5. POTENTIAL FOR HUMAN EXPOSURE

5.1 OVERVIEW

Ethion is released to the environment solely by human activities. Atmospheric emissions result from volatilization of the chemical during manufacturing and formulation, from soil and vegetation resulting from its use as an insecticide and acaricide or from drift during pesticide application or careless mixing and cleanup procedures during or after application. Ethion can be released to surface waters directly by point source dischargers, from drift during pesticide applications, and by nonpoint source runoff from agricultural and urban areas. Ethion is released to soils directly by pesticide application to the soil, from dripping off sprayed vegetation, when used as a seed treatment, and from careless mixing and cleanup procedures during and after application. No current information is available on total environmental releases of ethion from production and processing facilities to air, water, and soil because these facilities are not required to report releases to the Toxics Release Inventory (TRI) (EPA 1995e).

Although ethion is found in most environmental compartments, the compound shows a pronounced tendency to partition to soil and sediment. By using an equation for estimating the bioconcentration factor (BCF) of a chemical derived from its physical and chemical properties, it was determined that ethion has the potential to bioaccumulate in aquatic organisms (Kenaga 1980). However, no experimentally measured BCF values for ethion were located for fish, shellfish, or other aquatic organisms. The half-life of ethion in three tropical soils ranged from 9–15.5 days (Mithyantha and Agnihothrodu 1984), while in temperate sandy loam and organic soils of Ontario, Canada, the half-life values ranged from 7 to 8 weeks (49–56 days) (Miles et al. 1979). Given adequate time, ethion will be degraded by physical, chemical, and biological processes, however, the parent compound can persist at low concentrations from one growing season to the next (25% carryover), and these concentrations can build up slowly in the soil over several growing seasons (Chapman et al. 1984; Miles et al. 1978).

If released to the atmosphere, ethion can exist in both the vapor-phase and adsorbed-phase, although the adsorbed-phase will predominate (Eisenreich et al. 1981). In the vapor-phase, ethion will react with photochemically produced hydroxyl radicals at an estimated half-life (first-order kinetics) of 40.13 minutes (Meylan and Howard 1993; SRC 1995). Ethion in the adsorbed-phase will be subject to washout from the atmosphere by wet and dry deposition.

Ethion released to surface waters is subject to hydrolysis, volatilization, photolysis, and biodegradation. Volatilization, photolysis, and biodegradation are minor degradation processes that can remove small amounts of ethion in water. Hydrolysis, however, appears to be the most important mechanism for degradation, particularly in high alkaline conditions (pH >9) in water. Ethion is susceptible to very slow hydrolysis in water with half-lives ranging from 63 to 8.4 weeks at pH values ranging from 5 to 8. Hydrolysis becomes relatively rapid at alkaline pHs (pH 9 and above), resulting in half-life values of 1 day (Dierberg and Pfeuffer 1983). If released to water, this pesticide has the potential to bioaccumulate, assuming that rapid degradation of the compound by hydrolysis does not occur. Ethion has been detected only rarely in both surface water and groundwater monitoring studies typically at concentrations below 0.5 ppb.

If released to soils and sediments, microbial degradation of ethion is the most important process for the removal of the compound based on degradation studies with sterile versus nonsterile soils. The half-life of ethion in sterile sandy soil loam and organic soil was found to be greater than 24 weeks, while the half-life in these same nonsterile soils was 7–8 weeks (Miles et al. 1979). This suggests that microbial degradation is an important fate process. Ethion is generally only slightly mobile in some sandy soils with a low organic matter content (<3%). However, based on the compound's measured K_{oc} value in soils with moderate-to-high levels of organic matter, ethion is relatively immobile and does not leach into groundwater.

Although some historic information is available from large scale environmental monitoring efforts conducted in the 1970s, and 1980s (Carey et al. 1978; Cohen 1986; Gilliom 1985), recent monitoring efforts under national or regional programs have not analyzed for ethion in air, water, soil, sediment, or fish. This makes it difficult to provide current quantitative estimates on the fate, transport, and bioaccumulation of ethion in various environmental compartments. No information was located on measurement of ethion or of its oxons in the atmosphere. In addition, no information was located on ethion concentrations in air samples from rural or urban areas or in ambient indoor air. Ethion was detected in indoor air at a pesticide production facility, but not a pesticide storage area (Lewis and Lee 1976). This pesticide has been detected rarely in surface water and in groundwater, but little quantitative information is available. It has also been detected in soil and sediment in areas where it is extensively used in agriculture typically at concentrations less than 8 ppm (Miles and Harris 1978a). Current information is lacking on the total amount of ethion released to the environment and on the amount of ethion that partitions into each environmental compartment.

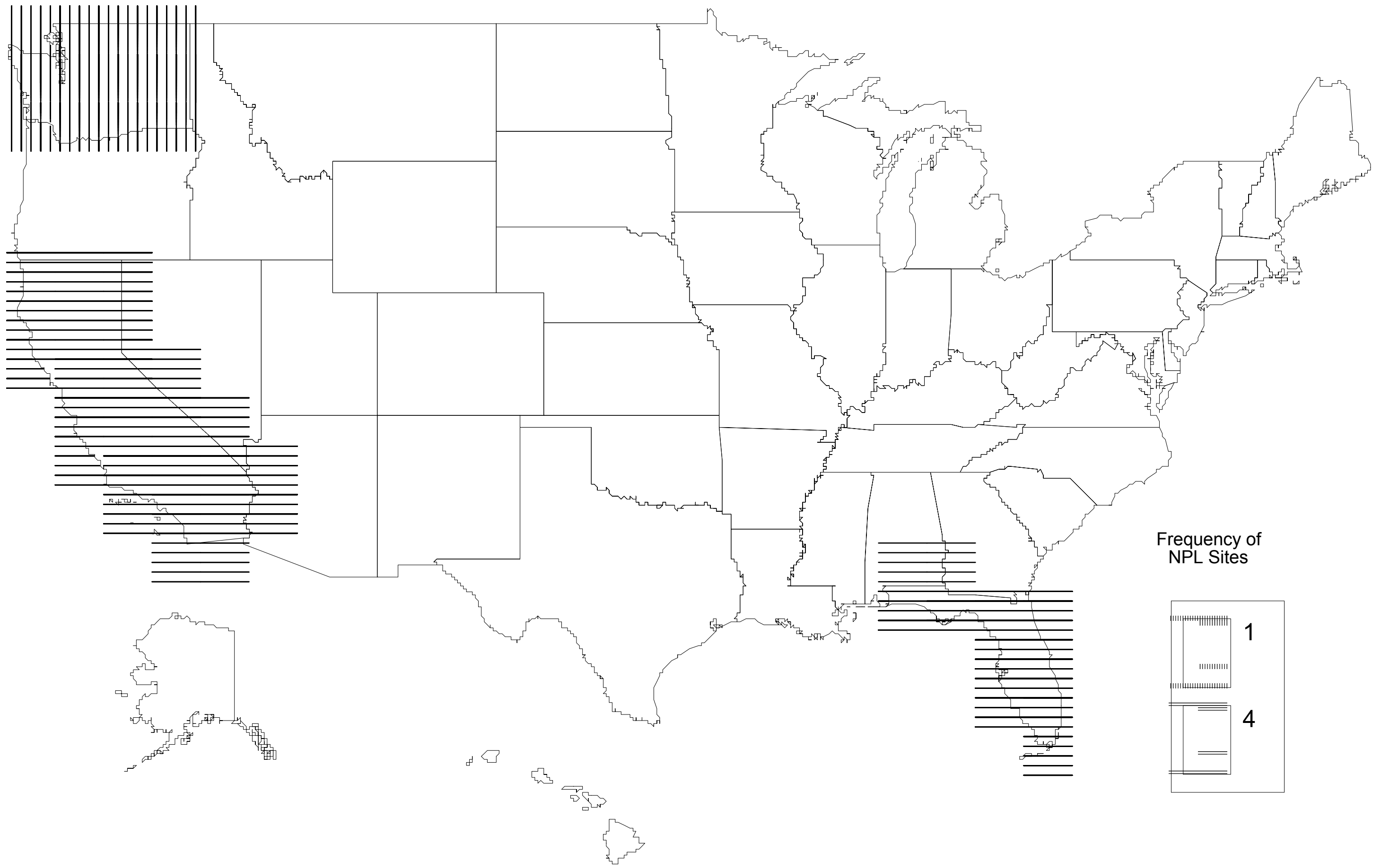
The best-documented concern over ethion relates to acute exposures of humans during or immediately following pesticide applications. This concern is warranted, since ethion is used for some applications in urban areas (lawns and gardens) that increase the possibilities of general population exposure. Ethion and its major oxygen analog, ethion monoxon, have significant acute toxicity to humans. The predominant exposure pathway for the general population appears to be via consumption of small amounts of the chemical in ethion-contaminated food, particularly fruits and root vegetables, and via inhalation both during or immediately following application in agricultural areas where this pesticide is extensively used (e.g., citrus crops). Relative to inhalation, oral exposure probably accounts for a major portion of the exposure of the general population.

In addition to small quantities of ethion that are ingested via ethion-contaminated food, infants and young children may be at increased risk via oral exposure if they put unwashed fingers, toys or other objects, or soil contaminated with ethion in their mouths. Children may also receive dermal exposure if they come in contact with freshly treated vegetation or soil around domestic structures, or if they unknowingly enter ethion-treated agricultural areas before appropriate reentry intervals have elapsed. Children living in households of farmers or agricultural workers that apply ethion or work in fields or orchards treated with ethion may be indirectly exposed if they come in contact with shoes and other contaminated clothing of their parents, or if these clothing articles are not separately washed and stored from other domestic laundry.

Occupational exposure may occur through inhalation and dermal exposure routes associated with the manufacture, formulation, and application of ethion. The magnitude of exposure is greatest for those individuals occupationally exposed to ethion, particularly those involved in production and manufacturing of ethion, those involved in its mixing and application for agricultural and commercial uses, and those workers involved in its disposal at hazardous waste sites. It should be noted that the amount of ethion detected by chemical analysis is not necessarily the amount that is bioavailable.

Ethion has been identified in at least 9 of the 1,577 hazardous waste sites that have been proposed for inclusion on the EPA National Priorities List (NPL) (HazDat 2000). However, the number of sites evaluated for ethion is not known. The frequency of these sites can be seen in Figure 5-1.

Figure 5-1. Frequency of NPL Sites with Ethion Contamination



Derived from HazDat 2000

5.2 RELEASES TO THE ENVIRONMENT

The TRI data should be used with caution because only certain types of facilities are required to report. This is not an exhaustive list. Facilities involved in the production or processing of ethion are not required to report the amount of releases of ethion to various environmental matrices (EPA 1995e, 1995f).

Ethion has been identified in a variety of environmental media (air, surface water, groundwater, soil, and sediment) collected at 9 of the 1,577 EPA National Priorities (NPL) hazardous waste sites (HazDat 2000).

5.2.1 Air

Ethion is released into the atmosphere solely by human activities associated with its production and use as a insecticide and acaricide. These releases include releases to ambient air from production and packaging facilities or agricultural applications. It appears that ethion, once field-applied, can undergo volatilization to the atmosphere. However, based on the vapor pressure for ethion (see Table 3-2), this appears to be a relatively minor fate process (Eisenreich et al. 1981; Thomas 1990).

