5. POTENTIAL FOR HUMAN EXPOSURE

5.1 OVERVIEW

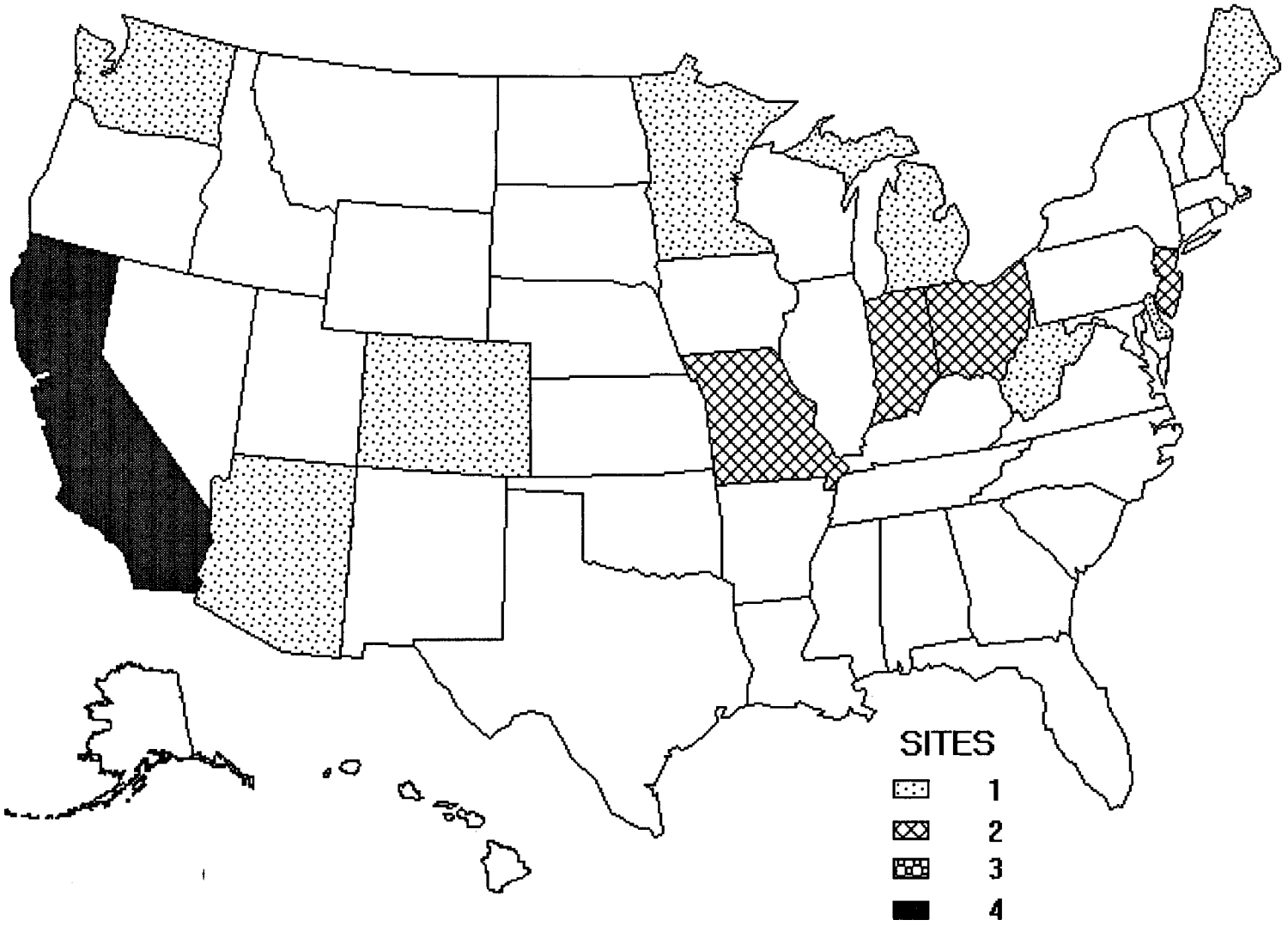
2-Butoxyethanol has been identified in at least 20 of the 1,430 current or former EPA NPL hazardous wastes sites (HazDat 1996). However, the number of sites evaluated for 2-butoxyethanol is not known. The frequency of these sites within the United States can be seen in Figure 5-l.

2-Butoxyethanol acetate has not been identified in any of the 1,430 current or former EPA NPL hazardous wastes sites (HazDat 1996). However, the number of sites evaluated for 2-butoxyethanol acetate is not known.

2-Butoxyethanol and 2-butoxyethanol acetate do not occur naturally. Little quantitative information was found in the available literature characterizing the release of these chemicals to the environment. 2-Butoxyethanol and 2-butoxyethanol acetate may be released to air, water, or soil from facilities where they are manufactured or processed. However, information about the release of 2-butoxyethanol is not available in the TRI database because the database contains such information only for the general toxic chemical category of glycol ethers and not for specific glycol ethers (EPA 1995). No information is available in the TRI database on the amount of 2-butoxyethanol acetate released to air, water, or soil by facilities that manufacture or process this compound because this compound is not included under SARA, Title III, and therefore, is not among the chemicals that facilities are required to report (EPA 1995).

2-Butoxyethanol and 2-butoxyethanol acetate may also be released to the environment from facilities that use these chemicals in the production of other materials, including resins, lacquers, varnishes, enamels, dry-cleaning compounds, soap, emulsifying agents, inks, and (to a minor extent) herbicides. These chemicals may also be directly released to the atmosphere by evaporation during the use of these products in occupational or household settings. There is a potential for atmospheric release of 2-butoxyethanol and 2-butoxyethanol acetate from hazardous waste sites; however, no data were found in the available literature. 2-Butoxyethanol is released to water via leachates from municipal landfills and hazardous waste sites (Dunlap et al. 1976a, 1976b; Stonebreaker and Smith 1980). It has been detected in surface water samples at 2 of the 20 NPL sites and in groundwater in samples at 7 of the 20 NPL sites where 2-butoxyethanol has been detected in some environmental media (HazDat 1996). It may also be directly released to air, soil, and plants during application of herbicides that contain this chemical and to surface water when sprayed in excessive amounts or drift occurs

Figure 5-1. Frequency of NPL Sites with 2-Butoxyethanol Contamination*



*Derived from HazDat 1997

(Dow 1993). 2-Butoxyethanol is also released to soil at hazardous waste sites. It has been detected in the soil samples at 3 of the 20 NPL sites and in sediment samples at 1 of the 20 NPL sites where this compound has been found in some environmental media (HazDat 1996). No information was found on detection of 2-butoxyethanol acetate in surface water, groundwater, or soil at any NPL hazardous waste sites.

Information on the transport and partitioning of 2-butoxyethanol and 2-butoxyethanol acetate is derived primarily from their physical and chemical properties (see Table 3-3 and 3-4). Any 2-butoxyethanol or 2-butoxyethanol acetate in the atmosphere would be almost exclusively in the vapor phase (Eisenreich et al. 198 1). They may be partitioned to soil and water by wet or dry deposition, with wet deposition predominating. Because of the relatively short atmospheric half-lives (<1 day) of these chemicals, they are not transported long distances in the atmosphere (Grosjean 1990; Howard 1993). Both 2-butoxyethanol and 2-butoxyethanol acetate volatilize only slowly from water, with the rate of volatilization somewhat slower for 2-butoxyethanol (Thomas 1990). These compounds remain in water primarily in the dissolved state with very little partitioning to suspended solids and sediment; the amount removed by sorption is somewhat higher for 2-butoxyethanol acetate than for 2-butoxyethanol (Swann et al. 1983). Based on bioconcentration factors (BCFs) estimated from quantitative structure-activity relationships (ASTER 1995a, 1995b), bioconcentration in aquatic organisms is not a significant process for either 2-butoxyethanol or 2-butoxyethanol acetate. Neither compound is expected to biomagnify in the food chain. The partitioning of 2-butoxyethanol and 2-butoxyethanol acetate from moist and dry soil to the atmosphere by volatilization is negligible. Both compounds are mobile in soil and leach to groundwater, with 2-butoxyethanol expected to leach more readily than 2-butoxyethanol acetate (Swann et al. 1983).

