# CHAPTER 5. POTENTIAL FOR HUMAN EXPOSURE

5.1 OVERVIEW

Chlordane has been identified in at least 285 of the 1,854 hazardous waste sites that have been proposed for inclusion on the EPA National Priorities List (NPL) (ATSDR 2017). However, the number of sites in which chlordane has been evaluated is not known. The number of sites in each state is shown in Figure 5-1. Of these sites, 283 are located within the United States and 1 is located in Puerto Rico (not shown).

Figure 5-1. Number of NPL Sites with Chlordane Contamination

Source: ATSDR 2017

Frequency of
NPL Sites
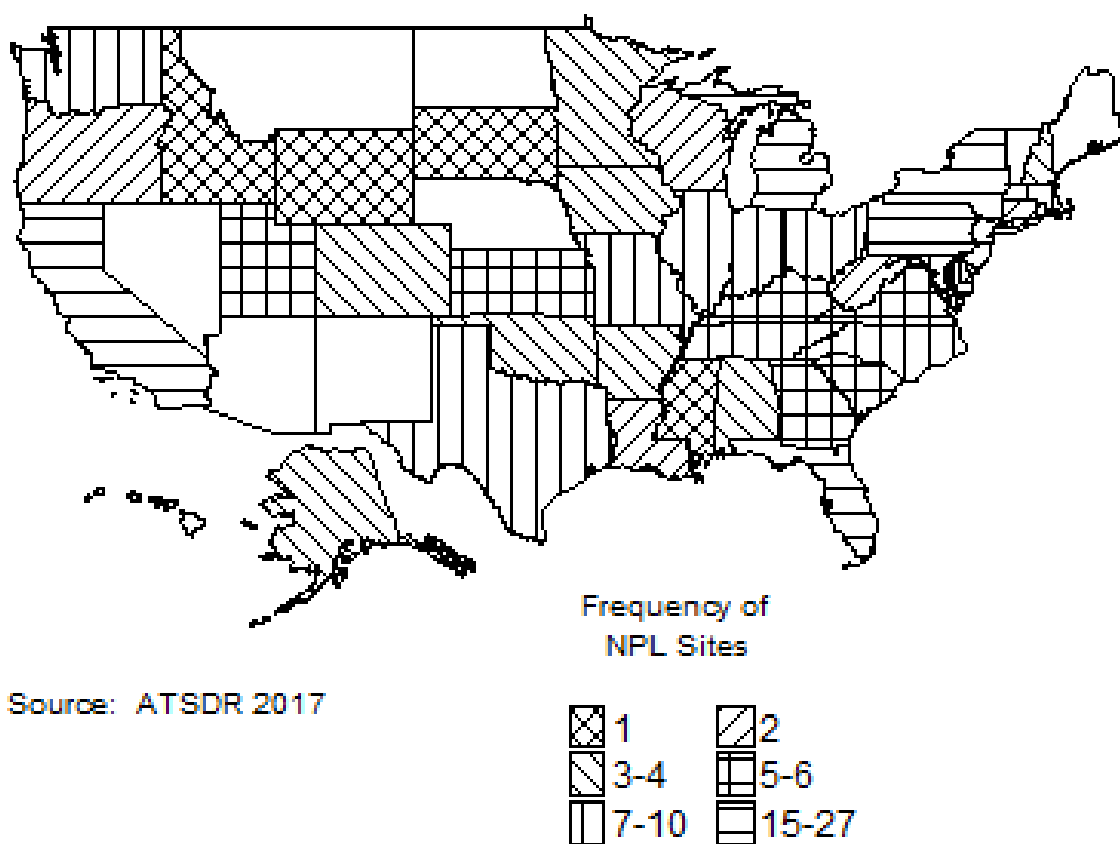
1 2
3-4 5-6
7-10 15-27

- The most likely sources of potential exposure of the general population to chlordane are from exposure in homes that were treated with chlordane to control termites or eating chlordane-contaminated food or drinking water than may have been contaminated from chlordane when it was used as a pesticide prior to 1988.

- People who live near hazardous waste sites containing chlordane may be exposed from contaminated air, surface water or groundwater, or soil.
- Daily intakes from food have been estimated.
- Chlordane would be expected to volatilize from surface water and surface soil; in air, chlordane is expected to degrade by photolysis and oxidation. Residues in soil that do not leach or volatilize appear to be persistent.

5.2 PRODUCTION, IMPORT/EXPORT, USE, AND DISPOSAL

5.2.1 Production

Chlordane is produced by chlorinating cyclopentadiene to form hexachlorocyclopentadiene and condensing the latter with cyclopentadiene to form chlordene. The chlordene is further chlorinated at high temperature and pressure to chlordane (Dearth and Hites 1991c; Whetstone 1964). EPA (1987g) estimated that ≈3.5–4.0 million pounds of chlordane were distributed in 1986. In 1990, Velsicol Chemical Company in Memphis, Tennessee, was the only U.S. manufacturer of chlordane; between 100,000 and 1 million pounds of chlordane were produced (SRI 1990; TRI90 1992). It was the only domestic manufacturer of chlordane at the time that the EPA canceled its registration for commercial production, delivery, sale, and use in the United States (EPA 1988c; SRI 1988). This cancellation became effective April 14, 1988 (EPA 1988c). Technical heptachlor contains 20–22% *trans*-chlordane (Kutz et al. 1991). The registration of heptachlor was also canceled by EPA. Table 5-1 summarizes information on U.S. companies that manufactured or used chlordane in 2016 (TRI16 2017).

Table 5-1. Facilities that Produce, Process, or Use Chlordane

State[a]	Number of facilities	Minimum amount on site in pounds[b]	Maximum amount on site in pounds[b]	Activities and uses[c]
AR	1	100,000	999,999	9, 12
CA	1	100	999	12
ID	1	1,000	9,999	12
IL	1	0	99	12
IN	1	0	99	1, 2, 9, 13, 14
NE	1	10,000	99,999	12
OH	2	100	99,999	12
OR	1	10,000	99,999	12
TX	2	1,000	99,999	1, 5, 11, 12

Table 5-1. Facilities that Produce, Process, or Use Chlordane

State[a]	Number of facilities	Minimum amount on site in pounds[b]	Maximum amount on site in pounds[b]	Activities and uses[c]
UT	1	100,000	999,999	9, 12
VA	1	100	999	9

[a]Post office state abbreviations used.
[b]Amounts on site reported by facilities in each state.
[c]Activities/Uses:

1. Produce	6. Impurity	11. Chemical Processing Aid
2. Import	7. Reactant	12. Manufacturing Aid
3. Onsite use/processing	8. Formulation Component	13. Ancillary/Other Uses
4. Sale/Distribution	9. Article Component	14. Process Impurity
5. Byproduct	10. Repackaging	

Source: TRI16 2017 (Data are from 2016)

5.2.2   Import/Export

Chlordane is not produced in the United States and is not imported from any sources.

5.2.3   Use

As of April 14, 1988, all commercial use of chlordane in the United States was canceled (EPA 1988c).
Between July 1, 1983 and April 14, 1988, the sole use for chlordane was to control subterranean termites
(EPA 1987g). For this purpose, chlordane was applied primarily as a liquid that was poured or injected
around the foundation of a building (Wallace 1991). Chlordane, in conjunction with heptachlor, was at
one time widely used as a pesticide for the control of insects on various types of agricultural crops and
vegetation. The use pattern for chlordane in the mid-1970s was as follows: 35% used by pest control
operators, mostly on termites; 28% on agricultural crops, including corn and citrus; 30% for home lawn
and garden use; and 7% on turf and ornamentals (HSDB 1988). On March 6, 1978, a final cancellation
notice was issued, which called for the suspension of the use of chlordane except for subsurface injection
to control termites and for dipping roots and tops of nonfood plants. Minor use of chlordane for treating
nonfood plants was canceled by 1983 (EPA 1987g). The use of chlordane decreased drastically in the
1970s when EPA moved to cancel all uses other than subterranean termite control (Kutz et al. 1991).

5.2.4   Disposal

Chlordane may be disposed of by dissolving it in a flammable solvent and incinerating it under controlled conditions. The incinerator should be equipped with an afterburner and an acid scrubber to remove halo acids from the effluent gas, and adequate ash disposal procedures should be followed (EPA 1991; HSDB 1988; OHM-TADS 1988). Before disposing waste residue containing chlordane (including waste sludge) on land, environmental regulatory agencies should be consulted for guidance on acceptable disposal practices (HSDB 1988). EPA promulgated standards for the disposal of waste chlordane in sewage sludge (EPA 1993).

In situ vitrification is a thermal treatment technology in which substantial quantities of energy are introduced into contaminated soil, thereby destroying organic compounds and immobilizing inorganic compounds (Dragun 1991). This technology has been applied to chlordane-contaminated soils.

5.3   RELEASES TO THE ENVIRONMENT

The Toxics Release Inventory (TRI) data should be used with caution because only certain types of facilities are required to report (EPA 2005). This is not an exhaustive list. Manufacturing and processing facilities are required to report information to the TRI only if they employ ≥ 10 full-time employees; if their facility is included in Standard Industrial Classification (SIC) Codes 10 (except 1011, 1081, and 1094), 12 (except 1241), 20–39, 4911 (limited to facilities that combust coal and/or oil for the purpose of generating electricity for distribution in commerce), 4931 (limited to facilities that combust coal and/or oil for the purpose of generating electricity for distribution in commerce), 4939 (limited to facilities that combust coal and/or oil for the purpose of generating electricity for distribution in commerce), 4953 (limited to facilities regulated under RCRA Subtitle C, 42 U.S.C. section 6921 et seq.), 5169, 5171, and 7389 (limited S.C. section 6921 et seq.), 5169, 5171, and 7389 (limited to facilities primarily engaged in solvents recovery services on a contract or fee basis); and if their facility produces, imports, or processes $\geq 25,000$ pounds of any TRI chemical or otherwise uses >10,000 pounds of a TRI chemical in a calendar year (EPA 2005).

5.3.1   Air

Estimated releases of 39 pounds (~0.02 metric tons) of chlordane to the atmosphere from 13 domestic manufacturing and processing facilities in 2016, accounted for about 0.13% of the estimated total

environmental releases from facilities required to report to the TRI (TRI16 2017). These releases are
summarized in Table 5-2.

Table 5-2. Releases to the Environment from Facilities that Produce, Process, or Use Chlordane[a]

| | | Reported amounts released in pounds per year[b] | | | | | | | |
| | | | | | | | Total release | | |
State[c]	RF[d]	Air[e]	Water[f]	UI[g]	Land[h]	Other[i]	On-site[j]	Off-site[k]	On- and off-site
AR	1	1	0	0	0	0	1	0	1
CA	1	0	0	0	235	0	235	0	235
ID	1	0	0	0	1,018	0	1,018	0	1,018
IL	1	No data	No data	No data	No data	No data	No data	No data	No data
IN	1	No data	No data	No data	No data	No data	No data	No data	No data
NE	1	23	0	0	6,183	0	23	6,183	6,206
OH	2	4	0	0	0	0	4	0	4
OR	1	0	0	0	22,256	0	22,256	0	22,256
TX	2	11	0	0	0	0	11	0	11
UT	1	No data	No data	No data	No data	No data	No data	No data	No data
VA	1	No data	No data	No data	No data	No data	No data	No data	No data
Total	13	39	0	0	29,691	0	23,548	6,183	29,731

[a]The TRI data should be used with caution since only certain types of facilities are required to report. This is not an exhaustive list. Data are rounded to nearest whole number.
[b]Data in TRI are maximum amounts released by each facility.
[c]Post office state abbreviations are used.
[d]Number of reporting facilities.
[e]The sum of fugitive and point source releases are included in releases to air by a given facility.
[f]Surface water discharges, waste water treatment-(metals only), and publicly owned treatment works (POTWs) (metal and metal compounds).
[g]Class I wells, Class II-V wells, and underground injection.
[h]Resource Conservation and Recovery Act (RCRA) subtitle C landfills; other onsite landfills, land treatment, surface impoundments, other land disposal, other landfills.
[i]Storage only, solidification/stabilization (metals only), other off-site management, transfers to waste broker for disposal, unknown
[j]The sum of all releases of the chemical to air, land, water, and underground injection wells.
[k]Total amount of chemical transferred off-site, including to POTWs.

RF = reporting facilities; UI = underground injection

Source: TRI16 2017 (Data are from 2016)

5.3.2   Water

There were no releases of chlordane to surface water or publicly owned treatment works (POTWs from 13 domestic manufacturing and processing facilities in 2016 required to report to the TRI (TRI16 2017). These releases are summarized in Table 5-2.

5.3.3   Soil

Estimated releases of 29,691 pounds (~13.47 metric tons) of chlordane to soils from 13 domestic manufacturing and processing facilities in 2016, accounted for about 99.9% of the estimated total environmental releases from facilities required to report to the TRI (TRI16 2017). No chlordane was released via underground injection (TRI16 2017). These releases are summarized in Table 5-2.

5.4   ENVIRONMENTAL FATE

5.4.1   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 (Bidleman et al. 1987). Concentrations of *cis*-chlordane ≤0.0054 ng/m^3 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 ≈3,300 kg of chlordane were 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 predominantly in the vapor phase (Atlas and Giam 1988; 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 are 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 (Bidleman 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 ≈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 (EPA 1985b), 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 species (bioconcentration factor 3,000–12,000 [Zaroogian et al. 1985]) and fresh water species (bioconcentration factor 18,500 in rainbow trout [Oliver and Niimi 1985]), 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 at three trophic levels in the Arctic marine food chain, namely, Arctic cod, ringed seals, and polar bears (Muir et al. 1988). Biomagnification was 7.3/4.7 from fish to seal (male/female) and 6.6/9.5 between seal (male/female) and bear (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, *Hydrillu verticillatu*, 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.

