6. POTENTIAL FOR HUMAN EXPOSURE

6.1 OVERVIEW

1,3-Butadiene has been identified in at least 13 of the 1,699 hazardous waste sites that have been proposed for inclusion on the EPA National Priorities List (NPL) (HazDat 2007). However, the number of sites evaluated for 1,3-butadiene is not known. The frequency of these sites can be seen in Figure 6-1.

1,3-Butadiene is a high-volume, volatile hydrocarbon used in the production of commercial plastics and synthetic rubbers (Chemical Market Reporter 2006). The chemical reactivity of this monomer is utilized in its transformation into polymeric materials (Sigsby et al. 1987).

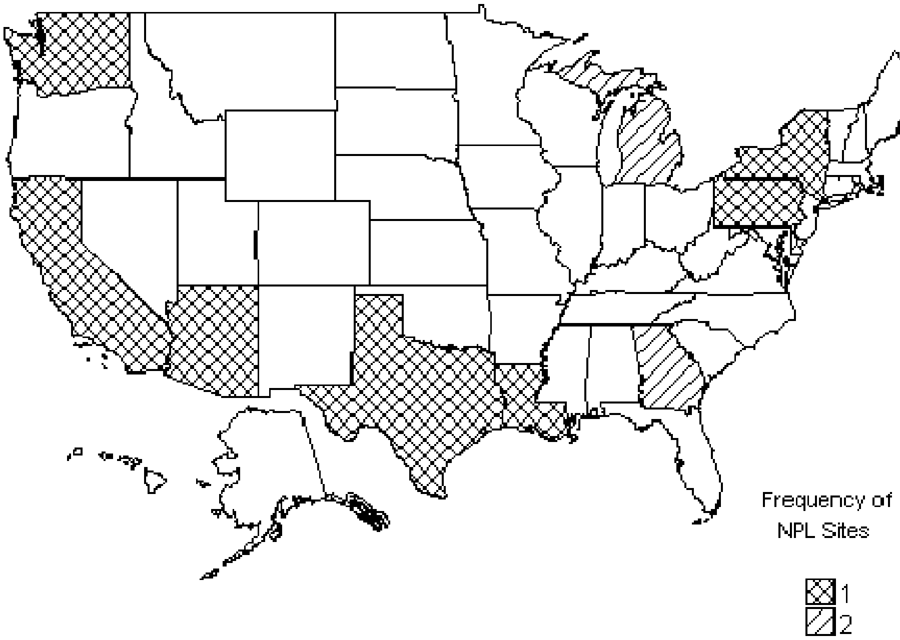
1,3-Butadiene may be released to the environment as an intentional or fugitive emission during its production, use, storage, transport, or disposal. Large amounts (1.17 million pounds) of this hydrocarbon are released to the atmosphere from commercial processes (TRI09 2011). Data on the detection of 1,3-butadiene in soil and water are scarce. In the past, it has been qualitatively detected in drinking water (EPA 1978; Kraybill 1980); however, more recent measurements are not available.

1,3-Butadiene is a highly volatile gas; therefore, it is expected to partition predominantly to the atmosphere. In the atmosphere, 1,3-butadiene is expected to undergo rapid destruction, primarily by photo-initiated reactions. The reaction with photochemically produced hydroxyl radicals has a calculated half-life of approximately 6 hours and is expected to be the dominant pathway for atmospheric removal (Atkinson 1989). Destruction of atmospheric 1,3-butadiene by the gas-phase reaction with tropospheric ozone and by the night-time reaction with nitrate radicals in urban areas is also expected to be significant (Atkinson and Carter 1984; Atkinson et al. 1984).

Limited data have been located on the fate of 1,3-butadiene in soil or water. Based on its physical properties, rapid volatilization of 1,3-butadiene from either soil or water to the atmosphere is expected to dominate over all other potential environmental processes. Based on estimated soil adsorption coefficient values, 1,3-butadiene is not expected to adsorb significantly to soil or sediment, nor is it expected to bioconcentrate in fish or aquatic organisms based on estimated bioconcentration and bioaccumulation factors.

Although 1,3-butadiene undergoes rapid photooxidation in the atmosphere, it is almost always present at very low concentrations in urban and suburban areas (Curren et al. 2006; Grant et al. 2007; Oguz et al.

Figure 6-1. Frequency of NPL Sites with 1,3-Butadiene Contamination



Derived from HazDat 2007

2003; Reiss 2006; Reiss and Griffin 2004; Sax et al. 2004). Automobile exhaust is a constant source of 1,3-butadiene release to the atmosphere. Because of the compound's ubiquity in the urban/suburban atmosphere, the general population is exposed to low ppb levels of 1,3-butadiene through inhalation (Higashino et al. 2007; Hughes et al. 2003). Exposure to 1,3-butadiene may also occur from the inhalation of cigarette smoke or the smoke from wood fires (Adam et al. 2006; Bartle et al. 1969; Blomberg and Widmark 1975; Brunnemann et al. 1990; Carmella et al. 2009; Counts et al. 2006; Gustafson et al. 2007; Lofroth et al. 1989; Pankow et al. 2004, 2007; Penn and Snyder 2007; Stump et al. 1989; Thweatt et al. 2007; Vainiotalo et al. 2008). Ingestion of contaminated food or drinking water may also lead to low levels of exposure, although current levels of this compound in food and water samples are not known, nor is there a good understanding of their frequency of detection (EPA 1978; Hughes et al. 2003; Kraybill 1980; Leber 2001; McNeal and Breder 1987; Startin and Gilbert 1984). The levels of 1,3-butadiene in soil are not known. Elevated levels of exposure for the general population may occur for those near its site of manufacture or facilities where it is made into polymeric materials.

Occupational exposure to 1,3-butadiene is expected to be limited to those working at facilities that manufacture 1,3-butadiene or convert it into commercial polymers (Anttinen-Klemetti et al. 2006; Begemann et al. 2001a; Fustinoni et al. 2004; Jones and Harris 1983; Lovreglio et al. 2006; Meinhardt et al. 1982; Sathiakumar et al. 2007; Tsai et al. 2001, 2005; Ward et al. 2001). Exposure by inhalation is expected to be the dominant pathway for exposure. Dermal exposure to liquified 1,3-butadiene could occur during an explosion of a pressurized storage tank or some other catastrophic event.

6.2 RELEASES TO THE ENVIRONMENT

The Toxics Release Inventory (TRI) data should be used with caution because only certain types of facilities are required to report (EPA 2005). This is not an exhaustive list. Manufacturing and processing facilities are required to report information to the TRI only if they employ 10 or more full-time employees; if their facility is included in Standard Industrial Classification (SIC) Codes 10 (except 1011, 1081, and 1094), 12 (except 1241), 20–39, 4911 (limited to facilities that combust coal and/or oil for the purpose of generating electricity for distribution in commerce), 4931 (limited to facilities that combust coal and/or oil for the purpose of generating electricity for distribution in commerce), 4939 (limited to facilities that combust coal and/or oil for the purpose of generating electricity for distribution in commerce), 4953 (limited to facilities regulated under RCRA Subtitle C, 42 U.S.C. section 6921 et seq.), 5169, 5171, and 7389 (limited S.C. section 6921 et seq.), 5169, 5171, and 7389 (limited to facilities primarily engaged in solvents recovery services on a contract or fee basis); and if their facility produces, imports, or processes ≥25,000 pounds of any TRI chemical or otherwise uses >10,000 pounds of a TRI chemical in a calendar year (EPA 2005).

