

5. POTENTIAL FOR HUMAN EXPOSURE

5.1 OVERVIEW

Human exposure to nitrobenzene results from releases to air and wastewater from industrial sources and from nitrobenzene as an air pollutant in ambient air, especially in urban areas. Its low volatility and weak sorption on soil suggest that surface waters and groundwater could be a route of exposure for the general population. Exposure is mitigated by environmental degradation, including photolysis and microbial biodegradation. Nitrobenzene is poorly bioaccumulated and not biomagnified through the food chain. A number of fairly stable degradation products of nitrobenzene are formed during environmental degradation; some have similar effects, while others operate by different mechanisms. Moreover, whether or not nitrobenzene will be completely broken down (mineralized) at a particular site seems to be questionable. Nitrobenzene may not be degraded in a given sewage treatment plant, and, when present at high concentrations, it also may inhibit the biodegradation of other wastes.

Occupational exposure is of great concern, since nitrobenzene can be taken up very readily through the skin as well as by inhalation. Monitoring studies reveal low and highly variable exposures through air and, more rarely, drinking water, with a generally downward trend in exposure levels over the past two decades. At this time, nitrobenzene has been found in 7 of the 1,177 NPL hazardous waste sites in the United States (VIEW 1989). The frequency of these sites within the United States can be seen in Figure 5-1.

Because of the relative ease of measurement of many of nitrobenzene's properties and its ready detectability by both chemical analysis and human olfaction (sense of smell), its release, transport and fate, and the consequent exposure of human beings have been studied over a considerable period of time. Thus, the potential for human exposure to nitrobenzene is better understood than that of many other chemicals.

5.2 RELEASES TO THE ENVIRONMENT

Most (97% to 98%) of the nitrobenzene produced is retained in closed systems for use in synthesizing aniline and other substituted nitrobenzenes and anilines (Dorigan and Hushon 1976; Chemical Marketing Reporter 1987). Most of these products go into the manufacture of various plastic monomers and polymers (50%) and rubber chemicals (27%); a smaller proportion goes into synthesis of hydroquinones (5%), dyes and intermediates (6%), drugs (3%), and pesticides and other specialty items (9%) (Dunlap 1981). A small fraction of the production is used directly in other processes or in consumer products (principally metal and shoe polishes).