There is no information on releases of ethion to the atmosphere from manufacturing and processing facilities because these releases are not required to be reported to the TRI Database (EPA 1995e). Ethion was detected in indoor air at a formulation plant in south Florida in 1974 at 4 $\mu g/m^3$ (Lewis and Lee 1976). By contrast, ethion was not detected in indoor air of a storage shed where ethion was stored in sealed containers.

Ethion has been identified in 1 outdoor air sample collected from 9 NPL hazardous waste sites where it was detected in some environmental media (HazDat 2000). The TRI data should be used with caution because only certain types of facilities are required to report. This is not an exhaustive list.

5.2.2 Water

Ethion can reach surface waters directly from point source discharges associated with its production and from nonpoint source inputs introduced from agricultural applications associated with spray drift or careless applications near water (Braun and Frank 1980; Frank et al. 1982; Miles and Harris 1978a, 1978b). Frank et al. (1982) found evidence in a study of 11 agricultural watersheds in the Canadian Great Lakes Basin from 1975 to 1977 that residues of ethion and other pesticides could reach surface waters from deposition close to or directly into stream water during the process of drawing water, mixing the pesticide, spraying, or by cleaning pesticide spraying equipment and by seepage from discarded containers in or around the spray site. In addition, heavy rainfall within a few days of a field application often led to the runoff of the pesticide and deposition in streams. In the Frank et al. (1982) study, ethion was only rarely (0.4% of the samples) found in surface waters during the 1975–1976 study and was not detected during the 1976–1977 study. Ethion was typically found in surface waters samples immediately after application. The oxons of ethion were not detected in any surface water samples. These authors estimated that ethion unit-area loadings (losses) to streams draining these watersheds totaled 10 mg/hectare (ha) with the mean and maximum unit-area loading in 1975–1976 of 0.1 and 0.6 mg/ha, respectively, and the mean and maximum in 1976–1977 of 0.0 and 0.0 mg/ha, respectively. For ethion, all spray-season losses of ethion were attributed to spills, drift, or direct application in surface waters rather than to runoff events. The overall mean concentration of ethion in water collected from these watersheds was <0.01 ppb (minimum [not detected] to maximum [0.4 ppb]) for 1975–1976, and the overall mean was not detected (minimum [not detected] to maximum [not detected]) for 1976–1977. In a study of the Holland Marsh drainage basin in Ontario, Canada, Miles and Harris (1978a) reported that the rate of ethion transfer was highest in the spring during maximum runoff periods.

In another study in the Great Lakes region, ethion was qualitatively identified in tributary stream feeding into Lake Ontario, Lake St. Clair, and Lake Huron (Great Lakes Water Quality Board 1983). Gilliom (1985) also reported that as part of the U.S. Geological Survey (USGS) and EPA Pesticide Monitoring Network conducted between 1975 and 1980, ethion was monitored in surface water at 174 stations nationwide, but was detected at only 0.6% of the stations sampled (detection limit=0.25 ppb).

Based on its K_{oc} value (see Table 3-2), ethion is moderately to highly immobile in soils under most typical soil conditions and is not likely to migrate through the soil and contaminate groundwater (Swann et al. 1983). Although detected only rarely, ethion has been found in some groundwater wells in agricultural areas in the United States (Cohen 1986). However, no quantitative information on groundwater concentrations were located for the United States. It has not been possible to obtain quantifiable estimates of ethion loadings to groundwater.

There is no information on releases of ethion to surface water from manufacturing and processing facilities because ethion releases are not required to be reported to the TRI Database (EPA 1995e).

Ethion has been identified in 1 surface water and 4 groundwater samples collected from 9 NPL hazardous waste sites, where it was detected in some environmental media (HazDat 2000).

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

5.2.3 Soil

Ethion is released into soils primarily from its registered uses on various agricultural crops, as an acaricide in veterinary applications against various sucking insects of domestic stock, and as a seed treatment, or via spills directly to soils associated with the process of mixing the pesticide, spraying, or by cleaning pesticide spraying equipment and by seepage from discarded containers in or around the spray site. Because of its affinity for binding to organic matter, soils are the ultimate repository for the majority of ethion applications.

In agricultural areas, ethion may also be transferred to aquatic sediments through drift or spillage or via improper disposal of the chemical after application (Frank et al. 1982; Miles and Harris 1978b; Miles et al. 1978). Miles and Harris (1978b) reported that ethion residues in bed sediments from the Holland Marsh agricultural drainage system, an area where ethion was extensively used, ranged from 0.043–0.073 ppm. Since ethion undergoes various chemical and biological degradation reactions in the course of time ranging from days to months, these loadings to soils and sediments typically are a temporary phenomena (Dierberg and Pfeuffer 1983; Miles et al. 1979); however, carryover from one year to the next can result in a build-up of ethion residues under some field conditions (Chapman et al. 1984; Miles et al. 1978). The lack of environmental data makes it difficult to estimate the actual build-up of ethion in basins that receive drainage waters from ethion-treated agricultural lands.

There is no information on releases of ethion to soil from manufacturing and processing facilities because these releases are not required to be reported to the TRI Database (EPA 1995e).
Ethion has been identified in 8 soil and 2 sediment samples collected from 9 NPL hazardous waste sites, where it was detected in some environmental media (HazDat 2000).

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

5.3 ENVIRONMENTAL FATE

Ethion can move into various environmental compartments (air, surface water, groundwater, soil, sediment, and biological organisms). For this chemical, the primary environmental reservoir or sink is soil and sediment. The compound is retained in soil for moderate periods of time, depending on soil temperature and the amount of organic matter content in the soil. Ethion can potentially bioaccumulate in aquatic food chains, although little quantitative information on concentrations in edible fish and shellfish was located.

5.3.1 Transport and Partitioning

Based on its vapor pressure (see Table 3-2), if ethion is released to the atmosphere, it will be expected to exist both in the vapor-phase and particulate phase, although the particulate phase will predominate (Kenaga 1980; Eisenreich et al. 1981). Ethion in the adsorbed particulate form will be subject to washout from the atmosphere by both wet and dry deposition. In the atmosphere, the kinetic motion of the pesticide molecules as well as air currents will cause their distribution (Haque and Freed 1974). The molecules will distribute vertically with the heavier molecules having the highest concentration at the bottom and the lighter molecules at the top. Vapor-phase ethion is heavier than air and will consequently concentrate on the bottom. The vapor pressure of a chemical can give a good estimate of air transport as long as the chemical is in the free state or is evaporating from an inert surface (Haque and Freed 1974). When the chemical is bound to a soil surface, the vapor pressure cannot be used to accurately predict vapor transport. The vapor pressure of ethion will be greatly attenuated by its strong sorption to soil surfaces (Sharom et al. 1980a; Swann et al. 1983). Therefore, ethion is not expected to exist in the vapor-phase at an appreciable level above soil surfaces.

Ethion released to water from both point and nonpoint sources may be emitted to the atmosphere by volatilization, sorbed to soils and sediments, or accumulated in aquatic organisms. Evaporation may not be significant based upon the Henry's law constant (see Table 3-2), and volatilization of ethion is not likely to be an important transport process (Racke 1992; Thomas 1990). Ethion released to water also may be adsorbed significantly by soils and sediments based on its K_{oc} values measured in soil (Sharom et al. 1980a; Swann et al. 1983). These authors reported that after 10 successive washes with distilled water, 13.9% of the ethion had leached from sandy soil, while only 1.2% had leached after 10 successive washes from organic soil. Because this pesticide is significantly adsorbed by soils with high organic content, leaching into groundwater is unlikely to occur to any significant extent except in soils with relatively low organic content (Miles et al. 1979).

Using the method of Kenaga (1980) to estimate the BCF value of ethion based on the compound’s physical-chemical properties, ethion was found to have the potential to significantly bioaccumulate in aquatic organisms. The estimated BCF for ethion ranged from 418 to 1,300, based on water solubility data and the K_{oc} value, respectively. The BCF value estimated from the log K_{oc} suggests that bioconcentration can be potentially significant for this compound. However, there were no experimentally measured BCF values located in the scientific literature to verify that bioaccumulation occurs in any fish, shellfish, or other aquatic organism. Despite the high lipid solubility of ethion, distribution studies in rats (Selim 1985a), goats (Mosha 1991), and chickens (Mosha et al. 1990a) have shown no preferential distribution to adipose tissue. The high lability of ethion to esterases in the blood and liver may explain these findings.

Ethion and its metabolites have not been widely monitored in aquatic species such as fish and shellfish. Since ethion and its metabolite ethion monoxon are toxic, a measure of caution may still be in order in cases where there is reason to believe edible fish or shellfish have had recent exposure to ethion. This is partially the basis for the EPA recommendation that states consider routine monitoring for ethion in edible fish and shellfish species as part of their state toxics monitoring programs, particularly in those watersheds where extensive use of ethion is identified (EPA 1995g).

Ethion released in soil from its registered uses partitions slightly to the atmosphere through volatilization, slightly to surface water via runoff, and only slightly to groundwater as a result of leaching. According to Kenaga (1980), chemical compounds with a K_{oc} of <100 are considered moderately to highly mobile; ethion with a K_{oc} value of 15,435, therefore, would be considered almost immobile. Additional parameters influencing the leaching potential of this chemical include the soil type (e.g., clay, organic matter, or sand), the amount of rainfall, the depth of the groundwater, and the extent of degradation. In laboratory tests of sand and organic soil, Sharom et al. (1980b) found that (after 5 successive 200 mL rinses with distilled water) 0.00, 0.4, 0.6, 1.0, and 1.5% of ethion leached from sand, respectively, and a total of only 13.9% of ethion added to the sand was leached after 10 successive 200 mL rinses with distilled water. In organic soil, however, (after 5 successive 200 mL rinses with distilled water) 0.0, 0.0, 0.03, 0.09, 0.11, and 1.2% of ethion leached from soil, respectively; and only 1.2% of ethion added to the organic soil was leached after 10 successive 200 mL rinses with distilled water. The amount leached from the sandy soil was over 10 times greater than that leached from the organic soil, although the leachability of ethion was far less than for many of the other organophosphates tested. While ethion can show high sorption in soils with high organic content (>3%), in most other soil types (sands), ethion has properties suggesting only a slight potential for leaching into groundwater (Sharom et al. 1980b).

In a study of groundwater contamination in California, ethion was detected, but not quantified in 5 out of an unspecified number of groundwater well samples (Cohen 1986). In the Great Lakes region of Ontario, Canada, Frank et al. (1982) reported that ethion was detected in only 0.4% of all surface water samples collected from 11 agricultural watersheds from 1975 to 1976 at a maximum concentration of 0.05 ppb. Ethion was not detected, however, during the 1976–1977 monitoring season (Frank et al. 1982).

