6. POTENTIAL FOR HUMAN EXPOSURE

6.1 OVERVIEW

Methoxychlor has been identified in at least 58 of the 1,613 hazardous waste sites that have been proposed for inclusion on the EPA National Priorities List (NPL) (HazDat 2002). However, the number of sites evaluated for methoxychlor is not known. The frequency of these sites can be seen in Figure 6-1.

Methoxychlor is released to the environment mainly as a result of its application to crops and livestock as a pesticide. Smaller amounts may be released during its production, formulation, storage, shipment, and disposal. There are no known natural sources of methoxychlor.

In air, methoxychlor exists in both the particulate and, to a small degree, vapor phase. Air levels exhibit seasonal variations, paralleling its use for pest control. Levels ranging from 0.002 to 0.6 ng/m^3 have been reported in ambient air in Canada and the United States. Methoxychlor may react with photochemically-produced hydroxyl radicals in air, but most is probably removed from the atmosphere by wet and dry deposition processes. The residence time for methoxychlor in the atmosphere is <1 month. In water, methoxychlor preferentially binds to sediments and organic matter, although some methoxychlor may remain dissolved in water. Methoxychlor bioconcentrates in a number of aquatic organisms including microorganisms, snails, clams, and some fish (see Section 6.3.1), but probably does not accumulate in mammalian species due to rapid metabolism and elimination. Methoxychlor in water and sediment is degraded to dechlorinated, dehydrochlorinated, and demethylated products by chemical, photochemical, and biological processes. Depending on the availability of sunlight, air, plant materials, and microorganisms, the half-life of methoxychlor in water may range from 2 to 5 hours to approximately 1 year. Both its degradation and its affinity for sediments and organic matter may explain, in part, why methoxychlor is generally not detected in surface water or groundwater in the United States. However, methoxychlor may be detected in waters near release sources.

Methoxychlor binds tightly to soils, but is not usually detectable in soil except in areas where it has been applied as a pesticide. Wind and rain can erode contaminated soils, resulting in the migration of methoxychlor-containing particulates. Some methoxychlor can persist in soils for more than a year after its application. However, most is degraded to dechlorinated, dehydrochlorinated, and demethylated products. The degradation of methoxychlor is mediated by microorganisms and is affected by the level

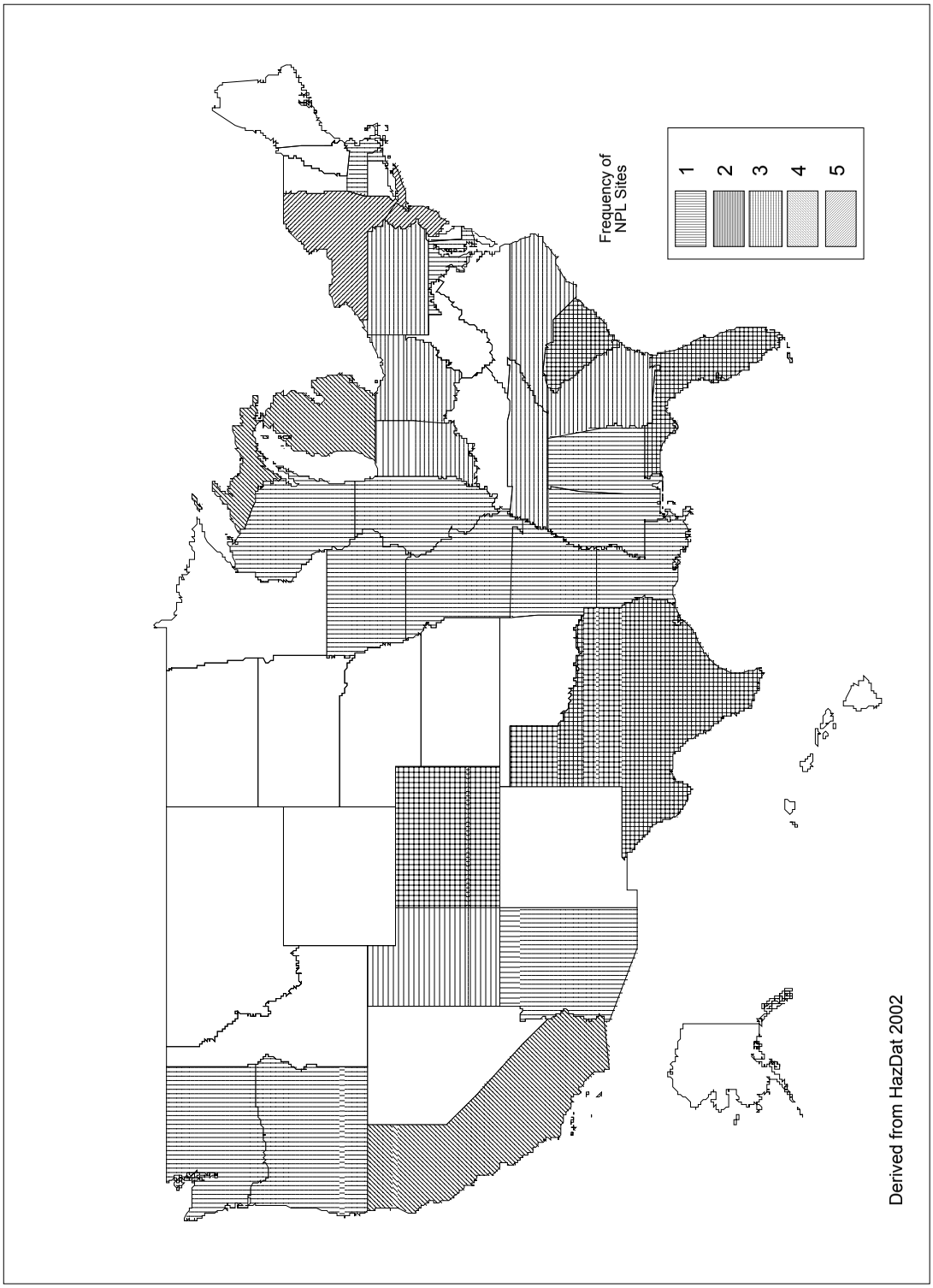

Figure 6-1. Frequency of NPL Sites with Methoxychlor Contamination

of aeration of the soil. Half-lives of <30 days in anaerobic soils (Fogel et al. 1982; Muir and Yarechewski 1984) and >100 days in aerobic soils were observed (Muir and Yarechewski 1984) for methoxychlor. In a study of the effect of methoxychlor on soil microflora, methoxychlor was found to be moderately persistent (30 days<$t_{1/2}$<1 year) (Howard et al. 1991) in soil under anaerobic conditions. Six months after the application of methoxychlor to the soil, 42% remained (Polyakova et al. 1984).

Methoxychlor is generally not detected in foods, although low levels (ranging from 0.001 to 0.004 mg/kg) have occasionally been detected in dairy products, grains, fruits, and vegetables. Higher levels (ranging from 10 to 120 µg/kg) have been infrequently reported in fish (Camanzo et al. 1987; Devault 1985). Most members of the general population have little or no exposure to methoxychlor. People who use products containing methoxychlor in farming, home gardening, professional landscaping, or animal care are more likely to be exposed to methoxychlor.

6.2 RELEASES TO THE ENVIRONMENT

Methoxychlor has been identified in a variety of environmental media (air, surface water, leachate, groundwater, soil, and sediment) collected at 58 of 1,613 current or former NPL hazardous waste sites (HazDat 2002).