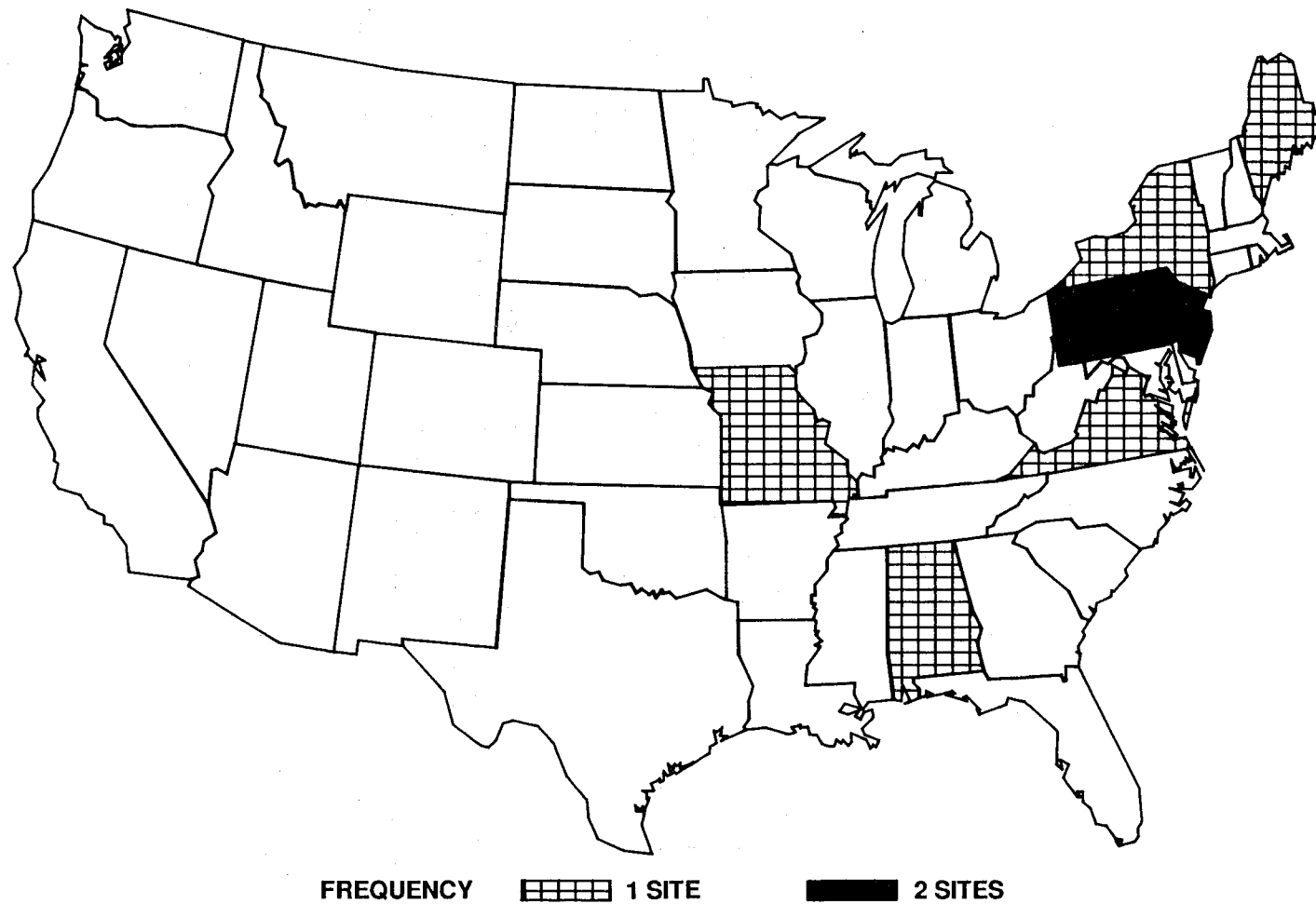


FIGURE 5-1. Frequency of Sites with Nitrobenzene Contamination

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The nitration of benzene in air leads to variable ambient levels in urban areas, making the assessment of releases to the air from waste sites difficult. Nevertheless, limited studies of municipal waste disposal facilities and the more complete evaluation of hazardous waste sites have found nitrobenzene infrequently present and, when present, concentrations have been generally low.

5.2.1 Air

Direct release of nitrobenzene to air during its manufacture is minimized by the passage of contaminated air through activated charcoal (EPA 1980a), and its subsequent use in closed systems as an intermediate similarly limits direct exposure during industrial processing. Nevertheless, as much as 8.3 million lbs/yr may be released from industrial processes (Dorigan and Hushon 1976). The fraction of these manufacturing losses to air is not known.

Use of nitrobenzene as a chemical intermediate or in consumer products such as metal and shoe polishes could contribute to losses via fugitive emissions, wastewater, spills, and end product usage. The extent to which these sources contribute to human exposure has not been evaluated quantitatively.

The third principal source of nitrobenzene is the atmospheric photo-chemical reaction of nitrogen oxides with benzene, which presumably is derived from automobile fuels and, to a lesser extent, solvent uses of benzene (Dorigan and Hushon 1976). As benzene releases decline, this source (not quantified) should diminish as well. The contribution of this source is difficult to estimate since most measurements of ambient atmospheric nitrobenzene have been made in urban areas near sites of nitrobenzene manufacture, use, and disposal (see Section 5.4.1). Seasonal variations and those associated with air pollution episodes suggest that this source, although limited, may form a significant proportion of nonoccupational human exposure.

5.2.2 Water

The effluent discharge produced during nitrobenzene manufacture is the principal source of nitrobenzene release to water. Losses to wastewater have been observed to be 0.09% of production in one plant and 2.0% in another (Dorigan and Hushon 1976).

The nitrobenzene in wastewater may be lost to the air, degraded by sewage organisms or, rarely, carried through to finished water. The EPA has surveyed nitrobenzene levels reported in effluents from 4,000 publicly-owned treatment works (POTWs) and industrial sites. The highest value in effluent was >100 ppm in the organic and plastics

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industry (Shackelford et al. 1983). Nitrobenzene was detected in one of 33 industrial effluents at a concentration greater than 100 µg/L (Perry et al. 1979). Reported nitrobenzene concentrations in raw and treated industrial wastewaters from several industries range from 1.4 to 91,000 µg/L (EPA 1983a). The highest concentrations are associated with wastewaters from the organic chemicals and plastics industries.