The most significant chemical reaction of 2-butoxyethanol or 2-butoxyethanol acetate in air is with photochemically generated hydroxyl radicals. Estimated atmospheric half-life values for 2-butoxyethanol range from 3.28 to 32.8 hours (Grosjean 1990; Howard et al. 1991). The atmospheric half-life value for 2-butoxyethanol acetate has been estimated to be approximately 18 hours (Grosjean 1990). The products of reaction of 2-butoxyethanol and 2-butoxyethanol acetate with hydroxyl radicals have not been identified. Neither photolysis nor reaction with ozone or nitrate radicals is an important atmospheric traniformation process for these compounds (Grosjean 1990; Howard 1993). Aerobic biodegradation appears to be the most important transformation process for both 2-butoxyethanol and 2-butoxyethanol acetate in water (Dow 1993; Price et al. 1974; Waggy et al. 1994; Zahn and Wellens 1980), with the biodegradation half-life of 2-butoxyethanol in natural bodies of surface waters estimated to be in the range of 7-28 days (Howard et al. 199 1).
The intermediate products of aerobic biodegradation of 2-butoxyethanol and 2-butoxyethanol acetate have not

been identified. However, by analogy with enzymatic degradation products found in human and animal studies, both compounds may be degraded to carbon dioxide and water via 2-butoxyacetic acid (Ghanayem et al. 1987c; Johanson et al. 1988). Neither direct photolysis nor hydrolysis is an important transformation process for these compounds in water (ASTER 1995a, 1995b; Harris 1990; Howard 1993). Because fugacity models predict that <1% of these compounds will partition into soil (ASTER 1995a, 1995b), little research has been conducted to determine their fate in this medium. By analogy with the fate of 2-butoxyethanol and 2-butoxyethanol acetate in water, it is possible that aerobic biodegradation may be the most important transformation process for these compounds in soil and sediment, with the rate of aerobic biodegradation decreasing with increasing depth (i.e., decreasing availability of oxygen). Consequently, both compounds may persist longer in deeper soils and sediments.

Except for occupational settings, data on levels of 2-butoxyethanol or 2-butoxyethanol acetate in the environment are very limited. Little information was found in the available literature on concentrations of 2-butoxyethanol in ambient air, surface water, sediment, or soil in the United States. In indoor air, 2-butoxyethanol has been found at an average concentration of 0.214 ppb volume per volume (v/v) (1.03 c(g/ m^3) (Shah and Heyderdahl 1988; Shah and Singh 1988). 2-Butoxyethanol has been found at a concentration of 23 µg /L in one surface water sample collected near the Valley of the Drums, Kentucky (Stonebreaker and Smith 1980). 2-Butoxyethanol has also been detected in one groundwater sample collected beneath a municipal landfill; however, the concentration was not reported (Dunlap et al. 1976a, 1976b). 2-Butoxyethanol has also been found in drinking water in six U.S. cities and in finished water from advanced waste treatment plants in six U.S. cities; however, no concentrations were reported (Lucas 1984). In other environmental media, 2-butoxyethanol has been found in waste water effluents at concentrations up to 100 µg /L (Jungclaus et al. 1976). No information was found in the available literature on concentrations of 2-butoxyethanol acetate in ambient or indoor air; surface water, groundwater, or drinking water; or sediment or soil. There may be a potential for contamination of food with 2-butoxyethanol and 2-butoxyethanol acetate from labeling and packaging materials or processing activities (FDA 1993a, 1993b, 1993c) or from the minor use of herbicides containing 2-butoxyethanol (Dow 1993; Leaf 1985 as cited in NIQSH 1990); however, no information was found in the available literature on detection of these compounds in food. It should be noted that the amounts of 2-butoxyethanol and 2-butoxyethanol acetate found by chemical analysis are not necessarily the amounts that are bioavailable.

The general population is exposed to 2-butoxyethanol and 2-butoxyethanol acetate primarily via inhalation or dermal absorption during use of common household products containing this compound as a solvent (see

Section 4.3). Non-occupational exposures to 2-butoxyethanol may also occur via ingestion of contaminated drinking water supplies (Lucas 1984).

Occupational exposures to 2-butoxyethanol and 2-butoxyethanol acetate also occur primarily via inhalation or dermal absorption. Estimates from the National Occupational Exposure Survey (NOES) conducted by the National Institute of Occupational Safety and Health (NIOSH) indicate that from 1981 to 1983 more than 2 million workers were potentially exposed to 2-butoxyethanol, and more than 150,000 workers were potentially exposed to 2-butoxyethanol acetate (NIOSH 1989b). In addition to occupational exposures related to the production, processing, or handling of these chemicals, workers may be exposed to 2-butoxyethanol and 2-butoxyethanol acetate in a wide variety of occupations in which products containing these compounds are used. These occupations include janitors.and cleaners, painters, mechanics, nurses and health aids, construction workers, printing machine operators, and furniture and wood finishers.

5.2 RELEASES TO THE ENVIRONMENT

5.2.1 Air

2-Butoxyethanol may be released to the atmosphere via emissions or effluents at sites where it is manufactured, processed, or used in the production of a wide variety of other materials (see Sections 4.1 and 4.3). These products include nitrocellulose resins, spray and quick drying paints and lacquers, varnishes, enamels, dry cleaning compounds, varnish and textile spot removers (in printing and dyeing), soap solutions, cosmetics, window cleaning agents, and emulsifying agents (Appelt 1990; Lewis 1993; NIOSH 1990; Rowe and Wolf 1982; Vincent et al. 1993); silicone caulk (Tichenor and Mason 1988); and herbicides (Dow 1993; BPA 1993b; Leaf 1985 as cited in NIOSH 1990). 2-Butoxyethanol may also be directly released to the atmosphere by evaporation during the use of these products.

Similarly, 2-butoxyethanol acetate may be released to the atmosphere via emissions or effluents at sites where it is manufactured, processed, or used in the production of paints, lacquers, thinners, inks, resins, and other materials (Lewis 1993; NIOSH 1990) (see Sections 4.1 and 4.3). It may also be directly released to the atmosphere by evaporation during the use of these products. The atmospheric emission rate of 2-butoxyethanol acetate (Butyl Cellosolve®acetate) from painting operations at a Janesville, Wisconsin, automobile assembly facility was estimated at 13.3 liters/hour (3.5 gallons/hour) (Sexton and Westberg 1980).

No information is available in the TRI database on the amount of 2-butoxyethanol released to the atmosphere by facilities that manufacture or process this compound because the database contains such information only for the general toxic chemical category of glycol ethers and not for specific glycol ethers (EPA 1995). No information is available in the TRI database on the amount of 2-butoxyethanol acetate released to the atmosphere by facilities that manufacture or process this compound because this compound is not included under SARA, Title III; it is therefore not among the chemicals that facilities are required to report (EPA 1995).

There is a potential for atmospheric release of 2-butoxyethanol and 2-butoxyethanol acetate from hazardous waste sites. However, no information was found on detection of these chemicals in air at any NPL hazardous waste sites (HazDat 1996).

5.2.2 Water

2-Butoxyethanol and 2-butoxyethanol acetate may be released to water by facilities that manufacture, process, or use these compounds in the production of other materials (see Sections 4.1 and 4.3). Information on releases to water from facilities that manufacture or process 2-butoxyethanol is not available in the TRI database because the database contains such information only for the general toxic chemical category of glycol ethers and not for specific glycol ethers (EPA 1995). No information is available in the TRI database on the amount of 2-butoxyethanol acetate released to water by facilities that manufacture or process this compound because this compound is not included under SARA, Title III; it is therefore not among the chemicals that facilities are required to report (EPA 1995).

2-Butoxyethanol may be released to water in leachates from municipal landfills and hazardous waste sites (Dunlap et al. 1976a, 1976b; Stonebreaker and Smith 1980). 2-Butoxyethanol has been detected in surface water samples at 2 of the 20 NPL sites and in groundwater samples at 7 of the 20 NPL sites where 2-butoxy-ethanol has been detected in some environmental medium (HazDat 1996). No information was found on detection of 2-butoxyethanol acetate in surface water or groundwater at any NPL hazardous waste sites (HazDat 1996).

2-Butoxyethanol may also be directly released to surface water when excessive amounts are sprayed or drift occurs during application of herbicides that contain this compound (Dow 1993). Direct release of 2-butoxyethanol to surface water may also occur during outdoor use of consumer products that contain this chemical (e.g., liquid cleaners, varnishes, paints); however, these releases are not expected to be significant.

5.2.3 Soil

2-Butoxyethanol and 2-butoxyethanol acetate may be released to soil by facilities that manufacture, process, or use these compounds in the production of other materials (see Sections 4.1 and 4.3). Information on releases to soil from facilities that manufacture or process 2-butoxyethanol is not available in the TRI database because the database contains such information only for the general toxic chemical category of glycol ethers and not for specific glycol ethers (EPA 1995). No information is available in the TRI database on the amount of 2-butoxyethanol acetate released to soil by facilities that manufacture or process this compound because this compound is not included under SARA, Title III and therefore, is not among the chemicals that facilities are required to report (EPA 1995).

2-Butoxyethanol and 2-butoxyethanol acetate may also be released to the soil and sediment at hazardous waste sites. 2-Butoxyethanol has been detected in soil samples at 3 of the 20 NPL sites and in sediment samples at 1 of the 20 NPL sites where this compound has been found in some environmental medium (HazDat 1996). No information was found on detection of 2-butoxyethanol acetate in soil or sediment at any NPL hazardous waste sites (HazDat 1996).

