6. POTENTIAL FOR HUMAN EXPOSURE

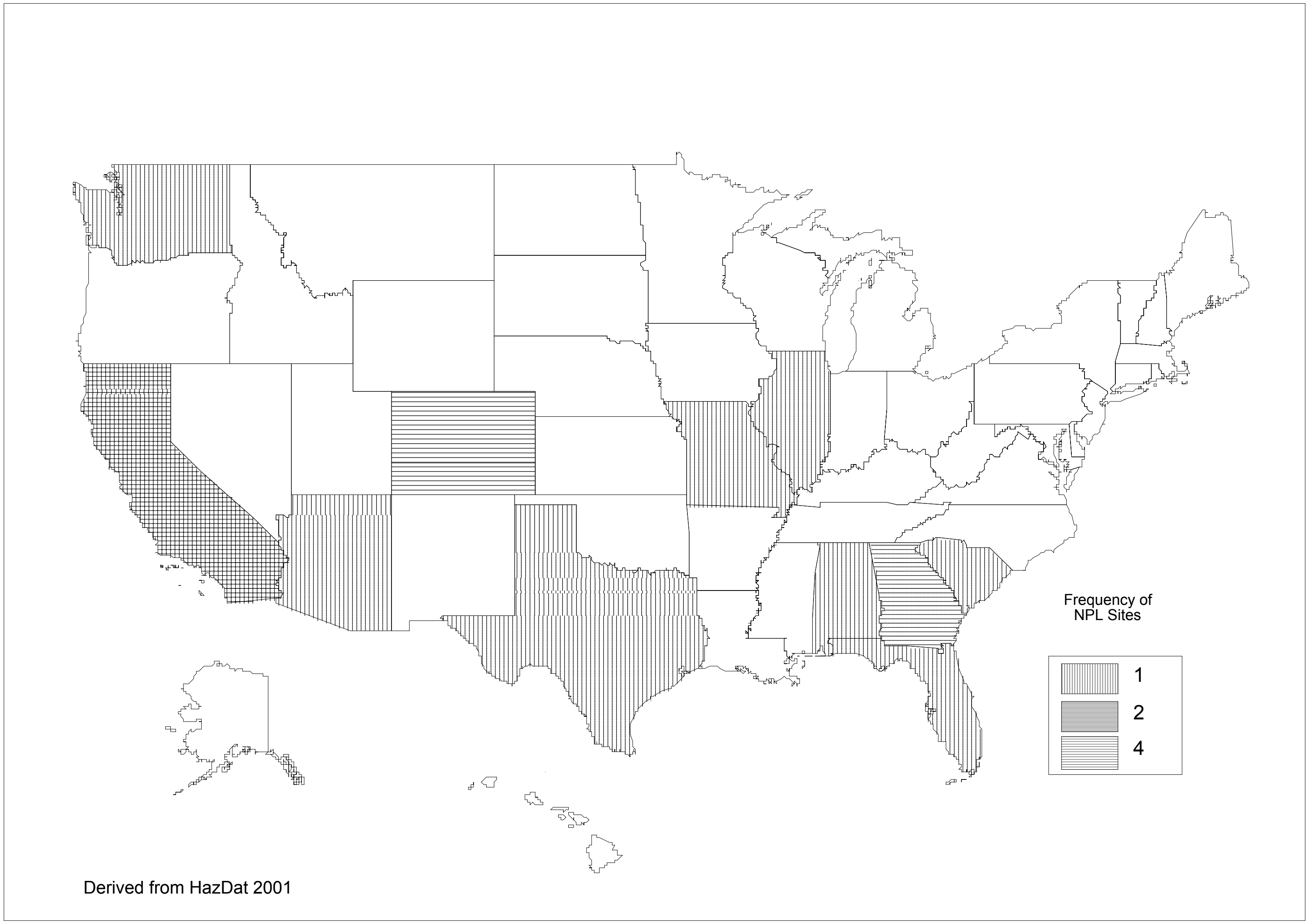
6.1 OVERVIEW

Methyl parathion is a broad-spectrum agricultural insecticide that is released to the environment primarily through spraying of the insecticide on a variety of agricultural products. Once methyl parathion is introduced to the environment, it is degraded by hydrolysis, photolysis, or by biodegradation from microorganisms found in most sediment, soils, and water. Methyl parathion is primarily confined to the application area, but some can be transported by rain, fog, and wind to other areas. Methyl parathion adsorbs to the soil and is relatively immobile. As a result, leaching into groundwater is not usually observed. Volatilization has been observed to occur from plants and soil postapplication, with volatilization from plants being the faster of the two. Limited studies show that bioconcentration of methyl parathion does not occur to a significant extent and that what is accumulated in plants and animals is rapidly metabolized. Methyl parathion is not widely dispersed or persistent in the environment. Residue amounts of methyl parathion have been detected in air, water, fish, soil, and agricultural crops consumed as foods.

Methyl parathion is approved by the EPA only for use on agricultural crops. As a result, the general population is not likely to be exposed to large amounts of methyl parathion. Some exposure to residues of methyl parathion is possible, however, as many studies show that methyl parathion has been detected in foods and atmosphere samples. Populations living within or very near areas of heavy methyl parathion use would have an increased risk of exposure to large amounts of methyl parathion through dermal contact with contaminated plants, by inhalation of the mist formed from the applied insecticide, or by ingestion of water or food-borne residues. Those likely to receive the highest levels of exposure are those who are involved in the production, formulation, handling, and application of methyl parathion. Dermal contact appears to be the major route of exposure, while inhalation may also be an important route of exposure for those working in these operations.

Methyl parathion has been identified in at least 16 of the 1,585 hazardous waste sites that have been proposed for inclusion on the EPA National Priorities List (NPL) (HazDat 2001). However, the number of sites evaluated for methyl parathion is not known. The frequency of these sites can be seen in Figure 6-1.

Figure 6-1. Frequency of NPL Sites with Methyl Parathion Contamination



Derived from HazDat 2001

6.2 RELEASES TO THE ENVIRONMENT

Methyl parathion has been released to the environment mainly as a result of its use as an insecticide on crops. It is applied to agricultural crops by aerial or ground spraying equipment. Methyl parathion has been detected in surface waters and sediments, rainwater, aquatic organisms, and food. There are no known natural sources of the compound. Methyl parathion has been identified in at least 16 of the 1,585 hazardous waste sites on the NPL (HazDat 2001).

According to recent Toxics Release Inventory (TRI) data, methyl parathion was discharged to air from two processing sites in the United States in 1999 (TRI99 2001). No releases to soil or water were reported. The TRI data should be used with caution because only certain facilities are require to report. This is not an exhaustive list.

6.2.1 Air

As a result of its use as an insecticide on cotton, fruit trees, vegetables, and other crops, methyl parathion is released directly to the atmosphere during application. It is applied primarily by spraying from aircraft or ground equipment (NPIRS 1986). Aerial application of methyl parathion to agricultural fields releases the insecticide to the air.

Methyl parathion may also be introduced into the air as a result of its volatilization from plant surfaces, and somewhat from soil, especially in the period just after application. Under simulated field conditions (20 EC; air velocity 1 meter/second; relative air humidity 40–60%), an emulsifiable concentrate formulation of methyl parathion was applied to bare soil and bean plants. After 24 hours, the amounts of methyl parathion that had volatilized from bare soil and bean plants were 5 and 64% of the applied amount, respectively (Rudel 1997).

Releases to the atmosphere from production facilities and disposal sites have also been reported. Studies have shown that releases of methyl parathion to the atmosphere occur in the vicinity of pesticide-producing factories. At two predominately downwind sites located 1 mile from a plant producing methyl parathion, average monthly concentrations were <0.57 and <0.64 ng/m^3 (Foster 1974). Air emissions from methyl parathion production facilities have been reported to contain 1.0 kg/1,000 kg pesticide produced. In addition, evaporation from holding ponds for pesticide waste potentially contributes 7.4 mg/1,000 kg pesticide produced to the atmosphere (EPA 1978d).