6.2.1 Air

Estimated releases of 1.17 million pounds (530 metric tons) of 1,3-butadiene to the atmosphere from 193 domestic manufacturing and processing facilities in 2009 accounted for about 99% of the estimated total environmental releases from facilities required to report to the TRI (TRI09 2011). These releases are summarized in Table 6-1.

The dominant sources for the release of 1,3-butadiene to the atmosphere are fugitive or accidental emissions during its manufacture, use, transport, and storage. Low levels of 1,3-butadiene are continuously emitted to the atmosphere from many sources including exhaust from motor vehicle engines using petroleum-based fuels.

EPA's National Emission Inventory database (NEI) contains detailed information about sources that emit criteria air pollutants and their precursors, and hazardous air pollutants for the 50 United States, Washington DC, Puerto Rico, and the U.S. Virgin Islands. Emission data for 1,3-butadiene in 2005 is presented in Table 6-2 and suggest that automobile usage accounts for approximately one-third of all emissions.

1,3-Butadiene was measured in the exhaust of typical automobiles and light trucks using both winter and summer gasoline formulations and accounted for up to 0.12% of total hydrocarbon emissions (Stump et al. 1989). An earlier study determined that the concentration of 1,3-butadiene in automobile exhaust was 20–60 ppb (Neligan 1962). 1,3-Butadiene has also been detected in the exhaust of diesel engines (Hayano et al. 1985) and high-altitude jet aircraft engines operating under simulated conditions (Katzman and Libby 1975).

There are several minor sources for the release of 1,3-butadiene to the atmosphere, all of which involve the thermal breakdown of other materials. 1,3-Butadiene has been detected as a component of the sidestream smoke from cigarettes (Adam et al. 2006; Bartle et al. 1969; Blomberg and Widmark, 1975; Carmella et al. 2009; Penn and Snyder 2007; Vainiotalo et al. 2008). The average amount of 1,3-butadiene in sidestream cigarette smoke is 205–361 μg/cigarette (Brunnemann et al. 1990), with an average airborne yield of 400 μg/cigarette (Lofroth et al. 1989).

Table 6-1. Releases to the Environment from Facilities that Produce, Process, or Use 1,3-Butadiene[a]

		Reported amounts released in pounds per year[b]							
							Total release		
State[c]	RF[d]	Air[e]	Water[f]	UI[g]	Land[h]	Other[i]	On-site[j]	Off-site[k]	On- and off-site
AL	2	3,069	0	0	47	0	3,069	47	3,116
AR	1	1,140	0	0	0	0	1,140	0	1,140
AZ	1	1,460	0	0	0	0	1,460	0	1,460
CA	17	6,116	0	0	8	0	6,116	8	6,124
CO	3	776	0	0	0	0	776	0	776
CT	1	32	0	0	0	0	32	0	32
DE	1	534	0	0	0	0	534	0	534
GA	2	3,732	0	0	0	0	3,732	0	3,732
HI	1	401	0	0	0	0	401	0	401
IA	1	4,766	0	0	0	0	4,766	0	4,766
IL	7	43,415	10	0	44	0	43,425	44	43,469
IN	5	3,859	5	0	0	0	3,864	0	3,864
KS	3	120	0	0	0	0	120	0	120
KY	5	15,246	0	0	726	0	15,246	726	15,972
LA	23	110,511	574	0	65	0	111,085	65	111,150
MI	2	3,585	0	0	0	0	3,585	0	3,585
MN	1	3,983	2	0	0	0	3,985	0	3,985
MS	1	809	0	0	0	0	809	0	809
MT	3	903	0	0	0	0	903	0	903
NC	3	858	0	0	0	0	858	0	858
ND	1	89	0	0	0	0	89	0	89
NJ	4	102	0	0	0	0	102	0	102
OH	13	35,145	6	0	4,161	5	39,311	6	39,317
OK	4	6,981	0	0	0	0	6,981	0	6,981
PA	4	2,258	0	0	0	0	2,258	0	2,258
SC	1	5,520	0	0	0	0	5,520	.	5,520
TN	4	4,648	0	0	0	0	4,648	0	4,648
TX	67	902,132	49	2,266	10	6	904,446	17	904,463
UT	2	1,069	0	0	0	0	1,069	0	1,069
VA	1	962	0	0	0	0	962	0	962
VI	1	1,039	0	0	0	0	1,039	0	1,039
WA	4	292	0	0	0	0	292	0	292
WI	1	156	0	0	0	0	156	0	156
WV	1	2,100	0	0	13	0	2,113	0	2,113

Table 6-1. Releases to the Environment from Facilities that Produce, Process, or Use 1,3-Butadiene[a]

		Reported amounts released in pounds per year[b]							
							Total release		
State[c]	RF[d]	Air[e]	Water[f]	UI[g]	Land[h]	Other[i]	On-site[j]	Off-site[k]	On- and off-site
WY	2	500	0	0	0	0	500	0	500
Total	193	1,168,307	646	2,266	5,074	11	1,175,391	913	1,176,304

[a] The TRI data should be used with caution since only certain types of facilities are required to report. This is not an exhaustive list. Data are rounded to nearest whole number.
[b] Data in TRI are maximum amounts released by each facility.
[c] Post office state abbreviations are used.
[d] Number of reporting facilities.
[e] The sum of fugitive and point source releases are included in releases to air by a given facility.
[f] Surface water discharges, waste water treatment-(metals only), and publicly owned treatment works (POTWs) (metal and metal compounds).
[g] Class I wells, Class II-V wells, and underground injection.
[h] Resource Conservation and Recovery Act (RCRA) subtitle C landfills; other onsite landfills, land treatment, surface impoundments, other land disposal, other landfills.
[i] Storage only, solidification/stabilization (metals only), other off-site management, transfers to waste broker for disposal, unknown
[j] The sum of all releases of the chemical to air, land, water, and underground injection wells.
[k] Total amount of chemical transferred off-site, including to POTWs.