According to the Toxics Release Inventory (TRI), methoxychlor processing facilities listed for 1998 (TRI99 2001) report that the major portion of methoxychlor released to the environment is released to the land. Table 6-1 lists releases to the environment in 1999 from facilities that manufacture or process methoxychlor. One facility that processes methoxychlor reports that 29 pounds were released to the air and none was released to land or water. Only certain types of facilities are legally required to report; therefore, this is not an exhaustive list.

The TRI data should be used with caution because only certain types of facilities are required to report. This is not an exhaustive list.

6.2.1 Air

Release of methoxychlor to the atmosphere occurs mainly as a result of its use as a pesticide. However, no data were located on the amount of methoxychlor released to air by this route. Releases to the

Table 6-1. Releases to the Environment from Facilities that Produce, Process, or Use Methoxychlor

		Reported amounts released in pounds per year[a]						
State[b]	Number of facilities	Air[c]	Water	Underground injection	Land	Total on-site release[d]	Total off-site release[e]	Total on and off-site release
AR	1	29	No data	No data	No data	29	14	43
OH	1	0	0	No data	No data	0	0	0
TX	1	0	No data	No data	No data	0	No data	0
Total	3	29	0	0	0	29	14	43

Source: TRI99 2001

[a]Data in TRI are maximum amounts released by each facility.
[b]Post office state abbreviations are used.
[c]The sum of fugitive and stack releases are included in releases to air by a given facility.
[d]The sum of all releases of the chemical to air, land, water, and underground injection wells
[e]Total amount of chemical transferred off-site, including to publicly owned treatment works (POTW)

atmosphere during production, formulation, and disposal of methoxychlor have been estimated to be 0.1 kg/metric ton produced (HSDB 2000). Based on the 423,832 pounds of methoxychlor produced in the United States in 1991 (Kincaid Enterprises 1992), atmospheric release during production may be estimated to be 42 pounds (19 kg). According to TRI (TRI99 2001), three processing facilities in the United States reported the release of 29 pounds of methoxychlor to the air in 1999. The TRI data (Table 6-1) should be used with caution since only certain types of facilities are required to report; therefore, this is not an exhaustive list. Methoxychlor has been identified in 1 air sample collected from 1,613 current or former NPL hazardous waste sites where it was detected in some environmental media (HazDat 2002).

Methoxychlor has been detected in air samples taken during monitoring studies conducted during the years 1986–1988 in the Jacksonville, Florida (EPA 1990e) and seasonal variation was reported. The mean outdoor concentration of methoxychlor was highest in winter months (0.1 ng/m^3; detection limits not reported); methoxychlor was not present at detectable levels during the spring and summer months.

6.2.2 Water

Methoxychlor can be released directly to surface waters on farms when used to control larvae of insects (Stoltz and Pollock 1982). Methoxychlor is approved for use on cranberries (EPA 1988b), which are grown in bogs, and therefore methoxychlor could be released directly to surface waters where cranberries are grown. Methoxychlor may be released to water from runoff from soil containing methoxychlor, industrial effluents or from leaks at storage and waste sites. According to TRI (TRI99 2001), three processing facilities in the United States reported that no methoxychlor was released to water in 1999. The TRI data (Table 6-1) should be used with caution since only certain types of facilities are required to report. This is not an exhaustive list. Methoxychlor has been identified in 19 groundwater and 7 surface water samples collected from 58 NPL hazardous waste sites, where it was detected in some environmental media (HazDat 2002).

6.2.3 Soil

Methoxychlor is released to soils primarily through its use as an insecticide for agricultural crops, home orchards, and ornamentals. Some methoxychlor may be released to soils through leaks at storage waste sites. According to TRI (TRI99 2001), three processing facilities in the United States reported that no

methoxychlor was released to soil in 1999. The TRI data should be used with caution since only certain types of facilities are required to report; therefore, this is not an exhaustive list.

Methoxychlor has been identified in 46 soil and 11 sediment samples collected from 58 NPL hazardous waste sites, where it was detected in some environmental media (HazDat 2002).

6.3 ENVIRONMENTAL FATE

This discussion applies primarily to *p,p'*-methoxychlor, the major component in technical grade methoxychlor. Please see Section 4.1 Chemical Identity for a detailed discussion of impurities and contaminants in technical grade methoxychlor, which is the primary form used for pesticide formulation. Little information is available on the environmental fate of impurities and contaminants in technical grade methoxychlor. Methoxychlor can contain as many as 50 contaminants (impurities) that are introduced during commercial production. The contaminants include 1-chloro-1,2,2-tris[4-methoxyphenyl]ethene (chlorotrianisene; TACE), a triphenylethylene derivative that exhibits estrogenic/anti-estrogenic characteristics. Other contaminants include polycylic hydrocarbons (e.g., 3,6-dimethoxy-9,10-bis (p-methoxyphenyl)phenanthrene, tetrakis(p-methoxyphenyl)ethylene, and 3,6,11,14-tetra-methoxydibenzo(g,p)chrysene), which have been studied for mutagenicity and putative carcinogenicity (Grant et al. 1976).

6.3.1 Transport and Partitioning

Methoxychlor is expected to exist in both the particulate (bound to particulate matter) and, to a small degree, vapor phase in the atmosphere (Kelly et al. 1994). The residence time and dispersion of methoxychlor in air is, therefore, a function of particle size, windspeed, and precipitation. Based on monitoring data, the majority of methoxychlor is removed by wet or dry deposition processes with a residence time of <1 month (Hoff et al. 1992). However, evidence of wide dispersion of methoxychlor in the atmosphere by its detection in Canadian arctic snow suggests that some methoxychlor may remain in air for extended periods of time (Welch et al. 1991). Methoxychlor has been frequently detected in rain (Strachan 1985, 1988). In a 6-year study (1986–1991) conducted in the Great Lakes Region, the mean annual concentration of methoxychlor in rain was 2.4 ng/L (Chan et al. 1994). These data suggest that wet deposition processes significantly contribute to the removal of methoxychlor from the atmosphere. However, wet deposition of methoxychlor will depend upon the amount of precipitation and will vary from year to year. Dry deposition due to gravity will also act to remove methoxychlor from air. In the

Great Lakes region, dry deposition of chlorinated pesticides was estimated to be 1.5–5.0 times as great as wet deposition (Eisenreich et al. 1981).

Methoxychlor is a relatively hydrophobic compound with estimated log octanol/water partition coefficient (log K_{ow}) values ranging from 4.68 to 5.08 (Howard 1991). Because of this, methoxychlor in water is expected to partition mainly to sediment and organic matter, although a significant fraction may remain in solution when the ratio of sediment mass to water volume is low (Wolfe et al. 1977). In sediments, the partitioning of methoxychlor was higher for silts and clays than it was for sand (Karickhoff et al. 1979). Sorption of methoxychlor to bacteria, algae, and fungi has been reported (Paris and Lewis 1976). Methoxychlor has an estimated vapor pressure of $1.4x10^{-6}$ mmHg (Howard 1991) and an estimated Henry's law constant of $1.6x10^{-5}$ atm-m^3/mole (Howard 1991). These values indicate that volatilization of methoxychlor from water may occur. A half-time of 4.5 days has been estimated for the volatilization of methoxychlor from a shallow river (Howard 1991). In addition, methoxychlor has been observed to slowly volatilize from foliage (Howard 1991). This process may contribute to the environmental cycling of methoxychlor.