The most recent TRI data indicate that six sites in the United States processed methyl parathion in 1999 (TRI99 2001). The total of reported releases to air was 15 pounds, representing 100% of all environmental releases (Table 6-1). The TRI data should be used with caution because only certain types of facilities are required to report. This is not an exhaustive list.

No information was found on the occurrence of methyl parathion in air samples collected at NPL sites.

6.2.2 Water

Methyl parathion can be released to surface waters by storm runoff from sprayed fields; atmospheric deposition following aerial application (wet deposition from rain and fog water); waste water releases from formulation, manufacturing, or processing facilities; and spills.

Methyl parathion has been detected in runoff water from a cotton field at a concentration of 15 ppb. A semi-empirical prediction formula used to predict maximum concentrations of pesticides in agricultural runoff water estimated methyl parathion concentrations could be as high as 40 ppb (Wauchope and Leonard 1980). Methyl parathion has been detected in fog water near sites of application (Schomburg et al. 1991) and in rainwater (Nations and Hallberg 1992), suggesting that methyl parathion can be released to surface waters by wet deposition, the process that occurs after airborne residues dissolve in water. Methyl parathion could be released to water through atmospheric deposition following aerial application, but no data are available for evaluating the importance of this route of surface water contamination. Methyl parathion can be released to surface water by the release of waste water containing pesticide residues. In one report, methyl parathion was detected in pre-, mid-, and posttreatment waste water from a methyl parathion production plant (EPA 1978e).

Spills may represent the greatest point source release of methyl parathion to groundwater and surface water. An accidental spill caused by a warehouse fire in Nebraska released methyl parathion to a drainage ditch that emptied into the Missouri River (Kawahara et al. 1967). In another incident, 10 tons of methyl parathion spilled in the Mediterranean Sea near Egypt as a result of a collision between two ships (Badawy et al. 1984).

The most recent TRI data indicate that no releases of methyl parathion to water for the six sites in the United States that processed methyl parathion in 1999 (TRI99 2001). The TRI data should be used with caution because only certain types of facilities are required to report. This is not an exhaustive list.

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

		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	No data	No data	No data	No data	No data	No data	No data
GA	1	5	No data	No data	No data	5	No data	5
MS	1	10	0	No data	No data	10	No data	10
NE	1	No data	No data	No data	No data	No data	No data	No data
TX	2	0	No data	No data	No data	0	No data	0
Total	6	15	0	0	0	15	0	15

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).

Methyl parathion is listed in the HazDat database of chemicals detected in surface water or groundwater at NPL sites.

6.2.3 Soil

Most of the methyl parathion deposited onto soils is through deposition of spray droplets that fall to the ground following spraying. An estimated 5.95 million pounds of methyl parathion were used on a variety of crops in the United States in 1992 (Gianessi and Anderson 1995).

Methyl parathion may also be released to soils by improper handling of pesticide formulations during processing or handling. In a sampling of soils collected from processing facilities in Illinois, methyl parathion was detected in soil at 2 of the 49 sites tested (Krapac et al. 1995).

The most recent TRI data indicate that no releases to soil were reported for the six sites in the United States that processed methyl parathion in 1999 (TRI99 2001). The TRI data should be used with caution because only certain types of facilities are required to report. This is not an exhaustive list.
Methyl parathion is listed in the HazDat database of chemicals detected in soils at NPL sites.

6.3 ENVIRONMENTAL FATE

The methyl parathion released to the atmosphere can be transported back to surface water and soil by wet deposition. Methyl parathion that is released to the atmosphere can also be transformed by indirect photolysis to its oxygen analog, methyl paraoxon, by oxidation with photochemically produced oxygen radicals. However, methyl parathion is not expected to undergo significant transformation to methyl paraoxon.

In surface waters, methyl parathion degrades by biotransformation, hydrolysis, volatilization, and photolysis (EPA 1978c, 1981a). Biodegradation is expected to be the predominant degradation process. Adsorption to sediment and suspended matter may significantly affect the degradation processes (Lartiges and Garrigues 1995).

In soil and sediments, methyl parathion adsorbs to soil and is expected to display moderate mobility (EPA 1980c). The major degradation process of methyl parathion in soil is biodegradation by microbes (Badway and El-Dib 1984). Degradation by hydrolysis has been observed to occur at higher temperatures

(Sharmila et al. 1988). Little methyl parathion appears to volatilize from soil (EPA 1984a) or leach into groundwater (Albanis et al. 1988a, 1988b; Jury et al. 1983, 1987a, 1987b; McLean et al. 1988).

6.3.1 Transport and Partitioning

Data indicate that methyl parathion generally does not remain in the air for long periods or migrate far from the application site following aerial application when wind conditions are satisfactory. Studies following application of methyl parathion indicate that it is rapidly removed from the atmosphere (Jackson and Lewis 1978), probably by wet and dry deposition. Methyl parathion has been detected in the water phase of fog (Glotfelty et al. 1987; Sharmila et al. 1988), suggesting wet deposition processes. Its deposition has been found to be confined primarily to the intended application site with negligible exposure estimated to occur 100 yards from the center of the target field (Draper and Street 1981). Wind conditions, which would be expected to be a factor in methyl parathion transport in air, were negligible in this study.

The vapor pressure of methyl parathion is relatively low (9.7×10^{-6} mmHg), as is the Henry's law constant (6.2×10^{-6} atm-m^3/mol) (EPA 1984a; HSDB 1999; Rice et al. 1997; Sanders and Seiber 1983). The volatilization of methyl parathion from soil and water has generally been found to be correspondingly low.

Mathematical models have also predicted a low volatility for methyl parathion (Jury et al. 1983; McLean et al. 1988). One study using a laboratory model designed to mimic conditions at soil pit and evaporation pond disposal sites (Sanders and Seiber 1983) did find a high volatility from the soil pit model (75% of the deposited material), but a low volatility for the evaporation pond model (3.7% of the deposited material). A study of methyl parathion and the structurally similar compound ethyl parathion, which have similar vapor pressures, found that methyl parathion underwent less volatilization than ethyl parathion; in a review of the data, the reduced level of volatilization for methyl parathion was determined to be due to its adsorption to the soil phase (Álvarez-Benedi et al. 1999).

Methyl parathion is only slightly soluble in pH 7 water (55–60 ppm). This affects its mobility in water and its ability to be leached or solubilized into the water phase of a soil-water system. Factors most likely to affect the adsorption of methyl parathion in soil are organic matter content and cation exchange capacity. In soils of low organic matter (e.g., subsurface soils), calcium concentration, which affects the hardness of the water, may also be important (Reddy and Gambrell 1987). Several studies have shown that, in most cases, methyl parathion does not move very far from the soil surface following application (Albanis et al. 1988a, 1988b; Jury et al. 1983, 1987a; McLean et al. 1988). One reason for this limited mobility is that most of the methyl parathion may degrade before significant migration can occur.

The solubility of methyl parathion is not sufficient to pose a problem in runoff water as determined by an empirical model of Wauchope and Leonard (1980). Some recent monitoring data, however, indicate that methyl parathion has been detected in surface waters (Senseman et al. 1997). In a study to determine the residue levels of pesticides in shallow groundwater of the United States, water samples from 1,012 wells and 22 springs were analyzed for methyl parathion. No methyl parathion was detected in any of the water samples (Kolpin et al. 1998). In a study of water from near-surface aquifers in the Midwest, no methyl parathion was detected in any of the water samples from 94 wells that were analyzed for pesticide levels (Kolpin et al. 1995). Leaching to groundwater does not appear to be a significant fate process.

