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Sorption of 75% DDT Water-Dispersible Powder on Different Mud Surfaces

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The loss of residual insecticide particles on absorbent mud surfaces due to the phenomenon of sorption has been well investigated from various physical, chemical and biological aspects. The present report describes an attempt to correlate the relative sorption capacities of representative Indian and African soils and a synthetic soil with the physicochemical characteristics of these soils and their surfaces. The investigation has further elucidated the mode of sorption of non-volatile residual insecticides on mud surfaces and the role of certain physicochemical factors.

The extensive use of DDT water-dispersible powders for mosquito control in rural areas soon showed that on porous mud surfaces the residual action of the insecticide was shorter than on impervious surfaces (Kruse & Konchady, 1950; Downs, Bordas & Navarro, 1951; Hadaway & Barlow, 1951). The work of Hadaway & Barlow (Hadaway & Barlow, 1951, 1952, 1953, 1955; Barlow & Hadaway, 1956) established that when insecticide was sprayed as a suspension on mud surfaces, the loss of activity of the insecticide particles was mainly due to the phenomenon of sorption. Sorption, in this case, meant essentially adsorption, absorption and persorption of the solid particles on a porous solid surface. Several other workers further confirmed the above general hypothesis and investigated the nature and degree of sorption in relation to other factors involved (Bertagna, 1959). In order to evaluate the comparative efficacy of 75% DDT water-dispersible powder, 50% dieldrin water-dispersible powder and a 50% dieldrin-resin water-dispersible powder when sprayed on mud surfaces, Sharma & Bami (1957) and Sharma, Bami & Krishnamurthy (1958) conducted trials in the laboratory and in rural mud houses around Delhi. In the case of the mud houses there was only a limited decline in mosquito density, although the same dosage of these insecticides, when sprayed on impervious surfaces in the laboratory, produced adequate mortality. Further physicochemical investigations threw considerable light on the inter-relationship between the nature of the mud involved, the particle size of the insecticide sprayed and the loss of insecticide through sorption. However, in view of the fact that normally a variety of mud surfaces existed in the field, further study of different representative soils was planned in this context.

Nearly 90% of Indian soils belong to four major groups—namely, black, alluvial, lateritic and red soils. Consequently, for the present studies, four typical soil samples were obtained from Poona (black soil A), Delhi (alluvial soil C), Cuttack (lateritic-alluvial soil D) and Bangalore (dull-red soil E). Their physicochemical properties were determined and correlated with their capacity to sorb DDT particles in the case of a standard 75% DDT water-dispersible powder. Afterwards, three samples were received from WHO, representing dark-brown soil B (WHO 591, humic soil from Taveta-Pare, East Africa), red soil F (WHO 583, red loam from Magugu, East Africa) and a white synthetic soil G (WHO 599) prepared by Dr J. Treboux. The physical characteristics of these soils were also determined and their sorption capacities evaluated in relation to Indian soils. It was decided to use only a standard commercial formulation of 75% water-dispersible powder, representative of the formulations now widely used for malaria control projects, the intention being to eliminate one of the variables —namely, the size of DDT particles sprayed—in the establishment of a relationship between the physicochemical properties of different soils and their capacity to sorb DDT under given conditions. An attempt was made to measure the degree of sorption on different surfaces by removing surface layers of

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DDT particles by means of transparent adhesive tape (Sellotape) and its subsequent chemical estimation. The possibility of chemical decomposition of DDT by Indian soils was also investigated.

EXPERIMENTS

Application of DDT on mud panels

Each soil sample was sieved through a 2-mm sieve, mixed with a little straw and worked into a thick paste using distilled water. Wooden frames (internal dimensions 5 inches × 0.5 inches)[1] were placed on glass panels (7 inches × 7 inches) moistened with water and evenly filled with clay. In this manner, several mud panels were made from each of the soil samples and allowed to dry at room temperature for a few days. During this period, any cracks that developed were mended either by pressing the wet panels or by filling them up. Afterwards, the mud panels were lifted from the glass surfaces, and small holes or cracks on the smooth side of the panel were filled carefully to give a uniform surface. The panels were allowed to dry for a further period of one week at room temperature.