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 >20 years (Beeman and Matsumura 1981; Bennett et al. 1974). Its behavior is somewhat dependent 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 20,000–76,000 (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 µg/L, compared to 30 µg/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 and Schomburg 1989; Glotfelty et al. 1984; 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 5.8×10^{-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 clay 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 to *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, 1991). The amount taken up varies with species and stage of plant development.

5.4.2   Transformation and Degradation

Air.   Chlordane degrades in air by both photolysis and oxidation. *trans*-Chlordane photochemically degrades more readily than *cis*-chlordane. 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 12.4×10^{-12} cm^3/molecule-second was calculated. Assuming an average ambient hydroxyl radical concentration of 5×10^5 molecules/cm^3, averaged over a 24-hour time period (Atkinson 1985), this reaction rate yields an atmospheric half-life of 1.3 days for chlordane vapor.

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. (198la, 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.

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 shorter times in other soils. Beeman and Matsumura (1981), Bennett et al. (1974), Lichtenstein and

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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 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 transformation 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 no detectable chlordane, while one of those with silt loam soil contained mean concentrations of total chlordane of 170 ppb (dry weight), 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. Hirano et al. (2007) evaluated the anaerobic biodegradation of *cis*- and *trans*-chlordane in sediment samples taken from a river in Japan; during 20 weeks of incubation in the dark at 30°C, an initial lag period of approximately 4 weeks was noted and 20-week residual ratios were 88 and 67%, respectively.

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 (198l), however, reported that a *Nocardiopsis* 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 fungus, *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.

5.5   LEVELS IN THE ENVIRONMENT

Reliable evaluation of the potential for human exposure to chlordane depends, in part, on the reliability of
supporting analytical data from environmental samples and biological specimens. Concentrations of
chlordane in unpolluted atmospheres and in pristine surface waters are often so low as to be near the
limits of current analytical methods. In reviewing data on chlordane levels monitored or estimated in the
environment, it should also be noted that the amount of chemical identified analytically is not necessarily
equivalent to the amount that is bioavailable.

Table 5-3 shows the lowest limit of detections that are achieved by analytical analysis in environmental
media. An overview summary of the range of concentrations detected in environmental media is
presented in Table 5-4.

Table 5-3. Lowest Limit of Detection Based on Standards[a]

Media	Detection limit	Reference
Air	0.15 µg/m^3	Hsu et al. 1988
Drinking water	0.002 µg/L	Reding 1987
Surface water and groundwater	0.14 µg/L	EPA 1986a
Soil	9.4 µg/kg	EPA 1986a
Sediment	0.14 µg/L	EPA 1986a
Whole blood	0.01 µg/L	Wariishi et al. 1986

[a]Detection limits based on using appropriate preparation and analytics. These limits may not be possible in all
situations.

Table 5-4. Summary of Environmental Levels of Chlordane

Media	Low	High	For more information
Outdoor air (ng/m^3)	<0.1	58	Table 5-6
Indoor air (ng/m^3)	0.01	1	Table 5-6
Surface water (ppb)	<0.1	8	Table 5-7
Ground water (ppb)	<0.1	830	Table 5-7
Drinking water (ppb)	<0.1	1,200,000	Table 5-7
Soil	<1.0	14.46	Table 5-8
Food (ppb)	<1.0	370	Table 5-9

Detections of chlordane in air, water, and soil at NPL sites are summarized in Table 5-5.

Table 5-5. Chlordane Levels in Water, Soil, and Air of National Priorities List (NPL) Sites

Medium	Median[a]	Geometric mean[a]	Geometric standard deviation[a]	Number of quantitative measurements	NPL sites
Chlordane					
Water (ppb)	0.6	0.81	22,000	29	20
Soil (ppb)	8,200	12,700	38,300	110	66
Air (ppbv)	0.008	0.027	1,897	10	8
cis-Chlordane					
Water (ppb)	0.15	1.55	109,000	12	11
Soil (ppb)	44	98.8	17,400	33	27
Air (ppbv)	No data				
trans-Chlordane					
Water (ppb)	0.077	0.0812	8,050	14	13
Soil (ppb)	59	78.6	16,500	33	28
Air (ppbv)	No data				

[a]Concentrations found in ATSDR site documents from 1981 to 2017 for 1,854 NPL sites (ATSDR 2017). Maximum concentrations were abstracted for types of environmental media for which exposure is likely. Pathways do not necessarily involve exposure or levels of concern.

5.5.1   Air

Table 5-6 summarizes results from studies that measured chlordane levels in air prior to 1992. Chlordane was detected in outside urban and rural air, in indoor air, and in the breathing zone during personal monitoring. In urban air, mean concentrations ranged from below detection limits (generally <0.1 ng/m^3) to 58 ng/m^3, whereas rural and background concentrations were much lower (generally <0.1–l ng/m^3).

Chlordane concentrations in indoor air were much higher than in either urban or rural air. Indoor air levels in the living areas of treated homes often exceeded 1 µg/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 sprayed with chlordane to control termites. Thus, the frequency of detection data 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 was poured or injected into soil around foundations of houses, the appearance of chlordane vapor in living quarters of treated houses may indicate the intrusion of soil gas through cracks, drains, or

Table 5-6. Detection of Chlordane in Air[a]

Media type/location	Sampling dates	Number of samples	Sample type	Analytical method	Concentration (ng/m^3) Range	Mean	Percent occurrence	Reference
Urban air								
Columbia, South Carolina	5/79–10/80	4[b]	High volume	GC/ECD	0.54–1.74	1.3	100	Billings and Bidleman 1983
Denver, Colorado	1/80	3[b]	High volume	GC/ECD	0.012–0.080	0.063	100	Billings and Bidleman 1983
New Bedford, Massachusetts landfill	6/80	1[b]	High volume	GC/ECD	0.20–0.36	0.24	100	Billings and Bidleman 1983
Baltimore, Maryland	8/67–8/68	4	Filter/impinger	GC/ECD	<0.1	ND	0	Stanley et al. 1971
Fresno, California	8/67–8/68	4	Filter/impinger	GC/ECD	<0.1	ND	0	Stanley et al. 1971
Riverside, California	8/67–8/68	4	Filter/impinger	GC/ECD	<0.1	ND	0	Stanley et al. 1971
Salt Lake City, Utah	8/67–8/68	4	Filter/impinger	GC/ECD	<0.1	ND	0	Stanley et al. 1971
Southeastern United States	8/85	9[b]	High/low volume	GC/ECD-MS	<1–210	58	67	Lewis et al. 1986
Bloomington, Indiana	11/85–10/86	2	Low volume	GC/MS	0.5–1.5	1.0	100	Anderson and Hites 1988
Miami, Florida	1973–1974	14	NS	NS	ND–2.3	0.2	7	Lewis and Lee 1976
Jacksonville, Florida	8/86–9/86	60	24-hour/low volume	GC/ECD	ND–628	38.4	23	EPA 1990b
Jacksonville, Florida	3/87–4/87	72	24-hour/low volume	GC/ECD	ND–66	9.5	12	EPA 1990b
Jacksonville, Florida	1/88–2/88	70	24-hour/low volume	GC/ECD	ND–175	27.4	73	EPA 1990b
Springfield/Chicopee, Massachusetts	5/87–6/87	49	24-hour/low volume	GC/ECD	ND–75	3.1	8	EPA 1990b
Springfield/Chicopee, Massachusetts	3/88	50	24-hour/low volume	GC/ECD	ND–89	2.0	16	EPA 1990b
Denver, Colorado	10/85, 1/86	8	High volume	GC/ECD	0.026–0.104[c]	0.060	100	Foreman and Bidleman 1990

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Table 5-6. Detection of Chlordane in Air[a]

Media type/location	Sampling dates	Number of samples	Sample type	Analytical method	Concentration (ng/m^3) Range	Mean	Percent occurrence	Reference
Rural air								
Buffalo, New York	8/67–8/68	4	Filter/impinger	GC/ECD	<0.1	ND	0	Stanley et al. 1971
Dothan, Alabama	8/67–8/68	4	Filter/impinger	GC/ECD	<0.1	ND	0	Stanley et al. 1971
Iowa City, Iowa	8/67–8/68	4	Filter/impinger	GC/ECD	<0.1	ND	0	Stanley et al. 1971
Orlando, Florida	8/67–8/68	4	Filter/impinger	GC/ECD	<0.1	ND	0	Stanley et al. 1971
Stoneville, Mississippi	8/67–8/68	4	Filter/impinger	GC/ECD	<0.1	ND	0	Stanley et al. 1971
College Station, Texas	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[d]	0.039[d]	100	Hoff et al. 1992
Background areas								
Everglades National Park, Florida	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, New York[e]	1985	4	High volume	GC/ECD	0.390–0.650	0.480	100	Knap and Binkley 1991
Newport News, Virginia[e]	1988	4	High volume	GC/ECD	0.015–0.129	0.054	100	Knap and Binkley 1991
Bermuda[e]	1985–1988	24	High volume	GC/ECD	0.003–0.062	0.019	100	Knap and Binkley
Canadian Arctic	2/88–4/88	10	High volume	GC/ECD	0.0014–0.0081[f]	0.0039[f]	100	Patton et al. 1991
Bering Sea	7/88–8/88	4	High volume	GC/MS	0.0053–0.0141[g]	0.0093[g]	100	Hinckley and Bidleman 1991
Northwest Atlantic	1/88, 7/89–8/89	8	High volume	GC/ECD	0.0077–0.0242[g]	0.015[g]	100	Bidleman et al. 1992

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Table 5-6. Detection of Chlordane in Air[a]

Media type/location	Sampling dates	Number of samples	Sample type	Analytical method	Concentration (ng/m^3) Range	Mean	Percent occurrence	Reference
Indoor air								
Southeastern United States	8/85	9[h]	High/low volume	GC/ECD-MS	<1–1,700	510	89	Lewis et al. 1986
New Jersey (living areas)	4/85–10/86	12[h]	Low volume	GC/ECD	<90–1,400	165	20–47[j]	Louis and Kisselbach 1987
New Jersey (nonliving areas)	4/85–10/86	12[h]	Low volume	GC/ECD	<90–5,870[i]	798	62–92[j]	Louis and Kisselbach 1987
New Jersey (living areas)	1976–1985	157[h]	Low volume	GC/ECD	<200–55,400	NS	12–34[k]	Fenske and Sternbach 1987
New Jersey (nonliving areas)	1976–1985	157[h]	Low volume	GC/ECD	<200–610,000	NS	44–48[k]	Fenske and Sternbach 1987
Military base apartments	1980	498[h]	Low volume	GC/ECD	NS–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[h]	Low volume	GC	2,750–5,810	NS	100	Wright and Leidy 1982
North Carolina	6/83–10/83	60[h,l]	NS	GC/ECD	<50–9,900	2,200	NS	Leidy et al. 1985; Fenske and Sternbach 1987
Bloomington, Indiana	11/85–10/86	12	Low volume	GC/MS	0.8–49	NS	100	Anderson and Hites 1988
Gainesville, Florida	1985–1986	11	Low volume	GC/ECD	ND–335	134	27	Moye and Malagodi 1987
Athens, Georgia	1985–1986	9	Low volume	GC/ECD	ND	ND	0	Moye and Malagodi 1987
Van Buren, Missouri	8/83	21	NS	NS	330–27,000	NS	NS	NIOSH 1984b
Jacksonville, Florida	8/86–9/86	65	24-hour/low volume	GC/ECD	ND–3,020	324.0	62	EPA 1990b
Jacksonville, Florida	3/87–4/87	72	24-hour/low volume	GC/ECD	ND–4,380	245.5	72	EPA 1990b

Table 5-6. Detection of Chlordane in Air[a]

Media type/location	Sampling dates	Number of samples	Sample type	Analytical method	Concentration (ng/m³) Range	Mean	Percent occurrence	Reference
Jacksonville, Florida	1/88–2/88	71	24-hour/low volume	GC/ECD	ND–2,050	220.3	71	EPA 1990b
Springfield/Chicopee, Massachusetts	5/87–6/87	49	24-hour/low volume	GC/ECD	ND–1,700	199.3	49	EPA 1990b
Springfield/Chicopee, Massachusetts	3/88	52	24-hour/low volume	GC/ECD	ND–735	34.8	51	EPA 1990b
Lincoln/Omaha, Nebraska (pretreatment)	NS	19[h]	4-hour at 2 L/minute	GC/ECD	NS	250	100	Kamble et al. 1992
Lincoln/Omaha, Nebraska (during treatment)	NS	19[h]	4-hour at 2 L/minute	GC/ECD	NS	1,210	100	Kamble et al. 1992
Lincoln/Omaha, Nebraska (24-hour posttreatment)	NS	19[h]	4-hour at 2 L/minute	GC/ECD	NS	690	100	Kamble et al. 1992
Lincoln/Omaha, Nebraska (180-day posttreatment)	NS	19[h]	4-hour at 2 L/minute	GC/ECD	NS	290	100	Kamble et al. 1992
Breathing zone								
Southeastern United States	8/85	9[b]	High/low volume	GC/ECD-MS	<1–4,200	680	67	Lewis et al. 1986
Jacksonville, Florida	8/86–9/86	63	24-hour/low volume	GC/ECD	ND–1,340	212.0	53	EPA 1990b
Jacksonville, Florida	3/87–4/87	71	24-hour/low volume	GC/ECD	ND–2,990	190.7	50	EPA 1990b
Jacksonville, Florida	1/88–2/88	71	24-hour/low volume	GC/ECD	ND–2,200	194.8	93	EPA 1990b
Springfield/Chicopee, Massachusetts	5/87–6/87	48	24-hour/low volume	GC/ECD	ND–2,200	252.9	50	EPA 1990b

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Table 5-6. Detection of Chlordane in Air[a]

Media type/location	Sampling dates	Number of samples	Sample type	Analytical method	Concentration (ng/m^3) Range	Mean	Percent occurrence	Reference
Springfield/Chicopee, Massachusetts	3/88	52	24-hour/low volume	GC/ECD	ND–467	35.9	87	EPA 1990b
Lincoln/Omaha, Nebraska (applicators)	NS	29	30 minutes at 2 L/minute	GC/ECD	610–116,330	16,600	100	Kamble et al. 1992

[a]No distinction is made between the isomers of chlordane. In cases where the original papers made a distinction, the data were combined.
[b]Sample periods.
[c]A 9th sample with vapor phase only contained 0.068 ng/m^3 of chlordane.
[d]Annual mean and range of *cis*-chlordane, *trans*-chlordane, and *trans*-nonachlor.
[e]Samples taken from aircraft at various altitudes.
[f]Sum of *cis*-chlordane, *trans*-chlordane, and *trans*-nonachlor in total (vapor and particulate) sample.
[g]Sum of *cis*-chlordane, *trans*-chlordane, and *trans*-nonachlor.
[h]Sample locations.
[i]High detection was in sample taken prior to treatment.
[j]Percent detectable varied with the time after treatment.
[k]Percent >5,000 ng m^{-3}.
[l]Site selection not influenced by application procedures.