When the concentrations of methyl parathion in soil are high, such as those found at hazardous waste or spill sites, leaching may be a significant source of contamination (Albanis et al. 1988b; Jury et al. 1987a). Several authors have found soil adsorption isotherms to be linear at lower concentrations, but nonlinear at higher concentrations (EPA 1980c; Rao and Davidson 1979). This suggests that while methyl parathion may be relatively immobile in soil at the lower concentrations used in agriculture, it may be more mobile at the higher concentrations found at hazardous waste sites and spills.

One of the most important factors affecting the mobility of methyl parathion in the environment is its strong adsorption to soils. One study showed that after a 49-day incubation, 54% of the initial applied methyl parathion remained in the soil (Gerstl and Helling 1985). Factors affecting the adsorption of methyl parathion are organic matter content of the soil and sediment, and the cation exchange capacity of the soil. Values for organic-carbon normalized soil adsorption coefficients, K_{oc}, in five soil types were determined by EPA (1980c) and were found to average 496, equal to a log K_{oc} of 2.7. Estimates of log K_{oc}, calculated from the octanol-water coefficient (K_{ow}), solubility, and melting point data ranged from 2.93 to 3.47, and compared favorably with literature values (Karickhoff 1981). McLean et al. (1988) estimated a lower K_{oc} of 39, equal to a log K_{oc} of 1.59. More recently, a K_{oc} of 5,100, equal to log K_{oc} 3.7, has been reported (HSDB 1999). These K_{oc} values indicate that methyl parathion is moderately mobile to immobile in soil (Swann et al. 1983).

Estimates of bioconcentration factors, BCF, in aquatic organisms, based on calculations from water solubility and K_{oc}, gave a log BCF of 1.80–2.89 (Kenaga 1980). Studies in outdoor ponds yielded log

BCF factors in fish ranging from 1.08 to 1.85, indicating that bioconcentration of methyl parathion is not an important fate process (Crossland and Bennett 1984). In another study, methyl parathion was added to the water of a carp-rearing pond and the concentration of methyl parathion was measured in water, soil, macrophytes, and carp over a 35-day period. Results showed that methyl parathion accumulated in macrophytes for 1 day and in carp for 3 days following exposure, and then dissipated. The concentrations of methyl parathion decreased in macrophytes by 94% by day 35 and by 98% in carp tissue by day 28 (Sabharwal and Belsare 1986). These data indicate the potential for biomagnification in the food chain is likely to be low because methyl parathion appears to be metabolized in aquatic organisms.

6.3.2 Transformation and Degradation

6.3.2.1 Air

Very little information exists in the literature on the transformation and degradation of methyl parathion in air. An early study indicated that direct photolysis of methyl parathion may occur; however, the products of this photolysis were not determined (Baker and Applegate 1974). A later study found a transformation product of methyl parathion, methyl paraoxon, in air samples taken from areas where methyl parathion had been applied. Formation of methyl paraoxon was attributed to the vapor phase oxidation of methyl parathion (Seiber et al. 1989). Recent monitoring studies in California have also found both methyl parathion and methyl paraoxon (Baker et al. 1996).

6.3.2.2 Water

Methyl parathion is rapidly degraded in natural water systems. The degradation of methyl parathion occurs much more rapidly in alkaline (pH 8.5) than in neutral (pH 7) or acidic (pH 5) conditions (Badawy and El-Dib 1984). A hydrolysis half-life of 72–89 days was calculated for fresh water at 25 EC and pH<8 (EPA 1978c; Mabey and Mill 1978) compared with about 4 days at 40 EC and pH$8 (EPA 1978c). Under conditions typically encountered in the environment, with pHs between 5 and 9, methyl parathion is not expected to be a significant fate process.

The degradation of methyl parathion by hydrolysis and biodegradation was studied in four types of water (ultrapure water, pH 6.1; river water, pH 7.3; filtered river water, pH 7.3; and seawater, pH 8.1) maintained at 6 and 22 EC, in the dark. The half-lives of methyl parathion at 6 EC in the four water types were determined to be 237, 95, 173, and 233 days, respectively, and the half-lives at 22 EC were determined to be 46, 23, 18, and 30 days, respectively. The study shows that degradation rates increase with pH and temperature, and are fastest in river water (Lartiges and Garrigues 1995).

Transformation and degradation of methyl parathion in water appear to be primarily biological (i.e., microbial), but chemical degradation (i.e., hydrolysis) may be important in some systems (EPA 1978c, 1981a). In oligotrophic waters (i.e., low in microbial populations), hydrolysis is the major degradation mechanism (Baughman and Lassiter 1978; EPA 1978c, 1981a). The rate of chemical hydrolysis depends on pH and temperature.

Studies in which methyl parathion is added to the water phase of sediment samples have detected no methyl parathion in the sediment, probably because the degradation rate exceeds the rate of deposition to the sediment (Crossland and Bennett 1984; EPA 1982b). This degradation appears to be primarily microbial. Experiments comparing the degradation of methyl parathion in tap water and natural pond water show similar rates of disappearance of methyl parathion. Loss rates increased in both water types when plants, sediment, or plants and sediment were added (Crossland and Bennett 1984). In experiments with seawater systems, seawater plus sediment contained only 3% of the applied methyl parathion after 7 days, compared with 75% in seawater alone and 104% in sterile seawater (EPA 1981a). Degradation in water alone was also found to be significantly less than in water plus sediment in an estuarine system (Pritchard et al. 1987). Several studies in water systems have demonstrated that methyl parathion is rapidly degraded by the bacteria within aufwuchs communities (i.e., the microorganisms attached to plants, sediments, and mats) found in aquatic ecosystems (Crossland and Bennett 1984; Holm et al. 1983; Lewis and Holm 1981). Chemical/toxicity testing using natural river die-off water with sediment and a toxicity sensitive organism (mysid shrimp) demonstrated that methyl parathion degraded rapidly (half-life of 2.3 days) to nontoxic products (Cripe et al. 1987).

In freshwater systems, the only biodegradation product detected was 4-nitrophenol, which was rapidly utilized and transformed to undetectable metabolites by the microorganisms present. In seawater, the main initial product was methyl aminoparathion, formed by reduction of the nitro group (Badawy and El-Dib 1984). Studies in raw river water showed that 4-nitrophenol and dimethyl thiophosphoric acid are the main degradation products (Eichelberger and Lichtenberg 1971).

Photolysis studies of methyl parathion have been reported. A study examining the photodegradation of methyl parathion in river and seawater at variable temperatures showed the half-lives to be 11 and 34 days, respectively (Lartiges and Garrigues 1995). During photolysis in natural water 50% of the original methyl parathion concentration was degraded in 8 days in the summer and 38 days in the winter (EPA 1978c). In a photolysis study of methyl parathion in fresh waters of Portugal, a half-life of 3 days in groundwater and a half-life of 4 days in river water were observed. The authors noted that the transformation products, which included methyl paraoxon, were more stable than the parent compounds studied (Castillo et al. 1997).

6.3.2.3 Sediment and Soil

In soils and sediments, microbial degradation and hydrolysis are important degradation processes. Studies have found that methyl parathion degrades more rapidly in anaerobic soil than in aerobic soils (Adhya et al. 1981, 1987; Brahmaprakash et al. 1987). An average half-life of 64 days was determined for nonflooded (aerobic) soils compared to an average half-life of 7 days in flooded (anaerobic) soils (Adhya et al. 1987). In experiments with ^{14}C-labeled methyl parathion, 35% of the labeled compound was recovered from nonflooded soil after 28 days, compared with 9% recovered from flooded soil (Brahmaprakash et al. 1987).

Results from other studies support the rapid degradation of methyl parathion in soils with a high water (i.e., low oxygen) content (Adhya et al. 1981, 1987; Brahmaprakash et al. 1987). Experiments in flooded and nonflooded soils showed that the redox potential affected both the rate of degradation and the transformation products of methyl parathion (Adhya et al. 1981, 1987). Transformation to volatile products was suggested by Brahmaprakash et al. (1987) as the reason that significant amounts of ^{14}C from labeled methyl parathion could not be accounted for, especially in flooded soils.