By means of a Hudson compression sprayer, 75% DDT water-dispersible powder, in a 5.0% DDT aqueous suspension, was sprayed on the panels using a mechanically movable horizontal platform to hold the panels. The arrangement was broadly similar to the one described by Alessandrini, Mosna & Placucci (1955), with the additional advantage that about 20 panels could be sprayed simultaneously. Mud, glass and plywood panels were sprayed with a dosage of 100 mg of DDT per square foot (1 g/m^2). The average dosage actually applied was determined by analysing the amount of DDT on several glass panels sprayed along with the mud panels.

Estimation of DDT on mud surfaces

The Sellotape method (Barlow;[2] Barlow & Hadaway, 1956) was suitably adapted for the removal of DDT from the mud surfaces, while the Schechter-Haller method (1945) was employed for the chemical estimation of the DDT itself. In this connexion, a standard reference curve for DDT estimation was obtained as follows:

(1) Six pieces of Sellotape (2 inches × 2 inches) were introduced into six test-tubes. To five of these test-tubes, 0.5, 1.5, 2.5, 4.0 and 6.0 mg of technical DDT in acetone were added. The sixth tube was left to serve as a blank.

(2) Distilled acetone (10 ml) was added to each of the six test-tubes and allowed to stand for five minutes with occasional shaking. The solvent extracts were then transferred to six 100-ml conical flasks.

(3) Acetone (approximately 10 ml) was added again to the test-tubes and the mixture was stirred with a glass rod for one minute. The extracts were again transferred to the respective conical flasks and the extraction procedure was repeated for the third and fourth time.

(4) The total acetone extract (about 50 ml in each case) was evaporated on a water-bath and the residue was dried for half an hour at 70°C.

(5) To each of the cooled flasks, 5 ml of a mixture of equal volumes of fuming nitric acid and concentrated sulfuric acid were added. The flasks were kept for half an hour on a boiling water-bath for nitration.

(6) The flasks were then cooled and 10 ml of ice-cooled distilled water added to each of them. The mixture was transferred to 50-ml glass-stoppered bottles with two additional washings of 10 ml each.

(7) To each of the bottles, thiophene-free redistilled benzene (25 ml) was added and the bottles were shaken for one minute.

(8) The acid layer was removed and 10 ml of a 5% sodium hydroxide solution were added to each of the bottles. The contents were shaken and the benzene layer was allowed to separate. The coloured aqueous layer was discarded and this alkali treatment was repeated once again. Dry sodium sulfate (5 g) was then added to each of the bottles containing benzene extract.

(9) Blank benzene extract (0.5 ml) was mixed with benzene (1.5 ml) and a clear colourless solution of 1.858 N sodium methylate (4 ml). Using a Klett-Summerson photoelectric colorimeter and a No. 54 filter, blank was set at zero. Against this blank, readings were taken for different concentrations of technical DDT in the remaining five extracts. Values obtained were plotted as a graph, which served to deduce DDT concentration in mg/sq.ft.

After the mud, glass and plywood panels had been sprayed with DDT suspension, they were allowed to dry for half an hour. In order to determine the surface concentration of DDT at this stage, two

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[1] 1 inch = 2.54 cm.

[2] Barlow, F. (1953) *A method for removing insecticide residues of wettable powders from sprayed surfaces* (unpublished working document WHO/Insecticides/22).

TABLE 1

SORPTION OF AQUEOUS SUSPENSION OF 75 % DDT WATER-DISPERSIBLE POWDER ON PANELS MADE OF INDIAN SOILS[a]

Panel surface	Surface DDT determined in mg/sq. ft[b] at different intervals						
	Dosage sprayed	0.5 hour	1 day	3 days	7 days	2 weeks	4 weeks
Black soil A	118.5	95.4 (80.5 %)[d]	91.8 (77.4 %)	97.2 (82.0 %)	[c]	99.0 (83.5 %)	[c]
Alluvial soil C	118.5	104.4 (88.1 %)	77.4 (65.3 %)	66.6 (56.2 %)	56.5 (47.6 %)	[c]	45.0 (37.9 %)
Lateritic-alluvial soil D	118.5	63.0 (53.1 %)	55.8 (47.0 %)	41.4 (34.9 %)	27.0 (22.7 %)	25.2 (21.2 %)	10.8 (9.1 %)
Dull-red soil E	118.5	75.6 (63.7 %)	54.0 (45.5 %)	37.8 (31.9 %)	24.1 (20.3 %)	43.2 (28.8 %)	14.4 (12.1 %)

[a] Maximum temperature 85°-90° F (29.5°-32° C); relative humidity 60 %-80 %.