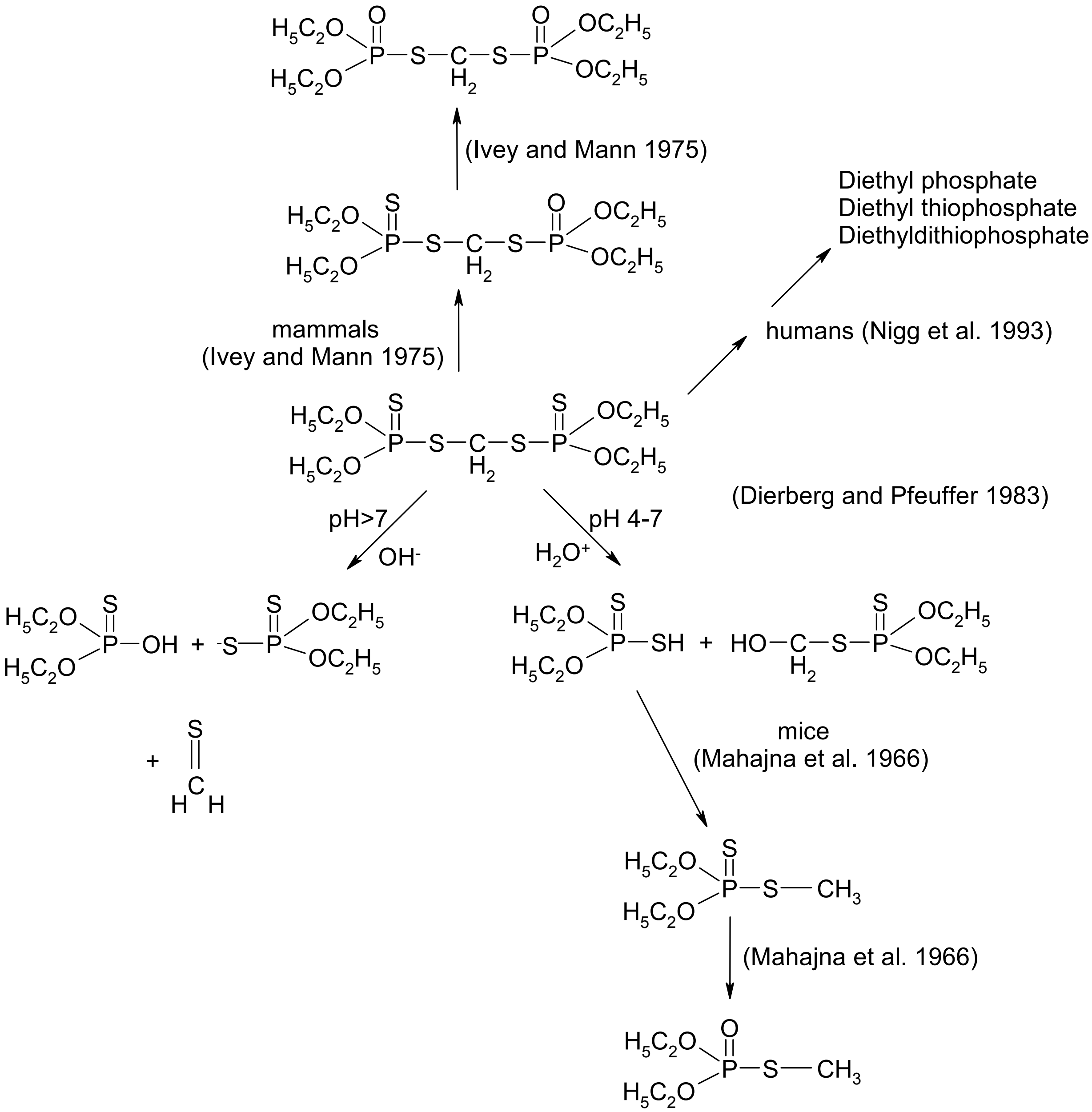
5.3.2 Transformation and Degradation

Ethion is subject to a variety of physical, chemical, and biological degradation processes in all environmental compartments. Some of these transformation pathways are shown in Figure 5-2.

5.3.2.1 Air

Ethion, once released to the atmosphere, may be subject to direct photolysis; however, because ethion does not absorb light in the spectrum above 290 nm (Gore et al. 1971), direct photolysis is likely to be only a minor fate process. In the vapor-phase, ethion can react rapidly, however, with photochemically produced hydroxyl radicals. The half-life (first-order kinetics) for the vapor-phase reaction of ethion with hydroxyl radicals in the atmosphere is estimated to be 40.13 minutes, assuming an atmospheric concentration of containing 5×10^5 hydroxyl radicals/m^3 at 25 EC (Meylan and Howard 1993; SRC 1995). No other information on the transformation processes of ethion in the atmosphere was located.

Figure 5-2. Transformation of Ethion



5.3.2.2 Water

Ethion released to water may be subject to both abiotic degradation (i.e., hydrolysis and photolysis) and biotic degradation by microorganisms. The rate of abiotic degradation is influenced strongly by pH and temperature. Cowart et al. (1971) studied the rate of hydrolysis of 7 organophosphate pesticides, including ethion in distilled water samples at a pH of 6. Over a 6-week study period, these authors reported that the percentage of undegraded ethion was 92, 84.2, 71.3, 38.9, 37.9, 31.2, 13.4, 6, and 5.2% at 2 hours, 1 day, 2 days, 1 week, 2 weeks, 3 weeks, 4 weeks, 5 weeks, and 6 weeks post-application, respectively. These authors found that ethion and parathion were the two most persistent organophosphates tested, and that as a general rule, the rate of hydrolysis in distilled water increases with decreasing sulfur content of the organophosphate tested. Chapman and Cole (1982) also studied the influence of pH on the degradation of ethion in sterile water at 25±3 EC. These authors reported estimated half-life values (first-order kinetics) for ethion of 99, 63, 58, 25, and 8.4 weeks at pH values of 4.5, 5, 6, 7, and 8, respectively. The lower temperature conditions of this study may account for the much slower ethion degradation rates in the acidic pH range. In a laboratory study, Dierberg and Pfeuffer (1983) reported that the hydrolysis half-life of ethion in buffered distilled water at 30 EC was 20.8 weeks at a pH ranging from 4 to 7 (first-order kinetics and independent of pH), 8.9 weeks at pH 8 (second-order kinetics), and 1 day at pH 10 (second-order kinetics). Degradation of ethion was most rapid under alkaline conditions.

Available studies conducted using natural water and sterilized natural water suggest that hydrolysis rather than microbial degradation is the most important degradation process for ethion in water. Dierberg and Pfeuffer (1983) reported that the half-life of ethion in natural and sterilized Florida canal water was very similar, between 24 and 26 days over a 12-week study period, which suggested that hydrolysis rather than microbial degradation was a significant mechanism of loss from Florida surface waters. This contrasts sharply with results obtained by Sharom et al. (1980a) using sterile and unsterile Ontario, Canada marsh water where half-lives of greater than 16 weeks were calculated. The incubation temperature of the Dierberg and Pfeuffer (1983) study was 4 EC higher and the initial ethion concentrations were lower; however, the similarity of the half-lives for the sterile and unsterile distilled water controls between the two investigations suggests that these differences were minor in accounting for the degradation rates in the two surface waters. Degradation was more affected by temperature, suggesting that hydrolysis was the primary mode of degradation. In contrast to the half-life of 26 days reported by Dierberg and Pfeuffer (1983) for unsterile canal water, is the half-life value (>8 weeks) given by Eichelberger and Lichtenberg (1971) for water from the Little Miami River, Florida incubated under similar laboratory conditions (except for the presence of light). The inclusion of light in the latter study demonstrates that photolysis may not be a competitive degradation pathway for ethion compared to hydrolysis.

Gore et al. (1971) reported that ethion in a hexane solvent did not absorb ultraviolet light above 260 nm, which suggests that direct photolysis does not readily occur. Frank et al. (1991) investigated the degradation of ethion in surface and groundwater samples for 164 days, but found little difference in the rate of ethion degradation in light and dark conditions, indicating that photolysis was not a major fate process. The half-life (first-order kinetics) of ethion of 51 days (light) and 58 days (dark) suggests that photolysis was not a major factor in degradation. The ambient temperature during this degradation experiment ranged from -3.8 to 37.0 EC. These authors also compared the degradation of ethion in two controlled temperature regimes of 4 and 21 EC at a pH of 8. These authors calculated a half-life (first-order kinetics) for ethion of 34 days at 21 EC as compared to 84 days at 4 EC.

Sharom et al. (1980a) studied the degradation of ethion under laboratory conditions using both distilled water and natural water samples. The rate of degradation was comparable (half-life >16 weeks) in natural water (pH 7.7), sterilized natural water, sterilized distilled water, or distilled water, suggesting biodegradation of ethion was not occurring. Under these experimental microcosm conditions, hydrolysis appears to be the major transformation process operative in the natural water system. Discrepancies in the rates of ethion degradation in water reported in the literature appear to be influenced by both abiotic and biotic factors.

Although ethion has been detected in groundwater samples only rarely in the United States (Cohen 1986; HazDat 2000), no studies were identified dealing with ethion transformation and degradation processes within aquifers. Based on theoretical considerations, abiotic hydrolysis mechanisms would be expected to degrade ethion within a few months to years (99 weeks to 8.4 weeks at a pH of 4.5 and 8, respectively) (Chapman and Cole 1982).

5.3.2.3 Soil Transformation and Degradation

Once released to soils and sediments, ethion can be degraded by hydrolysis, photolysis, and biodegradation. Hydrolysis may be a significant degradation process under alkaline soil conditions. Photolysis, while possible, is not likely to be a significant degradation process because ethion does not absorb ultraviolet (UV) light above 260 nm (Gore et al. 1971). Microbial degradation appears to be the major pathway for the degradation of ethion in soils (Miles et al. 1979). Ethion degraded with a half-life of 69–102 days in an aerobic soil metabolism study (EPA 1989b).

Miles et al. (1979) studied the persistence of 8 organophosphate pesticides including ethion in sterile and nonsterile mineral (sandy loam) and organic soils. Ethion was the most persistent of the organophosphates tested. These authors reported that 50% of the initial concentration of ethion still remained at >24 weeks in sterile sandy loam and sterile organic soil. In nonsterile soil, however, 50% of the initial concentration remained after 7 and 8 weeks in sandy loam and organic soil, respectively. Ethion was slightly more persistent in organic soil than in the sandy loam. These authors concluded that microbial degradation played a major role in the degradation of ethion from the soils tested.

Miles et al. (1978) studied the use of ethion as a seed furrow treatment for the control of onion maggots in the Holland Marsh in Ontario, Canada from 1972 to 1975. These authors reported that a 25% carryover of ethion residues in the soil occurred from one yearly application to the next. Ethion soil residues were 1.83±1.42 ppm (dry weight basis) in 1972, 6.93±8.31 ppm in 1973, 5.75±4.98 ppm in 1974, and 3.47±2.83 ppm in 1975. Chapman et al. (1984) also reported that concentrations of ethion in field microplots over a 3-year period suggested that some carryover was occurring. These authors reported that in the fall of 1977, concentrations of ethion in soil treated with a granular formulation to control onion maggots were 4.36 ppm. Soil concentrations in the spring and fall of 1978 were 1.85 and 3.06 ppm, respectively. Ethion residues in the spring of 1979 were not analyzed, and the fall concentrations were 7.77 ppm, and fell only slightly to 7.6 ppm in the spring of 1980 indicating slow degradation in winter.

Sherman et al. (1974) studied iron sulfide production from ethion-enriched soils by bacteria found in lagoonal sediments of the Indian River-Banana River in Florida. These authors reported that ethion enriched sediment samples from the Indian River were used as the source of sulfur-utilizing bacteria (probably *Clostridium*) in culture tube experiments. Inoculated media that contained both an iron wire and ethion gave evidence of darkening of the wire; but more significantly, they gave evidence of iron sulfide (FeS) production at the stab-line of the inoculation, after 12 hours of incubation. Upon further incubation, the FeS discoloration spread from the inoculation stab-line throughout the culture tube. The authors also concluded that this reaction was an anaerobic process because no FeS was found at the surface of the media slant. Inoculated media that contained iron wire, but had no ethion added, supported bacteria growth, but FeS was not produced. In uninoculated cultures containing both an iron wire and ethion, there was evidence of a chemical reaction of ethion with the wire as indicated by a darkening of the surface of the wire. However, there was no FeS production throughout the medium.

