5. POTENTIAL FOR HUMAN EXPOSURE

5.1   OVERVIEW

Chlorfenvinphos is currently released to the environment in the United States from runoff and leaching from hazardous waste disposal sites. Soil is the environmental medium most likely to be contaminated with chlorfenvinphos. The processes that may transport chlorfenvinphos from soil to other media include volatilization to the air, leaching to groundwater, runoff to surface water, and absorption by plants. Biodegradation appears to be the dominant process responsible for chlorfenvinphos loss from soil (Miles et al. 1979, 1983). Biodegradation, hydrolysis, and adsorption to organic matter are likely to be responsible for the loss of chlorfenvinphos from water (Beynon et al. 1971, 1973; Rouchaud et al. 1988).

If released to air from soil or water via volatilization, chlorfenvinphos is expected to exist primarily in the vapor phase, but can also be found associated with particulate matter (Eisenreich et al. 1981). In the vapor phase, chlorfenvinphos can react with hydroxyl radicals (estimated half-life value of 7 hours) or with ozone (estimated half-life value of 92 hours) (Atkinson and Carter 1984; Lyman et al. 1990; Meylan and Howard 1993).

If released to water, moderate adsorption to particulate matter will transport chlorfenvinphos from the water column and partition it to suspended solids and sediment (Swann et al 1983). The hydrolysis half-life value for chlorfenvinphos in water is highly dependent on pH and temperature. At a pH of 6 and 8 and a temperature of 20–30 EC, the half-life values were 170 and 80 days, respectively (Beynon et al. 1971).

Chlorfenvinphos does not appear to partition extensively from water into aquatic organisms. Estimated whole-body concentration factors for chlorfenvinphos were significant, but relatively low, ranging from 37 to 460 (Mackay 1982; Veith et al. 1979; Veith et al. 1980 in Bysshe 1990). No experimentally measured bioconcentration factor (BCF) values were located in the literature for any aquatic invertebrate or fish species. Chlorfenvinphos is absorbed by plants primarily from the soil, but residues generally decline fairly rapidly in the tissues through the course of the growing season (Beynon et al. 1968; Suett 1971, 1975a).

The estimated half-life value of chlorfenvinphos in sandy soil ranges from 28 days (4 weeks) to 210 days (30 weeks) (Beynon et al. 1973; Williams 1975a). The rate of degradation is influenced greatly by the soil type, amount of organic matter in the soil, soil temperature, soil moisture content, and

the history of chlorfenvinphos use. Repeated application of chlorfenvinphos to agricultural soils enhanced microbial degradation of the pesticide (Rouchaud et al. 1989a, 1991).

No information was found on concentrations of chlorfenvinphos in ambient air samples or in drinking water in the United States. Chlorfenvinphos was detected in surface and groundwater samples (concentrations not specified) at the one hazardous waste site where chlorfenvinphos was detected (HazDat 1996). Chlorfenvinphos was also detected in soil samples (concentrations not specified) at the one hazardous waste site where chlorfenvinphos was detected (HazDat 1996). It should be noted that the amount of chlorfenvinphos found by chemical analysis is not necessarily the amount that is bioavailable.

Currently, both domestic and imported foods (fresh fruits and vegetables) and lanolin-containing pharmaceutical products appear to be sources of some exposure for the general population. In the past, occupational exposure to chlorfenvinphos may have occurred through dermal contact and inhalation of dusts and sprays especially to workers applying the compound as a pesticide. Occupational exposure to chlorfenvinphos was reported in California in workers who handled flea control products (Ames et al. 1989).

Workers involved in disposal of chlorfenvinphos or chlorfenvinphos-contaminated wastes are also at a higher risk of exposure than the general population. People living in the vicinity of plants where chlorfenvinphos was manufactured or formulated, or living near dairy farms, cattle or sheep holding areas, or poultry producing facilities where chlorfenvinphos was used; and people living near hazardous waste sites containing chlorfenvinphos also are potentially at higher risk of exposure.

Chlorfenvinphos has been identified in at least 1 of the 1,428 current or former EPA National Priorities List (NPL) hazardous wastes sites (HazDat 1996). However, the number of sites evaluated for chlorfenvinphos is not known. The frequency of these sites within the United States can be seen in Figure 5-1.

5.2   RELEASES TO THE ENVIRONMENT

Information on historic production of chlorfenvinphos (including producers, production sites, production volumes and years of production) in the United States was not found. Releases of chlorfenvinphos are not required to be reported under SARA Section 313; consequently there are no data for this chemical in the 1993 Toxics Release Inventory (EPA 1995).

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

SITES

▨ 1
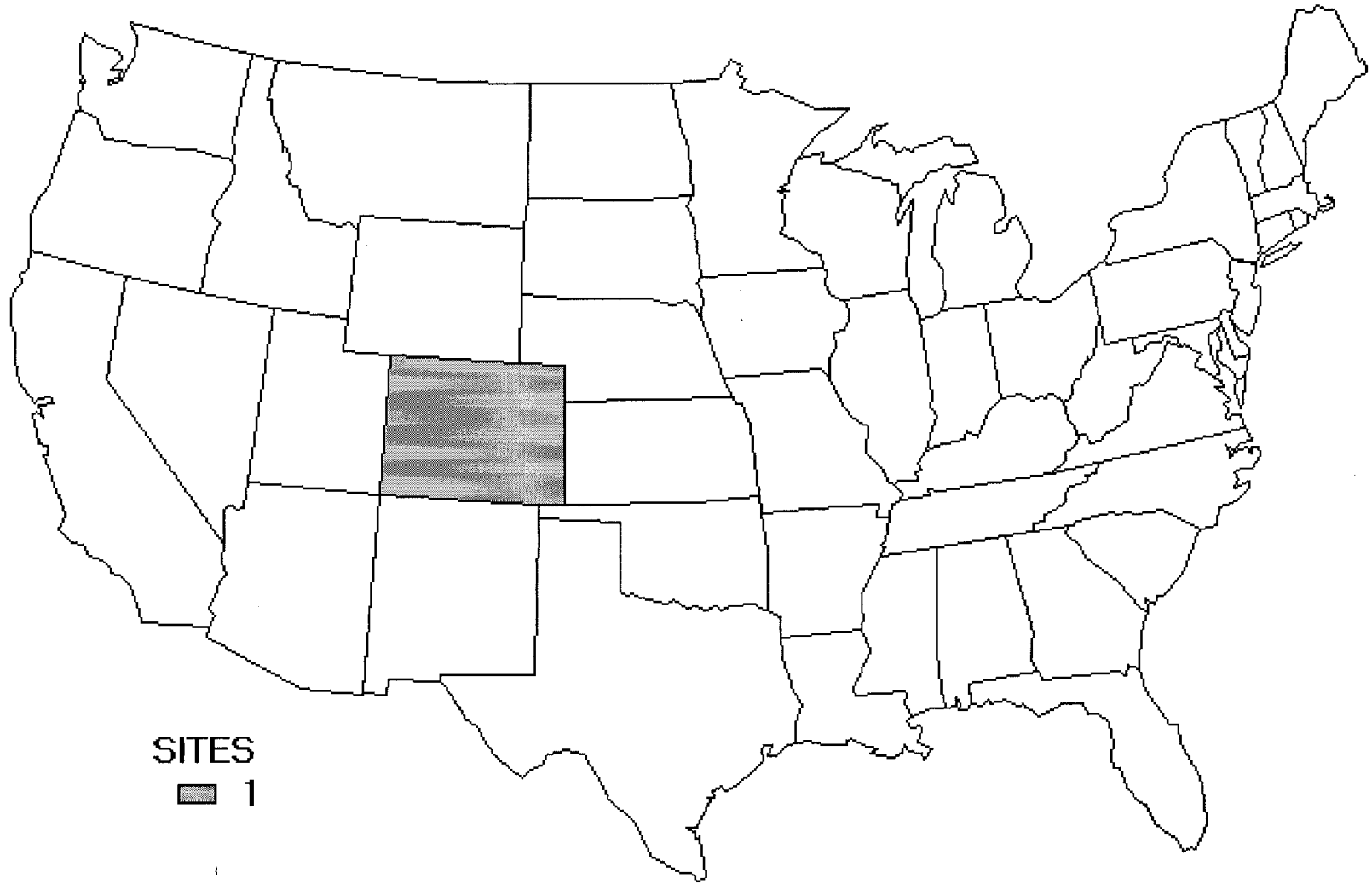
Derived from HazDat 1996

5. POTENTIAL FOR HUMAN EXPOSURE

There is one NPL hazardous waste site where chlorfenvinphos has been identified (HazDat 1996). Hazardous waste disposal sites appear to be the major source for release of this compound into the environment since there are currently no registered uses for it in the United States (REFS 1995).