In a study of the degradation of methyl parathion in flooded (anaerobic), alluvial (pH 6.2) soil, samples were maintained at 6, 25, and 35 EC for 12 days. Methyl parathion did not degrade at 6 EC, while at 25 EC, methyl aminoparathion, formed from the reduction of the nitro group, was the sole metabolite. At 35 EC, methyl aminoparathion was formed from the reduction of the nitro group, and 4-nitrophenol was formed by hydrolysis. For the 25 EC samples, 50 and 28% of the applied amount remained in the soil by day 4 and day 6, respectively. No methyl parathion remained in the soil by day 6 in the 35 EC samples (Sharmila et al. 1988). Studies show that methyl parathion forms bound residues in moist soils, and is degraded by reduction of the nitro group. The primary metabolites detected were 4-nitrophenol and 4-aminophenol, which were further transformed to carbon dioxide by the soil microbiota (Ou et al. 1983). Biodegradation is affected by temperature, pH, and moisture content of the soil (Adhya et al. 1987; EPA 1980c; Ou et al. 1983).

Low concentrations of methyl parathion, such as those associated with normal use, degrade fairly rapidly in the environment (EPA 1980c). For example, 75–85% of an applied concentration of 24.5 ppm was found to decompose in 52 days (EPA 1980c). Degradation rate is affected by temperature. Studies by Baker and Applegate (1970) showed that the methyl parathion loss over a 50-day period increased by a factor of 1.3–1.4 when the temperature was increased from 30 to 50 EC. The pH of the soil also affects degradation rate, with methyl parathion degrading faster at more alkaline pH values (Adhya et al. 1987). When the concentration of methyl parathion is high, as in bulk disposal and spills, degradation appears to be significantly retarded (Butler et al. 1981a; EPA 1980c). In a study simulating spill conditions (EPA 1980c) for an applied concentration of 10,015 ppm methyl parathion, losses of only 0.1% were observed after 52 days. In another simulated spill study, 42.7% of a concentration of 48,900 ppm of methyl parathion still remained in the soil after 1 year, and 35.8% remained after almost 4 years (Butler et al. 1981a).

Direct photolysis does not appear to be a significant transformation process in soils. Only 5–17% of the methyl parathion concentration was lost over 50–60 days (half-life equal to 330 days) during a photolysis study (Baker and Applegate 1970).

6.3.2.4 Environmental Media

Decomposition of methyl parathion was studied in central Greece in apples remaining on trees after spraying (emulsifiable concentrate; 40% active ingredient) and in apples harvested and stored under ambient-temperature, refrigerated-room temperature, and controlled-atmosphere conditions (Pappas et al. 1999). Methyl parathion degraded fastest on the apples remaining on the trees. Half-lives were found to be 8 days for apples on trees, 45 days for apples stored at ambient conditions, 68 days for apples stored in a controlled-atmosphere room, and 62 days for apples stored in a refrigerated room.

6.4 LEVELS MONITORED OR ESTIMATED IN THE ENVIRONMENT

6.4.1 Air

In a study to determine the concentrations of pesticides in air collected during times of peak pesticide use in California, air samples were collected at applications sites and at locations adjacent to the application sites (Baker et al. 1996). Of the samples collected adjacent to the application sites, 50% had levels of methyl parathion greater than the detectable limit of 0.2 ng/m^3, while 21% had levels of methyl paraoxon greater than the detectable limit of 0.2 ng/m^3. The maximum amount of methyl parathion detected was 26 ng/m^3; the maximum amount of methyl paraoxon detected was 4.8 ng/m^3. At the application sites, the maximum amount of methyl parathion detected was 520 ng/m^3. Air samples collected at the application sites were not analyzed for methyl paraoxon.

Air samples collected in the Sacramento Valley area of California near sites where methyl parathion was heavily used on rice were analyzed by Seiber et al. (1989). Methyl parathion concentrations ranged from 0.2 (minimum detectable level) to 25.67 ng/m^3 depending on the location and time of sampling. Methyl paraoxon, the oxygen analog of methyl parathion, was also detected at a maximum of 3.07 ng/m^3. The highest concentrations of both compounds were found at sites near locations of heaviest use.

Airborne pesticide residues were determined from air samples collected along the Mississippi River from Louisiana to Minnesota during a 10-day period in June of 1994. Methyl parathion, used throughout Mississippi and in parts of Louisiana and Arkansas primarily on cotton, was detected in 8 of the 10 samples collected over this 10-day study. The maximum concentration (0.30 ng/m^3 detection limit) of methyl parathion was 0.85 ng/m^3 (range of 0.05–3.4 ng/m^3), and the median concentration was 0.07 ng/m^3 (Majewski et al. 1998). In a similar study conducted in April–September 1995 at urban and agricultural sites along the Mississippi River in Mississippi, Iowa, and Minnesota, airborne methyl parathion (35 pg/m^3 detection limit) was detected in 70% of the samples collected at the Mississippi agricultural site, and was present at the highest level of any of the 19 insecticides monitored in the study, at a maximum concentration of 62 ng/m^3 (Foreman et al. 2000). In the same study, the median concentration of methyl parathion in all agricultural site air samples collected in the study was 2.5 ng/m^3, and methyl parathion was detected in the air samples of urban areas at a maximum concentration of 0.99 ng/m^3 (Coupe et al. 2000).

Atmospheric concentrations of methyl parathion following application of the pesticide to tobacco fields were studied by Jackson and Lewis (1978). They found that levels of methyl parathion decreased rapidly following application of either the emulsifiable concentrate or the microencapsulated form. Air concentrations for the emulsifiable concentrate ranged from 7,408 ng/m^3 immediately following application to 13 ng/m^3 9 days later. The corresponding measurements for the microencapsulated form were 3,783 and 16 ng/m^3.

6.4.2 Water

Several studies have been conducted to measure methyl parathion in streams, rivers, and lakes. A U.S. Geological Survey (USGS) of western streams detected methyl parathion in five river samples taken from four states during a 14-month period in 1970 and 1971. The amount of methyl parathion detected ranged from 0.04 to 0.23 µg/L (Schultz et al. 1973). A later and more extensive USGS study analyzed water samples from major rivers of the United States four times yearly in the period of 1975–1985. Of the 2,861 water samples, 0.1% had detectable levels of methyl parathion (Gilliom et al. 1985). In a study of Arkansas surface waters, samples of lake and river/stream water were collected and analyzed over a three-year period (Senseman et al. 1997). Of the 485 samples collected, methyl parathion was found in one river/stream sample at a maximum concentration of 3.5 µg/L. Results from an EPA study in California detected methyl parathion in 3 of 18 surface drain effluent samples at concentrations of 10–190 ng/kg. Subsurface drain effluent water had concentrations of 10–170 ng/kg in 8 of 60 samples (IARC 1983).

Groundwater has also been surveyed for methyl parathion. In a study of well water in selected California communities, methyl parathion was not detected (detection limit of 5 ppb) in the 54 wells sampled (Maddy et al. 1982), even though the insecticide had been used in the areas studied for over 15 years. An analysis of 358 wells in Wisconsin produced the same negative results (Krill and Sonzogni 1986). In a sampling of California well water for pesticide residues, no methyl parathion was detected in any of the well water samples (California EPA 1995). In a study to determine the residue levels of pesticides in shallow groundwater of the United States, water samples from 1,012 wells and 22 springs were analyzed. Methyl parathion was not detected in any of the water samples (Kolpin et al. 1998). In a study of water from near-surface aquifers in the Midwest, methyl parathion was not detected in any of the water samples from 94 wells that were analyzed for pesticide levels (Kolpin et al. 1995).

Methyl parathion has been reported in groundwater in Idaho at a median level of 0.01 ppb with contamination due to a point source (EPA 1988c). A study of tap water in Ontario showed no detectable methyl parathion at a detection limit of 1 ng/L (Le Bel et al. 1979).

