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ILLINOIS NATURAL HISTORY SURVEY
HARLOW B. MILLS, *Chief*

Characteristics of Residual Insecticides *Toxic to the House Fly*

WILLIS N. BRUCE

Printed by Authority of the
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Exposure of flies to surfaces treated with insecticides is quickly accomplished with the cages shown here. The cages are inverted and stacked, with a treated panel on each cage; then the sliding metal panel in each cage is withdrawn to allow flies in the cage to have direct contact with the treated panel.

Characteristics of RESIDUAL INSECTICIDES *Toxic to the House Fly*

WILLIS N. BRUCE

FOR centuries the house fly, *Musca domestica* Linnaeus, has been an annoying, disease-carrying menace to man and other animals. Spillman & Haushalter (1887) demonstrated the house fly to be a possible vector of *Bacillus tuberculosis*. Nuttal (1899) showed that *Spirillum cholerae* and staphylococci could be transmitted by house flies. Esten & Mason (1908) determined by counts that on an average a house fly carried 1,250,000 pathogenic organisms on its exterior surface. In a publication upon the typhoid or house fly, Felt (1909) estimated the indirect losses to our vital assets incurred by typhoid at 350 million dollars annually. Also, he suggested that house flies can spread plague, trachoma, and septicemic diseases. Howard (1909) wrote that the annual cost of screening against house flies in the United States is over 10 million dollars. Later, Herms (1911) stated that the public pays over 2 million dollars for fly traps, sticky fly paper, poisons, and sprays each year. Pipkin (1942) proved that *Musca domestica* can carry *Endamoeba histolytica* on its external surface and in its digestive system long enough to effect transmission. The evidence presented above, along with the list in Metcalf & Flint (1939) of 20 disease pathogens carried by flies, is more than sufficient reason to brand the house fly as potentially the animal most dangerous to human beings within the borders of the United States.

Although the house fly is important as an annoyance and as a vector of disease, it causes no direct injury to man or other animals. It is not equipped to bite or sting or in itself to cause disease by any of its life stages.

Pathogenic organisms may be carried on the surface of the fly's body, adhering to the numerous hairs, sticky pulvilli, wings, and mouthparts, or they may be carried in the alimentary canal to be spread by defecation or regurgitation. The filthy feeding and breeding habits of flies make inevitable the mechanical transmission of disease by these insects.

In Illinois, the house fly usually winters in the pupal or larval stage; a few adults live through the winter in protected places. The female fly deposits 2 to 21 batches of 100 to 150 eggs in manure or any other suitable decomposing organic matter. The whole life cycle through egg, larva, pupa to adult may be completed in 6 to 20 days. In Illinois there are usually 10 to 12 generations of house flies each summer. These facts account for the enormous build-up of flies that usually occurs during August or September in the temperate zone.

INSECTICIDES USED

The five chemicals described below are the principal insecticides used in the study reported here.

DDT (designation derived from the generic name dichloro-diphenyl-trichloroethane) was first synthesized by Zeidler (1874). Chemically this material is known as 2,2′ bis (parachlorophenyl) 1,1,1-trichloroethane. The technical grade that was used in the experiments reported here consisted of a mixture of para, para′; para, ortho; and ortho, ortho′ isomers. Pure DDT may be described as an odorless, stable, crystalline solid that is soluble in most organic solvents and insoluble in water. The first United States patent on it was granted to Paul Müller in 1943 for the Geigy Company Inc., of New York, N. Y. Although Wiesmann (1943) first described its usefulness as a residual insecticide for the control of house flies, Annand (1944) suggests that it was tested by Müller on house flies in 1940.

Rhothane D-3, or 2,2′ bis (parachlorophenyl) 1,1-dichloroethane, a material closely related to DDT, was found by Müller and others to be of less promise as an insecticide than DDT. However, the Rohm & Haas Company was convinced it possessed some valuable insecticidal properties and consequently obtained a patent for its manufacture. *Rhothane D-3* (also known as TDE, DDD, and D3) is soluble in the same solvents as DDT; it has a higher vapor pressure and a lower melting point than DDT.

Chlordan or 1,2,4,5,6,7,8,8-octachloro-4,7-methano-3a,4,7,7a-tetrahydroindane was first synthesized by Dr. Julius Hyman and first discussed as an insecticide by Kearns, Ingle, & Metcalf (1945), who showed that when tested in a Peet-Grady chamber chlordan was three to four times as toxic to flies as DDT. In the highly refined state chlordan is a light yellow, viscous, nearly odorless liquid that is soluble in aliphatic, aromatic, and chlorinated hydrocarbons. It is infinitely soluble in kerosene, deobase, and no. 9 oil. Such solubility is not true of DDT, *Rhothane D-3,* or hexachlorocyclohexane, mentioned below. Chlordan has a specific gravity of 1.61 and weighs about 13.5 pounds per gallon.

The chemical 1,2,3,4,5,6-hexachlorocyclohexane was described by Slade (1945) as an insecticide with outstanding properties. According to Slade, Michael Faraday in 1825 first described the synthesis of hexachlorocyclohexane (referred to by Slade as Gammexane or 666) by the reaction of chlorine with benzene in the presence of sunlight. In 1943, Slade found the gamma isomer to be the toxic principle in the crude hexachlorocyclohexane. Usually the technical material has 10 to 12 per cent by weight of the gamma isomer. Pure gamma hexachlorocyclohexane has a faint musty odor, is a colorless crystalline material melting at 112.5 degrees C., and is soluble in most organic solvents.

Toxaphene, a technical chlorinated camphene with an approximate empirical formula $C_{10}H_{10}Cl_8$, is a soft, waxy, light yellow material that melts at 65 to 90 degrees C. and has a density of 1.6. It is readily soluble in most organic solvents and insoluble in water. *Toxaphene,* formerly known as Hercules *Synthetic 3956,* is produced by the Hercules Powder Company of Wilmington, Delaware. Stearns (1947) indicates that *Toxaphene* has some promise as a household insecticide.

In addition to the insecticides described above are several on which preliminary studies were made.

PURPOSE OF STUDY

The purpose of this study was to obtain pertinent information about the residual insecticidal value of chlorinated hydrocarbons applied to various surfaces that had been exposed to different field conditions. The investigations conducted in 1943 at Orlando, Florida, by Lindquist *et al.* (1944) showed DDT to possess a high degree of residual toxicity to the house fly. They also showed a difference in toxicity of DDT when applied to painted and to unpainted wood. The need for the study reported here became apparent to the author when certain of his field applications of residual toxicants failed to effect adequate insect control. The results of this study, it is hoped, may serve as a guide to persons who are seeking to control insects through applications of residual insecticides and who are concerned with residues on plants.

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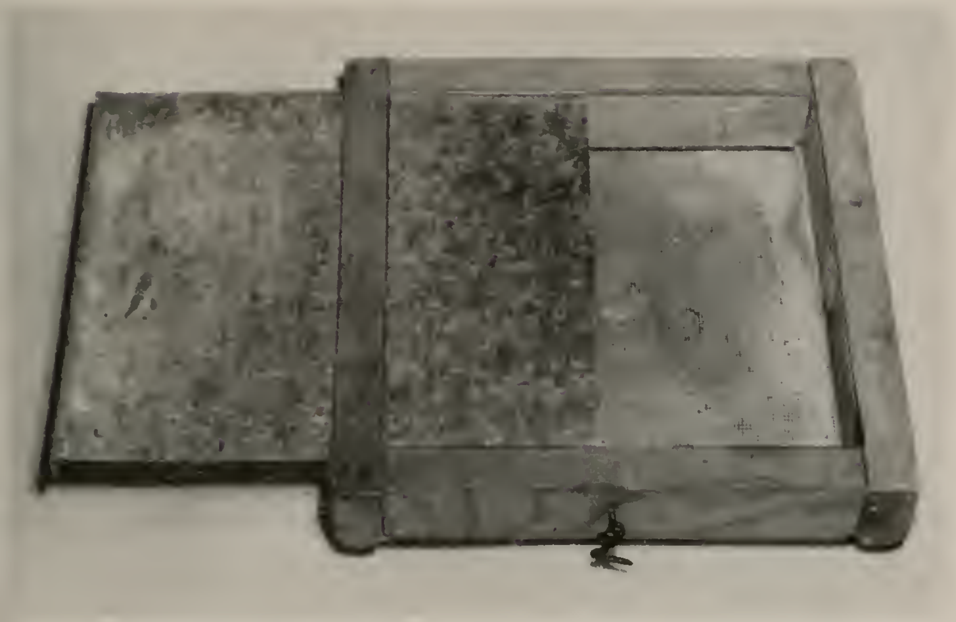

Fig. 1.—Exposure cage used in the experiments. As shown here, the cage is inverted, and the sliding panel is partly withdrawn.

Entomologist of the Illinois Natural History Survey, for constructive criticism of the manuscript.

TESTING PROCEDURE

A versatile flat exposure cage, fig. 1, was designed by the writer for use in the field, fig. 2, and for laboratory tests described below. The method of exposing cut film that photographers employ suggested its design. Made of a three-fourths inch white pine frame 8½ inches square by 1¾ inches deep, the cage is covered on one side by 16-mesh screen wire and fitted on the other side with a sliding panel of manila paper or sheet metal. It has an interior space of about 75 cubic inches. More than 300 cages of this design were required for the tests.

All house flies used in the tests were reared according to the accepted Peet-Grady method (Anonymous 1946). About 120 pupae (2.2–2.4 grams) were placed in each exposure cage via the sliding panel, fig. 1. Flies were supplied with food, a mixture of milk and water, by means of a small shell vial fitted with a piece of cheesecloth. A shell vial was inverted upon the screen top of each cage, permitting the adult flies to feed by contact, fig. 3. In each test of an insecticide, adult flies were exposed to a treated surface on their second day of oviposition, and on the following day the mortality counts were made.

The exposure process was simple. First the cage was placed on a clean, flat board and then the sliding panel was removed momentarily to allow the empty pupal cases and other debris to fall out. With the panel replaced, the cage was moved and secured to the treated surface. The sliding panel was then removed to allow the flies to have direct contact with the treated surface for the desired exposure period. Obviously because of the house flies' habit of seeking the ceiling as a resting place when illumination is reduced, preliminary tests under average laboratory lighting indicated that best replication was obtained by inverting the cages (screen side down) during the exposure, frontispiece. However, in bright light and at temperatures between 80 and 90 degrees F. there was little difference between results from the upright and the inverted position during exposure.

The treatment of the selected surfaces was simple and yet apparently reliable. In the early tests, the quantity of prepared insecticide, containing 1 per cent of the residual toxicant by weight, was measured with a pipette and spread evenly over the surface with the aid of a small brush, fig. 4. Additional water or solvent was used to wash the residue from the brush onto the surface.

In later tests the deposits were obtained by means of a 6-foot stainless steel settling spray tower, fig. 5. A Tattersfiel spray apparatus was fitted with smalle openings in order to reduce the particl size to 2–50 microns range. Even distr bution and good replication (less than per cent variation among deposits) we obtained with this apparatus, fig. 4.

The following are some of the commo formulations of the concentrates used i making 1 per cent sprays. Formulatior other than these are indicated in the di cussion of individual tests.

Fig. 2.—Practical method (not used in the experiments) of testing the toxicity of wall su faces treated with residual insecticides. The exposure cage is hooked to the treated wall, an the metal panel is withdrawn to give flies in the cage direct contact with the wall for a give period of time.

A. Emulsions:
 1. 62% chlordan + 5% *Atlox 1045-A* + 33% no. 9 oil by volume.
 2. 25% DDT, *Toxaphene,* gamma isomer of hexachlorocyclohexane or *Rhothane D-3* + 70% *PD 544-C* (solvent known also as *Sovacide 544-C*) + 2% emulsifier *B-1956* and 3% *Triton X-155* by weight.