5.2.1 Air

Chlorfenvinphos may have been released into the air in the past, during its production and processing. Historically, chlorfenvinphos may have volatilized into the air during its use in sprays applied to dairy, poultry, and cattle facilities to control flies and fly larvae, or from the skin of animals exposed to chlorfenvinphos in cattle dips or sprays. Because of the relatively low volatility of the compound and lack of registration for crop use in the United States (REFS 1995), releases to the air from registered uses would be expected to be negligible.

Chlorfenvinphos was not detected in air samples collected at the one NPL hazardous waste site where it was detected in some environmental media (HazDat 1996). No other information on releases of chlorfenvinphos to air was located; however, there are no current registered uses of this compound in the United States (REFS 1995; SRI 1993).

5.2.2 Water

In the past, chlorfenvinphos may have been released to surface water during its production and processing. Chlorfenvinphos also may have been released to water via runoff after its application to dairy, poultry, and cattle facilities to control flies and fly larvae, or when residues from sheep or cattle dip tanks were discharged onto soil (Inch et al. 1972). Because chlorfenvinphos was never registered for use on crops in the United States (REFS 1995), its releases to water from its registered uses would be expected to be minimal. Adsorption to particulate matter will eventually transport chlorfenvinphos from water to suspended solids and sediment.

Chlorfenvinphos has been detected in surface water and groundwater samples collected at the one NPL hazardous waste site where it was detected (concentrations unspecified) in some environmental media (HazDat 1996). No other information on releases of chlorfenvinphos to water was located; however, there are no current registered uses of this compound in the United States (REFS 1995; SRI 1993).

5.2.3   Soil

Chlorfenvinphos may have been released directly to soil during its production and processing and is likely to have been released during its disposal as the recommended disposal practice for small quantities was burial in a disposal pit or in clay soil (IRPTC 1985). The chemical may also have been released to soil and sediment indirectly from runoff from treated manure storage areas, and areas around poultry or cattle holding areas, or when residues from sheep or cattle dip tanks were discharged onto soil (Inch et al. 1972). Adsorption to particulate matter will eventually transport chlorfenvinphos from water to suspended solids and sediment. Because chlorfenvinphos was not registered for crop use in the United States, its releases to soil from its registered uses would be expected to be minimal.

Chlorfenvinphos has been detected in soil samples collected at the one NPL hazardous waste site where it was detected in some environmental media (HazDat 1996). No other information on releases of chlorfenvinphos to soil or sediments was located; however, there are currently no registered uses of this chemical in the United States (REFS 1995; SRI 1993).

5.3   ENVIRONMENTAL FATE

5.3.1   Transport and Partitioning

There is a paucity of experimental data regarding the transport and partitioning of chlorfenvinphos in the air. Given a vapor pressure ranging from 4.0×10^{-6} mm Hg (Worthing 1983) to 7.5×10^{-6} mm Hg (Merck 1989), chlorfenvinphos should exist in the atmosphere in the vapor phase, but will also partition to available airborne particulates (Eisenreich et al. 1981). The solubility of 145 mg/L (Merck 1989) ensures that at least partial removal of atmospheric chlorfenvinphos will occur by wet deposition.

The transport of chlorfenvinphos from water to air can occur due to volatilization. Henry's law constant provides a qualitative indication of the importance of volatilization. Compounds with a Henry's law constant (H) of $<10^{-5}$ atm-m^3/mol volatilize slowly from water (Thomas 1990). Chlorfenvinphos with an H value of 2.76×10^{-9} atm-m^3/mol (Domine et al. 1992), therefore, will volatilize slowly from water. Since H $<10^{-9}$ atm-m^3/mol, chlorfenvinphos is less volatile than water and its concentration in water may increase as water evaporates. Humidity in the air reduces the volatilization rate of water somewhat so the lower limit can be set at 10^{-7}; this means that chlorfenvinphos could be considered essentially nonvolatile (Thomas 1990).

Adsorption to particulate matter will transport chlorfenvinphos from water and partition it to suspended solids and sediment in water. The estimated organic carbon-adjusted soil sorption coefficient (K_{oc}) for chlorfenvinphos is 280 (Kenaga 1980). This K_{oc} value suggests that chlorfenvinphos in the water column adsorbs moderately to suspended solids and sediments based on criteria established by Swann et al. (1983), and this process may transport considerable amounts of chlorfenvinphos from water to particulate matter. Partitioning of chlorfenvinphos from water to solid suspended matter was studied in a field experiment. Chlorfenvinphos was sprayed at a rate of 74 kg/ha on to the surface of a pond so the water contained an average concentration of 6.1 ppm (Beynon et al. 1971). The concentration decreased to 2.0 ppm after 5 hours, and to 0.12 ppm after 1 month. The sediment concentrations increased and persisted for at least 34 days after treatment. Chlorfenvinphos disappears from water in two distinct phases, a rapid initial phase and a much slower second phase. It is suggested that the first phase represents the initial precipitation of the heavier particles and uptake in plankton containing the adsorbed pesticide. Later, chlorfenvinphos is gradually adsorbed to other suspended matter, which then precipitates much more slowly, or the second phase may represent the slower removal of the residues by biotic processes.

Based on structure and activity relationships, certain regression equations have been developed to estimate the bioconcentration factor (BCF) value for chlorfenvinphos from its water solubility and organic carbon partition coefficent (K_{oc}) values. Using these regression equations, the BCF value for chlorfenvinphos in aquatic organisms is estimated to be 37 (Kenaga 1980). A log octanol-water partition coefficent (K_{ow}) value of 3.806 was reported by Bowman and Sans (1983). Using regression equations involving log K_{ow}, the following BCF values were estimated; 306 (Mackay 1982), 343 (Veith et al. 1979), and 460 (Veith et al. 1980 in Bysshe 1990). No experimentally measured BCF values were located in the literature for any aquatic invertebrate or fish species. However, bioconcentration of chlorfenvinphos in aquatic organisms, although relatively low, ranging from 37 to 460, may have some environmental significance. No information was found on the biomagnification of chlorfenvinphos through aquatic or terrestrial food chains.

The transport processes that may move chlorfenvinphos from soil to other media are volatilization, leaching, runoff, and absorption by plants. Based on the estimated Henry's law constant, volatilization is not expected to be an important transport process for moving chlorfenvinphos from soil to other media. Like other pesticides, chlorfenvinphos in soil partitions between soil-sorbed and soil-water phases (Racke 1992). This latter phase may be responsible for the volatilization of chlorfenvinphos from soil; however, due to the low Henry's law constant value, the rate of chlorfenvinphos volatilization from the soil-water phase to the atmosphere would be low. In a laboratory study of volatilization from

soil, chlorfenvinphos was incorporated into sterilized sand and into a sterilized sandy loam at a concentration of 50 ppm. The media contained 25% moisture and were maintained at 20 EC in an open beaker. Forty-five days after incorporation, more than 95% of the chlorfenvinphos was still present in the beaker (Rouchaud et al. 1988). However, in a field study conducted by Williams (1975a), the author suggests that rapid loss (42% in 2 days) of surface-applied chlorfenvinphos (granular) was probably due to volatilization and/or photodecomposition. Subsurface application of the granular formulation at the same concentration showed only a 6% loss in 2 days post-application. In another field study, Suett (1977) reported that the combination of sunlight and warm wet soil for 48 hours immediately after application of chlorfenvinphos marginally increased isomerization on both the coarse and fine soil tilthes, but did not enhance volatilization.

