Bull. Environ. Contam. Toxicol. (1990) 45:675–680

Bulletin of Environmental Contamination and Toxicology

Variable Chlordane Residues in Soil Surrounding House Foundations in Louisiana

Keith S. Delaplane[1] and Jeffery P. La Fage[2]

[1]Department of Entomology, The University of Georgia College of Agriculture, Cooperative Extension Service, Athens, Georgia 30602, USA and [2]Department of Entomology, Louisiana Agricultural Experiment Station, Louisiana State University Agricultural Center, Baton Rouge, Louisiana 70803, USA

Chlordane was widely used in the United States as a soil termiticide from the late 1940's until 1988 when its use was banned by the US Environmental Protection Agency. When applied to soil surrounding or under foundations, chlordane provides excellent deterrence against invading termites. In US Department of Agriculture test plots, a water emulsion of 1% chlordane was persistent and deterred termites for 28 years (S. C. Jones, USDA Southern Forest Experiment Station, pers. comm.). Because it readily bonds to soil particles, there may be little or no contamination from its movement through the soil profile (Stewart and Chisholm, 1971; World Health Organization, 1984); however, some data suggest that chlordane moves downward more readily in sandy than in clayey soils (Leidy et al., 1985). Bennett et al. (1974) measured soil chlordane residues at various sampling depths and horizontal distances from original treatment site, and Leidy et al. (1985) compared chlordane residues at two soil types, two sampling depths, and three types of house construction. However, to our knowledge, no studies have estimated variability of soil chlordane residues at individual structures. Therefore, we sampled soil of 30 houses in metropolitan New Orleans, Louisiana, and here report on intra-structure variability of chlordane levels.

MATERIALS AND METHODS

We sampled the soil of 30 houses in three parishes of greater New Orleans, Louisiana. The soils in these areas are Commerce-Sharkey associations (alkaline natural river levee, loamy and clayey soil) or Swamp-made land associations (organic, clayey swamp soil covered with loamy fill). Thirteen of the structures were slab construction, 10 were crawl-space construction with

Send reprint requests to Keith S. Delaplane at the above address.

either concrete or masonry piers, and four were a combination of crawl and slab; construction type data were missing for three structures. These buildings had been treated by the same pest control firm and were under current re-inspection contract. Dates of most recent chlordane treatment ranged from February 1966 to July 1986; treatment date data were missing for three structures.

Soil samples were collected from 27 October to 30 October 1986. At each house, samples were taken at the center-most available site at each of the four outside walls; crawl space structures were sampled at the center-most pier at each outside wall. Grass and other debris were removed before collecting samples. Using a hand-held trowel, soil from each of two depths (0-5 cm and 6-10 cm) was taken at each site, for a total of eight samples (ca. 0.5 kg each) per house. Samples were individually placed in glassine-lined paper bags then returned to the laboratory to air dry. When dry, soil of each sample was passed through a 60 mesh brass sieve to provide a homogenous sample. From this, a 10 g subsample was transferred to a 100 mL volumetric flask and mixed with 60 mL hexane. The flask and its contents were shaken for two hr, after which it was made up to volume with hexane.

Extracts were analyzed for chlordane using a Tracor Model 540 gas chromatograph with dual electron capture detectors (nickel 63; 15 mCi). Two separate and different columns were used to separate the residues in the samples. The first, the quantitative column, was a 15.2 cm by 0.4 cm glass column, packed with 3% OV225. The second, the confirmation column, was the same size and was packed with 4% SE30 and 6% OV210 mixed phases. Analyses were run at 195°C isothermal. The injection port temperature was 200°C, and the detector temperature was 350°C. The carrier gas was "P5", a mixture of 95% argon and 5% methane carried at a flow rate of 100 mL per min. Quantities of residues (ppm) were measured using the peak-height method. Each sample was replicated two times, and the resulting mean was used for subsequent statistical analyses.

Although data for all houses are presented in Table 1, the six houses without construction type or treatment date data were removed from our statistical analyses. Data were analyzed in a split-plot design analysis of variance recognizing construction type as the whole-plot and sample depth as sub-plot (Proc GLM, SAS Institute, 1985, pp. 183-260). House effects nested within construction type was the error term used to test construction type, and depth by house interaction nested within construction type was used to test depth. Significance was accepted at the alpha = 0.05 level.

