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Impact of Long-Term Weathering, Mobility, and Land Use on Chlordane Residues in Soil

MARY JANE INCORVIA MATTINA,*
WILLIAM IANNUCCI-BERGER,
LAURE DYKAS,† AND JENNIFER PARDUS‡
Department of Analytical Chemistry, The Connecticut Agricultural Experiment Station, 123 Huntington Street, New Haven, Connecticut 06511

The use of technical chlordane, a mixture of 147 separate components, and chlordane-containing products has been illegal in the United States since 1988. Technical chlordane is a member of the persistent organic pollutants (POPs), all of which exhibit remarkably long half-lives in the environment. Due to its persistence, its former use at extremely high application rates, and its toxicity, technical chlordane in soil may be present at levels of concern to public health. Concentrations at a site for which the date and rate of application of technical chlordane were recorded permit an accurate description of its weathering and an assessment of its vertical and horizontal movement during the past several decades. This site also allows computation of half-life as an average across the 147 components in soil 38 years after application using explicitly stated assumptions. Levels of technical chlordane in soils spanning a variety of land uses including agricultural sites, residential lawns and gardens, and foundation sites are also presented.

Introduction

The pesticide technical chlordane was introduced in 1948, principally for use as an insecticide but also for herbicidal use (*1*). Technical chlordane is a member of the POPs, persistent organic pollutants (*2*), which include DDT, heptachlor, dieldrin, toxaphene, and aldrin. Due largely to technical chlordane's extreme persistence in the environment, the United States Environmental Protection Agency (U.S. EPA) initiated a cancellation of registration in 1978 for use on food crops, although the phase-out continued into 1983 (*3*). Following 1983, technical chlordane was used primarily as a termiticide, but in 1988 the domestic registration of technical chlordane and chlordane-containing products was canceled (*4*). Its manufacture in the United States was discontinued voluntarily in 1997.

The commercially available material, technical chlordane, is a mixture of over 140 different components (*5*), the most abundant of which are γ-(*trans*-)chlordane, α-(*cis*-)chlordane, and *trans*-nonachlor, totaling approximately 25 wt % of the technical mixture (*6*). The domestic manufacturer, Velsicol Chemical Company, also produced a refined version, AG chlordane (*7*) or HCS3260 (*8*), of which 95 wt % consisted of γ- and α-chlordane.

Data acquired in this laboratory from 1991 through 1998 indicate that POPs, such as chlordane, are present in food crops with a distinct preference for certain crop families (*9*). These data prompted speculation whether the observed selectivity was related to variation in soil chlordane concentration or plant physiology. One component of the investigation of this issue was a survey of technical chlordane concentration in Connecticut soils as a function of land use. Concentrations from numerous agricultural and residential sites are reported here.

The investigation of chlordane in soils and its uptake by crops was considerably enhanced by access to a portion of lawn on the New Haven campus of The Connecticut Agricultural Experiment Station (CAES) that had been treated with technical chlordane in the spring of 1960 as part of a crabgrass control experiment. This site provided a unique opportunity for study of the weathering profile and the vertical and horizontal movement of technical chlordane during the 38 years since its application. The results of these investigations are reported here. Studies on uptake of chlordane by specific crops will be reported separately.

Experimental Section

CAES Experimental Site. On April 28, 1960, a portion of the lawn at the New Haven facility of CAES was sprayed with a formulation containing 72 wt % of technical chlordane at a rate of 1.5 pints of formulation/1000 ft^2 (*10*), far higher than the 1.5−2 lb/acre recommended for insecticide use (*11*). As shown in Figure 1, the treated area measured 69.5 ft by 38.5 ft, sloped downhill from west to east at a 17% grade, and remained in turf for the ensuing 38 years.

In the spring of 1998, soil cores 1−10 were collected prior to preparing the hatched area for planting. Cores 11−26 were collected throughout the summer of 1998. Soil cores were collected using a clean 2.2 cm diameter stainless steel corer. The top layer of grass was removed before the core sample was collected. Each core was separated into a 0−15-cm portion and a 15−30-cm portion and stored separately in tightly capped 250-mL amber glass jars until analysis. The soil in the CAES plot was classified as sandy loam.

Agricultural Soils. Seven agricultural sites, which remained in crop production as of 1997, were sampled during July and August 1997. For each sample, the top 10 cm of soil was collected using a clean trowel and excluding grass, weeds, rocks, and other debris. Samples were collected in clean 250-mL amber glass jars, labeled with location and date of collection, and stored tightly sealed until analysis. One of the agricultural sites, A, at which 29 samples were collected, consisted of 15−20 acres in food crops. This site had been used until 1978 for tobacco cultivation. Another agricultural site, B, from which 12 samples were collected, was an ornamental nursery field of approximately 12 acres that was under continual *Taxus* production for more than 20 years. The remaining five sites were 5−10-acre parcels on which a variety of food crops were grown. One to five samples were collected from each of the smaller sites. It is estimated that chlordane use was terminated at all the agricultural sites by the early 1980s.