The reported K_{oc} value of 280 (Kenaga 1980) suggests that the adsorption of chlorfenvinphos to soil is moderately strong; therefore, the rates of leaching and runoff will be relatively minor processes in most soils. Very little leaching of chlorfenvinphos and no leaching of its degradation products was observed in several field studies. The leaching characteristics of chlorfenvinphos were studied by applying it to sloping arable land at 22 kg active ingredient/hectare (a.i./ha) and following its movement down a slope (Edwards et al. 1971). Only 0.18% of the chlorfenvinphos applied was leached through the soil, but this was nine times more than was observed with dieldrin in a similar experiment. Only very small amounts of chlorfenvinphos moved down the slope and were present in runoff. In one of the experiments there was a pond located at the bottom of the slope and residues could not be detected in the mud or water from this pond. Residues of the main soil degradation products were not detected in the pond water at 23 or 36 weeks post-application. More chlorfenvinphos leached vertically into drainage water than laterally over the soil surface. Chlorfenvinphos residues in soil following broadcast applications on the surface showed that even after 150 days, only 1–1.5% of the applied chlorfenvinphos leached to a depth of 7.5–15 cm despite 12 cm of rainfall that occurred during the first 60 days post-application (Williams 1975a). Furthermore, when the granular formulation was applied at a depth of 7.5 cm, there was little movement of chlorfenvinphos below a depth of 10 cm. In a similar study by Agnihotri et al. (1981), when chlorfenvinphos granules were applied to the 0–15 cm soil layer, no leaching of the compound occurred below the 15 cm depth over a period of 120 days.

Chlorfenvinphos is also transported from the soil of one area to soil of another area or from soil to surface water (rivers, lakes, and streams) via runoff. Pesticides with a water solubility >10 mg/L move mainly in solution phase in runoff water (Racke 1992). Chlorfenvinphos with a water solubility of 145 mg/L (Merck 1989) is expected to be found mainly in runoff water. This does not seem to be completely substantiated, however, by results of several field studies conducted in agricultural

watersheds. In one field study, only 0.3–0.6% of the applied chlorfenvinphos was found in runoff water after a rainfall event (Racke 1992). Braun and Frank (1980) analyzed pesticide residues in surface water samples over a 3-year period (1975–77) collected in 11 agricultural watersheds in Southern Ontario, Canada. Although chlorfenvinphos was known to have been used as a soil pesticide in at least one of the watersheds, it was not detected in any surface water samples (detection limit 1 µg/L [1 ppb]). In a more recent study, Frank et al. (1991) analyzed pesticide residues in surface water samples over a 5-year period (1986–90) collected from the mouths of the 3 major agricultural watersheds, the Grand, the Saugeen, and the Thames Rivers in Ontario, Canada. All three rivers flow into Lake Erie. Although it was known to have been used as a soil pesticide in the Thames River basin in 1988, no chlorfenvinphos residues were detected in any surface water samples during the study period (detection limit <1.0 µg/L [ppb]). Most recently, Wan et al. (1994) studied residues of several organophosphate pesticides including chlorfenvinphos in farm ditch water, and sediments and farm soils in the lower Fraser Valley of British Columbia, Canada, from July through December 1991. The farm ditches drained into three rivers: the Fraser, the Niicomekl, and the Sumas. During the study period, no sales of chlorfenvinphos were reported. Chlorfenvinphos was used as a soil insecticide in 1990, but was not recommended for this use in Canada in 1991. Although chlorfenvinphos was not detected in any of the farm ditch water or sediment samples analyzed at the 7 sampling sites, it was detected in 7% of the soil samples. Adsorption of chlorfenvinphos to particulate matter will transport the pesticide from the water column and partition it to suspended solids and sediment. From these results, it seems clear that surface water runoff and leaching of chlorfenvinphos into drainage water from treated agricultural fields is not likely to be a serious problem.

Adsorption of chlorfenvinphos from water solutions of hydrogen, calcium, sodium, and potassium ions were studied (Barba et al. 1991). In all cases, the saturating cations influenced the Freundlich-type adsorption, with adsorption decreasing in the following sequence: H^+> Ca^{2+}> Na^+> K^+ for adsorption on two clays, kaolinite and bentonite. The extent of adsorption of chlorfenvinphos was generally slower in kaolinite than in bentonite.

When it was first introduced, chlorfenvinphos was generally considered to be a non-systemic pesticide (i.e., when it is applied to soil it should not move into plants and when sprayed on plant foliage, it should not move from the treated leaves into other untreated parts of the plant) (Rouchaud et al. 1989b). This view was based on the fact that at plant maturity or at harvest, very low residues (<0.02 mg/kg [0.02 ppm]) were found in turnips, carrots, cabbages, white radishes, and potatoes planted or sown in chlorfenvinphos-treated soil (Beynon and Wright 1968; Beynon et al. 1968). In addition, no

translocation of chlorfenvinphos from treated leaves to other parts of plants was observed (Beynon et al. 1973). Earlier work with potato tubers under recommended field conditions also confirmed this finding (Beynon et al. 1968). Rouchaud et al. (1989b), however, found that in the foliage of the spring cauliflower, the concentration of chlorfenvinphos increased, reaching a peak concentration 15 days after soil treatment, then progressively decreased until harvest. The presence of chlorfenvinphos and two metabolites, trichloroacetophenone and 2,4-dichlorobenzoic acid, was the result of their absorption by the plant from the soil and of their biodegradation by the plant. Two crops were studied for their chlorfenvinphos uptake (Rouchaud et al. 1991). The periods of time required for chlorfenvinphos foliage concentrations to attain residues of 1 mg/kg (1 ppm) fresh weight were: cauliflower, 24–37 days; and Brussels sprouts, 41–45 days. Suett (1974, 1975a) also reported that carrots accumulated high residue concentrations of chlorfenvinphos applied to the soil and continued to accumulate the pesticide during the entire period of active plant growth. Thirty weeks after carrot seed was sown in soil treated with chlorfenvinphos at a depth of 10 cm, the peel of the carrots contained 88% of the total chlorfenvinphos residues found in the carrots. The upper 6 cm of carrot root always contained most of the chlorfenvinphos residue irrespective of the application mode. Significant residues of chlorfenvinphos were detected in immature onion bulbs (64–76 days after seeding), with the level of chlorfenvinphos residue being much higher in the roots and outer skin (Ritcey et al. 1991). The chlorfenvinphos concentrations in the bulbs dropped below the detection limit (unspecified) by 96 days after seeding (2 months before harvesting).

In recent experiments, plant cuticle was investigated as the first and rate-limiting barrier in foliar uptake of chlorfenvinphos. Mobility studies of chlorfenvinphos across the cuticular membranes of bitter orange (*Citrus aurantium*) leaves and green pepper (*Capsicum annuum*) fruits gave first-order rate constants of 6.7 ($\pm$3.3)x10^8/second and 10.2 ($\pm$3.4)x10^7/second, respectively (Bauer and Schönherr 1992). These correspond to penetration half-lives of 120 days (2,874 hours) and 7.8 days (189 hours), respectively.

5.3.2 Transformation and Degradation

5.3.2.1 Air

One of the important reactions for most organic pollutants in the atmosphere is with hydroxyl radicals. No rate constant for the reaction of hydroxyl radicals with chlorfenvinphos in air has been experimentally determined. Using an estimation method, the estimated rate constant value for the vapor-phase reaction of chlorfenvinphos with hydroxyl radicals is 5.31x10^{-11} cm^3/radical-sec at 25 EC (Atkinson 1988; Meylan and Howard 1993). Based on this value, and assuming an average annual