Nitrobenzene was reported at above detectable levels in 1.8% of the 1,245 reporting industrial stations (Staples et al. 1985) and in the finished effluent of only 3 of the POTWs and one oil refinery (Ellis et al. 1982). In analysis of runoff samples from 51 catchments in 19 cities, the National Urban Runoff Program found no nitrobenzene (Cole et al. 1984).

These results suggest that commercial and industrial users of nitrobenzene are dispersed throughout the country, so that concern regarding sources must extend beyond those four states in which nitrobenzene is manufactured.

Although nitrobenzene is sparingly soluble in water [1,900 ppm at 20°C (Verschueren 1983); 2,090 ppm at 25°C (Banerjee et al. 1980)], its pungent, characteristic odor ["bitter almonds," (Windholz 1983); "shoe polish," (Ruth 1986)] is detectable at water concentrations as low as 30 ppb (EPA 1980a). Hence, human exposures to large releases or accumulations in the environment appear unlikely to escape unnoticed. Nitrobenzene was detected in groundwater at 3 of 862 hazardous waste sites at a geometric mean concentration of 1,400 µg/L according to the Contract Laboratory Program (CLP) Statistical Database (CLPSD 1988). Nitrobenzene was not detected in any surface water samples from the 862 sites.

5.2.3 Soil

As a source of nitrobenzene exposure of humans, soil appears to rank a distant third in terms of its contribution. Nelson and Hites (1980) reported 8 ppm in the soil of a former dye manufacturing site along the Buffalo River, but failed to detect nitrobenzene in river sediments, as noted above. The presence of nitrobenzene in the soils of abandoned hazardous waste sites is inferred by its presence in the atmosphere above several sites (Harkov et al. 1985; LaRegina et al. 1986). Nitrobenzene was detected in soil/sediment samples at 4 of 862 hazardous waste sites at a geometric mean concentration of 1,000 µg/kg (CLPSD 1988). No further data on nitrobenzene levels released to soils were located.

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5.3 ENVIRONMENTAL FATE

Nitrobenzene has been scored in the Pre-Biologic Screen (PBS) (Gillett 1983) which estimates the environmental fate of neutral, unionized organic chemicals and the implications for ecotoxic and, to a lesser extent, health effects. Based on a three-dimensional matrix [for which the components are P ($\log K_{ow}$), H_c (log of dimensionless Henry's law constant), and $t_{1/2}$ (log biodegradation half-life)], the PBS scores a candidate chemical in each of the four following categories: A) bioaccumulation and multi-species/multi-media effects; B) bioaccumulation and chronic action; C) chronic action in the water column, including plant uptake and soil leaching; and D) indirect atmospheric action, including inhalation and plant fumigation. For nitrobenzene, the values in the PBS are $P = 1.83$ (Banerjee et al. 1980) and $H_c = -3.02$ (Hine and Mookerjee 1975). These values correspond well with observations that nitrobenzene is not bioaccumulated, does not accumulate in soils and sediments, can be taken up by plants, has been reported in groundwater, and has not been associated with either direct or indirect effects in the atmosphere. Half-life values for nitrobenzene indicate that it can be readily biodegraded aerobically in 7 days ($t_{1/2} = 0.06$) (Tabak et al. 1981); it is degraded anaerobically in 22 days ($t_{1/2} = 1.34$) (Hallas and Alexander 1983); and at high concentrations in water is resistant to biodegradation ($t_{1/2} = > 2$) (Korte and Klein 1982).

5.3.1 Transport and Partitioning

The movement of nitrobenzene in soil, water and air is predicted by its physical properties: (1) water solubility (1,900 ppm) (Verschuere 1983); (2) moderate volatility (0.15 mmHg at 20°C) (Mabey et al. 1982); (3) low octanol-water partition coefficient ($\log K_{ow} = 1.84$) (Geyer et al. 1984); and (4) soil/sediment sorption coefficient ($K_{sed} = 36$) (Mabey et al. 1982), ($K_{om} = 50.1$) (Briggs 1981). The dimensionless Henry's law constant for nitrobenzene (9.6×10^{-4}) suggests that transfer from water to air will be significant, but not rapid (EPA 1985a; Lyman et al. 1982). Sediment sorption and bioconcentration into aquatic and terrestrial animals are not likely to be significant (EPA 1985a). Plant uptake might be expected in terrestrial systems (McFarlane et al. 1987a, 1987b). Leaching through soil may occur.