Treatment dates were converted to the number of decimal years between treatment and our sampling date then analyzed as a covariate with our split plot model. To analyze within-house variation of chlordane residues, we determined the coefficient of variation (CV) of chlordane residues for each house, then tested the effect of construction type on CV with analysis of variance. According to Hartley's F_{max} statistic (Winer, 1971), variances for CV were unequal across construction types; this was corrected by weighting the analysis with the reciprocal of the construction type variances (Proc GLM, SAS Institute, 1985, p. 207). Linear contrast mean separation was used to identify construction type differences.

RESULTS AND DISCUSSION

Chlordane was present in all samples, and the overall mean (± SEM) was 870.6 ± 96.5 ppm with a range of 0.6 to 14464.0 ppm. Chlordane residues were not affected by construction type ($P = 0.4399$) or depth of sampling ($P = 0.946$) (Table 2); however, some inter-house differences were detected within construction types ($P = 0.049$). Leidy et al. (1985) also showed no differences in residues between crawl and crawl/slab structures, but both Leidy et al. (1985) and Bennett et al. (1974) demonstrated decreasing residues at increasing sampling depth. Using ca. 10 cm increments, Leidy et al. examined a depth range of 0 to 20 cm, and Bennett et al. sampled from 0 to 50.8 cm. However, our narrower range of depth sampling (0 to 10 cm) allowed a comparison of residues within the range actually trenched during application, and no differences in this range were apparent, even though the chlordane label calls for a shallow layer of untreated soil on top of the treated soil. Chlordane residues were unaffected by the number of years post-treatment ($P = 0.0549$), and this covariate term did not explain any residual error in our split plot analysis.

There was considerable variation of chlordane residues within individual structures. Furthermore, this within-house variation, measured as the coefficient of variation (CV), was affected by construction type ($P = 0.0127$); crawl space construction had significantly lower within-house variation than did slab construction, and crawl/slab construction did not differ from the other types (Table 3). It seems that technicians using chlordane, and probably any soil termiticide, treat crawl space structures more uniformly than they treat slabs.

According to the Louisiana Department of Agriculture, soil chlordane residues should vary from 500-800 ppm if label instructions were followed during application (J. Arcenaux, LA Dept. Agric., pers. comm.). The Department

Table 1. Chlordane residues (ppm) at houses in greater New Orleans, Louisiana.

House	Mean Residue	No. Samples < 100 ppm	No. Samples > 1000 ppm	Min. Residue	Max. Residue
1	304.2	4	0	0.7	743
2	966.3	3	4	0.9	2621
3	961.2	5	2	0.6	3610
4	1061.9	2	3	9	3916
5	2543.3	1	7	75	6479
6	686.8	1	2	75	1711
7	814.6	0	2	337	1490
8	767.9	1	4	15	1725
9	560.9	1	1	51	1872
10	264.5	2	0	3.9	930
11	317.0	2	0	35	589
12	695.1	2	2	1.4	2351
13	2542.9	2	3	1.9	14464
14	711.9	2	2	17	1838
15	1761.8	0	5	486	3308
16	792.1	1	1	84	3237
17	859.1	2	3	10	2334
18	22.6	8	0	4	95
19	850.8	0	1	234	3649
20	540.2	4	1	4.5	3210
21	464.1	2	1	4.9	1564
22	216.6	3	0	26	404
23	1572.0	0	2	163	5132
24	759.9	0	2	153	2464
25	823.8	4	3	21	2729
26	1246.1	2	3	80	3638
27	546.5	2	2	1.8	1416
28	200.5	3	0	4.2	519
29	866.8	2	1	28	4069
30	925.7	3	4	6.6	2674

accepts residues as low as 100 ppm, believing that this level of chlordane will protect against subterranean termites; however, there are no guidelines for residues which are too high. With no guidelines to follow, we established 2X (1000 ppm) as a target concern level for this study.