Experimental adsorption coefficients (K_{oc}) that have been reported for methoxychlor are as follows: 9,700–41,000 in sand, 80,000–100,000 in fine silt, and 73,000–92,000 in clay (Kenaga 1980; Prasad 1992). Because methoxychlor has a relatively high K_{oc} value, for example, an experimental K_{oc} of 79,433 was reported by Montgomery and Welkom (1990), methoxychlor has the potential to undergo significant adsorption to soils, especially those with high organic carbon content (Karickhoff et al. 1979; Richardson and Epstein 1971). Methoxychlor retention is also greater in finer-textured soils (particle size <0.08 μm) than in course-textured soils (particle size $0.08 μm) (Richardson and Epstein 1971). The mobility of methoxychlor may be higher in sandy soils, since adsorption was significantly less in soil with lower organic carbon content and larger particle size (Karickhoff et al. 1979; Richardson and Epstein 1971). In addition to soil adsorption, methoxychlor may become structurally bound to soil humic materials (Mathur and Morley 1978).

Methoxychlor is generally detected only in the uppermost layer (top 5 cm) of soil on which it was applied (Golovleva et al. 1984). Dechlorinated, dehydrochlorinated, and demethylated degradation products of methoxychlor were generally detected in lower levels of soil, suggesting that they are more mobile than methoxychlor (Golovleva et al. 1984).

The bioconcentration of methoxychlor has been investigated in microorganisms, lower invertebrates, and in fish. Because methoxychlor has a relatively high octanol/water partition coefficient, it is expected to have potential for bioconcentration. Reported bioconcentration factors (BCFs) for methoxychlor were 411–2,758 in *Aerobacter aerogenes* bacteria, 2,114–8,138 in *Bacillus subtilis* bacteria (Johnson and Kennedy 1973), 348–1,130 in stoneflies, 5,000–8,570 in snails (Anderson and DeFoe 1980), and 1,500 in clams (Hawker and Connell 1986). Methoxychlor has been reported to bioaccumulate in phytoplankton, and levels up to 80 µg/kg have been reported in samples from Lake Erie, Ontario. In a model ecosystem, BCFs of 1,500 for fish and 120,000 for mosquitos were reported (Kapoor et al. 1970). BCFs of 185 for fish (flowing water) and 1,550 for trout (static water) have also been reported (Prasad 1992). In sheepshead minnows, BCFs were found to be concentration dependent, ranging from 113 at 3 µg/L to 264 at 23 µg/L (Parrish et al. 1977). In fathead minnows, a BCF of 8,300 was reported (Veith et al. 1979). These data suggest that considerable species variation exists in the bioconcentration of methoxychlor in fish, perhaps as the result of species differences in the capacity to metabolize and eliminate methoxychlor. Methoxychlor has been reported to bioaccumulate in the blubber (0.68 µg/kg wet weight) and liver (0.1 µg/kg wet weight) of harp seals (Zitko et al. 1998). The primary source of methoxychlor contamination in seals is thought to be their diet, which consists largely of fish.

The persistence and disappearance (washoff or dryfall) of methoxychlor from mature soybean foliage was investigated in a small field plot study under natural rainfall conditions in 1977 and 1978 (Smith et al. 1981). Methoxychlor washoff rate was 8±4% of the amount on plants (prior to rain) per cm of rainfall, regardless of time after application. Total seasonal washoff for 1978 accounted for 33.5% of the applied pesticide; however, 30.5% of the total loss was removed by washoff on the second day after application. Dryfall or dislodgeable residue accounted for <1% of the amount applied. The amount of dryfall was greater in plots entered by workers than in those where entry was avoided.

6.3.2 Transformation and Degradation

The structures of many of the methoxychlor degradation products mentioned here are shown in Figure 3-2, Proposed Metabolic Pathways of Methoxychlor.

6.3.2.1 Air

Methoxychlor is expected to exist in both the particulate and, to a small degree, vapor phase in the atmosphere (Kelly et al. 1994). The rate constant for the vapor-phase reaction of methoxychlor with photochemically-produced hydroxyl radicals has been estimated to be $5.2x10^{-11}$ cm^3/molecule-second at 25 EC using a structure estimation method (Meylan and Howard 1993). This corresponds to an atmospheric half-life of about 7 hours at an atmospheric concentration of $5x10^5$ hydroxyl radicals/cm^3 (Meylan and Howard 1993). Particulate-phase methoxychlor is not expected to react with photochemically produced hydroxyl radicals and, therefore, will not be readily degraded in the atmosphere.

6.3.2.2 Water

Methoxychlor can be degraded in water by chemical, photochemical, and biological processes. Methoxychlor undergoes a spontaneous elimination reaction in aqueous solution to yield dehydrochlorinated products, including 1,1-bis(4-methoxyphenyl)-2,2-dichloroethylene (a proestrogenic derivative of methoxychlor discussed in Section 3.4.3; also known as methoxy-DDE). The half-life for the degradation of methoxychlor by this process was estimated to be approximately 1 year (Wolfe et al. 1977). Methoxychlor may also be oxidized by hydroxyl radicals or ozone in ozonated waters (Haag and Yao 1992; Yao and Haag 1991). The half-life of methoxychlor when reacted with ozone was estimated to be 2.1 minutes.

Methoxychlor is photochemically degraded by sunlight through loss of one chlorine atom to form a radical intermediate, which rearranges to the more stable 1,1-bis(4-methoxyphenyl)-2,2-dichloroethylene (also known as MDDE) (Zepp et al. 1976). A dramatic difference in half-life was observed for the photochemical degradation of methoxychlor in distilled water (4.5 months) and natural water (2–5 hours). Methoxychlor was found to form adducts extensively with plant materials via a photochemically-induced radical mechanism (Schwack 1988). This observation may explain the dramatic differences in the half-life of methoxychlor in distilled and natural waters.

DDE and 1,1-bis(4-methoxyphenyl)-2,2-dichloroethylene, respective degradation products of DDT and methoxychlor, rapidly undergo an unusual photoisomerization in solution when exposed to sunlight (Zepp et al. 1977). The isomerization involves the exchange of a vinyl chlorine and an ortho aromatic

hydrogen. Other photodegradation products identified were corresponding benzophenones and 1,1-bis(4-methoxyphenyl)-2-chloroethylene.

Methoxychlor is also degraded by bacteria under aerobic conditions to form dechlorinated products (Baarschers et al. 1982). Algae are also capable of degrading methoxychlor; however, the degradation products were not determined (EPA 1976b). The half-life of methoxychlor by this degradation process was reported to be <2 weeks with some organisms. Data regarding the biodegradation of methoxychlor in water under anaerobic conditions were not located. However, based on biodegradation of methoxychlor in soil under anaerobic conditions (see below), transformation via this process is likely to occur.

6.3.2.3 Sediment and Soil

First-order kinetics have been used to model the dissipation of methoxychlor in the environment (under anaerobic and aerobic conditions) because a half-life for the chemical can be defined. The half-life represents the calculated time for loss of the first 50% of the substance, but the time required for the loss of half of that which remains may be substantially longer, and the rate of disappearance may decline further as time progresses. The term half-life in this document is used to indicate the estimated time for the initial disappearance of 50% of the compound and does not necessarily imply that first-order kinetics were observed throughout the experiment unless otherwise noted.

Half-lives of <30 days in anaerobic soils (Fogel et al. 1982; Muir and Yarechewski 1984) and >100 days aerobic soils were observed (Muir and Yarechewski 1984) for methoxychlor. In a study of the effect of methoxychlor on soil microflora, methoxychlor was found to be moderately persistent (30 days<$t_{1/2}$<1 year) (Howard et al. 1991) under anaerobic conditions. Six months after the application of methoxychlor to the soil, 42% remained (Polyakova et al. 1984).