RF = reporting facilities; UI = underground injection

Source: TRI09 2011 (Data are from 2009)

Table 6-2. 1,3-Butadiene Emission Data for 2005[a]

Category name	Type	Annual emissions (tons)	Percentage
Fuel comb, residential fireplaces	Nonpoint	3,352.17	6.35
On-road vehicles, gasoline	Onroad	16,008.77	30.32
Miscellaneous sources	Nonpoint	17,627.65	33.39
On-road vehicles, diesel	Onroad	1,058.86	2.01
Agricultural field burning	Nonpoint	339.31	0.64
Fuel comb, residential woodstoves	Nonpoint	315.31	0.60
Graphic arts	Point	0.00	0.00
Gas stations	Point	0.01	0.00
Wildfires	Nonpoint	3,340.53	6.33
Bulk gasoline terminals	Point	5.11	0.01
Fuel comb, commercial/institutional	Nonpoint	0.07	0.00
Planes, trains, and ships	Nonroad	109.07	0.21
Prescribed fires	Nonpoint	164.95	0.31
Industrial process, storage and transfer	Nonpoint	2.61	0.00
Industrial process, NEC	Point	129.88	0.25
Surface coating, industrial	Point	16.81	0.03
Non-road equipment, diesel	Nonroad	364.74	0.69
Non-road equipment, gasoline	Nonroad	8,062.72	15.27
Industrial process, petroleum refineries	Nonpoint	1.30	0.00
Industrial process, petroleum refineries	Point	22.15	0.04
Industrial process, cement manufacturing	Point	64.37	0.12
Logging slash burning	Nonpoint	211.34	0.40
Fuel comb, electric utility	Point	2.30	0.00
Waste disposal, open burning	Point	0.03	0.00
Waste disposal, open burning	Nonpoint	123.52	0.23
Fuel comb, commercial/institutional	Point	0.78	0.00
Industrial process, oil and gas production	Point	7.71	0.01
Waste disposal	Nonpoint	1.52	0.00
Industrial process, chemical manufacturing	Point	603.65	1.14
Degreasing	Point	0.01	0.00
Industrial process, chemical manufacturing	Nonpoint	1.44	0.00
Solvent, NEC	Point	0.24	0.00
Planes, trains, and ships	Point	323.90	0.61
Fuel comb, industrial boilers, ICEs	Nonpoint	2.86	0.01
Fuel comb, industrial boilers, ICEs	Point	111.72	0.21
Waste disposal	Point	37.16	0.07
Industrial process, oil and gas production	Nonpoint	0.18	0.00
Industrial process, storage and transfer	Point	217.59	0.41

Table 6-2. 1,3-Butadiene Emission Data for 2005[a]

Category name	Type	Annual emissions (tons)	Percentage
Industrial process, pulp and paper	Point	0.30	0.00
Industrial process, metals	Point	161.81	0.31

[a] Emission estimates are subject to updates for subsequent revised versions of the 2005 National Emissions Inventory data. These numbers may be different than values published for previous versions of the 2005 data and may also be different than values for subsequent revisions of the data as generated by EPA.

ICEs = internal combustion engines; NEC = not elsewhere classified

Source: EPA 2008

The burning of plastics or rubber has been shown to release small amounts of 1,3-butadiene (Miller 1978). In a test designed to simulate a real-life electrical overload condition, 1,3-butadiene was detected when polyurethane coated wire was heated to 250 °C for 40 minutes (Rigby 1981). 1,3-Butadiene has also been measured as a component of the smoke from brush fire (Stephens and Burleson 1969), and as a stack emission from waste incinerators (Junk and Ford 1980). The concentrations of 1,3-butadiene were not presented in these studies. The mean, minimum, and maximum concentrations of 1,3-butadiene measured in the air of nine municipal structural fires were 1.03, 0.03, and 4.84 ppm, respectively (Austin et al. 2001). The sources of 1,3-butadiene were considered to be both the combustion of wood and the thermal degradation of polymeric materials. Forest fires are considered to be a natural source of 1,3-butadiene in the atmosphere (Curren et al. 2006). Detection of 1,3-butadiene while heating rapeseed oil indicates that the heating of cooking oils may be a source of 1,3-butadiene in indoor air (Pellizzari et al. 1995).

1,3-Butadiene has been identified in air samples collected at 8 of the 13 NPL hazardous waste sites where it was detected in some environmental media (HazDat 2007).

6.2.2 Water

Estimated releases of 646 pounds (0.29 metric tons) of 1,3-butadiene to surface water from 193 domestic manufacturing and processing facilities in 2009, accounted for about 0.05% of the estimated total environmental releases from facilities required to report to the TRI (TRI09 2011). An additional 913 pounds (0.08 metric tons) were transferred off-site which includes releases to publicly owned treatment works (POTWs) (TRI09 2011). These releases are summarized in Table 6-1.

Additional information regarding the release of 1,3-butadiene to water was not located in the available literature. 1,3-Butadiene has been identified in groundwater samples collected at 1 of the 13 NPL hazardous waste sites where it was detected in some environmental media (HazDat 2007). It was not identified in surface water at any of the NPL sites.

6.2.3 Soil

Estimated releases of 5,074 pounds (2.3 metric tons) of 1,3-butadiene to soils from 193 domestic manufacturing and processing facilities in 2009, accounted for about 0.43% of the estimated total environmental releases from facilities required to report to the TRI (TRI09 2011). An additional

2,266 pounds (1.03 metric tons), constituting about 0.19% of the total environmental emissions, were released via underground injection (TRI09 2011). These releases are summarized in Table 6-1.

Additional information regarding the release of 1,3-butadiene to soil was not located in the available literature. 1,3-Butadiene has been identified in soil samples collected at 2 of the 13 NPL hazardous waste sites where it was detected in some environmental media (HazDat 2007). It was not identified in sediment at any of the NPL sites.

6.3 ENVIRONMENTAL FATE

6.3.1 Transport and Partitioning

1,3-Butadiene’s high volatility suggests that it will partition predominantly to the atmospheric compartment, where it is not expected to be adsorbed to particulate matter to any significant extent (Eisenreich et al. 1981).

Based on the calculated Henry’s Law constant of 7.4×10^{-2} atm-m^3/mol, the half-life for volatilization of 1,3-butadiene is 2.2 hours from a model river (1 m deep, flowing at 1 m/second, with a wind velocity of 3 m/second) and 2.9 days from a model lake (1 m deep, flowing at 0.05 m/second, with a wind velocity of 0.5 m/second) (Lyman et al. 1990). Based on an experimental log octanol/water partition coefficient of 1.99 (Hansch et al. 1995), a calculated soil adsorption coefficient of 288 (Lyman et al. 1990) suggests that adsorption to sediment and suspended organic matter will not be a significant fate process. From the log octanol/water partition coefficient, a calculated bioconcentration factor of 19 (Lyman et al. 1990) indicates that 1,3-butadiene will not bioconcentrate in fish and aquatic organisms to any significant extent. However, no experimental data have been located to verify these theoretical values.

If released to soil, 1,3-butadiene is expected to volatilize rapidly from either moist or dry soil to the atmosphere. This follows from the estimated lack of any appreciable adsorption to soil, and consideration of 1,3-butadiene's calculated Henry's law constant for moist soil or its vapor pressure, 2,100 mm Hg at 25 °C (AIChE 2000), for dry soil. Both values suggest a rapid rate of volatilization from their respective media.

The calculated soil adsorption coefficient of 288 (Hansch et al. 1995; Lyman et al. 1990) suggests that 1,3-butadiene may display moderate mobility in soil (Swann et al. 1983). However, the expected rapid rate of volatilization and the possibility of rapid degradation in soil suggest that there is little potential for

1,3-butadiene to leach into groundwater. But until adequate groundwater monitoring for 1,3-butadiene has been performed, the partitioning of 1,3-butadiene in soil cannot be adequately addressed.

