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Indoor Air Levels of Chlordane in Residences in New Jersey

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Chlordane has been the most widely used chemical for residential termite control for the past three decades, but in recent years serious questions regarding human exposure and potential health effects have been raised (NAS, 1982; USEPA, 1983). In 1974 the U.S. Environmental Protection Agency cancelled all significant uses of chlordane, with the exception of subterranean termite control. At that time human exposure due to indoor air contamination was not considered to be a significant public health issue. However, since 1980 numerous studies have demonstrated measureable levels of chlordane inside treated homes (Livingston and Jones, 1981; Wright and Leidy, 1982; Louis and Kisselbach, 1987).

The public health risks associated with chlordane use are difficult to define due to incomplete toxicological and exposure assessment data. Two questions therefore focus the current regulatory debate. What exposure level, if any, is acceptable for occupants of homes treated with chlordane? What air concentrations are found in homes following treatment? In the absence of an adequate risk assessment of chlordane there is no consensus on the prudence of its use as a termiticide. While most states have imposed no restrictions beyond those required by U.S. EPA, a number of states have prohibited the sale or use of chlordane. New Jersey has chosen instead to develop a series of detailed use restrictions based on current scientific information. This paper presents an analysis of chlordane air monitoring data collected by the New Jersey State Department of Environmental Protection in an attempt to elucidate the issue of human exposure to chlordane.

MATERIALS AND METHODS

Indoor air monitoring data from 1976 to 1985 were obtained from the Bureau of Pesticide Control, New Jersey Department of Environmental Protection (NJDEP). Air

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monitoring was performed in response to complaints by New Jersey residents who suspected that termiticides had been applied improperly at their homes. Air samples from 1976 through 1985 are included. The large majority of air samples were collected by NJDEP investigators, although some samples were collected by private consulting laboratories. Samples analyzed by the State's laboratories were collected with MSA pumps using polyurethane foam plugs as the collection medium (Lewis et al. 1977). Sample duration was one hour at a flow rate of 4 L/min. Gas chromatography analysis was performed according to NIOSH method S278 (USDHHS, 1980). The limit of detection with these procedures was 0.2 ug/m^3. Residents were asked to close windows and turn on forced air heating systems prior to sampling. The location and number of samples collected in individual homes varied from case to case.

A total of 300 air samples, from 157 homes, are included in this study. Each sample is classified as either a "living area" [LA] sample or a "non-living area" [NLA] sample based on the location in the home from which it was taken. Living area refers to places in the home where residents spend significant time on a daily basis, including bedrooms, living rooms, dining rooms, kitchens, bath-rooms, and hallways connecting these rooms. Non-living area refers to parts of the home where residents would not be expected to spend significant time on a daily basis, including unfinished basements, crawlspaces, laundry rooms, and heating ducts. Rooms such as family rooms or bedrooms within a basement are considered living areas. LA samples thus provide an indication of the levels of chlordane to which residents may be exposed almost continuously when in the home, while NLA samples normally indicate residue levels near the application. In cases where multiple LA or NLA air samples were collected, the mean was used as a single representative value of airborne levels.

Different types of house construction require different combinations of treatment techniques (e.g., trenching, rodding and drilling), resulting in different pathways by which pesticides gain entry into the home. Residences were therefore categorized into five different home types based on foundation: 1) basement, 2) crawlspace, 3) concrete slab, 4) basement/slab, and 5) basement/crawlspace. Residences were also categorized according to the type of heating system in the home: 1) forced air/furnace in basement, 2) forced air/furnace in crawlspace, 3) forced air/heating ducts within or beneath a slab, and 4) radiant heat. The heating type categorization is based on the assumption that the source of intake air in forced air systems is related to the furnace location. Finally, residences were categorized by application status: 1) misapplication cited, and 2) misapplication not cited. NJDEP cited an applicator for failure to perform the termiticide application according to the pesticide label instructions on the following evidence: when swab or soil samples indicated the presence of termiticide at a "non target" site (where the chemical should not be found if applied properly); or if investigation at the home showed that proper application procedure had not been followed, e.g. failure to plug drill holes. Thus, application status was assigned independent of air sampling data.

Statistical analyses were performed using the Statistical Analysis System (SAS Institute, Inc., 1985). The distributions of both living area and nonliving area concentrations are markedly nonnormal, with a large number of values at or near zero and a few extremely high values. Since parametric statistical methods are not appropriate for such data, the median is used as a measure of central tendency and nonparametric statistical tests are employed. For Analysis of Variance tests raw data values were transformed into rank scores with the SAS RANK procedure and the ranks were then subjected to ANOVA through the SAS GLM procedure. The F-test performed on rank data is equivalent to the Kruskal-Wallis test. When appropriate a multiple comparison technique was applied to the rank scores (Conover and Iman,1981). Tukey's studentized range (HSD) test was chosen, as recommended by SAS. This test is considered to be the best method to use with unequal cell sizes and for controlling the maximum experiment-wise error rate under any complete or partial null hypothesis.