In soils and sediments, methoxychlor can be biodegraded under either aerobic or anaerobic conditions. Biodegradation of methoxychlor has been reported to be greater under anaerobic conditions than aerobic conditions; biodegradation of the compound has been observed to be more rapid as conditions become more strongly reducing (i.e., more anaerobic). For anaerobic biodegradation in flooded sediment and nitrogen atmosphere (reducing environment), methoxychlor degraded with a half-life of <28 days compared with half-lives of 49–50 days in flooded sediment maintained in static aerobic conditions and 115–206 days in aerobic (artificially aerated, oxidizing environment) flooded sediment (Fogel et al. 1982; Muir and Yarechewski 1984). The major degradation products consisted of 1,1-dichloro-

2,2-di(4-methoxyphenyl)ethene (DMDE), 1,1-dichloro-2,2-bis(4-methoxyphenyl)ethane (DMDD), 1-chloro-2,2-bis(4-methoxyphenyl)ethene (DMDU), 1,1,1-trichloro-2-(4-hydroxyphenyl)-2-(4-methoxyphenyl)ethane, 1,1,1-trichloro-2,2-bis(4-hydroxyphenyl)ethane, 1,1-dichloro-2-(4-hydroxyphenyl)-2-(4-methoxyphenyl)ethane, 1,1-dichloro-2-(4-hydroxyphenyl)-2-(4-methoxyphenyl)ethene, and 1,1-dichloro-2,2-bis(4-hydroxyphenyl)ethene (Muir and Yarechewski 1984). In another study, methoxychlor was found to degrade by >95% over 160 days in flooded sediment (anaerobic conditions; reducing environment) and by 70% over 185 days in aerated soil (aerobic conditions; oxidizing environment) Golovleva et al. (1984). Out of 709 strains of microorganisms found in soils, 17 were able to convert methoxychlor to 1,1-dichloro-2,2-bis(4-methoxyphenyl)ethene (DMDE), and 5 were able to convert it to nonchlorinated products (Golovleva et al. 1984). Some of the degradation products resulting from partial dechlorination of methoxychlor may accumulate in soils (degradation products were identified by chromatography/MS analysis; Golovleva et al. 1984). Data regarding the photodegradation of methoxychlor in surface soils were not located, but based on the photodegradability of methoxychlor in water (see Section 6.3.2.2) and the photodegradation of a structural analogue (ethoxychlor) in soil (Coats et al. 1979), this process is likely to occur, but only at the very surface of soil. Because methoxychlor is mostly found in the upper layer of soil, the photochemical and aerobic degradative processes would probably be more important for methoxychlor applied to crops.

6.3.2.4 Other Media

The degradation of methoxychlor has been studied under anaerobic conditions (incubation time = 48 hours) in microbial suspensions (Van Duck and Van de Voorde 1976). The bacterial strains studied, *Hydrogenomonas sp.*, *Mycoplana bullata*, *Mycoplana dimorpha*, *Pseudomonas aeruginosa*, *Bacillus subtilis*, *Candida albicans*, and *Escherichia coli* were found to be capable of degrading 85% of the methoxychlor at concentration levels of 20,000–160,000 µg/L. The microbial degradation of methoxychlor has been studied under anaerobic and aerobic conditions using four cultures: *Bacillus sphaericus*, *Rhodoccoccus erythropolis*, and *Acinetobacter calcoaceticus* 5 and 21 (Golovleva et al. 1984). All four cultures were found to degrade methoxychlor at a concentration of 100,000–200,000 µg/L. The most extensive degradation was observed to occur under anaerobic conditions (incubation time=7 days; degradation=75%) compared to aerobic conditions (incubation time=7 days; degradation=18%). In another study of the degradation of methoxychlor by the bacteria, *B. sphaericus*, methoxychlor was shown to be degraded under anaerobic and aerobic conditions (Polyakova et al. 1984). The bacteria degraded methoxychlor (at a concentration of 50,000 µg/L) more completely

under anaerobic conditions (incubation time = 10 days; degradation=83%) compared to aerobic conditions (incubation time=10 days; degradation=30%).

6.4 LEVELS MONITORED OR ESTIMATED IN THE ENVIRONMENT

6.4.1 Air

In a survey (conducted during the years 1987, 1988, and 1989) of pesticide levels in air in two U.S. cities, the mean levels of methoxychlor in indoor, outdoor, and personal air samples from Jacksonville, Florida were 200–300, 0–100, and 100–600 pg/m^3, respectively (EPA 1990e). Levels of methoxychlor were below the level of detection (approximately 36 pg/m^3) in these air samples in Springfield, Massachusetts.

In a survey of ambient air measurements, atmospheric levels of methoxychlor (from data taken at two locations in the United States from 301 samples) ranged from not detected to 7,000 pg/m^3 (Kelly et al. 1994). In Canada, the yearly mean level of methoxychlor in air was 1.7 pg/m^3 from 1988 to 1989 (Hoff et al. 1992). Air levels tended to be higher during insect control periods (up to 27 pg/m^3), whereas levels were generally below the detection limit (0.04–0.1 pg/m^3) during non-use periods. In the arctic, mean concentrations of methoxychlor in air samples were found to be 0.07–0.72 pg/m^3 for the year 1993 and 0.18–1.43 pg/m^3 for the year 1994 (Halsall et al. 1998). No data were found for methoxychlor degradation products and their levels in air.

6.4.2 Water

Methoxychlor is not commonly detected in surface, ground, or drinking waters. In a survey of major rivers in the United States, methoxychlor was not detected (detection limit =100 ng/L) at approximately 180 sites (Gilliom et al. 1985). Methoxychlor was occasionally detected in surface waters from the Great Lakes regions at concentrations ranging from 0.032 to 15 ng/L (Biberhofer and Stevens 1987; Konasewich et al. 1978; Kuntz and Warry 1983; Maguire et al. 1983). In a survey of 783 rural domestic wells and 566 community water systems across the United States, methoxychlor was generally not found above the reporting limit (300 ng/L) (EPA 1990f). Methoxychlor was not found above the detection limit (5,000 ng/L) in 54 wells in California (Maddy et al. 1982), was not detected above the detection limit (5–10 ng/L) in groundwater below irrigated farmland in Nebraska (Spalding et al. 1980), and was not detected above the detection limit (150 ng/L) in groundwater tested from 53 residential drinking wells in residential areas (non-agricultural past use) of Connecticut where home and garden pesticide use is

reported by 66% of homeowners (Eitzer and Chevalier 1999). In a survey of the drinking water in Jacksonville, Florida and Springfield, Massachusetts, methoxychlor was not detected in any samples (EPA 1990e). In the Great Lakes region, methoxychlor has been detected in rain and snow at concentrations ranging from 0.43 to 13.1 and 0.1 to 5.8 ng/L, respectively (Strachan 1985, 1988; Strachan and Huneault 1979). Methoxychlor has also been detected in snow in the Canadian arctic at levels of 0.2 ng/L (Welch et al. 1991). In an irrigation canal in which methoxychlor was intentionally added to control fly larvae, peak levels of 1,000 ng/L were detected at a site nearly 75 miles downstream, 45–46 hours after application (Stoltz and Pollock 1982). In another study, conducted during 1981–1986, methoxychlor residues were monitored in the Athabasca River in Canada after treatment for control of black fly larvae (Kumar and Byrtus 1993). Peak levels of 5,000 ng/L were detected (detection limit=0.03 µg/L) 47 miles downstream of the treatment location. Methoxychlor has been detected at high concentrations in waters near points of methoxychlor use or application. Shortly after the aerial application of methoxychlor to elm trees, levels of 40–160 mg/L were detected downstream in the top foot of a nearby river (Wallner et al. 1969). Methoxychlor was not detected (detection limit not reported) 100 feet downstream after 24 hours. Methoxychlor has also been detected in groundwater at waste disposal sites. A review of groundwater monitoring data from 479 site investigations indicates that methoxychlor was detected in groundwater at 14 (. 3%) of the sites (Plumb 1991). No data were found for methoxychlor degradation products and their levels in water.