6.3.2 Transformation and Degradation

6.3.2.1 Air

Butadiene is a reactive, electron-rich chemical that is expected to undergo rapid reactions with the electrophilic oxidants typically present in the atmosphere: ozone, photochemically produced hydroxyl radicals, nitrate radicals, and molecular oxygen. Among these, the most rapid reaction in the atmosphere is with photochemically produced hydroxyl radicals.

The atmospheric degradation of 1,3-butadiene by photo-initiated processes has been established empirically by early studies. These studies typically involved irradiating urban air samples in atmospheric chambers of varying complexity and monitoring the disappearance of each constituent. Using this technique, 1,3-butadiene, at an average concentration of 12.4 ppb, disappeared in 6 hours when irradiated with natural sunlight during October (Kopczynski et al. 1972). In another study, a half-life of 2 hours was determined for the atmospheric removal of 1,3-butadiene using natural sunlight in October or November (Altshuller et al. 1970). In smog chamber studies, the sunlight oxidation of 1,3-butadiene led to the formation of fairly potent eye irritants, suggesting destruction of this compound with concomitant formation of oxygenated species (Dimitriades et al. 1975; Heuss and Glasson 1968). It is believed that the destruction of 1,3-butadiene occurs by photo-initiated bimolecular processes rather than direct photochemical degradation (Kopczynski et al. 1972). It is important to note that the rate of destruction of 1,3-butadiene when it was irradiated with natural light depended on the time of day in which the irradiation occurred. Furthermore, these studies were performed in October and November, when the amount and the intensity of available sunlight is diminished over that of summer months; thus, these values probably represent the high end of the compound's atmospheric lifetime. The individual processes responsible for the destruction of 1,3-butadiene in the atmosphere are discussed below.

Numerous studies have determined the rate constant for the gas-phase reaction of 1,3-butadiene with photochemically produced hydroxyl radicals (Atkinson 1985; Atkinson and Aschmann 1984; Atkinson et al. 1977, 1979; Maldotti et al. 1980). The experimental rate constant 6.85×10^{-11} cm^3/molecule-second at 26 °C (Atkinson et al. 1977) is representative. Given an average hydroxyl radical concentration of 5×10^5 molecule/cm^3 (Atkinson 1985), the half-life for this second-order process is 5.6 hours. Major products of this reaction include acrolein and formaldehyde (Baker et al. 2005).

Gas-phase 1,3-butadiene also reacts with ozone in the atmosphere. Rate constants ranging from 6.7×10^{-18} to 8.4×10^{-18} cm^3/molecule-second at 25 °C have been published in the literature (Atkinson and Carter 1984; Jaspar et al. 1974). Using an average atmospheric ozone concentration of 7×10^{11} molecules/cm^3 (Atkinson and Carter 1984), half-lives ranging from 1.4 to 1.7 days can be calculated for this second-order process. Therefore, the reaction of 1,3-butadiene with ozone is expected to contribute to the overall destruction of atmospheric 1,3-butadiene. The initial products from the reaction of 1,3-butadiene with ozone are acrolein, formaldehyde, acetylene, ethylene, and formic anhydride (Niki et al. 1983). All of these products are susceptible to secondary reactions with ozone and other atmospheric oxidants.

The night-time degradation of 1,3-butadiene is also expected to occur via the gas-phase reaction with nitrate radicals; this tends to be significant in urban areas, where the concentration of this oxidant is typically higher than in rural areas (Altshuller and Cohen 1964; Gay and Bulfalini 1971; Maldotti et al. 1980). A rate constant of 5.4×10^{-14} cm^3/molecule-second at 22 °C has been determined for this reaction. This corresponds to a half-life of 14.9 hours using an average atmospheric nitrate radical concentration of 2.4×10^8 molecule/cm^3 (Atkinson et al. 1984), typical of mildly polluted urban centers. Acrolein has been identified as a primary product of this reaction.

In summary, there are three gas-phase pathways that degrade 1,3-butadiene in the troposphere. Depending on local conditions, any one or all of these reactions may occur. Destruction of atmospheric 1,3-butadiene by the gas-phase reaction with photochemically produced hydroxyl radicals is expected to be the dominant photo-initiated pathway. Degradation via nitrate radicals is expected to be a significant night-time process in urban areas.

6.3.2.2 Water

Data on the degradation of 1,3-butadiene in aquatic systems are limited. Experimental data are restricted to microbial degradation studies performed under aerobic conditions. The bulk of these data were obtained from isolated bacterial strains (pure cultures), not with mixed microbial populations typically found in natural systems, and are not considered to be representative of the biodegradation of 1,3-butadiene in the environment. However, results from these studies suggest that biodegradation of 1,3-butadiene proceeds through oxidation to form 3,4-expoxybutene (Hou et al. 1979, 1980, 1983; Patel et al. 1982a; Watkinson and Somerville 1976). Watkinson and Somerville (1976) reported further degradation.

6.3.2.3 Sediment and Soil

As is the case for the degradation of 1,3-butadiene in water, very limited data on the destruction of this compound in soil could be located in the available literature. Results from pure culture studies suggest a similar aerobic biodegradation pathway for 1,3-butadiene in soil compared to the pathway in water (Hou et al. 1979; Patel et al. 1979, 1982a, 1982b; VanGinkel et al. 1987; Watkinson and Somerville 1976).

6.3.2.4 Other Media

Specific information regarding the transformation or degradation of 1,3-butadiene in other environmental media was not located.

6.4 LEVELS MONITORED OR ESTIMATED IN THE ENVIRONMENT

Reliable evaluation of the potential for human exposure to 1,3-butadiene depends in part on the reliability of supporting analytical data from environmental samples and biological specimens. Concentrations of 1,3-butadiene in unpolluted atmospheres and in pristine surface waters are often so low as to be near the limits of current analytical methods. In reviewing data on 1,3-butadiene levels monitored or estimated in the environment, it should also be noted that the amount of chemical identified analytically is not necessarily equivalent to the amount that is bioavailable. The analytical methods available for monitoring 1,3-butadiene in a variety of environmental media are detailed in Chapter 7.

6.4.1 Air

1,3-Butadiene is widely detected at low ppb levels in urban air samples. Reported average concentrations range from 0.1 to 2 $\mu g/m^3$ (0.04–0.9 ppb) (Curren et al. 2006; Grant et al. 2007; Oguz et al. 2003; Reiss 2006; Reiss and Griffin 2004; Sax et al. 2004). A major source of 1,3-butadiene in urban air is automobile engine exhaust (Broderick and Marnane 2002; Sigsby et al. 1987; Stump and Dropkin 1985; Stump et al. 1989). Atmospheric emissions from industrial facilities that produce or use 1,3-butadiene are another major source of the compound in areas located near these facilities. Concentrations as high as 40 $\mu g/m^3$ (18 ppb) have been measured in the air near industrial sites (highest 24-hour level measured downwind from a major industrial source) (Grant et al. 2007). Curren et al. (2006) analyzed 3,267 air samples collected at eight rural locations in Canada and reported a mean 1,3-butadiene concentration of 0.02 $\mu g/m^3$ (0.009 ppb) at these sites. EPA (2003a) estimated that the average background concentration of 1,3-butadiene in the air of the United States is 0.13 $\mu g/m^3$ (0.058 ppb). McCarthy et al. (2006)

provided a lower estimate (<0.02 μg/m^3; 0.009 ppb) of 1,3-butadiene in the background air of North America. Table 6-3 lists reported concentrations of 1,3-butadiene measured in outdoor air.