RESULTS AND DISCUSSION

Detectable levels of chlordane were found in living areas of 74% of the 133 sampled homes and in non-living areas of 88% of the 82 sampled homes. Table 1 summarizes the air concentration values found in sampled homes. The median airborne chlordane concentrations of 1.72 ug/m^3 for LA samples and 3.51 ug/m^3 for NLA samples are significantly different (Mann Whitney U Test, $p < 0.0005$). One-fourth of LA values and nearly one-half of the NLA values exceed the NAS guideline of 5 ug/m^3. These data have been divided by date of application into two periods (1976-1982 and 1983-1985) to test the potential effect of the December 1982 issuance of regulations by NJDEP restricting the sale and use of chlordane to certified applicators. LA concentrations for the 1983-85 period are significantly lower than those recorded from 1976-82 (ANOVA-Rank, $p < 0.002$). This difference can be seen in the nearly three-fold decrease in the median value from 2.6 to 0.9 ug/m^3. It is also reflected in the decrease from 34% to 12% in the percent of homes above the 5 ug/m^3 guideline. These results suggest that application procedures have improved markedly since 1982, and that the restriction of chlordane use to certified applicators is an effective regulatory intervention for reducing concentrations within homes.

Table 1. Summary of residential air sampling data

Sample Type	N	Median (ug/m^3)	Range	Percent >$5ug/m^3$
Living Area				
All	113	1.72[a]	<0.2 - 55.4	24.8
1976-1982	64	2.60[b]	<0.2 - 55.4	34.4
1983-1985	49	0.89[b]	<0.2 - 46.0	12.2
Non-Living Area				
All	82	3.51[a]	<0.2 - 610	46.3
1976-1982	46	3.72	<0.2 - 130	47.8
1983-1985	36	3.06	<0.2 - 610	44.4

a: Mann-Whitney U Test; Z=3.31, $p < 0.0005$.
b: ANOVA-Rank; F=10.1, $p < 0.002$.

Results of the analysis of air sampling data by heating type are presented in Table 2. The median LA value for homes with crawlspaces and forced air heating systems was 11.2 ug/m^3, with four of the five sampled homes exceeding the NAS guideline. This value was significantly different from the relatively low median values of 0.33 and 0.93 ug/m^3 for basement homes with forced air and homes with radiant heat, respectively (ANOVA-Rank, $p < 0.001$; Tukey's HSD Test, $p < 0.05$). It is important to note here that all five crawlspace homes with forced air heat were classified as misapplication cases by NJDEP. The potential for missapplications in crawlspaces was noted by Maddy (1979) over eight years ago. The NJDEP data suggest that crawlspace contamination can have a direct effect on living area concentrations if forced air heating systems are in use.

Table 2. Analysis of living area air concentration data by heating type

Heating Type	N	Median (ug/m^3)	Range	Percent >$5ug/m^3$
Basement [FA][a]	35	0.33	<0.2 - 55.4	20.0
Crawlspace [FA]	5	11.20[b]	1.9 - 23.5	80.0
In-Slab Ducts [FA]	33	3.42	<0.2 - 46.0	33.3
Radiant	17	0.93	<0.2 - 27.8	5.9

a: [FA]=Forced air heating system
b: ANOVA-Rank; F=6.1, $p<0.001$. Crawlspace higher than basement or radiant [Tukey HSD Test, $p<0.05$].

The median LA level of 3.42 ug/m^3 for In-Slab Duct heating falls between the previously noted values. Of the 33 homes in this category, 22 (67%) were classified as misapplication cases. To further explore the effect of heating systems on indoor air concentrations, the relationship between LA and NLA levels was tested with the Spearman Rank Correlation test. LA and NLA values were strongly correlated in homes with In-Slab Duct heating (r_s=0.71, p <0.01, N=11). No correlations were evident for the other heating types. Clearly contamination of heating ducts leads to elevated levels of chlordane in living areas, as several other studies have suggested (Livingston and Jones, 1981; USAF, 1983). Analysis of air sampling data by home type yielded no significant differences. The percentage of LA samples exceeding the NAS guideline was very similar for all home types. It appears that all types of home construction are susceptible to considerable contamination if improper application is made.

Figure 1 presents the distribution of sampled homes by date of application, and also indicates the proportion of homes in each year which were assigned a "misapplication" status by the NJDEP. The number of consumer complaints investigated involving chlordane peaked in 1982, with 41 cases. Since that time such complaints have decreased consistently. This trend is probably due to several factors, including decreased use of chlordane by applicators, more efficient screening of complaints by NJDEP, and more careful application of the compound. The temporal pattern of misapplications is similar, with only nine citations in 1984 and six in 1985. Again, this decrease undoubtedly has multiple causes.

Table 3 presents the data according to the application status of each home. Analysis of variance of ranked data reveals significantly lower values in cases of no misapplication for both LA and NLA samples ($p < 0.001$). When misapplications occurred the median for LA samples was 3.28, with 40% of the samples exceeding 5 ug/m^3. However, when no violation of application procedures was noted, the median was less than 0.1 ug/m^3, 67% of the samples were less than 1 ug/m^3, and no samples exceeded the NAS guideline. A similar difference in misapplication versus no misapplication values was evident for the NLA samples. In four of the six NLA cases of no misapplication where levels exceeded 5 ug/m^3, evidence to support misapplication was found, but no citation was issued since the improper treatment had occurred during a previous termiticide application. These results indicate that application status is the most important factor influencing elevated levels of chlordane in indoor air.