Vapor densities reported for nitrobenzene relative to air range from 4.1 to 4.25 (Anderson 1983; Beard and Noe 1981; Dorigan and Hushon 1976; Dunlap 1981). Removal processes of nitrobenzene in air may involve settling of vapor due to its higher density relative to air (Dorigan and Hushon 1976). Washout by rainfall (either through solution in rain drops or by removal of nitrobenzene sorbed onto particulates)

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and dry fall of particulates are negligible, as estimated by Cupitt (1980) and expressly measured in field releases (Dana et al. 1984). Atmospheric residence time was estimated to be 190 days (Cupitt 1980).

Briggs (1981) compared the soil sorption coefficient (K_d) expressed in terms of organic matter (K_{om}), where $K_{om} = 100 \times K_d / (\% \text{ organic matter})$, for a wide variety of chemicals and soils to the octanol-water partition coefficient K_{ow} . Briggs (1973) classified soil mobility using $\log K_{ow}$ and \log organic matter (om) content and compared this classification to that of Helling and Turner (1968), based on soil thin layer chromatography. Nitrobenzene would be in mobility class III (intermediate).

Jury et al. (1984) also classified nitrobenzene as intermediately mobile, but noted that its loss from soil would be enhanced by evaporation of water. Moreover, because nitrobenzene has relatively poor diffusive flux, the material would tend to move as a bolus within soil. Jury et al. (1984) hypothesized that a deposit 10 cm deep in soil would have a half-life of about 19 days.

Other results also indicate that nitrobenzene is intermediately mobile in forest and agricultural soils (Seip et al. 1986). However, nitrobenzene was somewhat more mobile in soil with lower organic carbon content. The authors attribute this to hydrogen bonding interactions of nitrobenzene with organic matter in the soil.

Piwoni et al. (1986) found that nitrobenzene did not volatilize in their microcosms simulating land-application of wastewater, but was totally degraded. Enfield et al. (1986) employed a calculated Henry's law constant of $1.30 \times 10^{-3} \text{ kPa m}^3 \text{ mol}^{-1}$, and arrived at a biodegradation rate coefficient greater than 8 day^{-1} . They predicted that 0.2% of the added nitrobenzene could be accounted for in volatiles. The EXAMS computer model (Burns et al. 1981) predicts volatilization half-lives of 12 days (river) to 68 days (eutrophic lake) and up to 2% sediment sorption for nitrobenzene.

In a laboratory-scale waste treatment study, Davis et al. (1981) estimated that 25% of the nitrobenzene was degraded and 75% was lost through volatility in a system yielding a loss of about 80% of initial nitrobenzene in 6 days. In a stabilization pond study, the half-life by volatilization was about 20 hours, with approximately 3% adsorbed to sediments (Davis et al. 1983).

The measured bioconcentration factors (BCF) for nitrobenzene in several organisms indicate minimal bioconcentration in aquatic organisms. Veith et al. (1979) found the 28-day flow-through test for fathead minnows yielded a BCF of 15. A less satisfactory 3-day static measurement gave a BCF of less than 10 for the golden ore (Freitag

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et al. 1982). In the Metcalf model "farm pond" microcosm (Lu and Metcalf 1975), the Ecological Magnification Index (EM: ratio of concentration of parent material in organism to concentration of parent material in water) was about 8 in mosquitofish (Gambusia affinis) after a 24-hr exposure. Longer exposures of other species, however, did not increase the value; the EM in snails (Physa sp.) was 0.7, in mosquito (Culex quinquefasciatus) larvae was 0.8, in *Daphnia magna* was 0.15, and in alga (*Oedogonium*) was 0.03. Bioaccumulation from water is not considered significant at values of less than 300 (Trabalka and Garten 1981).

Nitrobenzene may bioconcentrate in terrestrial plants. The relatively rapid uptake of ¹⁴C-labeled nitrobenzene into mature soybean (Glycine max L Merr) plants was reported by McFarlane et al. (1987a, 1987b) and Nolt (1988). Plant uptake is, therefore, a possible route of human exposure to nitrobenzene.

5.3.2 Transformation and Degradation

5.3.2.1 Air

p-Nitrophenol and nitrosobenzene were reported to be the principal photodegradation products of nitrobenzene vapors exposed to UV light in air (Hastings and Matsen 1948). In another study, both o- and p-nitrophenols were found when O₂ was present and phenol was also found when O₂ was absent (Nojima and Kanno 1977). Photolysis by reaction with hydroxyl radicals or ozone was found to be insignificant in the troposphere (Atkinson et al. 1987). Based on laboratory studies, they projected half-lives of nitrobenzene of 180 days by reaction with hydroxyl radicals and more than 6 years by reaction with ozone in "clean" air. In typical, moderately "dirty" air, these values would decrease to 90 days and more than 2 years, respectively.

