

## 5. POTENTIAL FOR HUMAN EXPOSURE

### 5.1 OVERVIEW

Chlordane is an insecticide formerly used to treat field crops (especially corn) and other types of vegetation and to control termites. As such, it was intentionally applied to soils both in agricultural and urban settings. Table 5-1 lists releases from facilities in the United States that produced, processed, or used chlordane in 1990, according to TRI (TRI90 1992). All but 1 pound of these releases, which totaled 4,423 pounds, were released to air. These releases were almost exclusively from the sole producer of chlordane in the United States, Velsicol Chemical Corporation. Chlordane has been identified in at least 176 of the 1,350 hazardous waste sites that have been proposed for inclusion on the EPA's NPL (HAZDAT 1992). However, the number of sites evaluated for chlordane is not known. The frequency of these sites can be seen in Figure 5-1. Of these sites, 175 are located in the United States and 1 is located in the Commonwealth of Puerto Rico (not shown). Chlordane is extremely persistent in the environment. In some soils it may persist for >20 years. Volatilization appears to be the only major removal mechanism from soil. However, at waste sites that contain high levels of organic solvents, leaching to groundwater may occur. Adsorption to sediments and volatilization are important removal mechanisms in water. In air, chlordane exists predominantly in the vapor phase. However, the relatively small fraction of particle-bound chlordane appears to be of major importance in atmospheric deposition (Atlas and Giam 1988). Vapor-phase chlordane degrades by photolysis and hydroxyl radical reaction. Chlordane may be transported long distances and deposited by wet or dry deposition. As a result of this long range transport and its high bioconcentration factor, chlordane is now prevalent in the Arctic food web (Hargrave et al. 1992). Chlordane's persistence in the environment from its use as a termiticide is the major factor for exposure in the general population. Chlordane has been detected in the indoor air of homes 15 years after treatment. EPA (19878) estimated that over 80 million people in the United States have lived in homes treated with cyclodiene termiticides, and ≈65% of these people have lived in homes treated with chlordane. Thus, ≈52 million people have been exposed to chlordane in their homes. The total number of exposed people is much greater since some foods, especially fish, are contaminated with chlordane; additional intake may result from this ingestion of contaminated foods.

TABLE 5-1. Releases to the Environment from Facilities  
that Manufacture or Process Chlordane<sup>a</sup>

Facility	Location <sup>b</sup>	Reported amounts released in pounds						
		Air	Underground injection	Water	Land	Total environment <sup>c</sup>	POTW <sup>d</sup> transfer	Off-site waste transfer
Stennis Space Center	Stennis Space, MS	5	0	0	0	5	0	0
Velsicol Chemical Corp.	Memphis, TN	4,417	0	1	0	4,418	99	523

<sup>a</sup>Derived from TRI90 (1992)

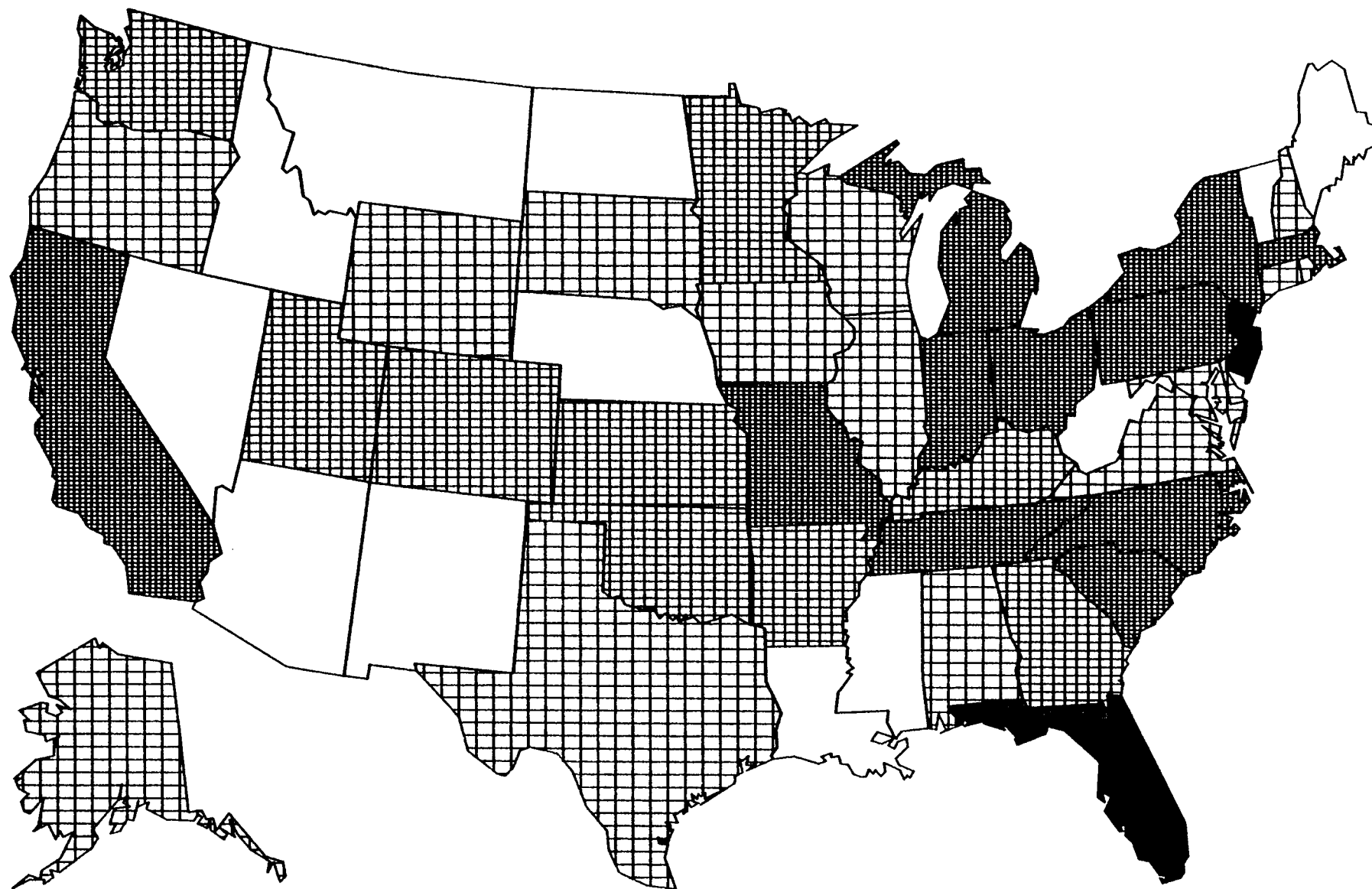
<sup>b</sup>Post Office state abbreviations

<sup>c</sup>The sum of all releases of the chemical to air, land, water, and underground injection wells by a given facility

<sup>d</sup>POTW = publicly owned treatment works

FIGURE 5-1. FREQUENCY OF NPL SITES WITH CHLORDANE CONTAMINATION \*

CHLORDANE



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FREQUENCY



1 TO 2 SITES

5 TO 10 SITES



3 TO 4 SITES

14 TO 17 SITES

\*Derived from HazDat 1993

## 5.2 RELEASES TO THE ENVIRONMENT

### 5.2.1 Air

According to TRI90 (1992), 4,422 pounds of chlordane were discharged to air from facilities that produced, processed, or used chlordane in the United States in 1990. These releases were almost exclusively from the sole producer of chlordane in the United States, Velsicol Chemical Corporation. At least in recent years in the United States, chlordane's use has been restricted and then banned; however, chlordane is still present in soil from its past use as a crop pesticide and termiticide. Chlordane, nonetheless, is present in the atmosphere, which is probably due to volatilization from soils and water as well as wind erosion. These processes are believed to account for the loss of chlordane into air at NPL sites. Several investigators have reported that chlordane volatilizes after termiticide application to soils at rates that vary depending on soil characteristics and application methods (Atallah et al. 1979; Glotfelty et al. 1984; Nash 1983a, 1983b). Volatilization also occurs following runoff into water bodies (Atlas et al. 1982; Mackay et al. 1986). In addition, chlordane has been detected in the indoor air of homes 15 years after treatment with chlordane for termites (Livingston and Jones 1981). These data suggest that chlordane is present in air as a result of its former use as a pesticide. No data are available regarding emissions of chlordane from NPL sites.

### 5.2.2 Water

Chlordane is not directly applied to water but is present in runoff from urban uses as a termiticide (EPA 19878; Nightingale 1987) and its former agricultural use on field crops. A field study in 12 urban areas in the Canadian Great Lakes Basin measured the concentrations of *cis*- and *trans*-chlordane in urban runoff and street sediment (Marsalek and Schroeter 1988). These mean concentrations combined with runoff volumes and sediment yields were then used to estimate pollutant loadings into the Great Lakes Basin. Total chlordane loadings into Lakes Erie, Huron, Ontario, St. Clair, and Superior were 0.59, 0.47, 2.48, 0.34, and 0.07 kg/year for a annual basin loading of 3.9 kg. According to sediment concentrations in EPA's STORET database, releases to water have been highest in the west north central region of the United States and lowest in New England (Phillips and Birchard 1991).

### 5.2.3 Soil

Chlordane was used for  $\approx 40$  years, mainly as a field crop insecticide and termiticide (EPA 19878). Both of these uses involve the intentional application of the chemical to the soil. The total environmental burden of chlordane for the past 40 years can be roughly estimated using several assumptions. Before 1978, chlordane was used for many applications and probably had a much higher production. An estimated 4.0 million pounds were used in 1986 when its use was limited to subterranean applications as a termiticide (EPA 1987g). On the basis of historic production figures, an estimated 70,000 tons of chlordane were produced since 1946, of which 25-50% still exists unaltered in the environment (Dearth and Hites 1991c). This material was exclusively released to soil. Chlordane was applied in a geographically disperse manner on both rural and urban soils. In recent years, the majority of use probably was from Pennsylvania and the lower New England states south and west to the lower portion of Colorado and up to northern California, since termite infestations are most common in these areas (EPA 1987g). The northern plains and mountain states and northern New England states have much lower incidence of termites although chlordane was used on field crops before 1978 in these states. EPA (1987g) estimated that  $\approx 19.5$  million structures have been treated with chlordane, which means that the soils around the treated houses may contain chlordane.

## 5.3 ENVIRONMENTAL FATE

### 5.3.1 Transport and Partitioning

Chlordane may be transported long distances in the atmosphere. The United States appears to be the main source of chlordane in the air over the North Atlantic (Bidelman et al. 1987). Concentrations of *cis*-chlordane  $\leq 0.0054$  ng/m<sup>3</sup> in the Norwegian Arctic are believed to originate in the Soviet Union, thousands of miles away (Pacyna and Oehme 1988). Similarly, the source of chlordane-related compounds in brown snow in the central Canadian Arctic, based on back-trajectories of air masses, was probably western China (Welch et al. 1991). It is estimated that  $\approx 3,300$  kg of chlordane are deposited annually in the Arctic regions (from 60° N. latitude to the pole) (Cotham and Bidleman 1991).

There is a large body of information concerning the transport and partitioning of chlordane in the environment. In outdoor air, chlordane exists predominately in the vapor phase (Atlas and Giam 1988;

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Bidleman et al. 1986; Bidleman and Foreman 1987; Foreman and Bidleman 1987), whereas particle-adsorbed chlordane will contribute relatively minor amounts to the environmental burden (Starr et al. 1974; Tucker and Preston 1984). Air monitoring data are derived by the following method: chlordane is first pulled through a fiber filter and then trapped on a solid adsorbent; the amounts of chlordane retained on the filter and on the adsorbent is used to estimate the proportion of particulate-bound and vapor phase chemical. Air monitoring data derived by this method indicate that 0.7% and 11% of chlordane is bound to particulate matter at 20° and 0°C respectively (Bidelman et al. 1986). At 28°C the average temperature at which one of the arctic air monitoring studies was performed, about 45% of chlordane is bound to particulate matter (Patton et al. 1991). However, the small amount of adsorbed chlordane at ordinary temperatures appears to play an important role in atmospheric deposition. In samples collected in a rural area of Texas, 98% of the chlordane scavenged rain was particle-bound chlordane, rather than vapor-phase chlordane that partitioned into rain drops (Atlas and Giam 1988). The chlordane concentration in rain was 1,900 times the concentration in air. The contribution of dry deposition to total (wet and dry) deposition in a 24-hour period was 8.9%. Chlordane applied to the foundation of homes for termite treatment can enter the home through cracks in the foundation or in heating ducts in the slabs. Chlordane disperses through the house by diffusion and convection (Livingston and Jones 1981).

Chlordane in water will both adsorb to bed and suspended sediments and volatilize. The partitioning of chlordane to sediment correlates with the organic carbon content of the sediment. The mean log  $K_{oc}$  for *trans*-chlordane to samples of suspended particulate matter from the St. Clair and Detroit Rivers was 6.3 (Lau et al. 1989). Where, concentrations of suspended sediment are high, such as in rivers near sources of industrial discharge, substantial amounts of pollutants like chlordane would be transported with suspended sediment. The rate of volatilization of chlordane from water depends to a large extent on the amount, size, and composition (i.e., percent organic matter) of the suspended material in the water body since adsorption to suspended solids and sediments attenuates the rate of volatilization (Oloffs et al. 1972, 1973). The rate of volatilization is also affected by temperature, wind, and water turbulence. Chlordane adsorbed almost completely to sediments in laboratory experiments over a period of  $\approx 6$  days (Oloffs et al. 1972, 1973). It also volatilizes reasonably rapidly from water (Huang 1970), and it appears that volatilization kinetics may be faster than adsorption kinetics. The majority of chlordane, however, probably enters water as runoff from urban and agricultural soils, and is adsorbed to particulates before entering a body of water. The chlordane repartitions in the water and volatilizes rapidly near the water surface. Using the EPA EXAMS model

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(EPA 1985c), the estimated volatilization half-lives of chlordane from a typical pond and lake are <10 days. Nonetheless, monitoring data indicate that sediment concentrations of chlordane are much higher than the overlying water, suggesting that volatilization from water may not be as fast as predicted. A field experiment was performed to study the persistence and mobility of technical chlordane applied to an intertidal sandflat (Smith et al. 1992). The chlordane was applied at mid-tide level to a depth of 10 cm and sediment cores to a depth of 10 cm were sampled before treatment and 1, 3, 5, 13, 19, 44, 71, 112, and 199 tides after treatment. The overall change of mass was about 62% over a period of 106 days with more than half occurring during the first tide cycle. The main decrease in concentration was in the top 2 cm where mass transport and bioaccumulation are most effective. Concentrations for the 2-5 and 5-10 cm depth intervals showed little change between tides 3 and 71. Thus, after some initial displacement, possibly into more organically enriched sediment, there was little vertical movement of chlordane. The composition of the technical chlordane was essentially constant during the experiment which suggested that processes such as hydrolysis, dechlorination, and volatilization were much less important pathways for chlordane removal from this environment than sediment transport.