Residential Soils. A total of 34 lawn and 45 foundation soil samples from private residences were collected by homeowners for inclusion in this survey. Instructions for the collection of samples indicated that the top 10 cm of soil free of debris was to be collected in the clean 250-mL amber glass jars provided by the laboratory. A clean trowel was to be used, and the jars were to be capped tightly, labeled, and kept cool prior to delivery to the lab. Foundation samples

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* Corresponding author phone: (203)974-8449; fax: (203)974-8502; e-mail: MaryJane.Mattina@po.state.ct.us.

† Student intern from Central Connecticut State University.

‡ Student intern from University of Connecticut.

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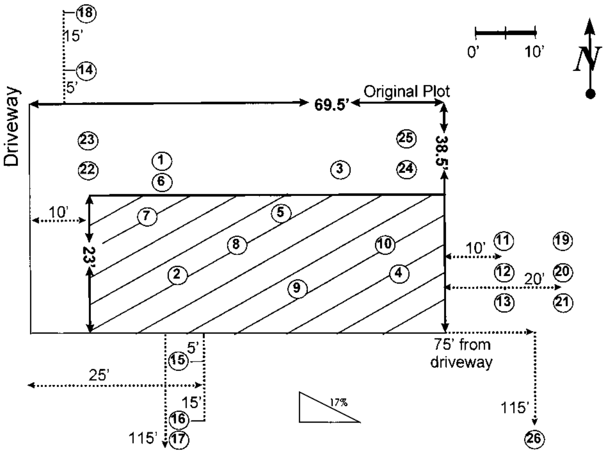

FIGURE 1. Map of CAES site.

were to be collected displaced 15 cm from the foundation wall. Although the more than 120 agricultural and residential soil samples were not individually classified, Connecticut soils are primarily sandy loam (*12*).

Extraction Procedure. The procedure that we employed is adapted from the microwave-assisted extraction (MAE) of soil developed by Fish and Revesz (*13*). Each 250-mL jar of soil was sieved in its as-received condition through a 2- or 2.5-mm mesh screen to remove nonsoil items and to provide a homogeneous sample of fine soil particles. A 3-g subsample was used for moisture determination and organic matter content. Moisture was determined from the weight of the sample before and after drying overnight at 95 °C. The dried sample was then ashed at 550 °C for 3 h, and the final weight was used to calculate percent organic content (*14*).

A second 3-g portion of soil was transferred to a Teflon PFA lined digestion vessel from the CEM MES-1000 microwave solvent extraction system (CEM Corporation, Matthews, NC). Fifty milliliters of 2:3 (v/v) hexane/acetone (Ultra-Resi-Analyzed, J. T. Baker, Phillipsburg, NJ) was poured over the soil; the vessel was capped and allowed to equilibrate for 45 min. Vessels were placed in the CEM MES-1000 oven and extracted using the following program: 100% power; 7 min ramp to 120 °C; 20 min hold time. After cool-down, the liquid was decanted into a Kuderna−Danish (K−D) flask fitted with a 10-mL concentrator tube, the soil remaining in the extraction vessel was rinsed with two 15-mL portions of 2:3 hexane/acetone, and the rinses were combined with the original extraction liquid. A Snyder column was fitted to the flask, and the solvent reduced to ≅1 mL using a hot water bath at 90 °C. Three milliliters of isooctane (Ultra-Resi-Analyzed, J. T. Baker, Phillipsburg, NJ) was added through the Snyder column and the liquid again reduced to ≅1 mL on the hot water bath. The apparatus was removed from the hot water bath, and a second 3-mL portion of isooctane was added through the Snyder. When the liquid had cooled to room temperature, the Snyder and K−D were removed, and the extract was made up to a final 10-mL volume with isooctane.

To confirm that the above soil extraction method performed adequately, we extracted a quality control soil containing γ-chlordane, α-chlordane, and *p,p′*-DDE (Environmental Resource Associates, Arvada, CO) using the same extraction procedure.

Quantitation. Quantitation of chlordane in the isooctane soil extract was accomplished using a Hewlett-Packard (Hewlett-Packard Co., Avondale, PA) 5890 gas chromatograph (GC) with a ^{63}Ni electron capture detector (ECD). The column was a 30 m × 0.53 mm 0.5 μm SPB-1 film (Supelco, Inc., Bellefonte, PA). The GC oven was programmed as follows: initial temperature 175 °C; ramped at 1 °C/min to 210 °C; then ramped at 2 °C/min to 250 °C and held for 15 min for a total run time of 70 min. The injection port was kept at 250 °C, and a 2 μL splitless injection was used. Helium was the carrier gas, and the makeup gas was 5% CH_4 in Ar with a flow of 20 mL/min and the ECD operating at 325 °C. All data were collected and processed using HP ChemStation B.02.05 software.

