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PHYSICOCHEMICAL MECHANISMS FOR THE REMOVAL OF INSECT WAX BY MEANS OF FINELY DIVIDED POWDERS

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RELATION OF LIPID ADSORPTIVITY OF POWDERS TO THEIR SUITABILITY AS INSECTICIDE DILUENTS

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RELATION OF LIPID ADSORPTIVITY OF POWDERS TO THEIR SUITABILITY AS INSECTICIDE DILUENTS[1]

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INTRODUCTION

It has been well established that sorptive powders can cause the death of insects, sometimes with remarkable rapidity, by removing a portion of the very thin layer of lipid, averaging about 0.25 μ in thickness, that covers the insect epicuticle and normally prevents desiccation (Alexander *et al.*, 1944;[4] Hurst, 1948; Helvey, 1952; Glynne Jones, 1955; Nair, 1957; Ebeling and Wagner, 1959; Wagner and Ebeling, 1959; Tarshis, 1959, 1960, 1961; and Micks, 1960).

It thus might be assumed that sorptive diluents should increase the insecticidal effectiveness of toxicants by adding their independent effect as lipid removers. However, preliminary tests showed that this is not always the case; with some toxicants, the sorptiveness of the diluent proved to be highly detrimental. Obviously, if an inert powder having the ability to cause the death of an insect is to be less effective as a diluent than one without insecticidal effect, some adverse action must take place when that powder is combined with the toxicant.

The purposes of the present investigation were (1) to determine the independent influence of sorptive and nonsorptive powders on the ultimate effects of the toxicants by applying them to insects for brief periods before the latter were treated with the toxicants; (2) to determine the effects of these same powders when used as diluents for the toxicants; and (3) to find an explanation for the differences in insecticidal effectiveness of toxic dusts that might be caused by the different types of diluents.

MATERIALS AND METHODS

The insect species used in this investigation were adult *Drosophila pseudoobscura;* adult males of the German cockroach, *Blattella germanica,* and of the brown-banded cockroach, *Supella supellectilium;* full-grown nymphs of the drywood termite, *Kalotermes minor,* and of the dampwood termite, *Zootermopsis angusticollis.*

Drosophila pseudoobscura is much larger than the familiar *D. melanogaster* and much more resistant both to the effects of toxicants and to the desiccating effect of sorptive powders. The flies used in the present investigation were obtained from the laboratory of Dr. Carl C. Epling, who rears them in large numbers throughout the year in connection with genetics investigations. The flies are reared in a uniform manner in half-pint milk bottles, and

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[4] See "Literature Cited" for citations, referred to in the text by author and date.

various lots are mixed together and aspirated from a single bottle, to insure representative samples for the tests.

The cockroaches were obtained from the laboratory of Dr. I. Barry Tarshis. They were reared in wide-mouthed gallon jars and thrived best on Purina Dog Chow Checkers. Each jar contained a roll of corrugated paper, to afford the necessary hiding and resting places for the cockroaches.

Drywood termites were obtained in large numbers from the dead limbs of walnut trees. Nymphs tapped from split sections of large limbs were placed on about ten disks of paper toweling that had been fitted into petri dishes. The uninjured insects crawled away from the top sheet of paper to find shelter among the sheets below. Those remaining on top were discarded. The termites could be kept for months in good condition between the sheets of paper, which they used for food. The full-grown nymphs were used in the experiments.

Dampwood termites were obtained through the cooperation of local termite operators.

The classifications of the diluents used, and some pertinent physical and chemical characteristics, are shown in table 1. Classifications as "sorptive" or "nonsorptive," referring to powders used alone or as diluents, were established as follows: Plastic vials with an average outer surface area of 61 sq. cm. were dipped into melted beeswax, to obtain a wax film averaging about 65 μ in thickness and about 290 mg. in weight. Twenty-four hours later, the vials were mechanically shaken in 50 cc. of powder for one hour. Five trials were made for each powder. The powder was removed by gentle washing with the aid of a cotton swab, and the quantity of wax removed by the powder was determined gravimetrically. This was done at temperatures ranging from 22° to 24° C. The powders that adsorbed 3 mg. or more of wax from these vials were considered to be "sorptive" and the remainder to be "nonsorptive." The "sorptive" powders included the silica aerogels, montmorillonite clays, attapulgite clays, and activated carbon. The "nonsorptive" powders included botanical powders, natural and synthetic oxides of silicon, oxides of iron, carbonates, sulfates, silicates, and volcanic minerals. It happens that this division also marks a striking difference in the ability of the powders to kill insects by desiccation.

Dibrom was initially used as the test toxicant because of a chance observation of the adverse effect of sorptive diluents on this compound. To prepare the diluted toxic dusts, a concentrate dust of 20 per cent Dibrom in Pikes Peak Clay was diluted with the various types of diluents to the required concentration. The results with Dibrom were so striking that a comparative evaluation of a wide variety of toxicants, as affected by their diluents in dust formulations, was considered to be desirable. Of all the toxicants tested, Dibrom and the closely related DDVP proved to be the most adversely affected by sorptive diluents of all the toxicants tested, although this tendency was noted, to a lesser extent, with the other organophosphorous compounds, malathion, parathion, and Dylox.