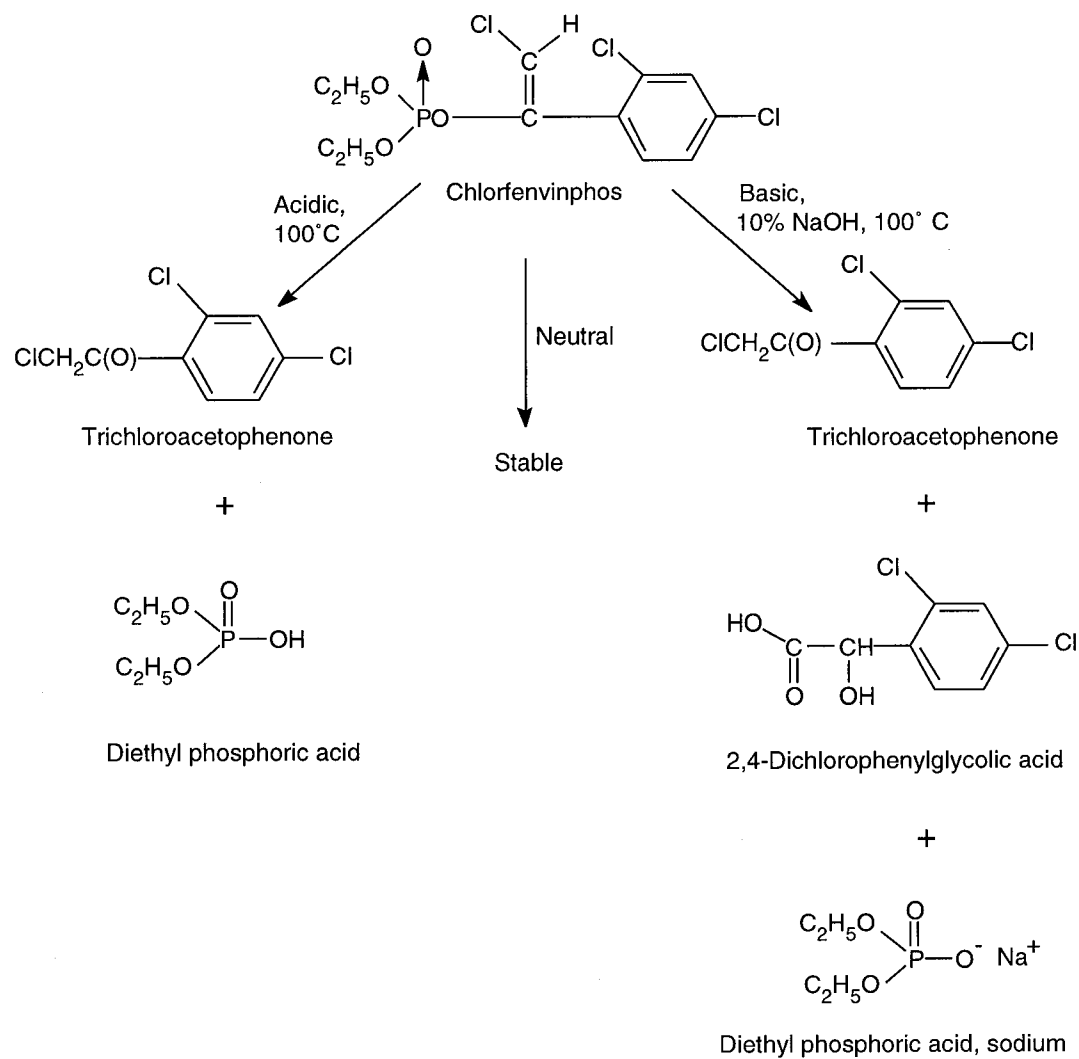atmospheric concentration of hydroxyl radicals in the northern hemisphere of 4.8×10^5 radicals/cm^3 (Lyman et al. 1990), the estimated half-life value (first-order kinetics) of chlorfenvinphos in the atmosphere due to this reaction is 7 hours. Thus, chlorfenvinphos is short-lived in the atmosphere. Chlorfenvinphos can also be degraded by ozonation in the atmosphere. However, no rate constant for the reaction of ozone with chlorfenvinphos in air has been experimentally determined. An estimated value of the rate constant is $3 \times 10^{-18} cm^3$/molecule-sec at 25 EC (Atkinson and Carter 1984; Meylan and Howard 1993). Based on this value and assuming an average atmospheric ozone concentration of 9.6×10^{11} molecules/cm^3 (Lyman et al. 1990), the estimated half-life value (first-order kinetics) of chlorfenvinphos in the atmosphere due to this reaction is 92 hours (3.4 days). Photolysis is probably the least significant of the atmospheric degradation processes. Chlorfenvinphos is not susceptible to direct photolysis in sunlight because its maximum absorption for ultraviolet light is 228 nm (Schlett 1991), which is less than the 290 nm wavelength limit for sunlight absorption to occur.

5.3.2.2 Water

The processes that can result in the transformation and degradation of chlorfenvinphos in water are hydrolysis, photosensitized oxidation, and biodegradation. Hydrolysis pathways for chlorfenvinphos in water are shown in Figure 5-2. Chlorfenvinphos is most stable in water at ambient temperatures and neutral pH. Chlorfenvinphos hydrolyzed slowly in water resulting in a half-life (first-order kinetics) value of 170 days at pH 6 and 80 days at pH 8 at 20–30 EC (Beynon et al. 1971). In laboratory studies, hydrolysis was observed under conditions of high temperature and extreme pH (highly alkaline or highly acidic), resulting in a half-life of >400 hours (>33 days) at pH 9.1, and >700 hours (58 days) at pH 1.1 at 38 EC (Agrochemicals Handbook 1991; Beynon et al. 1973; Hayes 1982). Hydrolysis probably does not contribute much to the initial disappearance of chlorfenvinphos from natural waters (Beynon et al. 1971). Based on hydrolysis studies (Ruzicka et al. 1967) conducted at 70 EC and correcting for temperature differences assuming an environmental temperature of 20 EC, the aqueous hydrolysis half-life (first-order kinetics) value of chlorfenvinphos is approximately 1–1.3 years (Harris 1990). Direct photolysis of chlorfenvinphos is negligible, since the compound does not significantly absorb ultraviolet wavelength light >290 nm. No information was found in the literature regarding the photosensitized reaction of chlorfenvinphos in water with ozone, hydroxyl radicals or singlet oxygen. Therefore, biodegradation appears to be the dominant degradation process in natural waters. This is likely, as microbial degradation is the dominant degradation process in soils (Miles et at. 1979, 1983; Rouchaud et al. 1988).

Figure 5-2. Hydrolysis Pathways for Chlorfenvinphos in Water

Chlorfenvinphos

Acidic, 100°C

Neutral

Basic, 10% NaOH, 100° C

Trichloroacetophenone

Stable

Trichloroacetophenone

+

+

Diethyl phosphoric acid

2,4-Dichlorophenylglycolic acid

+

Diethyl phosphoric acid, sodium

5.3.2.3 Sediment and Soil

Chlorfenvinphos in soil and sediment may undergo degradation and transformation by hydrolysis, and biotic processes. Various screening studies have demonstrated that microbial degradation is the dominant degradation process in soil (Miles et al. 1979, 1983; Rouchaud et al.1988, 1989a, 1989b). The hydrolysis of chlorfenvinphos may occur in the soil/sediment-water phase, as opposed to the soil/ sediment-sorbed phase. As a result, the rate of hydrolysis is expected to be comparable to that in water. Based on the slow hydrolysis rates observed in water (see Section 5.3.2.2), hydrolysis of chlorfenvinphos in soil is not expected to be significant. In the laboratory, chlorfenvinphos was incubated in sterilized and unsterilized soil for more than 2 months at 20 EC. The rate of disappearance of chlorfenvinphos from the sterilized soil was more than 15 times slower than that observed in unsterilized soil. The persistence of chlorfenvinphos was examined in sterile and natural mineral (sandy loam/organic matter = 2.7%, pH = 7.2) and organic (muck, organic matter = 48%, pH = 6.5) soils at a range of temperatures (3–28 EC) for 24 weeks (Miles et al. 1979, 1983). In general, chlorfenvinphos is less stable in sandy loam than in muck, less stable at higher temperatures (the exception was the stability of chlorfenvinphos in sterile sandy loam at all temperatures studied), and considerably less stable in natural soils (half-lives #11 weeks at 15 and 28 EC) compared to sterile soils (half-lives >24 weeks at all temperatures), indicating the major role microbes play in degrading chlorfenvinphos in soil. A summary of degradation pathways of chlorfenvinphos in soil is presented in Figure 5-3.

Chlorfenvinphos is degraded in soil to trichloroacetophenone, 2,4-dichloroacetophenone, α-(chloro-methyl)-2,4-dichlorobenzyl alcohol, and 1-(2',4'-dichlorophenyl)-ethan-1-ol (Rouchaud et al. 1988, 1991). Other degradation products identified are 2,4-dichlorobenzoic acid, 2-hydroxy-4-chlorobenzoic acid, and 2,4-dihydroxybenzoic acid. None of the degradation products retain any pesticide characteristics. Trichloroacetophenone is the main transformation product; when hydrolyzed, oxidized and decarboxylated, it becomes 2,4-dichlorobenzoic acid. Reduction of trichloroacetophenone to α-(chloromethyl)-2,4-dichlorobenzyl alcohol is a slow process, and replacement of a chlorine atom by a hydrogen atom to become 2,4-dichloroacetophenone and 1(-2',4'-dichlorophenyl)-ethan-1-ol is also slow. The degradation products 2-hydroxy-4-chlorobenzoic acid and 2,4-dihydroxybenzoic acid are produced from 2,4-dichlorobenzoic acid by replacement of chlorine atoms by hydroxyl groups.