TABLE 1. Chlordane Recovered Using MAE vs Soxhlet Extraction

sample code	MAE	Soxhlet
S3-2	0.023	0.021
F3-3	0.185	0.154
S2-2	0.529	0.412

Stock standards of γ-chlordane, α-chlordane, *trans*-nonachlor, and *p,p′*-DDE in toluene were prepared either from EPA analytical grade standards (EPA, Research Triangle Park, NC) or purchased as 100 μg/mL in methanol from Chem Service (West Chester, PA). The stock solution was diluted in isooctane to prepare the following calibration solutions: 200, 100, 50, 20, 10, 5, 2, 0.2 ng/mL. Standards of technical chlordane (lot no. 51710412, Velsicol Chemical Company, Memphis, TN) were prepared similarly. The limit of quantitation (LOQ) of each compound in the soil was chosen as 1 ng/g. For this limit, the area of the selected component peak in the chromatogram of the soil extract was equal to or greater than the area of the same component in the chromatogram of the 0.2 ng/mL standard. The signal-to-noise ratio for the 0.2 ng/mL standards was 50:1.

Results and Discussion

Suitability of MAE Method. Because this is the first time that data from a soil survey based on microwave extraction have been presented in the literature, it must be demonstrated that the data so obtained are in all regards comparable to data from older, established soil extraction methods. EPA Method 8081 for the determination of organochlorine pesticides in soil calls for a 16−24-h Soxhlet extraction of 10 g of soil with 300 mL of 1:1 hexane/acetone. As pointed out by Fish and Revesz (*13*), this solvent system boils as a 2:3 hexane/acetone azeotrope, resulting in this latter composition for the actual extracting solvent in the Soxhlet method. Thus, 2:3 hexane/acetone was chosen as the extraction solvent in the closed MAE system.

Table 1 compares the efficiency of MAE with Soxhlet extraction of soil samples originating from agricultural site A, which contain weathered chlordane residues at “low”, “medium”, and “high” levels. All concentrations in this paper are expressed as micrograms per gram (γ-chlordane + α-chlordane + *trans*-nonachlor) on a dry weight basis. Based on the recovery data, quantity of organic solvent, and time consumed, microwave-assisted extraction compares very favorably with the EPA Soxhlet extraction method for determining weathered chlordane residues in soil.

Since weathered soil contaminants are known to be more intractable to extraction than freshly spiked contaminants (*15*), weathered soil samples typical of low, medium, and high levels were each extracted consecutively by MAE. In all cases the extract from the second MAE of each sample contained no detectable chlordane.

Finally, 10 3-g portions of the ERA soil standard were extracted using the MAE procedure. In all cases, the data fell within the performance acceptance limits as specified by ERA. The recoveries are within QC ranges reported previously in the literature (*16*). Hence, no recovery correction was applied to any data reported in this paper.

Quantitation. The quantitation of multicomponent environmental contaminants, such as chlordane, toxaphene,

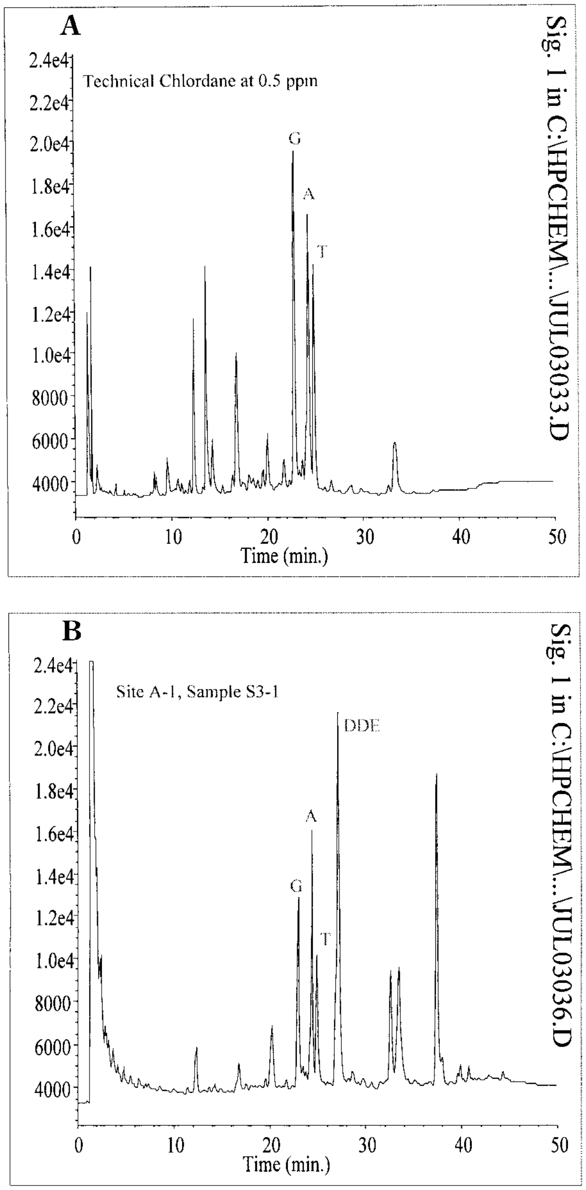

FIGURE 2. G = *trans*-chlordane, A = *cis*-chlordane, T = *trans*-nonachlor. (A) Chromatogram of technical chlordane. (B) Chromatogram of soil extract.