Mithyantha and Agnihothrodu (1984) studied the persistence of ethion in red, black, and laterite tropical soils under 2 moisture conditions (field capacity vs. submergence) using 2 application rates (25 and 50 ppm). These authors reported that ethion degraded more slowly in the acidic laterite soils followed by the red and black soils. Ethion degraded faster as the pH of the soil increased. The pH for the laterite, red, and black soils was 4.6, 6, and 7.8, respectively. Degradation rates for the 2 concentrations of ethion used were similar in each test. The half-life values (first-order kinetics) for ethion in these tropical soils ranged from 9 to 15.5 days when incubated at a temperature of 24±2 EC throughout the test period. The persistence of ethion in three different soil types at two treatment levels of ethion (25 and 50 ppm) is summarized in Table 5-1.

In a study of the fate of ethion in canals draining a Florida citrus grove, Dierberg and Pfeuffer (1983) reported that ethion adsorption to the sandy canal sediments was negligible following ethion applications to the citrus grove, and that ethion concentrations never exceeded 0.03 µg/g (ppm) (dry weight). Sharom et al. (1980b) reported that pesticides were desorbed to a greater degree from a sandy soil than a highly organic soil.

5.4 LEVELS MONITORED OR ESTIMATED IN THE ENVIRONMENT

Most information on ethion concentrations in various environmental media derived from large-scale monitoring networks dates from before the mid-1980s and no longer reflects current environmental conditions. There is a noticeable lack of recent national or regional monitoring studies that would allow meaningful estimation of current ethion concentrations associated with various environmental media.

Table 5-1. Percentage of Ethion Remaining in Various Types of Tropical Soils over Time

Soil type (pH) treatment level	% Ethion[a]				
	10 Days	22 Days	35 Days	45 Days	57 Days
Laterite soils (pH 4.6) 25 ppm	66 (16.26)	30 (7.46)	13 (3.36)	7.6 (1.91)	3.3 (0.83)
Laterite soils (pH 4.6) 50 ppm	69 (34.70)	39 (19.25)	20 (10.05)	7.7 (3.87)	2.1 (1.03)
Submerged laterite soils (pH 4.6) 25 ppm	59 (14.82)	35 (8.83)	20 (5.08)	7.2 (1.98)	3.3 (0.83)
Submerged laterite soils (pH 4.6) 50 ppm	48 (24.22)	26 (13.11)	15 (7.32)	4.3 (2.16)	2 (0.98)
Red soils (pH 6) 25 ppm	65 (16.22)	42 (10.61)	17 (4.32)	2.6 (1.03)	3.3 (0.83)
Red soils (pH 6) 50 ppm	67 (33.62)	39 (19.28)	18 (9.10)	6.4 (3.18)	2.1 (1.03)
Submerged red soils (pH 6) 25 ppm	58 (14.60)	32 (8.00)	16 (3.96)	3.6 (0.90)	3.3 (0.83)
Submerged red soils (pH 6) 50 ppm	53 (26.26)	28 (14.13)	16 (7.98)	5.2 (2.16)	2.1 (1.03)
Black soils (pH 7.8) 25 ppm	50 (12.60)	28 (7.11)	16 (4.00)	3.3 (0.83)	2.4 (0.59)
Black soils (pH 7.8) 50 ppm	48 (24.22)	24 (11.82)	12 (5.88)	2.6 (1.03)	0.8 (0.41)
Submerged black soils (pH 7.8) 25 ppm	42 (10.48)	20 (5.10)	10 (2.58)	2 (0.52)	1.8 (0.45)
Submerged black soils (pH 7.8) 50 ppm	48 (24.22)	25 (12.66)	12 (5.88)	2.6 (1.03)	1.7 (0.83)

[a] Values in paratheses are ethion soil concentrations in ppm

Source: Mithyantha and Agnihothrodu 1984

5.4.1 Air

Ethion concentrations or concentrations of its metabolite, monoxon, in the atmosphere were not monitored in several major national and regional study (Glotfelty et al. 1990; Schomberg et al. 1991; Whitmore et al. 1994). Ethion also was not an analyte included in the National Pesticide Monitoring Program during the early 1970s (Kutz et al. 1976). No quantitative information was located on air samples collected either in rural or urban areas, near production or formulation facilities, or in indoor air associated with its use for pest control in greenhouses.

However, ethion was detected at 4 $\mu g/m^3$ in indoor air at a formulation plant in south Florida in 1974 (Lewis and Lee 1976). By contrast, ethion was not detected in indoor air of a storage shed where ethion was stored in sealed containers at the same pesticide formulation plant.

Ethion has been identified in air samples (outdoor air) collected at 1 of the 9 NPL hazardous waste sites where it was detected in some environmental media (HazDat 2000).

5.4.2 Water

Although ethion is considered an extremely hazardous substance under Title III of the Superfund Amendments and Reauthorization Act (SARA) of 1986, also known as the Emergency Planning and Community Right-To-Know Act and is subject to reporting under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) of 1980, it has not been widely monitored in the United States in routine surface water or groundwater monitoring networks. Gilliom (1985) reported that as part of the USGS and EPA Pesticide Monitoring Network conducted between 1975 and 1980, ethion was monitored in surface water at 174 stations nationwide but was detected at only 0.6% of the stations sampled (detection limit=0.25 ppb).

In the Great Lakes region, ethion was detected in surface waters in several river basins in southern Ontario, Canada. Frank et al. (1982) monitored agricultural pesticide use and surface water concentrations in 11 agricultural watersheds in southern Ontario. All watersheds drained into the Great Lakes. During 1975, ethion use was estimated to range from 1 to 10 kg/ha. Ethion residues as a result of field use were detected rarely (0.4%) and were detected immediately during the spray season rather than throughout the year. The overall mean concentration of ethion in water collected from these watersheds was <0.01 ppb (minimum [not detected] to maximum [0.4 ppb]) for 1975–1976 and the overall mean was not detected (minimum [not detected] to maximum [not detected]) for 1976–1977. In another study in the Great Lakes region, ethion was qualitatively identified in tributary stream feeding into Lake Ontario, Lake St. Clair, and Lake Huron (Great Lakes Water Quality Board 1983). In a study of the occurrence of pesticides in Spanish surface waters, ethion was detected in 1 out of 6 water samples from the Segre River Basin (west of Catalonia) at an estimated concentration of 0.01 µg/L (Planas et al. 1997). A group of research scientists recently completed a study of pesticide concentrations in the Arno river which supplies over 90% of the drinking water to Florence, Italy (Griffini et al. 1997). Water samples were collected from the river entering the drinking water treatment plant of Florence and from the finished drinking water. Of the 167 water samples analyzed from 1992 to 1995, none contained any detectable amount of ethion (detection limit = 0.010 µg/L).

In a groundwater contamination study of 28 of California's 58 counties that evaluated over 50 pesticides (from both point and nonpoint sources), ethion was detected (but not quantified) in 5 samples out of an unspecified number of groundwater samples (detection limit not specified) (Cohen 1986). Ethion however, was not included as an analyte of interest in the EPA Pesticides in Ground Water Database (EPA 1989c). This database was developed to compile the results of monitoring studies conducted by pesticide registrants, universities and government agencies and identified the pesticides that have been looked for in groundwater, the areas monitored, and the pesticides that have been detected.

Ethion has been identified in 1 surface water and 4 groundwater samples collected from the 9 NPL hazardous waste sites where it was detected in some environmental media (HazDat 2000).

5.4.3 Sediment and Soil

Ethion has not been the focus of many recent national soil or sediment monitoring programs in the United States, but has been monitored in regional studies associated with agricultural applications in both the United States and Canada. Ethion was one of the organophosphate pesticides monitored in soils collected from 37 states as part of 1971 National Soils Monitoring Program (Carey et al. 1978). These authors reported that of 1,141 soil samples collected from 4 hectare sites throughout the US, ethion was detected in only 2 samples (0.2% positive detections) at concentrations ranging from 0.06 to 0.24 ppm. Ethion was detected only in samples collected in two states, California and Florida. Ethion was not detected in any crop samples that were analyzed for this study (detection limits 0.01–0.03 ppm).

Possibly because of its lack of detection in the 1971 National Soils Monitoring Program, ethion was not one of the 9 organophosphate pesticides monitored in soils collected as part of 1972 National Soils Monitoring Program (Carey et al. 1979).

Miles et al. (1978) reported on results of a regional study conducted on agricultural soils of high organic content in Holland Marsh, Ontario, Canada. These authors reported that ethion was used as a seed furrow treatment for control of first generation onion maggots and its use comprised 80% of the total organophosphate soil residues. Ethion was detected in soil at all 13 farms in the Holland Marsh study area from 1972 to 1975. Mean soil residues were 1.83±1.42 ppm, 6.93±8.31 ppm, 5.75±4.98 ppm, and 3.47±2.83 ppm (dry weight) for 1972, 1973, 1974, and 1975 respectively. The authors also demonstrated both in field and laboratory studies an ethion carryover rate of 25% from one planting season to the next when ethion was applied in a granular form.

Winterlin et al. (1984) reported that ethion was detected in soil collected from a lined evaporation bed used for disposal of pesticide wastes in California. Ethion was not detected in the soil horizon from the surface to a depth of 1 inch but was detected at concentrations of 4.1 to 4.6 ppm in the 1–6-inch soil horizon and was not detected in soil samples from the 6- to 12-inch soil horizon.

Gilliom (1985) reported that, as part of the USGS and EPA Pesticide Monitoring Network conducted between 1975 and 1980, ethion was monitored in bed sediments at 163 stations nationwide, but was detected at only 0.6% of the station (detection limit=0.25 ppb). Ethion has been detected in organic mud of the Holland Marsh drainage system in southern Ontario, Canada (Miles and Harris 1978b). Ethion was detected in these sediments at concentrations ranging from 0.043 to 0.073 ppm. Miles and Harris (1978a) also reported that ethion was detected in soil collected from 23 of 28 vegetable farms in southwestern Ontario, Canada. Soil concentrations ranged from trace amounts (<0.02 ppm) to 7.81 ppm at a maximum. On 15 of the farms, the ethion concentration in the soil was > 1.0 ppm and ethion was the major organophosphate residue reported.

Ethion has been identified in 8 soil and 2 sediment samples collected from the 9 NPL hazardous waste sites, where it was detected in some environmental media (HazDat 2000).

5.4.4 Other Environmental Media

Nigg et al. (1988) conducted a study of the distribution of ethion in Valencia oranges grown in Florida. The purpose of the study was to determine the distribution of ethion, ethion monoxon, and ethion dioxon between the peel and pulp of Florida Valencia oranges, and whether the concentration for the entire fruit was representative of ethion concentrations in the consumed portion (peeled orange). These authors found that ethion levels in whole mature fruit declined from 1.8 ppm at 3 days post-spraying to 0.6 ppm 35 days thereafter. The mature fruit samples collected prior to spraying ethion, contained ethion in the peel at 1.6 ppm. This mature harvestable crop, treated 9 months prior to sampling, contained ethion pulp residues below 0.02 ppm (unquantifiable trace level) and no detectable ethion monoxon or ethion dioxon. From these data, the authors concluded that the pulp (edible portion) contains a very small percentage of the whole fruit ethion.