Chlordane will bioconcentrate in both marine (bioconcentration factor 3,000-12,000 [Zarogian et al. 19851] and fresh water (bioconcentration factor 18,500 in rainbow trout [Oliver and Niimi 19851] species, as well as bacteria [bioconcentration factor of 200-55,900 (Grimes and Morrison 1975)]. See Gobas et al. (1988) and Isnard and Lambert (1988) for further information on bioaccumulation in fish. Biomagnification of chlordane-related compounds, including heptachlor epoxide, was studied in three trophic levels in the Arctic marine food chain, namely, Arctic cod, ringed seals, and polar bears (Muir et al. 1988). The biomagnification from fish to seal (male/female) was 7.3/4.7 and that between seal (male/female) and bear was 6.6/9.5 resulting in an overall fish to bear biomagnification factor of 44.2. Both chlordane isomers decrease in higher trophic levels with only the metabolite oxychlordane present in polar bears (Hargrave et al. 1992). It should be noted that biomagnification of chlordane is a tricky concept because the compositional pattern of chlordane compounds and metabolites varies among different trophic levels and species (Kawano et al. 1988). Chlordane is taken up by rooted aquatic vascular plants both from the water and from the sediment. The bioconcentration factor of chlordane in the submerged vascular plant, *Hydrilla verticillata*, was 1.060 (Hinman and Klaine 1992). Chlordane also bioconcentrates in the roots from contaminated sediment and translocates into the shoots. However, acropetal translocation is not extensive.

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In soil, chlordane adsorbs to the organic matter and volatilizes slowly over time. Chlordane does not leach significantly. In general, chlordane remains in the top 20 cm of most soils and for some soils, it stays at this level for over 20 years (Beeman and Matsumura 1981; Bennett et al. 1974). Its behavior is somewhat dependant on the composition of the soil (Bennett et al. 1974; Carter and Stringer 1971; Haque and Freed 1974; Jury et al. 1987a; Sears and Chapman 1979; Stewart and Chisholm 1971; Stewart and Fox 1971; Tafuri et al. 1977). A study by the California Department of Food and Agriculture classified chlordane as a “nonleacher” based on records of groundwater contamination following normal agricultural use (Gustafson 1989). The distribution coefficient between chlordane and geologic material collected near a hazardous waste site in Memphis, Tennessee ranged from 18 to 220 mL/g or  $K_{oc}$  of 20,000 to 76,000 (Johnson-Logan et al. 1992). Chlordane will bind tenaciously to dissolved organic carbon (DOC) in water which will result in increased apparent solubility and mobility in the presence of DOC. For example, the solubility of chlordane in groundwater downstream of a hazardous waste site in Memphis, Tennessee, was 150  $\mu\text{g/L}$  compared to 30  $\mu\text{g/L}$  in purified water due to the presence of DOC (Johnson-Logan et al. 1992). Therefore, it is expected that chlordane mobility will be enhanced at this site. Volatilization from soil is a major loss mechanism for chlordane; the rate depends on such parameters as the soil organic content, water content, temperature, and relative humidity as well as its vapor pressure and adsorption to soil (Atallah et al. 1979; Glotfelty et al. 1984; Glotfelty and Schomburg 1989; Jury et al. 1987b; Nash 1983a, 1983b; Wilson and Oloffs 1973). In general, sandy soils and soils with small amounts of organic matter retain chlordane less than soils with high clay and/or organic content (Wiese and Basson 1966). Soil moisture, however, is the most important factor. Within an hour of being sprayed on the surface of moist bare soil in a pesticidal mixture, the vapor pressure of chlordane near the soil surface was  $5.8 \times 10^{-7}$  mmHg (Glotfelty and Schomburg 1989). The time for 50% of the chlordane to volatilize is 2-3 days. In time, the spray penetrates the soil and longer term volatilization is controlled by back diffusion out of the soil layer. Losses are also highest near noon and lowest at night. It has been shown that the loss rate of chlordane applied to the surface of moist soil is proportional to the amount of remaining residue and inversely proportional to the square root of the daylight hours since application. In dry soil, the organic vapors are much more strongly adsorbed with a resulting decrease in volatilization (Glotfelty and Schomburg 1989; Nash 1983a). Incorporation of chlordane into the soil reduces volatilization because of dilution and because volatilization depends on slow diffusion and convective flow processes. It is estimated that 4.0 cm of sandy soil or 3.9 cm of clayey soil is sufficient to restrict chlordane volatilization losses to <0.7% of the mass incorporated in the soil (Jury et al. 1990). Volatilization in some cases will continue for many years, as evidenced by the detection



of indoor air concentrations of chlordane 15 years after application (Livingston and Jones 1981): Crop cover does not markedly alter the rate of volatilization. In a 3-year field experiment in which chlordane was incorporated into the top 10 cm of sandy loam soil, the half-lives of chlordane in cropped and fallow plots were 93.2 and 154 days, respectively (Singh et al. 1991). Initially, the dissipation rate of *cis*-chlordane was slightly higher in the fallow plots. *trans*-Chlordane disappeared from the soil column after 210 days but then reappeared, suggesting that *cis*-chlordane was isomerizing from *trans*-chlordane. At the end of the experiment, the highest residues were in the top 10 cm of soil for both the cropped and fallow plots. However, the proportion of *trans*-chlordane was markedly lower in the cropped plots. Small amounts of chlordane can translocate from contaminated soil into plants, and there is some evidence that *cis*-chlordane can isomerize to *trans*-chlordane in plants (Singh et al. 1990; Singh et al. 1991). The amount taken up varies with species and stage of plant development.

### 5.3.2 Transformation and Degradation

#### 5.3.2.1 Air

Chlordane degrades in air by both photolysis and oxidation. *trans*-Chlordane photochemically degrades more readily than the *cis* isomer. This is indicated from the fact that the *trans/cis* ratio of chlordane transported long distances to the Norwegian Arctic changes from around 1 in the winter to 0.5 in the summer (Oehme 1991). Many papers have been published that detail the photoproducts of chlordane (principally *cis*-chlordane) and mechanisms of photoproduct formation (Feroz et al. 1981; Ivie et al. 1972; Onuska and Comba 1975; Parlar and Korte 1973, 1977, 1979, 1980; Podowski et al. 1979; Vollner et al. 1971). The most common photoproduct for *cis*-chlordane is the cage configuration that results from proton migration to the dichloroethylene moiety and carbon-carbon bond formation from one of the cyclopentane carbons. These photoreactions may also occur on leaf surfaces (Parlar 1978; Podowski et al. 1979); although the significance of this reaction to the overall removal of chlordane is not clear. Hydroxyl radical reactions of chlordane may be a significant removal mechanism in addition to photolysis. Atkinson (1987) developed a method to estimate the rate of reaction for hydroxyl radicals with organic vapors in the atmosphere. This method is based on the molecular structure of the organic compound, Using this method, an overall reaction rate of  $12.4 \times 10^{-12} \text{ cm}^3/\text{molecule-sec}$  was calculated. Assuming an average ambient hydroxyl radical

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concentration of  $5 \times 10^5$  molecules/cm<sup>3</sup>, averaged over a 24-hour time period (Atkinson 1985), this reaction rate yields an atmospheric half-life of 1.3 days for chlordane vapor.

### 5.3.2.2 Water

The degradation of chlordane in water has not been extensively studied. Eichelberger and Lichtenberg (1971) reported results of a river die-away test in which 85% of the original concentration of chlordane added to river water remained at the end of 2 weeks and persisted at that level for 8 weeks. Oloffs et al. (1972) found that 2.3-50.7% of the chlordane added to three river water samples remained in the aqueous phase after 12 weeks. It was concluded that at least some of the loss was from volatilization. Speidel et al. (1972) reported that chlordane adsorbed to microbially generated floe, and Tabak et al. (1981a, 1981b) reported no degradation in 7 days using domestic waste water as a seed. These studies indicate that chlordane will not degrade rapidly in water and that transport is probably a faster removal mechanism than degradation. No information is available on whether chlordane undergoes photochemical reactions in the aquatic environment.

### 5.3.2.3 Sediment and Soil

Numerous papers have detailed the degradation of chlordane in soils. In general, chlordane appears to persist for potentially long periods of time (>20 years) in some soils, but much less in others. Beeman and Matsumura (1981), Bennett et al. (1974), Lichtenstein and Schulz (1959), Nash and Woolson (1967), Stewart and Chisholm (1971), and Stewart and Fox (1971) all reported finding chlordane residues in excess of 10% of the initially applied amount, 10 years or more after application. Other authors, (Harris and Sans 1976; Mullins et al. 1971; Tafuri et al. 1977; Wiese and Basson 1966) have reported faster removal from soils, but detectable concentrations appear to remain for at least 10 years for most application rates. At chlordane-treated subterranean sites on the University of Missouri-Columbia campus, >70% of the originally applied chlordane could be accounted for 7 years after application (Puri et al. 1990). The fact that the chromatographic profiles of the technical chlordane components were almost identical to the original formulation indicates that little chemical or biochemical transformations had occurred. Sethunathan (1973) reported that chlordane does not degrade under anaerobic conditions in flooded soils. A 1989 study of organochlorine pesticide residues in 12 vegetable farms (four of each of three soil types), in the Fraser Valley of British Columbia, found a marked difference in residue levels with soil type. Farms with loamy sand soil had

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no detectable chlordane, while one of those with silt loam soil contained mean concentrations of total chlordane of 170 ppb (dry wt), and three muck farms contained mean chlordane levels of 830 ppb (Szeto and Price 1991). Chlordane was used extensively on farms in this region as a soil insecticide on potatoes prior to the mid 1970s. These findings support the theory that organochlorine pesticides persist much longer in heavy soils with high organic content. The dissipation of chlordane from the loamy sand soil may be due to high initial volatilization.

Only a few microorganisms have been isolated that are capable of degrading chlordane. Iyengar and Prabhakara Rao (1973) reported that a pure culture of *Aspergillus niger* degraded chlordane after adaptation, but Beeman and Matsumura (1981) found it to be inactive and speculated that the former authors had not considered other factors such as adsorption to glass and volatilization. Beeman and Matsumura (1981), however, reported that a *Nocardioopsis* sp. isolated from chlordane treated soil was capable of degrading chlordane to dichlorochlordene, oxychlordane, heptachlor, heptachlor endoepoxide, chlordane chlorohydrin, and 3-hydroxy-*trans*-chlordane. More recently, the lignin-degrading white rot fungi, *Phanerochaete chrysosporium*, was found to extensively degrade chlordane (Kennedy et al. 1990). In inoculated soil cultures, 28% of the chlordane degraded and 14.9% mineralized to carbon dioxide in 60 days. In liquid cultures, 36.8% of the chlordane degraded and 9.4% mineralized in 30 days. More mineralization occurs under low nutrient nitrogen concentrations (Aust 1990). The bulk of the literature indicates that chlordane does not degrade rapidly in soils and persists for over 20 years in some cases.

## 5.4 LEVELS MONITORED OR ESTIMATED IN THE ENVIRONMENT

### 5.4.1 Air

Chlordane has been detected in outside urban and rural air, in indoor air, and in the breathing zone during personal monitoring (Table 5-2). In urban air, mean concentrations have ranged from below the detection limits (generally  $<0.1 \text{ ng/m}^3$ ) to  $58 \text{ ng/m}^3$ , whereas rural and background concentrations are much lower ( $0.01\text{-}1 \text{ ng/m}^3$ ).