and polychlorinated biphenyls, is a nontrivial analytical issue in all weathered matrixes. In Figure 2 are presented the GC/ECD chromatograms for (A) technical chlordane and (B) a typical soil extract. Comparison of Figure 2, panel A with panel B shows that most of the early eluting and more volatile components of technical chlordane are no longer present in the soil extract. However, γ-chlordane, α-chlordane, and *trans*-nonachlor remain the major chlordane-derived GC peaks in the soil extract as they are in technical chlordane. It is therefore justifiable to quantitate γ-chlordane, α-chlordane, and *trans*-nonachlor individually in the extract using standards prepared for each component. The three-component sum is then used as a surrogate for technical chlordane remaining in the weathered soil. Since there is a substantial alteration in the GC profiles between technical chlordane and the extract from the weathered soil, this approach should yield a more reasonable approximation of the technical chlordane remaining than a quantitation based on a series of technical chlordane standards, at least in the weathered soils that we examined.

The GC trace reproduced in Figure 2B is typical of all 179 soil extracts examined in this study. These observations agree with those of Beeman for soil treated 20 years earlier with 0.03% technical chlordane but contrast to Beeman's observation that extracts of soil that had been treated with 1% technical chlordane produced GC/ECD traces identical with technical chlordane (*17*). The data also do not support the findings of Brumley et al., who proposed that extensive weathering of soil chlordane residues may not significantly alter its composition (*18*).

Another issue in chlordane analysis, the relative and absolute amounts of γ-chlordane, α-chlordane, and *trans*-nonachlor in technical chlordane, must be mentioned here. More than 20 years ago, Cochrane and Greenhalgh (*19*) pointed out that the estimated percentages of α-chlordane (19%) and of γ-chlordane (24%) provided by Velsicol are "... 'normalized' responses of *cis*- and *trans*-chlordane when the total GLC response of standard technical chlordane is equated to 100% ... [and is not] ... an indication of the precise analyses of technical chlordane." This analytically important piece of information as well as the relative ratio of γ-chlordane and α-chlordane in technical chlordane have been subsequently misstated in the literature (*20*) and the error propagated (*16, 17, 22*). Table 2 provides a comparison of the percent by weight values of the three major components of technical chlordane and their relative amounts as determined in this laboratory and as reported in the literature. The standard deviations listed for the values determined in the CAES laboratories are for two different preparations of technical chlordane each quantitated with both EPA and Chem Service standards. It is worth noting that there is general agreement among the ratios listed in Table 2, even though several different analytical methods were used to arrive at these ratios.

Weathering of Technical Chlordane. Figure 3 presents the amounts of γ-chlordane, α-chlordane, and *trans*-nonachlor for the top 15 cm (A) and the 15−30-cm layer (B) of the 14 cores within the treated area. Figure 4 summarizes the amounts of γ-chlordane, α-chlordane, and *trans*-nonachlor for the top 15 cm (A) and the 15−30-cm layer (B) of the 12 cores outside the treated area.

Variation at a Site, Vertical and Horizontal Translocation. It is apparent from Figure 3A that there is distinct variation of values across the CAES site. Similar variation in chlordane values in the multiple samples from agricultural sites A and B was also noted. Chlordane was applied at the CAES site as a spray onto turf that was left undisturbed for 38 years. Application at agricultural sites A and B was onto cultivated fields that were tilled several times over the course of their use. Plowing may account for some of the intrasite variation observed at sites A and B. However, the lack of uniformity of the chlordane concentration in the soil across the CAES site suggests that the variation may also be introduced during application. The original plot soil was classified as a sandy loam with organic matter ranging from 5.2% to 8.2% in the 0−15-cm layer and from 3.3%to 7.0% in the 15−30-cm layer. No significant correlation between organic content and total chlordane concentration was observed.

When the total concentration in the top 15 cm is compared with that in the 15−30-cm layer at the same core within the treated area (Figure 3, panel A vs panel B), the value has dropped, in general, by an order of magnitude. Since the CAES site remained in turf for 38 years, the observed reduction in chlordane content in the surface layer cannot be attributed to dilution effects from deep tilling of the soil. Deep ploughing has been reported to be the sole cultivation practice that reduced soil γ-chlordane concentration (*24*). The minimal vertical movement observed is in agreement with data from Bennett and Stewart for weathered residues (*25, 26*) but not with data from a clay loam low in organic matter (*7*). Statistical analysis of variance (two-factor ANOVA) shows that con-

TABLE 2. Components of Technical Chlordane in Weight Percent and Component Ratios

	γ-chlordane	α-chlordane	*trans*-nonachlor	γ/α	α/*trans*	γ/*trans*
CAESGC/ECD	8.0+/−1.1	8.4+/−1.1	6.1+/−0.7	1	1.4	1.3
ref *19*GC/ECD	10.3	9.8	6.3	1.1	1.6	1.6
ref *6*ECNI/MS	10	9.2	6	1.1	1.5	1.7
ref *21*EI/SIM	14.5	13.0	6.0	1.1	2.2	2.4
ref *20*	24	19	7	1.3	2.7	3.4
ref *23*	11	11		1.0		

