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The model test of leaching behaviour of trifluralin, lindane and aldicarb through the plough layer in three types of soil

Wang Jinhai[1], Zhang Lianzhong[1] and Dai Guangmao [1]

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Abstract—A study on the leaching behaviour of triflûralin, lindane and aldicarb in three different types of soil was performed using soil column method. Leaching of trifluralin was not much influenced by soil types. Organic matter content showed an apparent influence on the leaching of lindane and aldicarb. Leaching depth of the pesticide was found to be negatively related to the organic matter content of the soil under study. It was also found that hydrophobic property of the pesticide increased the tendency of adsorption of the chemical to soil particles and hence reduced its leaching tendency. Thus, the leaching depths of the three pesticides in each of the three soils were observed in the order: aldicarb >lindane> trifluralin. Leaching behaviour of the three pesticides was also predicted based on the adsorption coefficients of the chemicals. For trifluralin and lindane, the predicted results were considerably in line with the results of the experiment.

Keywords: leaching; trifluralin; lindane; aldicarb.

Leaching is a process in which chemicals move downwards with percolating water in soil profiles. Like adsorption, leaching affects efficacy of pesticides and environmental quality. For example, pesticides may reach ground water through excessive leaching. The Environmental Protection Agency of the United States stated that leaching was a major factor leading to ground water pollution (USEPA, 1980).

Leaching of pesticide in soils depends on water movement and partition of pesticide between water and soil phases. According to chromatographic theory, leaching can be related to adsorption by an equation:

$$Kd = \varepsilon[1/Rf - 1] \tag{1}$$

where, Rf is the ratio of the travelling distance of pesticide concentration peak to that of the front of percolating water, ε is the ratio of water phase to soil phase, and Kd is the adsorption coefficient of the tested pesticide in the soil system. It can be observed from equation (1) that

[1]Research Center for Eco-environmental Sciences, Academia Sinica, P.O. Box 934, Beijing, 100083, China

the larger the value of Kd is, the smaller the Rf value would be. Therefore, Kd can be used to predict leaching tendency of a pesticide in a given soil system.

There are two conventional methods for leaching study: soil thin-layer chromatography (TLC) and column method (Garduer, 1957; Stookinger, 1961; Williams, 1968.).

The intention of this work was to study the leaching processes of trifluralin, lindane and aldicarb in three different soils, depict the column method for leaching study, and compare the observed leaching data with those predicted with equation (1).

EXPERIMENTAL

Three types of 0-18cm upper layer soil used in the study were collected from the suburb of Beijing. The soils were air dried and ground to pass a 1mm screen to remove plant roots and leaf residues. The physico-chemical properties of the soils are listed in Table 1.

Table 1 Composition and properties of the soils

Soil type		Baihua	Shahe	Hongni
pH		6.92	8.30	7.94
Organic carbon cotent, %		9.35	1.62	1.24
Mechanic composition, %	Sand	34.9	33.9	48.4
	Silt	55.9	46.5	42.2
	Clay	9.5	19.6	9.4

The three pesticides of aldicarb, lindane and trifluralin with purity of 95% were obtained from Dagu Chemical plant (Tianjin, China), Tianjin Institute of Pesticide Industry, and Institute of Organic Chemistry, Chinese Academy of Sciences, respectively. The physico-chemical properties of the pesticides are given in Table 2.

Leaching experiments were conducted in stainless steel pipes which can be taken apart into 3 cm segments. 250g of each type of soil was packed into a pipe. 1 ml of acetone solution of a given pesticide to be tested was added onto the top of the column packed with the soil under study. The application rates of the three pesticides were 0.25, 1.25 and 12.5 mg per column for trifluralin, lindane and aldicarb, respectively. The columns were left overnight at ambient temperature (25°C) so that acetone could be removed by evaporation. The columns fortified with trifluralin and lindane were eluted with 600 ml of distilled water, while the aldicarb fortified soil column was eluted with 200 ml of distilled water. Eluted water was collected and analyzed for pesticides. As soon as water elution stopped, the stainless steel pipes were taken apart into segments so that the soil columns could be sectioned. Water content and bulk density of each soil column were determined (Table 3) and the sections of the soil column were analyzed for pesticide contents so as to obtain vertical distribution of pesticide in the column.

Table 2 Physico-chemical parameters of the pesticides under study (Hartley, 1983)

	Aldicarb	Lindane	Trifluralin
Molecular weight	190	291	335
Melting point, °C	100	112–113	49
Vapor pressure, mPa	1.3×10^6	1.2×10^6	2.6×10^6
water solubility, mg/L	6000	10	0.3

Table 3 Soil bulk density and volumetric soil-water content

	Soil-water content, ml/ml	Bulk density, g/ml
Hongni soil	0.34	1.24
Shahe soil	0.42	1.33
Baihua soil	0.55	1.11

For the analysis of lindane and trifluralin, soil samples were Soxlet extracted with petroleum ether: acetone (V/V=1/1). The extracts were washed with water to remove acetone, dried with anhydrous sodium sulphate and analyzed with a SP-501 Gas Chromatograph, equipped with an electron capture detector and 2m × 2.5mm ID stainless steel column packed with 1.95% QF-1 + 1.5% OV-17 on Chromosorb W. The operation conditions for the gas chromatograph were as follows: column temperature, 190°C; detector temperature, 210°C; injector temperature, 220°C; and carrier gas (N_2) flow rate, 60ml/min.