MacNeil and Hikichi (1976) studied the degradation of ethion on pears and pear and grape foliage. Ethion concentration on pears treated with 8 lb/acre ethion (wettable powder–25%) decreased from 3.96±0.31 ppm at day 0 to 2.54±0.12 ppm, 1.95±0.08 ppm, 1.18±0.26 ppm, 1.19±0.01 ppm and 0.67±0.01 ppm after 1, 2, 3, 4, and 5 weeks, respectively. Pear leaves were treated with 8 lb/acre ethion (wettable powder–25%). Ethion concentrations on pear leaves declined from 3.34±0.56 ppm at day 0 to 3.41±1.78 ppm, 2.43±0.72 ppm, 1.21±0.26 ppm, 1.46±0.18 ppm, 0.40±0.19 ppm, 0.34±0.07 ppm, and 0.27±0.09 ppm at day 1, 3, 6, 14, 21, 28, and 35, respectively. Grape leaves were treated with 1 lb/acre ethion (wettable powder–25%). Ethion residues were 0.59±0.07 ppm on day 0 and declined to 0.40±0.07 ppm, 0.20±0.14 ppm, 0.10±0.06 ppm, 0.10±0.11, 0.02±0.01 ppm, 0.02±0.02 ppm, and 0.01±0.01 ppm at day 1, 3, 6, 14, 21, 28, and 35, respectively.

Ethion was found in 6 of 30 composite samples of fruit (at a maximum concentration of 0.265 ppm) collected from 30 markets in 24 different cities from June 1968 through April 1969. Corneliussen (1970) reported that average residues of ethion on fruit could be reduced from 0.024 ppm before processing to 0.014 ppm after processing. Furthermore, this author calculated the average retention of ethion residues on the fruit samples to be 58% after processing.

The FDA conducted a total diet study to determine dietary intake of selected pesticides, industrial chemicals, and heavy metals, including radionuclides, in 20 cities from October 1978 to September 1979 (Gartrell et al. 1985a). These authors reported that the average ethion concentrations (ppm) were

<0.0001 and 0.0014 for garden fruits and fruits, respectively, and that ethion exposures (µg/day) from garden fruits, fruits, and all groups of foods combined were 0.0018, 0.312 and 0.314, respectively. In a similar study conducted from October 1979 to September 1980, Gartrell et al. (1985b), reported that ethion was detected in root vegetables and fruits. The average ethion concentration (ppm) was 0.0008 and 0.0003, respectively, and the ethion exposures (µg/day) from root vegetables, fruits, and all foods combined were 0.0263, 0.0658, and 0.0921, respectively. Similarly, Gartrell et al. (1986) reported that ethion was detected in root vegetables, garden fruits, and fruits at 0.0001, 0.0007, and 0.0014 ppm, respectively. The average ethion exposures (µg/day) from root vegetables, garden fruits, fruits, and all groups of foods combined were 0.0021, 0.0482, 0.031, and 0.36, respectively, which rose slightly over the previous years.

Almost 20,000 samples of food and feed commodities were evaluated as part of a 5-year study from 1981 to 1986 conducted by the FDA Los Angeles District Laboratory to determine pesticide residues in domestic and imported foods and animal feeds (Hundley et al. 1988). These authors reported that ethion was detected in a wide variety of domestic foods: grapefruit, grapes, romaine lettuce, strawberries, and tomatoes; however, none of the samples exceeded EPA tolerance limits. Ethion was also detected in the following imported foods: apples, green beans, limes, cucumbers, pickling cucumbers, eggplant, Japanese eggplant, cantaloupe, honeydew melon, watermelon, nectarines, Chinese peas, peppers (Anaheim, bell, caribe, fresco, jalapeno, poblano, yellow) Italian squash, tomatoes, and cherry tomatoes; however, only residues in Chinese peas, bell peppers, and Serrano peppers exceeded the EPA tolerance limits. The overall violation rates for domestic and imported samples collected on a surveillance basis were 3.0 and 2.6%, respectively.

Luke et al. (1988) reported on a study of 19,851 samples of domestic and imported foods that were analyzed for pesticide residues by the FDA Los Angeles District Laboratory from 1982 through 1986. The authors reported that ethion was detected in 425 food samples; however, in only 2 of these samples did the concentrations of ethion exceed the 2 ppm tolerance limit.

Concentrations of ethion in ready-to-eat foods were monitored for 10 years from 1982 to 1991 through the FDA's Revised Market Basket Survey (KAN-DO Office and Pesticides Team 1995). Ethion was detected in 199 samples of 31 different foods at a mean concentration of 0.0053 µg/g (5.3 ppb), and the ethion oxygen analogue was detected eight times in five different foods at a mean concentration of 0.0029 µg/g (2.9 ppb). Ethion was detected in apples, cantaloupe, cherries, donuts, frankfurters, fruit cocktail, grapefruit and grapefruit juice, grape jelly, oranges, orange juice, orange drink, tomatoes, tomato juice, plums, prunes, raisins, and summer squash, and was also detected in the following baby foods: apple sauce, Dutch apple Betty, meat, beef and vegetables, orange and orange pineapple juice, pears or pears and pineapples. The ethion oxygen analogue was detected in the following adult foods: grapefruit juice, orange juice, and pears and in the following baby foods: orange or orange-pineapple juice.

Minyard and Roberts (1991) reported pesticide residue data for 27,065 samples of foods collected and analyzed in 10 state food laboratories from 1988 to 1989. They reported in 1988, that ethion was detected in 15 of 13,980 samples analyzed with an occurrence frequency of 0.107%, but in only 1 sample was the residue at a significant level. Likewise in the 1989 study, ethion was detected in 25 of 13,085 samples for a frequency of occurrence of 0.0191%, but in only 2 of the samples were the residues at a significant level.

Schattenberg and Hsu (1992) reported on results of a pesticide screening program conducted for 111 different pesticides and performed on 6,970 produce samples collected from 1989 to 1991 at a major food chain in San Antonio, Texas. Ethion concentrations were detected (detection limit of 0.100 ppm) in 3.3% of apples, 0.5% of grapes, 1.8% of oranges, 0.6% of peppers, and 1.3% of strawberries tested. The actual concentrations of ethion detected were not specified.

More recently, Roy et al. (1995) evaluated ethion residues in domestic and imported pears and tomatoes. Ethion was found in <1% of the domestic pears sampled and the maximum concentration detected was 0.03 ppm. Ethion was not detected on any of the imported pears tested. With respect to tomatoes, ethion was detected in <1% of domestic tomatoes at a maximum concentration of 0.21 ppm, and it was also detected in 7% of the imported tomatoes at a maximum concentration of 0.09 ppm. The EPA tolerance limit for both pears and tomatoes is 2 ppm.

Most recently, Berry et al. (1997) conducted a study of human exposures in the lower Rio Grande Valley (in and around the city of Brownsville, Texas) to a variety of pollutants including ethion derived from the consumption of foods and beverages. Ethion was detected in only 1 food sample, at a concentration of 0.009 ppm, during the spring of 1993; and ethion was not detected in any food or beverage samples during the fall of 1993.

The frequency of detection of ethion was 3% in both the FDA adult total diet study conducted from 1978 to 1982 (Yess et al. 1991) and the FDA adult total diet study from 1982 to 1984 (Gunderson 1988). More recently, the frequency of occurrence of ethion detections in the FDA total diet study has remained relatively constant from 2% in 1987 (FDA 1988), 2% in 1988 (FDA 1989), 3% in 1989 (FDA 1990), 2% in 1990 (FDA 1991), 2% in 1991 (FDA 1992), averaged 2% from 1986 to 1991 (FDA 1993), averaged 2% from 1991 to 1993 (FDA 1994), and was 2% in 1994 (FDA 1995).

Gelardi and Mountford (1993) analyzed for the presence of 34 pesticides, including ethion in infant formula. The detection limit range for ethion was <0.001–0.016 ppm. These authors reported that of 110 milk-based formulae and of 59 soy-based formulae analyzed, ethion was not detected in any samples of either formula.

Pesticide residues were evaluated in infant and toddler total diet samples from August 1976 to September 1977 (Johnson et al. 1984). These authors reported that of 117 infant foods tested, ethion was detected in 2 samples in trace amounts, while ethion was detected in only 2 of 132 toddler foods at a concentration of 0.001 ppm. Positive detections were made only in foods in the fruit or fruit juice category.

Yess et al. (1993) summarized the results of a study to monitor pesticide residues in infant and adult foods eaten by infants and children. With respect to surveillance monitoring of domestic foods, these authors reported that ethion (total) was detected in 22 of 2464 apple samples at a maximum concentration of 1.7 ppm, in 1 of 13 orange juice samples at a maximum concentration of 0.03 ppm, in 42 of 862 samples of oranges at a maximum concentration of 1.1 ppm and in 7 of 571 pear samples at a maximum concentration of 0.22 ppm. The concentration of ethion (total), however, did not exceed the EPA tolerances level (2.0 ppm) for any of the domestic foods tested which might be eaten by infants and children. With respect to surveillance monitoring of imported foods, these authors reported that ethion (total) was detected in 9 of 735 apple samples at a maximum concentration of 0.23 ppm, in 1 of 64 orange juice samples at a maximum concentration of 0.02 ppm, in 89 of 474 samples of oranges at a maximum concentration of 0.61 ppm and in 1 of 816 pear samples at a maximum concentration of 0.17 ppm. The concentration of ethion (total), however, did not exceed the EPA tolerances level (2 ppm) for any of the imported foods tested which might be eaten by infants and children. With regard to prepared foods for infants and children, Yess et al. (1993) also reported that the maximum concentrations of ethion (total) detected in Dutch apple Betty were 0.001 ppm, in 3 samples of applesauce or applesauce with other fruits were 0.002 ppm, in 21 samples of orange or orange pineapple juice were 0.01 ppm, in

3 samples of pears or pears and pineapples were 0.003 ppm, in 24 samples of frozen orange juice were 0.008 ppm, and in 6 samples of raw pears were 0.280 ppm. Again, all of the adult foods that might be consumed by infants and children that were tested contained ethion residues well below the EPA tolerance level of 2 ppm.

Ethion residues have also been detected in a variety of fish species in two studies conducted during the 1970s; however, no more recent data on tissue concentrations of ethion were located. Butler and Schutzmann (1978) summarized results of the National Pesticide Monitoring Program conducted from July 1972 through June 1976, that analyzed residues of pesticides in 1,524 samples of juvenile fish collected semi-annually in 144 estuaries nationwide. Composite samples of 25 whole fish were screened for 20 pesticides and PCBs. Ethion was detected in composite samples of juvenile fish collected in two states. Ethion was detected at a mean concentration of 0.169 ppm in 19 of 140 samples collected in Maryland and at a concentration of 0.083 ppm in 1 of 51 samples collected in Texas. Ethion residues were also detected in a regional study of fish collected from 1972 to 1975 from the Holland Marsh, Ontario, Canada (Miles and Harris 1978a). These authors reported that ethion was only detected in fish collected during 1974 at 0.01 ppm in silver bass, 0.01 ppm in catfish, 0.02 ppm in whitefish, and 0.05 ppm in carp. All of the ethion detections were made in fish collected in the agricultural drainage system associated with Holland Marsh, and not in the fish collected downstream in Lake Simcoe.