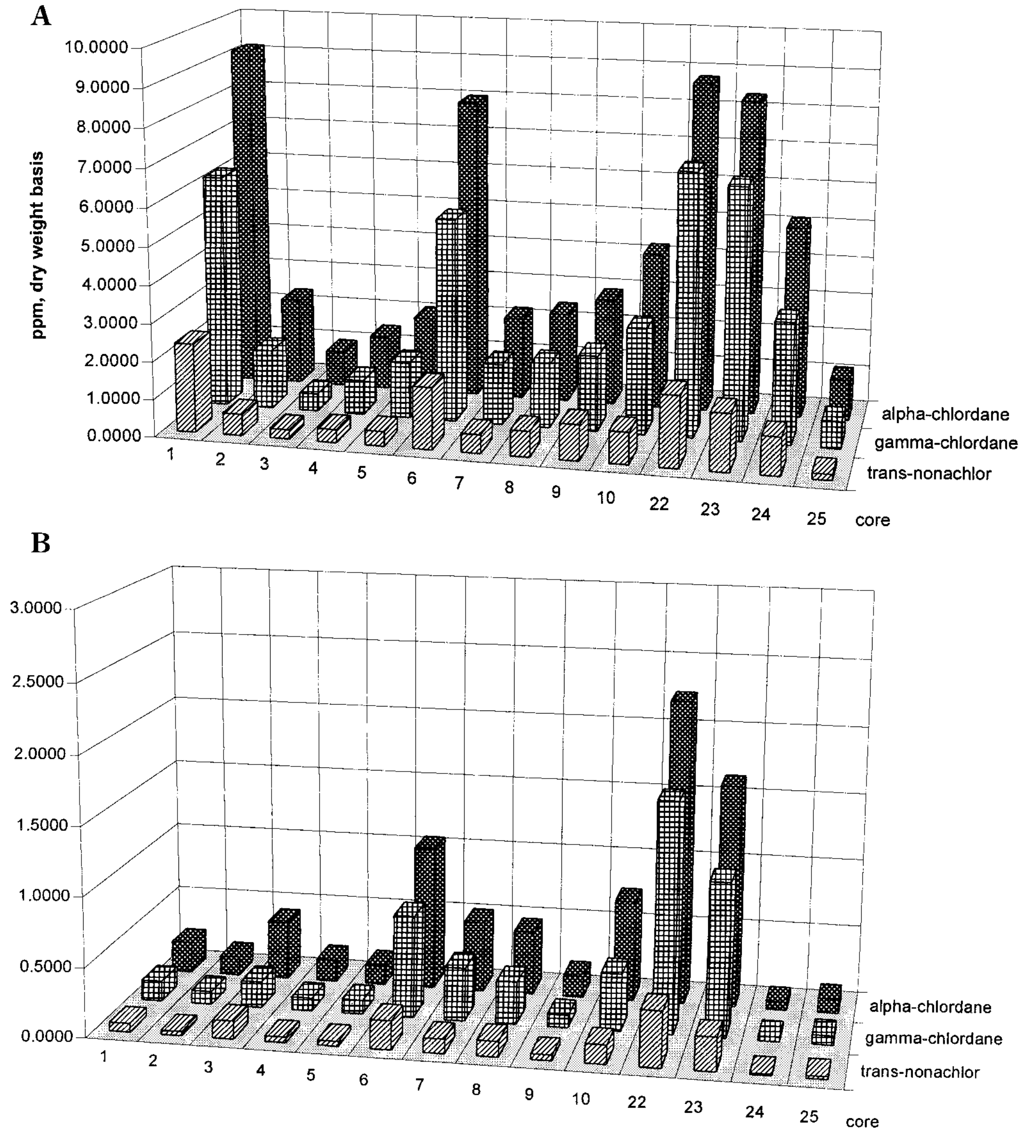

FIGURE 3. (A) Component concentrations of top 15 cm at sites within original plot. (B) Component concentrations of 15−30 cm layer at sites within original plot.

centration variation is accounted for by depth rather than lateral location for all 14 cores.

At all 14 cores from the original plot, the component concentrations are in the order *trans*-nonachlor < γ-chlordane ≤ α-chlordane for both the top 15 cm and the 15−30-cm layers. This is the same relative order of the three components in technical chlordane, suggesting that this order reflects direct application to the soil as the principal source impacting the chlordane residues within the original plot. The γ-chlordane/α-chlordane ratios from the cores inside the original plot have considerably less variation than the same ratio reported by Aigner et al. (*16*). In Aigner's report, half of the 40 sites show γ-chlordane/α-chlordane > 1, and half have γ-chlordane/α-chlordane < 1 with the range of values from 0.33 to 6. This may reflect differences among Aigner's samples in soil type, site history, and chlordane source, e.g., direct application of technical chlordane vs atmospheric transport to the site.

