

Movement of Pesticides in Soil

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The mobility of 11 insecticides in soil was studied using a standard column system. Chlorinated hydrocarbon insecticides were immobile; phorate and disulfoton were only very slightly mobile,

while diazinon and especially thionazin exhibited greater mobilities. The mobilities of the insecticides studied were compared with those of 28 herbicides evaluated earlier in the same standard system.

This study was undertaken to extend to some insecticides the use of a standard system for studying movement that has already been used with a number of herbicides (Harris, 1967). Studies of pesticide movement in soil have usually been limited to absolute measurements for one or a few pesticides. Reports on pesticide movement in soil have been summarized by Bailey (1966) and Upchurch (1966). Since it is generally accepted that the movement of a given pesticide in soil will vary with soil properties and the amount of water passing through the soil, information about the movement of a pesticide relative to the movement of other pesticides is valuable. Relative ratings of mobility make it possible to predict the movement of pesticides in different situations on the basis of another pesticide whose movement has already been observed in the different situations.

MATERIALS AND METHODS

The insecticides studied and the rates of application used are listed in Table I. Technical grade insecticides were used.

Columns were made from 2.5-cm. segments of 7.6-cm. (inside diameter) aluminum tubing with a wall thickness of 0.64 cm. Lanolin was used to waterproof the joints between segments. Air-dry soil was packed uniformly to a depth of 4.4 cm. in the aluminum columns. Insecticides in 10 ml. of 95% ethanol were applied to the columns at this

level. The treated surface was left exposed overnight to allow the ethanol to evaporate. Then the columns were completed by packing additional air-dry soil to a depth of 17.8 cm. All soil additions were made by weight to aid in uniformity of packing. Two soils used in this study were Hagerstown silty clay loam (4.3% organic matter, 30% clay, 12.5 meq. per 100 grams cation exchange capacity, pH 5.5, bulk density in columns = 1.2 grams per cc.) and Lakeland sandy loam (3.3% organic matter, 10% clay, 2.9 meq. per 100 grams cation exchange capacity, pH 6.2, bulk density in columns = 1.4 grams per cc.).

The columns were set up in 2-liter plastic containers so that they could be subirrigated. Water was added to the containers to a depth not exceeding 2.5 cm. and the units were placed in a hood with the fan operating. After 3 days, the columns were sliced and the segments were placed in disposable plastic cups to dry sufficiently to be in a workable physical condition. Each sample was passed through a 2-mm. screen, thoroughly mixed, and weighed. Immediately after weighing, one tenth of the sample (by weight) was placed in a 125-ml. Erlenmeyer flask.

Extraction and Determination. Add 50 ml. of solvent (3 parts of hexane plus 1 part of 2-propanol) to the soil (approximately 15 grams) in an Erlenmeyer flask and periodically swirl the contents. After 30 minutes, decant the solvent into another flask, rinse the soil twice with 12-ml. portions of solvent, and combine the rinsings with the original extract. Filter the extract through glass wool into a 125-ml. separatory funnel, and rinse the extract with equal volumes of water three times. Add one-half teaspoon of anhydrous sodium sulfate to the extract, and shake vigorously to remove any remaining water. Transfer the extract to a volumetric flask and make up to volume. Inject a 5- μ l. sample of extract into the gas chromatograph.

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Table I. Rates of Application and Recoveries of Insecticides from Layers in Soil Columns after Upward Movement of Water

Insecticide	Rate of Application, Lb./Acre	Insecticide Recovered, Mg.						Total	Total Recovery, % of Total Applied	Mobility Factor ^b
		Depth of Soil Layer, Inches								
		0-1	1-2	2-3	3-4	4-5	5-6 ^c			
Aldrin ^d	4	0.00	0.00	0.00	0.00	0.00	1.80	1.80	88	1.0
		0.00	0.00	0.00	0.00	0.00	1.39	1.39	68	1.0
<i>o,p'</i> -DDT	4	0.00	0.00	0.00	0.00	0.00	1.96	1.96	96	1.0
		0.00	0.00	0.00	0.00	0.00	1.71	1.71	84	1.0
<i>p,p'</i> -DDT	4	0.00	0.00	0.00	0.00	0.00	1.88	1.88	92	1.0
		0.00	0.00	0.00	0.00	0.00	1.63	1.63	80	1.0
DDE	4	0.00	0.00	0.00	0.00	0.00	1.77	1.77	87	1.0
		0.00	0.00	0.00	0.00	0.00	1.31	1.31	64	1.0
Diazinon	20	0.00	0.00	0.00	0.22	2.04	1.78	4.04	39	1.6
		0.00	0.00	0.00	0.43	2.99	5.04	8.46	82	1.4
Dieldrin	4	0.00	0.00	0.00	0.00	0.02	1.67	1.69	83	1.0
		0.00	0.00	0.00	0.00	0.00	1.35	1.35	66	1.0
Disulfoton	20	0.00	0.00	0.00	0.00	0.77	3.70	4.47	43	1.2
		0.00	0.00	0.00	0.00	0.61	5.66	6.27	61	1.1
Endrin	4	0.00	0.00	0.00	0.00	0.06	1.92	1.98	97	1.0
		0.00	0.00	0.00	0.00	0.00	1.67	1.67	82	1.0
Heptachlor	4	0.00	0.00	0.00	0.00	0.00	1.73	1.73	85	1.0
		0.00	0.00	0.00	0.00	0.00	1.67	1.67	82	1.0
Phorate	20	0.00	0.00	0.00	0.00	1.16	4.56	5.72	56	1.2
		0.00	0.00	0.00	0.00	1.11	6.07	7.18	71	1.2
Thionazin	20	0.05	0.19	0.33	0.34	0.20	0.19	1.30	12	3.2
		0.34	0.70	0.84	1.03	0.84	0.60	4.35	42	3.2

^a 1 lb./acre = 0.51 mg. per column.

