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Adsorption of Carbofuran and Movement on Soil Thin Layers

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Carbofuran is a widely used soil insecticide throughout the Midwest as a prophylactic treatment against corn rootworms. In Iowa and Illinois alone, approximately 3.5 million pounds of active ingredient were applied to the soil in 1979.[1] Since treated fields occur in both watershed and nonwatershed areas alike, it is desirable to describe the translocation potential of this insecticide. HELLING (1968) devised a mobility classification for agricultural chemicals based upon their movement on soil thin layers. Since carbofuran mobility has not been assessed by soil TLC, the objective of this study was to determine its movement using this method. Adsorption of carbofuran was also measured to elucidate the relationship between sorption and translocation.

MATERIALS AND METHODS

Seven agricultural soils were collected from various counties in Illinois. The soils were air-dried, passed through a 2 mm mesh sieve, and characterized by texture, organic carbon content, and cation exchange capacity (Table 1).

Adsorption was measured by batch equilibration. Briefly, 20 g of soil were shaken with 100 mL of 20, 10, 5, 1 and 0 ppm carbofuran in 0.01 M $CaCl_2$ for 6 h in a 25 $\pm$ 1°C water bath. After centrifugation, the supernatant was filtered and extracted twice with dichloromethane (1:1). The dichloromethane was evaporated and the extract was redissolved in methanol. Carbofuran concentration was determined by spectrophotometry (525 nm) after base hydrolysis and coupling with p-nitrobenzenediazonium fluoborate (MISKUS et al. 1959).

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TABLE 1

Adsorption and movement of carbofuran and dieldrin in relation to soil properties

Soil Type or Association	Texture[a/]	% OC[b/]	CEC[c/]	Carbofuran		Dieldrin	
				K_d[d/]	R_f[e/]	K_d	R_f
Plainfield-Bloomfield	s	0.4	1.7	0.25	0.95	39	0
Gilford-Hoopeston-Ade	sl	1.2	7.5	0.74	0.80	147	0
Bryce-Swygert	sic	2.7	34.4	1.40	0.56	265	0
Drummer	sicl	3.1	24.8	1.13	0.77	198	0
Flanagan	sil	3.5	27.7	1.39	0.75	260	0
Bryce	sicl	7.5	55.5	2.22	0.49	297	0
Houghton	m	16.8	72.4	8.74	0.30	1507	0

a/ s = sand
l = loam
c = clay
si = silt
m = muck

b/ OC = organic carbon

c/ CEC = Cation Exchange Capacity (meq/100 g)

d/ $K_d = \frac{\mu g \text{ insecticide adsorbed/g soil}}{\mu g \text{ insecticide/mL solution}}$

e/ R_f = furthest movement of carbofuran or dieldrin relative to water

Soil thin layer chromatography techniques have been described by HELLING (1971a). Soils were crushed to pass a 48 mesh sieve. A soil-water slurry was spread across 20 x 20 cm glass plates to a thickness of 0.5 mm for loamy soils and 0.75 mm for sandy soils. Approximately 0.016 µCi of ^{14}C-carbofuran (FMC Corp.) was spotted on each plate; the plate was immersed in 0.5 cm of water in a closed glass tank and leached 10 cm. After allowing the plate to air-dry, Kodak Blue Brand x-ray film was exposed to the plate for 12 days. The distance carbofuran moved on the plate relative to water (i.e., R_f values) was determined by visual inspection of the autoradiograph. ^{14}C-dieldrin (Amersham Searle Co.) was used as a reference compound on each soil plate. Adsorption of dieldrin was also measured for comparison with carbofuran.

RESULTS AND DISCUSSION

Carbofuran and dieldrin adsorption were expressed as the distribution between the soil phase and water phase, i.e.,

$$x/m = K_d C_{eq}$$

where K_d = distribution adsorption constant; x/m = µg insecticide adsorbed/g soil; and C_{eq} = equilibrium concentration as µg insecticide/mL supernatant (Table 1) (HAMAKER & THOMPSON 1972). K_d values were determined for each of four different insecticide concentrations and averaged together to yield a mean value.

The adsorption of both insecticides was positively correlated with organic carbon content (R^2 = 0.96 to 0.98). The observed relationship between adsorption constant and organic matter has been shown with a variety of other nonionic insecticides (FELSOT & DAHM 1979) and herbicides (HAMAKER & THOMPSON 1972). It is not surprising that there was also a positive correlation between K_d and cation exchange capacity (R^2 = 0.83 to 0.85) because organic matter is known to contribute from 25 to 90% of the total exchange capacity of many soils (VAN DIJK 1971).

R_f values for carbofuran ranged from 0.30 to 0.95 and were inversely proportional to the organic carbon content (Table 1). This observation implies that a direct relationship exists between insecticide adsorption and mobility in soil. This conclusion is supported by a comparison of the K_d values for carbofuran and dieldrin. All of the dieldrin adsorption constants were at least 150 times larger than those of carbofuran,

and dieldrin was immobile in all the soils. Inverse correlations between adsorption constants and R_f values have also been observed for a number of herbicides (RHODES et al. 1970).

It should be noted that the behavior of carbofuran and dieldrin on the Bryce-Swygert silty clay did not follow the same pattern with respect to organic carbon content as on the other soils. More insecticide was adsorbed on Bryce-Swygert soil than on Drummer and Flanagan soils even though Bryce-Swygert had a lower organic carbon content. Furthermore, carbofuran moved considerably less in the Bryce-Swygert soil than the latter two soils. Perhaps the higher cation exchange capacity of the Bryce-Swygert soil contributed to increased adsorption of carbofuran and therefore less mobility.

In conclusion, carbofuran was very mobile in the agricultural soils studied. On the more prevalent Illinois soils (i.e., the silt loams and silty clay loams), carbofuran would fit into HELLING'S (1968) mobility class 3 or 4. On the other hand, dieldrin was immobile on soil thin layers as previously reported by HELLING (1971b). When one considers the relationship shown between pesticide adsorption and mobility on soil thin layers, the results reported here offer one explanation for previous observations on the runoff losses of dieldrin and carbofuran in watershed areas (CARO et al. 1975). Although about 2% of the applied dose of both dieldrin and carbofuran were lost in runoff, most of the dieldrin was associated with runoff sediment whereas most of the carbofuran was associated with runoff water.

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