Several observations may be made regarding the cores outside the treated area. First, total concentration in the top 15 cm is approximately 1/100 that inside the treated area at the same depth. This includes cores 14 and 15 that are horizontally displaced by only 5 ft from the boundary of the original plot. Second, at the 15−30-cm depth, some samples contained no detectable components. And third, the *trans*-nonachlor < γ-chlordane ≤ α-chlordane pattern does not hold for these samples. Since it is a reasonable assumption that the soil inside and outside the original plot is similar in

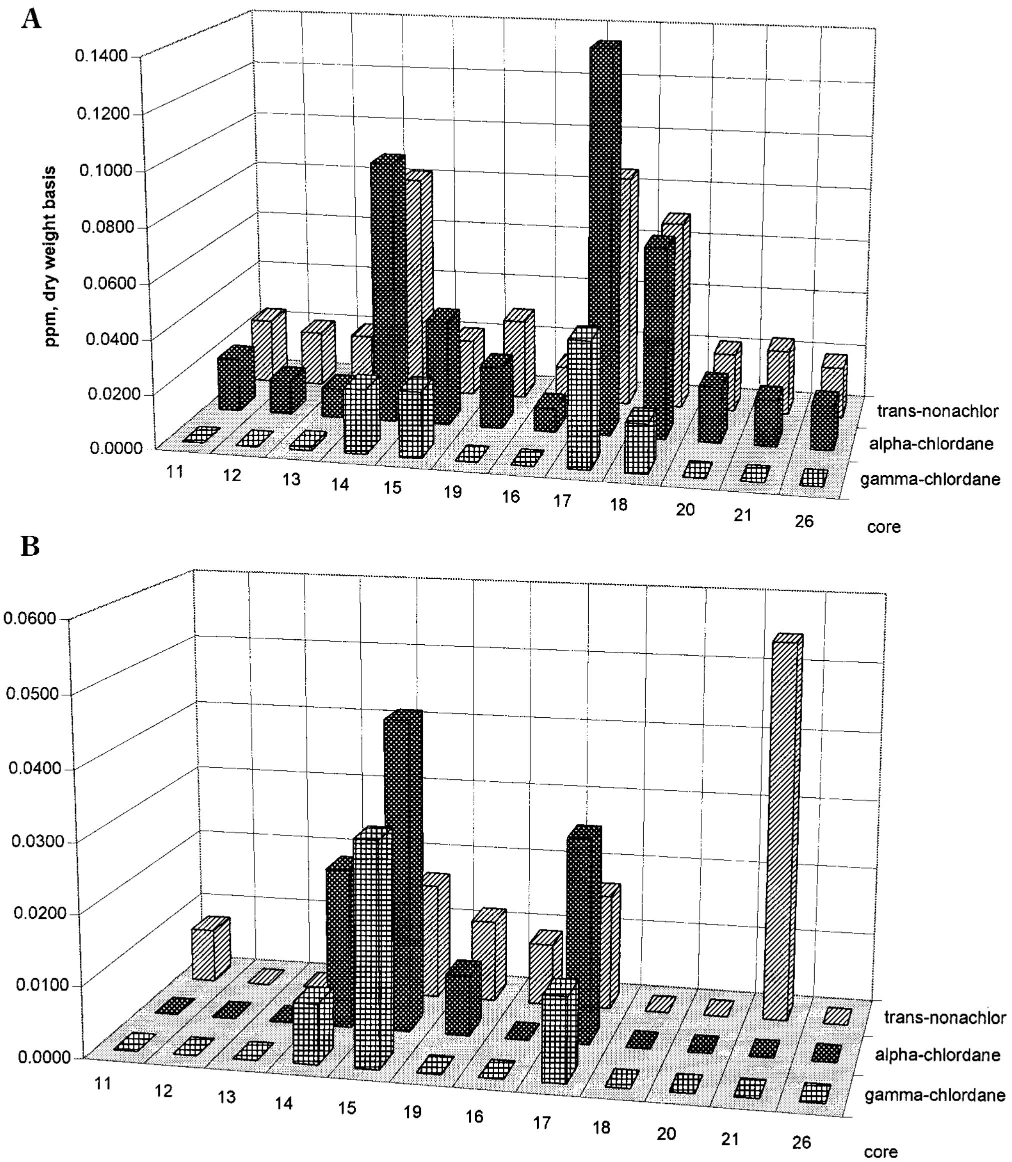

FIGURE 4. (A) Component concentrations of top 15 cm at sites outside original plot. (B) Component concentrations of 15–30 cm layer at sites outside original plot.

microbe population and organic matter content, the concentration in the cores outside the original plot may represent a different chlordane source or a combination of chlordane sources. These cores may be impacted by a considerable contribution from atmospheric deposition rather than from direct application of technical chlordane to the soil. To distinguish between directly applied chlordane and its atmospheric deposition, a study of the enantiomeric ratios (ER) for γ- and α-chlordane in the soil cores vs ER in atmospheric samples in the vicinity of the CAES lawn is planned.