Biodegradation of chlorfenvinphos is influenced by several factors: soil type, presence of organic matter, moisture content, soil temperature, and a history of chlorfenvinphos use. Chlorfenvinphos degrades fastest in

Figure 5-3. Environmental Degradation Pathways for Chlorfenvinphos in Soil

Chlorfenvinphos

Desethyl chlorfenvinphos

Trichloroacetophenone

(HO)₃P(O)
Phosphoric acid

α-(Chloromethyl)-2,4-dichlorobenzyl alcohol

2,4-Dichlorobenzoic acid

1-(2,4-Dichlorophenyl)-ethan-1,2-diol

2,4-Dichlorophenyl oxirane

2-Hydroxy-4-chlorobenzoic acid

2,4-Dihydroxybenzoic acid

2,4-Dichloroacetophenone

1-(2,4-Dichlorophenyl)-ethan-1-ol
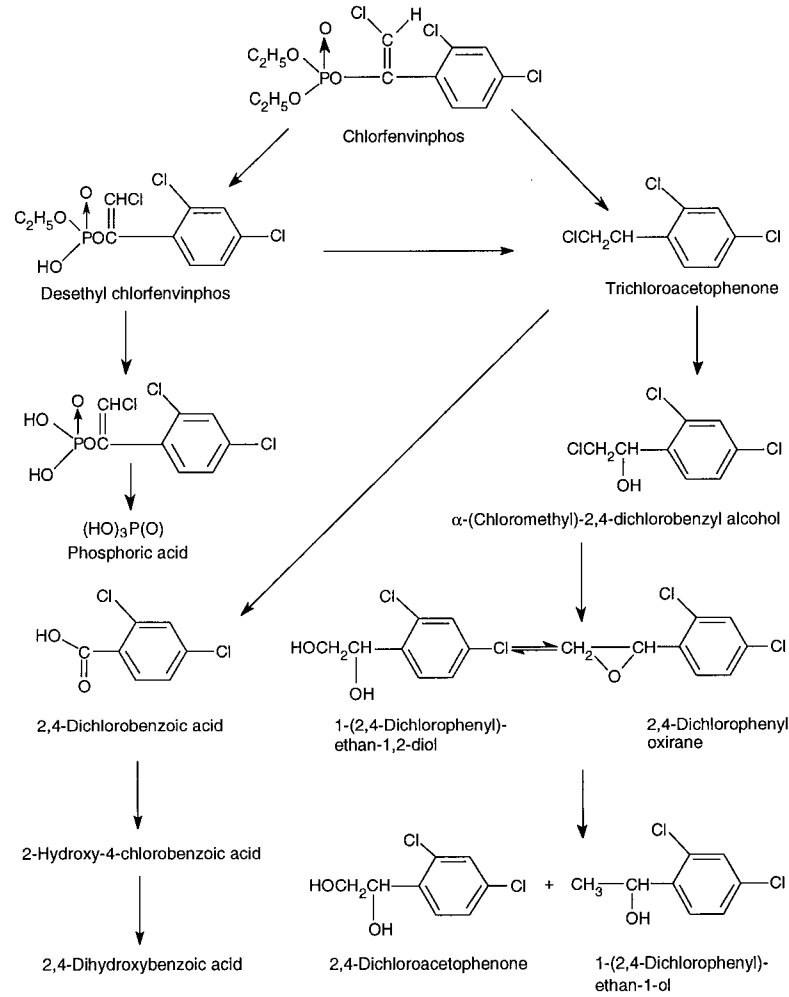
sandy soils and slowest in peat, probably because of its degree of adsorption to organic matter (Beynon et al. 1973; Williams 1975a). Because the rate of degradation by hydrolysis is greater than expected, breakdown is assumed to be mainly biotic. Initial half-life values of 4–30 weeks have been determined for sandy soils. In peat, chlorfenvinphos persists longer. Chlorfenvinphos was found to be very slowly degraded in a peat soil (47.8% organic matter), but was much less persistent on several sandy soils (1.6–2.2% organic matter) (Williams 1975a). In the peat (soil water pH = 6.0), 70% of the applied chlorfenvinphos remained after 21 weeks and 30% remained after nearly 12 months. In sandy soil (soil water pH = 6.9–7.5) only 3–15% of the applied chlorfenvinphos remained after a period of 15 weeks. The persistence in peat was attributed to strong adsorption rendering the pesticide unavailable to microorganisms and to plant roots. In sandy soil, rainfall was also correlated to increased loss of chlorfenvinphos.

Chlorfenvinphos was more stable and had increased persistence in soils that had been treated with organic fertilizer such as pig slurry, cow manure, city refuse, or mushroom cultivation composts compared to untreated control plots (Rouchaud et al. 1992a, 1992b). For example, the half-life of chlorfenvinphos at the Gembloux site was 18, 36, 35, and 43 days for the control, city refuse compost, cow manure, and mushroom compost plots, respectively. At another site (St. Katelijne-Waver), both a spring and summer application study were conducted. In the spring study, the half-life of chlorfenvinphos was 9, 13, 14, and 21 days and in the summer study, the half-life was 23, 42, 46, and 53 days for the control, city refuse compost, cow manure, and mushroom compost plots respectively. The humic acid concentrations and the total soil organic matter content were always higher in the organic fertilizer treated plots.

Rates of chlorfenvinphos loss from soil also appear to be related to soil moisture conditions. In dry seasons, although the initial rate of loss was high, the subsequent rate of degradation was slower than in wetter seasons of higher soil moisture content (Williams 1975a). Under conditions of average summer rainfall and relatively moist soils, the residues were less than 5% of applied dose, but when the soils were much drier than normal, residues were higher at 15% of applied dose after the same period of time (Miles et al. 1984).

Degradation of chlorfenvinphos ceases in soil at low temperatures (below 6–7 EC) (Suett 1975b). A granular formulation of chlorfenvinphos was broadcast at 2 kg active ingredient per hectare and incorporated to 10 cm into sandy-loam soil in May and in September 1971. When applied in September, the chlorfenvinphos persisted for a longer period than when applied in May. Degradation was slower during the winter while the mean soil temperature remained below 6–7 EC. Rising soil temperature during the following spring rapidly increased the rate of degradation. The late summer-
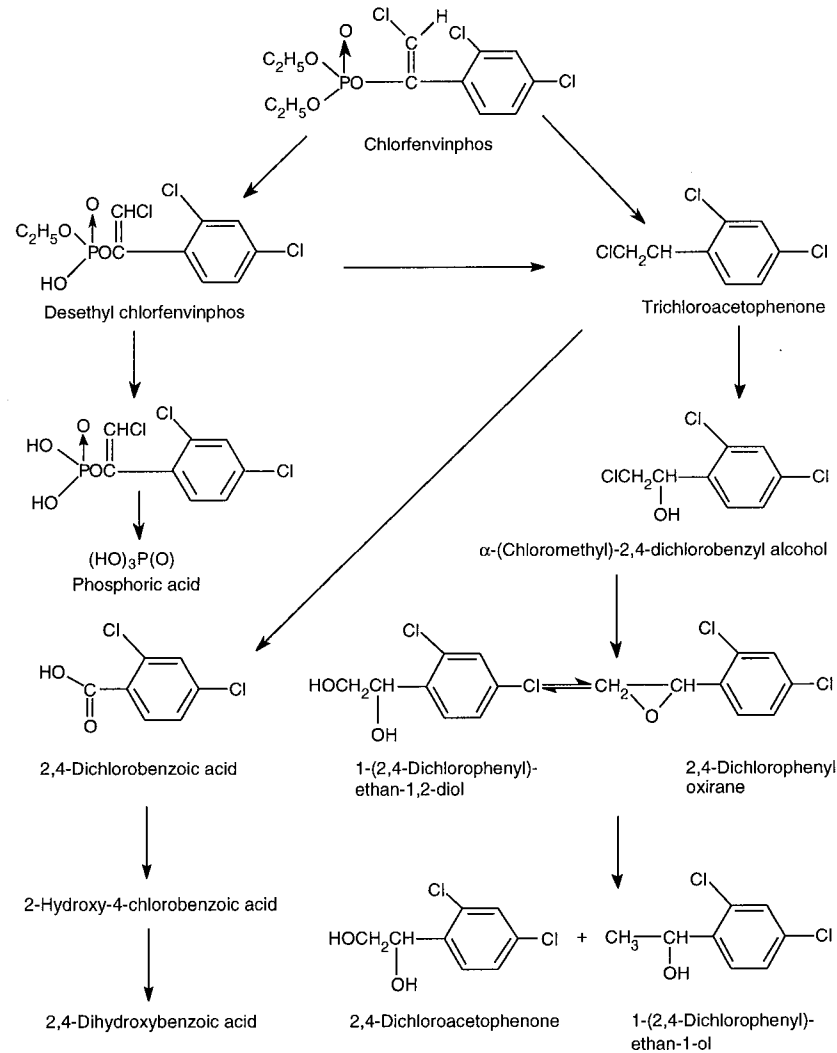
early fall applications to control carrot flies would leave appreciable residues of chlorfenvinphos in the soil at the beginning of the next growing season which might contribute to the terminal crop residues. Residues of chlorfenvinphos applied in May declined to less than 20% of the initially applied dose, and there was little loss subsequent to the December sampling. In the September application, more than 60% of the chlorfenvinphos applied still remained when the loss rates decreased in October. The relatively high concentration of chlorfenvinphos remaining then continued to decline only slowly throughout the winter until March when the rate of loss of chlorfenvinphos residues increased to rates similar to those of the previous September.