Chlordane concentrations in indoor air are much higher than in either urban or rural air. Indoor air levels in the living areas of treated homes often exceed  $1 \text{ } \mu\text{g/m}^3$  in the vapor phase. These data, however, may be skewed since most of the indoor monitoring was performed on homes that had been

TABLE 5-2. Detection of Chlordane in Air<sup>a</sup>

Media type/location	Sampling dates	No. of samples	Sample type	Analytical method	Concentration (ng/m <sup>3</sup> )		% Occurrence	Reference
					Range	Mean		
<b>Urban Air:</b>								
Columbia, SC	5/79–10/80	4 <sup>b</sup>	High volume	GC/ECD	0.54–1.74	1.3	100	Billings and Bidleman 1983
Denver, CO	1/80	3 <sup>b</sup>	High volume	GC/ECD	0.012–0.080	0.063	100	Billings and Bidleman 1983
New Bedford, MA Landfill	6/80	1 <sup>b</sup>	High volume	GC/ECD	0.20–0.36	0.24	100	Billings and Bidleman 1983
Baltimore, MD	8/67–8/68	4	Filter/impinger	GC/ECD	<0.1	ND	0	Stanley et al. 1971
Fresno, CA	8/67–8/68	4	Filter/impinger	GC/ECD	<0.1	ND	0	Stanley et al. 1971
Riverside, CA	8/67–8/68	4	Filter/impinger	GC/ECD	<0.1	ND	0	Stanley et al. 1971
Salt Lake City, UT	8/67–8/68	4	Filter/impinger	GC/ECD	<0.1	ND	0	Stanley et al. 1971
Southeastern U.S.	8/85	9 <sup>b</sup>	High/low volume	GC/ECD-MS	<1–210	58	67	Lewis et al. 1986
Bloomington, In	11/85–10/86	2	Low volume	GC/MS	0.5–1.5	1.0	100	Anderson and Hites 1988
Miami, FL	1973–1974	14	NS	NS	ND–2.3	0.2	7	Lewis and Lee 1976
Jacksonville, Fl	8/86–9/86	60	24-hour/low volume	GC/ECD	ND–628	38.4	23	EPA 1990b
Jacksonville, Fl	3/87–4/87	72	24-hour/low volume	GC/ECD	ND–66	9.5	12	EPA 1990b
Jacksonville, Fl	1/88–2/88	70	24-hour/low volume	GC/ECD	ND–175	27.4	73	EPA 1990b
Springfield/Chicopee, MA	5/87–6/87	49	24-hour/low volume	GC/ECD	ND–75	3.1	8	EPA 1990b
Springfield/Chicopee, MA	3/88	50	24-Hour/low volume	GC/ECD	ND–89	2.0	16	EPA 1990b
Denver, CO	10/85, 1/86	8	High volume	GC/ECD	0.026–0.104 <sup>c</sup>	0.060	100	Foreman and Bidleman 1990
<b>Rural Air:</b>								
Buffalo, NY	8/67–8/68	4	Filter/impinger	GC/ECD	<0.1	ND	0	Stanley et al. 1971
Dothan, AL	8/67–8/68	4	Filter/impinger	GC/ECD	<0.1	ND	0	Stanley et al. 1971
Iowa City, IA	8/67–8/68	4	Filter/impinger	GC/ECD	<0.1	ND	0	Stanley et al. 1971
Orlando, FL	8/67–8/68	4	Filter/impinger	GC/ECD	<0.1	ND	0	Stanley et al. 1971
Stoneville, MS	8/67–8/68	4	Filter/impinger	GC/ECD	<0.1	ND	0	Stanley et al. 1971
College Station, TX	1979–1980	16	High/low volume	GC/ECD	0.32–2.64	1.05	100	Atlas and Giam 1988
Southern Ontario	7/88–9/89	143	High volume	GC/ECD	0.00067–0.211 <sup>k</sup>	0.039 <sup>k</sup>	100	Hoff et al. 1992
<b>Background Areas:</b>								
Everglades National Park, FL	1973–1974	14	NS	NS	ND–0.8	0.06	7	Lewis and Lee 1976
Indian Ocean	3/86	6	High volume	GC/ECD	0.010–0.016	0.013	100	Wittlinger and Ballschmiter 1990
Adirondacks, NY <sup>d</sup>	1985	4	High volume	GC/ECD	0.390–0.650	0.480	100	Knap and Binkley 1991
Newport News, VA <sup>d</sup>	1988	4	High volume	GC/ECD	0.015–0.129	0.054	100	Knap and Binkley 1991
Bermuda <sup>d</sup>	1985–1988	24	High volume	GC/ECD	0.003–0.062	0.019	100	Knap and Binkley 1991
Canadian Artic	2/88–4/88	10	High volume	GC/ECD	0.0014–0.0081 <sup>g</sup>	0.0039 <sup>g</sup>	100	Patton et al. 1991
Bering Sea	7/88–8/88	4	High volume	GC/MS	0.0053–0.0141 <sup>l</sup>	0.0093 <sup>l</sup>	100	Hinckley and Bidleman 1991
Northwest Atlantic	1/88, 7/89–8/89	8	High volume	GC/ECD	0.0077–0.0242 <sup>l</sup>	0.015 <sup>l</sup>	100	Bidleman et al. 1992

TABLE 5-2. Detection of Chlordane in Air<sup>a</sup> (continued)

Media type/location	Sampling dates	No. of samples	Sample type	Analytical method	Concentration (ng/m <sup>3</sup> )		% Occurrence	Reference
					Range	Mean		
Indoor Air:								
Southeastern U.S.	8/85	9 <sup>c</sup>	High/low volume	GC/ECD-MS	<1-1,700	510	89	Lewis et al. 1986
New Jersey (living areas)	4/85-10/86	12 <sup>e</sup>	Low volume	GC/ECD	<90-1,400	165	20-47 <sup>f</sup>	Louis and Kisselbach 1987
New Jersey (nonliving areas)	4/85-10/86	12 <sup>c</sup>	Low volume	GC/ECD	<90-5,870 <sup>h</sup>	798	62-92 <sup>f</sup>	Louis and Kisselbach 1987
New Jersey (living areas)	1976-1985	157 <sup>c</sup>	Low volume	GC/ECD	<200-55,400	NS	12-34 <sup>l</sup>	Fenske and Sternbach 1987
New Jersey (nonliving areas)	1976-1985	157 <sup>c</sup>	Low volume	GC/ECD	<200-610,000	NS	44-48 <sup>i</sup>	Fenske and Sternbach 1987
Military base apartments	1980	498 <sup>c</sup>	Low volume	GC/ECD	NS to 37,800	1,900	73	Livingston and Jones 1981
Military housing	1981-1982	3,957	NS	NS	ND->5,000	NS	20.1	EPA 1983
North Carolina	NS	9 <sup>e</sup>	Low volume	GC	2,750-5,810	NS	100	Wright and Leidy 1982
North Carolina	6/83-10/83	60 <sup>e,j</sup>	NS	GC/ECD	<50-9,900	2,200	NS	Leidy et al. 1985; Fenske and Sternbach 1987
Bloomington, IN	11/85-10/86	12	Low volume	GC/MS	0.8-49	NS	100	Anderson and Hites 1988
Gainesville, FL	1985-1986	11	Low volume	GC/ECD	ND-335	134	27	Moye and Malagodi 1987
Athens, GA	1985-1986	9	Low volume	GC/ECD	ND	ND	0	Moye and Malagodi 1987
Van Buren, MO	8/83	21	NS	NS	330-27,000	NS	NS	NIOSH 1984b
Jacksonville, FL	8/86-9/86	65	24-hour/low volume	GC/ECD	ND-3,020	324.0	62	EPA 1990b
Jacksonville, FL	3/87-4/87	72	24-hour/low volume	GC/ECD	ND-4,380	245.5	72	EPA 1990b
Jacksonville, FL	1/88-2/88	71	24-hour/low volume	GC/ECD	ND-2,050	220.3	71	EPA 1990b
Springfield/Chicopee, MA	5/87-6/87	49	24-hour/low volume	GC/ECD	ND-1,700	199.3	49	EPA 1990b
Springfield/Chicopee, MA	3/88	52	24-hour/low volume	GC/ECD	ND-735	34.8	51	EPA 1990b
Lincoln/Omaha, NE (pretreatment)	NS	19 <sup>e</sup>	4-hour at 2 L/minute	GC/ECD	NS	250	100	Kamble et al. 1992
Lincoln/Omaha, NE (during treatment)	NS	19 <sup>e</sup>	4-hour at 2 L/minute	GC/ECD	NS	1,210	100	Kamble et al. 1992
Lincoln/Omaha, NE (24-hour posttreatment)	NS	19 <sup>e</sup>	4-hour at 2 L/minute	GC/ECD	NS	690	100	Kamble et al. 1992
Lincoln/Omaha, NE (180-day posttreatment)	NS	19 <sup>e</sup>	4-hour at 2 L/minute	GC/ECD	NS	290	100	Kamble et al. 1992

TABLE 5-2. Detection of Chlordane in Air<sup>a</sup> (continued)

Media type/location	Sampling dates	No. of samples	Sample type	Analytical method	Concentration (ng/m <sup>3</sup> )		% Occurrence	Reference
					Range	Mean		
Breathing Zone:								
Southeastern U.S.	8/85	9 <sup>b</sup>	High/low volume	GC/ECD-MS	<1-4,200	680	67	Lewis et al. 1986
Jacksonville, Fl	8/86-9/86	63	24-hour/low volume	GC/ECD	ND-1,340	212.0	53	EPA 1990b
Jacksonville, Fl	3/87-4/87	71	24-hour/low volume	GC/ECD	ND-2,990	190.7	50	EPA 1990b
Jacksonville, Fl	1/88-2/88	71	24-hour/low volume	GC/ECD	ND-2,200	194.8	93	EPA 1990b
Springfield/Chicopee, MA	5/87-6/87	48	24-hour/low volume	GC/ECD	ND-2,220	252.9	50	EPA 1990b
Springfield/Chicopee, MA	3/88	52	24-hour/low volume	GC/ECD	ND-467	35.9	87	EPA 1990b
Lincoln/Omaha, NE (applicators)	NS	29	30-minutes at 2 L/minute	GC/ECD	610-116,330	16,600	100	Kamble et al. 1992

<sup>a</sup>No distinction is made between the isomers of chlordane. In cases where the original papers made a distinction, the data were combined.

<sup>b</sup>Sample periods

<sup>c</sup>A 9th sample with vapor phase only contained 0.068 ng/m<sup>3</sup> of chlordane.

<sup>d</sup>Samples taken from aircraft at various altitudes.

<sup>e</sup>Sample locations

<sup>f</sup>Percent detectable varied with the time after treatment

<sup>g</sup>Sum of *cis*-chlordane, *trans*-chlordane, and *trans*-nonachlor in total (vapor and particulate) sample

<sup>h</sup>High detection was in sample taken prior to treatment.

<sup>i</sup>Percent >5,000 ng m<sup>-3</sup>

<sup>j</sup>Site selection not influenced by application procedures

<sup>k</sup>Annual mean and range of *cis*-chlordane, *trans*-chlordane, and *trans*-nonachlor

<sup>l</sup>Sum of *cis*-chlordane, *trans*-chlordane, and *trans*-nonachlor

GC/ECD = gas chromatography/electron capture detector; GC/MS = gas chromatography/mass spectroscopy; ND = not detected; NS = not specified

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sprayed with chlordane to control termites. Thus, the frequency of detection indicated in Table 5-2 may not be representative of the general population. Dust vacuumed from homes of controls, farmers, and formulators had mean chlordane levels of 7.6, 5.8, and 23.1 ppm, respectively (Starr et al. 1974). Since chlordane is poured or injected into soil around the foundation of houses, the appearance of chlordane vapor in the living quarters of treated houses may indicate the intrusion of soil gas into the home through cracks, drains, or ducting in the basement or ground floor (Anderson and Hites 1989; Wallace 1991). Several studies indicate that concentrations of chlordane are much higher in the basement than in living areas of homes (Anderson and Hites 1989; Fenske and Sternbach 1987). Anderson and Hites (1989) found that the basement concentrations of chlordane are often a factor of 3-10 higher than in living areas and 2-3 orders of magnitude higher than outdoors. Fenske and Sternbach (1987) additionally reported that homes with crawl spaces and forced air heating systems had significantly higher levels of chlordane (11.2  $\mu\text{g}/\text{m}^3$  median) than homes with basements and forced air heat (0.33  $\mu\text{g}/\text{m}^3$ ), radiant heat (0.93  $\mu\text{g}/\text{m}^3$ ), in-slab ducts and forced air heat (3.42  $\mu\text{g}/\text{m}^3$ ). However, misapplication of chlordane by the pest control company (as determined by the New Jersey Department of Environmental Protection) had occurred in all of the homes with the 11.2  $\mu\text{g}/\text{m}^3$  median level and in 67% of the home with the 3.42  $\mu\text{g}/\text{m}^3$  median level. When misapplication occurred, living area samples had median levels of 3.28  $\mu\text{g}/\text{m}^3$  with 40% of samples exceeding 5  $\mu\text{g}/\text{m}^3$ , compared with <0.1  $\mu\text{g}/\text{m}^3$  and no samples exceeding 5  $\mu\text{g}/\text{m}^3$  in homes with no misapplication (Fenske and Sternbach 1987).

#### 5.4.2 Water

Chlordane has been detected in surface water, groundwater, suspended solids, sediments, bottom detritus, drinking water, sewage sludge, urban runoff, and in rain (Table 5-3). Recent concentrations of chlordane in ocean and lake water are <0.0001 ng/L. Recent studies in the Great Lakes indicate that the levels of the cis isomer in water is roughly 2-3 times that of *trans*-chlordane (Biberhofer and Stevens 1987; Stevens and Neilson 1989). The presence of chlordane in drinking water appears to almost always result from an accidental event, such as back siphoning during dilution of a pesticide spray (CDC 1976), but concentrations can persist for months.