6.4.3 Sediment and Soil

In general, methoxychlor is infrequently detected in soils and sediments in the United States, but higher levels may be detected more frequently near release sources. In a survey of soils in the United States, methoxychlor was detected in 1 of the 1,729 cropland soil samples at a level of 0.28 µg/kg (IARC 1979). Methoxychlor was detected in 1 of the 45 random soil samples in Alabama at a level <100 µg/kg (Albright et al. 1974). The detection limit was not reported. At a hazardous waste site in Fresno, California, methoxychlor was detected at levels ranging from <150 to 17,000 µg/kg in subsurface soil (Agency for Toxic Substances and Disease Registry 1989a). Soil beneath elm trees sprayed with 12–16% methoxychlor was reported to contain 2,900–14,600 µg/kg 3 days after application, and 1,000–8,400 µg/kg 130 days later (Wallner et al. 1969). These data suggest that methoxychlor is moderately persistent (30 days<$t_{1/2}$<1 year) (Howard et al. 1991) in soil. In a survey of major rivers in the United States, methoxychlor was detected in sediment samples from only 1 out of 160 sites (detection limit =1 µg/kg) (Gilliom et al. 1985). In contrast, 51% of 70 sediments samples from the Niagara River contained detectable levels of methoxychlor, with a mean level of 7 µg/kg (standard deviation=14 µg/kg)

dry weight (Kuntz and Warry 1983). No data were found for methoxychlor degradation products and their levels in soil or sediment.

6.4.4 Other Environmental Media

Methoxychlor is generally not detectable or detectable only at very low levels in food. Methoxychlor was reported in only 5% of nearly 14,000 composite food samples obtained from 10 states in 1988, and in 11 of 13,000 samples in 1989 (Minyard and Roberts 1991). However, the levels of methoxychlor detected were not provided. In a market basket survey performed in 1980–1982, dairy products and cereals/grain products contained levels ranging from a trace to 4 µg/kg (Gartrell et al. 1986a). Methoxychlor was infrequently (0.3%) encountered in vegetables in the United States in 1969–1976, with a mean level of 1 µg/kg (Duggan et al. 1983). In a study conducted by the Food and Drug Administration (FDA) for incidence/level monitoring of domestic and imported fruits and vegetables, methoxychlor was not detected in tomatoes or pears (Roy et al. 1995). In Canada from 1980 to 1985, methoxychlor was generally not detected in vegetables, fruits, meats, or dairy products (Davies 1988; Frank et al. 1987b). However, low levels (4 µg/kg) were detected in strawberries (Frank et al. 1987a). Fish from the Great Lakes generally did not contain detectable levels of methoxychlor, but occasionally, some samples contained levels ranging from 10 to 120 µg/kg wet weight (Camanzo et al. 1987; Devault 1985). Giesy et al. (1994) studied several species of migratory fish in rivers above and below the Great Lakes. Methoxychlor was detected at levels ranging from not detectable to 1.4 µg/kg. Fish (bluegill and carp), taken from rivers that are downstream from irrigated farmland in California, did not contain detectable levels (limit of detection=0.04 mg/kg) of methoxychlor (Saiki and Schmitt 1986).

Methoxychlor has been detected in the blubber and liver of harp seals (Zitko et al. 1998). Levels detected were 0.68 µg/kg (wet weight) in the blubber and 0.1 µg/kg (wet weight) in the liver of male harp seals. Seal muscle tissue is used for human consumption, and there is a growing market for seal meat. The primary source of methoxychlor contamination in seals is thought to be their diet, which consists largely of fish.

Methoxychlor was detected on grain storage building surfaces in which methoxychlor was used for insect control, and this resulted in detectable levels in grain (NIOSH 1986; Watters and Grussendorf 1969).

In a survey of methoxychlor residues in house dust in 28 homes in an agricultural area of Colorado where pesticide use was common, levels (limit of detection for methoxychlor was not reported) ranged from 1.6

to 103 mg/kg (mean=14.9 mg/kg) in 8% of the homes of farmers, from 1.9 to 144 mg/kg (mean=18.2 mg/kg) in 9% of the homes of pesticide formulators, and from 1.5 to 29 mg/kg in 2% of the homes of the control group (Starr et al. 1974). It is not clear if the presence of methoxychlor in the homes of the control group was due to migration of methoxychlor from nearby buildings or fields where it was applied by farmers, or to in-house use of methoxychlor-containing products by the residents.

6.5 GENERAL POPULATION AND OCCUPATIONAL EXPOSURE

For the general population, the most likely source of methoxychlor exposure is from low-level contamination of food. In a study of exposure of the general population to chemical contaminants in food, the average daily exposure to methoxychlor was estimated by calculating exposures from individual foods and summing across food types (Dougherty et al. 2000). The sources of data for contaminant concentrations included the USDA Pesticide Data Program (for years 1992–1993 covering fruits and vegetables), FDA Total Diet Study (for years 1988–1993 covering 261 foods), USEPA Dioxin Report and USEPA/USDA Dioxin in Beef Study (for years 1989–1991, covering meat, dairy products, pork, chicken, milk, and eggs), and National Sediment Inventory (for years 1988–1993, covering fish and shellfish). Methoxychlor was detected in 93 of 29,180 samples and exposure to methoxychlor was estimated to be 5 ng/kg/day (nondetects = 0) and 70 ng/kg/day (nondetects = one half the limit of detection). The 5 ng/kg/day value is larger than the value calculated in the FDA's Total Diet Study Program, which may be attributed to higher concentrations of methoxychlor in raw fish than in other foods. The FDA's Total Diet Study program monitors chemical contaminants in the U.S. food supply and has calculated average daily intakes of methoxychlor (the limit of detection was not reported) in adults (age 25–65) ranging from 0.1 to 0.3 ng/kg/day for the period 1986–1991 (Gunderson 1995b), 0.6–0.9 ng/kg/day for the period 1984–1986 (Gunderson 1995a), and 4 ng/kg/day for the period 1980–1982 (Gartrell et al. 1986b). A decrease in the average daily intakes of methoxychlor is noted for period 1980–1991. Average daily intakes of methoxychlor for infants and children were also monitored (see Section 6.6). Exposure to methoxychlor from food may be elevated in persons who consume large amounts of fish and seafood from methoxychlor-contaminated waters. Because methoxychlor is usually not detected in ground or surface water sources, exposure to methoxychlor from drinking water is not expected to be significant for the general population. Based on the results of the Non-occupational Pesticide Exposure Study, inhalation exposure to methoxychlor ranged from 0.002 to 0.012 µg/day in one U.S. city (EPA 1990e). In a monitoring study of residential and commercial air and dust samples for the occurrence of air born endocrine disruptors, methoxychlor was detected in four out of six dust samples at 0.6–3.5 µg/g of dust. A methoxychlor metabolite, 2,2-bis (*p*-hydroxyphenyl)-1,1,1-trichloroethane (HPTE) was also detected at

0.14 µg/g in three of the four dust samples that contained methoxychlor. Methoxychlor was not reported to be detected in collected air samples. Exposures may be greater in individuals who use methoxychlor-containing products for home gardening or animal-care purposes. In a monitoring study of nonoccupational exposure to pesticides used in and around the home, methoxychlor was detected (air concentrations were not provided) in both indoor and outdoor samples (Lewis et al. 1988). Inhalation and dermal exposures may be greater for workers and farmers exposed to methoxychlor. The National Occupational Exposure Survey of 1981–1983 estimated that approximately 3,418 workers (agricultural services and personal services) were exposed to methoxychlor in the United States in 1980 (NIOSH 1992b). However, this number does not include farmers who are exposed by using methoxychlor on their crops and livestock. No quantitative data were located regarding blood, tissue, or urine levels of methoxychlor following occupational exposure to methoxychlor.