Samples of rainfall in Iowa have been analyzed for levels of pesticides (Nations and Hallberg 1992). Samples collected in April, May, and June of the three years in the study period of 1987–1990 had the highest levels of methyl parathion, corresponding to the application to crops. Methyl parathion was found in 4 of the 318 rain samples analyzed at a maximum concentration of 2.77 µg/L. In a study of pesticides in rain and air, conducted in April–September 1995 at urban and agricultural sites along the Mississippi River in Mississippi, Iowa, and Minnesota, methyl parathion was present at the highest level of any of the 47 pesticides monitored in the rain samples collected in the study (Coupe et al. 2000). Methyl parathion was detected in the agricultural and urban site rain samples at maximum concentrations of 22.9 μg/L (median of 0.12 μg/L) and 0.3 μg/L (median of 0.024 μg/L), respectively (Coupe et al. 2000). In the same study, at the agricultural site in Mississippi, the total wet deposition of methyl parathion during the 6-month study was 1,740 $\mu g/m^2$ (89% of the total wet depositional loading at that site), greater than the totals for each of the other 46 compounds monitored in the study (Majewski et al. 2000). Methyl parathion was not detected in the wet deposition at the Iowa site and was detected only once at each of the two Minnesota sites (Majewski et al. 2000).

Methyl parathion and methyl paraoxon concentrations were measured in the condensate from coastal fog in California. Levels ranged from 0.046 to 0.43 μg/L methyl parathion and from 0.039 to 0.49 μg/L methyl paraoxon. The authors noted that the transformation of the methyl parathion to the methyl paraoxon appeared to take place during atmospheric transport of methyl parathion away from the agricultural areas (Schomburg et al. 1991).

6.4.3 Sediment and Soil

In random samples of soil taken from five Alabama counties, only 3 of 46 soil samples contained methyl parathion. The concentration in these samples was <0.1 ppm (Albright et al. 1974). As part of the National Soils Monitoring Program, soil and crop samples from 37 states were analyzed for methyl parathion during 1972. Methyl parathion was detected in only 1 soil sample, at a concentration of <0.1 ppm and taken from South Dakota, out of 1,246 total samples taken from the 37 states (Carey et al. 1979). In soil and sediment samples collected from a watershed area in Mississippi, methyl parathion was not detected in the soil samples. In three wetland sediment cores, however, measurable concentrations of methyl parathion were detected during application season (Cooper 1991).

A USGS study analyzed bed sediment samples from major rivers of the United States twice yearly in the period of 1975–1985. Methyl parathion was not detected in any sediment sample (Gilliom et al. 1985).

In a study of a highly contaminated soil evaporation pit in California, methyl parathion was found to a depth of 90 cm in the soil bed. The concentration at this depth was 18 ppm. Highest concentrations were found in the top 7.5 cm of the soil surface and ranged from 32 to 392 ppm (Winterlin et al. 1989). In a study to determine if spills caused by poor handling, storage, or containment practices of agricultural products released pesticides to soil, samples were collected from agrichemical sites in Illinois (Krapac et al. 1995). Of the 822 soil samples collected at 49 sites, methyl parathion was found at 2 of the sites, at a median concentration of 112 ppb and a mean concentration of 584 ppb.

Marine sediments, adjacent to a pesticide manufacturing plant in Denmark, contained methyl parathion levels of 40.6 and 44.1 μg/kg dry weight at depths of 0–3 and 4–8 cm, respectively (Kjolholt 1985).

6.4.4 Other Environmental Media

Methyl parathion was monitored in crops from 37 states in 1972 as part of the National Soils Monitoring Program (Carey et al. 1979). The pesticide was detected in 40% of cotton stalk, 6.3% of cotton seed, 2.3% of mixed hay, and 9.1% of sorghum samples. Mean concentrations ranged from 0.15 ppm in cotton stalks to <0.1 ppm in cotton seeds, mixed hay, and sorghum. The compound has also been reported in the outer shuck of sweet corn at a concentration of 0.13–0.14 $\mu g/cm^2$, 1–2 days after application, but was not detectable in the inner shuck (Wicker et al. 1979). Imported flowers were reported to contain a mean concentration of 0.3 mg/kg in 10.5% of samples tested (Morse et al. 1979).

In a Food and Drug Administration (FDA) summary of the levels of pesticides in ready-to-eat foods in the 10-year period from 1982 to 1991, methyl parathion was found 12 times in 8 kinds of food, at an average concentration of 0.0035 ppm (Kan-Do Office and Pesticides Team 1995). A 5-year analysis of domestic and imported foods and animal feeds for the years 1982–1986 detected 94 samples out of 19,851 total samples that contained methyl parathion (Hundley et al. 1988). Eighty-nine of the samples had concentrations in the range of 0.05–0.5 ppm, and five had levels ranging from 1.0 to 2.0 ppm. Methyl parathion was found in celery, citrus, coriander, cantaloupe, Chinese peas, hay, alfalfa feed, Italian squash, lettuce, mustard greens, okra, parsley, peppers, spinach, strawberries, tomatillos, and tomatoes. An FDA study of pesticide residues in infant and adult foods eaten by infants/children for the period 1985–1991 reported results for methyl parathion as total parathion (Yess et al. 1993). Of the 2,464 apples analyzed, total parathion was detected in 158 samples at a maximum of 1.3 ppm. Of the 862 oranges analyzed, total parathion was detected in 25 samples at a maximum of 1.4 ppm. Of the 571 pears analyzed, total parathion was detected in 8 samples at a maximum of 0.12 ppm.

A large study of fruits and vegetables available in Canada examined 5,784 Canadian samples and 16,198 imported (including from the United States) samples (Neidert and Saschenbrecker 1996). Of the

Canadian samples analyzed, 1 sample (carrots) contained a methyl parathion residue at a level of <0.05 ppm. Of the imported samples, 14 contained methyl parathion residues. Levels of methyl parathion ranged from <0.05 ppm (in pears and snowpeas), to 0.10 ppm (in apples, oranges, pears, and tomatoes), to a maximum of 0.50 ppm (in grapes, apples, oranges, and pears, plus another unspecified sample).

Citrus fruits from markets in Spain were analyzed for residues of methyl parathion along with other organophosphorus insecticides (Torres et al. 1997). Of the 171 orange samples analyzed, 14 had levels of methyl parathion <0.2 ppm, while 5 had levels >0.2 ppm. Levels ranged from the 0.1 ppm limit of detection to 3.8 ppm depending on the type of orange. Of the 15 grapefruit samples analyzed, 1 was found to contain methyl parathion at a level of 0.3 ppm.

A study of estuarine fish in 21 coastal states conducted from 1972 to 1976 as part of the National Pesticide Monitoring Program detected a mean concentration of 47 ppb in 3.9% of the fish tissue samples collected (Butler and Schutzmann 1978). In another study (Cooper 1991), fish collected in a watershed area of Mississippi were analyzed for residues of methyl parathion. Methyl parathion was detected in seven species of fish, with white bass having the greatest mean concentration, at 15.96 ppm. Methyl parathion was found in 3 of the 32 fish samples collected before spraying of methyl parathion and in 12 of the 25 samples of fish collected after methyl parathion spraying.

Methyl parathion was not detected (detection limit of 1.0 ppb) in a study of 21 market samples and 4 producer samples of milk obtained in Portugal. However, the oxygen analog and metabolite of methyl parathion, methyl paraoxon, was found (detection limit of 1.0 ppb) in 22 of the 25 samples, at concentrations ranging from 1.5 to 8.7 ppb, with an average level of 3.6 ppb (Lino and da Silveira 1992). All of the market samples contained methyl paraoxon, while only one of the producer samples contained the compound. In a study of milk and cheese products obtained in Greece, of the 38 bovine milk samples analyzed, two contained methyl parathion at levels that ranged from 43 to 280 ppb of milk fat, with a mean concentration of 161 ppb of milk fat (Mallatou et al. 1997). In a study of milk and yogurt samples from Egypt, methyl parathion and its metabolites methyl paraoxon and 4-nitrophenol were not detected in any of the samples (Ahmed 2000).