Data from several cores also permit additional conclusions regarding lateral movement. Comparing the concentration in the downslope cores (3–5, 9, 10, 24, and 25) with the upslope cores (1, 2, 6–8, 22, 23) (Figure 3A) within the original plot does not indicate any concentration increase as the core site moves downslope. Neither can a concentration increase be detected in the downslope cores 11–13 and 19–21 just east of the boundary of the original plot when compared either with cores inside the original plot or any other cores outside the original plot. These core values permit us to conclude that both vertical and horizontal movement of chlordane in soil with characteristics similar to the CAES site is minimal, even when relatively large amounts of technical chlordane have been applied to a steeply graded area.

Calculation of $t_{1/2}$. Knowledge of the date and the rate of application of the 72 wt % formulation permit calculation of the half-life of technical chlordane by applying specific quantitative decisions. On the application date, 1.9 L of 72% technical chlordane was used on the original plot. From the rate and density of a 72 wt % formulation (1.33 g/mL), it is calculated that 1818 g of technical chlordane was applied in 1960. The (γ-chlordane + α-chlordane + *trans*-nonachlor) total is used as a reasonable approximation of the current amount of technical chlordane remaining in the soil. Using the commonly accepted value of 10^6 lb/3″ acre (*27*), the total amount remaining in the top 30 cm of soil in 1998 was calculated as 513 g or 28.2% of the original amount applied. This value yields a $t_{1/2}$ of 20.8 yr.

An alternate calculation to that just described is to compute the (γ-chlordane + α-chlordane + *trans*-nonachlor) amount in the technical chlordane applied to the original plot in 1960 and, using the analogous 1998 value, to determine the percent remaining. However, since this latter approach determines $t_{1/2}$ of (γ-chlordane + α-chlordane + *trans*-nonachlor) rather than the $t_{1/2}$ of technical chlordane, it is

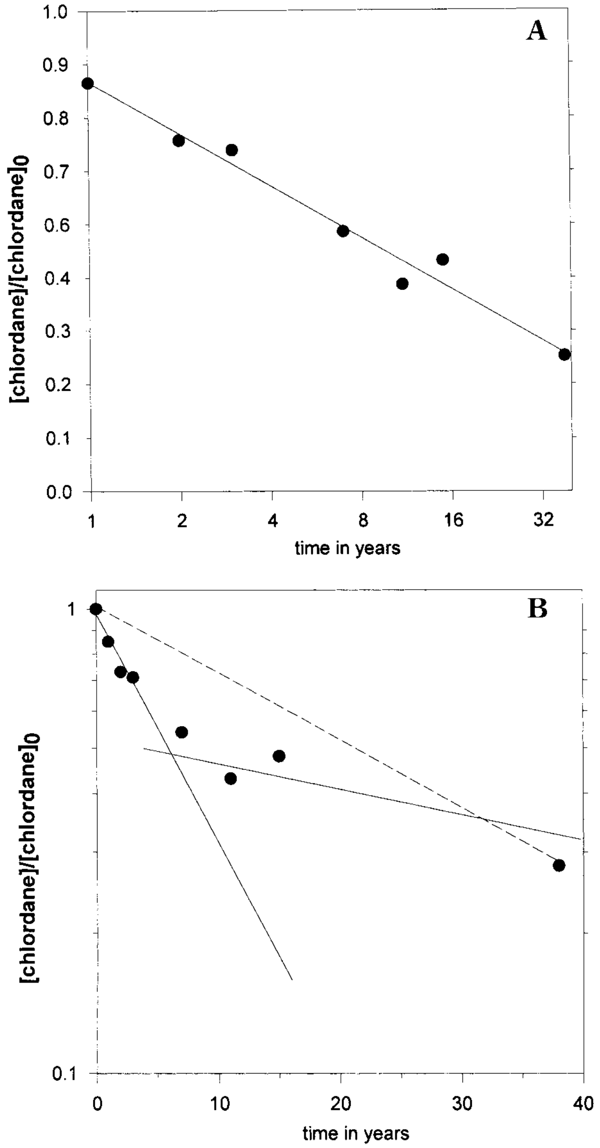

FIGURE 5. (A) Chlordane degradation in soil plotted using Nash data with CAES data on a logarithmic time scale. (B) Plot of Nash and CAES data points for chlordane degradation in soil showing biphasic kinetics.

not so reasonable an approach as that described above.