The catalytic degradation of chlorfenvinphos on H^+, Ca^{2+}, Na^+, and K^+ mono-ionic kaolinite and bentonite was found to be influenced by the nature of the exchange cations and their degree of hydration in the order $K^+ > Na^+ > Ca^{2+} > H^+/Al^{3+}$ (Cámara et al. 1992). In both types of clays, the process of hydrolysis occurred in two stages involving first-order kinetics, giving different hydrolysis rates. The first stage is characterized by a rapid hydrolysis rate of short duration; the second phase is long with a slow but continuous hydrolysis rate.

An inverse relationship between the history of chlorfenvinphos use in the soil and foliage concentrations was found that suggested enhanced biodegradation (Rouchaud et al. 1991). The longer the history of chlorfenvinphos use in a field, the lower the chlorfenvinphos residues and residues of its metabolites that were found; this suggests that specific soil microbial fauna adaptation was due to previous soil treatments. In soil from cauliflower, Brussels sprouts, and Chinese cabbage fields, the half-life of chlorfenvinphos was found to vary from 9 to 35 days; for chlorfenvinphos plus degradation products, the half-life ranged from 50 to 80 days (Rouchaud et al. 1989a). The fields in which chlorfenvinphos exhibited the shorter half-lives were those with the longer histories of chlorfenvinphos use in the soil, suggesting enhanced biodegradation was occurring.

Environmental transformation pathways for chlorfenvinphos in plants are summarized in Figure 5-4. A trans to cis rearrangement of chlorfenvinphos sprayed on plant foliage has been observed (Beynon et al. 1973). This conversion has been attributed to photochemical processes. The same conversion has not been observed for chlorfenvinphos applied directly to soil. The initial half-life value of chlorfenvinphos on foliage is 2–3 days, and the rate of degradation decreases thereafter. Over 50% of the radioactivity from ^{14}C-(vinyl)-trans-chlorfenvinphos disappeared from foliage in 4–7 days. It is not known whether it is released as chlorfenvinphos or as a degradation product. The major breakdown product of chlorfenvinphos on plant foliage is a conjugate of the ethan-1-ol [8], probably with a sugar.

Figure 5-4. Environmental Transformation Pathways for Chlorfenvinphos in Plants

Chlorfenvinphos

Desethyl chlorfenvinphos

Trichloroacetophenone

(HO)₃P(O)
Phosphoric acid

α-(Chloromethyl)-2,4-dichlorobenzyl alcohol

2,4-Dichlorobenzoic acid

1-(2,4-Dichlorophenyl)-
ethan-1,2-diol

2,4-Dichlorophenyl
oxirane

2-Hydroxy-4-chlorobenzoic acid

2,4-Dihydroxybenzoic acid

2,4-Dichloroacetophenone

1-(2,4-Dichlorophenyl)-
ethan-1-ol

5.4   LEVELS MONITORED OR ESTIMATED IN THE ENVIRONMENT

Reliable evaluation of the potential for human exposure to chlorfenvinphos depends on the reliability of supporting analytical data from environmental samples and biological specimens. In reviewing data on chlorfenvinphos levels monitored in the environment, it should also be noted that the amount of chemical identified analytically is not necessarily equivalent to the amount that is bioavailable.

5.4.1   Air

No information was located on the ambient concentrations of chlorfenvinphos in the atmosphere or on concentrations associated with domestic or occupational indoor air exposures in the United States.

5.4.2   Water

No information was located on the ambient concentrations of chlorfenvinphos in drinking water, surface water, or groundwater in the United States. Chlorfenvinphos was detected (concentration unspecified) in surface water and groundwater samples collected at the only hazardous waste site where it was detected in some environmental media (HazDat 1996).

Environmental monitoring data are available for surface waters from Canadian studies in the Great Lakes region and from British Columbia. Braun and Frank (1980) analyzed pesticide residues in surface water samples collected over a 3-year period (1975–77) in 11 agricultural watersheds in Southern Ontario, Canada. Although chlorfenvinphos was known to have been used as a pesticide in at least one of the watersheds, it was not detected in any surface water samples (detection limit 1 µg/L [1 ppb]). Frank et al. (1991) analyzed pesticide residues in water samples collected over a 5-year period (1986–90) from the mouths of the three major agricultural watershed rivers in Ontario, Canada: the Grand, the Saugeen, and the Thames. All three rivers flow into Lake Erie. Although it was known to have been used as a soil pesticide in the Thames River basin in 1988, no chlorfenvinphos residues were detected in any water samples during the study period (detection limit <1.0 µg/L [<1 ppb]). Most recently, Wan et al. (1994) studied residues of several organophosphate pesticides including chlorfenvinphos in farm ditch water and farm soils in the lower Fraser Valley of British Columbia, Canada, from July through December 1991. The farm ditches drained into three rivers: the Fraser, the Niicomekl, and the Sumas. During the study period, no sales of chlorfenvinphos were reported. Chlorfenvinphos was used as a soil insecticide in 1990, but was not recommended for this use in

Canada in 1991. Although chlorfenvinphos was not detected in any of the farm ditch water or sediment samples analyzed at the 7 sampling sites, it was detected in 7% of the soil samples. Residue results obtained in these Canadian studies may be inappropriate for estimating water residues in the United States, as chlorfenvinphos was never registered for use as a soil insecticide in the United States (REFS 1995).

5.4.3   Sediment and Soil

Chlorfenvinphos was detected (concentration not specified) in topsoil and subsoil samples (>3 inches deep) collected at one NPL hazardous waste site where it was detected in some environmental media (HazDat 1996). No other information was located on the concentrations of chlorfenvinphos detected in soil or sediment samples collected in the United States.

Environmental monitoring data are available, however, for agricultural soils from Canadian studies in the Great Lakes region and from British Columbia. Chlorfenvinphos residues in organic farm soils of the Holland Marsh in Ontario, Canada, were analyzed each fall from 1972 to 1975 and residue levels generally exceeded 0.1 ppm (Miles et al. 1978). The annual mean residues (dry weight basis) of chlorfenvinphos sampled in 13 farm soils were as follows: 1972, 0.12 ppm; 1973, 0.05 ppm; 1974, 0.36 ppm; and 1975, 0.13 ppm. Wan et al. (1994) studied residues of several organophosphate pesticides including chlorfenvinphos in farm soils from seven different sites in the lower Fraser Valley of British Columbia, Canada, from July through December 1991. Chlorfenvinphos was used as a soil insecticide in 1990, but was not recommended for this use in Canada, in 1991 (during the study period). Despite the fact that chlorfenvinphos was not used during the study period, it was detected in 7% of the soil samples analyzed. The mean chlorfenvinphos concentration found in soil at the Cloverdale site was 31 µg/kg (0.031 ppm), with a range of 12 to 60 µg/kg (0.012–0.060 ppm). The authors believed that these residues were a carryover from the previous years. Residue results obtained in these Canadian studies may be inappropriate for estimating soil residues in the United States, as chlorfenvinphos was never registered for use as a soil insecticide in the United States (REFS 1995).