The occurrence of methoxychlor in blood serum was studied in 39 men of varying occupations and similar age and weight, living Southern Honduras (Steinberg et al. 1989). Of the population studied, 20 men, representing the test group, lived and worked in and near farming cooperatives where pesticide use is extensive (16–30 times/year), and 19 of the men, representing a comparison group, lived in an area where pesticides are applied only once per season. The blood serum for all participants was analyzed using HPLC and GC/MS (EC detection; detection limits not specified). Methoxychlor was detected in the serum of one of the comparison group at 5.16 mg/L, but none was detected at or above the detection limit in the remaining participants. The absence of detectable levels of methoxychlor in serum of the majority of the participants may suggest a low exposure to the pesticide; the detection limit was 0.24–4.07 mg/L. However, since the majority of the participants were of lean weight (145 pounds; low adipose tissue), it may also suggest that in the absence of adipose, methoxychlor is not stored in the body.

In a study of human adipose tissue (taken from cadavers at autopsy) conducted in Kingston and Ottawa, Ontario, Canada, methoxychlor was not detected (using gel permeation chromatography and GC/MS) at the minimum level of detection of 13.5 ng/g of adipose (LeBel and Williams 1986). However, it could not be determined from the study whether any of the deceased individuals had ever lived in regions of high pesticide use or worked with products that contain methoxychlor.

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).

There are little data about children's exposure to methoxychlor or its degradation products. Like adults, children may be exposed to methoxychlor upon inhalation of contaminated air, ingestion of contaminated groundwater that is used as drinking water, ingestion of contaminated food, and dermal contact with contaminated soil or products treated with the substance. In addition, since small children may play close to the ground they are more likely than adults to come in contact with dirt and dust found in home carpets, dirt found outside the home, and lawns. Children and infants exhibit frequent hand-to-mouth activities, tend to put foreign objects in their mouths, and sometimes intentionally eat soil. This behavior may result in the ingestion of methoxychlor contaminated soil and dust. Playing in dirt may also cause dermal exposure and inhalation of airborne soil particles. Children may come in contact with and ingest pesticide products that are stored in the home or garage area. If a methoxychlor containing product is used on a pet, a child may be exposed through dermal contact or through contact with an applicator or animal dipping solution.

Children are more likely than adults to ignore no trespassing signs and wander into areas that may contain hazardous waste. A child playing in such an area may be at risk of exposure to elevated levels of methoxychlor from contact with or ingestion of soil since methoxychlor applied at the surface is known to adsorb to soil and remain near the surface. No data concerning the risk of exposure to methoxychlor or its degradates from ingestion of soil were found. There is no information on the bioavailability of methoxychlor from oral ingestion, dermal exposure, or inhalation of soil or dust.

A pilot study was conducted of nine residential homes to monitor potential exposures of children (age 6 months to 5 years) to pesticides (Lewis et al. 1994). Methoxychlor was detected in two of the older nine households (constructed in 1930 and 1962), but was not detected in newer homes. The mean concentration of methoxychlor found in sample test areas that included house dust, child hand rinse, air, entryway soil, walkway soil, and play area soil was not reported. In a later study conducted in residential areas of North Carolina (the Research Triangle area), house dust was collected, separated into seven size fractions (<4–500 μm in diameter), and monitored for pesticide residues (Lewis et al. 1999). The concentration of methoxychlor reported by the authors for various dust particle sizes is as follows: 250–500 μm, 120 ng/g; 150–250 μm, 210 ng/g; 106–150 μm, 310 ng/g; 53–106 μm, 570 ng/g; 25–53 μm, 740 ng/g; 4–25 μm, 680 ng/g; and <4 μm, 1,000 ng/g. The authors state that ingestion, dermal exposure, and inhalation of house dust may represent a substantial portion of a child's exposure to pesticides.

The FDA tested the occurrence of pesticide residues in domestic and imported adult foods eaten by infants/children. The foods were prepared for consumption prior to analysis using the FDA's regulatory monitoring methodology (Yess et al. 1993). Methoxychlor was found in apples (0.16% of samples, 0.38 ppm) and in plain milk (0.22% of samples, 0.38 ppm).

In another study, foods that are representative of the diets of eight population groups (ranging from infants to elderly adults) were prepared for consumption and analyzed for pesticide residues using the methods in the FDA's revised (April 1982) Total Diet Study (Gunderson 1995a). The mean daily intakes for children and adults for the test period 1986–1991 were calculated to be 0.4 ng/kg/day for 6–11-month-old infants, 0.9 ng/kg/day for 2-year-old children; 0.3 ng/kg/day for 14–16-year-old females; 0.4 ng/kg/day for 14–16-year-old males; and 0.1–0.3 ng/kg/day for 25–65-year-old adults (Gunderson 1995b). Intakes of methoxychlor for the test period 1984–1986 were calculated to be 1.0 ng/kg/day for 6–11-month-old infants; 2.4 ng/kg/day for 2-year-old children; 0.8 ng/kg/day for 14–16-year-old females; 0.6 ng/kg/day for 14–16-year-old males; and 0.6–0.9 ng/kg/day for 25–65-year-old adults (Gunderson 1995a). Intakes of methoxychlor for the test period 1980–1982 were calculated to be 19 ng/kg/day for 6–11-month-old infants, 4 ng/kg/day for 2-year-old toddlers, and 4 ng/kg/day for 25–65-year-old adults (Gartrell et al. 1986b). A reduction in the estimated daily intake of methoxychlor is noted for the period 1980–1991 for all population groups. More recent residue analysis from the total diet study 1991–1999 is available for various foods, but intakes for various age groups have not been calculated (FDA Residue Monitoring 1999).

The FDA has also collected and analyzed a number of baby foods (12 fruit juices or fruits, 4 fruit desserts, 4 grain products, and 1 vegetable) in addition to those covered under the Total Diet Study Program (FDA Residue Monitoring 1999). In 1998, methoxychlor was found in 1% of samples at a level of 0.001 ppm. In 1999, 20 different food items (7 fruit juices, 5 fruits, 4 fruit deserts, and 4 grain products) were analyzed and methoxychlor was not reported to be found at a detectable level (FDA Residue Monitoring 1999).

A possible source of exposure in infants to methoxychlor is breast or formula milk. No data were found on the presence of methoxychlor in breast milk in the United States. However, in a recent study conducted among regional populations in Kazakstan (represented by large urban centers, an agricultural region, a petrochemical region, and rural regions), human milk obtained from 92 donors was analyzed according to the World Health Organization Protocol for organochlorine pesticides (Hooper et al. 1997). Methoxychlor was not detected (limit of detection=5–100 pg/g of fat) in any of the samples. Methoxychlor was also not detected in infant formulas, canned milk, with and without iron (Gunderson 1995b; Yess et al. 1993). Methoxychlor was not detected in whole milk, infant formula (with or without iron), or soy-based infant formula according to the most recent FDA Total Diet Study (FDA Residue Monitoring 1999).

Other possible sources of concern for exposure of methoxychlor to children are parents' work clothes and equipment used to apply products that contain methoxychlor. This mode of exposure would be of special concern in agricultural areas and around homes where pesticides are applied for lawn and garden or indoor use. However, no data were found regarding increased levels of methoxychlor in children living in agricultural areas and no information is available on methoxychlor take-home exposure. See *Report to Congress on Workers' Home Contamination Study Conducted Under The Workers' Family Protection Act* (NIOSH 1995) for a good review of the literature and examples of other chemicals likely to be taken home inadvertently.