B. Water-wettable powders: 50% by weight of toxicant + 2% wetting agent *(Triton X-100)* + 48% by weight of *Cherokee* clay.

C. Oil solutions: 1.0% by weight of toxicant per volume of no. 9 oil.

After each test the cages were decontaminated in a mild KOH solution, washed thoroughly in soapy water, and allowed to dry in the sun for about 2 days. The manila sliding panels were discarded after being used once. With this procedure no contamination difficulties were met.

Fig. 3.—Method of feeding flies in exposure cage. A shell vial filled with milk and stoppered with one layer of cheesecloth is inverted and placed on the screen top of the exposure cage.

Experiment 1: ***Exposure Time for Knockdown and Mortality.***—In an experiment designed to reveal the exposure times necessary to give comparable mortalities for the five principal materials tested, as well as to indicate the relative initial surface toxicity and speed of knockdown of flies, lots of 100 to 120 flies each were exposed to deposits of 50 mg. per square foot (538 mg. per square meter) of glass for each of three replicates.

Table 1 clearly reveals the correlation between the length of exposure and the percentage of mortality and knockdown resulting from each of the five principal chlorinated hydrocarbons used. The surface toxicity as indicated by the exposure needed to effect mortality made DDT and gamma hexachlorocyclohexane appear to be the most toxic, with chlordan, *Rhothane D-3,* and *Toxaphene* following in order.

Monro, Beaulieu, & Delisle (1947) reported no difference in mortality among lots of flies exposed for 10, 20, 30, 40, and 50 minutes to DDT deposits. Their reported results are at variance with data obtained from the experiment described here. Table 1 exhibits clearly the relationship of exposure time to mortality. Perhaps Monro and his co-workers used surfaces on which only a small amount of DDT was available to the flies, and in the first few minutes of exposure the flies rapidly eroded or removed the DDT available. In speed of knockdown, gamma hexachlorocyclohexane was the material ranking first; it was followed in order by DDT, *Rhothane D-3,* chlordan, and *Toxaphene.* Fifty per cent knockdown of house flies when exposed to *Toxaphene* was reported by Block (1948*b*) to require in some instances only 12 minutes, a period that represents a much faster knockdown rate than the 4 to 6 hours for complete knockdown reported by Beacher & Parker (1948). Data in table 1 indicate that about 167 minutes of exposure to *Toxaphene* is needed to give 50 per cent knockdown and 253 minutes for 99 per cent knockdown. It was noticed in the experiment reported here that there was no correlation between time required for knockdown and time required for kill. *Rhothane D-3,* which possessed much less surface toxicity than chlordan, actually gave quicker knockdown. Surface toxicity depends upon the availability of the insecticide as well as the actual toxicity.

Fig. 4.—Three glass panels similar to those used in experiment. Left, panel with insecticide applied in settling spray tower; center, panel with insecticide being applied by means of brush and pipette; right, panel with insecticide already applied by means of brush and pipette.

Fig. 5.—Settling spray tower. Insecticide is introduced by a pipette into the atomizer at top ettling spray tower. A panel is placed on a sliding shelf in the bottom of tower. At 12.5 nds air pressure, and after 3 minutes are allowed for settling, the dosage per square foot of el is approximately 32.4 per cent of the quantity placed in the atomizer.

Table 1.—Effect of exposure time on mortality of house flies and time required various knockdowns of flies by five chlorinated hydrocarbons when applied as suspensions glass.

Water-Wettable Insecticide	Mg. Toxicant per Square Foot	Per Cent Mortality 24 Hours After Exposure Time of								Minutes Required for Knockdown o		
		5″*	15″	56″	3′45″	7.5′†	15′	60′	240′	10%	50%	90%
50% DDT	50 mg.	5.2	57.2	81.2	96.3	99.3	97.8	100.0	100.0	20	32	45
		12.4	64.5	75.4	90.1	100.0	100.0	100.0	100.0	29	35	46
		8.0	42.8	84.7	87.6	97.2	100.0	100.0	100.0	22	34	45
Mean.	. . . .	8.5	54.8	80.4	91.3	98.8	99.3	100.0	100.0	24	34	45
50% Chlordan	50 mg.	—	2.8	11.1	47.5	74.7	96.5	100.0	100.0	61	80	100
		—	5.0	16.4	53.9	82.6	98.9	99.2	100.0	64	84	110
		—	3.2	12.1	40.7	66.0	94.7	100.0	100.0	68	85	113
Mean.	. . . .	—	3.7	13.2	47.4	74.4	96.7	99.7	100.0	64	83	108
5.2% Gamma hexachloro-cyclohexane	50 mg.	—	12.6	36.9	79.7	67.6	84.4	100.0	100.0	13	17	33
		—	7.0	45.1	52.7	91.4	100.0	100.0	100.0	17	20	38
		—	19.8	35.8	67.3	83.7	100.0	100.0	100.0	15	29	45
Mean.	. . . .	—	13.1	39.3	66.6	80.9	94.8	100.0	100.0	15	22	39
25% *Toxaphene*	50 mg.	—	—	9.7	16.6	—	31.8	69.7	98.2	100	165	195
		—	—	3.8	12.1	—	28.4	72.5	95.0	120	160	197
		—	—	10.2	18.3	—	34.1	65.3	99.1	117	175	205
Mean.	. . . .	—	—	7.9	15.7	—	31.4	69.2	97.4	112	167	199
50% *Rhothane D-3*	50 mg.	—	—	1.7	2.0	—	20.0	79.5	100.0	40	57	80
		—	—	0.0	6.5	—	24.7	84.1	99.1	40	55	90
		—	—	0.9	3.9	—	17.8	87.1	100.0	47	58	84
Mean.	. . . .	—	—	0.9	4.1	—	20.8	83.6	99.7	42	57	85

* ″ = seconds. † ′ = minutes.

In table 1 are indicated the proper exposure periods to be used in the experiments on residual toxicities, as follows: DDT and gamma isomer of hexachlorocyclohexane, 15 minutes; chlordan, 1 hour; and *Rhothane D-3* and *Toxaphene*, 2 hours. Exposures to deposits of 50 mg. toxicant per square foot for the periods indicated produced nearly 100 per cent mortality for each material.

Experiment 2: *Effect of Deposits on Mortality*.—With what appears to be the best residual material (DDT) a study was conducted to establish if possible the influence of the amount of deposit on mortality of flies exposed 15 minutes. A series of glass plates were treated with a 50 per cent DDT water-wettable powder in a calculated range of 0.1875 mg. to 200 mg. (equivalent to 2,152 mg. per square

Table 2.—Mortalities of house flies expo 15 minutes to various DDT suspension depo on glass.

Deposit as Mg. of DDT per Square Foot of Glass	Per Cent Mortality 24 Hours After Treatment		
	Replicate 1	Replicate 2	Replicate 3
200 0	100.0	99.0	100 0
50 0	100.0	98.1	100 0
25 0	81.6	100.0	100 0
12 5.	89.8	100.0	94.3
6 25	75 0	85.5	100 0
3 125.	55.3	46.1	88.7
1.50.	25.0	28.1	37.8
0.75.	19.0	18.8	12.4
0.375.	0.0	5.7	0.0
0 1875.	0 0	3.1	0.0
0 0.	0 0	2.1	0.0

Note: A 50 per cent DDT water-wettable po was used to secure the DDT deposits.

Table 3.—Mortality of house flies exposed to surfaces sprayed with DDT at different ›sages and degrees of coverage.

ſG. OF DDT ·ER SQUARE FOOT	PER CENT OF SURFACE SPRAYED	PER CENT MORTALITY 24 HOURS AFTER EXPOSURE OF				
		3 Seconds	15 Seconds	1 Minute	4 Minutes	16 Minutes
50	100	24 7	88 5	99 1	99.8	100.0
100	25	5.5	15.0	75 8	100 0	99 7
25	100	19 2	86 0	96.5	99 0	100 0
10	100	10.4	25 0	82.5	94 8	99.1

›ter) DDT per square foot. Table 2 ows that a rather sharp drop in mortality d not occur until the deposit was 6.25 mg. r square foot or below. In this experi›nt, 25 mg. of DDT per square foot was arly as effective as a 200 mg. deposit; cal›lations were based on the 24-hour mor›lity resulting from a 15-minute exposure. here was evidence of mortality occur›ıg from a deposit as low as 0.375 mg. DDT per square foot. A dosage of 50 ;. of toxicant per square foot was select- as high enough for obtaining critical formation on persistence of deposits in cceeding tests. The writer felt that for tical residual studies excessive deposits ght obscure differences in persistence.

Experiment 3: *Relationship Be›een Coverage and Deposit.*—*Deen-* › water-wettable powder mixtures at rious dosages were sprayed in a settling ray tower upon glass plates in such a ıy as to obtain various degrees of cover›e, as indicated in table 3. A 25 mg. r square foot deposit over 100 per cent the surface was much more effective ın a 100 mg. per square foot deposit er only 25 per cent of the surface. A posit of 100 mg. of DDT on 25 per ıt of the surface was no more effective ın a 10 mg. deposit over the entire sur›e (about 0.4 as much actual DDT). sults show the greater importance of ›erage and the lesser importance of dos›e in effecting fly mortality.

No critical comparisons can be made ›ween data obtained in this experiment d data on coverage obtained by Turner Woodruff (1948), as in the Turner & oodruff report comparable specific in›mation is lacking on techniques of ıdy, dosages, exposure times, numbers flies used, and effect of flies on deposits.

Table 4.—Mortality of house flies exposed to surfaces sprayed for different degrees of coverage with 50 mg. DDT deposits per square foot.

PER CENT OF SURFACE SPRAYED	PER CENT MORTALITY 24 HOURS AFTER 4-MINUTE EXPOSURE
10	12.5
20	64 0
30	91.1
40	99 0
50	99 6
100	100 0

Experiment 4: *Coverage of Surface and Fly Mortality.*—As indicated in table 4, six panels were sprayed, with 10, 20, 30, 40, 50, and 100 per cent, respectively, of their surfaces covered with 50 mg. of DDT per square foot in the form of a water mixture of *Deenate* water-wettable powder.

On panels on which less than 30 per cent of the surface was treated, fly mortality resulting from a 4-minute exposure was low. Probably the fly does not have sufficient time to pick up a lethal dose of DDT in a 4-minute period of contact with a surface less than 30 per cent of which is treated.

Table 4 shows, in the random distribution of flies within a confined space, the desirability of extensive treatment, or as nearly complete a coverage as possible.

Table 3 indicates that a given amount of material is most effective when distributed over the whole surface. Therefore, in practical application, if a certain amount of material is to be used upon premises, it is advisable to cover all surfaces rather than to employ spot treatments, provided, however, that such an entire-coverage treatment does not con-

Table 5.—Mortality of house flies exposed to surfaces sprayed with DDT distributed heterogeneously and also homogeneously.

Formulation	Mg. DDT per Square Foot	Average Mg. DDT per Square Foot	Surface	Per Cent Mortality 24 Hours After Exposure of	
				15 Seconds	4 Minutes
No. 9 oil solution	20–200	110	Wood	96.0	100.00
No. 9 oil solution	110	110	Wood	93.2	100.00
No. 9 oil solution	50	50	Wood	87.0	99.08
Deenate water-wettable DDT powder in water	25–75	50	Glass	89.6	99.10
Deenate water-wettable DDT powder in water	50	50	Glass	88.1	99.40

taminate food or otherwise present a health hazard.