2-Butoxyethanol may also be directly released to soil during application of herbicides that contain this compound (Dow 1993). Direct release of 2-butoxyethanol to soil may also occur during outdoor use of consumer products that contain this chemical (e.g., liquid cleaners, varnishes, paints); however, these releases are not expected to be significant.

5.3 ENVIRONMENTAL FATE

5.3.1 Transport and Partitioning

The vapor pressure of 2-butoxyethanol is 0.76 mm Hg at 20°C (HSDB 1995; Lewis 1993) and 0.88 mm Hg at 25°C (Dow 1993). The vapor pressure of the acetate is 0.375 mm Hg at 20°C (HSDB 1995; Weber et al. 1981). Based on these vapor pressures, both compounds would be present almost exclusively in the vapor phase in the atmosphere (Eisenreich et al. 198 1). Compounds in the vapor phase are transported from the atmosphere to land and water by both wet deposition (via rain and snow scavenging) and dry deposition (via vapor exchange across the water and soil surfaces during impaction) (Bidleman 1988). Physical transport by wet deposition of both compounds is more important than transport arising from dry deposition since both

compounds are water soluble. The rate of transport of the compounds from one point to another point in the atmosphere will determine their ability to participate in long-distance transport. The longer the persistence time (or half-life) of a chemical in the atmosphere, the farther it is transported in air. The half-life of both chemicals is <1 day (see Section 5.3.2.1), indicating that neither is transported long distances in the air.

The unitless air/water partition coefficient or Henry's law constant (H) for 2-butoxyethanol in a 0.3M sodium chloride solution is $1.42x10^{-4}$ at 37°C (Johanson and Dynesius 1988). Conversion of this unitless value to the units commonly used for H (Thomas 1990) gives a value of $3.61x10^{-6}$ atm- m^3/mol. Other values ranging from $2.08x10^{-8}$ (HSDB 1995; SRC 1994) to $5.44x10^{-6}$ atm- m^3/mol (ASTER 1995a) for 2-butoxyethanol in water at 25 ºC have been estimated. Values of H ranging from $6.74x10^{-7}$ to $1.56x10^{-5}$ atm- m^3/mol (ASTER 1995b; Howard 1993; SRC 1994) have been estimated for 2-butoxyethanol acetate. Based on volatility characteristics associated with H (Thomas 1990), the volatilization of both compounds from water is slow, with the volatility of 2-butoxyethanol being somewhat less than that of the acetate. Based on estimated K_{oc} values of 62 and 186 for 2-butoxyethanol and 2-butoxyethanol acetate, respectively (ASTER 1995a, 1995b), the concentrations of both compounds are expected to be higher in water primarily in the dissolved state. Very little would be expected to partition into suspended solids and sediment in water, although 2-butoxyethanol acetate would be adsorbed to suspended solids and sediment to a greater extent than would 2-butoxyethanol (Swarm et al. 1983).

From quantitative structure-activity relationships, the bioconcentration factors (BCFs) for 2-butoxyethanol and 2-butoxyethanol acetate in fathead minnows *(Pimephales promelas*) have been estimated to be 2 and 9, respectively (ASTER 1995a, 1995b). Therefore, bioconcentration of either compound in aquatic organisms is not important. No information was located that would suggest that either compound biomagnifies in the food chain. This is not surprising, considering that the low K_{ow} values (see Tables 3-3 and 3-4) indicate low probability of lipid uptake.

Mackay Level 1 modeling was used to estimate the distribution of 2-butoxyethanol in various environmental compartments (air, soil, water, biota, suspended solids, sediment) (Staples 1997). The model uses physical properties (aqueous solubility, vapor pressure, soil and sediment distribution coefficient, biota concentration factor) and the assumption that environmental compartments are approximately proportional in size to the natural environment. The model calculates the general distribution of 2-butoxyethanol following the release of 100 moles. The model estimated that at equilibrium about 96% of the 2-butoxyethanol would be found in

water, with <0.1%, 2%, <0.1 %, <0.1 %, and 2% found in air, soil, biota, suspended solids, and sediment, respectively.

The transport of the two compounds from moist and dry soil to air via volatilization is negligible because of the low values for Henry's law constant and vapor pressure. The estimated K_{oc} values of 62 and 186 for 2-butoxyethanol and 2-butoxyethanol acetate, respectively (ASTER 1995a, 1995b), suggest that both compounds would be mobile in soils and would leach from soil to groundwater, although the leachability of 2-butoxyethanol is higher than that of 2-butoxyethanol acetate (Swann et al. 1983).

5.3.2 Transformation and Degradation

5.3.2.1 Air

The direct photolysis of 2-butoxyethanol in the atmosphere is not important since it does not absorb sunlight available in the troposphere (Howard 1993; Silverstein and Bassler 1963). The reactivity of 2-butoxyethanol with three important atmospheric reactants produced by photochemical reactions was estimated from structure-reactivity relationships (Grosjean 1990). The rates of reaction of 2-butoxyethanol with ozone and nitrate radicals were estimated to be too slow to be important (Grosjean 1990). The reactions of ozone and nitrate radicals with 2-butoxyethanol acetate, will also be negligible. The rate constant for reaction of 2-butoxyethanol with hydroxyl radicals has been estimated to range from 2.1 to 2.3×10^{-11} cm^3/molecule-set (Grosjean 1990; SRC 1995). If the average concentration of hydroxyl radicals during a 24-hour day is assumed to be 5×10^5 molecules/ cm^3, the half-life (first order kinetics) for 2-butoxyethanol can be estimated to range from approximately 3.28 to 32.8 hours (Grosjean 1990; Howard et al. 1991; Lyman 1990; SRC 1995). Therefore, 2-butoxyethanol does not persist in the atmosphere. Based on a structure-reactivity relationship method (Atkinson 1987), the rate constant for the reaction of 2-butoxyethanol acetate with hydroxyl radicals in the atmosphere was estimated to be 2.1×10^{-11} cm^3/molecule-set (Howard 1993; SRC 1995). Assuming an average (24-hour) day hydroxyl radical concentration of 5×10^5 molecules/ cm^3, the half-life (first order kinetics) for this reaction is approximately 18 hours (Grosjean 1990; Lyman 1990; SRC 1995). Therefore, 2-butoxyethanol acetate also does not persist in the atmosphere. The products of reaction of 2-butoxyethanol and 2-butoxyethanol acetate with hydroxyl radicals have not been identified.

5.3.2.2 Water

Functional groups in both alcohols and ethers are generally resistant to hydrolysis (Harris 1990). Therefore, hydrolysis of 2-butoxyethanol, which contains both alcohol and ether functional groups, is not expected. The estimated hydrolysis half-life (first order kinetics) for 2-butoxyethanol acetate of >1,000 days (ASTER 1995a) indicates that the hydrolysis of 2-butoxyethanol acetate in water is also not expected. 2-Butoxyethanol does not absorb light of wavelength >290 nm (Silverstein and Bassler 1963). Therefore, photolysis of this compound by absorption of sunlight is not important. Aerobic biodegradation screening studies with filtered sewage for inocula and theoretical biological oxygen demand (BODT) as a measure of complete biodegradation (mineralization of the compound to carbon dioxide and water) indicated 5% mineralization of 2-butoxyethanol in 5 days (Dow 1993), 57-74% in 10 days (Dow 1993; Price et al. 1974), and 72-88% in 20 days (Dow 1993; Price et al. 1974). The Organization for Economic Cooperation and Development (GECD) recommends a closed bottle biodegradation test with settled sewage as microbial inoculum for determining the biodegradation potential of organic chemicals. The biodegradation of 2-butoxyethanol was determined using the OECD test procedure, to be 47% in 5 days, 70% in 15 days, and 75% in 28 days (Waggy et al. 1994). Thus, the tests used both in the United States and in Europe to determine the biodegradation potential of organic chemicals indicate that 2-butoxyethanol is readily biodegradable. The aerobic biodegradation half-life (first order kinetics) of 2-butoxyethanol in natural bodies of surface water has been estimated to be in the range of 7-28 days, compared to an estimated aqueous anaerobic biodegradation halflife (first order kinetics) ranging from 28 days to 16 weeks (Howard et al. 1991). Hydrolysis is not likely to be an important transformation mechanism for 2-butoxyethanol (ATSDR 1995b). The biodegradation half-life (first order kinetics) of 2-butoxyethanol in groundwater has been estimated to range from 14 days to 8 weeks, based on the estimated aerobic biodegradation (unacclimated aqueous) half-life for this compound (Howard et al. 1991). The intermediate products of aerobic biodegradation of 2-butoxyethanol were not identified in any of the screening tests. However, as observed in human and animal studies (Johanson et al. 1989), 2-butoxy-ethanol acetate may enzymatically hydrolyze to 2-butoxyethanol and acetic acid as a result of biodegradation. By analogy to animal metabolism (Ghanayem et al. 1987c)< it is possible that any 2-butoxyethanol formed may undergo further enzymatic oxidation (e.g., via dehydrogenase) to the butoxyacetaldehydeand finally to 2-butoxyacetic acid before being degraded to carbon dioxide and water.