6.7 POPULATIONS WITH POTENTIALLY HIGH EXPOSURES

Farmers and pesticide applicators who use methoxychlor are the populations most likely to receive above average exposures. In addition, people who live on or near farms, methoxychlor-production plants, formulation plants, or hazardous-waste sites may be exposed to above-average levels of methoxychlor. Individuals who consume large amounts of seafood obtained from methoxychlor-contaminated waters may also be exposed to above-average levels of methoxychlor.

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 methoxychlor is available. Where adequate information is not available, ATSDR, in conjunction with the National Toxicology Program (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 methoxychlor.

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 relevant physical and chemical properties of methoxychlor (see Table 4-2) including water solubility (Budavari et al. 1989; EPA 1988a; HSDB 2000; Montgomery and Welkom 1990), K_{ow} (Howard 1991), K_{oc} (Montgomery and Welkom 1990), vapor pressure (Howard 1991), and Henry's law constant (Howard 1991) have either been measured experimentally or have been estimated accurately enough to permit the evaluation of the environmental fate and transport of methoxychlor. Technical grade methoxychlor contains between 10 and 12% impurities (IARC 1979; Lamoureux and Feil 1980), and GC/MS studies have identified >50 individual impurities at varying percentages (Lamoureux and Feil 1980). Additional data regarding the physical and chemical properties of the most abundant impurities in the technical grade product would be useful in assessing the environmental fate of methoxychlor.

Production, Import/Export, Use, Release, and Disposal. According to the Hazardous Substances Data Bank (HSDB), 17,700 pounds of methoxychlor were imported in 1978 (HSDB 1993). No information on current import volumes are available (HSDB 2000). A manufacturer of methoxychlor, Kincaid Enterprises, Inc., reported information on export volumes of technical grade methoxychlor in pounds as 25,750 in 1986; 86,000 in 1987; 22,600 in 1988; 47,150 in 1989; 10,350 in 1990; and 49,750 in 1991 (Kincaid Enterprises 1992). However, there is no information on current export volumes

of formulated products containing methoxychlor. No recent data were found for current production volume and import/export levels of methoxychlor. Information regarding current production volumes and import/export amounts are necessary in order to understand the current trends of usage and potential for human exposure in the United States.

Methoxychlor is a General Use Pesticide (GUP) and is available over the counter. It is predominately used for agriculture (57%) with lesser usage for industrial and commercial purposes (15%) and home and garden use (28%) (Kincaid Enterprises 1992). However, data regarding the widespread use of methoxychlor in the environment, in the workplace, or at home were not found. It would be useful to know the extent to which methoxychlor is used for estimating the percent of the population exposed to methoxychlor.

Approximately 25,486 pounds of methoxychlor were released to the environment in 1998, which included 12 pounds to air and 25,474 pounds to land (TRI99 2001). However, only certain types of facilities are legally required to report; therefore, this is not an exhaustive list. Releases of methoxychlor from industrial sources and operations are most likely minimal compared to the release to the environment from its use as a pesticide. Quantitative information on the frequency, extent, and actual application rate of methoxychlor when used as a pesticide would be valuable in estimating potential exposures to people who live or work at or near agricultural areas that use methoxychlor. Currently, the EPA does restrict the amount of methoxychlor that can be disposed of in landfills (EPA 1990d). Data for the quantity of methoxychlor disposed of in landfills would be useful for estimating exposure potentials for persons living near landfills.

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 TRI, which contains this information for 1998, became available in May of 2000. This database will be updated yearly and should provide a list of industrial production facilities and emissions.

Environmental Fate. In the atmosphere, methoxychlor exists in both the particulate and, to a small degree, vapor phase (Kelly et al. 1994). Vapor-phase methoxychlor is rapidly degraded by photochemically produced hydroxyl radicals with an estimated half-life of 7 hours, calculated from its estimated rate constant (Meylan and Howard 1993). Particulate-phase methoxychlor is removed from the atmosphere by wet and dry deposition (Hoff et al. 1992). Since methoxychlor is a hydrophobic substance, it is expected to partition to sediment and organic matter (Karickhoff et al. 1979; Richardson

and Epstein 1971). Methoxychlor is degraded in water and soil by chemical, photochemical, and biological processes, making it less persistent in the environment than its structural analogue, DDT (Baarschers et al. 1982; Golovleva et al. 1984; Wolfe et al. 1977; Zepp et al. 1976). Methoxychlor is biodegraded more rapidly under anaerobic conditions than under aerobic conditions. Half-lives of <28 days were reported in anaerobic flooded soil, compared with a half-lives of 49–50 days in flooded sediment (static aerobic conditions) and 115–206 days in aerobic artificially flooded sediment (Fogel et al. 1982; Muir and Yarechewski 1984). These half-lives only represent the time that it takes for 50% of the initial concentration to degrade, and may not be representative of true first-order kinetics. Degradation products of methoxychlor studied under laboratory conditions using lake and pond sediment have been identified as: 1,1-dichloro-2,2-di(4-methoxyphenyl)ethene (DMDE), 1,1-dichloro-2,2-bis(4-methoxyphenyl)ethane (DMDD), 1-chloro-2,2,-bis(4-methoxyphenyl)ethene (DMDU), 1,1,1-trichloro-2(4-hydroxyphenyl)-2-(4-methoxyphenyl)ethane, 1,1,1-trichloro-2,2-bis(4-hydroxyphenyl)ethane, 1,1-dichloro-2-(4-hydroxyphenyl)-2-(4-methoxyphenyl)ethane, 1,1-dichloro-2-(4-hydroxyphenyl)2-(4-methoxyphenyl)ethene, and 1,1-dichloro-2,2-bis(4-hydroxyphenyl)ethene (Muir and Yarechewski 1984). Additional data that not only identifies, but also quantifies degradation products of methoxychlor under field conditions would be useful in order to gain a complete understanding of the biodegradation process of methoxychlor in the environment. Since many of these derivatives are more polar than methoxychlor, they may be more mobile in soils and more water soluble than the parent compound. Further studies that investigate the persistence, mobility, and degradation of the estrogenic degradation products of methoxychlor (particularly estrogenic ones) in water and soil would be valuable in predicting their fate and transport at hazardous waste sites and in assessing exposure and hazard potential. Biodegradation data for the degradation products of methoxychlor were not located and information regarding the rate of degradation and possible degradation byproducts of these compounds would be useful in the determination of the persistence of toxic methoxychlor degradates.

Bioavailability from Environmental Media. No information was located regarding the bioavailability of methoxychlor from environmental media. Toxicokinetic and toxicity studies indicate that methoxychlor is absorbed following oral (Bal 1984; Chapin et al. 1997; Davison et al. 1982, 1983; Gray et al. 1988, 1989; Harris et al. 1974; Kapoor et al. 1970; Martinez and Swartz 1991; Morgan and Hickenbottom 1979) and dermal exposures (Davison et al. 1983; Haag et al. 1950; Skaare et al. 1982). No data are available regarding absorption following inhalation exposure. Studies regarding the absorption of methoxychlor following inhalation exposure would be useful since inhalation of ambient air and house dust may represent a potential route of human exposure (Lewis et al. 1999). The extent to which absorption occurs could be affected by the media in which methoxychlor is contained, but there are

no data on these subjects. Methoxychlor is strongly adsorbed to soil surfaces and this may ultimately limit methoxychlor's bioavailability from soils. Furthermore, it has been shown that the bioavailability of certain pesticides, such as DDT, in soil declines with time as the compound becomes sequestered into the soil (Alexander 1995, 1997; Robertson and Alexander 1998). Studies regarding the bioavailability of methoxychlor from aged soils would be useful in assessing its potential toxicity from soil surfaces. No data were located regarding the bioavailability of methoxychlor's degradation products. Since these compounds can accumulate in soil surfaces, studies regarding the bioavailability of these degradation products from soils would be useful.