Several assumptions have been used in this calculation of $t_{1/2}$ of technical chlordane. First, it is assumed that (γ-chlordane + α-chlordane + *trans*-nonachlor) is a reasonable surrogate for technical chlordane remaining in weathered soils. Second, first-order degradation kinetics for all the technical chlordane components during the 38-year period in question was assumed. The validity of both these assumptions can be checked using data from Nash and Woolson (*28*). In his study, Nash treated sandy loam soil with chlordane in 1951 at 100 and 50 μg/g and allowed it to weather for several years. At subsequent time points, insecticide remaining was determined from the total chlorine content of the treated soil minus the total chlorine content of a nontreated soil, except for the final measurement at 14 years, which was a GC assay. Nash's data at both 100 and 50 μg/g have been averaged and are plotted in Figure 5A on linear ordinate and logarithmic abscissa scales. The last data point in Figure 5A is 28.2% remaining at 38 years, as determined in the present study. Insertion of this data point into the data set of Nash has a minimal impact on the first-order regression coefficient of the plot, supporting the first assumption above. In Figure 5B, the same data are plotted on a logarithmic ordinate scale and a linear abscissa scale, expected by first-order kinetics to be a linear plot. It is obvious from Figure 5B that chlordane degradation is biphasic, with the first phase extending from 0 to approximately 8 years and the second phase from 8 years onward. It is not surprising that biphasic degradation kinetics is observed for a multicomponent material such as technical chlordane (*15*). Apparently the more volatile components dissipate rapidly following application, and the less volatile, recalcitrant components dissipate much more slowly. Observations limited to the first phase of degradation yield a value of $t_{1/2}$ of approximately 8 years (see also refs *23* and *29*). Estimations of $t_{1/2}$ of technical chlordane based on observations of the more persistent components, that is, during the second phase of degradation, over a shorter time period than in the present study, may underestimate the value of $t_{1/2}$ of technical chlordane (*25, 30*). However, the slope of the degradation curve during the second phase implies that $t_{1/2}$ calculated here may also be underestimated. Obviously, the second assumption above yields the dotted line in Figure 5B and gives an average approximation of $t_{1/2}$ for technical chlordane considered as a multicomponent mixture.

Agricultural Sites. A total of 53 soil samples at seven different agricultural locations was sampled throughout Connecticut. No muck soil was included at any site. The arithmetic mean of the sum (γ-chlordane + α-chlordane + *trans*-nonachlor) was 0.142 ± 0.120 μg/g, and the range of the sum was 0.529−0.008 μg/g. Three soil samples had no detectable amounts of technical chlordane components. Aigner (*16*) analyzed 38 agricultural sites and 2 garden sites in Illinois, Indiana, Ohio, and Pennsylvania. Omitting the muck soil and the termite-treated soil in Aigner's study, the arithmetic mean of the three component sum was 0.007 ± 0.009 μg/g, 2 orders of magnitude lower than the comparable average in our study. Nagami (*30*) found 0.015 and 0.020 μg/g on two different soil types for the three-component total. Falconer (*22*) found 0.00064 and 0.001 μg/g on silt soils and 0.388−1.9 μg/g on muck soils. Szeto (*31*) found a mean of 0.830 μg/g and a range of 0.284−1.8 μg/g on muck farms and 0.170 μg/g on a silt loam farm. Both the Falconer and Szeto values are the three-component sums.

Residential Sites. Soils from a total of 34 lawn/garden sites and 45 foundation sites were analyzed. Since technical chlordane was used as a termiticide at application rates considerably higher than that recommended for insect control in lawns and gardens, it was most appropriate to separate residential foundation samples from other residential soils. The lawn/garden soils in this survey ranged from 5.11 to 0.008 μg/g with nine samples having no detectable amounts of technical chlordane components. The arithmetic mean was 0.330 ± 0.987 μg/g in the lawn/garden soil samples and that of the foundation soil samples was 7.180 ± 14.296 μg/g with a range from 57.938 to 0.006 μg/g. Six samples had no detectable technical chlordane residues. When those soils were examined in which (γ-chlordane + α-chlordane + *trans*-nonachlor) $\geq$ 5 μg/g, an indication of direct application of technical chlordane to the soil, the components were once again in the ratio *trans*-nonachlor < γ-chlordane $\leq$ α-chlordane. This is the same observation presented in Figure 3 for all cores from inside the original plot, suggesting that the impact of other sources of technical chlordane, such as atmospheric transport, on the residues in soil is minimal when the initial application rate is high.

In soils from house foundations in Louisiana, Delaplane (*32*) found a range of 14464−1.9 μg/g among eight samples taken at a single location. The overall range for 30 houses was 0.7−14464 μg/g. Although not specified, it is assumed that the values given are for the technical chlordane concentration, not the sum of the three components. Values provided by Bennett in his study of chlordane termiticide persistence 21 years after application refer solely to the γ-chlordane component and range from 23.92 to 0.83 μg/g in the top approximately 6 in. around foundations of two homes (*25*).

The values for chlordane in residential foundation soils presented here indicate that in the temperate Northeast technical chlordane concentrations can be substantial. Comparison of the values for chlordane from residential lawn/garden sites with those from commercial agricultural operations in this study support the conclusion that pesticide concentrations in residential environments can exceed those in agricultural environments (*33*). The EPA has published a generic soil screening level of 0.5 μg/g chlordane in soil (*34*). The average chlordane concentrations in residential lawn/garden and agricultural soils examined in this study do not exceed this value using the three-component sum to measure chlordane concentration. Foundation soils, however, often contain chlordane residues at levels of concern.

Acknowledgments

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Supporting Information Available

Two tables giving the MAW recovery of chlordane from ERA soil standard and the calculation of chlordane half-life and two figures showing the location of the sites and the concentrations ≥ 5 μg/g in residential sites. This material is available free of charge via the Internet at http://pubs.acs.org.

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