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

ducting in basements or ground floor spaces (Anderson and Hites 1989; Wallace 1991). Several studies indicate that concentrations of chlordane were much higher in the basement than in upper levels of homes (Anderson and Hites 1989; Fenske and Sternbach 1987). Anderson and Hites (1989) found that the basement concentrations of chlordane were often a factor of 3–10 higher than in upper 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 $\mu g/m^3$ median) than homes with basements and forced air heat (0.33 $\mu g/m^3$), radiant heat (0.93 $\mu g/m^3$), or in-slab ducts and forced air heat (3.42 $\mu g/m^3$). 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 $\mu g/m^3$ median level and in 67% of the homes with the 3.42 $\mu g/m^3$ median level. When misapplication occurred, living area samples had median levels of 3.28 $\mu g/m^3$ with 40% of samples exceeding 5 $\mu g/m^3$, compared with <0.1 $\mu g/m^3$ and no samples exceeding 5 $\mu g/m^3$ in homes with no misapplication (Fenske and Sternbach 1987).

More recent reports are available regarding levels of chlordane compounds in outdoor and/or indoor air within various regions of North America (Aulagnier and Poissant 2005; Bidleman et al. 1998; Cortes et al. 1998; Hung et al. 2002; Jantunen et al. 2000; Leone et al. 2001; Moreau-Guigon et al. 2007; Offenberg et al. 2004; Shen et al. 2005; Sun et al. 2006). Chlordane levels in sampled outdoor air were consistently <1 ng/m^3. One study reported higher average air concentrations indoors than outdoors at test locations in Los Angeles County, California; Elizabeth, New Jersey; and Houston, Texas (average indoor levels of 1.98, 1.3, and 4.18 ng/m^3, respectively, versus average outdoor levels of 0.58, 0.17, and 0.28 ng/m^3, respectively) (Offenberg et al. 2004).

5.5.2   Water

Table 5-7 summarizes results from studies that measured chlordane levels in water and sediments prior to 1990. Chlordane was detected in surface water, groundwater, suspended solids, sediments, bottom detritus, drinking water, sewage sludge, urban runoff, and rain. Concentrations of chlordane in ocean and lake water were <0.0001 ng/L. Studies in the Great Lakes indicate that the level of the *cis*-chlordane in water were 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.

Table 5-7. Detection of Chlordane in Water and Sediments[a]

Media type/location	Sampling dates	Number of samples	Sample type	Analytical method	Concentration (ppb) Range	Mean	Percent occurrence	Reference
Surface water								
Wolf River, Tennessee	NS	30	Grab	NS	NS	0.15	NS	Jaffe et al. 1982
Wolf River, Tennessee	NS	0	Grab	NS	NS	0.42	NS	Jaffe et al. 1982
Mississippi River, Louisiana	1974	NS	Continuous	GC/ECD	0.00045–0.00115	NS	100	Brodtmann 1976
Niagara River, New York	4/79–12/81	NS	Continuous	GC/ECD	NS	0.004	66	Kuntz and Warry 1983
Lower Fox River, Wisconsin	1976–1977	250	Grab	GC+GC/MS	NS	NS	NS	Peterman et al. 1980
Surface waters in New Jersey	NS	603	NS	NS	<0.1–0.8	0.1[b]	56	Page 1981
Hawaii Kai Marina, Hawaii	4/74–7/74	12	Grab	GC/ECD	NS	NS	55	Tanita et al. 1976
Hawaii Kai Marina, Hawaii	4/72–11/72	5	Grab	NS	<0.001–0.01	NS	40	Tanita et al. 1976
Belmont Lake, New York	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[c]	Gilliom 1984
Gulf of Mexico and Southeast Coast[d]	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
Four 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[e]	0.00014[e]	100	Hinckley and Bidleman 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

Table 5-7. Detection of Chlordane in Water and Sediments[a]

Media type/location	Sampling dates	Number of samples	Sample type	Analytical method	Concentration (ppb) Range	Mean	Percent occurrence	Reference
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, Maine	11/80	8	Grab	GC/ECD	<0.03–9.8	1.8	75	Ray et al. 1983
Apalachicola River, Florida	8/79–5/80	12	Grab	GC	<1–3	NS	17	Elder and Mattraw 1984
Hawaii Kai Marina, Hawaii	4/74–7/74	12	Grab	GC/ECD	1.73–10.4	5.27	97	Tanita et al. 1976
Hawaii Kai Marina, Hawaii	1972–1973	11	Grab	NS	NS	5.32	100	Tanita et al. 1976
Belmont Lake, New York	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[c]	Gilliom 1984
Great Lakes harbors	5/89	5	Grab	GC/ECD	1.44–14.34[f]	3.66[f]	100	Verbrugge et al. 1991
NPL site (on-site) in Marshall, Illinois	NS	NS	NS	NS	ND–1,000,000	NS	NS	ATSDR 1989b
NPL site (off-site) in Marshall, Illinois	NS	NS	NS	NS	ND–250,000	NS	NS	ATSDR 1989b
Gulf of Mexico (51 site)[g]	1986	153	Surface	GC/ECD	<0.02–8.66[h]	0.26	77	Sericano et al. 1990
Gulf of Mexico (50 site)[g]	1987	148	Surface	GC/ECD	<0.02–43.5[h]	1.18	72	Sericano et al. 1990
Bottom detritus								
Apalachicola River, Florida	8/79–5/80	7	Grab	GC	1700–10,000	NS	100	Elder and Mattraw 1984
Groundwater								
Groundwaters in New Jersey	NS	1,076	NS	NS	<0.1–0.4	<0.1[b]	40	Page 1981
NPL site in Plumstead Township, New Jersey[i]	NS	NS	NS	NS	0.02	NS	NS	VIEW 1988

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Table 5-7. Detection of Chlordane in Water and Sediments[a]

Media type/location	Sampling dates	Number of samples	Sample type	Analytical method	Concentration (ppb) Range	Mean	Percent occurrence	Reference
NPL site in Cape Giradeau, Missouri[j]	NS	NS	NS	NS	830	NS	NS	VIEW 1988
NPL site in Holbrook, Massachusetts[j]	NS	NS	NS	NS	48	NS	NS	VIEW 1988
NPL sites at 11 other locations[k]	NS	NS	NS	NS	NS	NS	NS	VIEW 1988
NPL site (on-site) in Marshall, Illinois	NS	NS	NS	NS	ND–0.6	NS	NS	ATSDR 1989b
NPL site (off-site) in Marshall, Illinois	NS	NS	NS	NS	ND	NS	NS	ATSDR 1989b
Cape Cod golf courses	1986–1987	16[l]	Pump/bail	GC/ECD	ND–7.20	NS	44	Cohen et al. 1990
Drinking water								
Pittsburgh, Pennsylvania	12/80	NS	Grab	NS	<0.1–6600[m]	NS	NS	CDC 1981
Seven U.S. cities	1965–1967	63	Grab	NS	NS	NS	22	Schafer et al. 1969
Chattanooga, Tennessee	3/24/76	NS	Grab	GC/ECD	NS–1,200,000	NS	NS	Harrington et al. 1978
Kansas farmstead well survey[n]	12/85–2/86	103	Grab	GC/ECD	ND–0.53	NS	0.97	Steichen et al. 1988
Sewage sludge								
Unspecified states	NS	44	NS	NS	NS	NS	73	Fricke et al. 1985
Urban runoff								
Fresno, California	NS	NS	Grab	NS	0.1–0.3	0.1[b]	NS	Nightingale 1987
Lake Quinsigamond, Massachusetts and Kansas City, Missouri	NS–7/82	NS	Grab	NS	0.01–10[o]	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

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Table 5-7. Detection of Chlordane in Water and Sediments[a]

Media type/location	Sampling dates	Number of samples	Sample type	Analytical method	Concentration (ppb) Range	Mean	Percent occurrence	Reference
Street sediment								
11 Canadian Great Lakes basin sites	NS	110	Grab	GC/ECD	NS	0.046	35	Marsalek and Schroeter 1988
Rain								
Lake Superior	1983	NS	NS	GC/ECD	<0.00005	ND	0	Strachan 1985
College Station, Texas	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

[a]No distinction is made between the isomers of chlordane. In cases where the original papers made a distinction, the data were combined.
[b]Median.
[c]Percentage of stations with detections.
[d]Open-ocean seawater (filtrate) samples. Chlordane was not detected in microlayer samples.
[e]Sum of *cis*-chlordane, *trans*-chlordane, and *trans*-nonachlor.
[f]Wet weight.
[g]NOAA's Status and Trends Mussel Watch Program.
[h]*cis* isomer.
[i]On-site.
[j]Off-site.
[k]Arlington, Tennessee; Brick Township, New Jersey; Brunswick, Maine; Sorreto, Louisiana; Gallaway, Tennessee; Niagara Falls, New York; Lewisburg, Tennessee; Sacramento, California; Toone, Illinois; Marshall, Illinois; Jacksonville, Arkansas.
[l]Sites, includes background, green, tee, and fairway sites at four golf courses.
[m]Concentrations above the solubility limit may be the result of a cosolvent such as kerosene.
[n]Random sample.
[o]Range of positive detections.

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

Groundwater monitoring data from 479 disposal site investigations detected chlordane in 23 samples at 10 sites, ranking it 80th among the 208 RCRA Appendix IX organic chemicals investigated (Plumb 1991). According to the EPA database Pesticides in Groundwater, chlordane was 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 western 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.

5.5.3   Sediment and Soil

Table 5-8 summarizes results from studies that measured chlordane levels in soils prior to 1990. Chlordane was detected in both rural and urban soils 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 were, for the most part, from studies performed in the late 1960s to middle 1970s. Very few more recent general soil monitoring data were available; these data show that chlordane was still present in soils, but insufficient detections are available to estimate any trends. 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 LaFage 1990).

Sediment concentrations of chlordane in Great Lakes harbors and a tributary of the Missouri River in Missouri ranged 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 correlated with urban development (Puri et al. 1990). Chlordane levels in sediment from predominately agricultural areas were approximately 2 orders of magnitude lower than in urban areas. Based on average chlordane concentrations in EPA's STORET database for 1978–1987, the western 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).

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Table 5-8. Detection of Chlordane in Soils[a]

Media type/location	Sampling dates	Number of samples	Sample type	Analytical method	Concentration (ppm) Range	Mean	Percent occurrence	Reference
Urban								
Baltimore, Maryland	1971	156	NS	GC/ECD	0.01–12.35	0.21	37	Carey et al. 1979a
Gadsden, Alabama	1971	55	NS	GC/ECD	0.04–0.46	0.07	5	Carey et al. 1979a
Hartford, Connecticut	1971	48	NS	GC/ECD	0.02–141	4.0	48	Carey et al. 1979a
Macon, Georgia	1971	43	NS	GC/ECD	0.07–0.91	0.8	26	Carey et al. 1979a
Newport News, Virginia	1971	78	NS	GC/ECD	0.09–7.29	0.16	13	Carey et al. 1979a
Bakersfield, California	1969	50	Grab	GC/ECD	0.07–20.5	0.78	30	Wiersma et al. 1972
Camden, New Jersey	1969	50	Grab	GC/ECD	0.39–5.90	0.36	16	Wiersma et al. 1972
Houston, Texas	1969	50	Grab	GC/ECD	0.04–12.9	0.66	34	Wiersma et al. 1972
Manhattan, Kansas	1969	50	Grab	GC/ECD	0.03–4.86	0.30	40	Wiersma et al. 1972
Miami, Florida	1969	50	Grab	GC/ECD	0.04–16.9	1.59	64	Wiersma et al. 1972
Milwaukee, Wisconsin	1969	50	Grab	GC/ECD	0.05–10.2	0.45	34	Wiersma et al. 1972
Salt Lake City, Utah	1969	50	Grab	GC/ECD	0.02–7.50	0.41	38	Wiersma et al. 1972
Waterbury, Connecticut	1969	50	Grab	GC/ECD	0.02–8.74	0.96	28	Wiersma et al. 1972
Fresno-Clovis, California	NS	NS	Grab	NS	<0.03–2.70	NS	NS	Nightingale 1987
Belmont Lake, New York bank soil	1982	NS	Grab	GC/ECD	<0.002–0.003	NS	NS	Wood et al. 1986
New Orleans, Louisiana (30 treated homes)	10/86	240	Grab	GC/ECD	0.6–14,464	854.9	100	Delaplane and LaFage 1990

Table 5-8. Detection of Chlordane in Soils[a]