Table 1 presents soil chlordane residue data per house. Only one structure (#18) was clearly under-protected with a mean of 22.6 ppm. Conversely, only six structures had mean chlordane residues above 1000 ppm (#s 4, 5, 13, 15, 23, 26). However, there were 64 out of 240 samples (26.7%) under 100 ppm and 61 out of 240 (25.4%) over 1000 ppm. In all structures, at least one sample was either below 100 ppm or greater than 1000 ppm. Five structures

Table 2. Mean soil chlordane residues (ppm) at different construction types and sampling depths. Means were not significantly different.

Depth (cm)	Construction Type: crawl	crawl/slab	slab	Depth Means
0-5	729.3	1400.1	729.8	828.9
6-10	1017.6	1043.9	790.7	912.2
Construction Means	873.4	1222.0	760.2	

Table 3. Mean (± SEM) within-house variability (CV) of soil chlordane residues (ppm) as affected by construction type. Means with the same letter are not significantly different (linear contrast separation).

Construction Type	N	Mean CV
slab	13	127.4 ± 8.3 a
crawl/slab	4	123.1 ± 28.2 ab
crawl	10	93.3 ± 6.7 b

had at least half of their samples under 100 ppm, and five structures had at least half of their samples over 1000 ppm. There are numerous likely causes for high chlordane residues. One cause may be from homeowners using chlordane to spot-treat fire ant mounds near the structures. A second cause may be from pest control technicians retreating during annual inspections, as was commonly done in the late 1960's and early 1970's. A third, less likely, reason for high residues may be from homeowners providing their own termite re-treatment. This is unlikely, since all homes were under contract for termite control since the original treatment.

The mean values for soil chlordane residues suggest that these houses were generally well protected and that only a few (6) were potentially over-treated. Nevertheless, 26.7% of the samples contained less than 100 ppm chlordane. Fortunately, at only 17 of the 120 sampling sites (30 houses X 4 walls) were residues at both depths less than 100 ppm. However, the 100 ppm lower limit may be inadequate to deter the introduced Formosan subterranean termite (*Coptotermes formosanus* Shiraki), an aggressive, destructive pest common in greater New Orleans, which has been shown in laboratory studies to penetrate 5 cm of soil treated with up to 500 ppm chlordane (Beal and Smith, 1971). If termites can breach chlordane levels up to 100 ppm in the field, 17 of our sampled locations (14.2%) were unprotected.

Our data suggest that serious problems may exist in current soil termiticide application technology. The extreme within-house variation we noted is almost certainly not unique to chlordane, but reflects on soil termiticide use in general. Uniformity of insecticide application is clearly necessary to balance the need for adequate termite control with environmental responsibility.

ACKNOWLEDGEMENTS

Approved by the Director, Louisiana Agricultural Experiment Station, as manuscript number 89-17-3278. Technical assistance was provided by Jimmy Carroll.

REFERENCES

Beal RH, Smith VK (1971) Relative susceptibilities of Coptotermes formosanus, Reticulitermes flavipes, and R. virginicus to soil insecticides. J Econ Entomol 64:472-475

Bennett GW, Ballee DL, Hall RC, Fahey JE, Butts WL, Osmun JV (1974) Persistence and distribution of chlordane and dieldrin applied as termiticides. Bull Environ Contam Toxicol 11:64-69

Leidy RB, Wright CG, Dupree HE Jr, Sheets TJ (1985) Subterranean termite control: Chlordane residues in soil surrounding and air within houses. In: Honeycutt RC, Zweig D, Ragsdale N (eds) Dermal exposure related to pesticide use. ACS Symposium Series 273, Am Chem Soc, Washington DC, pp 265-277

SAS Institute Inc (1985) SAS/STAT Guide for personal computers, version 6 ed. SAS Institute, Cary, NC

Stewart DKR, Chisholm D (1971) Long-term persistence of BHC, DDT and chlordane in a sandy loam soil. Can J Soil Sci 51:379-383

Winer BJ (1971) Statistical principles in experimental design, 2nd ed. McGraw-Hill, New York, World Health Organization (1984) Chlordane. Environmental Health Criteria 34, Geneva

Received August 7, 1989; accepted February 8, 1990.