Experiment 5: *Effect of Heterogeneous Deposits Upon Flies.*—The effect upon flies of uneven deposits of insecticides was determined through a series of tests in which materials were sprayed on surfaces in alternating bands of heavy and light deposits. DDT, 3.2 per cent, in no. 9 oil was sprayed in 10 alternating bands of 20 and 200 mg. per square foot upon a wood surface, and the resulting mortality in flies exposed to this surface was compared with resulting mortalities in flies exposed to one 110 mg. and one 50 mg. treatment. There was, of course, a certain amount of run-together of the bands (estimated at about 25 per cent) so that the crystalline deposit appeared wavelike, or as a truly uneven deposit. There was no significant difference in fly mortality resulting from exposure to the 20–200 mg. deposit and the deposits of 110 and 50 mg. No significant differences in fly mortality resulted when *Deenate* water-wettable DDT was applied to glass in four strips of 25 and 75 mg. per square foot and in a uniform deposit of 50 mg., table 5.

The tests described above lead to the

Table 6.—House fly knockdown and mortality resulting from 15-minute exposures to surfaces treated with several formulations at a dosage of 50 mg. DDT per square foot.

Per Cent DDT in Water-Wettable Powder	Source of Toxicant	Surface	Minutes Required to Obtain Knockdown of			Mortality 25 Hours After a 15-Minute Exposure
			1%	50%	99%	
50 0	Rohm & Haas 50% water-wettable powder	Glass	20	33	57	100 0
25.0	Rohm & Haas 50% water-wettable powder	Glass	22	36	58	99.2
10.0	Rohm & Haas 50% water-wettable powder	Glass	29	49	145	89.1
5.0	Rohm & Haas 50% water-wettable powder	Glass	38	72	290	49.9
2.0	Rohm & Haas 50% water-wettable powder	Glass	50	140	540	14 0
0.5	Rohm & Haas 50% water-wettable powder	Glass	360	1,030	2,830	1 3
5.0	*Deenate* 50% water-wettable powder	Glass	35	58	315	46.2
5.0	*Deenate* 50% water-wettable powder	Wood	40	60	340	37.4
5.0	*Deenate* 25% emulsifiable concentrate	Glass	55	215	1,290	10.1
5.0	*Deenate* 25% emulsifiable concentrate	Wood	25	35	58	95.3

conclusion that perfectly uniform deposits may not be necessary or even advantageous on surfaces on which residual toxicant deposits are excessive. This conclusion confirms results of experiments in which there was no apparent difference in mortality rates resulting from deposits obtained by spraying and those obtained by painting. The painted deposits were obviously not perfectly uniform, fig. 4.

Experiment 6: ***Wall Coats Containing DDT.***—When many so-called wall coats containing DDT appeared upon the market, laboratory tests were progressing upon amounts of DDT in the suspension-type wall coats needed to produce the necessary lethal action. In addition, a means was being sought whereby a good wall coat might be produced. Formulations containing 0.5, 2.0, 5.0, 10.0, and 25.0 per cent DDT were prepared from Rohm & Haas wettable DDT powder and sprayed upon glass panels at the rate of 50 mg. actual DDT per square foot. The treated panels were permitted to dry and age 4 weeks before being tested.

The data in table 6 make it evident that mortality and knockdown were not changed until the concentration of DDT was reduced to 10 per cent or less. The writer is doubtful if any wall coat containing as little as 2 to 5 per cent DDT could compete in fly control with 50 per cent DDT water-wettable powder in field operations. In the 50 per cent water-wettable powder, approximately half of the surface particles are actual DDT, whereas in the wall coat probably 2 to 5 of 100 surface particles are actual DDT.

A few experiments with laboratory wall-coat formulations, in which 25 per cent DDT emulsifiable concentrate was reduced to 5 per cent DDT by mixture with *Cherokee* clay and used in place of the water-wettable powder, proved quite satisfactory. When this formulation was sprayed upon wood or other porous surfaces a highly toxic bloom occurred usually within a week. When applied to glass, the DDT "bloomed-in" and crystallized upon the glass beneath. Used commercially, such a formulation would probably not be sprayed upon glass or other highly polished surfaces and would likely surpass most wall coats being used in controlling flies.

Block (1948*a*) mentions a number of good references to research on insecticidal surface coatings. Also, he offers valuable information about such coatings, in which the toxicant appears to be retained longer than might ordinarily be expected. Most of Block's work was with coatings containing 20 per cent DDT, and his data are recorded in number of minutes required to give 50 per cent knockdown.

Experiment 7: ***Effect of Successive Exposures on Persistence of Toxic Residue.***—What wearing effect do numerous flies have upon a deposit of residual insecticide? Ten cages of flies were exposed for successive periods of 15 minutes each to each of the DDT-treated surfaces listed in table 7, and 24-hour mortality data were recorded.

Results of tests, designed to test fly erosion of DDT residues, indicate not only tenacity of deposits but also a stimulating seeding effect of flies when exposed to surfaces that are just beginning to bloom. On such surfaces it is evident that there exists a layer of blobs of supersaturated solvents that respond to various stimuli and bloom out in a dense mat of very fine crystals. These stimulated blooms (crystallization on the surface) are, according to the erosion test, very resistant to wear.

Examining the data by solvents and surfaces reveals some very interesting trends. *PD 544-C* emulsions, when applied to wood, form not only a good initial bloom but also a very dense secondary seeded mat of crystals, all of which resist wear. On glass the *PD 544-C* formulation maintains a rather low order of toxicity, with no apparent loss by fly erosion. Microscopic examination of deposits of DDT from the slower-drying solvents shows that the large crystals for the most part lie flat upon the glass surface, figs. 6, 9, and 10. The position of the crystals probably explains their low degree of toxicity and their long wear. A mixture of water-wettable powder that has been sprayed on glass erodes to some degree as evidenced by both biological and visual observations. Erosion of the residue is greatly retarded by the addition of 5 per cent bone glue by weight to the 50 per cent DDT water-wettable powder. The *Deenate* water-wettable powder appears to erode more

Table 7.—Influence of surfaces, solvents, formulations, method of application, and fly activity upon toxicity and maintenance of residual effectiveness of DDT deposits.

Panel No.	Solvent or Formulation	Method of Application	Age of Deposit in Days	Crystals	Surface	Per Cent Mortality 24 Hours After Stated Exposure of Flies to the Surface: 1st	2nd	3rd	4th	5th	6th	7th	8th	9th	10th
1	*PD 544–C**	Painted	6	Medium fine	Wood	100.0	100.0	100.0	100.0	92.0	90.0	87.0	99.0	98.0	83.0
2	*PD 544–C**	Painted	6	Medium fine	Wood	100.0	97.0	100.0	100.0	88.0	100.0	90.0	87.0	96.0	100.0
3	*PD 544–C**	Painted	6	Large	Glass	16.0	37.0	17.0	28.0	26.0	21.0	18.0	23.0	28.0	21.0
4	*PD 544–C**	Painted	6	Large	Glass	12.0	15.0	15.0	22.0	19.0	33.0	22.4	22.0	14 0	23.0
5	*PD 544–C**	Painted	6	Large	Glass	41.0	26.0	45.0	26.0	68.0	42.0	50.0	50.0	41.0	49.0
6	Laboratory water-wettable powder	Painted	6	—	Glass	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
7	*Deenate* water-wettable powder	Painted	6	—	Glass	100.0	100.0	100.0	100.0	100.0	100.0	97.3	98.2	98.5	76.7
8	*Deenate* water-wettable powder	Sprayed	6	—	Glass	100.0	100.0	100.0	100.0	96.5	100.0	100.0	99.2	64.2	83.0
9	*Deenate* water-wettable powder and glue	Sprayed	6	—	Glass	100.0	100 0	97.7	100.0	92.0	99.2	95.0	100.0	100.0	100.0
0	Controls	—	—	—	Glass	1.0	0.0	2.1	1.9	0 0	0.0	0 0	3.2	1.8	0.0
10	Ethyl alcohol	Sprayed	6	Superfine	Glass	100.0	100.0	100 0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
11	Ethyl alcohol	Painted	6	Superfine	Glass	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
12	*HB–40*†	Sprayed	6	Oily surface, none	Wood	36.4	27.3	41.5	32.7	26.7	28.6	25.2	26.7	43.0	16.8
12	*HB–40*†	Sprayed	11	None	Wood	0.0	2.6	0 0	0 0	0 0	0.0	0.0	2.4	0.8	0.9
12	*HB–40*†	Sprayed	18	Large	Wood	34.2	10.7	3.0	8.1	7.0	—	—	—	—	—
12	*HB–40*†	Sprayed	30	Large	Wood	80.0	—	—	—	—	—	—	—	—	—
13	Xylene†	Sprayed	6	Medium fine	Wood	100.0	88.7	65.7	44.5	37.5	34.8	39.6	48 0	43.2	42.0
13	Xylene†	Sprayed	11	Medium fine	Wood	100.0	68.7	54 4	24.2	13.6	6.8	4.2	4 6	12.6	17.2
13	Xylene†	Sprayed	18	Medium fine	Wood	13.1	14.8	4 0	1.8	1.0	—	—	—	—	—
13	Xylene†	Sprayed	30	Medium fine	Wood	7.9	—	—	—	—	—	—	—	—	—
14	*Velsicol AR–60*†	Sprayed	6	Oily surface, few medium	Wood	35.3	36.8	35.6	18.8	50 0	39.8	52.5	27 9	15 0	18.2
14	*Velsicol AR–60*†	Sprayed	11	Medium	Wood	100.0	99.2	88.0	98.4	64 6	34.5	52 0	92.3	38.4	79.0
14	*Velsicol AR–60*†	Sprayed	18	Medium	Wood	25.5	9.2	10.7	6 7	25.3	—	—	—	—	—
14	*Velsicol AR–60*†	Sprayed	30	Medium	Wood	16.0	—	—	—	—	—	—	—	—	—
15	Xylene + ethylene dichloride†	Sprayed	4	Medium fine	Wood	80.8	91.3	62.3	85.1	86.3	74.2	23.0	54 1	56.8	35.7

*2% *B-1956* + 3% *Triton X-155* emulsifiers.

Table 7 (continued)

Panel No.	Solvent or Formulation	Method of Application	Age of Deposit in Days	Crystals	Surface	Per Cent Mortality 24 Hours After Stated Exposure of Flies to the Surface									
						1st	2nd	3rd	4th	5th	6th	7th	8th	9th	10th
15	Xylene + ethylene dichloride†	Sprayed	15	Very fine and matted	Wood	100.0	99.1	100.0	100.0	100.0	88.7	85.8	91.2	94.9	99.2
16	Xylene + carbon tetrachloride†	Sprayed	4	Medium fine	Wood	100.0	100.0	99.3	71.2	75.2	46.8	27.8	66.2	31.4	24.1
16	Xylene + carbon tetrachloride†	Sprayed	15	Very fine and matted	Wood	100.0	100.0	100.0	99.1	95.3	99.2	100.0	100.0	100.0	100.0
17	Xylene†	Sprayed	2	Medium fine	Wood	100.0	100.0	95.7	86.4	63.0	31.2	20.0	28.4	37.8	44.4
17	Xylene†	Sprayed	15	Fine and matted	Wood	100.0	100.0	100.0	99.1	95.3	100.0	86.4	88.0	74.2	85.3
18	Xylene†	Sprayed	3	Medium fine	Wood	100.0	100.0	88.6	64.4	25.4	13.6	6.4	58.2	6.7	14.9
18	Xylene†	Sprayed	15	Medium fine	Wood	100.0	96.1	80.0	51.1	12.2	9.1	13.2	14.3	11.0	10.1
19	Xylene†	Sprayed	30	Medium fine	Wood	100.0	100.0	96.0	93.2	77.7	78.7	48.5	69.0	71.5	75.2
20	*PD 544-C**	Sprayed	6	Medium fine	Wood	100.0	100.0	99.2	97.3	85.7	97.2	100.0	81.0	88.2	91.0
20	*PD 544-C**	Sprayed	11	Very fine and matted	Wood	100.0	100.0	100.0	100.0	100.0	100.0	99.3	100.0	100.0	100.0
21	*PD 544-C**	Sprayed	6	Medium fine	Wood	100.0	100.0	100.0	96.1	100.0	100.0	97.1	79.2	84.3	88.3
21	*PD 544-C**	Sprayed	11	Very fine and matted	Wood	100.0	100.0	99.3	100.0	100.0	100.0	100.0	100.0	99.1	100.0
22	Xylene‡	Painted	2	Surface appearing wet; few medium fine	Glass	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
22	Xylene‡	Painted	15	Fine and very fine	Glass	100.0	100.0	100.0	100.0	100.0	100.0	99.8	97.4	100.0	94.8

* 2% *B-1956* + 3% *Triton X-155* emulsifiers.
† 5% *Atlox 1045-A* emulsifier.
‡ 10% *Triton X-100* emulsifier.

rapidly than the laboratory water-wettable powder formulation in which *Cherokee* clay is used as a diluent.