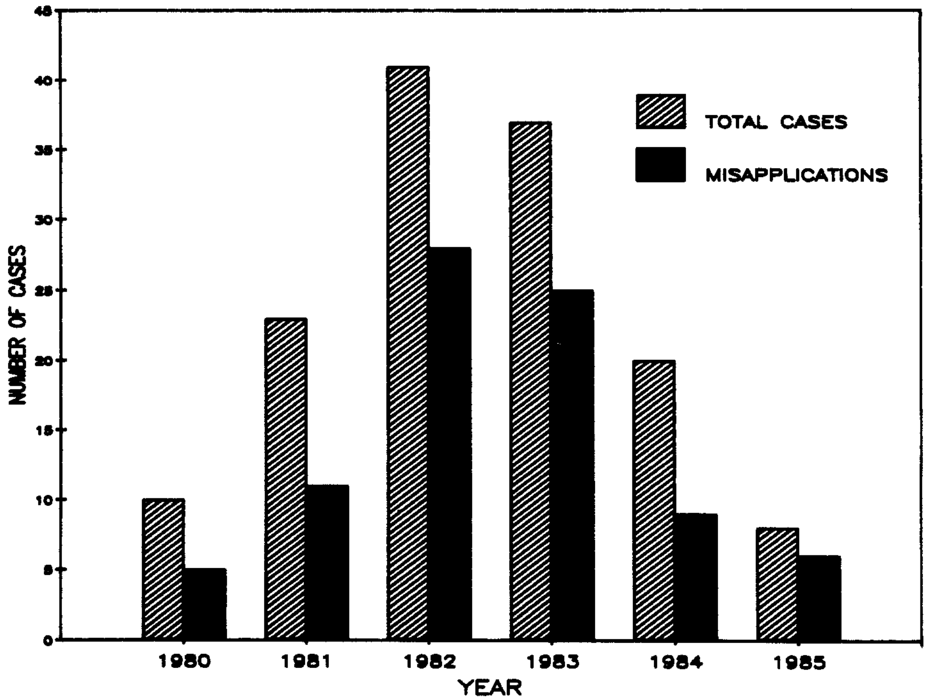

Figure 1. Chlordane applications investigated by NJDEP: 1980 to 1985

There is a growing body of evidence suggesting that when applications are conducted according to the label chlordane levels in living areas are low. Louis and Kisselbach (1987) found that living area chlordane levels ranged from <0.09 to 1.6 ug/m^3 following proper applications. Exposure monitoring by the manufacturer as part of a U.S. EPA data call-in found most homes below the 0.2 ug/m^3 limit of detection [NJDEP, 1987, personal communication]. The NJDEP data make clear that when misapplications occur substantially higher levels of

Table 3. Air concentration data by application status

Sample Type	N	Median (ug/m^3)	Range	Percent >5ug/m^3
Living Area				
Misapplication	72	3.28[a]	<0.2 - 55.4	40.3
No Misapplication	46	0.09[a]	<0.2 - 4.8	0
Non-Living Area				
Misapplication	55	6.20[b]	<0.2 - 610	60.0
No Misapplication	31	1.54[b]	<0.2 - 12.4	19.4

a: ANOVA-Rank; $F=43.2$, $p < 0.001$.
b: ANOVA-Rank; $F=18.2$, $p < 0.001$.

chlordane can be expected. Unfortunately, these data cannot be considered a survey of realistic use patterns, nor can those studies cited previously be judged as random samples. Only the recent study by Leidy et al (1985) selected homes with no knowledge of or influence over applications procedures. In this analysis of indoor chlordane levels in 60 homes, the median value of 120 samples was 2.2 ug/m^3, with a range of <0.05 to 9.9. This median value is similar to the 10 year New Jersey value of 1.72 ug/m^3, but is much higher than the 0.89 ug/m^3 median noted from 1983-1985. Conversely, in the Leidy study 7% of the samples exceeded 5 ug/m^3, while 25% (1976-1985) and 12% (1983-1985) exceedance rates were found in New Jersey. The higher rates recorded in New Jersey most likely reflect the bias toward cases of misapplication inherent in data based on consumer complaints.

The central problem raised by this study is the misapplication of termiticides. From a public health and regulatory perspective the issue of misapplication is generic, and not unique to chlordane. If a compound deemed less hazardous is substituted for chlordane, it is still not desirable to have homes contaminated through misapplications. A regulatory strategy aimed at reducing the incidence of misapplications is likely to include, at a minimum, the following elements: use restrictions specific to structures and to application techniques; a higher level of training and record keeping on the part of applicators; and, a routine program of random sampling of application sites combined with strong enforcement procedures. Perhaps the major benefit to be derived from the current controversy surrounding chlordane is a greater awareness of the need for more systematic approaches to the regulation of pesticides in urban environments.

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