A Preliminary Study of Potential Human Health Effects in Private Residences Following Chlordane Applications for Termite Control

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ABSTRACT. A cross-sectional epidemiological investigation of the health status of 261 people from 85 private households previously treated with chlordane for termite control was conducted to assess potential human health effects. When sinusitis, bronchitis, and migraine responses were compared to measured indoor air levels of chlordane in categories designated as low (< 1 $\mu g/m^3$), medium (1–5 $\mu g/m^3$), and high (> 5 $\mu g/m^3$), a dose-response relationship was found after controlling individually and simultaneously for age, sex, and smoking. Homes studied in this investigation having a proper chlordane application were observed to have chlordane air levels exceeding acceptable exposure limits.

CHLORDANE has been the leading chemical agent used for controlling termite infestations and damage to private homes in the United States.[1,2] Indoor air pollution by chlordane was first reported by the United States Air Force in 1970 and again in 1974 and 1978.[3] In 1979, the National Academy of Sciences issued a temporary guideline of 5 $\mu g/m^3$ for chlordane, but without a guarantee that biological effects in exposed humans would not occur below this level.[3] In an attempt to determine the veracity of health complaints related to chlordane, a cross-sectional epidemiological investigation was conducted in 85 chlordane-treated households with 261 people, where indoor air concentrations of chlordane or other cyclodiene termiticides were known.[4]

Methods

Indoor air sampling. Indoor air concentrations of chlordane, heptachlor, and other termiticides inside living areas from 107 homes were obtained from a customer database made available by an environmental consulting firm. The termiticide sampling approach employed was similar to that described by Wright and Leidy.[5] The National Institute of Occupational Safety and Health's (NIOSH) analytical method for chlordane detection and quantification was utilized.[6] The concentrations of termiticides were reported as micrograms per cubic meter of air ($\mu g/m^3$). The detection limit for chlordane, based upon an average sample volume of 0.24 m^3, was 0.42 $\mu g/m^3$. Results of the air analyses were provided to the customer in a written report but without any health interpretations.

Questionnaire survey. A health questionnaire was designed to collect data from the study population. A total of 20 questions addressed acute health symptoms experienced immediately after the chlordane termiticide treatments were performed and included symptoms often associated with acute exposure to chlori-

nated hydrocarbon pesticides.[8,9] Twenty-three chronic health conditions experienced by individuals during the past year were listed in the questionnaire and followed the format used by the National Center for Health Statistics in their 1979 National Health Interview Survey (NHIS).[7] As a measure of potential bias, some health conditions believed unrelated to termiticide exposure such as goiter, diabetes, hearing impairments, and ulcers were included.

A mail survey approach similar to that described by Dillman was used.[10] Questionnaires were mailed to the 107 households in June 1984. A total of 86 questionnaires were returned, which is considered a high cooperation rate (80%) for a mail survey."

Respondent's principal reasons for conducting air testing included news reports on chlordane (52%), perceived health problems (19%), and odor problems (10%). Questionnaires were returned from 19 states, with New York and New Jerseyconstituting 54% of the total.

Analysis of database. To analyze statistically the reported prevalence of selected chronic disease conditions in the chlordane-treated homes, using the NHIS data as a control, the 261 respondents were divided into four age categories: < 17 yr, 17–44 yr, 45–64 yr, and > 65 yr. Observed and expected cases of disease were computed for each selected chronic health condition, based on the age-specific rates from the NHIS study. Sex-specific rates were not computed. Chi-square analysis was performed after the observed and expected cases of disease were summed over the age strata. If the expected cases of disease were less than five for a chronic health condition, then the Poisson approximation to the binomial distribution was used to estimate the probability of such an occurrence.