As noted earlier, nitrobenzene is formed by reaction of benzene with NO₂ and Atkinson et al. (1987) reported that aniline is slowly oxidized to nitrobenzene by ozone. Further nitration of nitrobenzene appears to be negligible. These reactions are summarized in Figure 5-2.

Atmospheric photochemical decomposition is, therefore, thought to be an important removal route of nitrobenzene itself (EPA 1985a).

5.3.2.2 Water

There is no known mechanism of hydrolysis of nitrobenzene; however, photolysis and biodegradation are significant nitrobenzene degradation pathways in water (Callahan et al. 1979; Mabey et al. 1982).

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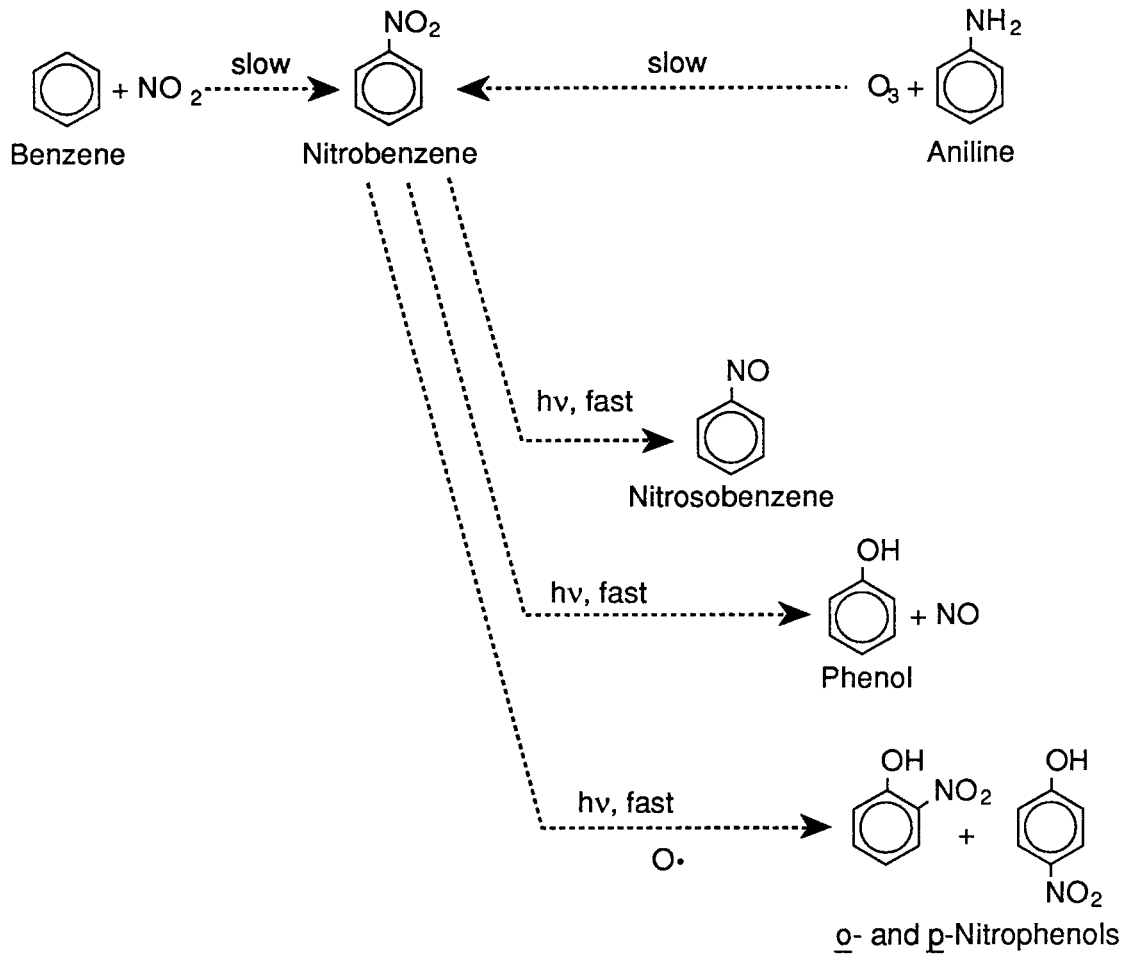


FIGURE 5-2. Atmospheric Reactions Generating and Removing Nitrobenzene

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Photolysis. Photochemical oxidation of nitrobenzene by hydrogen peroxide yields p-, o-, and m-nitrophenols (Draper and Crosby 1984) with an estimated half-life of 250 days (Dorfman and Adams 1973). Direct photolysis, measured by Zepp and Scholtzhauer (1983), has a half-life of 2.5 to more than 6 days near the surface of bodies of water in the vicinity of 40°N latitude.