[b] 100 mg/sq.ft = 1 g/m².

[c] Not determined.

[d] Figures in brackets indicate dosage as percentage of the dose initially sprayed.

panels were selected from each type under test. Half of each panel was covered with Sellotape 2 inches in width. Using an ordinary india-rubber pencil eraser, enough pressure was applied to ensure complete and even adhesion of the tape to the surface without crumbling the surface of the mud panels. The Sellotape was then gently removed, care being taken that the mud surface was not unduly scraped away with it. From the Sellotape removed from two similar panels, four 2 inch × 2 inch samples were cut and analysed separately for their DDT content in the manner described in paragraphs (1) to (9) above. The average of four such estimations was considered to be the dosage of DDT present at the surface as determined by this method. In this way, the concentration of DDT at various surfaces was determined within half an hour of spraying in every case. The mud panels were stored in the laboratory, and the daily maximum temperature and relative humidity were recorded throughout the period of test. The mud panels were tested at regular intervals for concentrations of DDT at the surface, and the data are recorded in Tables 1, 2 and 3.

Chemical decomposition of DDT by Indian soils

A 5.0-g sample of each of four Indian soils (A, C, D and E) was mixed with 200 mg of DDT in a 1% aqueous suspension prepared from the standard 75% DDT water-dispersible powder. At monthly intervals, a set of these samples (in triplicate) was extracted with acetone and analysed for their DDT content by the hydrolysable chlorine method. It was found that even after six months, the entire dose of DDT could be recovered in every case with no evidence of any chemical decomposition.

75% DDT water-dispersible powder

A standard sample of 75% DDT water-dispersible powder (of United States' origin) was selected at random and analysed for its DDT content, suspensibility, and other characteristics, according to the specifications of the WHO Expert Committee on Insecticides (1956). The particle-size distribution of the DDT contained in this powder was determined by the sedimentation method as outlined by Bami & Cheema (1957), Bami, Cheema & Dhatt (1958) and Bami & Dhatt (1959). The relevant data are as follows:

DDT content	74.4 %
Suspensibility	65.1 %
Suspensibility after accelerated tropical storage test	62.5 %
Particle-size distribution of DDT:	
below 5 μ	25.0 %
„ 10 μ	63.0 %
„ 20 μ	90.0 %
„ *u* μ	10.0 %
„ 74 μ	100.0 %

TABLE 2

SORPTION OF AQUEOUS SUSPENSION OF 75% DDT WATER-DISPERSIBLE POWDER ON PANELS MADE OF INDIAN SOILS AND ON PLYWOOD AND GLASS PANELS[a]

Panel surface	Surface DDT determined in mg/sq.ft[b] at different intervals						
	Dosage sprayed	0.5 hour	1 day	7 days	2 weeks	4 weeks	6 weeks
Black soil A	98.3	68.4 (69.5 %)[c]	55.8 (56.7 %)	54.0 (54.9 %)	45.0 (45.7 %)	43.2 (43.9 %)	34.2 (34.7 %)
Alluvial soil C	98.3	[d]	57.6 (58.6 %)	45.0 (45.7 %)	27.7 (28.1 %)	25.2 (25.6 %)	3.6 (3.6 %)
Lateritic-alluvial soil D	98.3	63.0 (63.0 %)	46.8 (47.6 %)	39.6 (40.2 %)	18.0 (18.3 %)	21.6 (21.9 %)	10.8 (10.8 %)
Dull-red soil E	98.3	[d]	45.0 (45.7 %)	21.6 (21.9 %)	7.2 (7.3 %)	12.6 (12.8 %)	0.2 (0.2 %)
Plywood	98.3	72.0 (73.2 %)	59.4 (60.4 %)	61.2 (62.2 %)	72.0 (73.2 %)	45.0 (45.7 %)	48.4 (49.2 %)
Glass	98.3	97.2 (98.8 %)	95.4 (96.8 %)	[d]	[d]	[d]	[d]

[a] Maximum temperature 80°-90° F (26.5-32° C); relative humidity 60%-80%.

[b] 100 mg/sq.ft = 1 g/m².

[c] Figures in brackets indicate dosage as percentage of the dose initially sprayed.

