

Chlorpyrifos in the Ambient Air of Houses Treated for Termites

C. G. Wright,¹ R. B. Leidy,² and H. E. Dupree, Jr.¹

¹Entomology Department and ²Pesticide Residue Research Laboratory, North Carolina State University, Raleigh, North Carolina 27695-7613

Chlorpyrifos (Dursban TC™, Dow Chemical Company, Midland MI) was labeled in the United States for termite control in 1980 (Anon 1980). Chlorpyrifos in ambient air and on surfaces of buildings following its application for control of cockroaches and other household pests have been reported by Wright and Leidy (1978, 1980) and Wright et al. (1981). Few data have been published on airborne levels of chlorpyrifos in homes treated for termites by commercial pest control companies. The objective of this study was to determine chlorpyrifos levels in the air of houses following their treatment with chlorpyrifos for termites by pest control companies and to compare data to the proposed National Academy of Sciences (NAS) guideline level of 10.0 $\mu\text{g}/\text{m}^3$ in the air of dwellings (NATIONAL RESEARCH COUNCIL 1982). This value is indicative of a "safe" level to individuals inhabiting the house approximately 16 hours per day.

MATERIALS AND METHODS

Sixteen single-family houses in North Carolina were selected for preventative or remedial subterranean termite treatment with 1.0% chlorpyrifos emulsion. Eight of the houses were in the Coastal region where loamy sands and sandy loam soils predominate. The other 8 were in the Piedmont region where clay and clay loam soils predominate. In the Coastal Plain region, four houses with crawl space under the entire house and four on full concrete slabs were selected; in the Piedmont region, four houses with crawl space under the entire house and four of split-level (combination crawl-slab) construction were chosen.

The houses were treated by pest control firms licensed by the North Carolina Department of Agriculture to apply chemicals for control of wood-destroying pests. The amount of insecticide applied was determined by the pest control firm's supervisor following label recommendations. The University researcher, present during all treatments, calculated and confirmed the amount of termiticide needed for each house before mixing. Air samples were taken in the bedroom and kitchen of each house before

Send reprint requests to C. G. Wright at the above address.

treatment to determine any background level of chlorpyrifos. Temperatures and relative humidities were measured in the test rooms during this and subsequent sampling times. Applications to the 16 houses were made between May 1984 and January 1985. Other air samples were collected during, immediately after, and 1-, 4-, 12-, 26-, 52-, and 104-weeks after application at the same site in each house. The air samples were secured using Byron Model 90 Sample Collectors™ (Byron Instruments, Raleigh NC) equipped with polyurethane foam (PUF) (2 cm od. by 3 cm) trapping devices (Wright and Leidy 1978). The collectors were operated at a flow rate of 2.0L/min for 120 min. The only exception in sampling time was for samples collected during application, where the sampling period corresponded with the amount of time required to apply the termiticide. Air samples were taken in the crawl space (slab houses excluded) during chlorpyrifos application. These samples were secured using Dupont™ Model P200A personal-type air sampling pumps (E. J. Dupont De Nemours and Company, Wilmington DE) with PUF as a trapping device and a flow rate of 0.2L/min. The holder and foam were removed, placed in plastic bags, and stored at -20°C until analyzed.

The PUF plug was removed from the glass collector with forceps and placed in a 250- mL beaker containing 150 mL of ethyl acetate. An additional 50 mL of ethyl acetate were poured through the glass collector into the beaker and the plug was squeezed against the sides of the beaker with a glass rod. This procedure was repeated three additional times at 15-min intervals. The solvent was poured through a stainless steel funnel into a 500 mL boiling flask and the beaker and plug were rinsed with an additional 50 mL of ethyl acetate. The combined extract was evaporated to 2 to 3 mL at 40°C under reduced pressure and transferred quantitatively to 12-mL tubes for analysis by gas-liquid chromatography.

The chromatograph was a Tracor Model 222 equipped with a Flame Photometric Detector operated in the phosphorus mode. A U-shaped glass column (183 by 0.2 cm id.) was packed with 4% SE-30 + 6% QF-1 on Gas Chrom Q (80/100). Nitrogen was the carrier gas at a flow rate of 35 mL/min. Temperatures were as follows: oven, 195°C.; detector, 185°C.; inlet, 200°C. Gases to the detector were hydrogen and air at flow rates of 50 and 80 mL/min, respectively. Data were quantitated by the peak height method using standards of known concentration.