For the evaluation of the diluents or insecticide dusts, one cubic centimeter of the powder was placed in a four-ounce jelly jar, with a bottom area of 45 sq. cm. and with a screened lid. The number of insects placed in each jar was as follows: *Drosophila*, about fifty, aspirated from the mixing jar; cockroaches, five; and termites, ten. All tests were made in triplicate, and the data in the accompanying tables are the averages of three tests.

"Knockdown" was considered to be the point at which *Drosophila* or termites were unable to move their entire bodies, even though appendages were still moving, and the point at which cockroaches turned over to lie on their backs. With any insect, "death" was considered to be the condition in which no further movements of the bodies or the appendages could be discerned.

The experiments in which the insects were exposed to sorptive or nonsorptive powders before they were treated with toxicants were made as follows: The insects were placed in the powder, as described above. After a predetermined period of contact with the powder, the latter was sieved through the screens on the jar lids. As much powder as possible was blown off the insects' bodies. They were then placed in a toxic dust prepared with a nonsorptive diluent.

Pretreatment with Sorptive and Nonsorptive Powders

In the evaluation of the effect of diluents in insecticide dusts, data on (1) their independent action (effect when applied previous to the application of the toxicant), and (2) their action when used as diluents, would appear to be pertinent. Tables 2 and 3 show the effects of pretreatment with sorptive and nonsorptive powders on the effectiveness of Dibrom against *Drosophila* and two species of cockroaches.

In the experiments with *Drosophila* (table 2), flies that were pretreated for ten minutes with highly sorptive powders (Olancha Clay, Pikes Peak Clay, and Santocel C), which are also effective in killing insects by desiccation, increased the average period required for 100 per cent knockdown of the flies 3.3-fold when compared with the average period required after pretreatment with walnut-shell flour, Mississippi Diluent, and blue talc, which are all relatively nonsorptive. The period for 100 per cent knockdown was increased 4.4-fold when the flies were pretreated for twenty minutes, but further pretreatment did not influence the period required for toxic action. The average period required for 100 per cent knockdown after pretreatment with walnut-shell flour, Mississippi Diluent (treated), and blue talc was about the same as when the insects were not pretreated.

With the German and brown-banded cockroaches (table 3), pretreatment with sorptive powders had an effect that was directly opposite to that obtained with *Drosophila.* Pretreatment with the sorptive powders (Pikes Peak Clay and Attaclay) *decreased* the period required for 100 per cent knockdown of the insects by a 2 per cent Dibrom dust. A ten-minute pretreatment had greater effect than a sixty-minute pretreatment. With sorptive powders, it decreased the period required for a 100 per cent knockdown by 60.6 per cent for the German cockroach and 66.7 per cent for the brown-banded cockroach, when compared with the untreated check. As with the *Drosophila,* the average effect of pretreatment with nonsorptive powders (walnut-shell flour and Insecticide Grade Pyrophyllite) was not significantly different from that with no pretreatment.

TABLE 1

CLASSIFICATIONS AND PROPERTIES OF SOME COMMON INSECTICIDE DILUENTS AND OTHER POWDERS

Class	Diluent	Particle size	Specific surface (meters^2/g.)	Oil adsorption* (per cent)	pH	Change in weight of beeswax film† (mg.)
BOTANICALS	Walnut-shell flour	97% 100-mesh	0.4–0.5	56	4–5	+ 1.0 ± 0.12
ELEMENTAL MINERALS	Electric Sulfur	98% 100-mesh	0.375	32	5–6.5	+ 1.8 ± 0.22
OXIDES OF SILICON						
Diatomites	Celite 209	91% < 10 μ	15–25	172	7	− 1.0 ± 0.15
	Dicalite 1G-5	90% 100-mesh	22	155	5.7–7.6	− 0.5 ± 0.10
Tripolites	Silica 400-mesh	99.5% 325-mesh	....	46	9.6	− 2.3 ± 0.43
	Silica DCR	100% 325-mesh	....	31	6.9–7.1	− 0.3 ± 0.09
Synthetics	Hi-Sil 233	Average 0.022 μ	160–175	170	7.3	− 3.7 ± 0.24
	Santocel C	"Typical" 3–5 μ	130–150	300	3.5	− 3.0 ± 0.26
	SG-67 (contains fluoride)	82% 0.1–4.8 μ	247	255	2.6	− 3.5 ± 0.48
	SG-68	82% 0.1–3.2 μ	300	300	7.0	− 4.2 ± 0.53
	Silikil D (contains fluoride)	86% 325-mesh	....	51	...	− 1.3 ± 0.21
OXIDES OF IRON	Red iron oxide	98% < 40 μ 70% < 0.5 μ	....	25	5.5	− 1.2 ± 0.18
CARBONATES						
Calcium limes	Mississippi Diluent	99% 325-mesh	0.55	18	9.3	+ 1.9 ± 0.37
			0.55	18	9.3	+ 2.3 ± 0.47