[d] Not determined.

Chemical composition and physical characteristics of soils

The chemical analysis of Indian soils A, C, D and E included an estimation of the percentage of soluble salts, organic matter, silica, total iron, total alumina, free iron and free alumina (Table 4). Among the physical properties of these soils, the nature, colour, plasticity, pH and percentage clay and silt content were determined. Using Keen-Raczkowski boxes (1921), the moisture-holding capacity, percentage pore space and volume expansion per 100 g of the soil were also determined. An approximate determination of total exchangeable ions was done according to Schofield's method

TABLE 3

SORPTION OF AQUEOUS SUSPENSION OF 75% DDT WATER-DISPERSIBLE POWDER ON PANELS MADE OF INDIAN AND AFRICAN SOILS AND A SYNTHETIC SOIL[a]

Panel surface	Surface DDT determined in mg/sq.ft[a] at different intervals								
	Dosage sprayed	0.5 hour	1 day	3 days	7 days	2 weeks	4 weeks	6 weeks	8 weeks
Dark-brown soil B	99.5	100.4	81.0	73.8	50.4	50.4	50.4	27.0	16.0
Alluvial soil C	99.5	97.2	92.5	72.0	55.8	45.0	18.0	7.2	8.0
Red soil F	99.5	64.8	64.8	50.4	43.3	28.8	18.0	13.8	13.5
Synthetic soil G	99.5	100.0	90.0	54.0	43.0	37.5	27.2	10.8	8.0

[a] Maximum temperature 65°-75° F (18.5°-24° C); relative humidity 50 %-65 %.

[b] 100 mg/sq.ft = 1 g/m².

TABLE 4

CHEMICAL ANALYSIS OF INDIAN SOILS

Soil	Soluble salts (%)	Organic matter (%)	Silica (%)	Total Fe_2O_3 (%)	Total Al_2O_3 (%)	Free Fe_2O_3 (%)	Free Al_2O_3 (%)
Black soil A	0.042	0.639	63.8	11.25	10.75	5.25	0.60
Alluvial soil C	0.147	1.345	79.1	6.87	6.50	2.62	0.35
Lateritic-alluvial soil D	0.168	0.974	93.6	2.60	2.15	1.06	1.37
Dull-red soil E	0.028	0.369	81.5	7.62	7.75	4.00	0.57

TABLE 5

PHYSICAL CHARACTERISTICS OF INDIAN AND AFRICAN SOILS AND A SYNTHETIC SOIL

Soil	Colour	pH	Clay (%)	Silt and clay (%)	Total exchangeable ions (m.e. %)	Pore space [a] (%)	Moisture-holding capacity [a]	Volume expansion per 100 g of soil [a]	Plasticity
Black soil A	Black	7.9	43.8	69.8	37.6	55.5	63.4	0.356	Highly plastic
Dark-brown soil B	Dark brown	7.8	46.4	63.1	57.6	55.6	57.2	0.13	„
Alluvial soil C	Light grey	7.8	21.8	53.8	59.2	52.1	49.3	0.0017	Plastic
Lateritic-alluvial soil D	Brownish grey	6.3	10.0	26.0	4.3	35.4	38.9	0.067	Moderately plastic
Dull-red soil E	Dull red	6.7	25.8	34.8	3.6	38.4	28.4	0.033	Poorly plastic
Red soil F	Red	6.3	39.4	41.8	3.9	47.3	41.1	0.008	„
Synthetic soil G [b]	White	8.3	58.6	74.1	95.2	27.1	41.1	0.0	Plastic

[a] These determinations were done with Keen-Raczkowski boxes.

[b] Synthetic soil sample consisted of 65 % kaolin, 10 % bentonite and 25 % quartz (below 1 mm particle size), as prepared by Dr J. Treboux, Geigy Ltd, Basle, Switzerland.

(1939). The above data have been presented in Table 5. Some physical properties of the panels made from Indian and African soils and the synthetic soil, such as percentage porosity (based on specific gravity and apparent density) and uptake of carbon tetrachloride were also determined (Table 6).

