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Dispersion of Chlorpyrifos in Soil beneath Concrete Slabs

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Termiticides are usually applied beneath building foundations by drilling and spraying a liquid dilution into the void between the concrete slab and soil surface (Beal et al. 1989). Methods for placing termiticides beneath concrete slabs include low pressure application at a rate of about 15 L of termiticide dilution per 3 linear m through holes drilled adjacent to the foundation footing. Termiticide product labels recommend that to achieve adequate coverage these application holes be spaced from 30.5 to 61 cm apart. The material beneath the slab and soil, such as sand or gravel, and the presence of a void between the slab are conditions that influence the spacing of application holes.

There is little information on the optimum spacing of application holes to achieve uniform and continuous distribution of termiticide in the soil following application beneath concrete slabs. Hedges (1989) recommended 30.4 to 45.7 cm hole spacing for treating slabs that were set on gravel or sand. Brehm (1991) evaluated the dispersion of liquid termiticide applied with a fan pattern-nozzle, and recommended spacing application holes 23 cm apart when treating slabs set on gravel. Thomas & Robinson (1991) evaluated dispersion of a liquid applied with a fan-pattern nozzle and concluded that effective hole spacing for application to subslab voids was 20 cm apart and 10 cm from the footing. The objective of the research presented here was to evaluate the effects of using a fan-pattern nozzle and three application hole spacings on the dispersion in the top layer of soil of a liquid termiticide applied beneath a concrete slab.

MATERIALS AND METHODS

Concrete slabs (0.6 x 0.6 m, 7.6 cm thick) were poured over a 10 cm thick layer of gravel ($\bar{x}$ 4.3 g/piece) on naturally compacted soil. The soil composition was 29% sand, 56% silt, 14% clay, and there was 2.3% organic matter, and 26% moisture. The wooden frame around the slabs simulated the foundation walls and footing of a house. After seven days, 1.2 cm diameter application holes were drilled through the slabs. The holes were 30.5 or 17.8 cm apart, and 5.1, 10.2, or 20.3 cm from the edge of the wood. A 1% (AI) water dilution of chlorpyrifos was applied beneath the slab (above the gravel) at the rate of 15 L per 3 linear m.

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The application rate for the 30.5 x 5.1 cm and the 30.5 x 20.3 cm hole spacing was 1.5 L per hole, and for the 17.7 x 10.2 cm hole spacing the rate was 0.9 L per hole. Applications were made at a pressure of 1.7 kg/cm2 and a flow rate of 3.7 L/min, with a 1.2 cm subslab termiticide injector (Model 486, B&G Equip. Co., Plumsteadville, PA), and using a fan-pattern (180°) nozzle with a 5° upward angle (Directional Nozzle No. 1, B&G Equip. Co.). Each hole spacings was replicated three times. The slabs were removed from the gravel base 24 hr after applying the termiticide. At least 5 g of the top 1 cm of soil were taken from four locations beneath the slab: below the application hole (A), adjacent to the wooden wall directly in front of the application hole (B), equal distance between two application holes (C), and adjacent to the wooden wall, equal distance between two application holes (D). Three pieces of gravel that were adjacent to the concrete slab, and adjacent to the soil were also taken from these four locations.

Five g of soil was mixed with 5 g of Ottawa sand and 10 g anhydrous sodium sulfate and let stand for 3 min. This mixture was then placed in a 250 ml bulb column with a glasswool plug. Two separate amounts of 50 ml of 1:1 acetone and hexane were added to the column and drained into a beaker at the rate of 3 ml/min. The total extracted liquid was reduced to 20 ml and placed in a 125 ml separatory funnel. After adding 60 ml of distilled water and 5 ml of a saturated solution of sodium sulfate, the mixture was shaken vigorously for 2 min, then set for 10 min, the water and hexane layers were drained into separate beakers. The water layer was returned to the separatory funnel and 8 ml of 15% methylene chloride added. The mixture was shaken for 2 min and set for 10 min. The water layer was discarded, and the second hexane layer was added to the hexane layer from the first separation, along with 20 ml of distilled water. This mixture was gently agitated for 30 sec and set for 10 min. The water layer was discarded, the hexane layer was drained through an anhydrous sodium sulfate column into a beaker and evaporated to near dryness. Hexane rinses of the beaker were used for analysis. Gravel pieces were weighed and then placed in 40 ml glass jars. Ten ml of hexane was added, followed by 30 min of sonication. The hexane extractant was analyzed for chlorpyrifos.