Gypsums	Barytes	99.7% 325-mesh	1.0	14	5.8	+ 1.8 ± 0.18
	Blue Diamond Gypsum	76.4% 325-mesh	....	23	...	+ 2.1 ± 0.36
	Calcined gypsum	79.6% 325-mesh	....	52	...	− 1.7 ± 0.22
SILICATES						
Mica	No. 1473 Mica	53.8% 325-mesh	....	34	9.0	+ 0.8 ± 0.16
Talc	Blue talc	99% 325-mesh	....	44	8.4	− 0.9 ± 0.12
	No. 2952 Clatal	99.8% 325-mesh	....	45	7.2	− 1.0 ± 0.14
	Emtal 23A	97.7% 325-mesh	....	36	8.5	+ 1.4 ± 0.24
SYNTHETIC CALCIUM SILICATES						
Pyrophyllites	Amcolite No. 1	96.8% 325-mesh	....	46	7	− 2.6 ± 0.27
	Insecticide Grade Pyrophyllite	93.5% 325-mesh	0.45	50	6–7	− 1.2 ± 0.22
Montmorillonites	Olancha Clay	91% 325-mesh	130	120	6.75	− 4.8 ± 0.48
	Pikes Peak Clay	95.8% 325-mesh	....	86	5.2	− 5.2 ± 0.50
	Wyoming Bentonite	95% 400-mesh	....	45	8.0	− 0.5 ± 0.08
Kaolinites	No. 1431 China Clay	99.3% 325-mesh	....	43	4.55	− 1.5 ± 0.22
	GX Kaolin	99.75% 325-mesh	1.8	22	5.2	− 1.3 ± 0.20
	Barden Clay	Average $< 1\ \mu$	23	35	5	− 1.6 ± 0.27
Attapulgites	Attaclay	85% 325-mesh	120	119	6.9–7.1	− 5.3 ± 0.44
	Diluex A	90–95% 325-mesh	120–140	120	6.8–7.1	− 4.6 ± 0.53
VOLCANIC MINERALS	Frianite K	98.9% 325-mesh	....	36	5.4–6.5	− 1.1 ± 0.17
VEGETABLE ORIGIN	Activated carbon	90% 325-mesh	545	130	9–11	− 5.8 ± 0.31

* Oil adsorption data were obtained from manufacturers, from Watkins and Norton (1955), or from tests made by the writers, but were in any case based on adsorption of linseed oil according to the rub-out test as described by Gardner (1930).

† Plastic vials with an outer surface area of 61 sq. cm. were dipped into melted beeswax, to obtain a film of wax averaging about 60 μ in thickness and about 290 mg. in weight. Twenty-four hours later, the vials were mechanically shaken in 50 cc. of powder for one hour. The powder was removed by gentle washing with the aid of a cotton swab, and the quantity of wax removed by the powder was determined gravimetrically. The temperature ranged from 22° to 25° C.

‡ The addition of 0.2 per cent fatty acids has resulted in a monomolecular film of calcium soap.

TABLE 2

EFFECT OF PRETREATMENT OF *DROSOPHILA* WITH DILUENTS ON THE PERIOD REQUIRED FOR 100 PER CENT KNOCKDOWN FROM 2 PER CENT DIBROM IN MISSISSIPPI DILUENT*

Diluents used in pretreatment	Period (minutes) required for 100 per cent knockdown after pretreatment in diluent for:		
	10 minutes	20 minutes	40 minutes
Walnut-shell flour	3	3	3
Mississippi Diluent	2.5	3	3
Blue talc	3	3.5	3
Olancha Clay	11	14	14
Pikes Peak Clay	8	17	14
Santocel C	9	11	11
None	2.5	2.5	2.5

* Temperature, 18° C.; relative humidity, 57 per cent.

TABLE 3

EFFECT OF PRETREATMENT OF COCKROACHES WITH DILUENTS ON THE PERIOD REQUIRED FOR 100 PER CENT KNOCKDOWN FROM 2 PER CENT DIBROM IN INSECTICIDE GRADE PYROPHYLLITE*

Species of cockroach	Diluents used in pretreatment	Period (minutes) required for 100 per cent knockdown after pretreatment in diluent for:	
		10 minutes	60 minutes
German	Walnut-shell flour	22	33
	Pyrophyllite	19	17
	Pikes Peak Clay	8	14
	Attaclay	7	13
	None	19	..
Brown-banded	Walnut-shell flour	18	23
	Pyrophyllite	13	11
	Pikes Peak Clay	7	9
	Attaclay	5	8
	None	18	..

* Temperature, 24° C.; relative humidity, 63 per cent.

A similar test was made with drywood termite nymphs. Only three powders were used in pretreatment, and the termites were then placed on a dust of 2 per cent Dibrom in Mississippi Diluent (treated). The average number of minutes required for 100 per cent knockdown after a ten-minute pretreatment with the various powders was as follows: SG-68, twenty-four; Insecticide Grade Pyrophyllite, thirty-two; and Mississippi Diluent, seventy-nine. Results were not significantly different when the termites were pretreated for one hour. The period required for 100 per cent knockdown when the termites were not pretreated was twenty-three minutes, approximately the same as with the sorptive powder SG-68.

Effect of Sorptive Powders When Used as Diluents

A stock dust of 20 per cent by weight of Dibrom in Pikes Peak Clay (highly sorptive) was diluted to 2 per cent by weight of Dibrom with thirty-one of the powders listed in table 1. Since the diluents varied widely in their bulk density, the quantity of Dibrom required varied accordingly. In table 4, the quantity of toxicant required per cubic centimeter of powder is shown.