Under laboratory conditions, direct photolysis of nitrobenzene in solvents such as isopropanol yields phenylhydroxylamine, which can be oxidized to nitrosobenzene by oxygen (Hurley and Testa 1966, 1967). Phenylhydroxylamine and nitrosobenzene can then combine to form azoxybenzene. However, these reactions may not be important under natural conditions in the absence of hydrogen donors (Mabey et al. 1982). Callahan et al. (1979) proposed that sorption of nitrobenzene to humics could enhance photolytic destruction of nitrobenzene. Simmons and Zepp (1986), however, found that photolysis of nitrobenzene was not appreciably enhanced by either a natural humic-containing water or a commercial humic sample. Zepp et al. (1987a) reported that hydrated electrons from dissolved organic matter could significantly increase photoreduction of compounds such as nitrobenzene, and that photolysis of nitrate ions to hydroxyl radicals increased nitrobenzene photodegradation (Zepp et al. 1987b). Algae do not enhance photolysis of nitrobenzene (Zepp and Scholtzhauer 1983). Photolysis may be an important pathway in natural waters (EPA 1985a), but probably only under conditions where biodegradation is poor or absent and where both UV irradiance and appropriate facilitating molecules occur in relatively clear waters.

Biodegradation. Nitrobenzene may be almost completely removed by activated sludge treatment (EPA 1983a). Pitter (1976) obtained 98% removal of chemical oxygen demand (COD) at a rate of 14 mg COD/hr/g dry weight of activated sludge with nitrobenzene as the sole carbon source. Tabak et al. (1981) obtained 100% biodegradation in settled domestic wastewater in 7 days. Hallas and Alexander (1983) reported 100% degradation in 10 days after a 6-day lag under aerobic conditions with municipal sewage effluent. Similar results have been reported by a number of researchers (Davis et al. 1981, 1983; Kincannon et al. 1983; Patil and Shinde 1988; Stover and Kincannon 1983) using a variety of model sewage treatment reactors and wastewater sources, including adapted industrial sludges.

Nitrobenzene is also degradable by anaerobic processes, but more slowly than described above. Chou et al. (1978) reported that nitrobenzene was 81% removed in 110 days by acclimated domestic sludge in an anaerobic reactor, and Hallas and Alexander (1983) found that 50% was degraded in 12 days under similar conditions. Canton et al. (1985)

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measured an 8% decrease in nitrobenzene after 8 days in unadapted media, but reported a half-life of less than 2 weeks in adapted media.

Nitrobenzene was either highly resistant to degradation or inhibited biodegradation of other components of the waste in several biodegradation studies (Barth and Bunch 1979; Davis et al. 1981; Korte and Klein 1982; Lutin et al. 1965; Marion and Malaney 1963). However, these effects were observed at concentrations (≥ 50 mg/L) of nitrobenzene much higher than those detected in ambient waters (see Section 5.4.2).

5.3.2.3 Soil

There is a paucity of studies of nitrobenzene in soil. Decomposition of nitrobenzene in a 1% suspension of Niagara silt loam took more than 64 days, while aniline and phenol, commonly metabolites of nitrobenzene, were completely degraded in 4 and 1 days, respectively (Alexander and Lustigman 1966). In contrast, a study of the efficacy of soil infiltration along the Rhine River in the Netherlands showed that nitrobenzene was removed completely in moving 50 cm through a peat-sand artificial dune (Piet et al. 1981).

5.4 LEVELS MONITORED OR ESTIMATED IN THE ENVIRONMENT

Monitoring of nitrobenzene in the environment reveals variably low levels in air, very infrequent occurrence in surface waters, and infrequent occurrence but higher levels in industrial wastewaters. Nitrobenzene may be present in soils at hazardous waste sites.