Media type/location	Sampling dates	Number of samples	Sample type	Analytical method	Concentration (ppm)		Percent occurrence	Reference
					Range	Mean		
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, California	1969	NS	Grab	GC/ECD	NR	0.01	NR	Wiersma et al. 1972
Cropland, New Jersey, Delaware, Maryland	1969	NS	Grab	GC/ECD	NR	<0.01	NR	Wiersma et al. 1972
Cropland, Florida	1969	NS	Grab	GC/ECD	NR	0.36	NR	Wiersma et al. 1972
Cropland, Wisconsin	1969	NS	Grab	GC/ECD	NR	0.01	NR	Wiersma et al. 1972

Table 5-8. Detection of Chlordane in Soils[a]

Media type/location	Sampling dates	Number of samples	Sample type	Analytical method	Concentration (ppm) Range	Mean	Percent occurrence	Reference
Urban								
Cropland, Arizona, New Mexico, Nevada, Utah	1969	NS	Grab	GC/ECD	NR	0.02	NR	Wiersma et al. 1972
Cropland, Maine, New Hampshire, Vermont, Massachusetts, Rhode Island, Connecticut	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[b]	Soil core	GC/ECD	ND–4.310	2.278[c]	58	Cohen et al. 1990
NPL sites								
Holbrook, Massachusetts	NS	NS	NS	NS	NS	NS	NS	VIEW 1988
Sorreto, Louisiana	NS	NS	NS	NS	NS	NS	NS	VIEW 1988
Cape Girardeau, Missouri	NS	NS	NS	NS	30[d]	NS	NS	VIEW 1988
Lewisburg, Tennessee	NS	NS	NS	NS	0.1[e]	NS	NS	VIEW 1988
Memphis, Tennessee	NS	NS	NS	NS	57[e]	NS	NS	VIEW 1988
West Chester, Ohio	NS	NS	NS	NS	NS	NS	NS	VIEW 1988
Toome, Tennessee	NS	NS	NS	NS	NS	NS	NS	VIEW 1988
Marshall, Illinois	NS	NS	NS	NS	48.3[e]	NS	NS	VIEW 1988
Jacksonville, Arkansas	NS	NS	NS	NS	NS	NS	NS	VIEW 1988
Marshall, Illinois	NS	NS	NS	NS	ND–69[d]	NS	NS	ATSDR 1989b

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Table 5-8. Detection of Chlordane in Soils[a]

Media type/location	Sampling dates	Number of samples	Sample type	Analytical method	Concentration (ppm) Range	Mean	Percent occurrence	Reference
Marshall, Illinois	NS	NS	NS	NS	ND–0.760[e]	NS	NS	ATSDR 1989b
Holbrook, Massachusetts	NS	36[f]	Grab	GC/ECD	ND–334	NS	86	Callahan et al. 1991

[a]No distinction is made between the isomers of chlordane. In cases where the original papers made a distinction, the data were combined.
[b]Three sites and four depths.
[c]Average of three surface cores; not detected at and below 2.0, 24, and 5.8 feet at three sites.
[d]On-site.
[e]Off-site.
[f]Locations.

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

More recently, Martinez et al. (2012) conducted an urban soil study analyzing chlordane in 66 soil samples taken on August 25th, 2008, in Cedar Rapids, Iowa, where major flooding occurred 70 days prior to the samples being taken. The samples were primarily taken from residential land use areas in the flooding zone downstream and west of the main urban river (Cedar River) that flooded. Chlordane levels in Cedar River had not been previously identified, though chlordane was detected at high levels in an urban lake that also flooded. Chlordane samples were analyzed using a gas chromatography/mass selective detector mode (GC/MSD) in selected ion monitoring mode. Chlordane concentrations in soil ranged from 0 to 7,500 ng/g dry weight, though the distribution was highly skewed (median 4 ng/g dry weight; mean 130 ng/g dry weight). Generally, *trans*-nonachlor (median 1.8 ng/g dry weight; mean 24.0 ng/g dry weight) was found at higher concentrations than *cis*-chlordane (median 1.0 ng/g dry weight; mean 64.0 ng/g dry weight) and *trans*-chlordane (median 0.86 ng/g dry weight; mean 40 ng/g dry weight). No spatial correlation between the samples was found. Additionally, no significant difference was found between samples collected inside or outside the flooding area. The mean ratios for the soil samples in this study are: *cis*-chlordane:*trans*-chlordane 1.40±0.48; *trans*-chlordane:*trans*-nonachlor 40±1.50; and *cis*-chlordane:*trans*-nonachlor 0.96±1.50. Given these ratios, it is likely that significant weathering of technical chlordane occurred if direct soil application was the source of the observed concentrations.

5.5.4   Other Media

Chlordane has been detected in many other media. Tables 5-9, 5-10, 5-11, and 5-12 summarize results from studies that evaluated chlordane in food, aquatic organisms, terrestrial organisms, and human samples, respectively, prior to 1992.

Based on average chlordane concentrations in EPA's STORET database for 1978–1987, the western 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 were 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).

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Table 5-9. Detection of Chlordane in Food[a]

Media type/ location	Sampling dates	Number of samples	Sample type	Analytical method	Concentration (ppm)		Percent occurrence	Reference
					Range	Mean		
Total adult food groups								
United States[b]	1990–1991	936	Composite	NS	NS	NS	1	FDA 1991
United States[b]	1989–1990	936	Composite	NS	NS	NS	<1	FDA 1990
United States[b]	1987–1988	1,170	Composite	NS	NS	NS	4	FDA 1989a
United States[b]	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[b]	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	Corneliussen 1972

Table 5-9. Detection of Chlordane in Food[a]

Media type/ location	Sampling dates	Number of samples	Sample type	Analytical method	Concentration (ppm)		Percent occurrence	Reference
					Range	Mean		
United States	1968–1969	360	Composite	GC/ECD+TLC	0.026–0.043[c]	0.035[c]	0.56	Corneliussen 1970
United States	1966–1967	360	Composite	GC/ECD+TLC	0.005–0.02[c]	0.013[c]	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[c]	0.019[c]	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

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Table 5-9. Detection of Chlordane in Food[a]

Media type/ location	Sampling dates	Number of samples	Sample type	Analytical method	Concentration (ppm)		Percent occurrence	Reference
					Range	Mean		
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[d]	NS	Lawrence et al. 1970
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[e]	ND	0	Schattenberg and Hsu 1992

[a]No distinction is made between the isomers of chlordane. In cases where the original papers made a distinction, the data were combined.
[b]FDA's Total Diet Study.
[c]Range of positive detection.
[d]Chlordane and a metabolite of chlordane (1-exo-2-endo-4,5,6,7,8,8-octachloro-2,3-exo-epoxy-2,3,3a,4,7,7a-hexahydro-4,7-methanoindene) were detected.
[e]Detection limit is 0.625 ppm.

ECD = electron capture detector; FDA = U.S. Food and Drug Administration; GC = gas chromatography; MS = mass spectroscopy; ND = not detected; NS = not specified; TLC = thin-layer chromatography

Table 5-10. Detection of Chlordane in Aquatic Organisms

Isomer	Sampling location	Dates	Number of samples	Sample type	Analytical method (detection limit)	Concentration (ppm) Range	Mean	Percent occurrence	Reference
Fish									
cis, trans	Major United States watersheds[a]	1980–1981	315	Whole fish, composite	GC (0.01 ppm wet weight)	ND–0.36	0.03	73.8	Schmitt et al. 1985
			315			ND–0.22	0.02	72.0	
cis, trans	Major United States watersheds[a]	1978–1979	NS	Whole fish, composite	GC (0.01 ppm wet weight)	ND–2.53	0.07	94.4	Schmitt et al. 1985
			NS			ND–0.54	0.02	70.4	
cis, trans	Major United States watersheds[a]	1976–1977	NS	Whole fish, composite	GC (0.01 ppm wet weight)	ND–0.93	0.06	92.5	Schmitt et al. 1985
			NS			ND–0.32	0.03	84.0	
cis, trans	13 Lake Michigan tributaries	Fall 1983	26	Whole fish, composite	GC/ECD (0.005 ppm wet weight)	ND–0.211	NS	NS	Camanzo et al. 1987
			26			ND–0.025	NS	NS	
cis, trans	Grand Traverse Bay (Lake Michigan)	Fall 1983	2	Whole fish[b,c] composite	GC/ECD (0.005 ppm wet weight)	0.015–0.037	NS	NS	Camanzo et al. 1987
			2			0.003–0.005	NS	NS	
cis, trans	Wabash River (Indiana)	NS	1	Whole fish, composite	MID GC/MS (0.0005 ppm wet weight)	–	0.00854	100	Kuehl et al. 1980
			1			–	0.01298	100	
cis and *trans*	Ashtabula River (Oklahoma)	NS	1	Whole fish, composite	MID GC/MS (0.0005 ppm wet weight)	–	ND	0	Kuehl et al. 1980
cis, trans	Great Lakes and major watersheds of the Great Lakes	1979	48	Whole fish, composite	MID GC/MS (0.020 ppm wet weight)	ND–0.61	0.090	79.2	Kuehl et al. 1983
			48			ND–0.52	0.098	87.5	
cis and *trans*	Major United States watersheds	1976	58	Whole fish, composite	GC/MS	NS	NS	36.2	Veith et al. 1979
cis and *trans*	13 sites located along a 125-mile stretch of the Kansas River	1986	25	Whole fish, composite	GC/ECD (0.03 ppm wet weight)	ND–2.1	0.25	68.0	Arruda et al. 1987

Table 5-10. Detection of Chlordane in Aquatic Organisms

Isomer	Sampling location	Dates	Number of samples	Sample type	Analytical method (detection limit)	Concentration (ppm)		Percent occurrence	Reference
						Range	Mean		
cis and trans	Siskiwit Lake on Isle Royal in Lake Superior	1983	4 / 4	Whole fish, composite[c]	GC/MS (0.001 ppm)[d]	0.23–0.77[d]	0.42[d]	NS	Swackhamer and Hites 1988
cis and trans	Siskiwit Lake on Isle Royal in Lake Superior	1983	3 / 3	Whole fish, composite[e]	GC/MS (0.001 ppm)[d]	0.14–0.33[d]	0.26[d]	NS	Swackhamer and Hites 1988
cis and trans	Lake Texoma (Texas and Oklahoma)	October 1979	14[f]	Fillets	GC/ECD (0.001 ppm)	0.002 (maximum)[f]	0.017 (median)[f]	NS	Hunter et al. 1980
			47[g]			0.008 (maximum)[g]	NS	NS	
			38[h]			0.024 (maximum)[h]	NS	NS	
cis and trans	Tuttle Creek Lake (Kansas)	1985	20	Fillets	EPA method 608 (0.0008 ppm)	ND–0.113	NS	90	KDHE 1988
trans	Atchafalaya River basin (Louisiana)	June 1981	NS	Whole fish, composite	GC/ECD (NS)	ND–0.1	NS	NS	Winger and Andreasen 1985
cis and trans	Chesapeake Bay and tributaries (Maryland)	1980	24	Fillets[i]	GC/ECD (0.001 ppm wet weight)	0.004–0.31	0.12	NS	Eisenberg and Topping 1985
cis and trans	Chesapeake Bay and tributaries (Maryland)	1979	98	Fillets[i]	GC/ECD (0.001 ppm wet weight)	ND–0.70	0.08	NS	Eisenberg and Topping 1985
cis and trans	Chesapeake Bay and tributaries (Maryland)	1978	15	Fillets[i]	GC/ECD (0.001 ppm wet weight)	ND–0.50	0.013	NS	Eisenberg and Topping 1985
cis and trans	San Joaquin River and tributaries (California)	July 1981	8	Whole fish, composite[j]	GC/ECD (0.004 ppm wet weight)	ND–0.021	0.011	50	Saiki and Schmitt 1986
cis and trans	San Joaquin River and tributaries (California)	July 1981	8	Whole fish, composite[b]	GC/ECD (0.004 ppm wet weight)	0.012–0.273	0.077	100	Saiki and Schmitt 1986

Table 5-10. Detection of Chlordane in Aquatic Organisms

Isomer	Sampling location	Dates	Number of samples	Sample type	Analytical method (detection limit)	Concentration (ppm)		Percent occurrence	Reference
						Range	Mean		
cis and *trans*	Lake Ontario (4 sites)	1977–1978	1,718	Whole fish	GC/ECD	0.04–0.14[c,k]	NS	NS	Borgmann and Whittle 1991
cis and *trans*	Major United States watersheds (112 sites)[l]	1984	321	Fish tissue, composite	GC/ECD	<1.01[m]	0.06	85[n]	Schmitt et al. 1990
Chlordanes[o]	Major United States watersheds (112 sites)[l]	1984	321	Fish tissue, composite	GC/ECD	<2.75[p]	0.11[q]	89[n]	Schmitt et al. 1990
trans	Lower Mississippi basin	7/87–8/87	17[u]	Whole catfish	GC/MS	0.011–0.170	0.062	100	Leiker et al. 1991
Oysters									
cis	Gulf of Mexico (49 site)[r]	1986	147	Composite	GC/ECD	0.91–96.3[s]	10.9	100	Sericano et al. 1990
cis	Gulf of Mexico (48 site)[r]	1987	143	Composite	GC/ECD	0.65–292[t]	14.1	100	Sericano et al. 1990

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Table 5-10. Detection of Chlordane in Aquatic Organisms

Isomer	Sampling location	Dates	Number of samples	Sample type	Analytical method (detection limit)	Concentration (ppm)		Percent occurrence	Reference
						Range	Mean		
Clams									
cis and *trans*	Portland (Maine)	November 1980	2	Whole body, composite	GC/FID (0.00003 ppm)	ND–0.0018	NS	50	Ray et al. 1983

[a]107 stations located at key locations in major rivers throughout the United States and Great Lakes.
[b]Carp.
[c]Lake trout.
[d]Expressed on a lipid basis.
[e]Whitefish.
[f]Herbivores (gizzard shad).
[g]Detrivores (carp, channel catfish, smallmouth buffalo, river carpsucker).
[h]Carnivores (striped bass, white crappie, largemouth bass, blue catfish, flathead catfish).
[i]Finfish.
[j]Bluegill sunfish.
[k]Range of annual logarithmic means.
[l]National Contaminant Biomonitoring Program.
[m]Highest station mean Honolulu, Hawaii (0.6 ppm), next highest station (0.3 ppm), Saugatuck, Michigan.
[n]Positive sites (for isomer with highest number of positive sites).
[o]*cis*- and *trans*-chlordane, oxychlordane, and *cis*- and *trans*-nonachlor.
[p]Highest station mean in Honolulu, Hawaii (1.8 ppm), next highest station (0.8 ppm), Saugatuck, Michigan. Component composition is 1.00 ppm *trans*-nonachlor, 0.66 ppm *cis*-chlordane, 0.45 ppm *cis*-nonachlor, 0.35 ppm *trans*-chlordane, and 0.29 oxychlordane.
[q]Component composition is 0.03 *trans*-nonachlor, 0.03 ppm *cis*-chlordane, 0.02 ppm *cis*-nonachlor, 0.02 ppm *trans*-chlordane, and 0.01 ppm oxychlordane.
[r]NOAA's Status and Trends Mussel Watch Program.
[s]The range, mean, and frequency for *trans*-nonachlor are 0.60–71.9 ppb, 10.0 ppb, and 100%, respectively.
[t]The range, mean, and frequency for *trans*-nonachlor are <0.25–289 ppb, 11.6 ppb, and 99%, respectively.
[u]Sites; number of fish per site varied from 1 to 4.