Chlordane has been reported in groundwater at NPL sites and in New Jersey (HAZDAT 1992; Page 1981), but it does not generally appear as a contaminant of groundwater. Groundwater monitoring data from 479 disposal site investigations detected chlordane in 23 samples at 10 sites, ranking it 80th

TABLE 5-3. Detection of Chlordane in Water and Sediments<sup>a</sup>

Media type/location	Sampling dates	No. of samples	Sample type	Analytical method	Concentration (ppb)		% Occurrence	Reference
					Range	Mean		
Surface Water:								
Wolf River, TN	NS	30	Grab	NS	NS	0.15	NS	Jaffe et al. 1982
Wolf River, TN	NS	0	Grab	NS	NS	0.42	NS	Jaffe et al. 1982
Mississippi River, LA	1974	NS	Continuous	GC/ECD	0.00045-0.00115	NS	100	Brodthmann 1976
Niagara River, NY	4/79-12/81	NS	Continuous	GC/ECD	NS	0.004	66	Kuntz and Warry 1983
Lower Fox River, WI	1976-1977	250	Grab	GC + GC/MS	NS	NS	NS	Peterman et al. 1980
Surface Waters in NJ	NS	603	NS	NS	<0.1-0.8	0.1 <sup>b</sup>	56	Page 1981
Hawaii Kai Marina, HI	4/74-7/74	12	Grab	GC/ECD	NS	NS	55	Tanita et al. 1976
Hawaii Kai Marina, HI	4/72-11/72	5	Grab	NS	<0.001-0.01	NS	40	Tanita et al. 1976
Belmont Lake, NY	1982	NS	Grab	GC/ECD	0.003-0.099	NS	NS	Wood et al. 1986
177 River Stations of the United States	1975-1980	2,943	Grab	NS	NS	NS	0.6 <sup>c</sup>	Gilliom 1984
Gulf of Mexico and Southeast Coast <sup>d</sup>	1987	9	Grab	GC/ECD	0.000004-0.000034	NS	NS	Sauer et al. 1989
Lake Ontario	10/83	14	Pump (1 m)	GC/ECD	0.000034-0.000108	0.000060	100	Biberhofer and Stevens 1987
4 Great Lakes, including Georgian Bay	1986	95	Pump (1 m)	GC/ECD	ND-0.000202	NS	71	Stevens and Neilson 1989
Bering Sea	7/88	1	Grab	NS	0.00014 <sup>e</sup>	0.00014 <sup>e</sup>	100	Hinckley and Bidelman 1991
Suspended Solids:								
Niagara River	NS	15	Grab	NS	0.006-0.011	0.0085	13	Maguire et al. 1983
Niagara River	4/79-12/81	NS	Continuous	GC/ECD	NS	4.5	73	Kuntz and Warry 1983
Sediments:								
Streams Near San Francisco Bay	2/72-3/72	29-39	Grab	GC/ECD-MS	ND-800	120	90	Law and Goerlitz 1974
Fore River and Back Cove, ME	11/80	8	Grab	GC/ECD	<0.03-9.8	1.8	75	Ray et al. 1983
Apalachicola River, FL	8/79-5/80	12	Grab	GC	<1-3	NS	17	Elder and Matraw 1984
Hawaii Kai Marina, HI	4/74-7/74	12	Grab	GC/ECD	1.73-10.4	5.27	97	Tanita et al. 1976
Hawaii Kai Marina, HI	1972-1973	11	Grab	NS	NS	5.32	100	Tanita et al. 1976
Belmont Lake, NY	1982	NS	Grab	GC/ECD	20-580	NS	NS	Wood et al. 1986
171 River Stations	1975-1980	1,014	Grab	NS	NS	NS	30 <sup>c</sup>	Gilliom 1984
Great Lakes harbors	5/89	5	Grab	GC/ECD	1.44-14.34 <sup>e</sup>	3.66 <sup>e</sup>	100	Verbrugge et al. 1991
NPL site (on-site) in Marshall, IL	NS	NS	NS	NS	ND-1,000,000	NS	NS	ATSDR 1989b
NPL site (off-site) in Marshall, IL	NS	NS	NS	NS	ND-250,000	NS	NS	ATSDR 1989b



TABLE 5-3. Detection of Chlordane in Water and Sediments<sup>a</sup> (continued)

Media type/location	Sampling dates	No. of samples	Sample type	Analytical method	Concentration (ppb)		% Occurrence	Reference
					Range	Mean		
Gulf of Mexico (51 site) <sup>f</sup>	1986	153	Surface	GC/ECD	<0.02–8.66 <sup>g</sup>	0.26	77	Sericano et al 1990
Gulf of Mexico (50 site) <sup>f</sup>	1987	148	Surface	GC/ECD	<0.02–43.5 <sup>g</sup>	1.18	72	Sericano et al 1990
Bottom Detritus:								
Apalachicola River, FL	8/79–5/80	7	Grab	GC	1,700–10,000	NS	100	Elder and Matraw 1984
Groundwater:								
Groundwaters in NJ	NS	1,076	NS	NS	<0.1–0.4	<0.1 <sup>b</sup>	40	Page 1981
NPL site in Plumstead Township, NJ <sup>h</sup>	NS	NS	NS	NS	0.02	NS	NS	VIEW 1988
NPL site in Cape Girardeau, MO <sup>i</sup>	NS	NS	NS	NS	830	NS	NS	VIEW 1988
NPL site in Holbrook, MA <sup>i</sup>	NS	NS	NS	NS	48	NS	NS	VIEW 1988
NPL sites at 11 other locations <sup>j</sup>	NS	NS	NS	NS	NS	NS	NS	VIEW 1988
NPL site (on-site) in Marshall, IL	NS	NS	NS	NS	ND–0.6	NS	NS	ATSDR 1989b
NPL site (off-site) in Marshall, IL	NS	NS	NS	NS	ND	NS	NS	ATSDR 1989b
Cape Cod Golf Courses	1986–1987	16 <sup>k</sup>	Pump/bail	GC/ECD	ND–7.20	NS	44	Cohen et al. 1990
Drinking Water:								
Pittsburgh, PA	12/80	NS	Grab	NS	<1.0–6,600 <sup>l</sup>	NS	NS	CDC 1981
Seven U.S. Cities	1965–1967	63	Grab	NS	NS	NS	22	Schafer et al. 1969
Chattanooga, TN	3/24/76	NS	Grab	GC/ECD	NS–1,200,000	NS	NS	Harrington et al. 1978
Kansas farmstead well survey <sup>m</sup>	12/85–2/86	103	Grab	GC/ECD	ND–0.53	NS	0.97	Steichen et al. 1988
Sewage Sludge:								
Unspecified Sites	NS	44	NS	NS	NS	NS	73	Fricke et al. 1985
Urban Runoff:								
Fresno, CA	NS	NS	Grab	NS	0.1–0.3	0.1 <sup>b</sup>	NS	Nightingale 1987
Lake Quinsigamond, MA and Kansas City, MO	NS–7/82	NS	Grab	NS	0.01–10 <sup>n</sup>	NS	5	Cole et al. 1984
11 Canadian Great Lakes Basin sites	NS	124	Grab	GC/ECD	NS	0.00121	20	Marsalek and Schroeter 1988
Street Sediment:								
11 Canadian Great Lakes Basin sites	NS	110	Grab	GC/ECD	NS	0.046	35	Marsalek and Schroeter 1988

TABLE 5-3. Detection of Chlordane in Water and Sediments<sup>a</sup> (continued)

Media type/location	Sampling dates	No. of samples	Sample type	Analytical method	Concentration (ppb)		% Occurrence	Reference
					Range	Mean		
Rain:								
Lake Superior	1983	NS	NS	GC/ECD	<0.00005	ND	0	Strachan 1985
College Station, TX	1979-1980	24	Collector	GC/ECD	0.0006-0.0091	0.00214	100	Atlas and Giam 1988
Great Lakes (4 remote sites)	2/86-7/86	93	Collector	GC/ECD	ND-0.0023	NS	33	Chan and Perkins 1989
Bermuda	1983-1984	36	Collector	GC/ECD	ND-0.000486	0.000077	97	Knap et al. 1988

<sup>a</sup>No distinction is made between the isomers of chlordane. In cases where the original papers made a distinction, the data were combined.

<sup>b</sup>Median

<sup>c</sup>Percentage of stations with detections

<sup>d</sup>Open-ocean seawater (filtrate) samples. Chlordane was not detected in microlayer samples.

<sup>e</sup>Wet weight

<sup>f</sup>NOAA's Status and Trends Mussel Watch Program

<sup>g</sup>cis isomer

<sup>h</sup>On-site

<sup>i</sup>Off-site

<sup>j</sup>Arlington, TN; Brick Township, NJ; Brunswick, ME; Sorreto, LA; Gallaway, TN; Niagara Falls, NY; Lewisburg, TN; Sacramento, CA; Toone, IL; Marshall, IL; Jacksonville, AR

<sup>k</sup>Sites, includes background, green, tee, and fairway sites at four golf courses

<sup>l</sup>Concentrations above the solubility limit may be the result of a cosolvent such as kerosene

<sup>m</sup>Random sample

<sup>n</sup>Range of positive detections

<sup>o</sup>Sum of *cis*-chlordane, *trans*-chlordane, and *trans*-nonachlor.

GC/ECD = gas chromatography/electron capture detector; GC/MS = gas chromatography/mass spectroscopy; ND = not detected; NPL = National Priorities List; NS = not specified

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among the 208 RCRA Appendix IX organic chemicals investigated (Plumb 1991). According to the EPA database Pesticides in Groundwater, chlordane has been confirmed in groundwater only in Massachusetts as a result of normal agricultural use and only in Idaho from a point source (Ritter 1990; Williams et al. 1988b). Based on average chlordane concentrations in EPA's STORET database for 1978-1987, the west south central section of the United States had the highest concentrations of chlordane in groundwater and New England had the lowest (Phillips and Birchard 1991). The presence of chlordane in groundwater at Cape Cod golf courses is thought to be due to macropore flow of particle-bound pesticide or contamination during well construction (Cohen et al. 1990). Chlordane was used at these golf courses from the 1950s to 1970s.

### 5.4.3 Sediment and Soil

Chlordane has been detected in both rural and urban soils (Table 5-4) in concentrations from <1 ppb to 141 ppm. In general monitoring programs of rural and urban soils, chlordane was consistently found; however, detections generally mirrored use patterns and are, for the most part, from studies performed in the late 1960s to middle 1970s. Very few recent general soil monitoring data are available; these data show that chlordane is still present in soils, but insufficient detections are available to estimate any trends (see Table 5-4). A sampling of soil around New Orleans' houses treated with chlordane showed that chlordane levels were variable. Mean residue levels sampled at 30 houses varied from 22 to 2,540 ppm (Delaplane and La Fage 1990).

Recent sediment concentrations of chlordane in Great Lakes harbors and a tributary of the Missouri River in Missouri range from 1.4 to 14 ppb and 1.5 to 310 ppb, respectively (Puri et al. 1990; Verbrugge et al. 1991). A Missouri study performed in the 1980s demonstrated that chlordane in sediment of Missouri streams were of recent origin and correlated with urban development (Puri et al. 1990). Chlordane levels in sediment from predominately agricultural areas were approximately two orders of magnitude lower than in urban areas. Based on average chlordane concentrations in EPA's STORET database for 1978-1987, the west north central section of the United States had the highest concentrations of chlordane in sediment, and New England had the lowest (Phillips and Birchard 1991)

TABLE 5-4. Detection of Chlordane in Soils<sup>a</sup>

Media type/location	Sampling dates	No. of samples	Sample type	Analytical method	Concentration (ppm)		% Occurrence	Reference
					Range	Mean		
Urban:								
Baltimore, MD	1971	156	NS	GC/ECD	0.01-12.35	0.21	37	Carey et al. 1979a
Gadsden, AL	1971	55	NS	GC/ECD	0.04-0.46	0.07	5	Carey et al. 1979a
Hartford, CT	1971	48	NS	GC/ECD	0.02-141	4.0	48	Carey et al. 1979a
Macon, GA	1971	43	NS	GC/ECD	0.07-0.91	0.8	26	Carey et al. 1979a
Newport News, VA	1971	78	NS	GC/ECD	0.09-7.29	0.16	13	Carey et al. 1979a
Bakersfield, CA	1969	50	Grab	GC/ECD	0.07-20.5	0.78	30	Wiersma et al. 1972
Camden, NJ	1969	50	Grab	GC/ECD	0.39-5.90	0.36	16	Wiersma et al. 1972
Houston, TX	1969	50	Grab	GC/ECD	0.04-12.9	0.66	34	Wiersma et al. 1972
Manhattan, KS	1969	50	Grab	GC/ECD	0.03-4.86	0.30	40	Wiersma et al. 1972
Miami, FL	1969	50	Grab	GC/ECD	0.04-16.9	1.59	64	Wiersma et al. 1972
Milwaukee, WI	1969	50	Grab	GC/ECD	0.05-10.2	0.45	34	Wiersma et al. 1972
Salt Lake City, UT	1969	50	Grab	GC/ECD	0.02-7.50	0.41	38	Wiersma et al. 1972
Waterbury, CT	1969	50	Grab	GC/ECD	0.02-8.74	0.96	28	Wiersma et al. 1972
Fresno-Clovis, CA	NS	NS	Grab	NS	<0.03-2.70	NS	NS	Nightingale 1987
Belmont Lake, NY bank soil	1982	NS	Grab	GC/ECD	<0.002-0.003	NS	NS	Wood et al. 1986
New Orleans, LA (30 treated homes)	10/86	240	Grab	GC/ECD	0.6-14,464	854.9	100	Delaplane and LaFage 1990
Rural:								
Illinois	1970	69	NS	GC/ECD	0.05-1.32	0.09	23	Carey et al. 1973
Indiana	1970	36	NS	GC/ECD	0.29-4.30	0.20	8.3	Carey et al. 1973
Iowa	1970	76	NS	GC/ECD	0.17-3.35	0.13	15	Carey et al. 1973
Kansas	1970	28	NS	GC/ECD	0.32-0.54	0.03	7.1	Carey et al. 1973
Kentucky	1970	1	NS	GC/ECD	ND	ND	0	Carey et al. 1973
Michigan	1970	14	NS	GC/ECD	ND	ND	0	Carey et al. 1973
Minnesota	1970	37	NS	GC/ECD	0.87	0.02	3	Carey et al. 1973
Missouri	1970	31	NS	GC/ECD	0.14-0.53	0.02	6	Carey et al. 1973
Nebraska	1970	47	NS	GC/ECD	ND	ND	0	Carey et al. 1973
Ohio	1970	29	NS	GC/ECD	ND	ND	0	Carey et al. 1973
South Dakota	1970	26	NS	GC/ECD	ND	ND	0	Carey et al. 1973
Wisconsin	1970	5	NS	GC/ECD	0.05	0.01	20	Carey et al. 1973
Everglades National Park	5/76	25	Grab	GC/ECD	<0.001-0.0048	0.00226	52	Requejo et al. 1979
Agricultural land, Florida	5/76	7	Grab	GC/ECD	<0.001-0.195	0.088	43	Requejo et al. 1979
Cropland, CA	1969	NS	Grab	GC/ECD	NR	0.01	NR	Wiersma et al. 1972
Cropland, NJ, DE, MD	1969	NS	Grab	GC/ECD	NR	<0.01	NR	Wiersma et al. 1972
Cropland, FL	1969	NS	Grab	GC/ECD	NR	0.36	NR	Wiersma et al. 1972
Cropland, WI	1969	NS	Grab	GC/ECD	NR	0.01	NR	Wiersma et al. 1972