By referring back to table 1, the change in weight of films of beeswax, when shaken with the various powders in a mechanical shaker for one hour, can be found for the powders listed in table 4. The plus quantities indicate an increase in weights of the films owing to the penetration of the hard, heavy, nonsorptive particles into the wax, from which many could not be removed by washing. These particles were, on the average, the least effective in killing *Drosophila* by desiccation, with no Dibrom added, and were, on the average, the most effective diluents for Dibrom, based on the period required for 100 per cent knockdown. For the thirty-one powders tested, their effectiveness as desiccants (without Dibrom) increased, and their effectiveness as diluents for Dibrom decreased, with increasing wax sorptiveness.

In general, the same relationship was noted with respect to linseed-oil sorptiveness, although there were two notable exceptions. These were the diatomites Celite 209 and Dicalite 1G-5, which have high linseed-oil sorptiveness despite their low beeswax sorptiveness.

It is conceivable that the wax sorptiveness of the powders may have a relationship to their effect on the performance of the toxicant when they are applied to the insects *before* the toxicant is applied (tables 2 and 3). However, with reference to table 4, the apparent inverse relationship of insecticidal effectiveness to the wax sorptiveness of the powders probably is owing to the fact that the powders that adsorb wax most effectively are also those that adsorb the toxicant most effectively. Consequently, the toxicant is not readily adsorbed by the insect's cuticle, resulting in decreased effectiveness.

As stated previously, the great differences in bulk densities of the powders resulted in corresponding differences in the quantity of Dibrom per cubic centimeter of powder required for a 2 per cent concentration. Therefore, in a separate test, for every powder heavier than Pikes Peak Clay, only the quantity of Dibrom per cc. required for a 2 per cent concentration in Pikes Peak Clay was used, namely, 6.1 mg. Thus, all these diluents had the same quantity of toxicant per unit volume. This detracted very little from the ratio of superiority of the nonsorptive diluents. As can be seen in table 4, the five most sorptive diluents still required 9.7 times longer to effect a 100 per cent knockdown of *Drosophila* than the five least sorptive diluents, even though they all contained the same amount of toxicant per cc.

Table 4 also contains data pertaining to tests with the German cockroach. Again the ability of the powders to kill the insects by desiccation was generally roughly proportional to their ability to adsorb beeswax, and their effectiveness as diluents was inversely proportional to their sorptiveness. Among the highly sorptive powders, the two attapulgites (Attaclay and Diluex A) were particularly ineffective as diluents. With 2 per cent by weight of Dibrom, they required about twenty-four times longer to effect a

TABLE 4

EFFECT OF THIRTY-ONE DILUENTS ON THE PERFORMANCE OF DIBROM AGAINST *DROSOPHILA*, AT 2 PER CENT BY WEIGHT AND AT A CONSTANT QUANTITY PER VOLUME OF DUST; AND AGAINST GERMAN COCKROACHES AT 2 PER CENT BY WEIGHT*

Diluent†	Toxicant per cc. at 2 w./% (mg.)	*DROSOPHILA* Period (minutes) for 100 per cent knockdown with Dibrom at:			GERMAN COCKROACH Period (minutes) for 100 per cent knockdown with Dibrom at 2 w./%
		None	2 w./%	6.1 mg./cc.	
Walnut-shell flour	12.0	265	3	4	32
Electric Sulfur	16.0	134	6	8	11
Celite 209	3.7	160	12	..	15
Dicalite 1G-5	4.7	220	16	..	23
Silica 400-mesh	12.4	110	12	20	35
Silica DCR	13.4	270	4	8	17
Hi-Sil 233	4.7	85	13	..	31
Santocel C	1.5	96	17	..	64
SG-67	1.8	52	10	..	11
SG-68	2.1	90	46	..	56
Silikil D	12.2	120	18	22	13
Red iron oxide	32.4	220	5	30	42
Mississippi Diluent	18.4	540	4	4	25
Mississippi Diluent (treated)	20.7	1,560	3	4	27
No. 1887 Cal. Dust A	25.3	185	4	6	32
Barytes	31.4	220	4	7	17
Blue Diamond Gypsum	21.0	200	4	5	15
Calcined gypsum	15.6	150	7	11	30
No. 1473 Mica	13.4	220	4	7	15
Blue talc	12.3	190	4	5	23
No. 2952 Clatal	9.5	150	7	11	28
Amcolite No. 1	15.4	103	14	34	143
Insecticide Grade Pyrophyllite	18.7	300	5	6	14
Olancha Clay	8.0	72	48	48	57
Pikes Peak Clay	6.1	80	42	42	72
Wyoming Bentonite	20.4	270	14	20	64
No. 1431 China Clay	10.4	137	18	22	48
GX Kaolin	14.2	147	7	13	30
Attaclay	7.8	85	54	58	343
Diluex A	7.8	78	55	60	363
Frianite K	16.4	235	6	8	20

* For the experiment with *Drosophila*, temperature 26° C.; relative humidity, 60 per cent. For the experiment with the cockroaches, temperature, 26° C.; relative humidity, 54 per cent. In both experiments, these data refer to conditions at the beginning of the experiment.
† See table 1 for classes of the various diluents.

100 per cent knockdown of cockroaches than such nonsorptive powders as certain oxides of silicon, gypsums, sulfur, mica, and pyrophyllite.