TABLE 6

PHYSICAL CHARACTERISTICS OF PANELS MADE FROM INDIAN AND AFRICAN SOILS AND A SYNTHETIC SOIL

Soil	Apparent density	Specific gravity	Porosity (%)	CCl_4 sorption (%)
Black soil A	2.02	2.47	18.3	4.9
Dark-brown soil B	1.95	2.47	21.2	9.5
Alluvial soil C	1.822	2.55	28.6	5.2
Lateritic-alluvial soil D	1.98	2.68	26.2	1.5
Dull-red soil E	1.94	2.59	25.1	6.6
Red soil F	2.28	2.59	12.0	8.0
Synthetic soil G	1.76	2.56	31.1	11.4

FINDINGS

Comparative sorption capacities of different soils and plywood

Among the methods for the removal of insecticide particles from the surface, Barlow's method[1] using Sellotape, as modified in this paper, was found to be quite efficient in the case of smooth surfaces. For

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[1] Barlow, F. (1953) *A method for removing insecticide residues of wettable powders from sprayed surfaces* (unpublished working document WHO/Insecticides/22).

instance, from non-absorbent glass surfaces, 97%-99% of the applied dosage could be recovered by this technique (Table 2). Evidently, the Sellotape method, when properly applied, could offer a comparative evaluation of the sorption capacity of different soils under given conditions. However, such results should be interpreted with caution because, under field conditions, rural mud houses would normally have irregular, corrugated and more porous surfaces.

Black soil A was the least sorptive as regards DDT particles. Nearly one-third of the sprayed dosage was still present at the surface six weeks after the spraying. After some initial sorption (within half an hour), the subsequent loss of surface DDT was very gradual. Alluvial soil C showed a nearly identical initial loss of DDT (20%-30%), but subsequently the rate of sorption was more accelerated. Approximately one-third of the initial dosage was left at the surface of soil C after four weeks, while within six weeks nearly complete sorption seemed to have taken place. Lateritic-alluvial soil D and dull-red soil E displayed a higher loss of DDT (nearly 40%) within half an hour of spraying, and even the subsequent rate of loss in the case of these two soils was more rapid than in that of soil C. For instance, within four weeks only 10%-20% of the initial dosage was left at the surface of soils D and E. Both these soils were highly sorptive, although there was some indication that soil E was slightly more so.

Comparative evaluation of the sorption capacities of African soils B and F, synthetic soil G and Indian soil C (Table 3) indicated that only in the case of red soil F was there an initial loss of nearly 35% of the applied dosage. Subsequently, whereas 50% of the original dose remained on the surface of dark-brown soil B for about four weeks, this concentration at the surface of red soil F was only maintained for about a week. Synthetic soil G showed a limited loss during the first three days, but ultimately it has been classed as highly sorptive when compared to dark-brown soil B and black soil A. The findings for alluvial soil C, which indicated that 50% of the sprayed dosage was still at the surface after a week, were similar to the results obtained previously (Tables 1 and 2).

From the above data it was concluded that in black soils consisting of montmorillonitic minerals with a high organic content (soils A and B) the loss of DDT particles would be minimal. The surfaces of these soils were smooth, hard and impervious, and the sprayed DDT was visible for a considerable time. On the other hand, alluvial soil C and lateritic-alluvial soil D presented a softer and less impervious surface with a consequently higher loss of DDT through sorption. These soils could be considered as moderately sorptive. Dull-red soil E and red soil F offered relatively coarse and more porous surfaces owing to their composition and lack of plasticity, and DDT particles were visible for only a short time; these soils have therefore been classed as highly sorptive. As a rule, highly sorptive soils displayed a higher initial loss of insecticide as well as a rapid sorption of DDT particles with the passage of time. On the other hand, soils with low sorptive capacity did not sorb the DDT particles efficiently at the outset and even the subsequent rate of disappearance was slower (Tables 1, 2 and 3). Although there was some initial sorption of DDT on the coarse plywood surface, the subsequent loss was very gradual. In fact, nearly 50% of the sprayed dosage was at the surface six weeks after spraying, and in this respect plywood was even better than the least sorptive soil A (Table 2).

During the first studies (Tables 1 and 2), which were carried out in the hot rainy season, the maximum room temperature varied between 85° and 90°F (29.5°-32°C) and the relative humidity between 60% and 80%. However, in subsequent studies (Table 3), which took place in early spring, the maximum temperature varied between 65° and 70°F (18.5°-21°C) and the relative humidity between 50% and 65%. The results only broadly indicated that the loss of surface DDT with time was comparatively less at lower temperatures and lower relative humidities. In both cases, however, only 10%-15% of the original dosage remained on certain mud surfaces after 6-8 weeks. Similar studies with the soils of several Eastern Mediterranean and African countries have also indicated that within 7-10 weeks only one-tenth of the sprayed dosage of DDT remained on the surface, while there was extensive initial loss of the insecticides in several instances (Alessandrini, Mosna & Placucci, 1955; Langbridge;[1] Bruce-Chwatt;[2] Barlow & Hadaway, 1958).