Biodegradation studies were conducted using the Zahn-Wellens screening test (a batch method in which biodegradation by activated sludge is determined indirectly by measurement of chemical oxygen demand and/or dissolved organic carbon removal). This study indicated that under the test conditions, the

biodegradation of 2-butoxyethanol acetate was 90% within 6.5 days, with a degradation rate of 12% per day as determined by measurement of chemical oxygen demand (Zahn and Wellens 1980). No lag period was observed for onset of biodegradation in the Zahn-Wellens test. Therefore, the acetate will biodegrade easily in natural bodies of surface water, but no estimate of biodegradation half-life was located in the literature.

5.3.2.3 Sediment and Soil

On the basis of a fugacity model, it has been estimated that 2-butoxyethanol partitions into different environmental compartments as follows: 15.98% into air, 0.05% into soil, 83.93% into water, and 0.04% into sediment (ASTER 1995a). 2-Butoxyethanol acetate partitions differently into environmental compartments as follows: 35.1% into air, 0.26% into soil, 64.37% into water, and 0.24% into sediment (ASTER 1995b). Neither compound was predicted to partition into suspended solids or aquatic biota (ASTER 1995a, 1995b). Because of these low partition probabilities into soil and sediment, little research effort has been made to elucidate the fate of either compound in these media. As discussed in Section 5.3.2.2, 2-butoxyethanol does not have any chromophoric group to absorb sunlight incident on the terrestrial surface. Therefore, photolysis of 2-butoxyethanol present in moist soil is not likely. Drawing an analogy from water (see Section 5.3.2.2), it can be concluded that, barring any catalytic effect by component(s) in moist soil or sediment, hydrolysis of 2-butoxyethanol or 2-butoxyethanol acetate is not significant. Aerobic screening studies in water (see Section 5.3.2.2) suggest that aerobic biodegradation is the most important transformation process for both compounds in soil and sediment. The aerobic biodegradation half-life (first order kinetics) of 2-butoxyethanol in soil has been estimated to be 7-28 days (Howard et al. 1991). However, for some soils, as the availability of oxygen decreases with the increase in depth of soil or sediment, the rate of aerobic biotransformation of both compounds decreases. Therefore, both compounds may persist longer in deeper soils and sediments. By direct analogy to estimates of aqueous biodegradation rates (Howard et al. 199 l), the rate of anaerobic biodegradation of 2-butoxyethanol in soil may be on the order of 4 times slower than aerobic biodegradation (half-life estimates range from 4 to 16 weeks).

5.4 LEVELS MONITORED OR ESTIMATED IN THE ENVIRONMENT

5.4.1 Air

Information on levels of 2-butoxyethanol in air is very limited. 2-Butoxyethanol was reported among 34 major compounds identified in high-volume air samples at a semi-rural site in the United Kingdom;

however, no concentrations were given (Welch and Watts 1990). Analysis of data from the National Ambient Volatile Organic Compounds (VOCs) Database indicates that, for 14 samples, the daily arithmetic mean and median indoor atmospheric concentrations of 2-butoxyethanol in a non-industrial office setting were 0.214 ppb (v/v) (1.03 µg /m^3) and 0.075 ppb (0.36 µg /m^3), respectively (Shah and Heyderdahl 1988; Shah and Singh 1988). 2-Butoxyethanol was found in only 1 of 6 samples of indoor air from 14 homes in northern Italy, at a concentration of 1.7 ppb (8 µg /m^3) (DeBortoli et al. 1986).

No information was found in the available literature on concentrations of 2-butoxyethanol acetate in air.

5.4.2 Water

Very little information was found in the available literature on concentrations of 2-butoxyethanol in water. 2-Butoxyethanol was detected at a concentration of 23 µg /L in 1 of 7 surface water samples collected in 1979 near The Valley of the Drums, Kentucky, where an estimated 100,000 drums of industrial waste were stored, buried, or dumped between 1967 and 1977 (Stonebreaker and Smith 1980). In Japan, 2-butoxyethanol has been found at concentrations of 1,310 and 5,680 ppb (µg/L) in surface water from the Hayashida River (Uasuhara et al. 1981). The contamination was attributed to effluents from the leather industry. 2-Butoxyethanol has also been found in one groundwater sample from an aquifer beneath a municipal landfill in Norman, Oklahoma (concentration not given) (Dunlap et al. 1976a, 1976b). 2-Butoxyethanol was identified as a contaminant in drinking water in Cincinnati, Ohio; Philadelphia, Pennsylvania; Miami, Florida; New Orleans, Louisiana; Ottumwa, Iowa; and Seattle, Washington. It was also found in finished water from advanced waste treatment plants in Pomona, Escondido, Lake Tahoe, and Orange County, California; Dallas, Texas; and Washington, DC. Concentrations were not reported (Lucas 1984).

Library searching of mass spectral data from water and soil samples from U.S. hazardous waste sites taken between late 1987 and mid-1989 identified 2-butoxyethanol in 110 samples (Eckel et al. 1996). The total number of samples examined was not stated, and the study authors indicate that these data represent minimum occurrences. Although the medium in which the compound was found was not indicated, the properties of 2-butoxyethanol led the study authors to suggest that it was most likely to have been found in water. Among the glycol ethers and related compounds for which the study authors searched, 2-butoxyetbanol was found most frequently. Ethylene glycol mono acetate and tripropylene glycol monoethyl ether, were the second and third most frequently identified chemicals.

No information was found in the available literature on the concentrations of 2-butoxyethanol acetate in surface water, groundwater, or drinking water.

5.4.3 Sediment and Soil

No information was found in the available literature on concentrations of 2-butoxyethanol or 2-butoxyethanol acetate in sediment or soil.

5.4.4 Other Environmental Media

2-Butoxyethanol was found in waste water from a tire plant at an approximate concentration of 0.03 (±0.009) mg/L (Jungclaus et al. 1976). The detection of 2-butoxyethanol in groundwater underlying a municipal landfill site suggests that this compound may be present in landfill leachates (Dunlap et al. 1976a, 1976b).

In the 1970s, it was estimated that more than 740 products marketed in the United States contained 2-butoxyethanol, at an average concentration of 2.8%; approximately half of these were products for household use (Consumer Products Safety Commission 1977). In a 1978-l 982 survey in the Federal Republic of Germany, both 2-butoxyethanol and 2-butoxyethanol acetate were found to occur in 0.4% of 275 different organic solvents commonly used for inks, degreasers, paints, and thinners (concentrations not reported) (Lehmann et al. 1986). A paint stripping formulation was found to contain 35% 2-butoxyethanol (Hahn and Werschulz 1986), whereas the concentration of 2-butoxyethanol in four different paint thinners was found to range from 0%(3 samples) to 5% (w/w) (1 sample) (Yamano et al. 1991). 2-Butoxyethanol has also been found as a volatile organic emission from silicone caulk (Ticbenor and Mason 1988). An epoxy resin contained 7% solvents (2-butoxyethanol, xylene, and methyl-n-amyl ketone) (Rempel et al. 1991). While not detected in a machine cutting fluid prior to use, 2-butoxyethanol was found in the used fluid at a concentration of 0.060 µg /g (60 ppb) (Yasuhara et al. 1986). In a recent survey in France of 1,242 cleaning agent formulations, 10% of the formulations contained 2-butoxyethanol (concentration range, 0.2-80% by volume); approximately 50% of window-cleaning agent formulations tested contained 2-butoxyethanol (concentration range, l-30% by volume) (Vincent et al. 1993). The concentration of 2-butoxyethanol in aqueous coating systems may vary between 2% and 5%, depending on the formulation (Appelt 1990). The concentration of 2-butoxyethanol acetate used as a retarder solvent m coating formulations is generally l-5% by volume (Leaf 1985 as cited in NIOSH 1990).

No information was found in the available literature on concentrations of 2-butoxyethanol or 2-butoxyethanol acetate in food. The estimated BCFs of 2-butoxyethanol and 2-butoxyethanol acetate of only 2 and 9, respectively, in fathead minnows *(Pimephales promelaas)* (ASTER 1995a, 1995b), and the evidence against biomagnification of these compounds in the food chain (see Section 5.3.1), indicate that these compounds would not be present in most foods. There is a potential for contamination of food with these compounds, however, from labeling, packaging, and processing activities Both 2-butoxyethanol and 2-butoxyethanol acetate are indirect food additives that may be used as components of adhesives (FDA 1993a). 2-Butoxyethanol may also be used as a solvent in materials intended for packaging, transporting, holding, or otherwise contacting dry food (FDA 1993b). 2-Butoxyethanol may also be used in washing or to assist in the peeling of fruits and vegetables with lye, and in flume water (at concentrations not to exceed 1 μg /rnL) for washing sugar beets (FDA 1993c). There may also be a potential for contamination of plant foods from the minor use of herbicides containing 2-butoxyethanol (Dow 1993; EPA 1993b; Leaf 1985 as cited in NIOSH 1990). A scheme that considered factors such as production volume, pattern of usage, possible fate in the environment, likelihood of the chemical entering the food chain, mechanism of entry into the food chain, persistence and accumulation in the food chain, and toxicity, was used to prioritize chemicals for their potential to contaminate food. A low priority score was obtained for 2-butoxyethanol on the basis of this scheme (Wearne et al. 1996). Among the 70 chemicals ranked, it was ranked lower than 45 chemicals, higher than 8 chemicals, and was given the same ranking as 16 other chemicals.