Ethion residues have also been reported in honey from the northwestern portion of Spain (Garcia et al. 1995). These authors reported that 177 honey samples collected from 1988 to 1990 contained residues of 6 pesticides, including ethion. These pesticides were detected in 69 of the 177 samples tested; however, ethion was detected in only 23 (13%) of the samples at a mean concentration of 3 ppb (range, 1–8 ppb).

Because ethion has been used in veterinary application as a dip to control ticks and other skin parasites, there is the potential for residues to occur in some animal products (Mosha et al. 1990a, 1990b, 1991). Lino and da Silveira (1994) detected ethion residues in the muscle and skin tissue of chickens sampled in Portugal. Ethion concentrations in muscle tissue ranged from 31.32 to 51.37 ppb, and concentrations in skin tissue ranged from 361.3 to 1,796.8 ppb. These authors reported that chickens could be exposed to ethion and other pesticides via feeds or the direct treatment of ethion on the chickens by external application of dusts or sprays, by oral administration in the feed, and/or use of ethion in the chicken houses. Ivey et al. (1975) reported on tissue residues of ethion and its metabolites (ethion monoxon and dioxon) in the body tissues of domestic turkeys reared in pens on soil treated with an emulsion of ethion (4 lb/gal effective concentration) at a rate of 4, 12, and 40 pounds active ingredient/acre or 4.48, 13.4, and 44.8 kg/ha, respectively. The maximum residues detected in turkey fat and skin, respectively, at 1 week post-application were 0.022 ppm (22 ppb) and 0.080 ppm (80 ppb)for the 4 lb/acre, 0.031 ppm (31 ppb) and 0.410 ppm (410 ppb)for the 12 lb/acre, and 0.295 ppm (295 ppb) and 0.666 ppm (666 ppb) for the 30 lb/acre application rates. Small residues of ethion monoxon were detected at 1–3 weeks post-application in the skin of turkeys only at a rate of 40 lb/acre, but no ethion dioxon was detected in any tissues. In an FDA study, Heikes and Craun (1992) reported the detection of 19 ppm ethion in 1 of 10 anhydrous lanolin samples analyzed in 1991. No ethion residues were detected in any lanolin samples analyzed in 1989. These same authors also detected ethion residues in two lanolin-containing pharmaceutical preparations: 0.28 ppm (280 ppb) in diaper rash ointment and 0.30 ppm (300 ppb) in ophthalmic ointment sampled in 1992. In an earlier 1988 study of the same pharmaceutical preparations, no ethion residues were detected.

5.5 GENERAL POPULATION AND OCCUPATIONAL EXPOSURE

While no quantitative information is available on the percentage of ethion released to each environmental compartment, ethion can be emitted to any or all environmental media (air, surface water, groundwater, soil, and sediment), depending on the source of the release, formulation used, and prevailing environmental conditions. General population exposure to ethion typically occurs through two major routes; inhalation and ingestion of contaminated food or drinking water. The major route of exposure to ethion for the general population is through ingestion of foods contaminated with small residues of ethion or consumption of ethion-contaminated drinking water. The general population may also be exposed to ethion through inhalation of contaminated ambient (outdoor) air, specifically in agricultural areas where ethion is extensively used to control some agricultural pests or in veterinary applications to control external parasites (Lewis and Lee 1976).

A comparison of ethion intakes for various age groups of children and adults derived from FDA total diet studies over the past 25 years are summarized in Table 5-2. Johnson et al. (1984) reported ethion intakes in mg/kg body weight/day for the total diet analysis conducted (1976 and 1977) for infants as trace amounts and $1.1\text{x}10^{-6}$, respectively; and for toddlers, trace amounts and $1.1\text{x}10^{-6}$, respectively. Ethion intakes, in mg/kg body weight/day, estimated for total diet analyses (1982–1984) were $6.4\text{x}10^{-6}$, $1.15\text{x}10^{-5}$, $2.2\text{x}10^{-6}$, $2.7\text{x}10^{-6}$, $2.5\text{x}10^{-6}$, $2.0\text{x}10^{-6}$, $3.1\text{x}10^{-6}$, and $2.2\text{x}10^{-6}$ for 6–11-month-old infants,

Table 5-2. Ethion Intakes from Foods for Infants, Children, and Adults in the U.S. Population (in mg/kg/day)

Period of the Total Diet Study	6–11-month-old infants	2-year-old children	14–16-year-old females	14–16-year-old males	25–30-year-old females	25–30-year-old males	60–65-year-old females	60–65-year-old males	Source
1976	Trace	Trace	No data	No data	No data	No data	No data	No data	Johnson et al. 1984
1977	$1.1x10^{-6}$	$1.0x10^{-6}$	No data	No data	No data	No data	No data	No data	Johnson et al. 1984
1982–1984	$6.4x10^{-6}$	$1.15x10^{-5}$	$2.2x10^{-6}$	$2.7x10^{-6}$	$2.5x10^{-6}$	$2.0x10^{-6}$	$3.1x10^{-6}$	$2.2x10^{-6}$	Gunderson 1988
1987	$1.68x10^{-5}$	No data	No data	$6.3x10^{-6}$	No data	No data	$7.0x10^{-6}$	No data	FDA 1988
1988	$1.19x10^{-5}$	No data	No data	$3.9x10^{-6}$	No data	No data	$3.3x10^{-6}$	No data	FDA 1989
1989	$1.67x10^{-5}$	No data	No data	$6.0x10^{-6}$	No data	No data	$6.0x10^{-6}$	No data	FDA 1990
1990	$1.44x10^{-5}$	No data	No data	$5.9x10^{-6}$	No data	No data	$5.1x10^{-6}$	No data	FDA 1991
1991	$1.28x10^{-5}$	No data	No data	$3.4x10^{-6}$	No data	No data	$3.5x10^{-6}$	No data	FDA 1992
1992	$1.46x10^{-5}$	$2.22x10^{-5}$	$4.0x10^{-6}$	$5.0x10^{-6}$	$4.5x10^{-6}$	$3.9x10^{-6}$	$4.9x10^{-6}$	$3.5x10^{-6}$	FDA 1993

2-year-old children, 14–16-year-old females, 14–16-year-old males, 25–30-year-old females, 25–30-year-old males, 60–65-year-old females, and 60–65-year-old males, respectively (Gunderson 1988). Ethion intakes in mg/kg body weight/day, estimated for the total diet analyses for 1987–1992 also increase from intakes estimated in the 1982–1984 analysis and were 1.68×10^{-5}, 6.3×10^{-6}, and 7.0×10^{-6} in 1987 (FDA 1988); 1.19×10^{-5}, 3.9×10^{-6}, and 3.3×10^{-6} in 1988 (FDA 1989); 1.67×10^{-5}, 6.0×10^{-6}, and 6.0×10^{-6} in 1989 (FDA 1990); 1.44×10^{-5}, 5.9×10^{-6}, and 5.1×10^{-6} in 1990 (FDA 1991); and 1.28×10^{-6}, 3.4×10^{-6}, and 3.5×10^{-6} in 1991 (FDA 1992) for 6–11-month-old infants, 14–16-year-old males, and 60–65-year-old females, respectively. Ethion intakes in mg/kg body weight/day, estimated for the total diet study were 1.46×10^{-5}, 2.22×10^{-5}, 4.0×10^{-6}, 5.0×10^{-6}, 4.5×10^{-6}, 3.9×10^{-6}, 4.9×10^{-6}, and 3.5×10^{-6} for 6–11-month-old infants, 2-year-old children, 14–16-year-old females, 14–16-year-old males, 25–30-year-old females, 25–30-year-old males, 60–65-year-old females, and 60–65-year-old males, respectively (FDA 1993).

No information was located on the levels of ethion or its oxygen analogs in human tissues, adipose tissue, blood, urine, or breast milk in members of the general population. Ethion was not one of the pesticides monitored as part of the NHANES study (Needham et al. 1990), in the National Adipose Tissue Study (EPA 1986; Phillips and Birchard 1991), or in urine of the general population of the U.S. (Kutz and Cook 1992).

In occupational settings, dermal exposure and subsequent absorption through intact skin represent the most important route of exposure, while inhalation exposure is generally less important (Jeyaratnam and Maroni 1994). Inhalation of ethion depends on its volatility, the type of formulation used, and the application technique employed. Occupational ingestion may occur as a result of poor work practices and/or lack of personal hygiene. Workers employed in industries that manufacture, formulate, package, or apply ethion and workers involved in the disposal of ethion or ethion-containing wastes may be exposed to the highest concentrations of ethion.

Except for professional pesticide manufacturers, formulators, applicators, or farm workers, the exposure risks from ethion appear relatively minor as long as label instructions are followed and safeguards are taken to avoid extensive dermal contact (e.g., use of protective clothing). Studies of dermal exposure typical of ethion suppliers and applicators (spray crews) in Florida citrus spray operations were reported by Wojeck et al. (1981). These authors reported dermal and respiratory exposures for workers mixing and loading ethion for application and for those applying ethion to citrus trees. The suppliers' mean exposures were 1,799±3,793.2 mg/hour and 0.005±0.004 mg/hour for dermal and inhalation exposure, respectively. The applicators' mean exposures were 1,972.5±244.6 mg/hour and 0.004±0.002 mg/hour for dermal and respiratory exposure, respectively. Dermal exposure accounted for 99% of total exposure, while respiratory exposure represented <1% for both the suppliers and applicators. For both suppliers and applicators, the hands received the highest exposures to ethion. These authors reported that dermal exposure of the hands represented 42% of the total body exposure for applicators and 76% for suppliers, and there were no significant differences in exposures to other areas of the body. A significant amount of variability existed between the groups of supplier and applicators tested, based on the procedures used. Ethion monoxon was detected in most samples, but did not exceed 5% of the total amount of toxicant. This study also points out that management of protective clothing worn by ethion applicators is important in reducing dermal exposures.

Kahn (1976) reported pesticide-related illness in California farm workers exposed to pesticide residues on the foliage of treated crops and in dusty soils of orchards, fields, and vineyards. Of the reported pesticide poisonings from 1949 to 1970, ethion was implicated in 4 separate incidents involving 46 farm workers; however, the incidence always involved ethion and 1 or more other pesticides.

Wolfe et al. (1978) conducted a study to determine the potential dermal and respiratory exposure of workers to ethion at an ethion formulating plant. The studies were conducted during the formulation of 25% water-wettable powder with adsorbed ethion. In order to determine the potential exposure in different work situations, exposure pad studies were carried out on (1) workers who inserted the proper proportions of ingredients into the formulating mixer (mixer), (2) workers who filled bags with the ethion formulation at the filler spout (bagger), and (3) workers who performed a combination of jobs such as packing bags into cartons for shipment or working at the mixing and bagging stations (mixer-bagger-carton packer). Dermal contamination was measured primarily by attaching absorbent pads to various parts of the workers' body and allowing them to be exposed during a timed period of work. Respiratory exposure was estimated from the contamination of special filter pads used in place of the usual outer absorbent filter pads which cover the filter cartridges of the respirators worn by the subjects. The authors calculated that the exposure to ethion for all workers was 126 mg/hour for dermal exposure and 1.71 mg/hour for respiratory exposure. However, the authors reported that dermal exposure at the bagging station (mean 116±234 mg/hour) was greater than at the mixing station (70±121 mg/hour), and exposure of the mixer-bagger-carton package was the highest exposure of all (237±324 mg/hour). Inhalation exposure followed a similar pattern whereby respiratory exposure at the bagging station (mean 1.63±1.56 mg/hour) was greater than at the mixing station (1.15±1.60 mg/hour), and exposure of the mixer-bagger-carton package was the highest exposure of all (2.67±2.32 mg/hour). Dermal exposure of all workers typically represented 98.7% of the total exposure, while inhalation exposure represented 1.3% of the total exposure. Again, this study points out that management of clothing and respirators is important in reducing exposures.