Physical characteristics of 75% DDT water-dispersible powder in relation to sorption

The particle-size distribution of DDT in standard 75% DDT water-dispersible powder indicated that

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[1] Langbridge, D. M. (1956) *The persistence of deposits of DDT, BHC and dieldrin on mud surfaces in Western Sokoto* (unpublished working document WHO/Mal/155).

[2] Bruce-Chwatt, L. J. (1955) *First annual report of the Western Sokoto Pilot Project* (mimeographed document).

100% of the DDT had a particle size of less than 40 μ, while 90% and 63% of the insecticide had particle sizes of less than 20 μ and 10 μ respectively. The results were similar to those obtained with currently produced commercial DDT water-dispersible powders (Bami & Cheema, 1957; Bami et al., 1958; Bami & Dhatt, 1959). Considering the inverse relationship between the tendency for loss through sorption and the particle size of the DDT sprayed (Hadaway & Barlow, 1952, 1955; Barlow & Hadaway, 1958), the formulation used would be highly prone to sorption. This was evident in the present studies from the accelerated loss of DDT particles on the various mud surfaces as a whole (Tables 1, 2 and 3).

Relationship between chemical composition and sorption capacity of soils

From sorption capacity data (Tables 1, 2 and 3) and the results of chemical analysis of Indian soils (Table 4), it was apparent that chemical composition offered no definite correlation with the degree of sorption of DDT particles. Studies on chemical composition of different types of mud from several other countries have also thrown little light on the component or components actually responsible for sorption (Bertagna, 1959). Apparently sorption was not limited to any type of chemical structure. Similarly, there was no chemical decomposition of DDT when sorbed on Indian soils for a period of over six months, and as such the role of iron or any other component in the decomposition of DDT also did not come into the picture (Riemschneider, 1950; Alessandrini, Mosna & Placucci, 1955; Alessandrini & Placucci, 1955; Barlow & Hadaway, 1958).

Relationship between physical characteristics and sorption capacity of different soils

Considering that sorption on mud surfaces is primarily a physical phenomenon, its measurement has been attempted by employing several physical characteristics (Bertagna, 1959). In Table 5, Indian and African soils and the synthetic soil have been arranged in order of their increasing capacity to inactive DDT particles through sorption, along with their physical characteristics. Contrary to some previous observations (Alessandrini, Mosna & Placucci, 1955; Alessandrini & Placucci, 1955; Paulini [1]), it has now been observed that, in these soils, the higher percentage of total exchangeable ions and the clay and silt content, coupled with good plasticity and moisture-holding capacity, ultimately resulted in a smaller loss of DDT particles through sorption. These results could perhaps be more adequately explained if the nature of the mud surface involved in the process of sorption were taken into primary consideration. For instance, montmonrillonitic soils with the above characteristics offered a hard, smooth and impervious surface through which the DDT particles had little chance to penetrate initially or on which they could later be quickly sorbed. In the case of muds with coarser particles and limited plasticity, the surface was relatively coarser and more porous. Not only were the DDT particles rapidly lost at the outset, but their subsequent disappearance was also much more accelerated.

Dark-coloured soils were the least sorptive, grey ones were medium sorptive and red-coloured soils the most sorptive. This general relationship between colour and sorption capacity supported previous observations.[1] The percentage porosity of mud panels has been considered inversely proportional to their capacity to inactivate DDT (Alessandrini & Placucci, 1955; Sharma et al., 1958). As the porosity values of the panels now studied (Table 6) were close to the minimum theoretical limit, perhaps they should be classed as highly sorptive. However, as all these soils had been artificially compacted in order to get smooth surfaces, this physical character could not be relied upon to give a practical correlation.