Three exposure groups were selected for evaluation, based upon the NAS guideline for chlordane: nondetectable or < 1 $\mu g/m^3$, from 1–5 $\mu g/m^3$ (within the NAS guideline), and > 5 $\mu g/m^3$ (above the NAS guideline). Because of the structural and toxicological similarity of heptachlor and aldrin to chlordane, measured air levels of these compounds were treated as "chlordane equivalent" and were included in the exposure groups.[12]

For further analysis of the study population, an internal control was used of those households having measured air levels of termiticides of < 1 $\mu g/m^3$. Tables of frequency of condition by exposure level were constructed for each chronic health condition. After chi-square analyses were performed for the various disease conditions, the frequency tables were stratified on levels of potential confounders, and Mantel-Haenszel summary chi-square statistics were computed." For those disease conditions found to be statistically significant, a test tor trend (with exposure) was computed to identify an increase in disease response with increasing chlordane air levels." To consider the effects of confounders in the test for trend, a Mantel extention of the Mantel-Haenszel statistic was computed." Finally, to further confirm a dose-response relationship found for disease conditions in the previous tests, a stepwise logistic regression model was constructed.

Results

Descriptive data. The range of time between completing the questionnaire and the last termiticide application at the residence was 1–24 yr. The mean time was 3.8 yr ± 3.66 (standard deviation [SD]). Approximately 50% of households fell in the 1–2 yr range since the last treatment with chlordane at their residence.

Time after chlordane treatment, categorized as less than or greater than 2 yr, was found to be unrelated to measured air levels of chlordane, which supports previous research that demonstrates chlordane air levels decline very slowly with time.[5,18,19] No statistical relationships between measured air levels of chlordane or other termiticides, either present or absent, and type of home (full basement, slab or crawl space) was found. In addition, no relationships were discovered between measured air levels of chlordane and the type of heating or air conditioning system used.

Headache was the most frequently reported acute symptom (22%) among respondents immediately following a chlordane termiticide application. Sore throat and respiratory infections were also cited frequently (16%), as were fatigue (14%), sleeping difficulties, blurred vision, weakness and fainting, or confusion. For chronic health conditions, sinus trouble was the most frequently reported symptom (21%) among respondents, followed by bronchitis (13%), migraine (8%), dermatitis (8%), asthma (5%), neuralgia or neuritis (5%), anemia (4%), and disease of the ovary and uterus (4%).

Statistical analysis of chronic health conditions. The incidence rates of anemia, migraine, neuralgia/neuritis, ovarian and uterine disease, bronchitis, sinusitis, dermatitis, and skin neoplasms were found to be significantly elevated ($p < .05$) in the chlordane-treated homes compared to the NHIS population. The prevalence of goiter, diabetes, hearing impairment, and ulcers in the study population thought to be unrelated to chlordane were similar to prevalence rates reported in the NHIS survey population, therefore increasing the

Table 1.—Results of the Test for Trend of Chlordane Exposure: Low, Medium, and High, and Self-Reported Chronic Health Conditions after Stratifying on Smoking, Age, Sex, and Number of Chlordane Treatments, Using the Mantel Extension of the Mantel-Haenszel Test*

Health condition	Number of chlordane treatments*	Smoking	Age	Sex
Migraine	χ^2 value: 3.26	1.21	4.55	4.76
	p value: (.071)	(.271)	(.033)	(.030)
Sinusitis	χ^2 value: 9.66	7.69	11.37	10.68
	p value: (.002)	(.004)	(.001)	(.001)
Bronchitis	χ^2 value: 7.88	6.11	6.91	7.30
	p value: (.005)	(.010)	(.008)	(.007)

Table 2.—Odds Ratios with 95% Confidence Intervals Estimated From a Logistic Model of Health Conditions as a Function of Pesticide Levels Simultaneously Controlling for Age, Sex, and Smoking

Dependent variable	Significant variables	p value	Odds ratio with 95% confidence interval
Migraine	> 5 μg/m³ chlordane	.0214	3.00 (1.18–7.45)
	Females	.0145	3.64 (1.30–10.30)
Sinusitis	> 5 μg/m³ chlordane	.0062	2.56 (1.31–5.00)
	Smoking	.0377	2.25 (1.05–4.83)
Bronchitis	> 5 μg/m³ chlordane	.0053	3.06 (1.40–6.73)
	17–44 yr age group	.0297	2.68 (1.10–6.51)

probability of homogeneity between the control and study populations.