5.5 GENERAL POPULATION AND OCCUPATIONAL EXPOSURE

The general population is exposed to 2-butoxyethanol primarily by inhalation of vapors or dermal absorption during use of common household products that contain this compound as a solvent. At room temperature, 2-butoxyethanol is a liqluid with a relatively low vapor pressure (see Table 3-3) and is readily absorbed through the skin (Bartnik et al. 1987; Dugard et al. 1984; Johanson 1988; Johanson and Boman 1991; Johanson et al. 1988, 1989; NIOSH 1990). Therefore, dermal absorption may be the primary route of exposure in cases where protective gloves or other clothing are not worn when using products containing 2-butoxyethanol. It was estimated that approximately half of the more than 740 products containing 2-butoxyethanol that were marketed in the United States in the 1970s were intended for household use. The average concentration of 2-butoxyethanol in these products was 2.8% (Consumer Products Safety Commission 1977). Common household products that contain glycol ethers include acrylic polymers, paints, brake fluids, waxes, cleaning agents, shampoos, degreasing agents, wood finishes, and silicone caulks (Appelt 1990; Browning and Curry 1994; Lewis 1993; NIOSH 1990; Tichenor and Mason 1988; Vincent et al. 1993).

Similarly, the widespread use of 2-butoxyethanol acetate as a solvent in a wide variety of household products such as inks, stains, paints, lacquers, varnishes, thinners, and degreasers (Lehmann et al. 1986; Lewis 1993; NIOSH 1990) can result in general population exposure through inhalation of vapors and dermal absorption. Non-occupational exposures to 2-butoxyethanol may also occur via ingestion, particularly among populations with contaminated drinking water supplies (Lucas 1984).

No quantitative information was found in the available literature on general population exposures to 2-butoxyethanol or 2-butoxyethanol acetate in the United States.

Occupational exposures to 2-butoxyethanol and 2-butoxyethanol acetate occur via both inhalation of vapors and dermal absorption (Angerer et al. 1990; Johanson et al. 1989; Sohnlein et al. 1993; Vincent et al. 1993, 1996). Because these compounds are liquids at room temperature with relatively low vapor pressures (see Tables 3-3 and 3-4), and are readily absorbed through the skin (Bartnik et al. 1987; Dugard et al. 1984; Johanson 1988; Johanson and Boman 1991; Johanson et al. 1988,1989; NIOSH 1990), dermal absorption may be predominant or may contribute significantly to overall exposure. Absorption from excessive contact with skin and eyes may occur, particularly when proper protective clothing is not worn.

OSHA requires employers of workers who are occupationally exposed to 2-butoxyethanol to maintain employee exposure at or below the permissible exposure limit (PEL) of 50 ppm (OSHA 1974). The American Conference of Governmental Industrial Hygienists (ACGlH) has recommended a time-weighted average threshold limit value (TWA-TLV) of 25 ppm for occupational exposure to 2-butoxyethanol (ACGIH 1994). The National Institute of Occupational Safety and Health (NIOSH) has set recommended exposure limits (RELs) of 5 ppm for both 2-butoxyethanol and 2-butoxyethanol acetate (NIOSH 1990, 1992). The REL is expressed as a time-weighted average (TWA) exposure for p to 10 hours per day over a 40-hour work week. These standards were set taking into account that airborne or direct exposure by the cutaneous route contributes to overall exposure. The NIOSH RELs prohibit direct dermal contact because 2-butoxyethanol and 2-butoxyethanol acetate are readily absorbed through the skin (NIOSH 1990).

Data from the National Occupational Exposure Survey (NOES) conducted by NIOSH from 1980 to 1983 indicate that an estimated 2,139,292 workers in 2,259 industry/occupation categories were potentially exposed to 2-butoxyethanol in the United States from 1981 to 1983, and an estimated 150,892 workers in 236 industry/occupation categories were potentially exposed to 2-butoxyethanol acetate (NIOSH 1989b). These numbers do not include workers potentially exposed to trade-name compounds that contain 2-butoxy-

ethanol or 2-butoxyethanol acetate. Occupations with the greatest potential for exposure to 2-butoxyethanol included janitors and cleaners; nurses and health aides; hairdressers and cosmetologists; printing, spray painting, metal plating, laundry, dry cleaning, and textile sewing-machine operators; electricians; mining workers; heating, air conditioning, and refrigeration mechanics; electrical power installers and repairers; bus, truck, aircraft, and stationary-engine mechanics; garage and service-station workers; miscellaneous food-preparation workers; plumbers, pipefitters, and steam fitters; automobile mechanics; clinical laboratory technologists and technicians; motor-vehicle assemblers; funeral directors; vehicle washers and equipment cleaners; painters; construction workers; telephone installers and repairers; and furniture and wood-finishers. Occupations with the greatest potential for exposure to 2-butoxyethanol acetate included wood-furniture assemblers and finishers; mining, textile sewing, spray painting, printing, and miscellaneous machine operators; secretaries; janitors and cleaners; automobile-body and related repairers; painters; construction workers; and heavy-equipment, bus, truck, and stationary engine mechanics (NIOSH 1989b).

A survey of chemical exposure in the workplace in Denmark estimated that there were a total of 55,000 exposures to 2-butoxyethanol in 1989 (Brandorff et al. 1995). The industry groups in which exposures occurred were as follows: the manufacture of fabricated metal parts; electrical machinery and apparatus; the manufacture of transport equipment; painters and carpenters; construction, publishing, and printing; wholesale trade; the manufacture of textiles and leather; the manufacture of wood and furniture; the manufacture of chemicals; the manufacture of paints, petroleum, and bitumen products; the manufacture of non-metallic mineral products; the manufacture of precision and optical instruments; the manufacture of plastic; boat building and repair; personal services, cleaning, and hair dressing; sewage and refuse disposal; agriculture, hunting, and forestry; and health services and pharmacies.

There is rather extensive information in the available literature documenting occupational exposures to 2-butoxyethanol. Extremely low exposures have been reported for non-industrial office settings. Data from the National Ambient VOCs database indicate that for 14 samples from non-industrial offices, the daily mean and median indoor atmospheric concentrations of 2-butoxyethanol were 0.2 14 ppb (v/v) (1.03 µg / m^3) and 0.075 ppb (0.36 µg /m), respectively (Shah and Heyderdahl 988; Shah and Singh 1988). Higher levels of exposure have been found in other occupational settings. Representative information on inhalation exposures of 2-butoxyethanol in various occupations in the United States is summarized in Table 5-l. These data indicate that personal exposures above the NIOSH REL of 5 ppm (24 mg/ m^3) have been found in silk screening, printing, furniture production, and asbestos/mastic removal, with maximum exposures of 36, 8.3, 9.9, and 22 ppm (174, 40, 48, and 106 mg/ m^3), respectively. It should be noted that the OSHA PEL, the

Table 5-1. Occupational Exposures to 2-Butoxyethanol by Work Site or Process

Work site or process	Number/type of samples	Concentration[a,b] Range	Concentration[a,b] Mean	Reference
Silk screening	6/P	1.1–5.3 (5.3–25.5)	3.4 (16.6)	Boiano 1983
Silk screening	3/P	3–5 (14–24)	4 (19)	Apol 1986
Silk screening	NR/P	1.4 (6.8) maximum[c]	NR	Clapp et al. 1984
Silk screening	14/P 8/A	13–36 (63–174) 23–169 (111–817)	25 (121) 63 (304)	Kullman 1988
Silk screening				Baker et al. 1985
Silk screeners	16/P	NR	6.8 (32.9)	
Spray painters	5/P	NR	2.6 (12.6)	
Controls	6/P	NR	0.3 (1.4)	
Silk screening/clean-up and maintenance	5/P	1.7–9.8 (8.2–47.4)	5.2 (25.1)	Salisbury et al. 1987
Printing press operation	3/P	<0.04–0.49 (<0.2–2.4)	<0.2 (<1.0)	Lewis and Thoburn 1981
Printing press operation	1/P	8.3 (40.1)	NR	Lee 1988
Printing press operation	2/P	ND[d]–0.53 (ND–2.6)	<0.33 (<1.6)	Kaiser 1990
Label production/plate makers and pressmen	7/P	1–2 (5–10)	2 (10)	Apol 1981
Spray painting	NR/P	0.75 (3.62)[e]	NR	Clapp et al. 1984

Table 5-1 (continued)