TABLE 5-4. Detection of Chlordane in Soils<sup>a</sup> (continued)

Media type/location	Sampling dates	No. of samples	Sample type	Analytical method	Concentration (ppm)		% Occurrence	Reference
					Range	Mean		
Urban:								
Cropland, AZ, NM, NV, UT	1969	NS	Grab	GC/ECD	NR	0.02	NR	Wiersma et al. 1972
Cropland, ME, NH, VT, MA, RI, CT	1969	NS	Grab	GC/ECD	NR	0.01	NR	Wiersma et al. 1972
Cropland, 37 states	1971	1,486	Grab	GC/ECD	0.01-6.98	0.06	8	Carey et al. 1978
Cropland, 37 states	1972	1,483	Grab	GC/ECD	0.01-7.89	0.05	7.9	Carey et al. 1979b
Other:								
Cape Cod Golf Courses	1986-1987	12 <sup>b</sup>	Soil core	GC/ECD	ND-4.310	2.278 <sup>c</sup>	58	Cohen et al. 1990
NPL sites:								
Holbrook, MA	NS	NS	NS	NS	NS	NS	NS	VIEW 1988
Sorroto, LA	NS	NS	NS	NS	NS	NS	NS	VIEW 1988
Cape Girardeau, MO	NS	NS	NS	NS	30 <sup>d</sup>	NS	NS	VIEW 1988
Lewisburg, TN	NS	NS	NS	NS	0.1 <sup>e</sup>	NS	NS	VIEW 1988
Memphis, TN	NS	NS	NS	NS	57 <sup>e</sup>	NS	NS	VIEW 1988
West Chester, OH	NS	NS	NS	NS	NS	NS	NS	VIEW 1988
Toone, TN	NS	NS	NS	NS	NS	NS	NS	VIEW 1988
Marshall, IL	NS	NS	NS	NS	48.3 <sup>e</sup>	NS	NS	VIEW 1988
Jacksonville, AR	NS	NS	NS	NS	NS	NS	NS	VIEW 1988
Marshall, IL	NS	NS	NS	NS	ND-69 <sup>d</sup>	NS	NS	ATSDR 1989b
Marshall, IL	NS	NS	NS	NS	ND-0.760 <sup>e</sup>	NS	NS	ATSDR 1989b
Holbrook, MA	NS	36 <sup>f</sup>	Grab	GC/ECD	ND-334	NS	86%	Callahan et al. 1991

<sup>a</sup>No distinction is made between the isomers of chlordane. In cases where the original papers made a distinction, the data were combined.

<sup>b</sup>Three sites and four depths

<sup>c</sup>Average of three surface cores, not detected at and below 2.0, 24, 5.8 feet at three sites

<sup>d</sup>On-site

<sup>e</sup>Off-site

<sup>f</sup>Locations

GC/ECD = gas chromatography/electron capture detector; ND = not detected; NPL = National Priorities List; NS = not specified

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**5.4.4 Other Environmental Media**

Chlordane has been detected in many other media. Table 5-5 summarizes the data available for food monitoring, Table 5-6 summarizes data for aquatic organisms, Table 5-7 summarizes data for terrestrial organisms, and Table 5-8 summarizes data for monitoring human samples. The data in these tables clearly show the widespread occurrence of chlordane throughout the United States. Based on average chlordane concentrations in EPA's STORET database for 1978-1987, the west south central section of the United States had the highest concentrations of chlordane in fish tissue, and New England had the lowest (Phillips and Birchard 1991).

Total chlordane concentrations in bluefish fillet are reduced an average 29% by trimming those portions of fillet with the highest concentrations of lipid, such as the skin, dorsal fat, and bellyflap (Sanders and Haynes 1988). Cooking did not significantly change the chlordane concentration in bluefish (Trotter et al. 1989).

**5.5 GENERAL POPULATION AND OCCUPATIONAL EXPOSURE**

A major route of exposure to chlordane in the United States is from living in chlordane treated houses. Many of these houses are in the deep south and far southwest where termites are a significant problem, but moderate to heavy use of chlordane extended from Pennsylvania and the lower New England states south and west to the lower portion of Colorado and up to northern California. Chlordane vaporizes gradually in treated homes for over 10 years. It accumulates in residents' bodies by inhalation of the vapor, by eating food that has adsorbed the vapor, or dermal contact with the chemical. Indoor air concentrations often exceed 1  $\mu\text{g}/\text{m}^3$  (see Table 5-2) and persist for many years (Livingston and Jones 1981). A recent study of chlordane concentrations in 19 houses treated for subterranean termite control indicated that the chlordane concentration in the air of treated homes occurred during treatment and declined significantly after 24 hours (Kamble et al. 1992). While there was a slight reduction in chlordane concentration from the 24-hour levels 7 days posttreatment, these changes were not significant. Concentrations of chlordane remained essentially the same from 30 to 180 days after treatment, and these concentrations were similar to pretreatment levels. The EPA (1987g) estimated that, up until 1988, 1.3-1.8 million people per year were exposed to cyclodiene termiticides, as occupants of newly treated structures. They further estimated that  $\approx 30$  million structures had been treated for termites with these chemicals resulting in the exposure of over

TABLE 5-5. Detection of Chlordane in Food<sup>a</sup>

Media type/location	Sampling dates	No. of samples	Sample type	Analytical method	Concentration (ppm)		% Occurrence	Reference
					Range	Mean		
Total adult food groups:								
United States <sup>b</sup>	1990-1991	936	Composite	NS	NS	NS	1	FDA 1991
United States <sup>b</sup>	1989-1990	936	Composite	NS	NS	NS	<1	FDA 1990
United States <sup>b</sup>	1987-1988	1,170	Composite	NS	NS	NS	4	FDA 1989a
United States <sup>b</sup>	1982-1984	1,872	Composite	NS	NS	NS	<1	Gunderson 1988
10 State Survey	1988-1989	13,085	Composite	NS	NS	NS	0.09	Minyard and Roberts 1991
10 State Survey	1987-1988	13,980	Composite	NS	NS	NS	0.05	Minyard and Roberts 1991
United States <sup>b</sup>	1978-1985	1,044	Composite	NS	NS	NS	7	Yess et al. 1991
United States	1980-1982	324	Composite	GC/MS	ND-0.0021	0.0004	1.2	Gartrell et al. 1986a
United States	1979-1980	240	Composite	GC/MS	ND-0.0107	0.003	0.42	Gartrell et al. 1985a
United States	1977-1978	240	Composite	NS	ND-0.001	NS	1.25	Podrebarac 1984a
United States	1976-1977	300	Composite	GC/MS	ND-trace	NS	0.67	Johnson et al. 1984b
United States	1975-1976	240	Composite	GC/MS	ND-trace	NS	0.83	Johnson et al. 1981a
United States	1973-1974	360	Composite	GC + TLC	ND-trace	NS	0.28	Manske and Johnson 1977
United States	1972-1973	360	Composite	NS	ND-trace	NS	0.28	Johnson and Manske 1976
United States	1971-1972	420	Composite	NS	ND-0.59	NS	0.24	Manske and Johnson 1975
United States	1969-1970	360	Composite	GC/ECD + TLC	ND	ND	0	Corneliusen 1972
United States	1968-1969	360	Composite	GC/ECD + TLC	0.026-0.043 <sup>c</sup>	0.035 <sup>c</sup>	0.56	Corneliusen 1970
United States	1966-1967	360	Composite	GC/ECD + TLC	0.005-0.02 <sup>c</sup>	0.013 <sup>c</sup>	0.56	Martin and Duggan 1968
United States	1965-1966	432	Composite	GC + TLC	ND-0.37	NS	0.23	Duggan et al. 1967
United States	1964-1965	216	Composite	GC/ECD + TLC	ND-0.033	NS	0.46	Duggan et al. 1966
Total toddler food groups:								
United States	1980-1982	143	Composite	GC/MS	ND-0.005	NS	0.7	Gartrell et al. 1986b
United States	1979-1980	110	Composite	GC/MS	ND-0.0008	NS	0.91	Gartrell et al. 1985b
United States	1977-1978	606	Composite	GC/MS	0.010-0.028 <sup>c</sup>	0.019 <sup>c</sup>	0.33	Podrebarac 1984b
United States	1976-1977	687	Composite	GC/MS	ND-trace	NS	0.15	Johnson et al. 1984a
United States	1975-1976	NS	Composite	GC/MS	ND-0.137	NS	NS	Johnson et al. 1981b
Total infant food groups:								
United States	1977-1978	417	Composite	GC/MS	ND-0.020	NS	0.24	Podrebarac 1984b
United States	1976-1977	445	Composite	GC/MS	ND-trace	NS	0.22	Johnson et al. 1984a
United States	1975-1976	NS	Composite	GC/MS	ND-trace	NS	NS	Johnson et al. 1981b
Dairy products:								
Illinois	1972-1981	3,618	Individual	GC, bovine milk	ND->0.3	NS	53.4	Steffey et al. 1984
United States	NS	NS	Cow milk, cheese	GC/MS	NS	Detected <sup>d</sup>	NS	Lawrence et al. 1970

TABLE 5-5. Detection of Chlordane in Food<sup>a</sup> (continued)

Media type/location	Sampling dates	No. of samples	Sample type	Analytical method	Concentration (ppm)		% Occurrence	Reference
					Range	Mean		
Animal products: Ontario, Canada	1986–1988	539	Abdominal fat	GC/ECD	<0.001	NS	NS	Frank et al. 1990
Domestic animals: Ontario, Canada	1986–1988	63	Hen's eggs	GC/ECD	<0.001	NS	NS	Frank et al. 1990
Seafood United States aquaculture areas	1990	172	Fish/shellfish	NS	<0.01–0.13	NS	5	FDA 1991
Produce United States	1989–1991	6,970	Fruits/vegetables	GC/ECD	ND <sup>c</sup>	ND	0	Schattenberg and Hsu 1992

<sup>a</sup>No distinction is made between the isomers of chlordane. In cases where the original papers made a distinction, the data were combined.

<sup>b</sup>FDA's Total Diet Study

<sup>c</sup>Range of positive detection

<sup>d</sup>Chlordane and a metabolite of chlordane (1-exo-2-endo-4,5,6,7,8-octachloro-2,3-exo-epoxy-2,3,3a,4,7,7a-hexahydro-4,7-methanoindene) were detected

<sup>e</sup>Detection limit is 0.625 ppm

GC/ECD = gas chromatography/electron capture detector; GC/MS = gas chromatography/mass spectroscopy; ND = not detected; NS = not specified; TLC = thin-layer chromatography



TABLE 5-6. Detection of Chlordane in Aquatic Organisms

Isomer	Sampling location	Dates	No. of samples	Sample type	Analytical method (detection limit)	Concentration (ppm)		% Occurrence	Reference
						Range	Mean		
Fish:									
<i>cis, trans</i>	Major United States watersheds <sup>a</sup>	1980–1981	315	Whole fish, composite	GC (0.01 ppm wet wt.)	ND–0.36	0.03	73.8	Schmitt et al. 1985
			315			ND–0.22	0.02	72.0	
<i>cis, trans</i>	Major United States watersheds <sup>a</sup>	1978–1979	NS	Whole fish, composite	GC (0.01 ppm wet wt.)	ND–2.53	0.07	94.4	Schmitt et al. 1985
			NS			ND–0.54	0.02	70.4	
<i>cis, trans</i>	Major United States watersheds <sup>a</sup>	1976–1977	NS	Whole fish, composite	GC (0.01 ppm wet wt.)	ND–0.93	0.06	92.5	Schmitt et al. 1985
			NS			ND–0.32	0.03	84.0	
<i>cis, trans</i>	13 Lake Michigan tributaries	Fall 1983	26	Whole fish, composite	GC/ECD (0.005 ppm wet wt.)	ND–0.211	NS	NS	Camanzo et al. 1987
			26			ND–0.025	NS	NS	
<i>cis, trans</i>	Grand Traverse Bay (Lake Michigan)	Fall 1983	2	Whole fish, <sup>b,c</sup> composite	GC/ECD (0.005 ppm wet wt.)	0.015–0.037	NS	NS	Camanzo et al. 1987
			2			0.003–0.005	NS	NS	
<i>cis, trans</i>	Wabash River (Indiana)	NS	1	Whole fish, composite	MID GC/MS (0.0005 ppm wet wt.)	—	0.00854	100	Kuehl et al. 1980
			1			—	0.01298	100	
<i>cis and trans</i>	Ashtabula River (Oklahoma)	NS	1	Whole fish, composite	MID GC/MS (0.0005 ppm wet wt.)	—	ND	0	Kuehl et al. 1980
<i>cis, trans</i>	Great Lakes and major watersheds of the Great Lakes	1979	48	Whole fish, composite	MID GC/MS (0.020 ppm wet wt.)	ND–0.61	0.090	79.2	Kuehl et al. 1983
			48			ND–0.52	0.098	87.5	
<i>cis and trans</i>	Major United States watersheds	1976	58	Whole fish, composite	GC/MS	NS	NS	36.2	Veith et al. 1979

TABLE 5-6. Detection of Chlordane in Aquatic Organisms (continued)