The fluoridated silica aerogel SG-67 was the one exception to the general rule that highly sorptive powders were ineffective diluents for Dibrom when used against *Drosophila* or cockroaches. This was particularly true with respect to the latter insects, for they are especially susceptible to the contact effect of fluorides. On the other hand, No. 1431 China Clay, Amcolite No. 1, and Wyoming Bentonite proved to have an adverse effect on Dibrom, despite their relatively slight ability to adsorb wax. Therefore, one may conclude that these diluents had great ability to adsorb Dibrom, despite their low wax sorptiveness. The practical experience of the insecticide industry confirms that Wyoming Bentonite, at least, has great ability to adsorb organic toxicants.

The powders listed in table 4 were divided into five groups, with respect to wax sorptiveness, as shown in table 5. The ability of these powders to knock down both *Drosophila* and the German cockroach by desiccation, and their effectiveness as diluents for Dibrom, are shown in this table. Their ability to knock down the insects by desiccation increased, and their value as diluents decreased, with increasing sorptiveness.

In some ways, the most interesting data were obtained from the experiments with the nymphs of two species of termites (table 6). Termites die very slowly from the effects of even the most potent of available toxicants. Therefore, it is understandable that they should live as long, on the average,

TABLE 5

RELATION OF THE ABILITY OF POWDERS TO ADSORB BEESWAX, AND TO KNOCK DOWN INSECTS BY DESICCATION, TO THEIR EFFECTIVENESS AS DILUENTS FOR DIBROM*

Group	Number of powders	Quantity of beeswax adsorbed from 60 sq. cm. of wax film (mg.)	Period for 100 per cent knockdown of *Drosophila*		Period for 100 per cent knockdown of German cockroach	
			Diluents alone (minutes)	Diluents with 2 per cent Dibrom (minutes)	Diluents alone (hours)	Diluents with 2 per cent Dibrom (minutes)
1	7	None	462	4.0	57.3	20.3
2	7	0.3 to 1.0	207	8.7	35.0	28.9
3	9	1.1 to 2.6	169	10.2	26.6	45.5
4	3	3.0 to 3.7	90	13.3	14.2	47.5
5	5	4.2 to 5.3	81	49.0	5.7	178.2

* The data were obtained from table 4. The data for Silikil D and SG-67 are not included, because these diluents contain a fluoride that increases their toxicity.

when treated with sorptive powders alone as when treated with the same powders with 2 per cent by weight of Dibrom. In either case, death occurred by desiccation, and no symptoms of toxication were observable. The termites evidently could adsorb very little toxicant from the highly sorptive diluents.

Both species of termites died more rapidly in sorptive powders without toxicants than in the nonsorptive powders with toxicants. This merely shows that these insects die more rapidly from desiccation than from Dibrom toxication.

Although much time is required to kill termites with toxicants, they may become paralyzed with comparative rapidity. When treated with Dibrom in nonsorptive diluents, which generally did not interfere with adsorption of the toxicant by the insect cuticle, the tendency was for the termites to become completely motionless, appearing at first as if they had died from the effect of the toxicant. If examination was periodically continued, however, it was found that the insects eventually resumed very feeble motions of the appendages. They remained in this moribund state for a greater period than that required for death by desiccation of the termites in sorptive powders. The period required for the beginning of paralysis, i.e., the initial complete cessation of activity, averaged 0.75 hour for drywood termites and 0.36 hour for dampwood termites (table 6).

TABLE 6

EFFECT OF DILUENTS ON THE EFFECTIVENESS OF 2 PER CENT DIBROM DUSTS AGAINST THE NYMPHS OF DRYWOOD AND DAMPWOOD TERMITES*

Diluents	Diluent alone		Diluent with 2 per cent Dibrom			
	Period for 100 per cent kill (hours)		Period to beginning of paralysis (hours)		Period for 100 per cent kill (hours)	
	Drywood termite	Dampwood termite	Drywood termite	Dampwood termite	Drywood termite	Dampwood termite
(Nonsorptive)						
Walnut-shell flour	100.5	32.0	0.58	0.31	7.4	8.7
Silica DCR	12.0	12.0	1.00	0.57	6.0	9.2
Mississippi Diluent	85.3	26.0	0.96	0.50	8.6	8.7
Barytes	12.0	11.0	0.57	0.25	6.9	7.4
Blue Diamond Gypsum	158.7	31.0	0.50	0.23	5.4	7.6
Blue talc	38.8	10.1	0.88	0.33	6.4	9.2
No. 1473 Mica	8.2	10.7	0.61	0.30	5.0	7.5
Silikil D	8.0	7.8	0.90	0.43	4.9	8.3
Average	52.9	17.6	0.75	0.36	6.3	8.3
(Sorptive)						
SG-67	2.1	4.6	....†	....	2.1	4.7
Hi-Sil 233	3.5	5.9	....	....	2.7	6.0
Olancha Clay	3.6	5.3	....	....	3.1	5.3
Pikes Peak Clay	4.0	5.3	....	....	3.6	5.7
Attaclay	4.2	6.0	....	....	4.0	5.4
Diluex A	4.1	5.9	....	....	4.0	6.1
Average	3.6	5.5			3.2	5.5

* The temperatures ranged from 20° to 29° C., and the relative humidities ranged from 60 per cent to 100 per cent. At the beginning of the experiment, the temperature was 23° C., and the relative humidity was 75 per cent.
† Paralysis never became apparent. Body movements gradually declined in intensity until time of death.