One FDA study (Roy et al. 1997) determined the levels of pesticide residues in rice and apples. Of the 769 domestic apples analyzed, methyl parathion was found in 72 samples at a maximum concentration of 0.15 ppm. Of the 1,062 imported apples analyzed, methyl parathion was found in 4 samples at a maximum concentration of 0.05 ppm. Of the 598 samples of domestic rice, methyl parathion was found in 4 samples at a maximum concentration of 0.13 ppm. Of the 612 imported rice samples analyzed, 1 sample contained methyl parathion, at a concentration of 0.04 ppm.

6.5 GENERAL POPULATION AND OCCUPATIONAL EXPOSURE

There are insufficient data to determine potential daily inhalation and dermal exposure levels. However, based on the information presented in Sections 6.3 and 6.4, exposure levels for the general population are probably very low by these routes. Inhalation exposure is not important for the general population, with the possible exception of those individuals living near areas where methyl parathion is frequently sprayed. Since methyl parathion is readily adsorbed through the skin, dermal contact may be the most relevant exposure pathway. Dermal contact is most likely to occur in people who are occupationally exposed.

In a study to determine if the general population living near an area of heavy pesticide use is exposed to high levels of pesticides from foods, the diets of occupants residing in nine homes in the Lower Rio Grande Valley were analyzed for residue levels of pesticides (Berry et al. 1997). Food samples obtained from markets in Texas or Mexico were analyzed in the summer and spring of the study year. In the 30 types of food analyzed in the spring and the 24 types analyzed in the summer, methyl parathion was detected in 1 food sample at a concentration of 0.018 ppm in the spring and 0.004 ppm in the summer. In another study in the Lower Rio Grande Valley region to determine pesticide exposure in certain homes, samples of air from both inside and outside the homes and household dust were analyzed (Mukerjee et al. 1997). Indoor air samples collected in the spring contained methyl parathion at <0.4 ng/m^3, while the outdoor air samples contained 0.4 ng/m^3. In the summer, the indoor air samples contained 13.8 ng/m^3 methyl parathion while the outdoor air samples contained 12.4 ng/m^3. The household dust was found to contain 21 ppb of methyl parathion in both the spring and summer. It is not known at this time if these levels are significant. Studies are currently underway to address this issue (EPA 1999b).

The FDA Total Diet Studies/Market Basket Surveys examine foods for levels of pesticides. Estimates are then made of the mean intake of a pesticide (in µg/kg/day) using the amounts of pesticides found in foods and food consumption patterns. For the period of 1984–1986, the estimates were <0.0001 µg/kg/day for all eight age groups: 6–11 months, 2 years, 14–16 years female, 14–16 years male, 25–30 years female, 25–30 years male, 60–65 years female, and 60–65 years male (Gunderson 1995a). For the period of 1986–1991, the estimates were 0.0002 µg/kg/day for the 6–11 months group, 0.0001 µg/kg/day for the 2 years group, <0.0001 µg/kg/day for the 14–16 years and 25–30 years groups, and 0.0001 µg/kg/day for the 60–65 years group (Gunderson 1995b). FDA Market Basket Surveys from 1979 to 1980 and from 1980 to 1982 estimated mean adult average daily exposure to pesticide residues to be 0.0126–0.0596 μg/day (Gartrell et al. 1985, 1986). No data indicate that inhalation or dermal exposure are concerns for the general population, except for people living near the areas where methyl parathion is used.

Exposure of the general population to higher concentrations of methyl parathion may result from contact with, or ingestion of, contaminated hazardous waste site media, principally soils and water. No information was found in the available literature regarding the size of the human population potentially exposed to methyl parathion through contact with contaminated waste site media.

NIOSH estimated that approximately 150,000 U.S. workers are potentially exposed to methyl parathion in occupational settings (NIOSH 1976). The OSHA workplace air environmental limit of 1.2 mg/m^3 is only exceeded for a short while after spraying and only within a short radius of the application area (Draper and Street 1981). Exposure is mainly through the dermal route, although inhalation can also be a route of exposure. Workers most likely to be exposed are those directly involved with the manufacture, application, and cleanup of the chemical, and field workers (NIOSH 1976). Studies on exposure to methyl parathion following reentry of workers into a sprayed field showed exposures to be above safe levels for up to 48 hours after application (Ware et al. 1973, 1974). Analyses of methyl parathion residues on protective garments before and after washing indicate that laundry workers cleaning these garments may also be exposed (Hild et al. 1989; Laughlin and Gold 1987, 1989a, 1989b; Leonas et al. 1989).

Samples of the indoor and outdoor air at the homes of workers occupationally exposed to pesticides, farmers and pesticide formulators, were taken monthly and analyzed for methyl parathion. Methyl parathion was found in 13 of 52 indoor air samples of formulators' homes at a mean concentration of 0.26 μg/m^3 (range of 0.04–9.4 μg/m^3). Outdoor air samples of formulators’ homes showed that 3 of 53 samples contained methyl parathion at concentrations ranging from 0.15 to 0.71 μg/m^3. Methyl parathion was not detected in the indoor and outdoor air samples from farmers' homes (Tessari and Spencer 1971).

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 3.7 Children's Susceptibility.

Children are not small adults. A child's exposure may differ from an adult's exposure in many ways. Children drink more fluids, eat more food, breathe more air per kilogram of body weight, and have a larger skin surface in proportion to their body volume. A child's diet often differs from that of adults. The developing human's source of nutrition changes with age: from placental nourishment to breast milk or formula to the diet of older children who eat more of certain types of foods than adults. A child's behavior and lifestyle also influence exposure. Children crawl on the floor, put things in their mouths, sometimes eat inappropriate things (such as dirt or paint chips), and spend more time outdoors. Children also are closer to the ground, and they do not use the judgment of adults to avoid hazards (NRC 1993).

Children and the general population living in areas far from where methyl parathion is sprayed are not likely to be exposed to high levels of methyl parathion. For those living near the areas where methyl parathion is used, the children within the general population are likely to be exposed to methyl parathion in the same way as the adults, by contact with sprayed plants, breathing contaminated air, eating contaminated foods, or drinking contaminated water. Children living in agricultural areas may be exposed to higher pesticide levels than other children because of pesticides that may get tracked into the homes by household members, by pesticide spray drift, or from playing in the fields near where methyl parathion has been sprayed. Dermal exposure is expected to be the most common route of exposure.

Methyl parathion has been illegally used inside the home to kill insects (ATSDR 1999; EPA 1999b). This practice can result in high exposure levels to the occupants, including children. In an analysis of samples taken from a home nearly two weeks after the home had been illegally sprayed with a 4% solution of methyl parathion, air samples contained 0.041 mg/m^3, and water samples, collected from water kept in an open jar, contained 138–275 ppb (0.138–0.275 mg/kg) (Dean et al. 1984). National Alerts published by the EPA and ATSDR (ATSDR 1999; EPA 1999b) on the illegal use of methyl parathion in the home state that children are particularly vulnerable to methyl parathion, and deaths have been reported. (See also Section 2.2.1.1.) A recent study of U.S. inner-city children's exposure to pesticides states that such children are still being exposed to illegally used pesticides, as when methyl parathion was illegally used in cities in 1996, with illegal spraying occurring in 1,100 homes in Chicago, Cleveland, and on the Gulf Coast (Landrigan et al. 1999).

Additionally, children of workers who are exposed to methyl parathion through their employment could be exposed to high levels of methyl parathion. The workers in the manufacture, formulation, and use of methyl parathion may come into contact with methyl parathion on their skin or clothing. Children who reside in the homes of these workers could be exposed to methyl parathion by contact with any methyl parathion that might be on the workers' clothing, hair, or skin, or from contact with tools or other contaminated items brought home from work. Also, if children of farm workers enter fields shortly after methyl parathion has been applied to crops, they may be exposed to high levels of methyl parathion from coming into contact with sprayed plants or by breathing the mist containing methyl parathion.