Work site or process	Number/type of samples	Concentration[a,b] Range	Concentration[a,b] Mean	Reference
Specialty chemical production	NR/P NR/A	ND[f]–0.1 (ND–0.5) ND–1.7 (ND–8.2)	NR, NR	Clapp et al. 1984
Furniture production/finishing	64/P	0.07–9.9 (0.34–48.0)	1.5 (7.1)	Zaebst 1984
Cabinet finishing	6/P	ND[f]–0.4 (ND–1.9)	NR	Newman and Klein 1990
Removal of asbestos-containing mastic	7/P	2–22 (8–107)[g]	12 (60)	Kelly 1993
Hospital housekeeping	4/P	All samples <0.2 (<1.0)	<0.2 (<1.0)	Apol and Cone 1983
Paint formulators	4/P	0.41–3.13	1.26	Foo et al. 1994

[a]Units are ppm, with mg/m^3 in parentheses.
[b]Time-weighted average
[c]Maximum 2-butoxyethanol acetate exposure was 0.75 ppm (4.9 mg/m^3).
[d]Limit of detection = 0.14 ppm (0.7 mg/m^3)
[e]Reported as "typical" atmospheric concentration
[f]Limit of detection not reported
[g]Six of seven exposures above the NIOSH REL of 5 ppm

A = area sample; ND = not detected; NIOSH = National Institute for Occupational Safety and Health; NR = not reported; P = personal (breathing zone) sample; REL = Recommend Exposure Limit

legally enforceable standard for 2-butoxyethanol, is 50 ppm (242 mg/ m^3) (OSHA 1974). A maximum exposure to 2-butoxyethanol acetate of 0.75 ppm (4.9 mg/ m^3) was reported for workers in a screen printing operation in the United States (Clapp et al. 1984). No other reports of occupational exposure to 2-butoxyethanol acetate in the United States were found in the available literature.

Exposures to 2-butoxyethanol and 2-butoxyethanol acetate were also found in a 1983 survey of 336 Belgian businesses (Veulemans et al. 1987a). In this study, 2-butoxyethanol was found in 25 of 94 air samples from sites using printing pastes; 10 of 8 1 samples where painting was done; 1 of 20 samples from automobile repair shops; and 17 of 67 samples from various other industrial sites where materials such as varnishes, sterilization agents, and cleaning agents were used. The geometric mean atmospheric concentrations (mg/ m^3) and ranges of 2-butoxyethanol at various sites were as follows: printing shops, 4.1 (0.8 ppm), range 1.5-17.7 (0.3-3.7 ppm); painting areas, 18.8 (3.9 ppm), range 3.4-93.6 (0.7-19.4 ppm); automobile repair shops, 5.9 (1.2 ppm) (one sample); various other industries, 8.5 (1.8 ppm), range 0.2-1,775 (<0.1-367 ppm). 2-Butoxy-ethanol acetate was found in 4 of 94 samples from sites using printing pastes, and in 3 of 67 samples from various other industrial sites using materials such as varnishes, sterilization agents, and cleaning agents. The geometric mean atmospheric concentrations (mg/m^3) of 2-butoxyethanol acetate were 12.7 (2.6 ppm) at these sites using printing pastes and 10.6 (2.2 ppm) at other industrial sites, respectively; corresponding concentration ranges (mg/ m^3) were 4.6-26.5 (1.0-5.5 ppm) and 8.9-11.7 (1.8-2.4 ppm).

Veulemans et al. (1987b) also performed a field study of the urinary excretion of ethoxyacetic acid (EAA) during repeated daily exposure to the ethyl ether of ethylene glycol and the ethyl ether of ethylene glycol acetate. The urinary excretion of EAA was studied in a group of five women daily exposed to the ethyl ether of ethylene glycol and the ethyl ether of ethylene glycol acetate during 5 days of normal production and 7 days after a 12-day production stop. The workers were exposed to a complex solvent mixture containing different ethylene glycol derivatives, esters, alcohols, ketones, and trichloroethane. 2-Butoxyethanol (mean concentration of 3.3 mg/ m^3; maximum concentration of 5.7 mg/ m^3) was one of the chemicals that the workers were exposed to.

In a survey of occupational exposure to glycol ethers in France that used both atmospheric and biological monitoring, the highest level of exposure to 2-butoxyethanol was among persons cleaning cars (Vincent et al. 1996). The average concentration of 2-butoxyethanol in air was 1.8 ppm, with pre- and post-shift urinary concentrations of 2-butoxyacetic acid of 15.1 and 96.5 mg/g creatinine, respectively. The study authors indicated that exposure of these workers was predominantly by dermal absorption.

5. POTENTIAL FOR HUMAN EXPOSURE

Based on measurements of air concentrations of 2-butoxyethanol in occupational settings and the levels found in consumer products, OECD (1997) has estimated mg/kg/day doses for various occupations and consumer activities. These dose estimates are presented in Table 5-2. Silk screening with a product containing 50% 2-butoxyethanol resulted in the highest dose estimate (18.2 mg/kg/day), followed by cleaning with a product containing 30% 2-butoxyethanol (l3.7 mg/kg/day). Painting for 6 hours with a coating containing 1.5% 2-butoxyethanol resulted in an estimated dose of 1.05 mg/kg/day. This report suggested that indirect exposure of the public to 2-butoxyethanol in the environment would be limited to the use of products containing 2-butoxyethanol in public places. Because of the low volatility of 2-butoxyethanol and its high biodegradability, they concluded that exposure in the environment would be minimal.

Because both 2-butoxyethanol and 2-butoxyethanol acetate are readily absorbed through the skin (Bartnik et al. 1987; Dugard et al. 1984; Johanson 1988; Johanson and Boman 1991; Johanson et al. 1988,1989; NIOSH 1990; Truhaut et al. 1979), environmental monitoring of breathing zone or air concentrations in the work area of these substances generally is not adequate to assess overall exposures to these compounds. Biological monitoring of the toxic metabolite, 2-butoxyacetic acid, in urine is considered preferable (Angerer et al. 1990; Johanson 1988; Johanson et al. 1989; Sohnlein et aL 1993; Vincent et aJ. 1993). Methods are available for the determination of 2-butoxyethanol in blood and urine (Johanson et al. 1986a; Smallwood et al. 1984) (see Chapter 6); however, the utility of 2-butoxyethanol as a biomarker of exposure is limited because of its short half-life (40 minutes) in blood and the small portion of the absorbed dose (<0.03%) excreted unchanged in urine (Johanson et al. 1986a, 1988). In contrast, the half-life of urinary 2-butoxyacetic acid was reported to be 5.77 hours after a controlled, 2-hour inhalation exposure to 2-butoxyethanol, with the amount of 2-butoxyacetic acid excreted in urine corresponding to 15-55% of the absorbed dose of 2-butoxyethanol (Johanson et al. 1986a). 2-Butoxyethanol acetate is rapidly metabolized to 2-butoxyethanol in the body, also resulting in 2-butoxyacetic acid in urine (Johanson 1988; Johanson et al. 1989). Thus, 2-butoxyacetic acid provides a measure of exposure to both 2-butoxyethanol and its acetate. Conjugates of 2-butoxyacetic acid with glutamine in urine have also been measured as a biomarker of exposure to 2-butoxyethanol and 2-butoxy-ethanol acetate; most exposed people excrete a combination of free and conjugated butoxyacetic acid (Rettenmeier et al. 1993; Sakai et al. 1994). The results of several recent studies evaluating o&upational exposures to 2-butoxyethanol and 2-butoxyetbanol acetate by environmental and biomonitoring are summarized below.

Twelve workers in a varnish production facility were found to be exposed to 2-butoxyethanol at an average concentration of 1 .1 ppm (5.3 mg/ m^3); individual exposures ranged from <0.1-8.1 ppm (<0.5-39 mg/ m^3)

Table 5-2. Estimated Occupational and General Exposure to 2-Butoxyethanol[a]

Exposure	Maximum vapor concentration	Percentage of exposure period with dermal exposure	Total dose (inhalation and dermal exposure)
Occupational[b]			
Manufacture of 2-butoxyethanol	3 ppm (14.5 mg/m^3)	1%	2.2 mg/kg/day
Formulation of products containing 2-butoxyethanol			
10%	2 ppm (9.7 mg/m^3)	20%	1.9 mg/kg/day
30%	10 ppm (145 mg/m^3)	20%	8.2 mg/kg/day
60%	10 ppm (145 mg/m^3)	20%	9.5 mg/kg/day
Cleaning with products containing 2-butoxyethanol			
0.1%	2 ppm (9.7 mg/m^3)	100%	1.4 mg/kg/day
1.0%	2 ppm (9.7 mg/m^3)	100%	1.6 mg/kg/day
10%	4 ppm (19.4 mg/m^3)	100%	5.0 mg/kg/day
30%	10 ppm (145 mg/m^3)	100%	13.7 mg/kg/day
Printing			
Silk screening 50%	10%	100%	18.2 mg/kg/day
General printing 20%	2%	100%	6.0 mg/kg/day
Consumer exposure			
Cleaning[c]	4	100% of 1 hour	0.58 mg/kg/event
Paints/surface coatings 1.5%[d]	2	100% of 6 hours	1.05 mg/kg/day
Cosmetics[e]			
Semi-permanent hair dye	Not applicable	Not applicable	5 mg/day
Permanent hair dye	Not applicable	Not applicable	3.6 mg/day
Environmental exposure	Not estimated	Not estimated	Likely to be minimal

[a]Derived from OECD (1997)

[b]For occupational exposure to vapor, a respiratory rate of 1.3 m^3/hour and a bioavailability of 0.75 were assumed. For dermal absorption, a skin absorption rate of 0.2 mg/cm^2/hour and a skin surface area of 1,000 cm^2 were assumed. A body weight of 70 kg, and an 8-hour workday were assumed.