The three formulations in which *HB-40,* xylene, and *Velsicol AR-60* were solvents, and *Atlox 1045-A* was used as the emulsifier, had different degrees of bloom and wear. The first test period 6 days after treatment showed considerable degradation of the well-crystallized DDT-xylene deposit; in the other two formulations, little loss of toxicity was noted from the first through the tenth exposure. Examination under a microscope revealed no crystals present where *HB-40* had been used and very few where *Velsicol AR-60* was employed. Five days later, when these same surfaces were again tested in like manner, the xylene treatment had eroded severely, that containing *AR-60* had eroded slightly, and the *HB-40* treatment showed no toxicity and no bloom. The *HB-40* treatment then appeared dry, whereas in the first series of tests it had a wet appearance. A third test of only five series of exposures on the eighteenth day and examination of deposits proved the appearance of crystals upon the surface of the *HB-40* treatment. The xylene treatment indicated a continued slow, inconspicuous bloom, and the *AR-60* treatment a more noticeable bloom. By the time of the last test, on the thirtieth day, of but one cage of flies, the results suggested that the rate of bloom is directly proportional to the rate of volatilization of the solvent. Thus, in 30 days *HB-40* had only begun to permit the crystallization of DDT; xylene had apparently passed its peak of crystallization by the fifth day, and *Velsicol AR-60* by the eleventh day. Probably some of the DDT remains bound in the wood as a supersaturated or saturated solution in any of these solvents for periods much longer than those indicated here.

Further studies with xylene as a solvent, as indicated in table 7, lead to the belief that, if the desirable secondary bloom is to be obtained, the flies, or whatever device is used for seeding the surface, should be on the surface not later than the second day. Thus, the period of seeding a xylene treatment seems somewhat limited. If, however, we add to the xylene emulsion-concentrate about 20 per cent ethylene dichloride or carbon tetrachloride we find that a deposit bearing DDT will react t the stimulus on the fourth day to produc a plainly visible heavy white crystallin mat of extremely small, fine crystals o the wood surface. Of all the seede blooms, these and the ones produced by th *PD 544-C* treatments were the heavies and most resistant to wear at a high leve of toxicity. Of all the formulations excep those made with water-wettable powder the 1.62 per cent DDT solution in 95 pe cent ethyl alcohol produced the most leth and tenacious deposits on glass surfac when either sprayed or brushed upon th surfaces. It produced the finest crystallin deposits, and its crystallization was th most rapid, fig. 8.

Microscopic study of all solution d posits on glass revealed that rarely wa crystallization complete. Usually a fe or many minute blobs of supersaturate solution persisted among the DDT cry tals, fig. 12. On glass and, less noticeabl on wood the size of the DDT crystals wa determined by the speed of crystallizatio which, in turn, was determined by th physical properties of the solvent, fig 6–13; rapid crystallization produced cry tals of minute size. This phenomenon wa especially noticeable where surface trea ments were seeded by fly activity at th proper time and crystallization was at onc initiated at the innumerable sites of fl contact. Often it was noted that dus dirt, and scratches stimulated the forma tion of crystals on glass, fig. 13.

Schmitz & Goette (1948) apparentl showed the degree of penetration of DD solutions into poplar wood. The opinio of the present writer is that the degre of penetration may be influenced by highl variable elements in the environment. Fo example, under a certain set of conditio it is possible that most of the DDT coul be crystallized on the surface of the woo if the solvent is highly supersaturate when the surface is stimulated. Withou the stimulation, much of the DDT coul remain dissolved and held in the wood b the solvent. Certain components of woo have shown a visible influence upon th bloom; it has been observed that frequentl bloom occurs on the soft part of the woo between the hard or resinous annual ring before a crystalline formation occurs o the annual rings. On certain pieces o

Fig. 6.—DDT crystallization from *PD 544-C* emulsion. ×40. Crystals of DDT formed m solvents that evaporate slowly tend to be large, lie flat on the glass, and exhibit low icity and high resistance to erosion.

Fig. 7.—DDT crystallization from no. 9 oil on glass. ×40. The large crystals are plainly ible to the unaided eye.

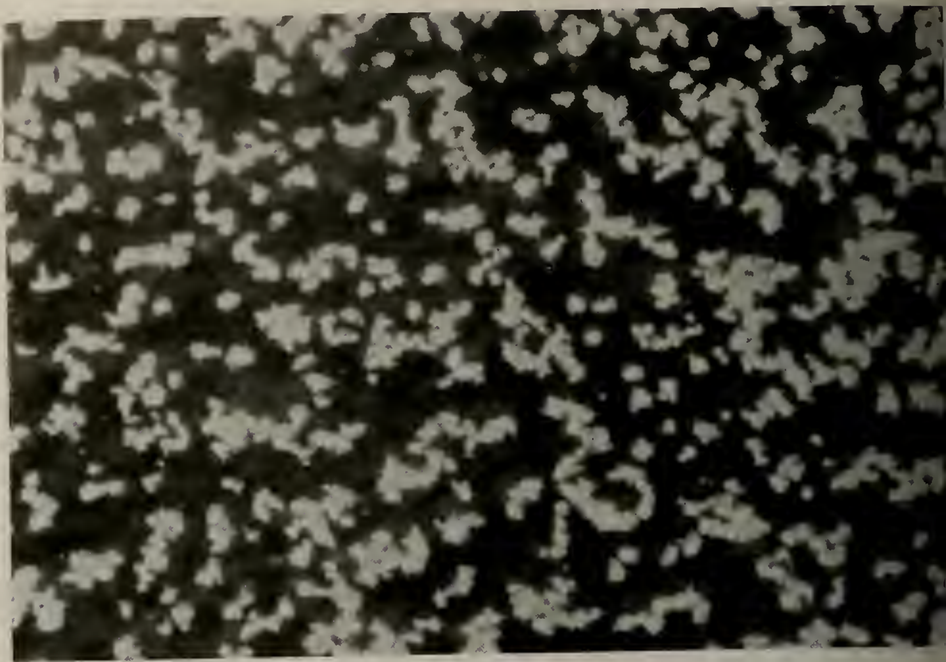

Fig. 8.—DDT crystallization from ethyl alcohol solution on glass. × 40. The minute crystal not visible individually but only as dense hemispherical masses, have high toxicity and a resistant to erosion.

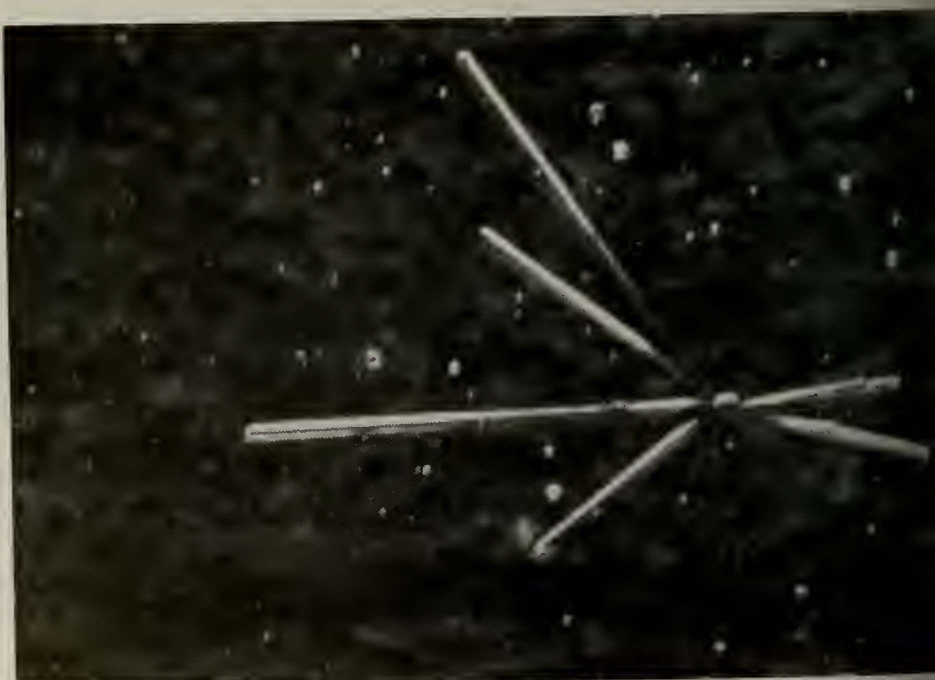

Fig. 9.—DDT in process of crystallizing from an *HB-40* solution. × 40. The very la crystals, which lie flat upon the glass, are characteristic of very slow crystallization.

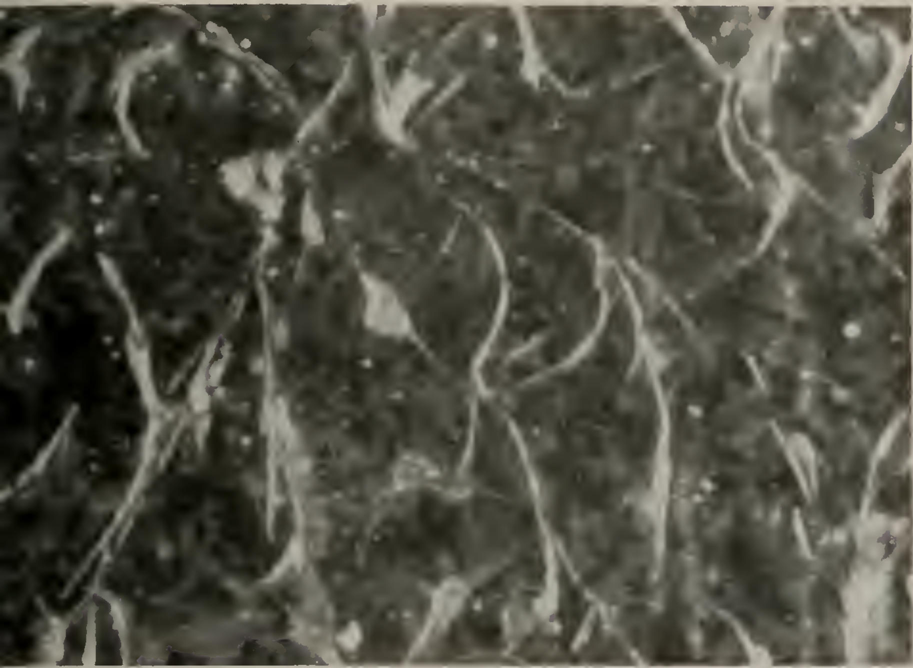

Fig. 10.—DDT crystallization from a *Velsicol AR-60* emulsion. ×40. The crystals lying and forming a network on glass, have low toxicity and are resistant to erosion.