1,3-Butadiene has also been detected in indoor air samples. Mean concentrations of 1,3-butadiene measured in indoor air of homes in New York were 1.0 μg/m^3 (0.5 ppb) during the winter and 1.2 μg/m^3 (0.54 ppb) during the summer (Sax et al. 2004). In Los Angeles, mean concentrations were 0.5 μg/m^3 (0.2 ppb) during the winter and 0.2 μg/m^3 (0.09 ppb) during the fall. The concentrations of 1,3-butadiene measured in a tavern were 11 and 19 μg/m^3 (5.0 and 8.6 ppb) in two separate studies, while the outside air concentration was ≤1 μg/m^3 (0. 5 ppb) at the same time (Lofroth et al. 1989). The difference in the indoor versus outdoor concentration may be ascribed to the presence of 1,3-butadiene in cigarette smoke. The concentration of 1,3-butadiene in a smoke-filled bar was 2.7–4.5 μg/m^3 (1.2–2.0 ppb) (Brunnemann et al. 1990). Higher 1,3-butadiene levels have been observed in air samples collected from the smoking areas of restaurants and pubs than in air samples collected from the nonsmoking areas of these buildings (Kim et al. 2001; Vainiotalo et al. 2008). Mean 1,3-butadiene concentrations measured in the indoor air of 32 smoking homes and 32 nonsmoking homes were 1.7 and 0.5 μg/m^3 (0.77 and 0.23 ppb), respectively (Kim et al. 2001). Mean 1,3-butadiene levels were 0.31–0.38 μg/m^3 (0.14-0.17 ppb) in the air of wood burning homes and 0.114 μg/m^3 (0.0515 ppb) in non-wood burning homes in Hagfors, Sweden (Gustafson et al. 2007). Table 6-4 lists reported concentrations of 1,3-butadiene measured in indoor air.

6.4.2 Water

No current information on the occurrence of 1,3-butadiene in water was located in the available literature.

1,3-Butadiene was found in 1 of 204 water samples taken in 1975–1976 from surface waters near known industrialized areas across the United States. The single positive sample was obtained in the Carquinez Strait, Posta Corta, California, at an approximate concentration of 2 ppb (Ewing et al. 1977).

No specific data on its presence in drinking water, such as monitoring dates or concentration, were located; however, 1,3-butadiene has been qualitatively detected in U.S. drinking water in the past (EPA 1978; Kraybill 1980).

6.4.3 Sediment and Soil

No data on the occurrence of 1,3-butadiene in soil were located in the available literature.

Table 6-3. 1,3-Butadiene Concentrations in Outdoor Air

	Concentration (μg/m^3)						
Location	n	>LOD	LOD	Mean	Median	Maximum	Reference
Urban							
New York City							Sax et al. 2004
Winter	31	14%	0.06	0.1	ND	0.7	
Summer	27	11%	0.06	0.1	ND	2.0	
Los Angeles							Sax et al. 2004
Winter	35	24%	0.06	0.2	ND	1.7	
Fall	32	3%	0.06	0.01	ND	0.3	
Houston							Reiss 2006
16 Locations	4,374	61%	0.02[a]	1.3	—	7.2	
Texas							Grant et al. 2007
47 Urban/ industrial sites	—	<30–74%	0.61	0.5	—	40	
Baltimore							Sapkota and Buckley 2003
Toll booth	56	100%	0.46	—	2–13.5[b]	19	
Baltimore							Kim et al. 2007
Parking garage	24[c]	—	—	—	0.2–0.5[d]	8	
Canada							Curren et al. 2006
30 Locations	5,160	—	0.001–0.02	0.22	0.17	2.58	
Rural							
Canada							Curren et al. 2006
8 Locations	3,267	—	0.001–0.02	0.02	—	—	
Background estimate							
United States	—	—	—	0.13	0.10	2.2	EPA 2003a
North America	—	—	—	<0.02	<0.02	<0.02	McCarthy et al. 2006

[a] Value is referred to as the reporting limit.
[b] Lower and upper median values correspond to measurements taken during 12–3 a.m. and 6–9 a.m., respectively.
[c] Seven-hour samples were collected on 18 week days and 6 weekend days.
[d] Lower and upper median values correspond to measurements taken on weekends and weekdays, respectively.

LOD = limit of detection; n = number of samples; ND = not detected

Table 6-4. 1,3-Butadiene Concentrations in Indoor Air

	Concentration ($\mu g/m^3$)						
Location	n	>LOD	LOD	Mean	Median	Maximum	Reference
New York City							Sax et al. 2004
Winter	36	64%	0.06	1.0	0.7	5.8	
Summer	30	44%	0.06	1.2	ND	12	
Los Angeles							Sax et al. 2004
Winter	40	60%	0.06	0.5	0.5	1.8	
Fall	32	38%	0.06	0.2	ND	1.5	
Arizona NHEXAS							Gordon et al. 1999
Home indoor	24	4%	0.38	ND	ND	0.6	
Home outdoor	14	0%	0.38	ND	ND	ND	
Ottawa, Canada							Graham et al. 2004
House background	17	65%	0.1	0.51	0.36	1.63	
Cold-start house[a]	17	100%	0.1	5.76	2.69	28.6	
Cold-start garage[a]	17	100%	0.1	82.8	84.7	166	
Birmingham, United Kingdom							Kim et al. 2001
6 smoking homes	32	100%	0.11	1.7	0.7	10.8	
6 nonsmoking homes	32	<100%	0.11	0.5	0.4	1.1	
Restaurants	6	—	0.11	1.5	—	—	
Pubs	6	—	0.11	3.0	—	—	
Other indoor[b]	43	—	0.11	0.2–0.9	—	—	
Helsinki, Finland							Vainiotalo et al. 2008
10 Restaurants							
Smoking area	20	100%	0.02	4.3	—	10.1	
Non-smoking area	20	100%	0.02	1.1	—	3.9	
Hagfors, Sweden							Gustafson et al. 2007
Wood burning homes	14	NR	0.03–0.15	0.31–0.38	0.20–0.23	0.90–1.54[c]	
Reference homes	10	NR	0.03–0.15	0.11	0.10–0.11	0.18–0.24[c]	
Area outdoor	9	NR	0.03–0.15	0.12	0.11	—	

[a] Concentrations measured in the house and garage after a cold vehicle engine was started in the attached garage.
[b] Includes offices, department stores, cinemas, perfume shop, libraries, and laboratories.
[c] 90th percentile values.