Small children are more likely than adults to come into contact with pesticide residues that may be present in soil outside the home and in dust inside the home. The tendency for young children to ingest soil, either intentionally through pica-related behavior or unintentionally through hand to mouth activity, may expose children to residues in the soil. Hand to mouth activity indoors may expose the children to residues that may be present in carpets or in dust on uncovered floors. Methyl parathion strongly adsorbs to soil, but after being adsorbed, it rapidly degrades. If the children are playing in soil in regions where methyl parathion is used on crops, then they may be exposed to elevated levels depending on the amount of time that has passed since the spraying has occurred. Since methyl parathion degrades rapidly in soil, it is anticipated that soil-borne exposure concentrations will decrease with increasing time from any spray event. Children who are playing in soil in regions far from where methyl parathion is used would not be expected to be exposed to soil-borne methyl parathion.

Some quantitative estimates of exposure in the infant and child populations have been reported in a number of FDA Total Diet Monitoring Studies conducted in the 1980s using the amounts of pesticide residues in foods thought to be in the diets of infants or children. Estimates of the mean intake of methyl parathion were made for the 6–11 months age group, 2 years age group, and the 14–16 years female and 14–16 years male age groups. For the period of 1984–1986, the estimates were <0.0001 μg/kg/day for all of the age groups (Gunderson 1995a). For the period of 1986–1991, the estimates were 0.0002 μg/kg/day for the 6–11 months group, 0.0001 μg/kg/day for the 2 years group, and <0.0001 μg/kg/day for both the female and male 14–16 years groups (Gunderson 1995b).

An extensive study was undertaken to determine if pesticide residues are present in any infant formula products (Gelardi and Mountford 1993). Milk- and soy-based formulas were analyzed, as was the water used to make the formula. No pesticide residues, including methyl parathion, were detected in any infant formula manufactured in the United States. Thus, it does not appear that infants will be exposed to methyl parathion residues through consuming formula. As reported previously, methyl parathion was not detected in a study of 21 market samples of milk obtained in Portugal (1 ppm detection limit). However, the oxygen analog of methyl parathion, methyl paraoxon, was found in all samples, ranging from 1.5 to 8.7 ppm, with an average level of 3 ppm (Lino and da Silveira 1992). In the analysis of bovine milk in Greece for pesticide residues, 2 of the 38 bovine milk samples had concentrations of methyl parathion that ranged from 43 to 280 ppb of milk fat (Mallatou et al. 1997). Samples (9 of 19) of cow's milk obtained from the Central Asian Republic of Kazakhstan were found to contain methyl parathion at concentrations that ranged from 3 to 20 ppb (Lederman 1996). These data suggest that milk from animals in the United States may also contain low levels of methyl parathion or methyl paraoxon and, thus, that children, who typically consume large volumes of milk relative to the general population, may be exposed to methyl parathion through milk consumption.

A potential source of exposure in infants is the presence of methyl parathion in breast milk. No data were found in the available literature on the presence of malathion or its residues in breast milk in the United States. However, data from foreign countries indicate that methyl parathion residues may be excreted in breast milk. In a study of breast milk samples obtained in 1988–1990 from 10 regions within the Central Asian Republics of Turkmenistan, Tajikistan, and Kazakhstan, samples from 5 of the regions contained methyl parathion residues (Lederman 1996). Of the 90 samples for which data were reported, 8 contained methyl parathion, at a range of 1–100 ppb. Methyl parathion was also detected in 11 of 50 breast milk samples obtained from two regions in Kazakhstan in 1987 and 1992, at a range of 1.6–80 ppb (Lederman 1996). In a study of the breast milk of 11 Italian women from which samples were obtained at both the 5th and 30th day of lactation, methyl parathion was not detected in any of the samples (Roggi et al. 1991).

6.7 POPULATIONS WITH POTENTIALLY HIGH EXPOSURES

Those populations most at risk for exposure to high levels of methyl parathion are workers who mix and apply the chemical and field workers who go into sprayed areas. Individuals living near the NPL sites currently known to be contaminated with methyl parathion and those living near production facilities or other point sources might also be at risk for higher exposure. People living in areas very close to application sites may be exposed to amounts higher than the general population. In addition, laundry workers who wash the garments worn by field workers or by workers involved with mixing and applying methyl parathion may be exposed to higher concentrations (Hild et al. 1989; Laughlin and Gold 1987, 1989a, 1989b; Leonas et al. 1989).

In a study of 135 workers in the chemical industry who handle methyl parathion, the methyl parathion concentration in plasma, the 4-nitrophenol concentration in urine, and the cholinesterase and acetylcholinesterase activities were determined to assess the pesticide burden in such workers (Leng and Lewalter 1999). The mean concentration of methyl parathion in the plasma of the workers was 233 μg/L; no clinical symptoms were reported by the workers. In an additional group of 19 workers handling methyl parathion, who were also exposed to the pyrethroid cyfluthrin, the mean concentrations of methyl parathion in plasma were 269 and 241 μg/L (for groups without and with clinical symptoms, respectively), and 7 of the workers exhibited skin paraesthesia, while none of the 427 workers exposed only to the pyrethroid experienced the symptom (Leng and Lewalter 1999).

Methyl parathion is only for use on agricultural crops. The reports that methyl parathion has been illegally/improperly used inside homes to kill insects (ATSDR 1999; EPA 1999b) show that people in homes that are sprayed with methyl parathion may be exposed to dangerously high levels of methyl parathion.

The sizes of these populations and the concentrations of methyl parathion in all of the contaminated media to which these people would potentially be exposed have not been adequately characterized.

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 methyl parathion 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 methyl parathion.

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

6.8.1 Identification of Data Needs

Physical and Chemical Properties. The physical and chemical properties of methyl parathion are sufficiently well characterized to allow assessment of the environmental fate of the compound to be made (Budavari 1989; EPA 1980c; Hawley 1987; Keith and Walters 1985; NFPA 1986; Ruth 1986; Sanders and Seiber 1983; Schimmel et al. 1983; Sunshine 1969; Tomlin 1994; Weiss 1986).

Production, Import/Export, Use, Release, and Disposal. Methyl parathion is commercially produced in the United States and abroad. Since 1977, production volume statistics for methyl parathion have been combined with those of ethyl parathion, also known as parathion. In 1983, the combined production capacity was estimated at 29 million kg for the United States and 10–15 million kg for western Europe (IARC 1983). Data on recent production in the United States were not located. In 1980, 413,000 kg of methyl parathion were imported (USITC 1981). Exports in 1984 amounted to 5.68 million kg (Bureau of the Census 1984). More current information on the manufacture, import, and export of the insecticide are needed so that an assessment can be made of potential human exposure to methyl parathion.

The use of methyl parathion as a broad-spectrum insecticide for a variety of food and nonfood crops, ornamentals, trees, and mosquito breeding areas is well documented (IARC 1983; International Labour Office 1983; Meister 1988; NPIRS 1986; Spencer 1982; Tomlin 1994; Weir and Hazleton 1981). While the annual use of methyl parathion, a restricted-use compound, in the United States has also been well documented in general (EPA 1999c; Giannessi and Anderson 1995), there are few studies that document the illegal use of the compound in the home (Landrigan et al. 1999). It would be helpful to have an estimate of the amounts of methyl parathion used illegally in the home and the frequency of these usages so that the potential for exposure to children in such homes can be assessed. It would also be helpful to have updated use information that was collected after EPA cancelled many of the food crop uses of the compound, including on several crops commonly eaten by children (EPA 1999d; 1999e).