[c]Assuming a respiratory rate of 0.8 m^3/hour and a body weight of 60 kg for a 1 hour cleaning event. For dermal absorption, a skin absorption rate of 0.2 mg/cm^2/hour and a skin surface area of 1,000 cm^2 were assumed.

[d]Assuming a respiratory rate of 0.8 m^3/hour and a body weight of 60 kg for a 6 hour painting period. For dermal absorption, a skin absorption rate of 0.2 mg/cm^2/hour and a skin surface area of 1,000 cm^2 were assumed.

[e]Assuming a concentration of 10% and application of 100 mL once per month for permanent dyes, and 35 mL once per week for semi-permanent dyes. Estimated that 1% of the amount applied may be absorbed.

(Angerer et al. 1990). Internal exposure was estimated through biological monitoring of 2-butoxyethanol in blood and 2-butoxyacetic acid in urine, where average post-shift (end of work shift) concentrations of these compounds were found to be 121.3 µg /L. and 10.5 mg/L respectively. A markedly lower pre-shift (beginning of work shift) concentration of 2-butoxyacetic acid in the urine (3.3 mg/L) was reported. Most of the exposure was attributed to dermal absorption.

In a study in Germany, 19 workers in the varnish production industry were evaluated for occupational exposures to glycol ethers on the first 2 days of the work week, after an exposure-free weekend (Sohnlein et al. 1993). Urine samples of the workers were collected on the morning of the first day (preshift) and at the end of the second day (postshift). Daily mean concentrations of 2-butoxyethanol from personal air monitoring were 0.5 ppm (2.4 mg/ m^3) on the first day and 0.6 ppm (2.9 mg/ m^3) on the second day; corresponding daily concentration ranges were <0. l-l .4 ppm (<0.5-6.8 mg/ m^3) and <0. l-l.0 ppm (<0.5-4.8 mg/ m^3). The mean urinary 2-butoxyacetic acid concentration was 0.2 mg/L on Monday pre-shift and 16.4 mg/L on Tuesday post-shift, with corresponding ranges of <0.02-l .3 mgL and 0.8-60.6 mg/L. Results of personal air monitoring were too low to account for the post-shift biological monitoring results, indicating the need to conduct biological monitoring to allow more reliable assessment of overall exposure to 2-butoxyethanol.

Similar conclusions were drawn in a recent study conducted in France to evaluate the occupational exposures to 2-butoxyethanol of 16 cleaning women and 13 automobile cleaners using window cleaning agents (Vincent et al. 1993). Concentrations of 2-butoxyethanol in the window cleaning preparations used by these workers ranged from 0.9% to 21.2% by volume. Cleaners of new cars experienced the highest exposures, with time-weighted average concentrations of 2-butoxyetbanol from personal samples ranging from <0.10 to 7.33 ppm (<0.5-35.4 mg/ m^3). 2-Butoxyacetic acid concentrations in post-shift urinary samples ranged from <12.7 to 371 mg/g creatinine, compared to a range of <2-98.6 mg/g creatinine in pre-shift samples; average 2-butoxyacetic acid concentrations in post- and pre-shift minary samples ranged from <2 to 178 mg/g creatinine and from <2 to 34.7 mg/g creatinine, respectively. Average urinary 2-butoxyacetic acid concentrations for specific job categories correlated well with work practices (i.e., utilization time and daily quantity of window cleaning agent used). Among workers with the highest exposures, the average 2-butoxy-ethanol time-weighted average concentration and the average 2-butoxyacetic acid urinary concentration were 2.33 ppm (11.3 mg/ m^3) and 111.3 mg/g creatinine, respectively. The authors noted that the high concentrations of urinary 2-butoxyacetic acid, relative to the 2-butoxyethanol time-weighted average concentrations, indicated that dermal absorption was the predominant route of worker exposure. They concluded that for workers in these occupations not wearing protective gloves, environmental sampling

probably underestimates the 2-butoxyethanol exposure due to dermal absorption, and that biomonitoring of urinary 2-butoxyacetic acid appears to be the best method for estimating overall exposures

Only one study (Johanson et al. 1989) involving biological monitoring of exposures to 2-butoxyethanol acetate was found in the available literature. 2-Butoxyethanol acetate was found in personal air samples from 5 of 19 workers in 4 Swedish silk screen printing facilities at an average time-weighted average concentration of 2.9 mg/ m^3 (0.44 ppm) (range, 0.1-10 mg/m^3 [0.015-1.5 ppm]). 2-Butoxyacetic acid was found in the urine of 12 of the 19 workers at an average concentration of 8 mol/L (1.2 mg/L) (range, 4-29 mol/L or 0.6-4.2 mg/L).

5.6 POPULATIONS WITH POTENTIALLY HIGH EXPOSURES

Workers in occupations involving the production, processing, or use of 2-butoxyethanol or 2-butoxyethanol acetate, or of products containing these substances (see Section 5.5), have the potential to be occupationally exposed to higher concentrations of these substances than the general population. People who live near hazardous waste sites containing 2-butoxyethanol or 2-butoxyethanol acetate and people who live in areas where drinking water is contaminated with 2-butoxyethanol and 2-butoxyethanol acetate may also be subject to exposures; however, no data were found in the available literature to characterize such exposures.

Among the general population, users of household products containing 2-butoxyethanol or 2-butoxyethanol acetate (see Section 5.5) and populations who live in areas where drinking water is contaminated with 2-butoxyethanol or 2-butoxyethanol acetate may be exposed to these chemicals; however, no data were found in the available literature to characterize such exposures. Failure to wear proper protective clothing (e.g., gloves) will increase the potential for high dermal exposures among both the general and worker populations.

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 2-butoxyethanol and 2-butoxyethanol acetate 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 2-butoxyethanol.

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.

5.7.1 identification of Data Needs

Physical and Chemical Properties. Several important physical properties of 2-butoxyethanol and 2-butoxyethanol acetate have yet to be experimentally determined. These include their octanol-water and soil-water partition coefficients, Henry's law constants, and bioconcentration factors in aquatic organisms. These data are important in estimating the fate of the released compounds in the environment and in determining the potential for human exposure. However, reliable estimated values for these parameters are available (ASTER 1995a, 1995b; Howard 1993; HSDB 1995; Lyman et al. 1982) and there is no critical need for experimental confirmation of the estimated values.

Production, Import/Export, Use, Release, and Disposal. Because 2-butoxyethanol and 2-butoxyethanol acetate are contained in a broad array of products that are widely used in the home and in industry (see Sections 4.3 and 5. l), the risk for human exposure may be substantial. The most recent U.S. production data available indicate an increase in production volume of 2-butoxyethanol from approximately 130 million pounds in 1972 to 271 million pounds in 1984 (Gibson 1984 as cited in Ghanayem et al 1987b; HSDB 1995), to more than 300 million pounds in 1986 (NIOSH 1990), and to 408.5 million pounds in 1995 (CMA 1997a). The production volume for 2-butoxyethanol acetate showed a slight decrease from approximately 13.4 million pounds in 1972 to 11 million pounds in both 1975 and 1977 (HSDB 1995; MOSH 1990). More recent production data, as well as data on projections of future production volumes are needed. Similarly, there is a need for recent import/export data for both 2-butoxyethanol and 2-butoxyethanol acetate. The most recent import/export data found for 2-butoxyethanol were from 1984 and indicated an increasing trend in exports from 9 million pounds in 1972 to 71 million pounds in 1984 (Gibson 1984 as cited in Ghanayem et al. 1987b); no import/export data for 2-butoxyethanol acetate were found in the available literature. Information on the uses of 2-butoxyethanol and 2-butoxyethanol acetate is extensive and appears to be adequate. Additional information is needed to characterize releases to the environment of 2-butoxyethanol and 2-butoxy-ethanol acetate, particularly from facilities that produce or process these chemicals.

