $\mu\text{g/kg}$, and a sediment sample from a waste-water holding pond adjacent to a plasticizer manufacturing plant outfall near the river had less than 100 $\mu\text{g/kg}$ (Peterson and Freeman 1982a). Further investigation of the Chester River to determine if a plasticizer manufacturing plant was responsible for elevating concentrations of phthalate esters in the river showed that although diethyl phthalate concentrations ranged from 11 to 44 $\mu\text{g/kg}$, concentrations could not be correlated with intentional or unintentional discharges from the plant (Peterson and Freeman 1984).

Sediment samples taken from tributaries of the Susquehanna River ranged from just above background to 35 $\mu\text{g/kg}$ diethyl phthalate (Russell and McDuffie 1983). Diethyl phthalate has also been detected in sediment from the San Luis Pass in Galveston Bay, Texas, at an average concentration of 5 $\mu\text{g/kg}$ dry weight (Murray et al. 1981). Sediment samples from the Inner Harbor Navigation Canal and Chef Menteur tributary to Lake Pontchartrain, Louisiana, contained diethyl phthalate at concentrations of 25 $\mu\text{g/kg}$ and 65 $\mu\text{g/kg}$ dry weight, respectively (McFall et al. 1985a).

Sediment core samples taken from the Chesapeake Bay below Baltimore Harbor, Maryland, contained diethyl phthalate at levels that reflected increasing water concentrations as a result of industrial production of phthalates. The sample taken closest to Baltimore had diethyl phthalate concentrations of 19 $\mu\text{g/kg}$ at a core depth corresponding to the years 1923-1929. These levels remained relatively constant until 1963-1968, when the diethyl phthalate level jumped to 35 $\mu\text{g/kg}$; diethyl phthalate was detected at the surface core level of 42 $\mu\text{g/kg}$ from 1974-1979. A core sample taken further down

5. POTENTIAL FOR HUMAN EXPOSURE

the bay at a core depth corresponding to the years 1884-1892 (110-120 cm in depth) had a diethyl phthalate concentration of 3.1 $\mu\text{g}/\text{kg}$. Sediment concentrations increased chronologically until they reached a maximum of 22 $\mu\text{g}/\text{kg}$ for the period 1972-1979. Production volumes were correlated ($R=0.83$) for both the sediment nearest Baltimore and for the more distant sample ($R=0.60$) (Peterson and Freeman 1982b).

Diethyl phthalate levels in water from the Rhine River in the Netherlands ranged from less than 0.15 to approximately 0.45 $\mu\text{g}/\text{L}$ over a 12-day period; on days 7 through 11, diethyl phthalate concentrations in suspended particulate matter from the river stayed relatively constant at 0.1 mg/kg . Water samples and suspended particulate matter from Lake Yssel, also in the Netherlands, contained diethyl phthalate at 0.02-0.08 $\mu\text{g}/\text{L}$ and <0.1-0.8 mg/kg , respectively (Ritsema et al. 1989). River water samples and sewage effluent collected in 1984 from the Rivers Irwell and Etherow near Manchester, England, contained 0.4-0.6 $\mu\text{g}/\text{L}$ of diethyl phthalate (Fatoki and Vernon 1990).

5.4.3 Soil

No studies were located on the levels of diethyl phthalate found in soil.

5.4.4 Other Environmental Media

Fish collected from Great Lakes tributaries in Wisconsin and Ohio during 1981 had diethyl phthalate in all tissue samples at concentrations of less than 0.02 mg/kg to less than 0.30 mg/kg (DeVault 1985). Lake trout (*Salvelinus namaycush*) and whitefish (*Coregonus culpeaforms*) taken from Lake Superior near Isle Royale, Michigan had elevated levels of diethyl phthalate (0.5 and 2.2 $\mu\text{g}/\text{g}$, respectively) compared with lake trout and whitefish taken from other parts of Lake Superior (both values below the level of quantification of 0.001 $\mu\text{g}/\text{g}$ wet weight). Fish taken from Siskiwit Lake on Isle Royale, Michigan, a pristine area supposedly unaffected by human activity, also had relatively high concentrations of diethyl phthalate in their tissue, 0.4 $\mu\text{g}/\text{g}$ for lake trout and 1.7 $\mu\text{g}/\text{g}$ for whitefish (Swain 1978). Diethyl phthalate was detected but not quantified in whole fish taken from 13 Lake Michigan tributaries and Grand Traverse Bay in Michigan (Camanzo et al. 1983).