Releases to air, land, and water occur primarily through its use as a restricted-use insecticide. The media of most importance for human exposure are contaminated air and soil. 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 Toxic Release Inventory (TRI), which contains this information for 1987, became available in May of 1988. This database is updated yearly and provides a list of industrial production facilities and emissions.

Methods suggested for the disposal of methyl parathion are incineration and open field burial at designated landfills (EPA 1974a). In the past, improved methods for the disposal of methyl parathion were being considered (EPA 1981b). Regulations pertaining to the disposal of methyl parathion include the requirement that containers contaminated with methyl parathion residues be emptied, decontaminated, and either recycled, incinerated, or disposed of in a landfill depending on their condition (EPA 1974a). No recent data are available. Thus, further information on the optimal method for disposal of methyl parathion is needed to evaluate the potential for the release of and exposure to methyl parathion.

Environmental Fate. While methyl parathion degrades fairly rapidly and is relatively immobile in the environment at lower concentrations, there is still some uncertainty regarding the degradation and mobility of very high concentrations of methyl parathion, such as might be found at spill sites, and at pesticide disposal and other hazardous waste sites (Albanis et al. 1988b; Butler et al. 1981a; EPA 1980c; Jury et al. 1987a; Rao and Davidson 1979). Further studies with high concentrations of methyl parathion are needed to assess the environmental fate of the compound in these particular situations. Additional studies of methyl parathion degradation in air, particularly to methyl paraoxon, and the subsequent degradation of methyl paraoxon, are needed to better assess releases to air. Additionally, the methyl aminoparathion metabolite, which forms under anaerobic soil conditions, binds strongly to organic matter (Sharmila et al. 1988). Studies on the fate of methyl aminoparathion and the potential for it to become oxidized to methyl parathion are needed to characterize the fate of methyl parathion in the environment.

Bioavailability from Environmental Media. Methyl parathion can be absorbed following inhalation or dermal contact with contaminated air and by ingestion of contaminated water or food (Dean et al. 1984; Fazekas 1971; Morgan et al. 1977; Nemec et al. 1968; Ware et al. 1973, 1974, 1975). Dermal contact with or ingestion of methyl parathion that is tightly bound to soil particles is an exposure route of concern at hazardous waste sites and areas where spills have occurred. No information is available on the absorption of methyl parathion from soil following ingestion or dermal contact with contaminated soils. Therefore, additional information is needed on the uptake of methyl parathion from contaminated soil following ingestion or dermal contact.

Food Chain Bioaccumulation. There are a few studies to determine residues of methyl parathion in organisms in the environment. These have consistently shown low methyl parathion residues, indicating that methyl parathion does not bioconcentrate to a significant extent in aquatic organisms, plants, or animals (Crossland and Bennett 1984; Sabharwal and Belsare 1986). The methyl parathion that does get into organisms is rapidly degraded (Sabharwal and Belsare 1986). Some recent analyses of fish in a watershed region in the United States indicates ppm (16 µg/g) levels of methyl parathion suggesting that methyl parathion sometimes persists long enough for uptake by fish to occur, and thus, could possibly play a role in bioaccumulation (Cooper 1991). Additional studies to verify that bioaccumulation is not occurring are needed.

Exposure Levels in Environmental Media. Methyl parathion has been detected in ambient air (Baker et al. 1996; Jackson and Lewis 1978; Majewski et al. 1998; Seiber et al. 1989), surface water (Gilliom et al. 1985; Senseman et al. 1997), groundwater (EPA 1988c), rainfall (Nations and Halbert 1992), coastal fog (Schomburg et al. 1991), soil (Albright et al. 1974; Carey et al. 1979; Krapac et al. 1995; Winterlin et al. 1989), sediments (Cooper 1991), fish (Butler and Schutzmann 1978; Cooper 1991), and foodstuffs (Neidert and Saschenbrecker 1996; Torres et al. 1997). Estimates of human intake of methyl parathion have been made for ingestion of foodstuffs (Gartrell et al. 1985, 1986), but improved estimates of exposure from air, water, and soil are needed to assess human exposure to methyl parathion. Information concerning concentrations in the air, water, and soil at the NPL hazardous waste sites known to be contaminated with these compounds are needed to estimate the exposure of populations living in the vicinity of these sites.

Exposure Levels in Humans. Methyl parathion has been detected in serum and tissue shortly after acute exposure (EPA 1978e; Ware et al. 1975). It is rapidly metabolized and does not persist in serum and tissues for long (Braeckman et al. 1983). Two metabolites of methyl parathion, 4-nitrophenol and dimethyl phosphate, can be detected in urine and tissues for up to 2 days following exposure (Morgan et al. 1977). These compounds are specific for methyl parathion when there is a history of exposure. Methyl parathion has been detected in blood within 1 day of exposure and is a specific biomarker (Fazekas 1971).

A recent method to screen the urine for alkyl phosphates as an indicator of exposure to organophosphate insecticides shows that the method can be used to determine environmental exposure to a specific organophosphate pesticide. The method was found to be sensitive, identifying low levels of exposure to insecticides in the environment by quantitation of urinary phosphates (Davies and Peterson 1997). The test is limited in that it is only useful for assessing recent exposure, due to the short half-life of the organophosphate pesticides.

A recent method, still in development, for determining total 4-nitrophenol in the urine of persons exposed to methyl parathion is based on solid phase microextraction (SPME) and GC/MS; previously, the method has been used in the analysis of food and environmental samples (Guidotti et al. 1999). The method shows promise for use in determining exposures at low doses, as it is very sensitive. There is a need for additional development of this method, as the measurement of acetylcholinesterase (the enzyme inhibited by exposure to organophosphates such as methyl parathion) is not an effective indicator of low-dose exposures.

Exposures of Children. More studies are needed to assess the exposures of children living in agricultural areas to methyl parathion residues in air, soil, or water. More studies are also needed to assess the exposures of children in the general population to residues of methyl parathion that might be present in food, milk, or water, or on contaminated clothing and skin from occupationally exposed household members.

Additional studies to determine breast milk contamination by methyl parathion are needed to be able to assess exposures to nursing infants.

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

Exposure Registries. No exposure registries for methyl parathion 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 methyl parathion.

6.8.2 Ongoing Studies

The Federal Research in Progress (FEDRIP) database provides additional information from a few ongoing studies that may fill in some of the data needs identified in Section 6.8.1. These studies are summarized in Table 6-2.

No ongoing studies regarding release, disposal, environmental fate, bioavailability, bioaccumulation, exposure levels, or exposure registries were located.

Table 6-2. Ongoing Studies of Methyl Parathion Found in Federal Research in Progress

Investigator	Affiliation	Research description
Brindley, WA	USDA	Planning insecticide resistance management for methyl parathion.
Chambers, HW	USDA	Investigation of the nature of esterases involved in organophosphate detoxification including methyl parathion.
Johnson, SJ	USDA	To determine the resistance by soybean looper insects to methyl parathion and permethrin.
Meinke, LJ	USDA	To study the influence of methyl parathion on western corn rootworm behavior and population dynamics.
Meinke, LJ	USDA	Western corn rootworm resistance to methyl parathion–development of resistance management strategies
Nesheim, ON	USDA	To collect, develop, and maintain information related to pesticides and the crops on which they are used for the state of Florida.
Obendorf, SK	USDA	Methods to limit worker exposure to various pesticides, including methyl parathion.
Webster, E	USDA	To collect, develop, and maintain information related to pesticides and the crops on which they are used for the state of Arkansas.
Wild, JR	USDA	To develop an effective and complete biological remediation system capable of hydrolyzing organophosphorous neurotoxins from agricultural and chemical warfare munitions, contaminations, and wastes.
Wright, RJ	USDA	To document the extent of adult corn rootworm beetles resistence to methyl parathion throughout Nebraska.

USDA = United States Department of Agriculture

Ongoing remedial investigations and feasibility studies conducted at the NPL sites known to be contaminated with methyl parathion will add to the available database on exposure levels in environmental media, exposure levels in humans, and exposure registries.