LOD = limit of detection; n = number of samples; ND = not detected; NHEXAS = National Human Exposure Assessment Survey; NR = not reported

6.4.4 Other Environmental Media

1,3-Butadiene is used to manufacture synthetic rubber and plastics that are frequently used for food packaging. Because residual 1,3-butadiene may be present in the polymers used to make the containers, both the packaging and the food contained therein have been analyzed. In one study, 1,3-butadiene at a concentration of 8–9 ng/g (ppb) was detected in three of three brands of olive oil packaged in 1,3-butadiene rubber-modified acrylonitrile-acrylic bottles (McNeal and Breder 1987). Analysis of the bottles themselves found 1,3-butadiene residues as high as 6,600 ng/g (ppb). Soft-plastic packaging tubs used as containers for potato salad, cottage cheese, and yogurt had residual 1,3-butadiene levels in the range of 21–1,700 ng/g (ppb). However, no 1,3-butadiene was detected in any of the food packed in these containers (detection limit 1 ppb). Chewing gum made with a 1,3-butadiene rubber base did not show residual traces of this diene (McNeal and Breder 1987). Soft-plastic margarine tubs from five major name brands in the United Kingdom contained 1,3-butadiene residues ranging from 5 to 310 μg/kg (ppb), but none of the monomer was detected in the margarine samples themselves (detection limit 0.2 μg/kg) (Startin and Gilbert 1984). The authors concluded that migration of the 1,3-butadiene monomer from plastic packaging to food is unlikely to present a problem. Residual levels of 1,3-butadiene in food containers are closely regulated by the Food and Drug Administration.

Pellizzari et al. (1995) measured 0.1 mg of 1,3-butadiene in rapeseed oil emissions during 20 minutes of heating the oil in a wok at 260 °C. The presence of 1,3-butadiene was attributed to the pyrolytic decomposition of unsaturated fatty acids in the oil.

6.5 GENERAL POPULATION AND OCCUPATIONAL EXPOSURE

1,3-Butadiene is almost always present in the air at low levels due to its emission from motor vehicles. Therefore, the general population is probably routinely exposed to ppb levels of this compound. Exposure to 1,3-butadiene by the general population is expected to be dominated by inhalation (Higashino et al. 2007; Hughes et al. 2003). Reported mean concentrations of 1,3-butadiene measured in urban air generally range from 0.1 to 2 μg/m^3 (0.4–0.9 ppb) (Curren et al. 2006; Grant et al. 2007; Oguz et al. 2003; Reiss 2006; Reiss and Griffin 2004; Sax et al. 2004). Sapkota et al. (2006) measured mean 1,3-butadiene personal air exposure levels of 1.22 μg/m$^{3.}$ (0.55 ppb) for suburban-weekend exposure, 1.47 μg/m^3 (0.66 ppb) for urban-week day exposure, and 2.88 μg/m^3 (1.3 ppb) for tollbooth worker exposure in the Baltimore, Maryland area.

Inhalation of 1,3-butadiene by the general population may also occur due to other sources. 1,3-Butadiene has been identified in cigarette smoke; therefore, smokers and those nearby are exposed to this compound (Adam et al. 2006; Bartle et al. 1969; Blomberg and Widmark 1975; Brunnemann et al. 1990; Carmella et al. 2009; Counts et al. 2006; Lofroth et al. 1989; Pankow et al. 2004, 2007; Penn and Snyder 2007; Thweatt et al. 2007; Vainiotalo et al. 2008). Reported delivery levels of 1,3-butadiene in the mainstream smoke of cigarettes range from 1.3 to 100 μg/cigarette (Pankow et al. 2004; Thweatt et al. 2007). Nazaroff and Singer (2004) calculated a 1,3-butadiene inhalation intake of 16–37 μg/day for nonsmokers who live with a smoker. This value was based on an exposure relevant emission factor of 515 μg 1,3-butadiene/cigarette and a 1,3-butadiene exposure concentration of 1.4–3.1 μg/m^3 (Nazaroff and Singer 2004). Counts et al. (2006) measured 1,3-butadiene concentrations ranging from 11.2 to 59.3 μg/cigarette in the mainstream smoke of 26 different commercial cigarettes sold in the United States.

1,3-Butadiene is present in the smoke from brush fires, wood fires, and municipal structural fires (Austin et al. 2001; Gustafson et al. 2007; Stephens and Burleson 1969), suggesting that inhalation of the smoke from wood fires will lead to low-level exposure to 1,3-butadiene. Gustafson et al. (2007) reported a mean 1,3-butadiene concentration of 0.33 μg/m^3 (0.15 ppb) in the personal air of individuals living in wood-burning homes and 0.14 μg/m^3 (0.063 ppb) in the personal air of a reference group. Its presence in waste incinerator emissions (Junk and Ford 1980) suggests that exposure to the general population may occur for those living nearby. Small amounts of 1,3-butadiene are produced by the thermal degradation of polyurethane-coated wire, an event that may occur during an electrical overload (Rigby 1981). The thermal degradation of other 1,3-butadiene-based plastics or rubbers may produce 1,3-butadiene (Miller 1978), also leading to low-level exposure of the general population by inhalation.

If the mean daily urban air concentration of 1,3-butadiene is 0.29 ppb (0.64 μg/m^3), as determined in an analysis and compilation of experimental reports of ambient monitoring data obtained from 1970 to 1987 (Shah and Heyerdahl 1988), a nonoccupational daily intake of 12.8 μg per person can be obtained based on an average human intake of 20 m^3 air/day. Marshall et al. (2006) calculated a 1,3-butadiene intake rate of 7.3 μg/day based on an exposure concentration of 0.55 μg/m^3 and a mean breathing rate of 13.1 m^3/day. Kim et al. (2002) measured mean personal air exposure concentrations of 1.1 μg/m^3 (0.50 ppb) during the night time and 0.8 μg/m^3 (0.36 ppb) during the day time for 12 residents of Birmingham, United Kingdom who were nonsmokers.

No data are available that quantify general population exposure to 1,3-butadiene by other routes of intake, such as ingestion of contaminated drinking water. Low-level exposure by ingestion of contaminated drinking water may occur as 1,3-butadiene has been qualitatively detected in U.S. drinking water supplies (EPA 1978; Kraybill 1980). Given that residues of 1,3-butadiene have been found in plastic and rubber food containers and in a few samples of the food contained in these containers (McNeal and Breder 1987), very low-level exposure to the general population may occur by ingestion of contaminated foods packaged in these containers (Hughes et al. 2003; Leber 2001). Leber (2001) estimated an upper-bound 1,3-butadiene intake of 44 ng/day from food contact sources which include styrene butadiene rubber-containing chewing gum, polymeric coatings, closures with sealing gaskets, and other indirect additives.