Quantitative studies that determine whether methoxychlor contained in soil or food is as well absorbed as methoxychlor dissolved in water or oil (form used in most toxicity and pharmacokinetic studies) would be useful in estimating the absorbed dose of methoxychlor received by individuals living at or near hazardous waste sites. Since young children might be exposed to methoxychlor (or its degradation products) orally, dermally, or by inhalation of soil, information on bioavailability from air, water, soil, or plant material would be desirable in evaluating risk to the subpopulation.

Food Chain Bioaccumulation. There are no data regarding food chain biomagnification of methoxychlor. BCFs have been measured for microorganisms, lower invertebrates, and fish (Anderson and DeFoe 1980; Hawker and Connell 1986; Johnson and Kennedy 1973; Prasad 1992; Veith et al. 1979). Although the lower species tend to bioconcentrate methoxychlor, fish generally have low BFCs. There are sparse data regarding the concentrations of methoxychlor in aquatic and terrestrial animals. However, harp seals had detectable concentrations of methoxychlor in various tissues which was attributed to the consumption of fish in the seal's diet (Zitko 1998). Since some populations use seals as a dietary meat source, it is possible that this may be a potential route of exposure in the human food chain. Studies in laboratory animals indicate that methoxychlor is rapidly metabolized and eliminated (Kapoor et al. 1970), and thus, biomagnification of methoxychlor further up the food chain does not appear to be of concern. More monitoring data of animals are required in order to ascertain that methoxychlor is not bioaccumulated up the aquatic and terrestrial food chains. There is no information regarding the plant uptake of methoxychlor following its application as a pesticide. Such information would be useful in assessing human exposure via ingestion of agricultural products, including home grown vegetables treated with methoxychlor.

Exposure Levels in Environmental Media. Information on the levels of methoxychlor in air (EPA 1990e; Kelly et al. 1994), surface water (Biberhofer and Stevens 1987; Konasewich et al. 1978; Kuntz and Warry 1983; Maguire et al. 1983), groundwater and drinking water (EPA 1990f; Maddy et al. 1982; Plumb 1991), and soil (Albright et al. 1974; IARC 1979) are available. In general, methoxychlor is detected in the pg/m^3 to the ng/m^3 range in the ambient atmosphere of the United States. Methoxychlor is not frequently detected in groundwater, drinking water, or surface water, but has been detected at high concentrations in waters near points of methoxychlor use or application (Wallner et al. 1969). Methoxychlor is infrequently detected in soils and sediments in the United States, but is detected more frequently near release sources that use methoxychlor as a pesticide. Common ranges in soils have been reported as <150–17,000 µg/kg (Agency for Toxic Substances and Disease Registry 1989a; Wallner et al. 1969). Methoxychlor is generally found in low levels in foods. Methoxychlor was identified, but not quantified, in 5% of nearly 14,000 composite food samples obtained from 10 states in 1998, and in 11 of 13,000 samples in 1989 (Minyard and Roberts 1991).

No data exist for methoxychlor degradation products and their levels in environmental media. Since these degradation products may accumulate in soils (Golovleva et al. 1984), information regarding the frequency and levels detected in soils would be useful.

For the general population, exposure to methoxychlor is expected to occur primarily from low-level contamination of foods. Levels of methoxychlor contamination in a variety of foods and food groups as well as estimates of human intake from those foods have been studied (Dougherty et al. 2000; EPA 1992, 1994; FDA 1994; USDA 1995; Winters et al. 1994). Estimates of the average daily intake of methoxychlor in adults (ages 25–65) range from 0.1 to 0.3 ng/kg/day for the period 1986–1991 (Gunderson 1995b), 0.6–0.9 ng/kg/day for the period 1984–1986 (Gunderson 1995a), and 4 ng/kg/day for the period 1980–1982 (Gartrell et al. 1986b). The intake for children and young adults has been estimated as 0.4 ng/kg/day for 6–11-month-old infants, 0.9 ng/kg/day for 2-year-old children; 0.3 ng/kg/day for 14–16-year-old females; 0.4 ng/kg/day for 14–16-year-old males; and 0.1–0.3 ng/kg/day for 25–65-year-old adults (Gunderson 1995b).

Exposure Levels in Humans. Methoxychlor has been detected in blood of 1 of 39 males living at or near farming cooperatives in southern Honduras where there is extensive use (16–30 times/year) of pesticides, but levels are generally below the limit of detection in blood (Steinberg et al. 1989), adipose tissue (LeBel and Williams 1986), and milk (Mes 1981). No biomonitoring data for methoxychlor were

located for populations living near hazardous waste sites or working at methoxychlor production, formulation, or disposal facilities.

Collecting data on the level of methoxychlor in human blood or tissue along with estimates of environmental exposure levels would be useful in estimating recent exposures in these populations. This information would aid in assessing the need to conduct health studies on these populations.

Exposures of Children. Data on exposure levels and body burden measurements of methoxychlor in children are needed to determine what extent children are exposed to this compound. Children may be exposed to methoxychlor through the ingestion of contaminated media (food or drinking water) and inhalation of ambient air or household dust particles since methoxychlor has been detected in household dusts in homes where pesticides have been used (Starr et al. 1974). Additionally, children may be exposed dermally through play activities from contaminated soils, gardens, or lawns that have recently had methoxychlor applied. Since methoxychlor is also commonly used for controlling insects on animals, children may also be exposed through contact with family pets or livestock. Exposure may also arise when children ingest soil either intentionally through pica or unintentionally through hand-to-mouth activity. Methoxychlor has been measured in residential house dust (Lewis et al. 1999); children might be exposed to such dust by crawling on the floor. Bioavailability data needs related to dust and soil exposure have been discussed above under the subsection for Bioavailability from Environmental Media. In the FDA's Total Diet Study Program for 1986–1991 exposures, daily average intakes for various age ranges were calculated; ranges were from 0.9 ng/kg/day for 2-year-old children to 0.1–0.3 ng/kg/day for 25–65-year-old adults (Gunderson 1995b). More recent data about residue amounts on various food products are available for the period of 1991–1999, but the weight adjusted intakes have not been published yet (FDA Residue Monitoring 1999). A possible source of exposure in infants to methoxychlor is breast or formula milk. No data were found on the presence of methoxychlor in breast milk in the United States. However, in a recent study conducted among regional populations in Kazakstan (represented by large urban centers, an agricultural region, a petrochemical region, and rural region), human milk obtained from 92 donors was analyzed according to the World Health Organization Protocol for organochlorine pesticides (Hooper et al. 1997). Methoxychlor was not detected (limit of detection=5–100 pg/g of fat) in any of the samples. Methoxychlor was also not detected in infant formulas, canned milk, with and without iron (Gunderson 1995b; Yess et al. 1993). Methoxychlor was not detected in whole milk, infant formula (with or without iron), or soy-based infant formula according to the most recent FDA Total Diet Study (FDA Residue Monitoring, 1999). Monitoring data on levels of

methoxychlor in breast milk in the United States are needed because this is an important potential route of exposure for infants.

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 methoxychlor were located. This substance is not currently one of the compounds for which a subregistry has been established in the National Exposure Registry. The substance will be considered in the future when chemical selection is made for subregistries to be established. The information that is amassed in the National Exposure Registry facilitates the epidemiological research needed to assess adverse health outcomes that may be related to exposure to this substance.

6.8.2 Ongoing Studies

No ongoing studies were located regarding the environmental fate or potential for human exposure to methoxychlor.