Isomer	Sampling location	Dates	No. of samples	Sample type	Analytical method (detection limit)	Concentration (ppm)		% Occurrence	Reference
						Range	Mean		
<i>cis</i> and <i>trans</i>	13 sites located along a 125 mile stretch of the Kansas River	1986	25	Whole fish, composite	GC/ECD (0.03 ppm wet wt.)	ND-2.1	0.25	68.0	Arruda et al. 1987
<i>cis</i> and <i>trans</i>	Siskiwit Lake on Isle Royal in Lake Superior	1983	4 4	Whole fish, composite <sup>e</sup>	GC/MS (0.001 ppm) <sup>d</sup>	0.23-0.77 <sup>d</sup>	0.42 <sup>d</sup>	NS	Swackhamer and Hites 1988
<i>cis</i> and <i>trans</i>	Siskiwit Lake on Isle Royal in Lake Superior	1983	3 3	Whole fish, composite <sup>e</sup>	GC/MS (0.001 ppm) <sup>d</sup>	0.14-0.33 <sup>d</sup>	0.26 <sup>d</sup>	NS	Swackhamer and Hites 1988
<i>cis</i> and <i>trans</i>	Lake Texoma (Texas and Oklahoma)	Oct. 1979	14 <sup>f</sup> 47 <sup>g</sup> 38 <sup>h</sup>	Fillets	GC/ECD (0.001 ppm)	0.002 (max) <sup>f</sup> 0.008 (max) <sup>g</sup> 0.024 (max) <sup>h</sup>	0.017 (median) <sup>f</sup> NS NS	NS NS NS	Hunter et al. 1980
<i>cis</i> and <i>trans</i>	Tuttle Creek Lake (Kansas)	1985	20	Fillets	EPA method 608 (0.0008 ppm)	ND-0.113	NS	90	KDHE 1988
<i>trans</i>	Atchafalaya River basin (Louisiana)	June 1981	NS	Whole fish, composite	GC/ECD (NS)	ND-0.1	NS	NS	Winger and Andreasen 1985
<i>cis</i> and <i>trans</i>	Chesapeake Bay and tributaries (Maryland)	1980	24	Fillets <sup>i</sup>	GC/ECD (0.001 ppm wet wt.)	0.004-0.31	0.12	NS	Eisenberg and Topping 1985
<i>cis</i> and <i>trans</i>	Chesapeake Bay and tributaries (Maryland)	1979	98	Fillets <sup>i</sup>	GC/ECD (0.001 ppm wet wt.)	ND-0.70	0.08	NS	Eisenberg and Topping 1985

TABLE 5-6. Detection of Chlordane in Aquatic Organisms (continued)

Isomer	Sampling location	Dates	No. of samples	Sample type	Analytical method (detection limit)	Concentration (ppm)		% Occurrence	Reference
						Range	Mean		
<i>cis</i> and <i>trans</i>	Chesapeake Bay and tributaries (Maryland)	1978	15	Fillets <sup>1</sup>	GC/ECD (0.001 ppm wet wt.)	ND-0.50	0.013	NS	Eisenberg and Topping 1985
<i>cis</i> and <i>trans</i>	San Joaquin River and tributaries (California)	July 1981	8	Whole fish, composite <sup>1</sup>	GC/ECD (0.004 ppm wet wt.)	ND-0.021	0.011	50	Saiki and Schmitt 1986
<i>cis</i> and <i>trans</i>	San Joaquin River and tributaries (California)	July 1981	8	Whole fish, composite <sup>b</sup>	GC/ECD (0.004 ppm wet wt.)	0.012-0.273	0.077	100	Saiki and Schmitt 1986
<i>cis</i> and <i>trans</i>	Lake Ontario (4 sites)	1977-1988	1,718	Whole fish	GC/ECD	0.04-0.14 <sup>ck</sup>	NS	NS	Borgmann and Whittle 1991
<i>cis</i> and <i>trans</i>	Major United States watersheds (112 sites) <sup>1</sup>	1984	321	Fish tissue, composite	GC/ECD	<1.01 <sup>m</sup>	0.06	85 <sup>n</sup>	Schmitt et al. 1990
chlordanes <sup>o</sup>	Major United States watersheds (112 sites) <sup>1</sup>	1984	321	Fish tissue, composite	GC/ECD	<2.75 <sup>p</sup>	0.11 <sup>a</sup>	89 <sup>n</sup>	Schmitt et al. 1990
<i>trans</i>	Lower Mississippi basin	7/87-8/87	17 <sup>u</sup>	Whole catfish	GC/MS	0.011-0.170	0.062	100	Leiker et al. 1991
Oysters: <i>cis</i>	Gulf of Mexico (49 site) <sup>f</sup>	1986	147	Composite	GC/ECD	0.91-96.3 <sup>s</sup>	10.9	100	Sericano et al. 1990
<i>cis</i>	Gulf of Mexico (48 site) <sup>f</sup>	1987	143	Composite	GC/ECD	0.65-292 <sup>t</sup>	14.1	100	Sericano et al. 1990

TABLE 5-6. Detection of Chlordane in Aquatic Organisms (continued)

Isomer	Sampling location	Dates	No. of samples	Sample type	Analytical method (detection limit)	Concentration (ppm)		% Occurrence	Reference
						Range	Mean		
Clams:									
<i>cis</i> and <i>trans</i>	Portland (Maine)	November 1980	2	Whole body, composite	GC/FID (0.00003 ppm)	ND-0.0018	NS	50	Ray et al. 1983

<sup>a</sup>107 stations located at key locations in major rivers throughout the United States and the Great Lakes

<sup>b</sup>Carp

<sup>c</sup>Lake trout

<sup>d</sup>Expressed on a lipid basis

<sup>e</sup>Whitefish

<sup>f</sup>Herbivores (gizzard shad)

<sup>g</sup>Detritivores (carp, channel catfish, smallmouth buffalo, river carpsucker)

<sup>h</sup>Carnivores (striped bass, white crappie, largemouth bass, blue catfish, flathead catfish)

<sup>i</sup>Finfish

<sup>j</sup>Bluegill sunfish

<sup>k</sup>Range of annual logarithmic means

<sup>l</sup>National Contaminant Biomonitoring Program

<sup>m</sup>Highest station mean Honolulu, HI (0.6 ppm), next highest station (0.3 ppm), Saugatuck, MI

<sup>n</sup>positive sites (for isomer with highest number of positive sites)

<sup>o</sup>*cis*- and *trans*-chlordane, oxychlordane, and *cis*- and *trans*-nonachlor

<sup>p</sup>Highest station mean in Honolulu, HI (1.8 ppm), next highest station (0.8 ppm), Saugatuck, MI. Component composition is 1.00 ppm *trans*-nonachlor, 0.66 ppm *cis*-chlordane, 0.45 ppm *cis*-nonachlor, 0.35 ppm *trans*-chlordane, 0.29 oxychlordane

<sup>q</sup>Component composition is 0.03 *trans*-nonachlor, 0.03 ppm *cis*-chlordane, 0.02 ppm *cis*-nonachlor, 0.02 ppm *trans*-chlordane, 0.01 ppm oxychlordane

<sup>r</sup>NOAA's Status and Trends Mussel Watch Program

<sup>s</sup>The range, mean, and frequency for *trans*-nonachlor is 0.60-71.9 ppb, 10.0 ppb, 100%.

<sup>t</sup>The range, mean, and frequency for *trans*-nonachlor is <0.25-289 ppb, 11.6 ppb, 99%.

<sup>u</sup>Sites; number of fish per site varied from 1 to 4

GC/ECD = gas chromatography/electron capture detector; GC/FID = gas chromatography/flame ionization detector; GC/MS = gas chromatography/mass spectroscopy; EPA = Environmental Protection Agency; MID GC/MS = multiple ion detector-gas chromatography/mass spectroscopy; ND = not detected; NS = not stated

TABLE 5-7. Detection of Chlordane in Terrestrial Organisms<sup>a</sup>

Species/location	Sampling dates	No. of samples	Sample type	Analytical method	Concentration (ppm)		% Occurrence	Reference
					Range	Mean		
Birds:								
Herons, egrets, kingfishers, sandpipers:								
Corpus Christi, TX	1983	10	Eggs	GC/ECD	ND-0.88	0.14 <sup>b</sup>	NS	White and Krynitsky 1986
Loving, NM	1983	10	Eggs	GC/ECD	ND	ND	NS	White and Krynitsky 1986
Artesia, NM	1983	10	Eggs	GC/ECD	ND-0.36	0.07 <sup>b</sup>	NS	White and Krynitsky 1986
Louisiana	1978-1979	<10	Whole body	GC/ECD	<0.05	ND	NS	Dowd et al. 1985
Colorado, Wyoming	1979	147	Eggs	GC/ECD + MS	0.08-0.23 <sup>c</sup>	0.14	5.4	McEwen et al. 1984
United States	1966-NS	105	Carcass	GC/ECD + MS	ND-1.8 <sup>d</sup>	NS	23.8	Ohlendorf et al. 1981
United States	1966-NS	48	Brains	GC/ECD + MS	ND-1.4	NS	42.2	Ohlendorf et al. 1981
Sheboygan River, WI	1976-1980	11	Carcass, brains	GC/ECD + MS	ND-0.22	NS	NS	Heinz et al. 1984
Red-footed booby, sooty tern and shearwater:								
Hawaii	1980	143	Eggs, stomach	GC/ECD + MS	ND	ND	0	Ohlendorf and Harrison 1986
Brown or white pelicans:								
Louisiana	1971-1976	117	Eggs	GC/ECD	ND-1.31	0.36	NS	Blus et al. 1979
Klamath Basin, CA	1969-1981	45	Eggs	GC/MS	<0.1-0.12	NS	6.7	Boellstorff et al. 1985
Comorant, black skimmer, western grebe:								
Galveston Bay, TX	1980-1981	6	Eggs	GC/ECD + MS	ND-0.6	NS	<50	King and Krynitsky 1986
Galveston Bay, TX	1980-1982	13	Eggs	GC/ECD + MS	ND-0.7	NS	<50	King and Krynitsky 1986
South Texas and Mexico	1983	30	Carcass	NS	<0.1-<0.3	NS	20	White et al. 1985
Klamath Basin, CA	1981	12	Eggs	GC/MS	<0.1-0.25 <sup>c</sup>	NS	>16.7	Boellstorff et al. 1985
Clapper rails, gallinules and limpkins, dunlins:								
Avalon, NJ	1973	NS	Carcass	GC/ECD + MS	ND-0.12 <sup>f</sup>	NS	NS	Klaas and Belisle 1977
VA, SC, NJ	1972-1973	49	Eggs	GC/ECD + MS	ND-<0.10 <sup>f</sup>	NS	20 <sup>e</sup>	Klaas et al. 1980
FA, SC, LA	1973-1974	NS	Eggs	GC/ECD + MS	ND	ND	0	Klaas et al. 1980
Sarnish Bay, WS	1980	8	Whole body	GC/MS	0.008-0.06	0.02	100	Schick et al. 1987
Bowerman Basin, WS	1980	5	Whole body	GC/MS	0.003-0.005	0.004	100	Schick et al. 1987

TABLE 5-7. Detection of Chlordane in Terrestrial Organisms<sup>a</sup> (continued)

Species/location	Sampling dates	No. of samples	Sample type	Analytical method	Concentration (ppm)		% Occurrence	Reference
					Range	Mean		
<b>Gulls, common eider:</b>								
Virginia, Maine	1977	116	Eggs	GC	0.00-0.50 <sup>f</sup>	0.09 <sup>c</sup>	>26.7	Szaro et al. 1979
Appledore Island, MA	1977	30	Eggs	GC	ND	ND	0	Szaro et al. 1979
Appledore Island, MA	1977	28	Eggs	GC	0.0-0.50	0.04	21.4	Szaro et al. 1979
Appledore Island, MA	1977	28	Eggs	GC	0.0-0.43 <sup>f</sup>	0.22	96.4	Szaro et al. 1979
Galveston, TX	1980-1981	10	Eggs	GC/ECD + MS	0.1-1.2 <sup>c</sup>	0.29	>50	King and Krynetsky 1986
Bangs Island, MA	1977	30	Eggs	GC	ND	ND	0	Szaro et al. 1979
<b>Ducks:</b>								
Atlantic Flyway	1976-1977	NS	Wings	GC/ECD	0.01-0.06	NS	57	White 1979
Mississippi Flyway	1976-1977	NS	Wings	GC/ECD	0.01-0.02	NS	22	White 1979
Central Flyway	1976-1977	NS	Wings	GC/ECD	0.01-0.02	NS	14	White 1979
Pacific Flyway	1976-1977	NS	Wings	GC/ECD	0.01-0.02	NS	14	White 1979
United States	1981-1982	NS	Wings	GC/MS	<0.01-0.05	NS	10 <sup>g</sup>	Prouty and Bunck 1986
Chesapeake Bay, MD	1973, 1975	142	Carcass	GC/MS	ND-NS	0.19	6.3	White et al. 1979
<b>Osprey, eagles, owls, hawks:</b>								
Barnegat Bay, NJ	1971, 1974	9	Eggs	GC/ECD + MS	ND-0.55 <sup>e</sup>	0.20 <sup>c</sup>	78	Wiemeyer et al. 1978
Avalon-Stone Harbor, NJ	1979, 1972	8	Eggs	GC/ECD + MS	ND-0.08 <sup>e</sup>	0.03	50	Wiemeyer et al. 1978
United States	1964-1973	26	Carcass, brains	GC/ECD + MS	<0.1-1.7 <sup>e,h</sup>	NS	>69.2	Wiemeyer et al. 1980
United States	1971-1974	38	Carcass	GC/MS	NS	27 <sup>e</sup>	NS	Barbehenn and Reichel 1981
United States	1971-1974	38	Brain	GC/MS	NS	0.27 <sup>e</sup>	NS	Barbehenn and Reichel 1981
United States	1971-1974	24	Carcass	GC/MS	NS	15 <sup>f</sup>	NS	Barbehenn and Reichel 1981
United States	1971-1974	24	Brain	GC/MS	NS	0.15 <sup>f</sup>	NS	Barbehenn and Reichel 1981
United States	1969-1979	6	Eggs	GC/ECD + MS	ND-3.6	0.39 <sup>c</sup>	63.5	Wiemeyer et al. 1984
Maryland, Alabama	1978-1981	2	Carcass, brains	NS	1.1-2.4	1.65	100	Blus et al. 1983
Corvallis, OR	1980	1	Brains	NS	0.1	1.1	100	Blus et al. 1983