5. POTENTIAL FOR HUMAN EXPOSURE

Oysters collected from the Inner Harbor Navigation Canal and clams from the Chef Menteur and Rigolets tributaries to Lake Pontchartrain, Louisiana, contained 1,100 µg/kg, 450 µg/kg, and 340 µg/kg wet weight diethyl phthalate, respectively (McFall et al. 1985a).

5.5 GENERAL POPULATION AND OCCUPATIONAL EXPOSURE

The Total Exposure Assessment Methodology (TEAM) study conducted by EPA using nine New Jersey residents monitored the subjects' exposure to volatile chemicals. Diethyl phthalate was detected in 1 of 8 ambient air samples, 2 of 12 exhaled breath samples, and in 1 of 1 drinking water sample; there was no indication of whether any of the monitoring or breath samples were from volunteers considered to be occupationally exposed nor were the diethyl phthalate concentrations quantified (Wallace et al. 1984).

Based on an average concentration of diethyl phthalate in Toronto, Canada, drinking water of 0.0107 µg/L, the mean human drinking water exposure for the years 1978–1984 was estimated to be 0.0058 mg/year assuming an average consumption of 1.5 L water/day (Davies 1990).

Baked foods packaged in cardboard boxes with cellulose acetate windows (containing 16–17% weight to weight [w/w] diethyl phthalate) had diethyl phthalate concentrations of 1.7–4.5 mg/kg. It was suggested that diethyl phthalate may volatilize from the plastic window to the food without direct contact or be adsorbed in condensate on the window, which would then fall back onto the food (Castle et al. 1988). Diethyl phthalate was quantified from food at concentrations of 0–0.51 mg/kg (Giam and Wong 1987). Based on the levels of diethyl phthalate found in food by Castle et al. (1988), Kamrin and Mayor (1991) estimated a total daily dietary exposure to diethyl phthalate of 4 mg based on a daily ingestion of 1 kg of cellulose-acetate wrapped food containing 4 mg/kg diethyl phthalate. Diethyl phthalate was not detected in the aqueous leachate of solid foam polystyrene (Wu 1991).

Diethyl phthalate is listed as an ingredient in 67 cosmetic formulations at concentrations ranging from ≤0.1% to 50%, although most products contain less than 1% diethyl phthalate. The products may be applied to skin, eyes, hair, and nails, and they may come in contact with mucous membranes and the respiratory tract; contact may be frequent (several times a day) and of prolonged duration (years).

5. POTENTIAL FOR HUMAN EXPOSURE

Diethyl phthalate is also approved for use as a component of food-manufacturing equipment and packaging at unlimited concentrations (Anonymous 1985) and in drug product containers (Kamrin and Mayor 1991).

Diethyl phthalate was detected in 42% of the human adipose tissue samples taken from children and adults (cadavers and surgical patients) in the various regions of the United States during 1982 (see table below). Concentrations ranged from below the level of detection (0.20 µg/sample) to a maximum of 0.65 µg/g wet tissue weight (EPA 1986a).

Diethyl Phthalate in Human Adipose Tissue

U.S. region	Age (years)*		
	0-14	15-44	≥45
New England	+	+	+
Middle Atlantic	-+	+-	-
East north central	-+	-+-	-+-
West north central	-	+	++
South Atlantic	--	-++-	-+-
East south central	+	+	-
West south central	+	+-	-
Mountain	-	-	+
Pacific	-	-	-

* The number of symbols for each age group indicates the number of composite samples analyzed.