According to the National Occupational Exposure Survey (NOES) conducted by NIOSH between 1980 and 1983, 9,456 workers, of which 286 are women, were estimated to be exposed to 1,3-butadiene (NIOSH 1989). The NOES database does not contain information on the frequency, concentration, or duration of exposure of workers to any chemicals listed therein. These surveys provide only an estimate of the number of workers potentially exposed to chemicals in the workplace. During a study involving 13,130 men who had been employed for at least 1 year at any of eight synthetic rubber plants in the United States or one in Canada between 1943 and 1992, it was estimated that 10,429 (79%) of these individuals had occupational exposure to 1,3-butadiene (Delzell et al. 2001; Macaluso et al. 2004). Occupational exposure to 1,3-butadiene is expected to be limited to inhalation of this compound, although dermal contact with liquified 1,3-butadiene may occur during a large spill, tank explosion, pipeline rupture, or similar catastrophic event. Specific industrial classifications or job descriptions involving exposure to 1,3-butadiene are provided below.

Levels of 1,3-butadiene measured in the air at styrene-butadiene rubber (SBR) plants have been reported (Anttinen-Klemetti et al. 2006; Jones and Harris 1983; Meinhardt et al. 1982; Sathiakumar et al. 2007; Ward et al. 2001). Table 6-5 lists 1,3-butadiene air concentrations associated with typical SBR operations. These concentrations were measured in air samples collected at different times between 1977 and 1991 at a synthetic rubber plant in Canada (Sathiakumar et al. 2007). These data show that individuals directly involved in the production of styrene-butadiene rubber have the greatest exposure to 1,3-butadiene at these facilities, although high concentrations were also associated with some equipment maintenance and control technician operations as well. Air concentrations associated with tank farm and transfer pumphouse operations (mean, 103 mg/m^3; 56.6 ppm) were at least an order of magnitude greater than those of any of the other operations. Maximum concentrations measured at this facility were as high as 1,490 mg/m^3 (673 ppm).

Table 6-5. Air Concentrations of 1,3-Butadiene Corresponding to Typical Operations Within a Styrene-Butadiene Rubber (SBR) Plant[a]

		Concentration (mg/m^3)			
Operation	n	Mean	Median	Minimum	Maximum
SBR production					
Polymerization					
Tank farm, transfer pumphouse	231	103	33.1	0.13	1,490
Reactor, blowdown, panel board	261	9.9	2.2	0.04	146
Recovery, compressor house, high solids recovery	333	22.5	3.5	0.04	1,200
Unspecified operative	35	2.4	0.91	0.00	34.3
Coagulation, blending, solutions prep	314	2.1	0.44	0.04	42.0
Finishing					
Baler, packager, reclaim	111	0.64	0.33	0.07	4.2
Dryer, baler dryer	134	2.9	0.44	0.11	271
Unspecified operative	39	0.29	0.15	0.04	1.5
Maintenance, production, maintenance field					
Foreman, engineer	15	0.44	0.40	0.04	1.5
Instrument worker, meter person, electrician, maintenance inspector	56	4.9	0.42	0.04	108
Pipefitter, oiler, mechanic, blacksmith, boilermaker, outside machinist	250	9.7	1.8	0.04	234
Cleanup crew, laborer, work pool, utility person	74	3.1	1.1	0.11	40.0
Technical/lab					
Rubber control, technician	210	30.1	2.1	0.00	1,150
Butadiene control, hydrocarbon control, technician	41	4.9	0.15	0.00	67.4
Shipping/distribution					
Labor, utility person, service person	24	0.20	0.15	0.00	0.66
Utilities					
Copolymer effluent operative	103	1.3	0.88	0.00	17.5
Unspecified/miscellaneous operative	114	0.42	0.22	0.00	4.2

[a] Air samples were collected at different times at a Canadian synthetic rubber plant between 1977 and 1991.

Source: Sathiakumar et al. 2007

1,3-Butadiene has been measured in the air of petrochemical facilities (Begemann et al. 2001a; Fustinoni et al. 2004; Lovreglio et al. 2006; Tsai et al. 2001, 2005). Mean time-weighted average concentrations of 1,3-butadiene were 10.23 mg/m^3 (4.55 ppm) between 1979 and 1996 and 0.56 mg/m^3 (0.25 ppm) between 1997 and 2003 at the Deer Park and Norco Manufacturing complexes owned by Shell Oil Company (Tsai et al. 2005). Short-term exposures to this substance were as high as 987 mg/m^3 (439 ppm) in 1979–1996 and 337 mg/m^3 (150 ppm) in 1997–2003. The decline in 1,3-butadiene levels in air at these facilities in recent years is attributed to the implementation of new health standards in 1996 (Tsai et al. 2001, 2005). A walk-through survey of 11 monomers, 17 polymers, and 2 end-user plants found that personal exposures ranged from <0.006 ppm to 374 ppm (0.013-827 mg/m^3) (Fasen et al. 1990).

Two studies have reported levels of 1,3-butadiene measured in human blood, breath, and urine. Perbellini et al. (2003) measured average 1,3-butadiene concentrations of 1.0, 1.9, and 1.0 ng/L in the alveolar air, blood, and urine, respectively, of 46 forestry workers who were nonsmokers and 3.6, 11.4, and 3.9 ng/L in the alveolar air, blood, and urine, respectively, of 15 forestry workers who were smokers. The individuals had not been involved in forestry work for 2 months; therefore, occupational exposure was not considered to be a contributing factor. Fustinoni et al. (2004) measured end-shift 1,3-butadiene levels of 2.4, 3.8, and 4.3 ng/L in the exhaled air, urine, and blood, respectively, of 42 workers with a mean personal exposure of 11.5 μg/m^3 (5.20 ppb) and levels of 2.3, 3.1, and 5.9 ng/L in the exhaled air, urine, and blood, respectively, of 43 workers with a mean personal exposure of 0.9 μg/m^3 (0.4 ppb). Pre-shift levels in exhaled air and urine were 2.4 and 3.8 ng/L, respectively, for the higher exposed workers and below detection for the lower-exposed workers.

Other occupations where exposures to 1,3-butadiene may occur include petroleum refinery workers, professional bus, truck, and taxi drivers, parking garage attendants, tollbooth workers, and employees working in areas where smoking is permitted.

6.6 EXPOSURES OF CHILDREN

This section focuses on exposures from conception to maturity at 18 years in humans. Differences from adults in susceptibility to hazardous substances are discussed in Section 3.7, Children’s Susceptibility.

Children are not small adults. A child’s exposure may differ from an adult’s exposure in many ways. Children drink more fluids, eat more food, breathe more air per kilogram of body weight, and have a larger skin surface in proportion to their body volume. A child’s diet often differs from that of adults.

The developing human’s source of nutrition changes with age: from placental nourishment to breast milk or formula to the diet of older children who eat more of certain types of foods than adults. A child’s behavior and lifestyle also influence exposure. Children crawl on the floor, put things in their mouths, sometimes eat inappropriate things (such as dirt or paint chips), and spend more time outdoors. Children also are closer to the ground, and they do not use the judgment of adults to avoid hazards (NRC 1993).