5.4.1 Air

Most of the information on nitrobenzene levels in air is derived from a series of reports from New Jersey, in which ambient air in urban, rural, and waste disposal areas were monitored extensively. In the initial study (Bozzelli et al. 1980), nitrobenzene was not detected above the level of 0.01 ppb in about 260 samples collected in 1979. In 1978, nitrobenzene levels averaged 0.40 ppb in industrial areas, and 0.02 and 0.09 ppb in two residential areas, but that in 1982, levels in residential areas were approximately 0.3 ppb or less, while levels in industrial areas were 0.9 ppb or more (Bozzelli and Kebbekus 1982). Again, most of the samples were negative for nitrobenzene. The highest values were 3.5 to 5.7 ppb.

Harkov et al. (1983) reported low levels of nitrobenzene (0.07 to 0.1 ppb) in approximately 85% of air samples of nitrobenzene in their study of airborne toxic chemicals in summer. Nitrobenzene was not detected during the winter (Harkov et al. 1984; Liroy et al. 1983).

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Studies of air over waste disposal sites (Harkov et al. 1985) are confounded by weather and timing. Air at one landfill showed a mean nitrobenzene concentration of 1.32 ppb and another of 0.3 ppb; but at two other sites (measured during snow and/or rain), nitrobenzene was not detected. LaRegina et al. (1986) summarized these studies by noting that the highest value for nitrobenzene was 14.48 ppb at a hazardous waste site, whereas nitrobenzene was often undetectable elsewhere (especially in rural areas or at sanitary landfills) or anywhere in the air during the winter.

Very little information is available for other areas of the United States. Pellizzari (1978b) found only one positive value of 107 ng/m³ (20 ppb) at a plant site in Louisiana. Early data (summarized in EPA 1985a) show less than 25% of United States air samples positive with a median concentration of about 0.01 ppb.

5.4.2 Water

A nitrobenzene concentration of about 20 ppb in the final effluent of a Los Angeles County municipal wastewater treatment plant in 1978 and less than 10 ppb in 1980 was reported (Young et al. 1983). Nitrobenzene was not reported in runoff samples in 1982 in a nation-wide project (Cole et al. 1984). Kopfler et al. (1977) list nitrobenzene as one of the chemicals found in finished tap water in the United States, but do not report its concentrations or locations. Levins et al. (1979) reported only one positive sample (total sample number not stated) in Hartford, Connecticut, sewage treatment plant influents, and no nitrobenzene was detected in samples taken from three other major metropolitan areas. Nitrobenzene was detected in only 0.4% of the 836 ambient surface water stations involved in EPA's STORET database (Staples et al. 1985). No data were located on occurrence of nitrobenzene in groundwater.

Nitrobenzene is detected more frequently and at higher concentrations in effluents from industrial sources. The STORET database shows that 1.8% of the 1,245 reporting stations on industrial wastewaters have had measurable values (Staples et al. 1985).

5.4.3 Soil

The only measurement of nitrobenzene in soil located was a value of 8 ppm detected in soil at one of two sampling sites along the bank of the industrially polluted Buffalo River in New York (Nelson and Hites 1980). Nitrobenzene was not detected at any of three sediment sampling sites in this study.

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5.4.4 Other Media

Nitrobenzene has not been found in other environmental media. It has not been detected as a bioaccumulated material in fish samples (Staples et al. 1985). No monitoring of plant tissues has been reported, even though uptake of nitrobenzene by plants has been observed (McFarlane et al. 1987a, 1987b). Data on nitrobenzene occurrence in foods were not located in the available literature.

5.5 GENERAL POPULATION AND OCCUPATIONAL EXPOSURE

Apparently general exposure of the population to nitrobenzene is limited to variable concentrations in air and possibly drinking water. Air levels can be high in the vicinity of manufacturing or production facilities (especially petroleum refining, leather finishing and some chemical manufacturers). Urban areas have much higher levels in the summer than winter due to both the formation of nitrobenzene by nitration of benzene (from motor vehicle fuels) and the higher volatility of nitrobenzene during the warmer months. Ambient exposure in the winter may be negligible.

Occupational exposure can be significantly higher than the exposure of the general population. NIOSH (1988) identified about 10,600 workers (mainly chemists, equipment servicers, and janitorial staff) as potentially exposed workers in facilities where nitrobenzene is used. Because nitrobenzene is readily absorbed through the skin, as well as taken up by inhalation and ingestion, industrial exposure necessitates worker protection, and this has been recognized for decades. At an industrial exposure level of 5 mg/m³ (1 ppm), a worker would receive about 25 mg during an 8-hour day (Dunlap 1981).