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 information for 1994, became available in May of 1996. This database will be updated yearly and should provide a list of industrial production facilities and emissions. Currently, no information is available in the TRI database for 2-butoxyethanol because the database contains such information only for the general toxic chemical category of glycol ethers and not for specific glycol ethers (EPA 1995). No information is available in the TRL database for 2-butoxyethanol acetate because this chemical is not included under SARA, Title III, and therefore is not among the chemicals that facilities are required to report (EPA 1995). There is a need for such information in order to assess the potential for human exposure to these chemicals from their release from industrial production facilities. Limited or no information was found in the available literature on current disposal methods (including efficiencies, the need for improvement, and the amount disposed of) for 2-butoxyethanol; no information in these areas was found for 2-butoxyethanol acetate. Additional information on disposal methods and the amounts of 2-butoxyethanol and 2-butoxyethanol acetate disposed of by each method is needed.

Environmental Fate. There is a paucity of experimental data regarding the environmental fate of 2-butoxyethanol and 2-butoxyethanol acetate. Fates of these two compounds estimated from their physicochemical properties indicate that a few critical areas need further elucidation. Although it has been estimated that hydrolysis of 2-butoxyethanol acetate is not an important fate process in the environment (ASTER 1995b), experimental confirmation of the rate of hydrolysis under conditions typically found in water and moist soil (pH 5-9) would be helpful. If hydrolysis of 2-butoxyethanol acetate is found to be an important fate detetmining process, it would be important to identify the products of hydrolysis and assess the health and environmental impacts of the degradation products. Biodegradation studies in natural bodies of water and soil would also be helpful. Both experimental screening studies (Dow 1993; Price et al. 1974; Zahn and Wellens 1980) and estimated half-life values of 7-28 days (Howard et al. 1991) indicate that biodegradation of 2-butoxyethanol and 2-butoxyethanol acetate is one of the important fate determining processes in water and soil. However, biodegradation screening studies conducted with sewage water as inocula may be used to predict the biodegradability under conditions used in water treatment plants. These studies may not be suitable for estimating biodegradability of organic compounds in natural bodies of water and soil. Therefore, it would be helpful to experimentally determine the rates of biodegradation of both of these compounds in soil and natural bodies of water (e.g., by river die-away experiments), and to identify the biodegradation products in these media.

Bioavailability. 2-Butoxyethanol and 2-butoxyethanol acetate are known to be absorbed following inhalation, ingestion, and dermal contact (Bartnik et al. 1987; Corley et al. 1997; Dugard et al. 1984; Johanson 1988; Johanson and Boman 1991; Johanson et al. 1988,1989; NIOSH 1990; Truhaut et al. 1979). The environmental factors that may influence the bioavailability of 2-butoxyethanol and 2-butoxyethanol acetate from contaminated air, water, soil, or plant material have not been studied. Because these compounds are not strongly sorbed to soil or sediments (see Section 5.3.1), sorption may not be a significant determinant in assessing the bioavailability of 2-butoxyethanol and 2-butoxyethanol acetate from different soils or waters. There is a need for data characterizing the factors that affect the bioavailability of these compounds from environmental media.

Food Chain Bioaccumulation. 2-Butoxyethanol and 2-butoxyethanol acetate do not bioconcentrate significantly in fish (ASTER 1995a, 1995b). The low estimated BCF and K_{ow} values of 2-butoxyethanol and 2-butoxyethanol acetate (see Section 5.3.1 and Tables 3-3 and 3-4), and the ease with which these compounds are metabolized in higher trophic level animals (see Section 2.3) indicate that these compounds will not biomagnify in the food chain. Experimental data on BCFs and food chain bioaccumulation, however, are very limited. Additional data would be desirable.

Exposure Levels in Environmental Media. No data were found in the available literature on concentrations of 2-butoxyethanol and 2-butoxyethanol acetate in ambient outdoor or indoor air. Because of the short half-lives (<1 day; see Section 5.3.2.1) of these chemicals in the atmosphere, neither compound will persist in the atmosphere or be transported long distances. Consequently, significant ambient outdoor concentrations would be expected only in areas near potential emission sources (e.g., production facilities, disposal sites). Data on ambient outdoor and indoor air concentrations of 2-butoxyethanol and 2-butoxyethanol acetate near potential emission sources and at background sites in the United States would be useful. Because of the widespread use of household products containing 2-butoxyethanol and 2-butoxyethanol acetate, additional data on indoor air concentrations of these compounds would be useful to assess indoor exposures of the general population. 2-Butoxyethanol was found in drinking water in a U.S. survey that included Washington, DC, and cities in California, Texas, Ohio, Pennsylvania, Florida, Louisiana, Iowa, and Washington; however, concentrations were not reported (Lucas 1984). Because of the relatively widespread 2-butoxyethanol contamination of U.S. drinking water indicated by this survey, more recent data are needed to assess the potential for exposure of the general public from this source. Data on levels of 2-butoxyethanol acetate in drinking water would also be desirable. 2-Butoxyetbanol was detected at a concentration of 23 µg /L in a surface water sample collected in 1979 at a site in Kentucky where it has been estimated that as many as

100,000 drums of industrial waste were disposed of between 1967 and 1977 (Stonebreaker and Smith 1980). Examination of mass spectral libraries of data from water and soil samples from U.S. hazardous wasted sites taken between late 1987 and mid-1989 identified 2-butoxyethanol in 110 samples (Eckel et al. 1996). The media in which the compound was found was not indicated. No other data were found in the available literature on the levels of 2-butoxyethanol or 2-butoxyethanol acetate in surface or groundwater, or in soil or sediment; such data would be useful to assess the potential for exposure from these media. The low estimated BCF and K_{OW},values of 2-butoxyethanol and 2-butoxyethanol acetate (see Section 5.3.1 and Tables 3-3 and 3-4), and the ease with which these compounds are metabolized in higher trophic level animals (see Section 2.3) indicate that these compounds will not biomagnify in the food chain and, consequently, that concentrations in food will be insignificant; however, there may be some potential for food contamination from packaging and washing procedures (see Section 5.4.4). The minor use of 2-butoxyethanol in herbicides (see Section 4.3) may also present the potential for food contamination by this compound. Data on concentrations of 2-butoxyethanol and 2-butoxyethanol acetate in food would be useful to confirm that consumption of contaminated foods is not a significant route of exposure.

2-Butoxyethanol has been detected in surface water (2 sites), groundwater (7 sites), soil (3 sites) and sediment (1 site) out of 20 of the 1,430 current or former EPA National Priorities List (NPL) hazardous wastes sites where it has been detected in some environmental media, whereas 2-butoxyethanol acetate has not been detected at any of the current or former NPL hazardous waste sites (HazDat 1996). The number of sites evaluated for these substances is not known, however. No data were found in the available literature on the concentrations of 2-butoxyethanol and 2-butoxyethanol acetate at NPL sites in any medium.

Reliable monitoring data for the levels of these substances in contaminated media at hazardous waste sites (and background sites) are needed. The information obtained on levels of 2-butoxyethanol and 2-butoxy-ethanol acetate in the environment can be used in combination with the known body burdens of 2-butoxy-ethanol and 2-butoxyethanol acetate to assess the potential risks of adverse health effects in populations living in the vicinity of hazardous waste sites.

No information was found in the available literature on estimates for human intake of 2-butoxyethanol or 2-butoxyethanol acetate from the various environmental media. Such information is necessary to estimate the overall risk of exposure to these substances.

Exposure Levels in Humans. Because both 2-butoxyethanol and 2-butoxyethanol acetate are readily absorbed through the skin (Bartnik et al. 1987; Dugard et al. 1984; Johanson 1988; Johanson and Boman 199 1; Johanson et al. 1988,1989; NJOSH 1990; Truhaut et al. 1979), environmental monitoring of breathing zone or work area air concentrations of these substances generahy is not found to be adequate to assess overall exposures to these compounds. Biological monitoring of the toxic metabolite, 2-butoxyacetic acid, in urine is considered preferable (Angerer et al. 1990; Johanson 1988; Sohnlein et al. 1993; Vincent et al. 1993). Limited data on urinary 2-butoxyacetic acid concentrations are available for occupationally exposed groups of the population (see Section 5.5); however, more extensive biomonitoring of workers in a broad range of occupations with potentially high exposures would be useful. Data on urinary 2-butoxyacetic acid concentrations in control groups and in the general population are not available. In addition, biomonitoring data are not available for populations living near hazardous waste sites where 2-butoxyethanol or 2-butoxyethanol acetate are known to be present. These data would be useful in assessing whether this group is being exposed to 2-butoxyethanol or 2-butoxyethanol acetate at levels higher than the general population. This information is necessary for assessing the need to conduct health studies on these populations.

Exposure Registries. No exposure registries for 2-butoxyethanol or 2-butoxyethanol acetate were located. These substances are not currently among the compounds for which subregistries have been established in the National Exposure Registry. These substances 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 exposure to these substances.

5.7.2 Ongoing Studies

A search of the Federal Research in Progress database (FEDRIP 1995) indicates that no research studies are in progress to fill the data gaps discussed in Section 5.7.1. The Consumer Products Safety Commission is working on a report concerning the uses of ethylene glycol ethers including 2-butoxyethanol.