The chlorpyrifos in the samples was analyzed by gas chromatography (Trecor 540, Trecor Instruments, Austin, TX), using electron capture detectors and NI63 as an ionization source, and nitrogen as the carrier gas. Operating conditions were: oven temperature 210 C, injector temperature 215 C, and detector temperature 350 C. The column was packed with 1.5% OV-17, 1.9% OV-210 on 100/120 Chromosorb WHP. Mean ($\pm$ SD) retention time for chlorpyrifos standards was 5.28 $\pm$ 0.01 min. Peak areas were determined with an integrator (Hewlett-Packard Model 3394A, Avondale, PA). Method sensitivity, based on sample weight and volume, permitted detection of 0.4 ng (0.4 ppm) chlorpyrifos per mg soil. The mean ($\pm$ SD) recovery rate for soil, 48% $\pm$ 5%, was determined by analysis of soil samples to which 2 ug of chlorpyrifos had been applied. The mean ($\pm$ SD) recovery rate for gravel, 84% ($\pm$ 2%), was determined by analysis of gravel samples to which 2 ug of chlorpyrifos had been applied. Results were calculated on a dry weight basis. Data was evaluated by analysis of variance, and differences were considered significant at P>

0.05% level (SAS Institute 1985). The amounts of chlorpyrifos in the soil and on the gravel are given as means with associated SD values.

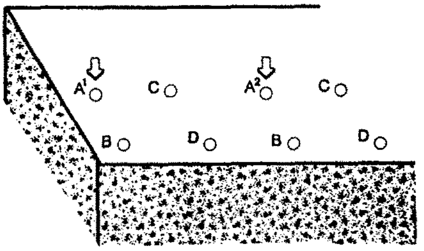

Figure 1. Location of soil sampling sites beneath the concrete slab and gravel; A, below the application hole (arrow); B, adjacent to the wooden wall directly in front of the application hole; C, equal distance between two application holes (A1 and A2), and D, adjacent to the wooden wall, equal distance between two application holes.

RESULTS AND DISCUSSION

The subslab application of 1% chlorpyrifos at all three hole spacings resulted in a band of insecticide-treated soil adjacent to the wooden frame (footing). There was no difference in the amount of chlorpyrifos detected at any of the soil sample sites (Table 1). There was no difference between the three hole spacings in the amount (ug) of chlorpyrifos detected on the gravel pieces at the sample sites (Table 2). There were no areas of untreated soil or pieces of untreated gravel detected at any sample site.

Table 1. Mean ug/ppm (SD) per 5 g of chlorpyrifos in the top 1 cm of soil 24 h after application beneath a concrete slab using a directional tip nozzle and three application hole spacings.

	$\bar{x}$ ug/ppm (SD) chlorpyrifos		
Location	Application hole spacing x distance (cm) from wall		
	30.5 x 5.1	0.5 x 20.3	17.8 x 10.2
Hole (A)	452.3 (173)	343.1 (237)	306.6 (188)
	122 (47)	92 (64)	82 (51)
Wall (B)	459.2 (242)	358.0 (233)	293.4 (63)
	124 (66)	97 (63)	79 (17)
Gap (C)	353.1 (351)	376.1 (182)	188.2 (215)
	95 (95)	102 (49)	51 (58)
Overlap (D)	700.2 (462)	484.2 (269)	270.1 (299)
	189 (125)	131 (73)	73 (81)