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

Table 5-11. Detection of Chlordane in Terrestrial Organisms[a]

Species/location	Sampling dates	Number of samples	Sample type	Analytical method	Concentration (ppm) Range	Mean	Percent occurrence	Reference
Birds								
Herons, egrets, kingfishers, sandpipers								
Corpus Christi, Texas	1983	10	Eggs	GC/ECD	ND–0.88	0.14[b]	NS	White and Krynitsky 1986
Loving, New Mexico	1983	10	Eggs	GC/ECD	ND	ND	NS	White and Krynitsky 1986
Artesia, New Mexico	1983	10	Eggs	GC/ECD	ND–0.36	0.07[b]	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[c]	0.14	5.4	McEwen et al. 1984
United States	1966–NS	105	Carcass	GC/ECD+MS	ND–1.8[d]	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, Wisconsin	1976–1980	11	Carcass, brains	GC/ECD+MS	ND–0.22	NS	NS	Heinz et al. 1984
Re-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, California	1969–1981	45	Eggs	GC/MS	<0.1–0.12	NS	6.7	Boellstorff et al. 1985
Comorant, black skimmer, western grebe								
Galviston Bay, Texas	1980–1981	6	Eggs	GC/ECD+MS	ND–0.6	NS	<50	King and Krynitsky 1986
Galviston Bay, Texas	1980–1982	13	Eggs	GC/ECD+MS	ND–0.7	NS	<50	King and Krynitsky 1986

Table 5-11. Detection of Chlordane in Terrestrial Organisms[a]

Species/location	Sampling dates	Number of samples	Sample type	Analytical method	Concentration (ppm) Range	Mean	Percent occurrence	Reference
South Texas and Mexico	1983	30	Carcass	NS	<0.1–<0.3	NS	20	White et al. 1985
Klamath Basin, California	1981	12	Eggs	GC/MS	<0.1–0.25[e]	NS	>16.7	Boellstorff et al. 1985
Clapper rails, gallinules and limpkins, dunlins								
Avalon, New Jersey	1973	NS	Carcass	GC/ECD+MS	ND–0.12[f]	NS	NS	Klaas and Belisle 1977
Virginia, South Carolina, New Jersey	1972–1973	49	Eggs	GC/ECD+MS	ND–<0.10[c]	NS	20[c]	Klaas et al. 1980
Florida, South Carolina, Louisiana	1973–1974	NS	Eggs	GC/ECD+MS	ND	ND	0	Klaas et al. 1980
Sarnish Bay, Washington	1980	8	Whole body	GC/MS	0.008–0.06	0.02	100	Schick et al. 1987
Bowerman Basin, Washington	1980	5	Whole body	GC/MS	0.003–0.005	0.004	100	Schick et al. 1987
Gulls, common eider								
Virginia, Maine	1977	116	Eggs	GC	0.00–0.50[f]	0.09[c]	>26.7	Szaro et al. 1979
Appledore Island, Massachusetts	1977	30	Eggs	GC	ND	ND	0	Szaro et al. 1979
Appledore Island, Massachusetts	1977	28	Eggs	GC	0.0–0.50	0.04	21.4	Szaro et al. 1979
Appledore Island, Massachusetts	1977	28	Eggs	GC	0.0–0.43[f]	0.22	96.4	Szaro et al. 1979
Galviston, Texas	1980–1981	10	Eggs	GC/ECD+MS	0.1–1.2[c]	0.29	>50	King and Krynitsky 1986
Bangs Island, Massachusetts	1977	30	Eggs	GC	ND	ND	0	Szaro et al. 1979

Table 5-11. Detection of Chlordane in Terrestrial Organisms[a]

Species/location	Sampling dates	Number of samples	Sample type	Analytical method	Concentration (ppm) Range	Mean	Percent occurrence	Reference
Ducks								
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[g]	Prouty and Bunck 1986
Chesapeake Bay, Maryland	1973, 1975	142	Carcass	GC/MS	ND–NS	0.19	6.3	White et al. 1979
Osprey, eagles, owls, hawks								
Barnegat Bay, New Jersey	1971, 1974	9	Eggs	GC/ECD+MS	ND–0.55[e]	0.20[c]	78	Wiemeyer et al. 1978
Avalon-Stone Harbor, New Jersey	1979, 1972	8	Eggs	GC/ECD+MS	ND–0.08[e]	0.03	50	Wiemeyer et al. 1978
United States	1964–1973	26	Carcass, brains	GC/ECD+MS	<0.1–1.7[e,h]	NS	>69.2	Wiemeyer et al. 1980
United States	1971–1974	38	Carcass	GC/MS	NS	27[e]	NS	Barbehenn and Reichel 1981
United States	1971–1974	38	Brain	GC/MS	NS	0.27[e]	NS	Barbehenn and Reichel 1981
United States	1971–1974	24	Carcass	GC/MS	NS	15[f]	NS	Barbehenn and Reichel 1981
United States	1971–1974	24	Brain	GC/MS	NS	0.15[f]	NS	Barbehenn and Reichel 1981
United States	1969–1979	6	Eggs	GC/ECD+MS	ND–3.6	0.39[c]	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, Oregon	1980	1	Brains	NS	0.1	1.1	100	Blus et al. 1983

Table 5-11. Detection of Chlordane in Terrestrial Organisms[a]

Species/location	Sampling dates	Number of samples	Sample type	Analytical method	Concentration (ppm) Range	Concentration (ppm) Mean	Percent occurrence	Reference
Starling								
United States	1979, 1982	NS	Carcass	GC/MS	<0.01–0.04	0.02[c]	3.3[i]	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 Maryland	1979	56	Eggs	GC/ECD+MS	ND–<0.008[f]	ND	28.6[f]	Clark and Krynitsky 1985
New Jersey, Maryland	1981–1982	32	Visceral fat	GC/ECD+MS	ND–>9.33[f]	3.9[c]	>88[f]	Albers et al. 1986
Crocodiles								
Patuxent Wildlife Research Center, Laurel, Maryland	1977–1978	23	Eggs	GC/ECD	<0.01–0.07	0.02[f,c]	87.5[j]	Hall et al. 1979
Raccoons								
Lake Verret, Louisiana	1978–1979	<10	Leg muscles	GC/ECD	<0.05	ND	NS	Dowd et al. 1985
Plaquemine-Brule, Louisiana	1978–1979	<10	Leg muscles	GC/ECD	<0.05	ND	NS	Dowd et al. 1985
East Franklin, Louisiana	1978–1979	<10	Leg muscles	GC/ECD	<0.05–NS	0.017[k]	NS	Dowd et al. 1985
Big brown bats								
Gaithersburg, Maryland	1973	18	Carcass, brains	GC/ECD	ND–<0.40[f]	NS	50	Clark and Lamont 1976
Earthworms								
Holbrook, Massachusetts	NS	29[l]	Whole body	GC/ECD	0.8–12.9	NS	45	Callahan et al. 1991

Table 5-11. Detection of Chlordane in Terrestrial Organisms[a]

Species/location	Sampling dates	Number of samples	Sample type	Analytical method	Concentration (ppm) Range	Mean	Percent occurrence	Reference
Insects								
Moths								
Washington, DC–Baltimore, Maryland	1977–1979	NS	Whole body	GLC/MS	<0.05–0.75	0.22	NS	Beyer and Kaiser 1984
Meadow grasshopper								
Palermo, New Jersey	1973	NS	NS	GC/ECD+MS	ND–0.02[e]	NS	NS	Klaas and Belisle 1977
Honey bees								
Connecticut	1983–1985	NS	Whole body, 20 brood combs	GC/ECD	0.06–0.69[c]	NS	7.5[m]	Anderson and Wojtas 1986

[a]No distinction is made between the isomers of chlordane. In cases where the original papers made a distinction, the data were combined.
[b]Geometric mean.
[c]Range of positive detections.
[d]Oxychlordane and *trans*-nonachlor were reported in paper at ranges of ND–0.87 and ND–3.0, respectively.
[e]*cis*-Chlordane and/or *trans*-nonachlor.
[f]Oxychlordane included in mixture.
[g]Value describes number of detections divided by the number of pools.
[h]Oxychlordane was also detected, range ND–0.15, frequency >12%.
[i]Percent of pools with detectable residues of organochlorine compounds.
[j]*cis*-Chlordane, *trans*-nonachlor or oxychordane was detected in 7 out of 8 clutches.
[k]Mean was exceeded by the standard error.
[l]Earthworms were exposed on-site for 7 days.
[m]Chlordane was detected in 4 out of 57 apiaries.

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

Table 5-12. Detection of Chlordane in Human Samples[a]

Media type/location	Sampling dates	Number of samples	Sample type	Analytical method	Concentration (ppb) Range	Mean	Percent occurrence	Reference
Human adipose tissue								
United States	1976–1980	785	General	GC/ECD+MS	ND–>10[b]	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[b]	193	100	Barquet et al. 1981
United States	1972–1975	NS	General	GC/ECD+MS	ND–>100[b]	100[c]	>90	Kutz et al. 1979
Bloomington, Indiana	1987–1988	23	Breast	GC/ECD+MS	0.6–10.2 / 42–260[b]	2.0[d] / 88[d]	100 / 100	Dearth and Hites 1991a
North Texas	1987–1988	35	Abdominal	GC/ECD	12–261[b,e]	95[d,f]	100	Adeshina and Todd 1990
Canada	1985	108	General	GC/ECD+MS	<11 / <103[b]	4 / 33	100 / 100	Mes et al. 1990
British Columbia, Canada	NS	25	Most abdominal[g]	GC/ECD	<134.20[h]	42.5[i]	100	Mes 1992
Japan[j]	1986–1988	23	NS	GC/ECD	130–2,160	670	100	Sasaki et al. 1991a
Human blood sera								
United States	1976–1980	4,200	General	GC/ECD+MS	ND–>1[b]	NS	4	Murphy et al. 1983
Welds County, Colorado	1968	358	Nonoccupational	GC/ECD	ND	ND		Starr et al. 1974
Welds County, Colorado	1968	93	Farm	GC/ECD	ND	ND	0	Starr et al. 1974
Welds County, Colorado	1968	175	Occupational	GC/ECD	60–233[k]	151	3.4	Starr et al. 1974
British Columbia, Canada	NS	25	Whole blood[g]	GC/ECD	<0.30[l]	0.10[m]	100	Mes 1992
Japan[j]	1986–1988	23	General	GC/ECD	ND–280	0.58	100	Sasaki et al. 1991a

Table 5-12. Detection of Chlordane in Human Samples[a]

Media type/location	Sampling dates	Number of samples	Sample type	Analytical method	Concentration (ppb) Range	Mean	Percent occurrence	Reference
Japan	1989–1990	240	General	GC-MS	0.06–3.85[n]	0.34[o]	100	Hirai and Tomokuni 1991b
Human milk								
United States	NS	1,436	General	GC/ECD	ND–>500[b]	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[p]	70[p]	90	Bordet et al. 1993
Human seminal fluid								
United States	NS	NS	General	GC/ECD	ND–detected	NS	NS	Dougherty et al. 1980

[a]No distinction is made between the isomers of chlordane. In cases where the original papers made a distinction, the data were combined.
[b]Oxychlordane.
[c]Approximate number.
[d]Geometric mean.
[e]Occupational unexposed people.
[f]Geometric mean (age group): 38 ppb (21–40 years), 88 ppb (41–60 years), and 154 ppb (61+ years).
[g]Paired blood and biopsy fat samples from selected patients. Relationship established for oxychlordane at 99% confidence level.
[h]Sum of oxychlordane (44.9), α-chlordane (2.1), γ-chlordane (2.2), *trans*-nonachlor (74.0), and *cis*-nonachlor (11.0).
[i]Median. Sum of oxychlordane (16.5), α-chlordane (0.3), γ-chlordane (0.5), *trans*-nonachlor (22.6), and *cis*-nonachlor (2.6).
[j]Total chlordane; same individuals sampled for adipose tissue and serum.
[k]All positive samples were obtained from one individual.
[l]Median. Sum of oxychlordane (0.07), α-chlordane (0.02), and γ-chlordane (0.01).
[m]Sum oxychlordane (0.16), α-chlordane (0.05), γ-chlordane (0.05), and *trans*-nonachlor (0.04).
[n]Nonachlor. Ranges for chlordane and oxychlordane are ND–0.60 ppb and ND–0.62, respectively.
[o]Median.
[p]ng of α-chlordane plus γ-chlordane/g of milk fat.