+ = diethyl phthalate detected in sample at trace or quantifiable level
 - = diethyl phthalate not detected

An air sampling survey of three rubber products manufacturing plants in Italy found that diethyl phthalate, although not used as an actual product in any of the processes, was present in the workplace air at all three facilities at concentrations of 0-120 µg/m³ at a shoe-sole factory; 0-30 µg/m³ in the vulcanization area of a tire-retreading factory; 0-1 µg/m³ in the extrusion area of the retreading

5. POTENTIAL FOR HUMAN EXPOSURE

factory; and 1-3 $\mu\text{g}/\text{m}^3$ in the extrusion area of an electrical cables insulation plant (Cocheo et al. 1983).

The National Occupational Exposure Survey, conducted between 1981 and 1983, estimated that 239,149 workers (including 108,580 women) in 16,408 facilities were exposed to diethyl phthalate in the workplace in 1980 with employees in the personal services (hairdressers, cosmetologists) and health services industries having the greatest potential exposure (NOES 1990). The American Conference of Governmental Industrial Hygienists has established an 8-hour time-weighted average threshold limit value of 5 mg/m³ for diethyl phthalate (ACGIH 1990).

5.6 POPULATIONS WITH POTENTIALLY HIGH EXPOSURES

People receiving medical treatments that involve the use of polyvinyl chloride tubing may be exposed to diethyl phthalate as a result of its leaching from the tubing. Diethyl phthalate was found to be leached from polyvinyl chloride dialysis tubing containing aqueous electrolyte solution, human blood, or bovine plasma perfusates. The tubing was perfused with the aqueous electrolyte solution for 22-96 hours, resulting in a level of diethyl phthalate ranging from 18 to 26 mg/L as determined by ultraviolet spectrometry. Even with only 1 hour of perfusion, diethyl phthalate levels reached 20 mg/L although the levels dropped with extended perfusion time. When the tubing was perfused with either human blood or bovine plasma for 8 hours, infrared spectrometry showed diethyl phthalate levels 2-4 times greater than with water, suggesting that diethyl phthalate has greater solubility in lipid-containing fluids than in inorganic solutions (Christensen et al. 1976).

5.7 ADEQUACY OF THE DATABASE

Section 104(i)(5) of CERCLA, as amended, directs the Administrator of ATSDR (in consultation with the Administrator of EPA and agencies and programs of the Public Health Service) to assess whether adequate information on the health effects of diethyl phthalate is available. Where adequate information is not available, ATSDR, in conjunction with NTP, is required to assure the initiation of a program of research designed to determine the health effects (and techniques for developing methods to determine such health effects) of diethyl phthalate.

5. POTENTIAL FOR HUMAN EXPOSURE

The following categories of possible data needs have been identified by a joint team of scientists from ATSDR, NTP, and EPA. They are defined as substance-specific informational needs that, if met, would reduce or eliminate the uncertainties of human health assessment. This definition should not be interpreted to mean that all data needs discussed in this section must be filled. In the future, the identified data needs will be evaluated and prioritized, and a substance-specific research agenda may be proposed.

5.7.1 Identification of Data Needs

Physical and Chemical Properties. The physical and chemical properties of diethyl phthalate are sufficiently well defined to allow assessments of the environmental fate of diethyl phthalate to be made. Therefore, no additional information is needed at this time.

Production, Import/Export, Use, and Release and Disposal. Production, import, use, and release of diethyl phthalate are thoroughly described in the literature. There are no available data reporting U.S. export volumes of diethyl phthalate. The data indicate that the potential for human exposure is considerable and is most likely to occur from inhalation of contaminated air or ingestion of contaminated drinking water or foods. The two methods of disposal mentioned in the literature are landfill and incineration (HSDB 1994). More information on the amounts of diethyl phthalate disposed of by each means and the efficiency of each method would be helpful in estimating potential exposure.

According to the Emergency Planning and Community Right-to-Know Act of 1986, 42 U.S.C. Section 11023, industries are required to submit chemical release and off-site transfer information to the EPA. The Toxics Release Inventory (TRI), which contains this information for 1988, became available in May of 1990. This database will be updated yearly and should provide a list of industrial production facilities and emissions. However, diethyl phthalate is not currently included in the Toxics Release Inventory as a reportable chemical.