Elutriation of the Toxicant

In the previous experiments, the dilute dusts were made by mixing inert powders with a concentrate dust of Pikes Peak Clay containing 20 per cent by weight of Dibrom. The dilutions were made with a wide variety of sorptive and nonsorptive powders. In the following experiment, an attempt was made to determine the residual toxicity of nonsorptive diluents after the Dibrom concentrate dust had been removed by air elutriation. For this purpose, unusually heavy and distinctly colored powders had to be used. A carborundum passing through a 100-mesh screen and an iron oxide dust with 90.5 per cent of its particles less than 5 μ in diameter (a theoretical 2,500-mesh) were chosen for this purpose. Elutriation was accomplished by blowing compressed air into the diluted dust formulation in a four-ounce jar. This was done in a fume hood in which the light Pikes Peak Clay-Dibrom concentrate was continuously drawn away after arising from the jar. Complete elutriation was assumed when the material left in the jar could not be distinguished from the diluent (carborundum or iron oxide), either by appearance or by odor.

Table 7 shows the ineffectiveness of carborundum and iron oxide as dust desiccants, their outstanding effectiveness as diluents for 2 per cent Dibrom (equaling that of gypsum), and their surprising degree of effectiveness even after practically all the original Pikes Peak Clay-Dibrom concentrate had been removed. This is in sharp contrast to the results with activated carbon. This is generally the most effective of all dust desiccants with which the writers have experimented, but it adsorbs Dibrom so firmly that little is available to the insect. Thus, with 2 per cent by weight of Dibrom, activated carbon was less effective than carborundum and iron oxide from which practically all the Dibrom had been removed. The extremely small quantity of Dibrom adhering to the hard, nonporous surfaces of the particles of carborundum and iron oxide was adsorbed by the insect cuticle in larger quantities than was the large amount of Dibrom held within the porous particles of the activated carbon.

TABLE 7

TOXICITY TO *DROSOPHILA* OF DILUENTS AIR-ELUTRIATED FROM DUSTS CONTAINING 2 PER CENT DIBROM DILUTED FROM A 20 PER CENT MIXTURE IN PIKES PEAK CLAY*

Materials	Period for 100 per cent knockdown (minutes)
Carborundum (100-mesh)	360
Carborundum with 2 per cent Dibrom	2
Carborundum with the Dibrom elutriated	9
Iron oxide	453
Iron oxide with 2 per cent Dibrom	3
Iron oxide with the Dibrom elutriated	8
Gypsum	297
Gypsum with 2 per cent Dibrom	3
Activated carbon	58
Activated carbon with 2 per cent Dibrom	32

* Temperature at beginning of experiment, 25° C.; relative humidity, 54 per cent.

Difference in Rate of Decrease in Insecticidal Effectiveness of Various Dust Formulations of Dibrom When Progressively Diluted

Various concentrations of Dibrom were prepared by diluting a concentrate of 20 per cent Dibrom in Pikes Peak Clay with increasing proportions of a number of sorptive and nonsorptive powders. Their effectiveness against *Drosophila* was determined. The results are shown in table 8. The sorptive powders (SG-68, Pikes Peak Clay, and Attaclay) were less effective diluents, even with as high as 10 per cent concentrations of Dibrom. In addition, they decreased in effectiveness with subsequent dilutions at a much greater rate than the nonsorptive powders. The increases in period required for knockdown of *Drosophila* between 10 per cent concentrations and 0.2 per cent concentrations of Dibrom averaged 18.4-fold for the sorptive powders, compared with 1.2-fold for the least sorptive of the powders (walnut-shell flour, Electric Sulfur, and Barytes). Blue talc and Barden Clay showed the effects of their moderate sorptiveness, when compared with the other "nonsorptive" powders, particularly after the dilution from 2.0 to 0.2 per cent. Barden Clay, particularly, may be considered as an intermediate between the powders of least sorptiveness and the highly sorptive powders such as the silica aerogels and certain montmorillonite and attapulgite clays.

Comparative Tests with Various Toxicants

To determine whether the influence of the diluents might vary with different toxicants, some experiments were made in which organophosphorous toxicants (Dibrom, DDVP, parathion, malathion, and Dylox), chlorinated

TABLE 8

EFFECT OF PROGRESSIVELY GREATER DILUTIONS OF DIBROM IN SORPTIVE POWDERS, COMPARED WITH NONSORPTIVE POWDERS, WHEN USED IN DUST FORMULATIONS AGAINST *DROSOPHILA**

Class	Powder	Period (minutes) for 100 per cent knockdown with toxicant at:				
		10%	5%	2%	0.2%	0.0%
Botanical	Walnut-shell flour	2	2	2	2.5	285
Elemental mineral	Electric Sulfur	2	2	2	2.3	310
Gypsum	Barytes	2	2	2	2.5	344
Talc	Blue talc	2	2	3	9	283
Kaolinite	Barden Clay	3	5	7	52	336
Silica aerogel	SG-68	8	14	20	120	142
Montmorillonite	Pikes Peak Clay	5	12	21	96	110
Attapulgite	Attaclay	6	13	42	135	127

* Temperature, 27° C.; relative humidity, 58 per cent.

hydrocarbons (chlordane, dieldrin, and lindane), and a carbamate (Sevin) were used. The experiments followed the same pattern as the preceding ones. With each insecticide, the effect of pretreatment with the sorptive and nonsorptive powders on the subsequent action of the toxic dust was determined. As before, the toxic dust was prepared with nonsorptive diluents: Mississippi Diluent (treated) or Insecticide Grade Pyrophyllite. This test was always followed by a test of the influence of the sorptive and nonsorptive powders when used as diluents for the above toxicants. The sorptive powders were Pikes Peak Clay, Attaclay, and SG-68. The nonsorptive powders were Electric Sulfur, Mississippi Diluent (treated), Barytes, Emtal 23A, and Insecticide Grade Pyrophyllite. The data in tables 9 and 10 pertain to the averages of all sorptive and all nonsorptive powders.