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

5.6   GENERAL POPULATION 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. Prior to 1992,
indoor air concentrations often exceed 1 $\mu g/m^3$ (see Table 5-6) and persisted for many years (Livingston
and Jones 1981). A study of chlordane concentrations in 19 houses treated for subterranean termite
control indicated that the chlordane concentration in the indoor air 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 ≈30 million structures had been treated for termites with these
chemicals, resulting in the exposure of over 80 million people. Of these structures, ≈65% were treated
with chlordane, or 19.5 million structures, resulting in the exposure of 52 million people. The exact
concentrations to which they were exposed 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^3 over all three
seasons, with 50–93% of samples containing detectable levels of chlordane. The corresponding results
for Springfield/Chicopee were 36 ng/m^3 in winter and 253 ng/m^3 in the spring; 50–87% of the samples

had detectable levels of chlordane. Several observations were made from the study. Indoor levels of chlordane were 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 (~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) estimated yearly dietary intake of chlordane since 1965 for 16–19-year-old males. In more recent years, toddlers and infants were included in these estimates (Gunderson 1988). FDA (1989a, 1990, 1991) estimated dietary chlordane intake for various age/sex groups for 1982–1984, 1989, 1990, and 1991. Their results are listed in Table 5-13. 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 originated). In addition, infants and toddlers would generally have higher intakes of chlordane than adults because of the high fat content of the foods they eat. The results for the 1991 FDA Total Diet Study were 0.0013 µg/kg/day for infants and 0.0005–0.0015 µg/kg/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 was 0.0051 µg/kg/day for infants, 0.0065 µg/kg/day for toddlers, and 0.002–0.0027 µg/kg/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.

Table 5-13. Chlordane Intake from Food[a]

| Year | Chlordane intake (µg/kg body weight/day) | | | |
	14–19-Year-old males[b]	60–65-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

Table 5-13. Chlordane Intake from Food[a]

Year	14–19-Year-old males[b]	60–65-Year-old females	Toddlers	Infants
	Chlordane intake (µg/kg body weight/day)			
1980	0.003	Not reported	0.005	0.003
1981–1982	0.004	Not reported	0.003	0.002
1984[c]	0.0025	0.0026	0.0065	0.0051
1989[d]	0.0007	0.0010	Not reported	0.0007
1990[d]	0.0001	0.0001	Not reported	0.001
1991[d]	0.0005	0.0015	Not reported	0.0013

[a]Data from Duggan et al. (1983) and Gartell et al. (1985a, 1985b, 1985c, 1985d, 1986a, 1986b) unless otherwise noted.
[b]16–19-Year-old males for studies in years 1965–1982, 14–16-year-old males for studies 1984–1991.
[c]Gunderson 1988.
[d]FDA 1989, 1990, 1991.

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 or *trans*-nonachlor) 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 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 showed 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).

The Fourth National Report on Human Exposures to Environmental Chemicals (CDC 2009) includes information regarding serum levels of chlordane metabolites oxychlordane and *trans*-nonachlor according to various age groups, sex, and race/ethnicity for the years 1999–2004. Tables 5-14 and 5-15 depict lipid adjusted and whole weight oxychlordane levels, respectively. Tables 5-16 and 5-17 depict lipid adjusted and whole weight *trans*-nonachlor levels, respectively. Lipid adjusted and whole weight oxychlordane levels for the years 2005–2009 (CDC 2017) are depicted in Tables 5-18 and 5-19, respectively. Lipid adjusted and whole weight *trans*-nonachlor levels for the years 2005–2009 (CDC 2017) are depicted in Tables 5-20 and 5-21, respectively. These data demonstrate that the U.S. population continues to exhibit measurable amounts of chlordane metabolites in serum; concentrations are higher in older age groups than younger age groups without significant male-female or race/ethnicity differences.

Table 5-14. Geometric Mean and Selected Percentiles of Serum Oxychlordane (Lipid Adjusted) Serum Concentrations (in ng/g of Lipid or Parts per Billion on a Lipid-Weight Basis) for the U.S. Population from the National Health and Nutrition Examination Survey (NHANES) 1999–2004

| | Survey years[a] | Geometric mean (95% CI) | Selected percentiles (95% CI) | | | | Sample size |
			50th	75th	90th	95th	
Total	1999–2000	*[b]	<LOD[c]	20.8 (17.8–23.0)	34.4 (30.5–38.6)	44.8 (40.2–49.6)	1,661
	2001–2002	11.4 (<LOD–12.5)	11.1 (<LOD–12.5)	21.7 (19.3–24.4)	36.4 (31.5–41.4)	49.7 (42.0–61.2)	2,249
	2003–2004	9.37 (8.69–10.1)	10.3 (9.20–11.0)	18.0 (16.8–20.1)	29.0 (26.8–32.1)	37.7 (34.8–43.8)	1,978
Age group							
12–19 years	1999–2000	*	<LOD	<LOD	<LOD	<LOD	663
	2001–2002	*	<LOD	<LOD	<LOD	11.5 (<LOD–12.6)	752
	2003–2004	*	<LOD	<LOD	9.20 (<LOD–11.5)	11.5 (8.10–18.9)	595
≥20 years	1999–2000	*	<LOD	23.3 (21.0–25.9)	37.7 (32.3–43.5)	47.7 (43.1–50.8)	998
	2001–2002	12.9 (11.7–14.3)	13.3 (11.4–14.9)	23.9 (21.2–26.7)	38.5 (33.4–45.9)	53.1 (44.1–65.9)	1,497
	2003–2004	10.6 (9.82–11.5)	11.4 (10.6–12.4)	19.9 (17.9–21.5)	31.3 (28.8–33.2)	39.2 (36.5–44.8)	1,383
Gender							
Males	1999–2000	*	<LOD	18.1 (16.1–19.6)	31.3 (25.9–38.2)	42.4 (35.3–49.6)	793
	2001–2002	11.1 (<LOD–12.6)	11.1 (<LOD–12.6)	20.6 (16.6–24.9)	33.1 (27.5–43.8)	48.1 (40.2–56.9)	1,049
	2003–2004	9.10 (8.20–10.1)	9.90 (8.30–11.2)	17.1 (15.6–18.4)	27.6 (25.3–32.2)	36.0 (32.7–39.2)	963
Females	1999–2000	*	<LOD	22.3 (20.1–25.9)	36.9 (31.5–40.3)	46.2 (39.1–51.8)	868
	2001–2002	11.7 (10.7–12.7)	11.0 (<LOD–12.9)	23.1 (20.7–25.0)	37.5 (34.5–42.1)	52.8 (42.7–70.0)	1,200
	2003–2004	9.63 (8.89–10.4)	10.6 (9.10–11.3)	20.1 (17.4–21.7)	30.3 (27.5–32.7)	41.9 (36.3–45.5)	1,015
Race/ethnicity							
Mexican Americans	1999–2000	*	<LOD	16.3 (<LOD–19.9)	28.9 (18.8–42.0)	39.9 (26.8–61.0)	628
	2001–2002	*	<LOD	13.9 (11.0–18.4)	27.2 (21.0–33.1)	37.9 (29.9–42.0)	557
	2003–2004	*	<LOD	12.8 (10.1–15.8)	22.9 (15.8–31.4)	31.4 (22.4–51.6)	462
Non-Hispanic blacks	1999–2000	*	<LOD	18.7 (<LOD–32.2)	39.9 (26.5–47.3)	48.6 (43.5–65.5)	350
	2001–2002	11.7 (<LOD–13.6)	<LOD	22.8 (17.2–28.3)	41.4 (30.6–53.7)	56.5 (41.8–73.5)	501
	2003–2004	8.74 (<LOD–10.2)	8.70 (<LOD–10.6)	18.9 (15.9–21.5)	35.1 (25.4–40.2)	44.2 (37.7–56.8)	493

Table 5-14. Geometric Mean and Selected Percentiles of Serum Oxychlordane (Lipid Adjusted) Serum Concentrations (in ng/g of Lipid or Parts per Billion on a Lipid-Weight Basis) for the U.S. Population from the National Health and Nutrition Examination Survey (NHANES) 1999–2004

	Survey years[a]	Geometric mean (95% CI)	Selected percentiles (95% CI)				Sample size
			50th	75th	90th	95th	
Non-Hispanic whites	1999–2000	*	<LOD	21.8 (18.6–24.6)	34.2 (28.9–40.9)	44.0 (37.2–49.8)	559
	2001–2002	12.1 (11.0–13.3)	11.8 (10.5–13.9)	23.0 (20.1–25.7)	37.5 (31.6–45.1)	52.2 (41.0–67.4)	1,031
	2003–2004	10.2 (9.36–11.1)	11.2 (10.0–12.1)	19.7 (17.2–21.7)	30.3 (26.8–33.6)	37.7 (34.3–45.5)	898

[a]The limit of detection for survey years 1999–2000, 2001–2002, and 2003–2004 were 14.5, 10.5, and 7.8 ng/g, respectively.
[b]Not calculated: proportion of results below limit of detection was too high to provide a valid result.
[c]Less than the limit of detection.

CI = confidence interval; LOD = limit of detection

Source: CDC 2009, 2017

Table 5-15. Geometric Mean and Selected Percentiles of Serum Oxychlordane (Whole Weight) Serum Concentrations (in ng/g of Serum or Parts per Billion) for the U.S. Population from the National Health and Nutrition Examination Survey (NHANES) 1999–2004

	Survey years[a]	Geometric mean (95% CI)	Selected percentiles (95% CI)				Sample size
			50th	75th	90th	95th	
Total	1999–2000	*[b]	<LOD[c]	0.140 (0.120–0.150)	0.260 (0.200–0.290)	0.310 (0.290–0.340)	1,661
	2001–2002	0.070 (<LOD–0.077)	0.070 (<LOD–0.080)	0.140 (0.130–0.160)	0.250 (0.220–0.300)	0.350 (0.290–0.440)	2,249
	2003–2004	0.057 (0.053–0.062)	0.063 (0.058–0.068)	0.119 (0.106–0.133)	0.204 (0.189–0.213)	0.269 (0.246–0.291)	1,978
Age group							
12–19 years	1999–2000	*	<LOD	<LOD	<LOD	<LOD	663
	2001–2002	*	<LOD	<LOD	<LOD	0.060 (<LOD–0.070)	752
	2003–2004	*	<LOD	<LOD	0.047 (<LOD–0.063)	0.066 (0.048–0.092)	595
≥20 years	1999–2000	*	<LOD	0.150 (0.140–0.180)	0.280 (0.230–0.300)	0.330 (0.300–0.400)	998
	2001–2002	0.082 (0.074–0.091)	0.080 (0.070–0.090)	0.160 (0.140–0.180)	0.270 (0.230–0.320)	0.370 (0.310–0.450)	1,497
	2003–2004	0.067 (0.061–0.073)	0.073 (0.066–0.079)	0.130 (0.115–0.146)	0.210 (0.203–0.227)	0.286 (0.258–0.320)	1,383

Table 5-15. Geometric Mean and Selected Percentiles of Serum Oxychlordane (Whole Weight) Serum Concentrations (in ng/g of Serum or Parts per Billion) for the U.S. Population from the National Health and Nutrition Examination Survey (NHANES) 1999–2004

	Survey years[a]	Geometric mean (95% CI)	Selected percentiles (95% CI)				Sample size
			50th	75th	90th	95th	
Gender							
Males	1999–2000	*	<LOD	0.120 (0.100–0.140)	0.220 (0.180–0.280)	0.300 (0.260–0.340)	793
	2001–2002	0.069 (<LOD–0.079)	0.070 (<LOD–0.080)	0.130 (0.120–0.160)	0.230 (0.190–0.300)	0.320 (0.250–0.430)	1,049
	2003–2004	0.056 (0.050–0.063)	0.063 (0.055–0.076)	0.115 (0.100–0.126)	0.189 (0.168–0.207)	0.258 (0.216–0.302)	963
Females	1999–2000	*	<LOD	0.140 (0.130–0.170)	0.270 (0.200–0.310)	0.320 (0.290–0.400)	868
	2001–2002	0.071 (0.065–0.077)	0.070 (<LOD–0.080)	0.150 (0.130–0.160)	0.260 (0.230–0.310)	0.370 (0.280–0.510)	1,200
	2003–2004	0.058 (0.053–0.064)	0.063 (0.057–0.068)	0.126 (0.104–0.146)	0.208 (0.199–0.231)	0.286 (0.245–0.331)	1,015
Race/ethnicity							
Mexican Americans	1999–2000	*	<LOD	0.100 (<LOD–0.130)	0.210 (0.130–0.320)	0.290 (0.190–0.410)	628
	2001–2002	*	<LOD	0.100 (0.070–0.130)	0.200 (0.150–0.240)	0.280 (0.210–0.360)	557
	2003–2004	*	<LOD	0.083 (0.066–0.104)	0.149 (0.108–0.230)	0.230 (0.148–0.373)	462
Non-Hispanic blacks	1999–2000	*	<LOD	0.110 (<LOD–0.170)	0.240 (0.170–0.290)	0.320 (0.240–0.430)	350
	2001–2002	0.066 (<LOD–0.077)	<LOD	0.130 (0.090–0.170)	0.260 (0.180–0.350)	0.350 (0.240–0.560)	501
	2003–2004	0.049 (<LOD–0.057)	0.050 (<LOD–0.062)	0.112 (0.087–0.136)	0.225 (0.165–0.287)	0.315 (0.253–0.348)	493
Non-Hispanic whites	1999–2000	*	<LOD	0.140 (0.120–0.170)	0.270 (0.200–0.300)	0.320 (0.280–0.380)	559
	2001–2002	0.075 (0.068–0.083)	0.080 (0.070–0.090)	0.150 (0.130–0.170)	0.250 (0.220–0.310)	0.370 (0.280–0.450)	1,031
	2003–2004	0.063 (0.058–0.070)	0.070 (0.063–0.077)	0.128 (0.110–0.148)	0.207 (0.190–0.223)	0.271 (0.242–0.315)	898

[a]The limit of detection for survey years 1999–2000, 2001–2002, and 2003–2004 were 14.5, 10.5, and 7.8 ng/g, respectively.
[b]Not calculated: proportion of results below limit of detection was too high to provide a valid result.
[c]Less than the limit of detection.