Several studies have tested the use of various protective clothing or have made recommendations for reducing total dermal exposure to ethion. Wojeck et al. (1981) reported that exposure to the hands represented the largest percentage of total exposure to ethion in workers (suppliers and applicators) and recommended that the use of elbow-length vinyl gloves, washed inside and out with a strong alkaline detergent on a regular basis, would eliminate much of the potential hazard from dermal exposure. Davies et al. (1982) also reported that pesticide illness in agricultural workers often resulted from excessive dermal exposure to pesticides. These authors assessed the protection afforded by changing daily into freshly laundered 100% cotton coveralls. They reported that coveralls provided significantly greater protection from ethion exposure than did regular clothing and the use of respirators. Nigg et al. (1992) conducted a field evaluation of various coverall fabrics to assess heat stress and pesticide penetration. These authors reported that lighter weight, untreated fabrics marginally ameliorated heat stress under severe summer time temperatures in Florida citrus groves, but they also allowed more ethion penetration.

According to the National Institute for Occupational Safety and Health (NIOSH 1994), the Occupational Safety and Health Administration (OSHA), proposed an 8-hour time-weighted average (TWA) permissible exposure level (PEL) for ethion of 0.4 mg/m^3 for skin. However, this standard was vacated by a court decision. Two other organizations, however, adopted the proposed OSHA value. The National Institute for Occupational Safety and Health (NIOSH) recommends that the occupational exposure level not exceed 0.4 mg/m^3 (skin) for a 10-hour TWA workday (NIOSH 1997). In addition, the American Conference of Governmental Industrial Hygienists has recommended a TWA limit (TWA-TLV) of 0.4 mg/m^3 (skin) for occupational exposure to ethion (ACGIH 1997b).

5.6 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 2.7 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).

Information on the effects of ethion on humans is limited, and information on the effects of ethion on children is even more limited. One well documented case report of an acute poisoning incident was reported by Comstock et al. (1967) in which a 6-month-old infant received 6 ounces of milk from an 8-ounce bottle used previously to measure a concentrated solution of ethion in kerosene. The child's exposure represented a dose of 15.7 mg/kg. Ethion is not a pesticide that is used in the home, and no exposure studies on individuals likely to have significant exposure (formulators and applicators) are available in the literature. No information was located on measurements of ethion or its metabolite levels in amniotic fluid, meconium, cord blood, or neonatal blood that indicate prenatal exposure. Ethion and its active metabolite ethion monoxon are highly lipophilic molecules so there should be no significant barrier to crossing the placenta.

In addition, no information was located on measurements of ethion or its metabolite levels in breast milk that might result in post-natal exposure of an infant. Ethion and its active metabolite ethion monoxon are highly lipophilic molecules so their passage into breast milk is possible. This has been examined in animal models. Radioactivity derived from labeled ethion was present in goats' milk after oral exposure (Jobsis and Zeitlow 1985); however, the chemical identity of the radioactivity was not determined. Unchanged ethion (the monoxon was not measured) was detected in goats' milk after oral and dermal exposure to ethion (Mosha et al. 1990b). A total of 0.04–0.05% of the dose appeared in milk, after dermal exposure, and 1.4% after oral exposure.

Children may receive higher ethion doses from dermal exposures if they play on freshly treated grass or soil, or enter a treated agricultural area prematurely (Youngren et al. 1991). It is important that children not be allowed entry into ethion treated areas until the sprays have dried, dusts have settled, or vapors have dispersed to perform hand labor or to play. The reentry intervals described for farm workers should be strictly adhered to with respect to all human exposures (EPA 1989d). In addition, children may receive potentially higher oral doses from ingestion of ethion treated soils from their hands while playing in contaminated areas. Because soil may be a reservoir for ethion in the environment, consumption of contaminated soil from unwashed hands during hand to mouth activity or from putting contaminated toys or other objects in their mouths could be a major source of ethion-contamination for children. Dermal absorption of ethion is not likely, however, to be significant based on the relatively low amount (3.3%) that is absorbed through the skin (Feldman and Maibach 1974). The vapor pressure of ethion is 1.5×10^{-6} mmHg (EPA 1989b; Merck 1989) suggesting that some of it may volatilize from soil surfaces. However, due to its high Koc value, vapor pressure is expected to be greatly attenuated (Haque and Freed 1974). Thus, children's exposure to vapor-phase ethion while playing outdoors on the ground is not expected to be significant. As time goes by, ethion is expected to degrade in the environment through both biodegradation and hydrolysis. Ethion degraded to 50% of its initial concentration after 7 and 8 weeks in nonsterile sandy loam and organic soils, respectively (Miles et al. 1979). Hydrolysis in moist soils may also contribute to the decrease in ethion concentration. Estimated half-life values for the first-order hydrolysis of ethion in sterile water at 25±3 EC was 99, 63, 58, 25, and 8.4 weeks at pH values of 4.5, 5, 6, 7, and 8, respectively (Chapman and Cole 1982). Based on these degradative processes, ethion concentrations in soil are not expected to persist unless there is a continuous source of ethion contamination.

Ethion is not intended for indoor use except within greenhouses (EPA 1989b, 1989d). Therefore, children are not expected to be exposed to ethion indoors unless it is transported inside through contaminated materials or applied illegally indoors.

It is important that children of occupational users of pesticides, not be exposed to the contaminated work clothes or shoes of their parent (NIOSH 1995). Worker protection statements for pesticides state that workers should take off all work clothes and shoes and shower using soap and water, and then put on clean clothes. Personal clothing worn during work must be laundered and stored separately from personal family clothing. Heavily contaminated clothing should be destroyed according to state and local regulations (EPA 1989b). Since some ethion is applied as a dust formulation (see Section 4.3) (liquid ethion adsorbed to a particle matrix), children may be exposed dermally, orally via hand to mouth activities, or via inhalation of dust particles while playing on contaminated floors or carpeting where ethion-contaminated particles may have fallen from contaminated work clothes. However, no literature could be located documenting ethion's transfer to the home from contaminated work clothes or other articles.

Levels of ethion concentrations in infant and toddler foods and in baby formula are discussed in Section 5.4.4. Gelardi and Mountford (1993) analyzed for the presence of 34 pesticides including ethion in infant formula. The detection limit range for ethion was <0.001–0.016 ppm. These authors reported that of 110 milk-based formula and of 59 soy-based formula analyzed, that ethion was not detected in any samples of either formula. Similarly, pesticide residues were evaluated in infant and toddler total diet samples from August 1976 to September 1977 (Johnson et al. 1984). These authors reported that of 117 infant foods tested, ethion was detected in 2 samples in trace amounts, while ethion was detected in only 2 of 132 toddler foods at a concentration of 0.001 ppb. Positive detections were made only in foods in the fruit or fruit juice category. Yess et al. (1993) summarized the results of a study to monitor pesticide residues in infant and adult foods eaten by infants and children. These authors reported that ethion (total) was detected in 22 of 2,464 apple samples (maximum concentration of 1.7 ppm), in 1 of 13 orange juice samples (maximum concentration of 0.03 ppm), in 42 of 862 samples of oranges (maximum concentration of 1.1 ppm), and in 7 of 571 pear samples (maximum concentration of 0.22 ppm). These authors also reported that ethion (total) was detected in several imported foods including 9 of 735 apple samples (maximum concentration of 0.23 ppm), in 1 of 64 orange juice samples (maximum concentration of 0.02 ppm), in 89 of 474 samples of oranges (maximum concentration of 0.61 ppm), and in 1 of 816 pear samples (maximum concentration of 0.17 ppm). The concentration of ethion (total), however, did not exceed the EPA tolerances level (2 ppm) for any of the domestic or imported foods tested which might be eaten by infants and children.

With regard to prepared foods for infants and children, Yess et al. (1993) also reported that the maximum concentrations of ethion (total) detected in Dutch apple Betty were 0.001 ppm, in 3 samples of applesauce or applesauce with other fruits were 0.002 ppm, in 21 samples of orange or orange pineapple juice were 0.010 ppm, in 3 samples of pears or pears and pineapples were 0.003 ppm, in 24 samples of frozen orange juice were 0.008 ppm, and in 6 samples of raw pears were 0.280 ppm. Again, all of the adult foods that might be consumed by infants and children that were tested contained ethion residues well below the EPA tolerance level of 2 ppm. Concentrations of ethion in ready-to-eat foods were monitored for 10 years from 1982 to 1991 through the FDA's Revised Market Basket Survey (KAN-DO Office and Pesticides Team 1995). Ethion was detected in 199 samples of 31 different foods at a mean concentration of 0.0053 μg/g (5.3 ppb) and the ethion oxygen analogue was detected 8 times in 5 different foods at a concentration of 0.0029 μg/g (2.9 ppb). Ethion was detected in the following baby foods: apple sauce, Dutch apple Betty, meat, beef and vegetables, orange and orange pineapple juice, pears or pears and pineapples. The ethion oxygen analogue was detected in the following baby foods: orange or orange-pineapple juice. Based on these studies, it appears to be unlikely that food containing ethion residues will pose a major health risk to infants and young children except in those instances where the infants and children live on farms where large amounts of ethion are used and they consume large amounts of farm-raised fruits and vegetables.

A comparison of ethion intakes for various age groups of children and adults derived from FDA total diet studies over the past 25 years are summarized in Table 5-2. Trends for adults are discussed specifically in Section 5.5. Johnson et al. (1984) reported ethion intakes in mg/kg body weight/day for the total diet analysis conducted (1976 and 1977) for infants as trace amounts and 1.1×10^{-6}, respectively; and trace amounts and 1.0×10^{-6} for toddlers, respectively. Ethion intakes, in mg/kg body weight/day, estimated for total diet analyses (1982–1984) increased and were 6.4×10^{-6} and 1.15×10^{-5}, respectively, for 6–11-month-old infants, and 2-year-old children. Ethion intakes in mg/kg body weight/day, estimated for the total diet analyses for 1987–1992 also increased from intakes estimated in the 1982–84 analysis and were 1.68×10^{-5}, in 1987 (FDA 1988); 1.19×10^{-5} in 1988 (FDA 1989); 1.67×10^{-5} in 1989 (FDA 1990); 1.44×10^{-5} in 1990 (FDA 1991); and 1.28×10^{-5} in 1991 (FDA 1992) for 6–11-month-old infants. Ethion intakes in mg/kg body weight/day, estimated for the total diet study were 1.46×10^{-5} and 2.22×10^{-5} for 6–11-month-old infants and 2-year-old-children, respectively (FDA 1993).