To determine the efficiency of the analytical method, PUF plugs were fortified with known amounts of chlorpyrifos varying from 0.05 to 12.0 µg per plug. Using the same pipette, an equivalent amount was added to a 12.0 mL tube, which was stoppered and refrigerated until the samples were analyzed. Thirty fortified plugs and the equivalent tube, diluted to the same final volume, were analyzed with the air samples. Recoveries ranged from 89 to 131% with an average recovery of 97%. The data were not corrected for recovery values.

Chlorpyrifos residue data were analyzed by an analysis of variance (ANOVA). Sources of variation were: type of soil, type of construction, temperature, relative humidity, and time interval after application.

RESULTS AND DISCUSSION

Details of the 16 applications, such as the amount of chlorpyrifos applied and house size, soil type, or construction-type of house, are listed in Table 1. Application rates given on the label for different conditions, such as type of foundation, the presence or absence of dirt-filled porches and concrete slabs, all influenced the amount of termiticide applied per house.

Inside temperature and humidity data are listed in Table 2. Mean temperatures by month during air sampling ranged from an average of 19°C (Jan) to 27°C (Oct). The lowest mean relative humidity by month occurred in January (37%) and the highest (70%) in August.

Seven of the 16 houses had detectable chlorpyrifos in air samples taken in the living spaces (kitchen and/or bedroom) before application (Table 3). The highest preapplication levels detected in a kitchen and a bedroom were 0.62 and 0.32 $\mu\text{g}/\text{m}^3$, respectively, both occurring in the same house. The presence of chlorpyrifos in preapplication air samples might have resulted from its earlier use in the houses. All air samples taken in both rooms during and at all time intervals after application contained measurable amounts of chlorpyrifos. Levels of chlorpyrifos detected in post application air samples ranged from 0.10 to 8.54 $\mu\text{g}/\text{m}^3$. Air samples from treated houses on sandy soils contained significantly ($P<0.01$) more chlorpyrifos following its application than that from houses on clay soil (Table 3). Levels detected during and immediately after application in kitchens and bedrooms were probably related to the application of chlorpyrifos into the soil and house wall voids and the continuous air movement in the buildings. Termiticide air levels in one house of crawl construction on clay soil were higher, but below NAS prescribed guideline levels, in air samples taken immediately after application and those taken one week after application; with mean levels (combined bedroom and kitchen) of 4.17, 4.78, and 3.45 $\mu\text{g}/\text{m}^3$, for the three sampling times. These higher levels were probably related to the fact that a bedroom was being renovated and there was an opening of about 6.7 m^2 in the floor during the three sampling intervals, which allowed direct movement of chlorpyrifos from the crawl area where the levels were higher to the living areas. At 4 weeks the hole was closed and the mean level for the two rooms dropped to 0.94 $\mu\text{g}/\text{m}^3$. Residue levels for the 3 sampling times were not included in the ANOVA and means data because the opening in the floor did not constitute a "normal" condition in the home. Since the majority of the houses (13) were treated May through September, most of the air samples at 1, 4, 12, 52, and 104

Table 1. Amount of chlorpyrifos (1.0%) applied in treating 16 houses on two soils and three types for termites.

Geographical area	Construction type	House size (m ²)	Amount of emulsion applied (L)	L/m ²
Coastal plain	Crawl	100	435	
		114	549	
		74	379	
		114	568	
	\bar{x}	100	458	4.83
	Slab	86	700	
		145	1355	
		86	511	
		185	1268	
	\bar{x}	128	958	7.48
Piedmont	Crawl	132	946	
		96	379	
		170	662	
		95	454	
	\bar{x}	123	610	4.62
	Split ^a	121	662	
		143	946	
		151	587	
		150	662	
	\bar{x}	141	714	5.06

^aSplit type construction houses had part of the house on a slab and the remainder over a crawl space.

weeks were taken during the warm months of the year. In most instances only the 24-week sample was collected during the cool months. At 1 week following treatment chlorpyrifos levels in the air were lower ($P<0.01$) than at subsequent sampling times. The reason for this low residue level is unknown. Monitoring produced significantly ($P<0.01$) higher levels of chlorpyrifos in the 52-wk samples than in the 104-wk samples.