Considering the wide differences in chemical composition and physical characteristics of soils in nature, it was hoped that a single determination based on the uptake of a non-polar solvent such as carbon tetrachloride might give an indication of the capacity of a soil to sorb DDT (Bertagna, 1959). From the analysis of the data now presented (Table 6), as well as the findings of other workers (Bruce-Chwatt;[2] Hadaway & Barlow, 1955; Paulini [1]), it appeared doubtful if the carbon tetrachloride method could be employed successfully. Another objection to this method was that since the DDT molecule is larger than either that of water or that of carbon tetrachloride it might experience stereochemical hindrance to lodging in the layer lattice space of an expanding type of clay such as montmorillonite (Kulkarni, Charpurey & Biswas,

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[1] Paulini, E. (1958) *Some characteristics of the mud used for building purposes in Brazil* (WHO Expert Committee on Specifications and Chemistry of Pesticides, working paper No. 23 Add. 7).

[2] Bruce-Chwatt, L. J. (1955) *First annual report on the Western Sokoto Pilot Project* (mimeographed document).

1959). Even in the absence of such hindrance, water and carbon tetrachloride could easily migrate into the mud surface in the vapour phase, while this would be an extremely slow process for DDT, which is a solid with very low vapour pressure. Such a phenomenon could not of course occur in the case of non-expanding clays such as kaolinite. However, adsorption on the outer surface of the above types of clay particle could not be ruled out, especially when sorption was primarily concerned with the surface of the mud and the clay particles in the immediate vicinity.

It is accepted that sorption of non-volatile residual insecticide particles on porous mud surfaces did lead to a loss of surface insecticide and to a consequent fall in biological efficacy. The complex nature of the phenomenon of sorption and the multitude of influencing factors have, however, prevented the accurate determination of the sorption capacity of different mud surfaces or its correlation with any physicochemical property. All the same, successful malaria control with a single application of DDT has been achieved for 2-6 months in several tropical countries where rural mud houses were the normal dwellings (Macdonald, 1958; WHO Expert Committee on Insecticides, 1958, 1959). How far the phenomenon of sorption has ultimately undermined the efficacy of insecticides such as DDT for anopheline control was therefore hard to determine directly (Bertagna, 1959). However, application of an increased dosage of insecticide, availability of more impervious types of surface and spraying under conditions of lower temperature and lower humidity are some of the main factors which would counteract the loss of insecticide through sorption on porous mud surfaces.

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RÉSUMÉ

La sorption des insecticides par les surfaces a été étudiée sur quatre sols typiques de l'Inde, deux sols d'Afrique et un sol synthétique. Les caractères physico-chimiques de ces sols ont été précisés en fonction de leurs propriétés sorbantes. Un seul type de préparation insecticide a été utilisé — de la poudre mouillable de DDT à 75 % — afin d'éliminer la variable que représentent les dimensions diverses des particules.

D'après l'analyse, le DDT ne paraît subir aucune décomposition chimique dans les sols de l'Inde. A juger d'après la méthode de prélèvement des dépôts de DDT au moyen du Sellotape, il semble que le sol noir de l'Inde est le moins sorbant. Six semaines après la pulvérisation, on retrouvait 1/3 du DDT pulvérisé. Il en fut de même, au début, du sol alluvionnaire, mais par la suite, le taux de sorption s'accéléra et après 6 semaines, tout le DDT avait disparu de la surface. Dans le sol latéritique-alluvionnaire et le sol rouge sombre, la perte en DDT fut de 40 % dès la première demi-heure, et après 4 semaines, il ne restait que 10-20 % du DDT initial. C'est donc dans le sol noir, à surface dure, lisse et peu perméable, composé de montmorillonite à teneur organique élevée que la sorption fut la plus faible. La sorption est moins forte dans les sols foncés que dans les sols rouges. On peut admettre d'une façon générale que la sorption est d'autant plus faible que sont plus élevées la proportion des ions interchangeables, la teneur en argile et en limon, la plasticité et la faculté de retenir l'humidité. Cependant ni la composition chimique ni les propriétés physiques telles que le pH, la porosité, la faculté d'absorber le tétrachlorure de carbone ne fournissent des critères satisfaisants du pouvoir de sorption d'un sol.

La complexité du phénomène de sorption et le nombre des facteurs qui le déterminent rendent difficile une estimation expérimentale précise. Il n'est guère plus aisé d'évaluer dans quelle mesure ce phénomène intervient pour diminuer l'efficacité des pulvérisations d'insecticides.

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