5.4.4   Other Environmental Media

Chlorfenvinphos was not monitored in many of the federal, regional, and state food studies conducted from the late 1960s through the mid-1980s (Corneliussen 1970; Duggan and Corneliussen 1972; Duggan et al. 1983; Gartell et al. 1986; Gunderson 1988; Hundley et al. 1988). The FDA's monitoring

program for domestic and imported food commodities detected chlorfenvinphos in unspecified foods at unspecified concentrations during fiscal years 1978–82 (Yess et al. 1991a) and during fiscal years 1983–86 (Yess et al. 1991b). During 1982–86, the FDA Los Angeles District Laboratory analyzed 19,851 samples of domestic and imported food and feed commodities (Luke et al. 1988). Chlorfenvinphos was not detected in any sample of the 6,391 domestic agricultural commodities or in any of the 12,044 imported agricultural commodities analyzed. Chlorfenvinphos was detected in unspecified foods at unspecified concentrations and at an unspecified detection frequency in 14,492 domestic and imported food samples analyzed as part of the FDA pesticide monitoring program for 1986–87 (FDA 1988). In a pesticide residue screening program conducted in 1989–91 in San Antonio, Texas, on 6,970 produce samples, chlorfenvinphos was detected (0.75 ppm detection limit) in one produce sample of tomatoes (frequency of <0.5%) (Schattenburg and Hsu 1992). In a similar study conducted by Agriculture Canada of 13,230 domestic and imported food items analyzed during the same period (1989–91), chlorfenvinphos was not detected in any domestic foods, but was detected in 13 imported food samples (frequency <0.1%) (Neidert et al. 1994). Detectable residues were found in fresh oranges, peppers, pineapples, and spinach. As part of the FDA's Pesticide Monitoring Program for domestic and imported foods, chlorfenvinphos residues have been detected in unspecified foods at unspecified concentrations and at unspecified detection frequencies during 1988–89, 1989–90, 1990–91, 1991–92, 1992-93 (FDA 1990, 1991, 1992, 1993, 1994), but residues were not detected in 1993–94 during the most recent regulatory monitoring period (FDA 1995).

The effect of cooking on chlorfenvinphos concentrations in raw foods was examined by Askew et al. (1968). These authors spiked samples of raw potato and cabbage mash with 2 ppm of chlorfenvinphos and boiled the samples for 30 minutes to simulate the effect of cooking raw vegetables contaminated with chlorfenvinphos. Total residues were reduced by 37–53% for potato and 56–86% for cabbage mash. A cooking process such as boiling leads to a partial reduction of chlorfenvinphos residues, but does not completely eliminate the pesticide. A similar study examined the effects of milk processing procedures on organophosphate residues in milk (Skibniewska and Smoczynski 1985). These authors reported that boiling in an enamel vessel to simulate home cooking, and three pasteurization procedures involving heating for 30 minutes at 62 EC, for 2 minutes at 72 EC, and for 5 seconds at 85 EC, resulted in about a 20% decrease in the residues of organophosphates including chlorfenvinphos. Reduction of the pesticide residues was more affected by the duration of heating rather than the temperature to which the milk was heated.

Nagayama et al. (1989) studied the residue levels of chlorfenvinphos on commercial tea leaves grown in Japan and the leaching of the pesticide into tea. Chlorfenvinphos was detected at concentrations

ranging from trace to 3.4 ppm on tea leaves and more that 12% of the chlorfenvinphos was found to leach from the leaves into the tea.

Heikes and Craun (1992) analyzed the residues of several pesticides including chlorfenvinphos in anhydrous lanolin and lanolin-containing pharmaceutical preparation sampled from 1988 through 1992. Concentrations of chlorfenvinphos in anhydrous lanolin samples collected in 1989 ranged from 0.60 to 5.9 mg/kg; those collected in 1991 ranged from 0.81 to 10 mg/kg. In 1988, chlorfenvinphos was detected in a wide range of pharmaceutical preparations including A & D ointment, analgesic balm, nitroglycerin cream, atropine sulfate ointment, and dibucaine ointment at concentrations ranging from 0.08 to 1.1 mg/kg (ppm). In 1992, chlorfenvinphos was detected in antibiotic, cold sore, and ophthalmic ointments at concentrations ranging from trace to 0.32 mg/kg (ppm).

5.5   GENERAL POPULATION AND OCCUPATIONAL EXPOSURE

Currently, the general population is primarily exposed to chlorfenvinphos by ingesting food containing chlorfenvinphos, particularly fresh fruits and vegetables imported from countries where this pesticide still is used. In addition, the general population may be dermally exposed to chlorfenvinphos concentrations in lanolin and lanolin-containing pharmaceutical products.

No information is available on the concentrations of chlorfenvinphos in ambient air. However, because this pesticide currently has no registered uses in the United States, the extent of exposure of the general population to chlorfenvinphos from inhalation is probably insignificant. No information is available on the concentrations of chlorfenvinphos in drinking water. Because chlorfenvinphos was not used as an agricultural pesticide on crops in the United States, it was not monitored extensively in groundwater. As a result of its relatively limited use, current exposure of the general population to chlorfenvinphos from consumption of drinking water is probably negligible.

Chlorfenvinphos has been detected in both domestic and imported foods, but especially in imported fresh fruits and vegetables (see Section 5.4.4). Thus, consumers can be exposed to chlorfenvinphos by ingesting contaminated food. No information was available on the FDA-estimated daily food intakes of chlorfenvinphos for different age/sex groups in the United States for fiscal years 1982–84 (Gunderson 1988) or 1986–91 (FDA 1993). However, because exposure to the general population from consumption of chlorfenvinphos-contaminated foods comes primarily from imported foods and

because residues in raw vegetables and fruits are reduced during food preparation by washing and cooking procedures, the risk to the general U.S. population appears negligible.

Workers who were involved in the manufacture, formulation, handling, or application of chlorfenvinphos are likely to have been exposed to higher concentrations by dermal exposure and inhalation of chlorfenvinphos particles than the general population. Workers who are currently involved in the disposal of chlorfenvinphos-contaminated wastes are likely to be exposed to higher concentrations by dermal contact and inhalation of chlorfenvinphos particles or chlorfenvinphos-contaminated soil particles than the general population. Occupational exposure to chlorfenvinphos was reported to have occurred in workers in California who handled flea control products. However, chlorfenvinphos was not associated with statistically elevated symptom frequency (Ames et al. 1989).

No information was found in the National Occupational Exposure Survey (NOES) conducted by NIOSH from 1981 to 1983 on the number of workers and the number of facilities where workers could be potentially exposed to chlorfenvinphos in the United States (NOES 1990). NIOSH (1992) did not provide recommendations for occupational exposure levels to chlorfenvinphos for a 10-hour time weighted average (TWA) workday. An Occupational Safety and Health Administration (OSHA) permissible exposure limit (PEL) for workplace air does not exist (OSHA 1974).

5.6   POPULATIONS WITH POTENTIALLY HIGH EXPOSURES

In the past, individuals who were occupationally exposed to chlorfenvinphos during its production, formulation, packaging, distribution, use, or disposal, were exposed to higher-than-background concentrations of chlorfenvinphos.

At the present time, several groups within the general population may receive potentially high exposures to chlorfenvinphos. These groups include individuals living near chemical manufacturing or processing sites or those currently involved in the disposal of chlorfenvinphos or chlorfenvinphos-contaminated materials, those living on dairy, beef, sheep, or poultry farms where chlorfenvinphos was extensively used, and those living near hazardous waste sites. Individuals living near these sites may be exposed to potentially higher concentrations of chlorfenvinphos or its metabolites in their drinking water if they obtain tap water from wells near these sources. Children playing in chlorfenvinphos-contaminated soils may consume this pesticide or its degradation products from their exposed hands.

5.7 ADEQUACY OF THE DATABASE

Section 104(i)(5) of CERCLA, as amended, directs the Administrator of ATSDR (in consultation with the Administrator of EPA and agencies and programs of the Public Health Service) to assess whether adequate information on the health effects of chlorfenvinphos is available. Where adequate information is not available, ATSDR, in conjunction with the NTP, is required to assure the initiation of a program of research designed to determine the health effects (and techniques for developing methods to determine such health effects) of chlorfenvinphos.