Chronic disease rates in homes having 1-5 μg/m³ (medium exposure) or > 5 μg/m³ (high exposure) of a termiticide were compared to those for the control (low-exposure) group by chi-square analysis. Migraine (p = .031), bronchitis (p = .004), and sinusitis (p = .004) were the self-reported health conditions for which a statistical relationship to measured air levels of chlordane or other termiticide were seen. Using the Mantel-Haenszel chi-square test, and controlling for smoking, age, and sex, sinusitis, bronchitis, and migraine were found to remain statistically significant at probability (p) values of .05 or less.

The results of the Mantel extension analysis for migraine, sinusitis, and bronchitis (Table 1) indicate that the measured pesticide air level was found to be significantly associated with the chronic health conditions of sinusitis, bronchitis, and migraine. Results of the stepwise logistic regression (Table 2) revealed statistically significant associations between sinusitis, bronchitis, and migraine at air levels of chlordane or other termiticides ≥ 5 μg/m³.

Discussion

The study population in this investigation was self-selected: individuals concerned about chlordane or health problems paid to have their homes tested. A health survey on randomly selected homes would have provided more definitive conclusions regarding a relationship between indoor air levels of chlordane and human health effects. Due to potential, uncontrolled bias in this study, further epidemiological studies and indoor air measurements of chlordane and other termiticides would be required on larger populations of randomly slected residences in order to draw firm conclusions. The finding of a dose-response relationship between the indoor air concentrations of chlordane and three self-reported chronic health conditions (migraine, sinusitis, and bronchitis), using an internal control and considering potential confounders, suggests that chlordane could have chronic human health impacts.

The association found between chlordane and migraine and bronchitis is consistent with previous reports of these symptoms in chlordane poisoning or incident cases.[4,8,12,13] Although sinusitis, per se, has not been reported for chlordane or other cyclodiene termiticides, the observation has been made that the cyclodiene termiticides are inhalent and skin irritants.[4,8,14] Aplastic and acute refractory megaloblastic anemia and effects on the female reproductive system have also been associated with chlordane and/or heptachlor exposure.[10,13,16,17]

In our study, half the homes judged to have had a proper termiticide application had detectable air levels of chlordane, an average of 2.7 μg/m³, months to years following the last application. Very similar results have been reported in other studies.[5,18,19] Derivations of acceptable exposure limits to chtordane using animal toxicological data suggest that indoor air concentrations of chlordane would need to be < 1 μg/m³ (as low as 0.2 μg/m³) to provide an adequate margin of safety from noncarcinogenic effects on the liver.[21]

As the cyclodienes are considered to be animal carcinogens, long-term exposure to these compounds warrant concern.[2,4,21-23] Using the exposure information and termite treatment frequency data from this and other studies, potential cancer risks would range from approximately 10^{-4} to 10^{-3} (1 in 10,000 to 1 in 1,000) for a chlordane air concentration of 1–5 μg/m³, a 2–5-yr exposure period, and treatments every 3–7 yr.[19,20] Such indoor air cancer risks would be second only to those derived for indoor radon exposure, estimated to be in the range of 10^{-2} to 10^{-3}.[24] The United States Environmental Protection Agency (USEPA) has often considered lifetime cancer risks exceeding 10^{-6} (one in a million) as unacceptable.[25] An air level of ≤ 0.1 μg/m³, which appears unachievable, may need to be required to have cancer risks within an acceptable range. On August 11, 1987, on the basis of new evaluations regarding the safety of the cyclodiene termiticides, EPA announced the cancellation of virtually all termiticide uses of chlordane, heptachlor, aldrin, and dieldrin.[26]

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