The results of the pretreatment experiments are shown in table 9. Contact of *Drosophila* with sorptive powders for periods of ten to forty minutes decreased their susceptibility to the organophosphorous toxicants. On the other hand, pretreatment with sorptive powders increased the susceptibility of the flies to lindane and the carbamate Sevin.

Contact of German cockroaches with the sorptive powders for periods of ten to sixty minutes increased the susceptibility of the insects to all the toxicants used in these tests. It is apparent that the independent effect of sorptive powders may be either detrimental or beneficial, depending on the insect to be treated and the toxicant involved.

The tendency was for insects that were not pretreated in a powder to die, when exposed to the toxicant, in approximately the same period as when they were pretreated in a nonsorptive powder.

Table 10 shows that, regardless of the independent effect of the sorptive powders, as indicated in the pretreatment experiments (see table 9), when they were used as diluents, they decreased the susceptibility of *Drosophila* to all toxicants except Sevin and lindane.

In the experiments with the German cockroach, the data for dieldrin and chlordane are not applicable to the present problem because the slowness of their toxic action resulted in death by desiccation, when sorptive diluents were used, long before toxication became evident. The period required to knock down and kill cockroaches with chlordane or dieldrin in sorptive diluents was never significantly different from the period required to knock them down or kill them with the corresponding sorptive powders alone. However, when no toxicant is present, a certain percentage of the cockroaches have a tendency to die without first lying on their backs. Therefore, when they no longer move about, they must be forcibly turned so as to lie on their backs. If they can no longer get back on their feet, they are considered to be "knocked out."

The sorptive powders, when used as diluents, decreased the susceptibility of the cockroaches to the organophosphorous toxicants, had no effect with respect to lindane, and increased their susceptibility to Sevin.

It is noteworthy that regardless of their independent action in pretreatment, the sorptive powders always decreased the effectiveness of the organophosphorous toxicants with both species of test insects. This adverse effect of the sorptive powders, when used as diluents, is believed to be the result of their ability to adsorb the toxicant so firmly that it is not readily available to the insect. It may logically be assumed that the toxicants that are liquids in their pure state would be the most adversely affected by adsorption. Among the toxicants used, Dibrom, DDVP, parathion, malathion, Dylox, and chlordane are liquids, although chlordane is rather viscous. Dylox is a solid in the pure state, but remained in a nonvolatile solvent as used in the present experiments.

Lindane and Sevin, which are crystalline solids in the pure state, were not adversely affected by sorptive diluents and, in fact, Sevin was benefited in the test with cockroaches (table 9). The crystalline solids are possibly subject to a certain amount of adsorption, but the independent action of the sorptive diluent may be beneficial and balance the adverse effect of adsorption. This would be most apt to be the case with Sevin and lindane, for their action against both *Drosophila* and cockroaches was markedly enhanced by pretreatment of the insects with sorptive powders.

Of all the toxicants used, Dibrom, DDVP, and Dylox were by far the most adversely affected by sorptive diluents. With Dibrom, the ratio of superiority of the nonsorptive diluents, when compared with the sorptive diluents, was

TABLE 9

EFFECTS OF PRETREATMENT OF INSECTS WITH SORPTIVE AND NONSORPTIVE POWDERS ON THE EFFECTIVENESS OF VARIOUS TOXICANTS AGAINST *DROSOPHILA* AND COCKROACHES*

Insect	Toxicant	Concentration (per cent)	Period of pretreatment (minutes)	Temperature (°C.)	Relative humidity (per cent)	Period (minutes) for 100 per cent knockdown when pretreated with:		Difference	L.S.D. at $p = 0.05$
						Sorptive powders†	Nonsorptive powders‡		
Drosophila	Dibrom	0.2	10	24	57	9	3	6	1
	Dibrom	0.2	20	24	57	14	3	11	3
	Dibrom	0.2	40	24	57	13	3	10	1
	DDVP	1	20	25	50	11	1	10	2
	Parathion	2	25	24	27	33	23	10	4
	Malathion	2	25	24	49	33	14	19	4
	Dylox	5	25	21	36	36	15	21	5
	Lindane	2	20	25	50	9	14	5	2
	Sevin	2	25	27	22	21	37	16	5
German cockroach	Dibrom	2	10	24	63	7	21	14	2
	Dibrom	2	60	24	63	13	25	12	7
	DDVP	1	20	22	12	7	10	3	2
	Parathion	2	10	24	43	36	42	6	6
	Malathion	2	10	25	38	45	65	20	11
	Dylox	5	20	22	40	64	91	27	17
	Lindane	2	15	24	38	15	26	11	8
	Sevin	2	10	24	32	14	42	28	8

* The insects were placed in 1 cc. of diluent in four-ounce jelly jars, then screened and blown free of excess diluent before being placed in a mixture of toxicant and nonsorptive diluent.