Fig. 11.—DDT crystallized from xylene emulsion on glass. ×40. Network of crystals is nilar to that from *Velsicol AR-60*, but the individual crystals are smaller.

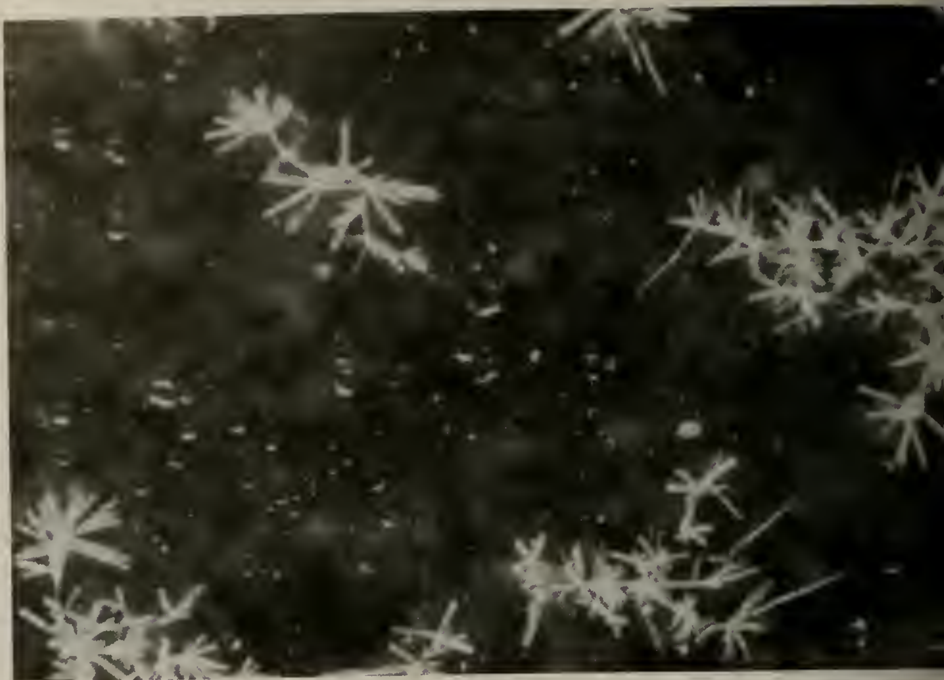

Fig. 12.—DDT in process of crystallizing from xylene solution on glass. ×40. T xylene droplets (center of picture) among the crystals are susceptible to seeding by dust or fli

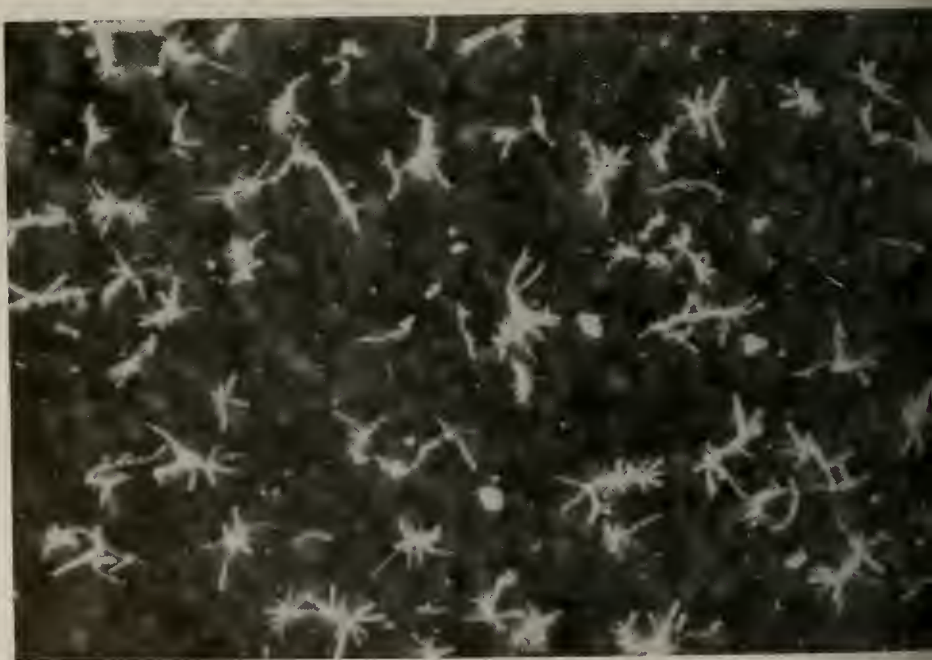

Fig. 13.—DDT in process of crystallizing from xylene solution. ×40. The solution on glass shown here was seeded by dust, and crystallization started sooner than on glass sho in fig. 12.

ood, when a bloom occurs on the soft rt of the wood, it does not occur the annual rings. Thus, it seems that netration or retention of DDT in the ood depends upon the physical properties the solvent and the particular piece of ood used, in addition to environmental ments.

Experiment 8: *Fumigation Properties.*—During the course of the studies, ficulty was encountered with contamination of air in the room containing the fly-ck cage. Investigation of this situation vealed that the only possible source of ntamination was chlordan-treated surfaces at the opposite end of the room. Preliminary tests indicated that *Toxaphene, nothane D-3,* and DDT did not act as migants to any noticeable extent; on the her hand, chlordan and gamma hexachlorocyclohexane seemed very toxic as migants.

A study was made of the fumigation tion of chlordan and gamma hexachlorocyclohexane. Caged flies were placed in a ge battery jar (11.6 liters capacity) th 18 square inches of treated surface. The top of the jar was sealed with a glass plate smeared with a glycerine-betonite jell. Exposure times of six groups of flies to the air in the jars were, respectively, 15, 30, 60, 120, 240, and 480 minutes. The results of four replicates are shown in table 8. The losses of weight from the treated surfaces were used to calculate the dosage as milligrams per 1,000 cubic feet or 28.365 cubic meters. One mg. per 1,000 cubic feet is equivalent to 0.0353 mg. per cubic meter. It was difficult to believe that the calculated dosages actually existed as a vapor, but rather existed as condensations or adsorptions over the entire inside surface of each jar. It seemed conceivable that there was a transfer of the toxicant to the lipoid material in the insect's body and consequently that a lethal concentration of the toxicants accumulated. These data indicate the high order of toxicity to house flies of vapors that were given off from chlordan and hexachlorocyclohexane. Chlordan and hexachlorocyclohexane were compared with HCN, one of the most toxic fumigants, and found to be approximately 62 and 206 times as toxic, respectively. Fly fumigation data

Table 8.—Mortality of house flies 24 hours after exposures of various periods to vapors chlordan and hexachlorocyclohexane residues.

TOXICANT	PER CENT MORTALITY 24 HOURS AFTER EXPOSURE OF					
	15 ′*	30 ′	60 ′	120 ′	240 ′	480 ′
lordan	2 6	30 0	58.0	68 5	82.8	98.1
lordan	1 0	4.9	24 5	91.8	99.2	100.0
lordan	1 9	20.9	63.7	83 2	100.0	100.0
lordan	0 9	6 3	24 1	81 4	97.0	100.0
an	1.6	15 5	42.8	81.2	94 8	99.5
erage dosage calculated as mg. per 1000 ubic feet	1 51	3.04	6.07	12.14	24 28	48.56
mma isomer of hexachlorocyclohexane	1 0	14 8	25 6	64 0	99.1	100 0
ne as above	1 9	6.1	25 0	71.4	95.2	100 0
ne as above	1 0	14 7	42.1	75 0	99 1	100.0
ne as above	0 0	4.1	20 0	54 1	88 2	99.2
an	1 0	9 9	28.2	66.1	95.4	99.8
erage dosage calculated as mg. per 1000 ubic feet	0 52	1.06	2.11	4 22	8.44	16 88
eck						0.0
eck						1 1
eck						0.0
eck						1 9
an						0 75

* ′ = minutes.

by Eddy (1929) were used in the calculations. The use of chlordan or hexachlorocyclohexane as residual fumigants within confined spaces is suggested by results of this experiment.

Experiments 9 and 10: *Testing Periods*.—To limit the reduction of surface toxicity by fly erosion, the number of test periods in these experiments was held to a minimum.

Table 9.—Mortality of house flies 24 hours after exposure to various treated surfaces subjected to several combinations of environmental elements. Surfaces were tested 2, 22, and 182 days after treatment with commercial emulsions of residual insecticides.

Toxicant	Exposure	Surface	Mean Per Cent Mortality in Three Replicates		
			2 Days After Treatment	22 Days After Treatment	182 Days After Treatment
DDT	South outside	Wood	99.70	11.90	0.00
	North outside	Wood	99.43	31.07	0.00
	North sheltered	Wood	99.07	46.53	8.07
	Inside	Wood	100.00	100.00	88.83
	South outside	Glass	46.23	100.00	3.83
	North outside	Glass	43.23	99.40	10.83
	North sheltered	Glass	42.83	56.97	19.53
	Inside	Glass	45.33	35.63	21.17
	South outside	Painted wood*	0.33	2.33	—
	Inside	Painted wood*	0.63	19.93	0.00
	South outside	*Cellutex*	97.80	9.90	—
	Inside	*Cellutex*	96.67	97.27	36.30
	South outside	Brick	74.97	6.33	—
	Inside	Brick	71.87	38.33	11.87
	South outside	Concrete	0.97	0.00	—
	Inside	Concrete	1.30	0.80	0.00
	South outside	Whitewash	2.30	4.07	—
	Inside	Whitewash	1.57	5.06	0.00
	South outside	Galvanized	57.73	8.47	—
	Inside	Galvanized	38.80	26.57	67.43
Chlordan	South outside	Wood	98.37	14.27	0.00
	North outside	Wood	98.17	7.93	0.00
	North sheltered	Wood	98.93	16.30	0.00
	Inside	Wood	98.77	14.17	0.00
	South outside	Glass	98.97	15.93	0.00
	North outside	Glass	99.10	22.70	0.37
	North sheltered	Glass	99.43	10.80	0.30
	Inside	Glass	97.33	43.30	0.00
	South outside	Painted wood*	69.13	2.92	—
	Inside	Painted wood*	68.30	3.93	0.60
	South outside	*Cellutex*	85.97	7.10	—
	Inside	*Cellutex*	88.70	17.41	0.30
	South outside	Brick	84.53	0.90	—
	Inside	Brick	83.35	3.17	—
	South outside	Concrete	64.60	2.37	—
	Inside	Concrete	56.50	4.23	—
	South outside	Whitewash	67.07	3.00	—
	Inside	Whitewash	76.23	29.37	—
	South outside	Galvanized	94.67	25.53	—
	Inside	Galvanized	96.50	35.20	0.00
Rhothane D-3	South outside	Wood	66.33	10.43	0.00
	North outside	Wood	60.07	11.37	0.00
	North sheltered	Wood	59.43	27.60	6.63
	Inside	Wood	58.60	19.07	12.00
	South outside	Glass	58.23	13.27	0.00
	North outside	Glass	70.90	16.43	0.60
	North sheltered	Glass	73.57	40.40	7.60
	Inside	Glass	65.43	35.70	31.03

* Flat white wall paint containing vegetable oil vehicle.