5.6 POPULATIONS WITH POTENTIALLY HIGH EXPOSURES

Based on the New Jersey air studies and on estimates of releases during manufacture, only populations in the vicinity of manufacturing activities (i.e., producers and industrial consumers of nitrobenzene for subsequent synthesis) and petroleum refining plants are likely to have any significant exposure to anthropogenic nitrobenzene. However, consideration of possible groundwater and soil contamination and uptake of nitrobenzene by plants expands the potentially high exposure group to include people living in and around abandoned hazardous waste sites.

The numbers of people actually exposed to ambient concentrations of nitrobenzene are unknown. Based on the locations of production and other manufacturing facilities, tens of millions of people might be exposed to low levels of this compound.

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5.7 ADEQUACY OF THE DATABASE

Section 104(i)(5) of CERCLA, 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 nitrobenzene is available. Where adequate information is not available, ATSDR, in conjunction with the 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 nitrobenzene.

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. In the future, the identified data needs will be evaluated and prioritized, and a substance-specific research agenda will be proposed.

5.7.1 Identification of Data Needs

Physical and Chemical Properties. No specific data needs, are identified for these properties, for which available values are generally accepted.

Production, Use, Release and Disposal. Available data indicate that most nitrobenzene produced in the United States is consumed in the production of aniline, but current quantitative data on the amount of nitrobenzene released to the environment during nitrobenzene production and use are sparse. Collection of this information would be helpful in evaluating the effect of current industrial practices on environmental levels of nitrobenzene.

According to the Emergency Planning and Community Right to Know Act of 1986 (EPCRTKA), (§313), (Pub. L. 99-499, Title III, §313), industries are required to submit release information to the EPA. The Toxic Release Inventory (TRI), which contains release information for 1987, became available in May of 1989. This database will be updated yearly and should provide a more reliable estimate of industrial production and emission.

Environmental Fate. The environmental fate of nitrobenzene is fairly well understood within the context of recognition of the importance of conditions in estimating or modelling environmental concentrations. The most critical condition is the presence/absence of a viable, competent and functioning population of microorganisms for biodegradation. The next most critical factor is the amount of sunlight. For exposure assessment modelling accuracy, more data are

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needed on fate in soil, both in the root zone where plants are exposed and in the saturated and unsaturated zones where groundwater may become contaminated. Metabolism in plants is poorly characterized to date, so that information on the nature and quantity of plant metabolites would assist assessment of exposure via that route.

Bioavailability from Environmental Media. The available information indicates that nitrobenzene is well absorbed following inhalation, oral or dermal exposure. It is expected to be well absorbed by persons breathing or having dermal contact with contaminated air or ingesting water, soil, plants or any environmental materials that contain it. It would be useful to have information on its absorption after dermal contact with contaminated soil or plant material.

Food Chain Bioaccumulation. Uptake and accumulation of nitrobenzene through food chains are well understood regarding animal tissues, especially fish. However, more information about plant tissues would be helpful.

Exposure Levels in Environmental Media. Because nitrobenzene is a priority pollutant, extensive data are available on its occurrence in surface waters, sediments, and aquatic animals. It would be useful to have data on its presence in soils and groundwater and correlations of measured air concentrations to soil levels and of plant levels to soil concentrations.

Exposure Levels in Humans. There is very little information on human exposure to nitrobenzene outside of the workplace. More detailed exposure analyses that take transformation pathways into account need to be performed for local sites and the potentially impacted populations. Further, it would be useful to know more about the relationship of the organoleptic properties of nitrobenzene with respect to tolerable exposures. For example, it would be useful to know whether its taste and aroma are deterrents to high levels of human exposure.

Exposure Registries. No exposure registries for nitrobenzene were located. This compound is not currently one of the compounds for which a subregistry has been established in the National Exposure Registry. The compound 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 compound.

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5.7.2 On-going Studies

No long-term research projects or other on-going studies of occupational or general population exposures to nitrobenzene were identified.

As part of the Third National Health and Nutrition Evaluation Survey (NHANES III), the Environmental Health Laboratory Sciences Division of the Centers for Disease Control, will be analyzing human urine samples for p-nitrophenol and other phenolic compounds. Since p-nitrophenol is a major metabolite of nitrobenzene, the presence of p-nitrophenol in the urine can be used to indicate exposure to nitrobenzene. These data will give an indication of the frequency of occurrence and background levels of these compounds in the general population.