5. POTENTIAL FOR HUMAN EXPOSURE

Environmental Fate. Diethyl phthalate released to air, water, or soil partitions to sediment or is adsorbed to organic matter in water (EPA 1979, 1989; Tomson et al. 1981; Wolfe et al. 1980a). In soils with low organic content, diethyl phthalate may be relatively mobile and consequently may percolate down to groundwater (Russell and McDuffie 1986). Diethyl phthalate is aerobically biodegraded in soils and with sewage sludge (O'Grady et al. 1985; Sugatt et al. 1984; Tabak et al. 1981; Urishigawa and Yonezawa 1979). It is also biodegraded under anaerobic conditions but at a slower rate (Zhang and Reardon 1990). Up to 75% of the total releases of diethyl phthalate potentially result from low-temperature burning at hazardous disposal sites (HSDB 1994). Volatilization will be slow because of low vapor pressure. Vapors will react with photochemically generated hydroxyl radicals, with an estimated half-life of 22.2 hours at 25°C (HSDB 1994). Further information is needed on the volatilization of diethyl phthalate from plastic and other products and its subsequent transformation in air. This information would be useful in identifying the most important pathways of human exposure to diethyl phthalate.

Bioavailability from Environmental Media. The limited toxicity data available in animals provide indirect evidence that uptake of diethyl phthalate occurs following ingestion (Brown et al. 1978; Lamb et al. 1987; Smyth and Smyth 1962). Additional information is needed on the absorption of diethyl phthalate as a result of inhalation of contaminated air.

Food Chain Bioaccumulation. Diethyl phthalate has been detected in aquatic organisms and has been found to bioconcentrate modestly in these organisms (Camanzo et al. 1983; DeVault 1985; McFall et al. 1985a). The database is, however, too limited to determine a representative range of bioaccumulation potential throughout the food chain. Further data on the accumulation potential for diethyl phthalate, including biomagnification in terrestrial and aquatic food chains, does not seem necessary.

Exposure Levels in Environmental Media. Diethyl phthalate has been detected in ambient and workplace air (Shields and Weschler 1987), drinking water (EPA 1989; Keith et al. 1976; Kopfler et al. 1977), surface waters (Fatoki and Vernon 1990; Ray and Giam 1984; *Staples et al.* 1985), sediments (Staples et al. 1985), and food (Castle et al. 1988; Giam and Wong 1987); however, limited

5. POTENTIAL FOR HUMAN EXPOSURE

current monitoring data were found. Diethyl phthalate has been detected in the surface waters, groundwater, and soil samples taken at a limited number of NPL sites. Additional information on the concentrations of diethyl phthalate in hazardous waste-site media is needed. This information will be helpful in identifying the most important exposure pathways for populations living near these sites.

Exposure Levels in Humans. Detection of diethyl phthalate in human semen, tissue, and fat has been used as an indicator of exposure to diethyl phthalate (Giam and Chan 1976; Van Lierop and Van Veen 1988; Waliszewski and Szymczynski 1990). Because diethyl phthalate is readily absorbed from the gastrointestinal tract, additional information on the concentration of diethyl phthalate in biological tissue and fluids of populations living in the vicinity of NPL sites would be helpful in assessing the extent to which these populations have been exposed to diethyl phthalate.

Exposure Registries. No exposure registries for diethyl phthalate were located. This substance is not currently one of the compounds for which a subregistry has been established in the National Exposure Registry. The substance will be considered in the future when chemical selection is made for subregistries to be established. The information that is amassed in the National Exposure Registry facilitates the epidemiological research needed to assess adverse health outcomes that may be related to the exposure to this substance.

5.7.2 On-going Studies

Remedial investigations and feasibility studies currently being conducted at the NPL sites contaminated with diethyl phthalate will add to the database on exposure levels in environmental media and in humans and will contribute information for exposure registries. Investigations at these sites will also increase the current knowledge regarding the transport and transformation of diethyl phthalate at hazardous waste sites. No other long-term research studies regarding the environmental fate and transport of diethyl phthalate or the occupational and general population exposure to this compound were identified.