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

5.7.1 Identification of Data Needs

Physical and Chemical Properties. As seen in Table 3-2, the relevant physical and chemical properties of chlorfenvinphos are known (Bowman and Sans 1983; Domine et al. 1992; HSDB 1994; Kenaga 1980; Merck 1989; Worthing 1983) and predicting the environmental fate and transport of this compound based on the K_{oc}, K_{ow}, and Henry's law constant is possible. No further information is required.

Production, Import/Export, Use, Release, and Disposal. Chlorfenvinphos was introduced into the United States in 1963 (Hayes 1982) by the Shell International Chemical Company, Ciba-Geigy AG, and by Allied Chemical Corporation (Worthing 1983). No historic import/export information was available for this chemical. In the United States, chlorfenvinphos use appears to have been limited to uses in dairies, feedlots, or poultry yards to reduce adult fly populations; in manure containment areas to reduce adult and larval fly populations; as a cattle and sheep dip to reduce ectoparasites, and as a wettable powder (WP), granular form, or contained in a collar for killing fleas and ticks in dogs (EPA 1994; REFS 1995). While chlorfenvinphos has been extensively used in agricultural applications in other countries, especially for root and cole crops, this pesticide was not used for crop applications in the United States (Farm Chemicals Handbook 1984, 1993; Spencer 1982; The Agrochemicals Handbook 1991; Worthing 1983). More complete information on the production and

import/export of chlorfenvinphos would be useful to assess the possible routes of exposure, potential for environmental contamination and human exposure. Information on the number of producers and production sites, locations of production facilities, years of production, and the volume of production in the United States would be helpful. Information on import/export volumes and estimates of yearly usage during those years prior to the cancellation of its pesticide registration would also be useful. While adequate information on disposal procedures exists (IRPTC 1985), more recent information would be helpful.

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 1993, became available in May of 1995. This database will be updated yearly and should provide a list of industrial production facilities and emissions. No information is available from TRI93 because chlorfenvinphos is not one of the toxic chemicals that producers currently are required to report (EPA 1995).

Environmental Fate.   Information regarding the fate of chlorfenvinphos in the air was not located in the literature. Given a vapor pressure ranging from $4x10^{-6}$ to $7.5x10^{-6}$ mm Hg (Merck 1989; Worthing 1983), chlorfenvinphos should exist in the atmosphere in the vapor phase, but will also partition to available airborne particulates (Eisenreich et al. 1981). The solubility of 145 mg/L (Merck 1989) ensures that at least partial removal of atmospheric chlorfenvinphos will occur by wet deposition. Based on these chemical and physical properties, the atmospheric concentrations of chlorfenvinphos are expected to be low because chlorfenvinphos is not highly volatile. Additional information would help predict the residence time and distance of its aerial transport. The fate of chlorfenvinphos in water has been more extensively studied (see Section 5.3.1) (Barba et al. 1991; Beynon et al. 1971, 1973; Braun and Frank 1980; Frank et al. 1991; Wan et al. 1994), including information on its degradation under various environmental conditions. The fate of chlorfenvinphos in soil, including information on its mobility and biodegradation, has also been well documented (see Section 5.3.1) (Beynon et al. 1973; Edwards et al. 1971; Miles et al. 1979, 1983; Racke 1992; Rouchaud et al. 1988, 1989a, 1989b, 1989c, 1991, 1992a, 1992b; Williams 1975a). Additional information on the degradation of chlorfenvinphos in air and groundwater would be helpful in estimating exposure to chlorfenvinphos under various conditions of environmental release for purposes of planning and conducting meaningful follow-up exposure and health studies.

Bioavailability from Environmental Media.   Available information regarding the rate of chlorfenvinphos absorption following inhalation, oral, and dermal contact has been discussed in the

Toxicokinetics section (see Section 2.3) (Hunter 1969; Hutson and Wright 1980; Pach et al. 1987). Although no data on chlorfenvinphos' bioavailability from contaminated air are available, the bioavailability from inhalation exposure is expected to be relatively low because the compound is likely to partition to available particulates. No data are available on the bioavailability of chlorfenvinphos from water, soil, or plant material. Chlorfenvinphos is adsorbed moderately to soil (Beynon et al. 1973; Edwards et al. 1971; Racke 1992). Chlorfenvinphos is expected to have reduced bioavailability from soil and water, since the part that remains adsorbed to soil or sediment may be only partially bioavailable. Additional data on the bioavailability of chlorfenvinphos from environmental media and the difference in bioavailability from different media would be helpful in assessing the potential body burdens that may occur as a result of exposure to environmental concentrations.

Food Chain Bioaccumulation.   The only information on bioconcentration factors for chlorfenvinphos was derived from equations based on information on physical and chemical properties (see Section 5.3.1) Estimated whole-body concentration factors calculated for chlorfenvinphos were significant, but relatively low, ranging from 37 to 460 (Mackay 1982; Veith et al. 1979; Veith et al. 1980 in Bysshe 1990). No measured BCFs for any aquatic organisms were found in the literature. Available data indicate that chlorfenvinphos applied to plant foliage is transported across the cuticular membrane (Bauer and Schönherr 1992). Chlorfenvinphos applied to the soil is accumulated in the roots, stem and leaves of plants (Ritcey et al. 1991; Rouchaud et al. 1989b; Suett 1974, 1975b). No information was found on the biomagnification of chlorfenvinphos in aquatic or terrestrial food chains. These data would be helpful in assessing the potential for human exposure as a result of consuming contaminated food.

Exposure Levels in Environmental Media.   No data were located on the concentrations of chlorfenvinphos in ambient air or in occupational settings; therefore, no estimate of inhalation exposure to chlorfenvinphos can be obtained for the general population, or for any occupationally exposed groups. No data on the concentration of chlorfenvinphos in drinking water, surface water, or groundwater in the United States were located in the literature. Monitoring data for surface waters are available from several Canadian studies conducted in the Great Lakes region and British Columbia; however, monitoring results from these Canadian studies may be inappropriate for estimating water residues in the United States, as chlorfenvinphos was never registered for agricultural use as a soil insecticide. Current monitoring data on the concentrations of chlorfenvinphos in ambient air, in drinking water, surface water, groundwater, and in soil from the United States would be helpful. Many of the federal, regional, and state food studies conducted from the late 1960s through the mid-1980s did not monitor chlorfenvinphos concentrations in foods

(Corneliussen 1970; Duggan and Corneliussen 1972; Duggan et al. 1983; Gartell et al. 1986; Gunderson 1988; Hundley et al. 1988), despite the fact that chlorfenvinphos was most extensively used in the United States during this period (see Section 4.3). Recent FDA monitoring studies on imported and domestic foods have detected chlorfenvinphos residues; however, the foods in which chlorfenvinphos was detected and the residue concentrations were not specified (FDA 1990, 1991, 1992, 1993). Additional quantitative information on chlorfenvinphos concentrations in food and the estimated daily human intake of chlorfenvinphos from foods would be helpful in assessing current exposure levels to this pesticide.

Reliable monitoring data for the concentrations of chlorfenvinphos in contaminated media at hazardous waste sites are needed so that the information obtained on levels of chlorfenvinphos in the environment can be used in combination with the resulting body burden of chlorfenvinphos to assess the potential risk of adverse health effects in populations living in the vicinity of hazardous waste sites.

Exposure Levels in Humans. No data on chlorfenvinphos levels in various human tissues and body fluids of unexposed populations, populations near hazardous waste sites, or occupationally exposed groups in the United States are available. Although chlorfenvinphos is a hydrophilic substance, it has not been widely found in human tissues because of its relatively short half-life. However, in a recent study conducted in the Federal Republic of Germany, chlorfenvinphos was found in some of the 41 specimens of cervical mucus, follicular and sperm fluids, and human milk that were examined. Chlorfenvinphos concentrations of 13.66, 1.69, 2.02, and 1.89 µg/kg were detected in 4 of the 11 samples of cervical mucus. Chlorfenvinphos was also detected at concentrations of 0.42 µg/kg in 1 of the 10 sperm fluid samples and 1 of the 10 human milk samples, respectively (Wagner et al. 1990). Additional data on the concentrations of chlorfenvinphos and its metabolites in body tissues and fluids are needed to estimate the extent of exposure to chlorfenvinphos. This information is necessary for assessing the need to conduct health studies on these populations.

Exposure Registries. No exposure registries for chlorfenvinphos 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.

5.7.2   Ongoing Studies

A search of the Federal Research in Progress database (FEDRIP 1995) indicated that no research
studies are in progress to fill the data gaps discusses in Section 5.7.1.