TABLE 5-7. Detection of Chlordane in Terrestrial Organisms<sup>a</sup> (continued)

Species/location	Sampling dates	No. of samples	Sample type	Analytical method	Concentration (ppm)		% Occurrence	Reference
					Range	Mean		
Starling: United States	1979, 1982	NS	Carcass	GC/MS	<0.01-0.04	0.02 <sup>c</sup>	3.3 <sup>i</sup>	Bunck et al. 1987
Pheasants: Kansas	1982-1983	NS	Carcass	NS	ND	ND	0	Layher et al. 1985
Other vertebrates:								
Turtles:								
Merritt Island National Wildlife Refuge, Laurel, MD	1979	56	Eggs	GC/ECD + MS	ND-<0.008 <sup>f</sup>	ND	28.6 <sup>f</sup>	Clark and Krynitsky 1985
New Jersey, Maryland	1981-1982	32	Visceral fat	GC/ECD + MS	ND->9.33 <sup>f</sup>	3.9 <sup>c</sup>	>88 <sup>f</sup>	Albers et al. 1986
Crocodile:								
Patuxent Wildlife Res. Cntr. Laurel, MD	1977-1978	23	Eggs	GC/ECD	<0.01-0.07	0.02 <sup>fc</sup>	87.5 <sup>j</sup>	Hall et al. 1979
Raccoon:								
Lake Verret, LA	1978-1979	<10	Leg muscles	GC/ECD	<0.05	ND	NS	Dowd et al. 1985
Plaquemine-Brule, LA	1978-1979	<10	Leg muscles	GC/ECD	<0.05	ND	NS	Dowd et al. 1985
East Franklin, LA	1978-1979	<10	Leg muscles	GC/ECD	<0.05-NS	0.017 <sup>k</sup>	NS	Dowd et al. 1985
Big brown bats:								
Gaithersburg, MD	1973	18	Carcass, brains	GC/ECD	ND-<0.40 <sup>f</sup>	NS	50	Clark and Lamont 1976
Earthworms:								
Holbrook, MA	NS	29 <sup>l</sup>	Whole body	GC/ECD	0.8-12.9	NS	45	Callahan et al. 1991
Insects:								
Moths:								
Washington, DC-Baltimore, MD	1977-1979	NS	Whole body	GLC/MS	<0.05-0.75	0.22	NS	Beyer and Kaiser 1984

TABLE 5-7. Detection of Chlordane in Terrestrial Organisms<sup>a</sup> (continued)

Species/location	Sampling dates	No. of samples	Sample type	Analytical method	Concentration (ppm)		% Occurrence	Reference
					Range	Mean		
Meadow grasshopper: Palermo, NJ	1973	NS	NS	GC/ECD + MS	ND-0.02 <sup>e</sup>	NS	NS	Klaas and Belisle 1977
Honey bees: Connecticut	1983-1985	NS	Whole body, 20 brood combs	GC/ECD	0.06-0.69 <sup>c</sup>	NS	7.5 <sup>m</sup>	Anderson and Wojtas 1986

<sup>a</sup>No distinction is made between the isomers of chlordane. In cases where the original papers made a distinction, the data were combined.

<sup>b</sup>Geometric mean

<sup>c</sup>Range of positive detections

<sup>d</sup>Oxychlordane and *trans*-nonachlor were reported in paper at ranges of ND-0.87 and ND-3.0 respectively

<sup>e</sup>*cis*-Chlordane and/or *trans*-nonachlor

<sup>f</sup>Oxychlordane included in mixture

<sup>g</sup>Value describes number of detections divided by the number of pools

<sup>h</sup>Oxychlordane was also detected, range = ND-0.15, frequency = >12%

<sup>i</sup>Percent of pools with detectable residues of organochlorine compounds

<sup>j</sup>*cis*-Chlordane, *trans*-nonachlor or oxychlordane was detected in 7 out of 8 clutches

<sup>k</sup>Mean was exceeded by the standard error

<sup>l</sup>Earthworms were exposed on-site for 7 days

<sup>m</sup>Chlordane was detected in 4 out of 57 apiaries

GC/ECD = gas chromatography/electron capture detector; GC/MS = gas chromatography/mass spectroscopy; ND = not detected; NS = not specified



TABLE 5-8. Detection of Chlordane in Human Samples<sup>a</sup>

Media type/location	Sampling dates	No. of samples	Sample type	Analytical method	Concentration (ppb)		% Occurrence	Reference
					Range	Mean		
<b>Human adipose tissue:</b>								
United States	1976-1980	785	General	GC/ECD + MS	ND->10 <sup>b</sup>	NS	95	Murphy et al. 1983
United States	NS	8	General	NCI/MS	ND->1	NS	87.5	Dougherty et al. 1980
Florida	1978	10	General	GC/ECD	ND	ND	0	Barquet et al. 1981
Florida	1978	10	General	GC/ECD	70-490 <sup>b</sup>	193	100	Barquet et al. 1981
United States	1972-1975	NS	General	GC/ECD + MS	ND->100 <sup>b</sup>	100 <sup>c</sup>	>90	Kutz et al. 1979
Bloomington, IN	1987-1988	23	Breast	GC/ECD + MS	0.6-10.2	2.0 <sup>d</sup>	100	Dearth and Hites 1991a
					42-260 <sup>b</sup>	88 <sup>d</sup>	100	
North Texas	1987-1988	35	Abdominal	GC/ECD	12-261 <sup>b,c</sup>	95 <sup>d,f</sup>	100	Adeshina and Todd 1990
Canada	1985	108	General	GC/ECD + MS	<11	4	100	Mes et al. 1990
					<103 <sup>b</sup>	33	100	
British Columbia, Canada	NS	25	Most abdominal <sup>g</sup>	GC/ECD	<134.20 <sup>h</sup>	42.5 <sup>i</sup>	100	Mes 1992
Japan <sup>j</sup>	1986-1988	23	NS	GC/ECD	130-2,160	670	100	Sasaki et al. 1991a
<b>Human blood sera:</b>								
United States	1976-1980	4,200	General	GC/ECD + MS	ND->1 <sup>b</sup>	NS	4	Murphy et al. 1983
Welds County, CO	1968	358	Nonoccupational	GC/ECD	ND	ND		Starr et al. 1974
Welds County, CO	1968	93	Farm	GC/ECD	ND	ND	0	Starr et al. 1974
Welds County, CO	1968	175	Occupational	GC/ECD	60-233 <sup>k</sup>	151	3.4	Starr et al. 1974
British Columbia, Canada	NS	25	Whole blood <sup>g</sup>	GC/ECD	<0.30 <sup>l</sup>	0.10 <sup>m</sup>	100	Mes 1992
Japan <sup>j</sup>	1986-1988	23	General	GC/ECD	ND-280	0.58	100	Sasaki et al. 1991a
Japan	1989-1990	240	General	GC-MS	0.06-3.85 <sup>n</sup>	0.34 <sup>o</sup>	100	Hirai and Tomokuni 1991b
<b>Human milk:</b>								
United States	NS	1,436	General	GC/ECD	ND->500 <sup>b</sup>	95.8	74	Savage et al. 1981
United States	NS	1,436	General	GC/ECD	ND	ND	0	Savage et al. 1981
Hawaii and U.S. mainland	1979-1980	156	General	GC/ECD	ND	ND	0	Takei et al. 1983
U.S. mainland	1979-1980	102	General	GC/ECD	ND-440	54	99	Takei et al. 1983
Hawaii	1979-1980	54	General	GC/ECD	11-550	68	100	Takei et al. 1983
France	1991	20	General	GC/ECD	ND-294 <sup>p</sup>	70 <sup>p</sup>	90	Bordet et al. 1993

TABLE 5-8. Detection of Chlordane in Human Samples<sup>a</sup> (continued)

Media type/location	Sampling dates	No. of samples	Sample type	Analytical method	Concentration (ppb)		% Occurrence	Reference
					Range	Mean		
Human seminal fluid: United States	NS	NS	General	GC/ECD	ND-detected	NS	NS	Dougherty et al. 1980

<sup>a</sup>No distinction is made between the isomers of chlordane. In cases where the original papers made a distinction, the data were combined.

<sup>b</sup>Oxychlordane

<sup>c</sup>Approximate number

<sup>d</sup>Geometric mean

<sup>e</sup>Occupational unexposed people

<sup>f</sup>Geometric mean (age group): 38 ppb (21–40 years), 88 ppb (41–60 years), 154 ppb (61+ years)

<sup>g</sup>Paired blood and biopsy fat samples from a selected patients. Relationship established for oxychlordane at 99% confidence level.

<sup>h</sup>Sum of oxychlordane (44.9),  $\alpha$ -chlordane (2.1),  $\gamma$ -chlordane (2.2), *trans*-nonachlor (74.0), and *cis*-nonachlor (11.0)

<sup>i</sup>Median. Sum of oxychlordane (16.5),  $\alpha$ -chlordane (0.3),  $\gamma$ -chlordane (0.5), *trans*-nonachlor (22.6), and *cis*-nonachlor (2.6)

<sup>j</sup>Total chlordane; same individuals sampled for adipose tissue and serum

<sup>k</sup>All positive samples were obtained from one individual

<sup>l</sup>Median. Sum of oxychlordane (0.07),  $\alpha$ -chlordane (0.02), and  $\gamma$ -chlordane (0.01)

<sup>m</sup>Sum of oxychlordane (0.16),  $\alpha$ -chlordane (0.05),  $\gamma$ -chlordane (0.05), and *trans*-nonachlor (0.04)

<sup>n</sup>Nonachlor. Ranges for chlordane and oxychlordane are ND–0.60 ppb and ND–0.62, respectively.

<sup>o</sup>Median

<sup>p</sup>ng of  $\alpha$ -chlordane plus  $\gamma$ -chlordane/g of milk fat

GC/ECD = gas chromatography/electron capture detector; GC/MS = gas chromatography/mass spectroscopy; NCI/MS = Negative chemical ionization/mass spectroscopy; ND = not detected; NS = not specified

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80 million people. Of these structures,  $\approx 65\%$  were treated with chlordane, or 19.5 million structures, resulting in the exposure of 52 million people. The exact concentrations they were exposed to are difficult to estimate from the available data. A Japanese study showed that the concentration of chlordane and oxychlordane in the milk fat of lactating women living in chlordane-treated houses was 13.8 and 33.6 ppb, respectively, versus 3.6 and 19.3 ppb for unexposed controls (Taguchi and Yakushiji 1988). Chlordane and oxychlordane levels in milk increased with years since treatment.

A major study of general population exposure to pesticides, including chlordane, was included in the Nonoccupational Pesticide Exposure Study (NOPES) (EPA 1990b). This study applied probabilistic population sampling techniques, indoor, outdoor, and personal breathing zone air monitoring, and human activity pattern data for multiple routes of exposure to assess total human exposure. These techniques were applied to the communities of Jacksonville, Florida, and Springfield/Chicopee, Massachusetts, over three and two seasons, respectively. For Jacksonville, the personal breathing zone air concentration was relatively stable, and the yearly means for 1986-1988 ranged from 191 to 212 ng/m<sup>3</sup> over all three seasons, with 50-93% of samples containing detectable levels of chlordane. The corresponding results for Springfield/Chicopee was 36 ng/m<sup>3</sup> in winter and 253 ng/m<sup>3</sup> in the spring; 50-87% of the samples had detectable levels of chlordane. Several observations were made from the study. Indoor levels of chlordane are highest in summer and lowest in winter. They were higher in older housing units and households with reported termiticide use. For chlordane, mean air exposure in homes with detectable levels of chlordane was always much higher ( $\sim 25$  times) than exposure from food. Routine sampling of the public water supplies prior to NOPES and tap water in Jacksonville, Florida, and Springfield/Chicopee, Massachusetts, revealed no detectable levels of chlordane in drinking water.

In addition to living in chlordane-treated structures, ingestion of contaminated food is another major route of exposure. Duggan et al. (1983) and Gartrell et al. (1985a, 1985b, 1985c, 1985d, 1986a, 1986b) have estimated yearly dietary intake of chlordane since 1965 for 16- to 19-year-old males. In more recent years, toddlers and infants have been included in these estimates (Gunderson 1988). FDA (1989a, 1990, 1991) has estimated dietary chlordane intake for various age/sex groups for 1982-1984, 1989, 1990, and 1991. Their results are listed in Table 5-9. The data show a relatively steady intake over the years from 1977 to 1982, indicating that chlordane residues had not decreased significantly in agricultural soils (if that is where the chlordane originates). In addition, infants and toddlers will generally have higher intakes of chlordane than adults because of the high fat content of the foods they

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**TABLE 5-9. Chlordane Intake from Food<sup>a</sup>**

Year	Chlordane Intake ( $\mu\text{g}/\text{kg}$ body weight/day)			
	14- to 19-Year-old males <sup>c</sup>	60- to 65-Year-old females	Toddlers	Infants
1965-1970	Not detected	Not reported	Not performed	Not performed
1971	Not detected	Not reported	Not performed	Not performed
1972	0.01	Not reported	Not performed	Not performed
1973	Trace	Not reported	Not performed	Not performed
1974	Trace	Not reported	Not performed	Not performed
1975	Trace	Not reported	Not performed	Not performed
1976	Trace	Not reported	Not performed	Not performed
1977	0.004	Not reported	0.005	0.001
1978	0.004	Not reported	0.032	0.010
1979	0.004	Not reported	0.003	<0.001
1980	0.003	Not reported	0.005	0.003
1981-1982	0.004	Not reported	0.003	0.002
1984 <sup>b</sup>	0.0025	0.0026	0.0065	0.0051
1989 <sup>d</sup>	0.0007	0.0010	Not reported	0.0007
1990 <sup>d</sup>	0.0001	0.0001	Not reported	0.0001
1991 <sup>d</sup>	0.0005	0.0015	Not reported	0.0013

<sup>a</sup>Duggan et al. 1983, Gartrell et al. 1985a, 1985b, 1985c, 1985d, 1986a, 1986b; unless otherwise indicated

<sup>b</sup>Gunderson 1988

<sup>c</sup>16- to 19-year-old males for studies in year 1965-1982, 14- to 16-year-old males for studies 1984-1991

<sup>d</sup>FDA 1989, 1990, 1991

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eat (Table 5-9). The results for the 1991 FDA Total Diet Study are 0.0013  $\mu\text{g}/\text{kg}/\text{day}$  for infants and 0.0005-0.0015  $\mu\text{g}/\text{kg}/\text{day}$  for teenagers and adults (FDA 1991). The total daily dietary intake of chlordane per unit body weight, according to results of the 1982-1984 FDA's Total Diet Study is 0.0051  $\mu\text{g}/\text{kg}/\text{day}$  for infants, 0.0065  $\mu\text{g}/\text{kg}/\text{day}$  for toddlers, and 0.002-0.0027  $\mu\text{g}/\text{kg}/\text{day}$  for teenagers and adults (Gunderson 1988). The Total Diet Study analyzes foods prepared for consumption. After 1982, 234 foods were selected to represent 5,000 different food items identified in dietary surveys.