For the analysis of aldicarb, a Shimazu Company produced high performance liquid chromatograph with UV detector was used. A ZORBAX-CN column and a mobile phase of petroleum ether: methylene chloride: methanol (V:V:V=1:1:1) were used for the separation of aldicarb from co-extracts. The flow rate of the mobile phase and operation temperature were 1 ml/min and 40°C, respectively.

RESULTS AND DISCUSSION

The levels of trifluralin, lindane and aldicarb in different depths of soil columns after leaching, expressed in recoveries, were shown in Table 4, 5, and 6. It can be seen from the tables that total recoveries for all the three pesticides were lower than 100%. Degradation and irreversible adsorption to soil particals may be two important factors resulting in the decrease of total recoveries of the pesticides. Among the three chemicals, aldicarb is the most unstable one which is easy to be oxidized to aldicarb sulphoxide and aldicarb sulphone in soils, therefore, the total recoveries for aldicarb, especially in high organic matter content soil, were determined to be lower than the other two chemicals. Similar results have been reported (Leistra, 1976).

The distributions of trifluralin, lindane and aldicarb can also be schematically described in Fig. 1, 2, and 3.

It was found that trifluralin moved very little with percolating water in all the soil columns with peak concentration in upper 0–1.5 soil layers, regardless of soil types. However, from the levels of trifluralin detected in 3–6 layer of soil, it can be found that soil type did affect leaching

Table 4 Leaching of trifluralin in soils

Depth, cm	Recovery, %		
	Shahe soil	Hongni soil	Baihua soil
0–1.5	69.9	71.5	81.9
1.5–3.0	8.1	5.6	7.1
3.0–4.5	0.5	0.8	T
4.5–6.0	0.2	0.2	T
6.0–9.0	T	T	T
9.0–12.0	T	T	T
Leachate	0.3	0.2	0.1
Total	79.0	78.5	89.1

T—Trace

Table 5 Leaching of lindane in soils

Depth, cm	Recovery, %		
	Shahe soil	Hongni soil	Baihua soil
0–1.5	11.1	5.4	67.8
1.5–3.0	1.9	5.2	26.7
3.0–4.5	20.9	26.6	T
4.5–6.0	20.0	28.6	T
6.0–9.0	8.0	8.5	T
9.0–12.0	0.4	0.4	T
12.0–15.0	T	T	T
15.0–18.0	T	T	T
18.0–21.0	T	T	T
Leachate	1.0	1.5	0.2
Total	63.3	76.2	94.7

T—Trace

of trifluralin, i. e. the lower the soil organic matter contents is, the deeper the chemicals would be leached. Thus, the leaching depths of trifluralin in different soils were observed to be in an order: Hongni > Shahe> Baihua, of which the organic matter contents were determined to be in the reversed order.

Leaching of lindane was also affected by soil organic matter contents. Thus, peak concentrations of lindane occured at 4.5–6.0cm in Hongni soil, 3.0–4.5cm in Shahe soil, and 0–1.5cm in Baihua soil, in accord with the organic matter contents of the soils.

Aldicarb was found to leach to much deeper layer of soil than the other two chemicals. No clear concentration peak of aldicarb in soil column was observed. However, higher concentrations of aldicarb were found in 18–21cm of hongni soil column, 15–18cm of Shahe soil column and 12–18cm of Baihua soil column, showing the same effect of soil organic matter content on leaching as that on the leaching of trifluralin and lindane.

Table 6 Leaching of aldicarb in soils

Depth, cm	Recovery, %		
	Shahe soil	Hongni soil	Baihua soil
0–3.0	T	T	T
3.0–6.0	T	T	0.7
6.0–9.0	T	T	1.0
9.0–12.0	T	T	1.6
12.0–15.0	1.3	T	2.1
15.0–18.0	18.9	0.4	1.3
18.0–21.0	10.7	10.1	0.3
Leachate	32.0	80.7	4.5
Total	62.9	91.2	11.5