Table 2. Mean temperature and relative humidity by month inside houses treated with chlorpyrifos for termite control.

No. houses			
MO	sampled	Temp ($^{\circ}\text{C}$) ^a	%RH ^a
J	4	19 \pm 4	37 \pm 11
F	7	16 \pm 6	46 \pm 11
M	1	20 \pm 0	47 \pm 0
A	2	25 \pm 2	57 \pm 5
M	5	23 \pm 3	57 \pm 11
J	7	26 \pm 3	65 \pm 7
J	7	27 \pm 3	69 \pm 11
A	10	26 \pm 2	70 \pm 7
S	5	23 \pm 3	62 \pm 8
O	8	21 \pm 3	67 \pm 11
N	6	20 \pm 3	57 \pm 8
D	5	20 \pm 3	56 \pm 4

^aMean with standard deviation.

There was no difference in chlorpyrifos levels by room (kitchen vs bedroom), type of house construction, temperature or relative humidity. The highest level detected in a room was $8.54 \mu\text{g}/\text{m}^3$, and this amount is lower than the NAS interim guideline level of $10 \mu\text{g}/\text{m}^3$. Although the guideline levels expired in 1985, no new recommendations have been made, because sufficient data have not been generated to reassess the original, proposed levels. Thus, one must continue to rely upon the interim guideline level of $10 \mu\text{g}/\text{m}^3$.

$\mu\text{g}/\text{m}^3$ and below as causing no adverse health effects upon the inhabitants. Levels in air samples taken during actual termiticide application time in the crawl areas ranged from 3 to $108 \mu\text{g}/\text{m}^3$ (Table 4). It must be stressed that crawl areas are not living spaces and are not considered under the $10 \mu\text{g}/\text{m}^3$ interim guideline suggested by the government.

Table 3. Chlorpyrifos measured in the ambient air of houses treated for termites with a 1.0% chlorpyrifos emulsion.

Sampling time	Sand soil		Clay soil	
	Slab constr	Crawl constr	Crawl constr	Slab-crawl constr
$\mu\text{G}/\text{M}^3$ DETECTED IN A 2-H SAMPLING PERIOD ^{a, b}				
Pre	0.07 ± 0.02	0.07 ± 0.04	0.16 ± 0.22	0.10 ± 0.06
Immed	1.06 ± 1.06	0.80 ± 0.31	2.44 ± 1.75	1.17 ± 0.66
after				
1wk	0.57 ± 0.20	0.47 ± 0.55	1.30 ± 1.35	0.66 ± 0.28
4wk	1.05 ± 0.79	1.58 ± 1.53	0.70 ± 0.29	0.99 ± 0.61
12wk	2.53 ± 2.97	2.00 ± 1.09	0.81 ± 0.43	0.45 ± 0.29
24wk	0.97 ± 0.46	0.62 ± 0.20	0.74 ± 0.23	0.58 ± 0.37
52wk ^c	3.05 ± 2.27	3.13 ± 1.67	1.38 ± 1.53	2.76 ± 1.90
104wk ^c	1.56 ± 1.30	1.82 ± 1.68	1.32 ± 1.21	1.66 ± 1.24

^aMean \pm standard error of 4 houses by each soil-construction type. Bedroom and kitchen levels averaged. NAS guideline of $10.0 \mu\text{g}/\text{m}^3$ chlorpyrifos for continuous exposure in living areas of the house for a heterogenous population.

^bThe ambient air in all rooms contained significantly ($P < 0.01$) more chlorpyrifos following its application for termite control, with higher levels ($P < 0.01$) in houses on sand soil than in those on clay soil.

^cChlorpyrifos levels were significantly ($P < 0.01$) higher at 52 wk than during the preceding 4 sampling intervals and at the 104 wk sampling time.

Table 4. Chlorpyrifos ($\mu\text{g}/\text{m}^3$) detected in the ambient air of crawl spaces in houses during its application for termites.^a

House	Sand soil		Clay soil	
	Slab constr	Crawl constr	Crawl constr	Slab-crawl constr
1	NA	NA	12(87)	50(52)
2	NA	NA	3(22)	7(94)
3	NA	8(44)	36(58)	4(70)
4	NA	35(38)	108(54)	8(58)

^aLiters of ambient air sampled in parenthesis. NA = air samples not taken.

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