Table 9 (continued)

Toxicant	Exposure	Surface	Mean Per Cent Mortality in Three Replicates: 2 Days After Treatment	22 Days After Treatment	182 Days After Treatment
Gamma isomer of hexachlorocyclohexane	South outside	Wood	94.23	0.70	0.00
	North outside	Wood	97.17	3.63	0.33
	North sheltered	Wood	97.53	1.00	0.00
	Inside	Wood	98.33	31.97	1.57
	South outside	Glass	99.13	0.43	—
	North outside	Glass	97.00	0.70	—
	North sheltered	Glass	98.66	9.23	0.27
	Inside	Glass	97.87	45.93	0.90
	South outside	Painted wood*	61.70	12.33	—
	Inside	Painted wood*	60.37	32.33	0.00
	South outside	*Cellutex*	72.63	3.60	—
	Inside	*Cellutex*	73.77	10.33	—
	South outside	Brick	69.03	1.67	—
	Inside	Brick	90.67	5.20	—
	South outside	Concrete	50.03	0.00	—
	Inside	Concrete	43.97	0.90	—
	South outside	Whitewash	89.00	1.13	—
	Inside	Whitewash	86.90	9.30	—
	South outside	Galvanized	99.80	11.90	3.20
	Inside	Galvanized	99.47	0.00	0.00
Toxaphene	South outside	Wood	70.33	4.43	—
	North outside	Wood	64.77	1.30	—
	North sheltered	Wood	71.60	44.67	0.00
	Inside	Wood	71.13	63.90	0.93
	South outside	Glass	99.37	22.47	0.00
	North outside	Glass	98.90	6.37	0.00
	North sheltered	Glass	98.53	62.10	3.80
	Inside	Glass	98.33	84.37	5.27
Control	—	—	1.17	0.67	0.63
	—	—	1.57	—	—
	—	—	1.47	—	—
	—	—	0.57	—	—
Mean difference necessary for significance, 0.05 level			9.11	25.54	4.95
Mean difference necessary for significance, 0.01 level			21.11	33.66	6.58

* Flat white wall paint containing vegetable oil vehicle.

In experiment 9, only three test periods were used and in experiment 10 four test periods. If, at the end of 22 days in experiment 9, a material had lost its toxicity it was considered to be of little value as a residual insecticide in fly control on farms. If it proved to be toxic at the end of 22 days, it was considered for further testing at the 182-day test period. Any material that showed toxicity at the end of 182 days was regarded as very persistent and possessed of adequate residual kill properties for any practical application.

In experiment 10, 2-, 12-, 32-, and 152-day test periods were employed. Two- and 12-day periods were used to obtain data on panels coated with materials having a short residual life. The 32-day period was used to measure materials with a satisfactory period of toxicity for most structural pest control purposes, and the 152-day period was used to obtain information needed on those materials of truly long residual activity such as those desirable for fly control on farms or those presenting a residue problem on foodstuffs.

Experiment 9: *Field Persistence of Residues From Commercial Emulsions.*—Five toxicants were applied to eight surfaces—planed fir, glass, painted wood (1 month old), *Cellutex* (similar to *Celotex*), brick, concrete, whitewashed wood (1 month old), and galvanized iron —at a rate of 50 mg. per square foot, table 9. Treatments on wood and glass were exposed to various elements of the weather. Three replicates of each treatment on glass and wood were placed in situations on the South Farm of the University of Illinois so that one set was inside; another was outside on the south side of buildings exposed to all the elements; the third was on the north side of buildings; and the fourth was under a shelter that gave protection from sun and rain. The four positions may be described simply as the inside, the south exposure, the north exposure, and the sheltered. Surfaces other than glass and planed fir were placed in two positions—the south outside exposure and the inside. The objective of this experiment was to obtain information on the persistence of the five toxicants on the eight surfaces under various conditions. A study of table 9 will reveal the insecticides that were found to be most persistent under various conditions and also the surfaces on which insecticides were retained the greatest length of time.

Experiment 10: ***Field Persistence of Residues From a Standardized Formulation of Emulsions.***—The plan of this experiment was essentially the same as that of experiment 9. The variable of formulation was eliminated, and better-defined positions of exposure to the climatic elements were set up. Treated panels were exposed by means of suitable supports, fig. 14, on top of a flat-roofed

Fig. 14.—Securing treated panels to pipe rack for determining the effects of weathering upon toxicities of residues.

building. Some panels were secured to a pipe rack in north and south outside positions. Others were placed on racks beneath a shelter designed to keep out rain and sunshine. Still others were kept in the laboratory. The same solvent and emulsifying agent were used in all formulations. The emulsifiable concentrates contained 65 per cent xylene, 10 per cent *Triton X-100*, and 25 per cent by weight of the toxicant. These were diluted with water to give an emulsion containing 1 per cent of the insecticide. Incorporated with this experiment were tests with DDT water-wettable powder; it was hoped that such a formulation would overcome some of the surface hazards encountered with emulsions.

Experiments 9 and 10: ***Discussion.***—Results of these tests are shown in tables 9 and 10. DDT was the outstanding residual insecticide. *Rhothane D-3* was the next most persistent material, with *Toxaphene* a good third choice. Gamma hexachlorocyclohexane and chlordan were the least persistent. Probably one of the greatest hazards was dust. Dust particles falling upon treated surfaces introduced a variant, not measureable. Nevertheless, dust presents one of the conditions frequently found under field conditions.

Analysis of these data made it evident that differentiation among elements is difficult. Rain appeared by visual evidence and biological assay to be the prime element in the degradation of the residual deposits. The deposits that were exposed to rain were more persistent on hard impervious surfaces (glass and galvanized iron) than on porous surfaces (brick, fir wood, and *Cellutex*). On painted wood, concrete, and whitewashed wood the initial and residual toxicity of the insecticides to house flies was lower than on other surfaces. The deposit from 50 per cent DDT water-wettable powder gave promising results on all surfaces. At the end of 152 days, the DDT suspension deposits were significantly toxic on all inside surface treatments except whitewashed wood.

The emulsion containing *PD 544-C* and DDT that was used to obtain data in table 9 shows the typical high toxicity of the initial tests on wood; considerable losses were incurred as a result of erosion and degradation by the twenty-second day of the test. Those panels with south exposure (exposed to all the elements) showed the greatest losses; those with north exposure (exposed to all elements except sunshine) showed approximately 20 per cent greater killing power. These losses may be accounted for by one or both of two possibilities: (1) direct sunlight or the heat produced by solar radiation; (2) rain driven onto the panels by a prevailing southwest wind. Wood panels sheltered from rain as well as sun exhibited about 15 per cent greater mortality to flies than the ones with north exposure. Wood panels placed within buildings retained their toxicity beyond the 22nd day and even to the 182nd day. The difference in toxicity between those wood panels held indoors and those in sheds where they were sheltered from external elements (sunshine and rain) might be assigned to one or both of two possibilities: wind erosion and dust accumulation found in the sheds.

The second series of tests (experiment 10) with uniform emulsions reveals no significant differences between those panels retained within the laboratory and those kept in a shelter constructed on top of a building. Both sites were relatively dust-free in contrast to the interior of the sheds used in the first test. In light of available information, it must be assumed that the real cause of degradation of the surfaces in the sheltered positions of the first series of tests (experiment 9) was dust accumulation and not wind erosion.

The glass panels treated with DDT emulsions may at first appear to offer somewhat contradictory evidence of toxicity unless the difference in solvents and emulsifiers used in the first and second series of tests is kept in mind.

In experiment 9, with a commercial *PD 544-C* emulsion of DDT on glass, the deposits and the test clearly showed that the rain, wind, or some other element found in the outside positions caused the DDT residue, a large part of which existed as a supersaturated solution in *PD 544-C* and emulsifier, to bloom or crystallize out. A microscopic comparison of the residues on the panels at the time of testing on the twelfth day revealed the presence of practically no supersaturated blobs on the glass panels from the two outside positions in contrast to much supersaturated fluid on those inside, particularly those sheltered from all the elements, including the wind. By the 182nd day, however, the order of residual toxicity was reversed by the wear of the elements.

In tests with uniform emulsions (experiment 10) where xylene was the solvent, seeded crystallization occurred on glass earlier (probably as a result of the initial fly action) than in experiment 9; that is, the xylene had probably slowly evaporated so that by the end of the first test period the blobs produced were easily crystallized when contacted by flies. There are other possible explanations for the high level of toxicity observed in the first two test periods. One is that the *Triton X-100* emulsifier containing some dissolved DDT

Table 10.—Mortality of house flies 24 hours after exposure to various treated surfaces subjected to several combinations of environmental elements. Surfaces were tested 2, 12, 32, and 152 days after treatment with standard laboratory emulsions of residual insecticides.

Toxicant	Exposure	Surface	Mean Per Cent Mortality in Three Replicates			
			2 Days After Treatment	12 Days After Treatment	32 Days After Treatment	152 Days After Treatment
DDT	South outside	Wood	99.07	14.47	3.67	—
	North outside	Wood	99.73	16.90	7.03	—
	North sheltered	Wood	100.00	98.33	99.07	—
	Inside	Wood	98.87	99.13	98.93	93.63
	South outside	Glass	96.17	78.27	6.00	—
	North outside	Glass	95.50	55.87	8.63	—
	North sheltered	Glass	91.00	97.77	9.80	—
	Inside	Glass	96.77	86.23	26.10	7.10
	South outside	Painted wood*	8.40	6.18	0.30	—
	Inside	Painted wood*	11.03	4.00	1.43	0.90
	South outside	*Cellutex*	95.90	12.47	3.33	—
	Inside	*Cellutex*	93.50	99.37	61.60	36.23
	South outside	Brick	97.00	28.10	2.97	—
	Inside	Brick	98.00	100.00	74.83	62.43
	South outside	Concrete	10.17	3.23	—	—
	Inside	Concrete	7.17	2.57	0.33	0.00
	South outside	Whitewash	13.33	2.40	—	—
	Inside	Whitewash	14.53	3.03	0.20	0.30
	South outside	Galvanized	67.33	59.63	6.10	—
	Inside	Galvanized	79.70	100.00	92.70	53.07
Chlordan	South outside	Wood	95.47	1.47	—	—
	North outside	Wood	95.80	0.57	—	—
	North sheltered	Wood	99.50	1.57	—	—
	Inside	Wood	97.67	7.63	2.00	1.70
	South outside	Glass	100.00	0.27	—	—
	North outside	Glass	100.00	1.30	—	—
	North sheltered	Glass	100.00	88.37	5.10	—
	Inside	Glass	100.00	88.10	3.97	1.50
	South outside	Painted wood*	37.43	0.87	—	—
	Inside	Painted wood*	41.43	6.43	—	—
	South outside	*Cellutex*	73.00	1.47	—	—
	Inside	*Cellutex*	65.30	7.67	—	—
	South outside	Brick	98.93	6.93	—	—
	Inside	Brick	94.80	7.10	—	—
	South outside	Concrete	55.63	1.80	—	—
	Inside	Concrete	47.07	3.83	—	—
	South outside	Whitewash	66.53	1.83	—	—
	Inside	Whitewash	46.40	11.43	4.93	0.30
	South outside	Galvanized	91.23	1.53	—	—
	Inside	Galvanized	93.70	26.97	0.00	1.30

* Flat white wall paint containing vegetable oil vehicle.

Note: Emulsions were applied at the rate of 5 ml. of 1% toxicant per square foot. Each emulsifiable concentrate consisted of 25% by weight of toxicant + 10% *Triton X-100* + 65% xylene.