T—Trace

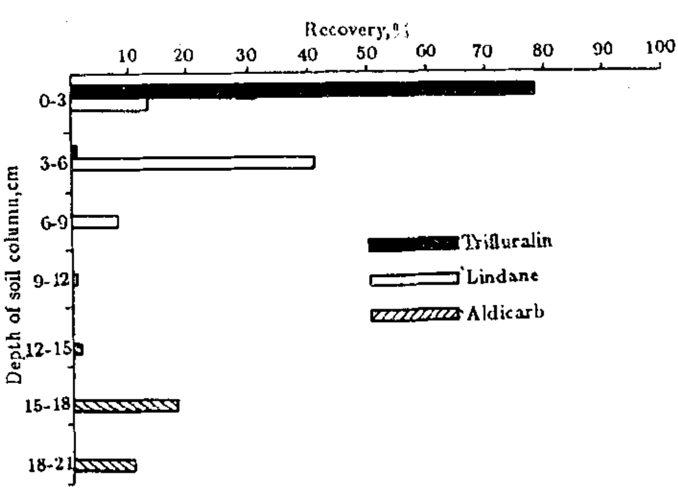

Fig. 1 Leaching of the three pesticides in Shahe soil

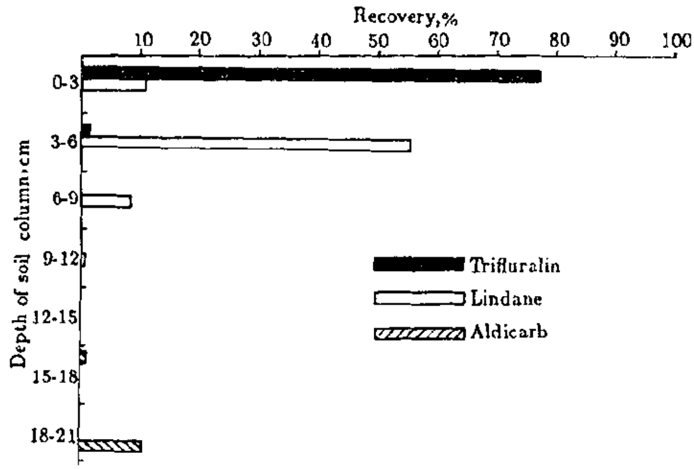

Fig. 2 Leaching of the three pesticides in Hongni soil

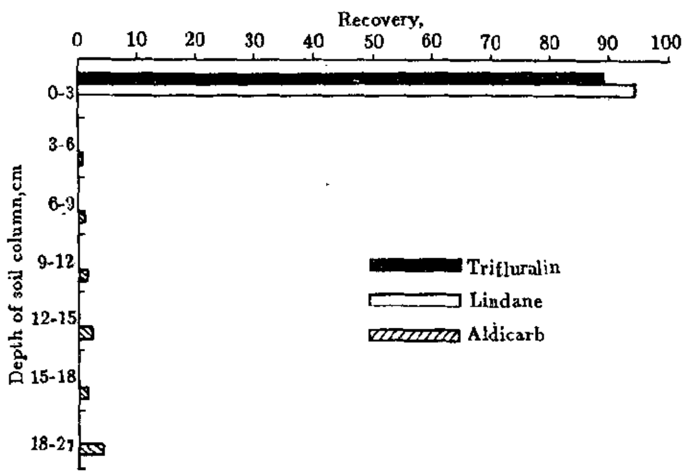

Fig. 3 Leaching of the three pesticides in Baihua soil

Comparing the leaching behaviour of the three pesticides, it can be found that aldicarb with the highest water solubility (6000μg/ml) and the smallest organic carbon adsorption coefficient (34.7–88.3; Wang, 1989) leached to much deeper layer of soil than the other two pesticides did. In contrast, trifluralin with much lower water solubility (1 μg/ml) and much larger organic carbon adsorption coefficient (3087–3747) did not move much in the soil columns as mentioned above. Lindane possesses a water solubility (19μg/ml) and an organic carbon adsorption coefficient (810–906) between those of trifluralin and aldicarb. As a result, the leaching depths of lindane were also between those of trifluralin and aldicarb. From the above discussion, it is not difficult to come to the conclusion that hydrophobic property of a chemical and organic matter content of the soil in which the chemical leaches are the two major factors governing the leaching behaviour of the chemical. In fact, the two factors affect leaching process through influencing the adsorption of the chemical by soil particals. Leaching distance can be related to adsorption coefficient Kd by equation:

$$1/Rf = 1 + \rho Kd/\theta \tag{2}$$

where, ρ is soil bulk density and θ is volumetric soil water content. The depth of pesticide concentration peak in soil column can be predicted from multiplying percolating water front depth by Rf value calculated from above equation. Results of prediction were given in Table 7.

Table 7 Calculated depths of pesticide concentration peak

	Pesticide concentration peak depth, cm					
	Using Kd values determined with column method			Using Kd values determined with batch slurry method		
	Trifluralin	Lindane	Aldicarb	Trifluralin	Lindane	Aldicarb
Baihua soil	0.15	0.60	5.5	0.1	0.5	1.7
Shahe soil	0.80	3.1	15	0.61	2.5	7.3
Hongni soil	1.03	4.5	19.0	0.95	4.3	10.0

For trifluralin and lindane, predicted and determined concentration peaks in soil columns after leaching were considerably in line with each other. However, for aldicarb, predicted values did not coincide with determined values. This may be caused by the extremely high water solubility of this chemical.

SUMMARY

The above study demostrated that besides the movement of percorlating water, leaching behaviour of a chemical in a soil system mainly depends on the tendency of adsorption of the chemical by soil particles. While the tendency of adsorption is governed by two important factors, i. e. the hydrophobic property of the chemical and the organic matter content of the soil under consideration. Hence, leaching tendency of a chemical in a given soil system can

be prodicted based on the knowledge concerning the movement of percorlating water and the physical properties of the chemical and the soil.

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