CI = confidence interval; LOD = limit of detection

Source: CDC 2017

Table 5-16. Geometric Mean and Selected Percentiles of Serum *trans*-Nonachlor (Lipid Adjusted) Serum Concentrations (in ng/g of Lipid or Parts per Billion on a Lipid-Weight Basis) for the U.S. Population from the National Health and Nutrition Examination Survey (NHANES) 1999–2004

| | Survey years[a] | Geometric mean (95% CI) | Selected percentiles (95% CI) | | | | Sample size |
			50th	75th	90th	95th	
Total	1999–2000	18.3 (16.7–20.0)	17.9 (16.1–20.1)	31.9 (28.9–36.0)	55.1 (48.4–62.6)	79.4 (67.6–88.1)	1,933
	2001–2002	17.0 (15.2–18.9)	17.9 (15.5–20.5)	33.7 (30.2–37.2)	56.3 (49.6–66.0)	78.2 (64.0–113)	2,286
	2003–2004	14.7 (13.1–16.5)	14.8 (13.5–17.0)	30.2 (26.7–32.5)	49.0 (42.6–54.7)	68.3 (58.6–82.3)	1,955
Age group							
12–19 years	1999–2000	*[b]	<LOD[c]	<LOD	18.8 (<LOD–20.6)	25.2 (19.1–28.4)	664
	2001–2002	*	<LOD	<LOD	13.4 (11.8–16.4)	19.2 (15.2–23.5)	758
	2003–2004	*	<LOD	8.70 (<LOD–12.5)	16.1 (10.7–23.7)	22.6 (16.1–34.6)	589
≥20 years	1999–2000	20.8 (19.0–22.8)	20.7 (18.0–23.5)	35.4 (30.9–40.3)	59.9 (51.8–67.6)	82.7 (74.9–89.6)	1,269
	2001–2002	19.8 (17.6–22.3)	20.9 (19.0–23.1)	36.6 (32.8–41.1)	60.6 (52.5–69.9)	84.9 (66.0–123)	1,528
	2003–2004	16.9 (15.1–18.9)	17.3 (14.6–20.0)	31.8 (28.9–35.3)	51.4 (45.9–58.6)	74.7 (59.8–90.0)	1,366
Gender							
Males	1999–2000	17.7 (16.5–19.1)	17.2 (14.9–20.1)	30.2 (27.7–34.2)	51.1 (47.3–58.6)	78.2 (60.2–88.1)	922
	2001–2002	17.0 (14.8–19.5)	18.3 (14.8–21.1)	34.4 (28.3–39.3)	54.8 (45.0–68.9)	78.2 (59.7–113)	1,062
	2003–2004	14.8 (12.7–17.3)	14.6 (12.2–18.0)	30.8 (26.7–35.3)	51.0 (42.0–59.4)	68.6 (56.0–93.8)	955
Females	1999–2000	18.8 (16.7–21.1)	18.4 (16.1–22.2)	32.9 (29.0–38.3)	59.0 (48.4–67.6)	80.8 (71.5–95.5)	1,011
	2001–2002	17.0 (15.4–18.7)	17.6 (15.0–20.3)	32.8 (30.4–36.7)	56.9 (51.9–65.5)	78.1 (65.5–111)	1,224
	2003–2004	14.5 (13.1–16.1)	15.0 (13.8–16.3)	28.2 (25.3–32.8)	48.1 (41.4–52.7)	68.3 (56.8–79.9)	1,000
Race/ethnicity							
Mexican Americans	1999–2000	*	<LOD	25.1 (22.7–29.5)	40.7 (35.1–51.8)	56.3 (45.8–77.2)	650
	2001–2002	11.9 (<LOD–14.6)	10.6 (<LOD–14.5)	26.0 (19.3–30.4)	47.9 (36.3–57.2)	59.8 (49.3–74.1)	558
	2003–2004	10.2 (7.86–13.2)	9.10 (<LOD–11.1)	20.7 (11.1–34.7)	39.5 (25.9–65.5)	62.2 (36.0–93.4)	457
Non-Hispanic blacks	1999–2000	20.3 (17.0–24.1)	17.5 (15.4–23.5)	35.7 (28.9–45.5)	77.0 (60.8–90.7)	107 (84.0–143)	404
	2001–2002	18.8 (15.4–22.9)	19.2 (14.7–22.0)	36.8 (28.3–50.5)	73.6 (50.8–110)	112 (68.7–160)	514
	2003–2004	14.4 (12.2–17.0)	13.8 (11.2–16.3)	30.8 (26.5–36.1)	59.9 (47.7–77.7)	86.6 (56.8–129)	486

5. POTENTIAL FOR HUMAN EXPOSURE

Table 5-16. Geometric Mean and Selected Percentiles of Serum *trans*-Nonachlor (Lipid Adjusted) Serum Concentrations (in ng/g of Lipid or Parts per Billion on a Lipid-Weight Basis) for the U.S. Population from the National Health and Nutrition Examination Survey (NHANES) 1999–2004

	Survey years[a]	Geometric mean (95% CI)	Selected percentiles (95% CI)				Sample size
			50th	75th	90th	95th	
Non-Hispanic whites	1999–2000	19.1 (17.2–21.1)	19.0 (16.9–22.2)	32.8 (28.0–37.6)	52.5 (44.9–64.4)	74.0 (62.3–86.7)	722
	2001–2002	17.5 (15.6–19.7)	19.0 (16.3–21.1)	34.0 (29.7–38.1)	55.5 (45.9–69.4)	78.7 (59.1–126)	1,052
	2003–2004	15.8 (13.7–18.2)	16.0 (13.8–19.3)	30.8 (26.4–35.0)	48.8 (42.1–55.7)	67.6 (57.5–87.3)	889

[a]The limit of detection for survey years 1999–2000, 2001–2002, and 2003–2004 were 14.5, 10.5, and 7.8 ng/g, respectively.
[b]Not calculated: proportion of results below limit of detection was too high to provide a valid result.
[c]Less than the limit of detection.

CI = confidence interval; LOD = limit of detection

Source: CDC 2009, 2017

Table 5-17. Geometric Mean and Selected Percentiles of Serum *trans*-Nonachlor (Whole Weight) Serum Concentrations (in ng/g of Serum or Parts per Billion) for the U.S. Population from the National Health and Nutrition Examination Survey (NHANES) 1999–2004

	Survey years[a]	Geometric mean (95% CI)	Selected percentiles (95% CI)				Sample size
			50th	75th	90th	95th	
Total	1999–2000	0.109 (0.099–0.119)	0.110 (0.090–0.120)	0.210 (0.190–0.240)	0.370 (0.330–0.420)	0.550 (0.470–0.630)	1,933
	2001–2002	0.104 (0.093–0.116)	0.110 (0.100–0.120)	0.220 (0.190–0.250)	0.390 (0.330–0.480)	0.590 (0.430–0.800)	2,286
	2003–2004	0.089 (0.080–0.100)	0.094 (0.084–0.108)	0.191 (0.171–0.211)	0.324 (0.290–0.371)	0.470 (0.410–0.558)	1,955
Age group							
12–19 years	1999–2000	*[b]	<LOD[c]	<LOD	0.090 (<LOD–0.110)	0.120 (0.100–0.130)	664
	2001–2002	*	<LOD	<LOD	0.070 (0.060–0.080)	0.090 (0.080–0.130)	758
	2003–2004	*	<LOD	0.041 (<LOD–0.060)	0.081 (0.054–0.117)	0.109 (0.081–0.161)	589
≥20 years	1999–2000	0.128 (0.116–0.141)	0.130 (0.110–0.150)	0.230 (0.210–0.260)	0.400 (0.360–0.460)	0.580 (0.490–0.690)	1,269
	2001–2002	0.125 (0.111–0.141)	0.130 (0.120–0.150)	0.240 (0.210–0.280)	0.420 (0.350–0.540)	0.640 (0.470–0.840)	1,528
	2003–2004	0.106 (0.095–0.119)	0.112 (0.096–0.127)	0.210 (0.186–0.237)	0.355 (0.301–0.405)	0.520 (0.430–0.594)	1,366

Table 5-17. Geometric Mean and Selected Percentiles of Serum *trans*-Nonachlor (Whole Weight) Serum Concentrations (in ng/g of Serum or Parts per Billion) for the U.S. Population from the National Health and Nutrition Examination Survey (NHANES) 1999–2004

	Survey years[a]	Geometric mean (95% CI)	Selected percentiles (95% CI)				Sample size
			50th	75th	90th	95th	
Gender							
Males	1999–2000	0.106 (0.098–0.114)	0.100 (0.090–0.120)	0.210 (0.180–0.220)	0.350 (0.310–0.400)	0.520 (0.400–0.630)	922
	2001–2002	0.105 (0.091–0.122)	0.110 (0.090–0.130)	0.220 (0.190–0.260)	0.380 (0.310–0.500)	0.580 (0.390–0.830)	1,062
	2003–2004	0.092 (0.079–0.108)	0.098 (0.085–0.126)	0.202 (0.177–0.232)	0.343 (0.285–0.395)	0.458 (0.395–0.594)	955
Females	1999–2000	0.111 (0.099–0.125)	0.110 (0.090–0.130)	0.220 (0.190–0.250)	0.390 (0.310–0.460)	0.580 (0.460–0.690)	1,011
	2001–2002	0.103 (0.093–0.113)	0.110 (0.090–0.120)	0.220 (0.180–0.240)	0.400 (0.340–0.450)	0.590 (0.430–0.830)	1,224
	2003–2004	0.087 (0.078–0.097)	0.092 (0.079–0.098)	0.183 (0.161–0.210)	0.317 (0.286–0.367)	0.470 (0.409–0.565)	1,000
Race/ethnicity							
Mexican Americans	1999–2000	*	<LOD	0.170 (0.120–0.210)	0.310 (0.240–0.340)	0.390 (0.320–0.520)	650
	2001–2002	0.071 (<LOD–0.091)	0.060 (<LOD–0.090)	0.160 (0.120–0.210)	0.330 (0.270–0.390)	0.470 (0.360–0.590)	558
	2003–2004	0.062 (0.047–0.082)	0.055 (<LOD–0.069)	0.135 (0.069–0.237)	0.288 (0.158–0.559)	0.414 (0.279–0.651)	457
Non-Hispanic blacks	1999–2000	0.112 (0.093–0.134)	0.100 (0.080–0.130)	0.220 (0.180–0.300)	0.490 (0.340–0.600)	0.760 (0.510–0.960)	404
	2001–2002	0.106 (0.085–0.131)	0.110 (0.080–0.130)	0.220 (0.160–0.310)	0.490 (0.320–0.680)	0.680 (0.410–1.20)	514
	2003–2004	0.080 (0.068–0.096)	0.078 (0.061–0.093)	0.186 (0.145–0.242)	0.417 (0.272–0.565)	0.573 (0.497–0.684)	486
Non-Hispanic whites	1999–2000	0.116 (0.104–0.129)	0.120 (0.100–0.140)	0.220 (0.190–0.240)	0.370 (0.300–0.440)	0.510 (0.440–0.630)	722
	2001–2002	0.108 (0.096–0.122)	0.120 (0.100–0.130)	0.220 (0.190–0.250)	0.390 (0.310–0.490)	0.600 (0.400–0.930)	1,052
	2003–2004	0.098 (0.085–0.113)	0.103 (0.090–0.124)	0.205 (0.173–0.234)	0.327 (0.288–0.390)	0.461 (0.397–0.576)	889

[a]The limit of detection for survey years 1999–2000, 2001–2002, and 2003–2004 were 14.5, 10.5, and 7.8 ng/g, respectively.
[b]Not calculated: proportion of results below limit of detection was too high to provide a valid result.
[c]Less than the limit of detection.