Table 10 (continued)

TOXICANT	EXPOSURE	SURFACE	MEAN PER CENT MORTALITY IN THREE REPLICATES			
			2 Days After Treatment	12 Days After Treatment	32 Days After Treatment	152 Days After Treatment
iamma isomer of hexachloro-cyclohexane	South outside	Wood	100.00	12.47	—	—
	North outside	Wood	100.00	4.90	—	—
	North sheltered	Wood	99.67	3.47	—	—
	Inside	Wood	100.00	27.80	0.77	2.17
	South outside	Glass	98.67	0.75	—	—
	North outside	Glass	100.00	3.83	—	—
	North sheltered	Glass	100.00	11.83	0.00	—
	Inside	Glass	99.67	99.70	2.07	1.50
	South outside	Painted wood*	68.07	8.60	3.30	—
	Inside	Painted wood*	65.10	28.60	3.90	—
	South outside	*Cellutex*	92.80	26.17	2.13	—
	Inside	*Cellutex*	87.37	7.37	1.13	—
	South outside	Brick	100.00	10.40	—	—
	Inside	Brick	99.40	7.13	—	—
	South outside	Concrete	67.77	3.10	—	—
	Inside	Concrete	65.40	1.40	—	—
	South outside	Whitewash	85.43	3.07	—	—
	Inside	Whitewash	74.37	19.17	—	—
	South outside	Galvanized	48.80	7.37	—	—
	Inside	Galvanized	43.23	3.83	—	—
hothane D-3	South outside	Wood	32.60	6.77	—	—
	North outside	Wood	37.97	0.97	—	—
	North sheltered	Wood	34.57	2.17	—	—
	Inside	Wood	36.27	17.47	20.43	13.73
	South outside	Glass	87.67	99.73	9.50	—
	North outside	Glass	84.93	99.43	24.47	—
	North sheltered	Glass	80.40	94.97	10.57	—
	Inside	Glass	85.97	90.87	29.97	25.00
oxaphene	South outside	Wood	51.30	1.77	—	—
	North outside	Wood	42.40	3.67	—	—
	North sheltered	Wood	44.40	1.00	—	—
	Inside	Wood	46.37	7.60	6.13	0.63
	South outside	Glass	100.00	0.63	—	—
	North outside	Glass	100.00	1.70	—	—
	North sheltered	Glass	100.00	100.00	74.70	—
	Inside	Glass	99.73	99.77	91.57	82.97
DT as from a 50% water-wettable powder	South outside	Whitewash	100.00	14.07	0.60	—
	Inside	Whitewash	100.00	99.67	55.4	14.90
	South outside	Painted wood*	100.00	6.80	6.83	—
	Inside	Painted wood*	100.00	7.97	5.83	0.57
	South outside	Galvanized	100.00	95.87	1.43	—
	Inside	Galvanized	100.00	100.00	95.80	89.20
	South outside	Wood	94.80	9.33	4.97	—
	Inside	Wood	95.97	93.03	91.00	58.70
Control	—	—	1.27	0.80	0.70	0.00
	—	—	1.00	0.57	0.67	0.30
Mean difference necessary for significance, 0.05 level			13.10	6.30	25.47	8.82
Mean difference necessary for significance, 0.01 level			17.29	8.32	33.66	11.80

* Flat white wall paint containing vegetable oil vehicle.

NOTE: Emulsions were applied at the rate of 5 ml. of 1% toxicant per square foot. Each emulsifiable concentrate consisted of 25% by weight of toxicant + 10% *Triton X-100* + 65% xylene.

acted as a contact poison. Another is that, previous to the first test, dust in the laboratory stimulated or seeded the drying deposit. The DDT deposits on glass or galvanized iron in all instances were more tenacious than those on porous surfaces such as wood, brick, and *Cellutex,* where erosion was significantly high. DDT on painted wood did not appear to be toxic either initially or residually. No doubt the DDT was absorbed into the paint and retained. There was no evidence in these tests that the DDT eventually bloomed, as would be expected if the solvent capacity of the oil paint were exceeded. On *Cellutex* and brick, the DDT residues were similar in longevity and erosion to those on wood. The degradation of DDT deposits was most evident upon whitewashed and concrete surfaces. In all probability the alkalinity of these substrates caused a dehydrohalogenation decomposition. DDT emulsions on galvanized iron exhibited high toxicity and longevity.

The residual longevity of the remaining four toxicants listed in tables 9 and 10 was influenced by the same external environmental degradants as was DDT, with a few exceptions that are discussed in the following paragraphs.

Chlordan-treated wood panels were little influenced by any external factors since greatest loss of chlordan was through volatilization or absorption. In the field test, where chlordan was formulated with no. 9 oil and emulsified with *Atlox 1045-A,* no erosion by rain or degradation by other elements was discernible. In experiment 10, with standardized formulations, the toxicity of chlordan on wood had declined to such a low level by the time of the first test after exposure to weathering that no conclusions were possible. In contrast, erosion of chlordan by rain was plainly evident on glass panels. When no. 9 oil (experiment 9) was used as the diluent, the residual toxic life of a chlordan deposit was at least twice as long as when a xylene formulation (experiment 10) was employed. Similarly, when *PD 544-C* was used as the solvent (experiment 9), the residual toxicity of a hexachlorocyclohexane deposit was longer than when a xylene was employed (experiment 10).

Gamma hexachlorocyclohexane also reacted to its environment in a manner similar to the action of DDT, but hexa chlorocyclohexane degraded rapidly out of doors or in strong wind currents. Most of its loss was attributed to its volatility.

Rhothane D-3 was significantly more tenacious on glass than on wood, and responded to its environment in much the same manner as did DDT.

Toxaphene lost its toxicity on wood much more rapidly than on glass panels held in the laboratory. Simple physical absorption of *Toxaphene* by the wood i suggested as an explanation.

Experiment 11: ***Formulation Studies.***—The data obtained in the laboratory study of the persistence of oil solutions emulsions, and suspensions are given in table 11. Studies of duration of residual toxicity were conducted to see if any one formulation was more persistent on th hazardous surfaces—whitewashed wood concrete, and painted wood—that caus apparently rapid loss of toxicity. The results show that water-wettable powder were generally superior to the other formulations on all these surfaces.

The initial toxicity of oil solutions and emulsions of DDT, as evidenced by th data in table 11, was very low on white washed wood, painted wood, concrete, an unpainted wood, and very high on glass The results here are similar to others i this study, which indicate that oil solution or emulsions of DDT are low in toxicit on porous surfaces and very high on hard smooth surfaces, such as glass, if teste before crystals have started to form.

The second test period 7 days afte treatment gave high fly mortalities o wood panels and lower on glass panel The water-wettable powders of DD were significantly more toxic on painte wood, whitewashed wood, and concret than were the oil solutions or emulsion Even with the wettable powder the alka linity of the whitewash and concrete mus have reached the DDT to cause a declin in the toxicity. This action was probabl accomplished through adsorbed wate On painted wood the toxicity decrease without any apparent reason; a possibl explanation is that the oils in the underly ing paint were capable in some manner o penetrating the wettable powder and di solving away the DDT. On glass an

Table 11.—Mortality of house flies 24 hours after exposure to various surfaces treated ith oil solutions, emulsions, and water-wettable powders of DDT and chlordan. Flies were posed to surfaces 1, 7, and 45 days after the surfaces had been treated.

Residual Insecticide Formulation	Surface	Mean Per Cent Mortality in Three Replicates		
		1 Day After Treatment of Surface	7 Days After Treatment of Surface	45 Days After Treatment of Surface
DT oil solution	Whitewash	0.0	0.6	0.0
	Painted wood*	4.9	3.5	2.2
	Concrete	0.0	1.7	0.0
	Glass	100.0	77.9	75.8
	Wood	10.7	100.0	99.4
DT emulsion	Whitewash	0.6	4.2	0.4
	Painted wood*	1.1	2.6	0.0
	Concrete	0.6	1.2	0.0
	Glass	95.5	35.1	24.6
	Wood	3.5	98.6	94.4
DT suspension	Whitewash	100.0	92.9	32.9
	Painted wood*	100.0	28.0	2.5
	Concrete	99.7	41.2	12.2
	Glass	100.0	100.0	91.2
	Wood	98.3	96.6	83.2
hlordan oil solution	Whitewash	95.7	32.9	0.3
	Painted wood*	4.5	8.1	0.0
	Concrete	16.8	5.8	0.0
	Glass	100.0	23.8	2.2
	Wood	99.4	34.5	1.0
hlordan emulsion	Whitewash	84.3	31.6	6.6
	Painted wood*	93.0	1.6	0.3
	Concrete	42.7	4.8	0.0
	Glass	99.3	81.9	2.8
	Wood	100.0	27.0	0.3
lordan suspension	Whitewash	69.0	27.5	2.5
	Painted wood*	92.9	12.1	4.2
	Concrete	41.0	7.1	0.5
	Glass	100.0	5.2	0.5
	Wood	100.0	37.9	1.9
ntrol	—	0.60	1.90	0.00
	—	1.00	0.90	0.90
ean difference necessary for significance, 0.5 level		5.53	3.78	8.46
ean difference necessary for significance, 0.1 level		7.37	5.04	11.26

* Flat white wall paint containing vegetable oil vehicle.

od panels the toxicity of the wettable wders remained at a high level.

There was no important advantage in ing a chlordan water-wettable powder surfaces where DDT water-wettable wder was superior to the DDT emulsion d oil solutions. In fact, upon glass the lordan water-wettable powder was sigficantly less effective than were the oil lutions and emulsions. The reason for e short residual action of the chlordan water-wettable powder on glass may have been associated with the greater surface area of the finely divided powder, responsible for a rapid rate of loss through evaporation. The greater loss of toxicity from the glass panels treated with chlordan oil solutions, in contrast to the emulsions, was perhaps influenced by an increase in surface area produced by a continuous film. The emulsions left a discontinuous film, which was not so subject to evaporation.

In addition, the emulsions had an emulsifier of high vapor pressure, which retards chlordan evaporation.

Experiment 12: ***Laboratory Persistence of Deposits.***—A plan was made to test more fully the residual properties of the three most promising toxic residual materials. At frequent intervals during a 31-day period, house flies were exposed for 15-minute periods to panels treated with DDT and gamma hexachlorocyclohexane and for 60-minute periods to panels treated with chlordan. The results are shown in table 12. The order of persistence on wood or glass was, from the most persistent to the least, DDT, chlordan, and gamma hexachlorocyclohexane. The suspension of hexachlorocyclohexane retained its toxicity at a high level for 10 days; then its toxicity declined rapidly. Chlordan lost its toxicity gradually through the test period, whereas DDT emulsion on wood seemed to increase in effectiveness.

The lower toxicity exhibited by the emulsion of DDT and *PD 544-C* on glass than on wood from the first day to the last is typical of DDT residues in which a slowly volatilizing solvent is used and crystallization is progressive. In other words, the frequent exposure of flies to these surfaces did not permit sufficient supersaturated fluid to accumulate, which is essential for the production of high toxicity residues composed of minute crystals. Again, a physical law determining crystal size was responsible for the toxicity attained. The number of crystals per unit mass is directly proportional to the rate of crystallization, which is dependent upon the degree of supersaturation. Blooming of DDT on wood occurred between the second and sixth days and produced a residue that remained toxic throughout this experiment.

The thick white residue of the gamma hexachlorocyclohexane water-wettable powder was slightly more toxic and persistent when applied to glass than to wood. The longevity of the chlordan and hexa-

Table 12.—Mortality of house flies 24 hours after exposure to wood and glass panels treated with DDT, hexachlorocyclohexane, and chlordan. Flies were exposed to treated surfaces at designated periods of time after the surfaces had been treated.