Children are expected to be exposed to 1,3-butadiene primarily through inhalation of low levels in air. Children who live near areas of heavy vehicle traffic or near industrial facilities where 1,3-butadiene is produced or used may be exposed to higher levels of 1,3-butadiene. The available data indicate that exposure to 1,3-butadiene through ingestion of food and drinking water is expected to be low relative to inhalation exposure. Biomonitoring data for children, including levels of 1,3-butadiene and its metabolites measured in breast milk, neonatal blood, cord blood, and meconium fluid have not been located in the available literature.

6.7 POPULATIONS WITH POTENTIALLY HIGH EXPOSURES

High levels of exposure to 1,3-butadiene are likely to be limited to those resulting from an occupationally related use of this compound. Inhalation is the most likely route of high exposure to 1,3-butadiene. 1,3-Butadiene is stored and transported in pressurized tanks, and it is possible that high levels of exposure by inhalation or dermal contact with the liquified gas may occur during the loading and unloading of these tanks, or by the accidental rupture of these tanks. Occupations where potentially high exposures to 1,3-butadiene may occur include those in styrene-butadiene rubber facilities, those in petroleum refineries, professional bus, truck, and taxi drivers, parking garage attendants, tollbooth workers, and employees working in areas where smoking is permitted. Individuals who live near facilities where 1,3-butadiene is produced or used have the potential for high exposure to this substance. Individuals who are frequently exposed to smoke from combustion sources, such as firefighters, may have high exposures to 1,3-butadiene (Austin et al. 2001). Individuals living very close to high traffic roads may be exposed to higher levels of butadiene.

6.8 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 1,3-butadiene 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 1,3-butadiene.

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 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 will be proposed.

6.8.1 Identification of Data Needs

Physical and Chemical Properties. The physical and chemical properties of 1,3-butadiene are well documented (Amoore and Hautala 1983; Hansch et al. 1995; HSDB 2009; Lewis 2007; Lide 2008; McAuliffe 1966; O’Neil et al. 2006; NIOSH 2005), and its environmental fate can be estimated from these properties (Lyman et al. 1982). No data needs are identified.

Production, Import/Export, Use, Release, and Disposal. According to the Emergency Planning and Community Right-to-Know Act of 1986, 42 U.S.C. Section 11023, industries are required to submit substance release and off-site transfer information to the EPA. The TRI, which contains this information for 2009, became available in February of 2011. This database is updated yearly and should provide a list of industrial production facilities and emissions.

The trends in the production and use of 1,3-butadiene are well documented (Chemical Market Reporter 2006; Chemical Week 2008; Grub and Loser 2005; Kirshenbaum 1978; SRI 2008; Sun and Wristers 2002), and there do not appear to be any critical information gaps. 1,3-Butadiene monomer does not occur in most products used in the home, although residues of this compound in commercial packages, especially food containers (McNeal and Breder 1987), are not well described. It is clear that the majority of 1,3-butadiene is released to the atmosphere (TRI09 2011). The disposal of 1,3-butadiene appears to be a straightforward process (HSDB 2009). No data needs are identified.

Environmental Fate. The fate of 1,3-butadiene in the atmosphere is well understood (Atkinson 1985; Atkinson and Carter 1984; Atkinson et al. 1984; Kopczynski et al. 1972). The fate of 1,3-butadiene in soil and water is not well understood, and partitioning from these media has to be determined from the physical and chemical properties of this compound (Lyman et al. 1982). A reliable method capable of detecting 1,3-butadiene in soil and water was not located in the available literature, and it is not clear whether 1,3-butadiene is absent from these media or simply not yet detected. The persistence of 1,3-butadiene in soil and water is not known, and the degree of partitioning from one environmental compartment to another can only be estimated. Exposure via ingestion or dermal contact to populations surrounding hazardous waste sites cannot, therefore, be accurately determined. Experimental data that address the partitioning of 1,3-butadiene in the environment, its potential to enter drinking water supplies, and its lifetime in soil and water are necessary to completely characterize the environmental fate of this compound.

Bioavailability from Environmental Media. Numerous toxicokinetic and toxicity studies in humans and animals have demonstrated the bioavailability of 1,3-butadiene from air. No data on the bioavailability of 1,3-butadiene from other sources (water or soil, for example) were located in the available literature. In conjunction with the data needs for determining 1,3-butadiene in environmental media, bioavailability studies from environmental media would be useful.

Food Chain Bioaccumulation. In theory, 1,3-butadiene is not believed to bioconcentrate significantly in fish and aquatic organisms; thus, it is not expected to biomagnify in the food chain (Hansch and Leo 1995; Lyman et al. 1982). No data addressing this point, however, were located in the available literature. Validation of these theories by valid experimental studies will aid in establishing a quantitative determination of 1,3-butadiene exposure to the general public.

Exposure Levels in Environmental Media. Reliable monitoring data for the levels of 1,3-butadiene in contaminated media at hazardous waste sites are needed so that the information obtained on levels of 1,3-butadiene in the environment can be used in combination with the known body burden of 1,3-butadiene to assess the potential risk of adverse health effects in populations living in the vicinity of hazardous waste sites.

Data on the levels of 1,3-butadiene in environmental media are limited. Extensive data on the occurrence of 1,3-butadiene in ambient air samples are available (Curren et al. 2006; Grant et al. 2007; Oguz et al. 2003; Reiss 2006; Reiss and Griffin 2004; Sax et al. 2004), but more data would be helpful. Data on the occurrence of 1,3-butadiene in water samples are very limited (Ewing et al. 1979). The presence of 1,3-butadiene in drinking water has been noted in the literature, but no concentrations or frequency of detection are available (EPA 1978; Kraybill 1980). The development of reliable analytical techniques for the analysis of 1,3-butadiene in soil and water will establish unambiguously the levels at which this compound is found in environmental media.

Exposure Levels in Humans. Limited data on levels of occupational exposure to 1,3-butadiene were available in the literature; however, occupational exposure to this compound appears to be limited to a readily definable group of industrial classifications (NIOSH 1989; Sathiakumar et al. 2007). Exposure levels for the general population are not well defined. Studies that correlate personal exposure with daily activities are necessary to adequately establish exposure levels for 1,3-butadiene. Biological monitoring studies cannot be performed until acceptable experimental techniques are developed. Exposure levels for those living near hazardous waste sites are not available and should be established.

This information is necessary for assessing the need to conduct health studies on these populations.

Exposures of Children. No information regarding exposures of children to 1,3-butadiene are currently available. Biomonitoring data for children, including levels of 1,3-butadiene and its metabolites measured in breast milk, neonatal blood, cord blood, and meconium fluid have not been located in the available literature. Studies are needed to help determine if there are differences between childhood and adult exposure to 1,3-butadiene.

Child health data needs relating to susceptibility are discussed in Section 3.12.2, Identification of Data Needs: Children's Susceptibility.

Exposure Registries.

No exposure registries for 1,3-butadiene were located. This substance is not currently one of the compounds for which a sub-registry has been established in the National Exposure Registry. The substance will be considered in the future when chemical selection is made for sub-registries 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 exposure to this substance.

6.8.2 Ongoing Studies

Ongoing studies related to the potential for human exposure to 1,3-butadiene were not located.