Dermal exposures may result from children or adults coming into contact with contaminated soils or house dust near treated houses, lawns, or gardens. Dermal exposures cannot be quantified with the available information.

Previous exposure to chlordane is often gauged by the concentration of chlordane compounds (usually oxychlordane) in human adipose tissue. According to EPA's National Human Monitoring Program and other broad based U.S. surveys, the geometric mean concentration of oxychlordane in human adipose tissue has ranged from 90 to 120 ppb between 1971 and 1983 with no clear temporal trend (Adeshina and Todd 1990; Kutz et al. 1991). North Texas and Canadian studies show increasing oxychlordane levels with age in selected age groups, but no difference in levels according to sex (Adeshina and Todd 1990; Mes et al. 1990). It is not clear whether higher oxychlordane levels in older age groups are due primarily to longer exposure or decreased use of chlordane.

Workers may be exposed to chlordane during its manufacture, formulation, shipping, storage, application, and disposal. The National Occupational Exposure Survey (NOES) conducted by NIOSH from 1981 to 1983 estimated that 3,732 workers were potentially exposed to chlordane in the workplace in the United States (NIOSH 1989a). The NOES was based on field surveys of 4,490 businesses employing nearly 1.8 million workers and was designed as a nationwide survey based on a statistical sample of virtually all workplace environments in the United States in which eight or more persons are employed in all standard industrial codes except mining or agriculture.

Workplace monitoring data are available from two studies conducted simultaneously by Velsicol (Cahill et al. 1979) and the State of California (Maddy et al. 1979). In these studies, patches were attached to the inside and outside of the applicators' coveralls, and breathing zone air was monitored while chlordane was applied to six houses (three with a crawl space and three on a concrete slab). Cahill et al. (1979) reported that 0.015-7.96  $\text{mg}/\text{cm}^2$  (median 0.175  $\text{mg}/\text{cm}^2$ , 24 samples) was found on

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the 100 cm<sup>2</sup> denim patches attached just above the knees and elbows of the applicators coveralls, whereas Maddy et al. (1979) found 0.005-2.9 mg/cm<sup>2</sup> (median 0.12 mg/cm<sup>2</sup>, 23 samples) for 100 cm<sup>2</sup> duck cotton cloth (similar to denim) patches attached below the knees and elbows. Concentrations inside the coveralls were determined by Cahill et al. (1979) by attaching a denim patch to the work pants (worn under the coveralls) at the knee and to the inside of the coveralls at the elbow (but not overlapping the outside elbow patch). Maddy et al. (1979) determined inside concentrations by attaching eight layers of cotton cheese cloth backed by aluminum foil to the inner surface of the duck cloth patches attached below the knees and elbows of the applicators. Cahill et al. (1979) found 0.0053-0.127 mg/cm<sup>2</sup> (median 0.024 mg/cm<sup>2</sup>, 24 samples) on the inside patches, whereas Maddy et al. (1979) found 0.009-1.9 mg/cm<sup>2</sup> (median 0.082 mg/cm<sup>2</sup>, 23 samples) on the cheese cloth backing.

Air impingers were worn by the applicators both on the lapel and on the chin inside the respirator. Air concentrations were reported for both inside and outside the respirator by Maddy et al. (1979), but only one value was reported by Cahill et al. (1979). Cahill et al. (1979) reported finding chlordane in all four samples analyzed (0.16-14.2 mg/m<sup>3</sup>), whereas Maddy et al. (1979) found 0.007, 0.008, and 0.110 mg/m<sup>3</sup> in three of five samples taken outside the respirator and 0.011 and 0.27 mg/m<sup>3</sup> in two of six samples taken inside the respirator. No detection limit was reported by Maddy et al. (1979); therefore, no information is available concerning the samples with concentrations too low to detect.

Kamble et al. (1992) studied the exposure of 29 commercial applicators exposed to Termide<sup>®</sup> EC (technical chlordane 39.22% plus heptachlor 19.6%), diluted to 0.75% (active ingredient) during subterranean termite treatment of homes. Dermal exposure was monitored using 14 gauze pads for each applicator attached to exterior and interior parts of clothing for an average duration of 138 minutes. Exposure to hands was monitored by hand rinses immediately after application. Respiratory exposure was assessed with personnel-type air samplers (see Table 5-2). Total dermal exposure to applicators to chlordane was 2.5 µg/kg/hour. The most exposed body regions in descending order were: hands, forearms, head, lower legs, thighs, back trunk, front trunk, upper arms, and back neck. Approximately 25% of the chlordane on the exterior surface of clothing was likely to penetrate through the fabric. Respiratory exposure was 0.04 µg/kg/hour.

Elia et al. (1983) reported that chlordane was detected in the water and air of a sewage treatment plant near Memphis, Tennessee, and suggested that occupational exposures to semi-volatile compounds such as chlordane could occur at these plants. No chlordane data, however, were presented. Former

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occupational exposures, in addition to termite control, include chlordane manufacturing, formulation, distribution, and agricultural and lawn care pesticide application. Since chlordane is no longer used commercially in the United States (EPA 1988c), many of these occupational exposures no longer exist. No data are available that would allow the estimation of workplace levels during manufacture and use.

**5.6 POPULATIONS WITH POTENTIALLY HIGH EXPOSURES**

A segment of the general population with potentially high exposure to chlordane includes those people living in structures that have been treated with chlordane for termite control or people digging in soil around these houses. The majority of these structures are located in the deep south and far southwest where termites are a significant problem, but moderate to heavy use of chlordane extended from Pennsylvania and the lower New England states south and west to the lower portion of Colorado and up to northern California. The available data indicate that these exposures will be much greater than exposures from other sources of chlordane. Persons involved in the manufacture of chlordane and persons involved in the application of chlordane before its use was banned on April 14, 1988 may have been exposed to relatively high levels. Similarly, lawn care workers and farmers that handled chlordane before above-ground uses were banned may have been exposed to high levels of the chemical. Populations living near waste disposal sites containing chlordane may have been exposed to elevated levels of chlordane.

**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 chlordane 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 chlordane.

The following categories of possible data needs have been identified by a joint team of scientists from ATSDR, NVP, 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.** The physical and chemical properties of chlordane listed in Table 3-2 are not complete. These properties are difficult to specify since the technical product is a mixture of over 140 compounds. The composition of technical chlordane varies according to conditions during its manufacture. In addition, properties of a mixture differ from the properties of the components. Even minor components can affect physical and chemical properties. Some of the properties reported in Table 3-2 are those of particular components such as *cis*- and *trans*-chlordane. The value for log  $K_{ow}$  listed in Table 3-2 is a particularly crude estimate for technical chlordane since this value was estimated for the chlordane structure. In addition the values for water solubility of chlordane vary widely. This is probably due to differences in composition of the chlordane studied. Suntio et al. (1988) and Weil et al. (1974) did not indicate whether the chlordane used in their studies was technical grade or a mixture of chlordane isomers. Despite the limitations discussed above, the physical chemical properties available for chlordane are adequate to estimate its partitioning in the environment. More significantly, there are numerous monitoring studies that have been performed over several decades that give us this information concerning chlordane's fate in the environment.

**Production, Import/Export, Use, Release, and Disposal.** Although the use of chlordane in the United States has been banned since April 1988, chlordane is still manufactured for export. Since chlordane is extremely persistent in the environment, knowledge of the former use pattern for this compound is useful in making estimations concerning potential for human exposure and sources of release. Environmental burdens of chlordane can be roughly estimated by relying on production and use data and by using a few basic assumptions. Production methods for chlordane are documented in the literature, however recent production volumes are not available. A breakdown of the former uses of chlordane and its use pattern is available, which indicates that chlordane was widely used in the home, on food and nonfood crops, and on lawns and gardens. Disposal information is useful in determining environmental burden and potential concentrations where environmental exposures may be high. This type of information may be obtained by polling the manufacturer or other commercial organizations to determine methods of chlordane disposal. For example, asking exterminators how they disposed of contaminated materials or unused product may provide disposal information for much



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of the chlordane not directly applied to soils or dwellings. Current disposal practices are not known. Chlordane has been designated as a hazardous waste, and regulations guide the disposal of such waste. Chlordane is also regulated in effluent by provisions of the Clean Water Act.

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 1988, became available in May of 1990. This database will be updated yearly and should provide a list of industrial production facilities and emissions.

**Environmental Fate.** Data are available (Atallah et al. 1979; Atlas and Giam 1988; Beeman and Matsumura 1981; Bennett et al. 1974; Bidelman et al. 1987; Bidleman and Foreman 1987; Bidleman et al. 1986; Cotham and Bidleman 1991; Foreman and Bidleman 1987; Glotfelty and Schomburg 1989; Glotfelty et al. 1984; Gustafson 1989; Jury et al. 1987a; Lau et al. 1989; Oliver and Niimi 1985; Oloffs et al. 1972, 1973; Pacynba and Oehme 1988; Singh et al. 1991; Zarogian et al. 1985) to characterize the partitioning and transport of chlordane. We also know from monitoring studies that chlordane is very persistent in soil, lasting over 20 years in some soils (Beeman and Matsumura 1981; Bennett et al. 1974; Harris and Sans 1976; Lichtenstein and Schulz 1959; Mullins et al. 1971; Nash and Woolson 1967; Stewart and Chisholm 1971; Stewart and Fox 1971; Szeto and Price 1991; Tafuri et al. 1977; Wiese and Basson 1966). However, chlordane's degradation products in soil have not been reported. However, more information would be useful on the transformation of chlordane in the environment. There are data needs regarding biodegradation and photolysis of chlordane in water systems and oxidation of this compound in air. Natural water grab sample biodegradation studies carried out under both aerobic and anaerobic conditions would be useful in establishing the biodegradation half-life of chlordane. A number of studies have been carried out that show chlordane is photolyzed in air; however, there is a lack of data pertaining to photolysis of chlordane that is adsorbed to particulate matter in air or in water and its significance for the removal of chlordane from these media. A photolysis study carried out under conditions simulating those found in the environment would be useful in establishing the significance of this reaction in air and natural waters. One of the dominant removal mechanisms for vapor phase chlordane in air is expected to be reaction with photochemically generated hydroxyl radicals; however, no experimental data are available concerning the kinetics of this reaction, the reaction pathway, or the products of these types of

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reactions. Photolysis, photooxidation, and biodegradation of particulate-bound chlordane is unknown. These types of data would be useful in understanding the fate of this compound in the environment.

**Bioavailability.** Data are available that correlate length of exposure to atmospheric chlordane and levels of chlordane and/or metabolites in human blood and milk (Kawano and Tatsukawa 1982; Saito et al. 1986; Taguchi and Yakushiji 1988; Takamiya 1987). Similar data are not available for human exposure to chlordane in water or soil. A deficiency in the inhalation studies is that exposure concentrations have not been quantified. Therefore it is not possible, based on current knowledge, to correlate levels of chlordane and/or metabolites in human biosamples with specific concentrations in air, soil, or water. Studies in animals may provide valuable information regarding bioavailability and bioaccumulation of chlordane residues from air, water, and soil.

**Food Chain Bioaccumulation.** Chlordane has been found to bioconcentrate in marine and freshwater fish and shellfish, and biomagnify in animals that prey upon these fish. Available data indicate that organisms that have bioaccumulated chlordane are geographically distributed across the United States. This type of information is useful in determining how levels in the environment affect the food chain and potentially impact on human exposure levels.

**Exposure Levels in Environmental Media.** In general, the monitoring database for chlordane is not very broadly based or recent. Data for soils are especially out of date. Chlordane levels in soil and sediment are particularly important, as these are the repositories for chlordane, and broadly-based monitoring data in these media are the best way of assessing environmental trends.

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

**Exposure Levels in Humans.** Estimates have been made for the human intake of chlordane from food, air, and water. Chlordane has been measured in adipose tissue, blood, serum, sebum, and seminal fluid. Only data in adipose tissue is of recent origin.

This information is necessary for assessing the need to conduct health studies on these populations.

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**Exposure Registries.** No exposure registries for chlordane 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 On-going Studies

ATSDR has funded a grant to the Missouri Department of Health to determine exposure levels from consuming fish from selected Missouri rivers and to better quantify the risk of eating contaminated fish (ATSDR 1992). This study will compare the serum levels of chlordane and other organochlorine compounds in different groups of people. Results are expected in FY 1992. A study on the transport and degradation of organic substances in streams is investigating whether differences in the concentrations of chlordane and nonachlor can be used to distinguish whether these compounds resulted from resuspension of bottom sediments or from surface runoff (Rathbun 1992). Work is continuing on the degradation of chlordane by white rot fungi and its enzymes (Aust 1992). Work is starting on a project that is designed to build a database of chlordane and other contaminant concentrations in the most contaminated tributaries emptying into Lake Michigan in northeast Indiana and using this information will be used to assess contaminant mobility and loading into Lake Michigan (FEDRIP 1993).