Insecticide	Deposit of Toxicant in Mg. per Square Foot	Surface	Replicate No.	Per Cent Mortality 24 Hours After Exposure to Surface Stated Number of Days After Treatment of Surface								Exposure Time in Minutes
				1	2	4	6	10	12	24	31	
DDT emulsion	50	Wood	1	37	40	57	93	91	100	100	100	15
	50	Wood	2	49	48	60	96	81	75	85	100	15
	50	Wood	3	21	49	97	100	100	100	100	100	15
			Mean	35.7	45.7	71.3	96.3	90.7	91.7	95.0	100.0	—
	50	Glass	1	46	27	18	22	20	16	22	12	15
	50	Glass	2	76	24	19	15	15	13	12	13	15
	50	Glass	3	56	31	19	27	30	17	16	15	15
			Mean	59.3	27.3	18.7	21.3	21.7	15.3	16.7	13.3	—
Gamma isomer (5.2 per cent) hexachlorocyclohexane in a water-wettable powder	50	Wood	1	99	98	54	74	56	12	6	2	15
	50	Wood	2	100	96	65	86	43	17	7	3	15
	50	Wood	3	94	94	66	77	40	16	10	2	15
			Mean	97.7	96.0	61.7	79.0	46.3	15.0	7.7	2.3	—
	50	Glass	1	100	100	100	100	84	71	21	8	15
	50	Glass	2	100	100	100	100	100	81	16	4	15
	50	Glass	3	100	100	100	100	90	86	10	0	15
			Mean	100.0	100.0	100.0	100.0	91.3	79.3	15.7	4.0	—
Chlordan emulsion	50	Wood	1	96	92	75	69	62	54	19	15	60
	50	Wood	2	98	95	80	77	60	33	22	6	60
	50	Wood	3	92	88	57	54	50	18	17	11	60
			Mean	95.3	91.7	70.7	66.7	57.3	35.0	19.3	10.7	—
	50	Glass	1	100	100	52	52	34	19	9	0	60
	50	Glass	2	100	100	52	55	33	25	14	3	60
	50	Glass	3	100	100	74	67	45	17	17	7	60
			Mean	100.0	100.0	59.3	58.0	37.3	20.3	13.3	3.3	—

chlorocyclohexane residues was nearly equal. Chlordan seemed slightly more lasting on wood, and hexachlorocyclohexane lasted longer on glass.

In this particular experiment, table 12, chlordan was of about equal effectiveness on wood and on glass, while in most of the previous work the chlordan emulsion residue on glass gave more lasting toxicity than on wood. If an explanation of these results is desired, it might be found in the difference in the composition of the wood panels or the environment in which the panels were held. The cause of the degradation of chlordan on glass was attributed to dust and debris that accumulated upon the oily surface. In the experiment described above, dust and debris left on the surface by the flies may have been more important than that floated in by air currents. Not only will dust and dirt mask the chlordan, but may assist evaporation by increasing the evaporation area just as with water-wettable powder (experiment 11). It is not beyond reason to believe that the chlordan-treated glass surface was roughened by the fly contacts of the frequent exposures, resulting in greater surface area for evaporation. Also, the higher initial toxicity of chlordan-treated panels suggests a greater loss incurred by physical contact of the flies.

Experiment 13: ***Laboratory Study of DDT Emulsion on Glass and Wood.***—The results of experiments summarized in table 12 seemed to indicate some peculiar properties of the initial toxicity of DDT emulsions on glass and wood. Another experiment was undertaken to broaden the scope of the investigation. This involved a closer study of the initial toxicity periods. Consequently, data were obtained from deposits of DDT that were less than 1 day old. The results obtained, summarized in table 13, disclose the "blooming out" (crystallization of DDT on the surface) period of DDT on wood and reveal in the treatment on glass the loss of toxicity that occurred as the emulsion dried.

In this experiment, as in previous tests, no toxic bloom of fine powdery crystals occurred on glass, since fly stimulation and seeding of surface were too frequent to permit the accumulation of supersaturated solvents. Consequently, there was a gradual formation of large crystals of low toxicity. The greatest fly mortality from exposures to glass panels occurred before any DDT crystals were found; the opposite was true in the case of DDT emulsions on wood. Besides the seeding action by flies, many environmental components may influence the rate and kind of DDT bloom to appear on a surface. The same solvent may yield large crystals one day, and the next day, when the temperature is higher and air movements greater, it may produce small crystals.

Experiment 14: ***Approximate Residual Toxicity of Several New Insecticides to the House Fly.***—Several new insecticides that have recently come under study are briefly considered here and compared with DDT and chlordan. Ten per cent solutions of *Marlate* (4,4′-dimethoxy-diphenyl trichloroethane), *E4* (diethyl *p*-nitrophenyl phosphate), *Pyrenone* (actually 10 per cent piperonyl butoxide and 0.5 per cent pyrethrins), *118* (1,2,3,4,10,10-hexachloro-1:4, 5:8-diendomethano-1,4,4a,5,8,8a-hexahydronaphthalene), parathion (diethyl *p*-nitrophenyl thiophosphate), heptaklor 1 (or 3a),4,5,6,7,8,8-heptachloro-3a,4,7,7a-tetrahydro-4,7-methanoindene, and *497* (oxygen

Table 13.—Mortality of house flies exposed 15 minutes to wood and glass panels at stated intervals after treatment of panels with 1 per cent DDT emulsion.

Deposit of DDT in Mg. per Square Foot	Surface	Replicate	Per Cent Mortality 24 Hours After Exposure to Surface Stated Period of Time After Treatment of Surface						
			4 Hours	8 Hours	1 Day	3 Days	5 Days	17 Days	24 Days
50	Wood	1	4 1	13 4	29 0	100.0	100 0	100 0	100 0
50	Wood	2	3 9	14 5	47 5	100 0	100 0	100 0	100 0
50	Glass	1	100.0	59 0	36 0	29 1	21 9	22 0	15 9
50	Glass	2	100.0	66 0	58 0	75 0	28 0	21.6	12 1

analogue of *118*) in *Velsicol AR-60* (methylated naphthalenes) were sprayed in triplicate upon glass and wood panels to produce deposits of 50 mg. per square foot. Flies were exposed for 30-minute periods to these panels each week until the toxicants had degraded to a low level. One set of three panels of wood and glass was exposed to direct sunlight and wind but protected from rain; a similar set was kept in the laboratory.

Table 14 was designed to help evaluate the residual activities of the toxicants in periods of weeks needed to degrade a deposit to 50 per cent of its initial toxicity.

Table 14.—Approximate number of weeks required for residual insecticides to degrade to 50 per cent of their initial toxicity to house flies. Flies were exposed 30 minutes to each panel which had been treated with insecticide at the rate of 50 mg. per square foot of treated surface.

Material Dissolved in *Velsicol AR-60*	Outside		Inside	
	Wood	Glass	Wood	Glass
Marlate	1.5	1.0	4.5	2.0
V4	1.0	1.5	7.5	14.5
Pyrenone	0.5	0.5	2.5	4.5
DDT	4.0	2.0	12.0	5.5
118	1.0	1.0	5.5	1.5
Parathion	0.5	0.5	1.5	2.0
Heptaklor	1.5	1.0	5.5	1.5
Chlordan	1.0	1.0	5.0	2.0
497	—	—	10.0	7.0

The residual values of the volatile toxicants in particular were extended by the relatively nonvolatile solvent, *Velsicol AR-60*. Experiments with *Pyrenone* in xylene gave a 50 per cent degradation value on glass in only 1.25 weeks; *Pyrenone* in *Velsicol AR-60* required 4.5 weeks for 50 per cent degradation. Similarly, chlordan in xylene had a 50 per cent degradation value on wood in 2 weeks; chlordan in *Velsicol AR-60* required 5 weeks in the experiment described above to sink to the same degradation value. The same kind of solvent effect was noted in experiments described earlier in this study. Undoubtedly there are, among the insecticides listed in table 14, toxicants that would serve well as substitutes for DDT when house-fly tolerance for DDT becomes too high to effect practical control.

SUMMARY

DDT, gamma hexachlorocyclohexane, chlordan, *Rhothane D-3,* and *Toxaphene* were applied on various surfaces and exposed to different environmental conditions in several experiments to determine their residual toxicities to the house fly, *Musca domestica* Linnaeus. The toxicities of the residues were determined by exposing the flies in specially constructed exposure cages to the treated surfaces for certain periods of time and holding the flies for a 24-hour mortality count.

The conclusions for the experiments herein reported are as follows:

1. DDT and gamma hexachlorocyclohexane were initially the most toxic compounds. The other three materials were, in order of their diminishing toxicity, chlordan, *Rothane D-3,* and *Toxaphene.*

2. Hexachlorocyclohexane gave the most rapid knockdown, followed by DDT, *Rhothane D-3,* chlordan, and *Toxaphene.*

3. Degree of coverage of surface affected mortality more than the dosage variations or uneven distribution of DDT.

4. A wall coat containing 5 per cent DDT (formulated from a 25 per cent DDT emulsifiable concentrate) was nearly as effective on wood as 50 per cent water-wettable DDT powder.

5. When DDT water-wettable powder was applied at different dosages to glass, a dosage mortality relationship was not evident above 12.5 mg. toxicant per square foot; a dosage range of 12.5 to 200.0 mg. resulted in nearly 100 per cent mortality. Below 12.5 mg. a typical sigmoid dosage-mortality curve was obtained.

6. In fly-erosion tests, there was little significant difference in fly mortality among 10 cages exposed successively to the same deposit of 50 mg. DDT per square foot.

7. Fly erosion was noticeable in tests with *Deenate* water-wettable powder on glass and xylene-DDT, *Velsicol AR-60*-DDT, and *HB-40*-DDT emulsions on wood, except when secondary blooming occurred.

8. Secondary or seeded blooms that occurred with certain formulations were very toxic and resisted fly erosion. On wood, those DDT emulsion formulations containing *PD 544-C* or xylene (with either ethyl-

ene dichloride or carbon tetrachoride) as the solvents produced exceedingly heavy mats of very fine crystals of high toxicity when seeded by fly activity. Bone glue 5 per cent, added to *Deenate* water-wettable powder improved tenacity. DDT, 1.26 per cent, in 95 per cent ethyl alcohol when applied to glass produced a deposit of extremely fine crystals of high toxicity and tenacity.

9. DDT-xylene emulsion deposits on glass or wood when seeded early (within 2 days after application) produced a fairly effective secondary bloom.

10. High toxicity and tenacity of deposits were associated with the fineness of DDT crystallization upon the surface.

11. No difference in toxicity or tenacity of deposits could be attributed to the method of application (spraying or painting).

12. Vapors from gamma hexachlorocyclohexane were about three times as toxic to flies as those from chlordan; both were extremely toxic as fumigants. The fact that toxic vapors are given off from chlordan and hexachlorocyclohexane deposits accounts for their short-lived residual action on exposed surfaces.

13. Solvents of low volatility increased the residual toxicity of the more volatile insecticides.

14. DDT was the most persistent insecticide tested. The residual toxicity of DDT emulsions was better indoors on porous surfaces, such as wood, brick, and *Cellutex,* than on glass and galvanized iron. Out of doors, residues were more persistent on the nonporous glass and galvanized iron panels.

15. The order of persistence of the residual treatments was, from the most to the least, DDT, *Rhothane D-3, Toxaphene,* chlordan, and hexachlorocyclohexane.

16. The oil solutions and emulsions of the chlorinated hydrocarbons were relatively nontoxic to flies when applied to whitewash, painted wood, and concrete. Water-wettable powders produced effective residual deposits on these same three surfaces.

17. Sunshine, rain, and wind were found to be significant climatic factors in the degradation of the residual surface toxicities of the materials tested. Wind was apparently the least significant of the three.

18. With a few exceptions, when DDT emulsions were applied to wood, the toxicity increased as the DDT "bloomed out"; when the emulsions were applied to glass, the toxicity decreased as the emulsions dried and crystals formed parallel to the glass surface.

19. In a study on newer insecticides, *V4* and *497* on wood and glass produced residues of significant longevity with high toxicity. Other materials tested were less persistent.

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