In comparison, ethion intakes for older children were more comparable to adult intakes and were 2.2×10^{-6} and 2.7×10^{-6} for 14–16-year-old females and 14–16-year-old males, respectively (see Table 5-2) (Gunderson 1988). Ethion intakes in mg/kg body weight/day, estimated for the total diet analyses for 1987–1992 also increased slightly from intakes estimated in the 1982–1984 analysis and were 6.3×10^{-6} in 1987 (FDA 1988); 3.9×10^{-6} in 1988 (FDA 1989); 6.0×10^{-6} in 1989 (FDA 1990); 5.9×10^{-6} in 1990 (FDA 1991); and 3.4×10^{-6} in 1991, (FDA 1992) and 5.0×10^{-6} in 1992 for 14–16-year-old males (FDA 1993). Ethion intakes in mg/kg body weight/day, estimated for the total diet study also increased in 1992 and were 4.0×10^{-6} for 14–16-year-old females (FDA 1993).

Infants and children receive approximately 2–3 times more ethion in their diets per unit body weight than adults due to higher consumption of fruits and fruit drinks (FDA 1993). Studies have not been done in infants and children on the relationship between dietary intake and the activity of cholinesterases in red blood cells and plasma.

5.7 POPULATIONS WITH POTENTIALLY HIGH EXPOSURES

In addition to individuals who are occupationally exposed to ethion during its production, formulation, packaging, distribution, use or disposal (see Section 5.5), there are several groups within the general population that have potentially high exposures (higher than background levels) to ethion. These populations include individuals living in proximity to sites where ethion is produced or processed or sites where ethion was disposed, and individuals living near one of the 9 NPL hazardous waste sites where ethion has been detected in some environmental media (HazDat 2000). Other populations at risk of exposure to ethion and its oxygen analogs include recreational and subsistence fishers who may fish in ethion-contaminated waters and who typically consume larger amounts of locally caught fish and shellfish than the general population. However, no fish consumption advisories are currently in effect in the United States for ethion (EPA 1995g). Subsistence farmers and their families living in areas where ethion is heavily used in agriculture who may consume their own farm-raised fruits and vegetables or who may unknowingly consume drinking water from a ethion-contaminated well are at greater risk of exposure.

5.8 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 ethion 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 ethion.

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

5.8.1 Identification of Data Needs

Physical and Chemical Properties. While the principal properties of ethion are well characterized (Bowman and Sans 1983; Chapman and Cole 1982; Dierberg and Pfeuffer 1983; EPA 1989b; HSDB 1998; Merck 1989; Sax 1984; Sharom et al. 1980a, 1980b; Tomlin 1994), there are data gaps for odor thresholds, flammability limits, autoignition temperature, and flash point for the compound. Additional information on these properties would be helpful in assessing the compound's environmental fate. There are also data gaps for some spontaneously produced degradation products, some of which may be as toxic or more toxic than ethion.

Production, Import/Export, Use, Release, and Disposal. As with most pesticide agents, no current information was found on production or import and export volumes for ethion (FASE 1996). This lack of current information seriously compromises efforts to design monitoring programs to study fate and transport and can seriously jeopardize proper assessments of exposure opportunities and their associated health risks for this compound. Information on current production, import/export volumes, uses, releases to various environmental matrices, and disposal methods is needed to conduct a more accurate assessment of exposure pathways.

According to the Emergency Planning and Community Right-to-Know Act of 1986, 42 U.S.C. Section 11023, industries are required to submit chemical release and off-site transfer information to the EPA. The Toxics Release Inventory (TRI), which contains this information for 1996, will become available in May of 1998. This database will be updated yearly and should provide a list of industrial production facilities and emissions. No information was available on facilities involved in the production or processing of ethion because it is not one of the chemicals that facilities are required to report to the TRI (EPA 1995e).

Environmental Fate. In the atmosphere, ethion is subject to only minor degradation due to photolysis (Gore et al. 1971), however, reactions with hydroxyl radicals result in an estimated half-life of less than an hour (SRC 1995). No information was located on ethion’s reaction with ozone in the air. In water, ethion is subject primarily to hydrolysis, with photolysis and biodegradation being minor fate processes (Dierberg and Pfeuffer 1983; Eichelberger and Lichtenberg 1971; Frank et al. 1991; Gore et al. 1971). The rate of degradation of ethion in water is strongly influenced by pH (Chapman and Cole 1982; Dierberg and Pfeuffer 1983; Frank et al. 1991; Sharom et al. 1980a) and temperature (Dierberg and

Pfeuffer 1983; Gore et al. 1971; Sharon et al. 1980a). The rate of ethion degradation increases in alkaline pH and at higher temperatures. Ethion can be degraded in soils and sediment by hydrolysis (Chapman and Cole 1982) and by biodegradation by microorganisms (Miles et al. 1979; Sherman et al. 1974). Ethion is moderately to highly immobile in most soil types, particularly those with moderate amounts of organic matter (Kenaga 1980; Sharom et al. 1980b). Information on the mobility of ethion is available (Sharom et al. 1980b); however, no information was located on mobility of its major degradation products in various soil types. Additional information on the persistence and mobility of major degradation products of ethion would be useful. Additional information on environmental parameters governing the degradation rate of ethion in soil also would be helpful in evaluating the environmental fate of ethion and its degradation products.

Bioavailability from Environmental Media. Ethion can be absorbed following inhalation, dermal, or oral exposures. Absorption through the skin is of major concern for occupational exposures of manufacturers and formulators, farmers, farm workers, commercial applicators or homeowners related to the use of ethion as an insecticide or acaricide (Jeyaratnam and Maroni 1994; Kahn 1976; Wojeck and Nigg 1980; Wojeck et al. 1981; Wolfe et al. 1978). Additional information on the bioavailability of concentrations of ethion in soils, surface water, groundwater, and fish and shellfish, particularly from environments near hazardous waste sites, is needed to determine the bioavailability of ethion in these media.

Food Chain Bioaccumulation. Ethion has an estimated high bioconcentration potential (BCF=1,300) (Kenaga 1980) in aquatic organisms; however, there is little experimental or environmental monitoring data to confirm that bioaccumulation occurs in edible fish and shellfish species (Butler and Schutzmann 1978; Miles and Harris 1978a). Additional information on measured BCF values for edible fish and shellfish would be helpful, as would information on tissue residues of ethion and its major degradation products in edible tissues of livestock and poultry. Little information was found on studies associated with plant uptake (Leffingwell et al. 1975; Nigg et al. 1988), but ethion is rarely detected above EPA tolerance limits (Berry et al. 1997; Corneliussen 1970; FDA 1988, 1990, 1991, 1992, 1993, 1994, 1995; Gelardi and Mountford 1993; Gunderson 1988; Hundley et al. 1988; Johnson et al. 1984; KAN-DO Office of Pesticide Team 1995; Minyard and Roberts 1991; Roy et al. 1995; Schattenberg and Hsu 1992; Yess et al. 1991, 1993). Bioaccumulation of ethion in aquatic food chains appears to be potentially important. Based on results obtained from a BCF estimating equation using the compound's chemical and physical properties, a substantial BCF value as high as 1,300 was calculated (Kenaga

1980). However, experimental data on bioaccumulation and biomagnification of ethion in aquatic species are needed to verify that the estimated theoretical BCF values are actually attained.

Exposure Levels in Environmental Media. Ethion is distributed in all environmental media and has been detected in ambient air (HazDat 2000; Lewis and Lee 1976), indoor air at a manufacturing plant (Lewis and Lee 1976), surface water (Frank et al. 1982), groundwater (Cohen 1986; HazDat 2000), and sediment (Carey et al. 1978; HazDat 2000; Miles et al. 1978). While some information is available on historic levels of ethion in environmental media, current levels of ethion in air, water, groundwater, soil, and sediment in the United States have not been well documented. There is a need for more information from national or large regional studies on current exposure levels in these environmental matrices. Adequate information from the late 1960s through to the present time are available for various raw and prepared foods as ethion has been monitored in many FDA total diet studies as well as compliance and surveillance monitoring programs (Berry et al. 1997; Corneliussen 1970; FDA 1988, 1990, 1991, 1992, 1993, 1994, 1995; Gelardi and Mountford 1993; Gunderson 1988; Hundley et al. 1988; Johnson et al. 1984; KAN-DO Office of Pesticide Team 1995; Minyard and Roberts 1991; Roy et al. 1995; Schattenberg and Hsu 1992; Yess et al. 1991; Yess et. al. 1993). Additional information on tissue residues of ethion and on its major degradation products in edible fish and shellfish species would be particularly helpful in quantifying health risk from consumption of contaminated species.

Reliable monitoring data for the levels of ethion in contaminated media at hazardous waste sites are needed so that the information obtained on levels of ethion in the environment can be used in combination with the known body burden of ethion to assess the potential risk of adverse health effects in populations living in the vicinity of hazardous waste sites. Monitoring information from piezometer and producing water wells around hazardous waste sites for ethion and monitoring of water wells in areas that have high agricultural usage of ethion are considered essential.

Exposure Levels in Humans. Recent and historic data regarding levels of ethion in human tissues (adipose tissue, blood, urine, breast milk) from environmental exposures of members of the general population, populations living near hazardous waste sites, or occupationally exposed groups are not available. It is arguable that these levels are knowable because of the rapid metabolism and clearance of ethion after it enters the body. Studies are needed to determine ethion and ethion monoxon residues in breast milk from women with high exposure risks (e.g., individuals that live near hazardous waste sites where ethion has been detected or in agricultural areas of high ethion use (particularly citrus-growing regions). Data on the relationship between environmental exposure to ethion and effects on biomarkers (blood cholinesterases) are needed to estimate the extent of exposure to ethion. This information is necessary for assessing the need to conduct health studies on these populations.

Exposures of Children. Children may be exposed to ethion primarily from consumption of small amounts of ethion in contaminated fruits, by consumption of ethion-contaminated dirt and soil from unwashed hands or other contaminated objects put into the mouth, or via ingestion of ethion-contaminated well water. Exposure and body burden studies for children would be helpful. There is no information on ethion residues in breast milk of members of the general population nor in women residing in areas of high ethion usage in agriculture and in areas near hazardous waste sites. Well water surveys should be conducted in areas of high ethion usage. These pathways via ingestion of ethion- contaminated breast milk or drinking water could be important routes of exposure in children.

Young children might be exposed to ethion through both pica and hand-mouth activity if they play in or around contaminated vegetation and soil. Soil and sediment may be contaminated with ethion and there are no studies of the transfer of ethion via both oral and dermal routes of exposure in children nor are there studies of the bioavailability of the chemical from soil and sediment.

Current information on whether children are different in their weight-adjusted intake of ethion via oral and dermal exposures was not located; however, information from older studies was available. Children, specifically 6–10-month-old infants and 2-year-old toddlers, are different in their weight-adjusted intake of ethion from food as compared to 14-year-olds as demonstrated by intake data (FDA 1988, 1989, 1990, 1991, 1992, 1993; Gunderson 1988; Johnson et al. 1984). The highest intakes were for 2-year-old-toddlers and 6–11-month-old-infants respectively (FDA 1993; Gunderson 1988). Intakes for children (14-year-olds) were lower than in infants and toddler and were more comparable to data from 25-year-olds and 65-year-old adults (FDA 1993; Gunderson 1988).

Child health data needs relating to susceptibility are discussed in Section 2.12.2 Identification of Data Needs: Children’s Susceptibility.

Exposure Registries. No exposure registries for ethion 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.

5.8.2 Ongoing Studies

No additional information was located on current studies that would fill existing data needs for ethion (FEDRIP 1998).