The fan-pattern nozzle effectively directed the liquid termiticide from the application site laterally, and towards the wooden frame that was 5 or 20 cm in front of the application hole. The 30.5 x 5.1 cm application hole spacing confined the spray to a narrow (5 cm wide) band of gravel and soil adjacent to the wood frame. This hole spacing apparently permitted the liquid to reach the wood frame and also overlap with the liquid from adjacent spray patterns. The 30.5 x 20.3 cm and the 17.8 x 10.2 cm hole spacings were less restrictive than the 30.5 x 5.1 cm spacing. Although the 10.2 to 20.3 cm space between the application hole and the wood frame provided more area for the liquid spray to cover, there was apparently continuous insecticide coverage of the soil for these two spacings. A large amount ($\bar{x}$ 700.2 $\pm$ 462 ug) of chlorpyrifos was detected in the soil at the sample site D in the 30.5 x 5.1 cm spacing. This might be the result of the narrow (5.1 cm) space between the application hole and wooden frame, and the overlap of liquid from the two adjacent application holes.

There was limited variation in the amount of chlorpyrifos detected on the gravel pieces taken from each location (Table 2). The small amount (< 1.0 ug) of chlorpyrifos detected on the top gravel pieces taken from sites B, C, and D for the 30.5 x 20.3 cm spacing is probably a result of the distance these gravel pieces were from the termiticide application hole. The upward deflection of the liquid from the nozzle may have limited the amount of spray reaching the top and bottom gravel pieces in these three locations.

Table 2. Mean ug of chlorpyrifos on gravel pieces at the top and bottom of fill, 24 h after application beneath a concrete slab using a directional tip nozzle and three application hole spacings.

Location	$\bar{x}$ ug (SD) chlorpyrifos — Application hole spacing by distance (cm) from wall		
	30.5 by 5.1	30.5 by 20.3	17.8 by 10.2
Hole (A)			
top	261.7 (208)	368.8 (119)	189.4 (89)
bottom	253.3 (105)	319.3 (78)	167.1 (74)
Wall (B)			
top	132.1 (60)	< 1.0 (0.58)	188.3 (165)
bottom	158.6 (114)	36.1 (30)	149.8 (63)
Gap (C)			
top	104.1 (179)	< 1.0 (0.33)	127.4 (106)
bottom	158.1 (163)	393.2 (163)	199.1 (28)
Overlap (D)			
top	103.6 (179)	< 1.0 (0.19)	41.3 (59)
bottom	66.8 (92)	78.8 (100)	208.8 (78)

The variation in the amount of chlorpyrifos detected in the soil may have been the result of such factors as soil compaction, the distance between the application hole and the wood frame, or the nozzle spray pattern. The fan-pattern nozzle used to apply the termiticide distributed the majority (60%) of liquid in the center area of the spray swath. This distribution pattern may have resulted in more liquid termiticide delivered at the application hole and directed at the wooden frame, sites A and B, and less directed laterally to sites C and D. The upward direction of the spray may have also altered the dispersion of the liquid beneath the slab by forcing some of the spray against the underside of the slab. Soil compaction and surface features, such as small depressions and obstacles, may have varied in each of the plots. Liquid termiticide on the soil surface may have drained from some slightly elevated areas and may have pooled in some depressed areas. Beal & Carter (1968) reported that soil compaction and composition should be considered when interpreting termiticide penetration in soil.

The data presented here show that the use of a fan-pattern nozzle and applying the manufacturer-recommended volume of termiticide dilution can result in a band of treated soil and gravel beneath a concrete slab. In this study the band of treated soil extended from the point of application to a wall within 20.3 cm from the application hole. A termiticide barrier in the top 1 cm of soil resulted from application of chlorpyrifos beneath the slab at the three application hole spacings. Termiticidal activity can be indicated by the quantity of insecticide that is toxic or repellent to the target pest. Su & Scheffrahn (1990) reported that a minimum of 8.9 ppm of chlorpyrifos in soil was necessary to prevent workers of the Eastern subterranean termite, *Reticulitermes flavipes* Kollar, from tunneling into more than 5% of 50 mm of soil treated with chlorpyrifos. Forty-seven ppm of chlorpyrifos was necessary to inhibit similar tunneling by workers of the Formosan subterranean termite, *Coptotermes formosanus* Shiraki.

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