CI = confidence interval; LOD = limit of detection

Source: CDC 2009, 2017

**Table 5-18. Weighted Arithmetic Mean and Unadjusted Standard Error of Pooled
Serum Concentrations of Serum Oxychlordane (Lipid Adjusted) (in ng/g
of Lipid or Parts per Billion on a Lipid-Weight Basis) for the
U.S. Population from the National Health and Nutrition
Examination Survey (NHANES) 2005–2008**

Category	Age (years)	Survey years[a]	Weighted arithmetic mean[b]	Unadjusted standard error[c]	Number of pools[d]
Non-Hispanic white male	12–19	2005–2006	4.80	1.1	9
		2007–2008	3.52	0.52	6
	20–39	2005–2006	6.50	1.06	12
		2007–2008	6.93	0.75	15
	40–59	2005–2006	14.9	1.4	12
		2007–2008	12.1	0.5	16
	60+	2005–2006	25.4	2.5	15
		2007–2008	26.1	1.4	23
Non-Hispanic white female	12–19	2005–2006	2.98	0.3	10
		2007–2008	3.66	0.74	7
	20–39	2005–2006	5.64	0.56	16
		2007–2008	5.79	0.51	13
	40–59	2005–2006	13.7	1	13
		2007–2008	11.8	0.8	17
	60+	2005–2006	28.9	2.6	17
		2007–2008	31.8	2.3	21
Non-Hispanic black male	12–19	2005–2006	4.08	0.49	13
		2007–2008	2.80	0.75	6
	20–39	2005–2006	4.53	0.9	6
		2007–2008	5.72	0.28	6
	40–59	2005–2006	12.0	1	5
		2007–2008	12.1	1.1	6
	60+	2005–2006	32.7	5.3	5
		2007–2008	26.6	2.5	8
Non-Hispanic black female	12–19	2005–2006	2.92	0.31	14
		2007–2008	*[e]	*	5
	20–39	2005–2006	5.56	0.68	7
		2007–2008	4.45	0.79	8
	40–59	2005–2006	14.5	0.8	7
		2007–2008	14.3	1	8
	60+	2005–2006	52.9	11.7	5
		2007–2008	38.1	1.7	7

Table 5-18. Weighted Arithmetic Mean and Unadjusted Standard Error of Pooled Serum Concentrations of Serum Oxychlordane (Lipid Adjusted) (in ng/g of Lipid or Parts per Billion on a Lipid-Weight Basis) for the U.S. Population from the National Health and Nutrition Examination Survey (NHANES) 2005–2008

Category	Age (years)	Survey years[a]	Weighted arithmetic mean[b]	Unadjusted standard error[c]	Number of pools[d]
Mexican American male	12–19	2005–2006	2.54	0.33	11
		2007–2008	2.76	0.45	6
	20–39	2005–2006	5.84	1.22	9
		2007–2008	4.93	0.38	9
	40–59	2005–2006	11.0	1.4	4
		2007–2008	12.0	0.7	6
	60+	2005–2006	18.6	2.4	4
		2007–2008	21.9	2.2	5
Mexican American female	12–19	2005–2006	2.39	0.25	16
		2007–2008	*	*	5
	20–39	2005–2006	4.39	0.5	9
		2007–2008	4.17	0.55	8
	40–59	2005–2006	13.7	1.8	6
		2007–2008	13.4	2.2	6
	60+	2005–2006	27.4	3.8	3
		2007–2008	28.2	4.3	5

[a]The limit of detection for survey years 2005–2006 and 2007–2008 were 1.46 and 1.4 ng/g, respectively.
[b]Weighted arithmetic means are not comparable to weighted geometric means.
[c]Unadjusted standard errors do not incorporate survey design effects.
[d]Each pool was composed of serum from 8 persons.
[e]Not calculated: proportion of results below limit of detection was too high to provide a valid result.

Source: CDC 2017

Table 5-19. Weighted Arithmetic Mean and Unadjusted Standard Error of Pooled Serum Concentrations of Serum Oxychlordane (Whole Weight) (in ng/g of Serum or Parts per Billion) for the U.S. Population from the National Health and Nutrition Examination Survey (NHANES) 2005–2008

Category	Age (years)	Survey years[a]	Weighted arithmetic mean[b]	Unadjusted standard error[c]	Number of pools[d]
Non-Hispanic white male	12–19	2005–2006	0.026	0.006	9
		2007–2008	0.018	0.003	6
	20–39	2005–2006	0.049	0.01	12
		2007–2008	0.047	0.006	15
	40–59	2005–2006	0.113	0.013	12
		2007–2008	0.089	0.005	16
	60+	2005–2006	0.171	0.015	15
		2007–2008	0.167	0.009	23
Non-Hispanic white female	12–19	2005–2006	0.016	0.002	10
		2007–2008	0.017	0.004	7
	20–39	2005–2006	0.037	0.004	16
		2007–2008	0.035	0.003	13
	40–59	2005–2006	0.101	0.01	13
		2007–2008	0.079	0.006	17
	60+	2005–2006	0.210	0.017	17
		2007–2008	0.214	0.017	21
Non-Hispanic black male	12–19	2005–2006	0.020	0.002	13
		2007–2008	0.013	0.003	6
	20–39	2005–2006	0.027	0.005	6
		2007–2008	0.032	0.002	6
	40–59	2005–2006	0.076	0.006	5
		2007–2008	0.077	0.007	6
	60+	2005–2006	0.193	0.028	5
		2007–2008	0.162	0.017	8
Non-Hispanic black female	12–19	2005–2006	0.014	0.001	14
		2007–2008	*[e]	*	5
	20–39	2005–2006	0.032	0.004	7
		2007–2008	0.022	0.004	8
	40–59	2005–2006	0.093	0.006	7
		2007–2008	0.086	0.008	8
	60+	2005–2006	0.347	0.067	5
		2007–2008	0.229	0.012	7

Table 5-19. Weighted Arithmetic Mean and Unadjusted Standard Error of Pooled Serum Concentrations of Serum Oxychlordane (Whole Weight) (in ng/g of Serum or Parts per Billion) for the U.S. Population from the National Health and Nutrition Examination Survey (NHANES) 2005–2008

Category	Age (years)	Survey years[a]	Weighted arithmetic mean[b]	Unadjusted standard error[c]	Number of pools[d]
Mexican American male	12–19	2005–2006	0.014	0.002	11
		2007–2008	0.014	0.002	6
	20–39	2005–2006	0.041	0.007	9
		2007–2008	0.034	0.004	9
	40–59	2005–2006	0.089	0.014	4
		2007–2008	0.087	0.009	6
	60+	2005–2006	0.137	0.025	4
		2007–2008	0.156	0.011	5
Mexican American female	12–19	2005–2006	0.013	0.001	16
		2007–2008	*	*	5
	20–39	2005–2006	0.029	0.003	9
		2007–2008	0.024	0.004	8
	40–59	2005–2006	0.100	0.011	6
		2007–2008	0.090	0.014	6
	60+	2005–2006	0.208	0.035	3
		2007–2008	0.193	0.03	5

[a]The limit of detection for survey years 2005–2006 and 2007–2008 were 1.46 and 1.4 ng/g, respectively.
[b]Weighted arithmetic means are not comparable to weighted geometric means.
[c]Unadjusted standard errors do not incorporate survey design effects.
[d]Each pool was composed of serum from 8 persons.
[e]Not calculated: proportion of results below limit of detection was too high to provide a valid result.

Source: CDC 2017

Table 5-20. Weighted Arithmetic Mean and Unadjusted Standard Error of Pooled Serum Concentrations of Serum *trans*-Nonachlor (Lipid Adjusted) (in ng/g of Lipid or Parts per Billion on a Lipid-Weight Basis) for the U.S. Population from the National Health and Nutrition Examination Survey (NHANES) 2005–2008

Category	Age (years)	Survey years[a]	Weighted arithmetic mean[b]	Unadjusted standard error[c]	Number of pools[d]
Non-Hispanic white male	12–19	2005–2006	9.03[e]	2.84	9
		2007–2008	6.06	1.08	6
	20–39	2005–2006	11.3	2	12
		2007–2008	11.1	1.5	15
	40–59	2005–2006	26.9	3.9	12
		2007–2008	21.5	1.2	16
	60+	2005–2006	49.4	7.9	15
		2007–2008	50.6	4.2	23
Non-Hispanic white female	12–19	2005–2006	4.94	0.52	10
		2007–2008	6.70	0.89	7
	20–39	2005–2006	9.70	1.44	16
		2007–2008	8.95	0.97	13
	40–59	2005–2006	21.8	2.3	13
		2007–2008	16.4	1.5	17
	60+	2005–2006	50.2	6.1	17
		2007–2008	51.7	6.1	21
Non-Hispanic black male	12–19	2005–2006	6.50	0.67	13
		2007–2008	4.71	0.65	6
	20–39	2005–2006	8.24	0.86	6
		2007–2008	8.87	0.97	6
	40–59	2005–2006	22.0	2.6	5
		2007–2008	21.7	2.1	6
	60+	2005–2006	66.4	13.2	5
		2007–2008	54.4	4.9	8
Non-Hispanic black female	12–19	2005–2006	4.44	0.54	14
		2007–2008	3.39[e]	1.18	5
	20–39	2005–2006	9.32	1.22	7
		2007–2008	6.42	0.6	8
	40–59	2005–2006	24.1	1.5	7
		2007–2008	20.4	1.7	8
	60+	2005–2006	89.0	15.4	5
		2007–2008	68.0	3.9	7

**Table 5-20. Weighted Arithmetic Mean and Unadjusted Standard Error of Pooled
Serum Concentrations of Serum *trans*-Nonachlor (Lipid Adjusted) (in ng/g
of Lipid or Parts per Billion on a Lipid-Weight Basis) for the
U.S. Population from the National Health and Nutrition
Examination Survey (NHANES) 2005–2008**

Category	Age (years)	Survey years[a]	Weighted arithmetic mean[b]	Unadjusted standard error[c]	Number of pools[d]
Mexican American male	12–19	2005–2006	3.71	0.49	11
		2007–2008	3.91	0.81	6
	20–39	2005–2006	7.58	0.75	9
		2007–2008	8.43	0.97	9
	40–59	2005–2006	18.8	2.4	4
		2007–2008	24.5	2.9	6
	60+	2005–2006	30.7	6.3	4
		2007–2008	40.3	4.5	5
Mexican American female	12–19	2005–2006	3.53	0.23	16
		2007–2008	*[f]	*	5
	20–39	2005–2006	6.40	0.75	9
		2007–2008	7.55	0.9	8
	40–59	2005–2006	18.5	1.7	6
		2007–2008	22.6	4.4	6
	60+	2005–2006	46.4	9.8	3
		2007–2008	46.9	8	5

[a]The limit of detection for survey years 2005–2006 and 2007–2008 were 0.77 and 1.4 ng/g, respectively.
[b]Weighted arithmetic means are not comparable to weighted geometric means.
[c]Unadjusted standard errors do not incorporate survey design effects.
[d]Each pool was composed of serum from 8 persons.
[e]Standard error of the mean estimate is >30%.
[f]Not calculated: proportion of results below limit of detection was too high to provide a valid result.

Source: CDC 2017

Table 5-21. Weighted Arithmetic Mean and Unadjusted Standard Error of Pooled Serum Concentrations of Serum *trans*-Nonachlor (Whole Weight) (in ng/g of Serum or Parts per Billion) for the U.S. Population from the National Health and Nutrition Examination Survey (NHANES) 2005–2008

Category	Age (years)	Survey years[a]	Weighted arithmetic mean[b]	Unadjusted standard error[c]	Number of pools[d]
Non-Hispanic white male	12–19	2005–2006	0.048[e]	0.015	9
		2007–2008	0.030	0.005	6
	20–39	2005–2006	0.086	0.019	12
		2007–2008	0.076	0.011	15
	40–59	2005–2006	0.206	0.034	12
		2007–2008	0.159	0.012	16
	60+	2005–2006	0.331	0.049	15
		2007–2008	0.325	0.028	23
Non-Hispanic white female	12–19	2005–2006	0.026	0.003	10
		2007–2008	0.031	0.004	7
	20–39	2005–2006	0.063	0.01	16
		2007–2008	0.054	0.007	13
	40–59	2005–2006	0.161	0.019	13
		2007–2008	0.108	0.009	17
	60+	2005–2006	0.362	0.04	17
		2007–2008	0.352	0.045	21
Non-Hispanic black male	12–19	2005–2006	0.032	0.003	13
		2007–2008	0.022	0.003	6
	20–39	2005–2006	0.049	0.006	6
		2007–2008	0.050	0.006	6
	40–59	2005–2006	0.140	0.014	5
		2007–2008	0.138	0.013	6
	60+	2005–2006	0.390	0.071	5
		2007–2008	0.331	0.032	8
Non-Hispanic black female	12–19	2005–2006	0.022	0.003	14
		2007–2008	0.016[e]	0.005	5
	20–39	2005–2006	0.054	0.007	7
		2007–2008	0.032	0.003	8
	40–59	2005–2006	0.154	0.009	7
		2007–2008	0.124	0.012	8
	60+	2005–2006	0.588	0.088	5
		2007–2008	0.409	0.027	7

Table 5-21. Weighted Arithmetic Mean and Unadjusted Standard Error of Pooled Serum Concentrations of Serum *trans*-Nonachlor (Whole Weight) (in ng/g of Serum or Parts per Billion) for the U.S. Population from the National Health and Nutrition Examination Survey (NHANES) 2005–2008

Category	Age (years)	Survey years[a]	Weighted arithmetic mean[b]	Unadjusted standard error[c]	Number of pools[d]
Mexican American male	12–19	2005–2006	0.020	0.002	11
		2007–2008	0.020	0.004	6
	20–39	2005–2006	0.054	0.005	9
		2007–2008	0.058	0.008	9
	40–59	2005–2006	0.153	0.022	4
		2007–2008	0.176	0.024	6
	60+	2005–2006	0.228	0.06	4
		2007–2008	0.289	0.028	5
Mexican American female	12–19	2005–2006	0.019	0.001	16
		2007–2008	*[f]	*	5
	20–39	2005–2006	0.042	0.005	9
		2007–2008	0.044	0.006	8
	40–59	2005–2006	0.135	0.011	6
		2007–2008	0.151	0.029	6
	60+	2005–2006	0.360	0.095	3
		2007–2008	0.323	0.058	5

[a]The limit of detection for survey years 2005–2006 and 2007–2008 were 0.77 and 1.4 ng/g, respectively.
[b]Weighted arithmetic means are not comparable to weighted geometric means.
[c]Unadjusted standard errors do not incorporate survey design effects.
[d]Each pool was composed of serum from 8 persons.
[e]Standard error of the mean estimate is >30%.
[f]Not calculated: proportion of results below limit of detection was too high to provide a valid result.

Source: CDC 2017

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 mg/cm^2 (median 0.175 mg/cm^2, 24 samples) was found on the 100 cm^2 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^2 (median 0.12 mg/cm^2, 23 samples) for 100 cm^2 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^2 (median
0.024 mg/cm^2, 24 samples) on the inside patches, whereas Maddy et al. (1979) found 0.009–l.9 mg/cm^2
(median 0.082 mg/cm^2, 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^3), whereas Maddy et al. (1979) found 0.007, 0.008, and 0.110 mg/m^3
in three of five samples taken outside the respirator and 0.011 and 0.27 mg/m^3 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® 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 5-6). Total dermal exposure of 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 of the 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 occupational

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

5.7 POPULATIONS WITH POTENTIALLY HIGH EXPOSURES

A segment of the general population with potentially high exposure to chlordane includes those people living in structures that were 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 would 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.