^b Calculated as described by Harris (1967) by substituting mg. of insecticide recovered for per cent growth reduction.

^c All insecticide treatments applied to 5- to 6-inch layer of soil.

^d For each insecticide, upper set of data is from Hagerstown silty clay loam and lower from Lakeland sandy loam.

A Research Specialties Model 600 gas chromatograph equipped with an electron capture detector (10-mc. ⁹⁰Sr source) and a Westronics 5.5-mv. recorder were used. For the chlorinated hydrocarbons, a 180-cm. column (0.32-cm. I.D.) of 10% DC-200 on 100- to 120-mesh Gas-Chrom Q was used with nitrogen carrier gas flow rate of 120 ml. per minute; temperatures of 220°, 220°, and 240° C. for the injector, column, and detector, respectively; and a high voltage setting of 3 volts. For the phosphorus-containing insecticides, the column packing was 1.3% Versamid 900 on 60- to 80-mesh Diataport S, and the temperatures were 215°, 175°, and 230° C. for the injector, column, and detector, respectively.

Known amounts of the insecticides were used as standards in the gas chromatographic determinations. Peak heights from the recorder charts were used to establish standard curves for each insecticide and, by comparison, to determine the concentration of insecticide in the unknown samples.

Mobility factors, as described by Harris (1967), were calculated by using milligrams of insecticide recovered from each segment of the column in place of the growth reduction data that were used in the calculations for herbicides. The insecticide recovery data for the individual segments were normalized in such a way that the sum for all segments in each column equaled 1.0. The normalized values then were weighted by multiplying them by the numbers 1

through 6—that is, 1 times the value for the lowest depth, 2 times the value for the next depth, and so on. The total of the weighted values was designated the mobility factor for the pesticide concerned in the soil used. The range of possible mobility factor values was from 1.0 for no movement out of the treated segment to 6.0 for maximum movement in the system.

All experiments were repeated once and data reported are the averages of the two observations. Monuron was included to ensure that the system was performing in a way comparable to the prior studies with herbicides.

RESULTS AND DISCUSSION

The recoveries of insecticides from the various segments of the developed columns and the mobility factors calculated from the recovery data are listed in Table I. The chlorinated hydrocarbon insecticides did not move out of the layer where they were applied, and their mobility factors were calculated to be the minimum value, 1.0. Phorate and disulfoton exhibited slight movement out of the area of application into the next segment and their mobility factors were 1.1 to 1.2. Diazinon moved more and its mobility factor was 1.4 to 1.6. Thionazin was the most mobile of the insecticides studied, and spread throughout the columns to give a mobility factor of 3.2. Results for the two soil types were essentially the same.

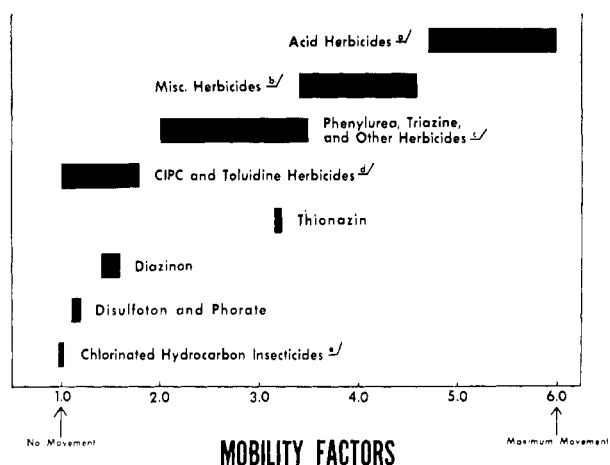


Figure 1. Relative mobilities of pesticides in a subirrigated column system

Data for herbicides taken from a previous study (Harris, 1967)

^a Includes dicamba, tricamba, 2,3,6-TBA, amiben, methoxyfenac, and fenac.

^b Includes DNBP, pyriclor, 7175, norea, and cycluron.

^c Includes monuron, buturon, linuron, diuron, atrazine, simazine, propazine, prometryne, EPTC, pebulate, vernolate, and diphenamid.

^d Includes benefin, planavin, CIPC, trifluralin, and dipropalin.

^e Includes aldrin, *o,p'*-DDT, *p,p'*-DDT, DDE, dieldrin, endrin, and heptachlor.

For a comparison of the mobilities of insecticides with mobilities of herbicides, mobility factors from this study and from a previous study with 28 herbicides are depicted in Figure 1. Under the standard column conditions employed, maximum differences in movement were observed from no movement of the chlorinated hydrocarbon in-

secticides to maximum movement for some of the benzoic acid herbicides. The *s*-triazine and substituted phenylurea herbicides, which are generally considered relatively immobile in the soil, were much more mobile than disulfoton, phorate, and the chlorinated hydrocarbons. Only thionazin, of the insecticides studied, exhibited as much movement as the *s*-triazines and phenylureas.

These results, when considered in the light of the literature on herbicide movement (Upchurch, 1966), suggest that there is little probability that the chlorinated hydrocarbons, diazinon, disulfoton, or phorate, will be moved below the plow layer of soils by percolating water. Thionazin, on the other hand, may move considerably in some soils as a result of percolating water, since it moved in the soil columns similarly to monuron, which has moved below the plow layer under some conditions (Burnside *et al.*, 1963). These insecticides would be subject to lateral movement by erosion, and they could be moved downward in the soil profile as a result of tillage operations and soil cracking.

ACKNOWLEDGMENT

The technical assistance of Thomas Twomey is gratefully acknowledged.

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Received for review July 26, 1968. Accepted October 22, 1968.