† The sorptive powders were Pikes Peak Clay, Attaclay, and the silica aerogel SG-68.

‡ The nonsorptive powders were Electric Sulfur, Mississippi Diluent (treated), Barytes, Emtal 23A, and Insecticide Grade Pyrophyllite.

TABLE 10

COMPARATIVE PERFORMANCES OF VARIOUS DILUENTS WITH DIFFERENT TOXICANTS AGAINST *DROSOPHILA* AND COCKROACHES*

Insect	Toxicant	Concentration (per cent)	Temperature (°C.)	Relative humidity (per cent)	Period (minutes) for 100 per cent knockdown when toxicant diluted with:		Difference	L.S.D. at $p = 0.05$
					Sorptive diluents	Nonsorptive diluents		
Drosophila	Dibrom	2	26	60	47	5	42	4
	DDVP	1	24	29	52	1	51	11
	Parathion	2	24	36	47	19	28	6
	Malathion	2	26	21	54	12	42	6
	Dylox	5	22	40	62	7	55	13
	Chlordane	5	25	54	71	63	8	7
	Dieldrin	5	23	44	100	76	24	18
	Lindane	2	22	44	30	32	2	5
	Sevin	2	24	54	37	34	3	7
German cockroach	Dibrom	2	26	52	157	18	139	46
	DDVP	1	22	41	93	7	86	34
	Parathion	2	26	18	48	36	12	3
	Malathion	2	25	19	60	36	24	18
	Dylox	5	22	21	242†	93	..	..
	Chlordane	5	22	50	203†	1,356	..	..
	Dieldrin	5	23	48	330†	1,485	..	..
	Lindane	2	22	48	34	33	1	6
	Sevin	2	22	50	18	40	22	7

* The insects were placed in 1 cc. of toxic powder in four-ounce jelly jars. The sorptive and nonsorptive diluents were the same as those used in the experiments shown in table 9.

† The cockroaches appeared to have died of desiccation, so the effect of the diluent on the toxicant could not be determined.

9.4 to 1 with *Drosophila* and 8.2 to 1 with the German cockroach. With DDVP, the superiority of the nonsorptive diluents was 52 to 1 with *Drosophila* and 13.3 to 1 with the German cockroach. With Dylox, the superiority of the nonsorptive diluents was 8.9 to 1 with *Drosophila* and over 2.6 to 1 with the cockroach. Death of the cockroaches occurred before toxication took place.

TABLE 11

COMPARATIVE PERFORMANCE OF A PYROPHYLLITE AND A MONTMORILLONITE CLAY WITH EQUAL QUANTITIES OF TOXICANT PER VOLUME OF DILUENT*

Insect	Toxicant	Pikes Peak Clay formulations		Insecticide Grade Pyrophyllite formulations		Difference (minutes)	L.S.D. at $p = 0.05$
		Per cent by weight	100 per cent knockdown (minutes)	Per cent by weight	100 per cent knockdown (minutes)		
Drosophila....	Dibrom............	4	22	2	5	17	3
	DDVP.............	2	16	1	3	13	2
	Parathion..........	4	39	2	18	21	4
	Malathion..........	4	36	2	16	20	4
	Dylox..............	10	63	5	10	53	6
	Lindane............	4	14	2	14	0	3
	Chlordane..........	10	55	5	58	3	8
	Dieldrin............	10	56	5	54	2	8
	Sevin...............	4	40	2	38	2	6
German cockroach..	Dibrom............	4	18	2	12	6	3
	DDVP.............	2	14	1	8	6	3
	Parathion..........	4	35	2	37	2	5
	Malathion..........	4	28	2	30	2	4
	Dylox..............	10	66	5	58	8	8
	Lindane............	4	28	2	30	2	5
	Chlordane..........	10	117†	5	436	..	..
	Dieldrin............	10	120†	5	450	..	..
	Sevin...............	4	9	2	12	3	2

* Pikes Peak Clay has approximately one-half the bulk density of Insecticide Grade Pyrophyllite; therefore, the per cent by weight of toxicant was made twice as high in the Pikes Peak Clay formulation in order to insure the same quantity of toxicant per unit volume in the two formulations. Temperature, 23° C.; relative humidity, 45 per cent.

† The cockroaches were knocked down and killed by desiccation before any appreciable toxic action could take place. The period for 100 per cent knockdown for cockroaches treated with Pikes Peak Clay alone was 118 minutes and, for pyrophyllite alone, twenty-one hours.

Diluents with Equal Quantities of Toxicant per Unit Volume

It is shown in table 4 that when an equal quantity of Dibrom was used per unit volume of sorptive and nonsorptive powders, the latter were still greatly superior as diluents. An experiment was made to determine if this would hold true for certain other toxicants.

It happens that the bulk density of Insecticide Grade Pyrophyllite (nonsorptive) is practically twice that of Pikes Peak Clay (sorptive). Therefore, if toxicants are used in twice the concentration in the latter diluent, the quantity per unit volume will be approximately the same in the two diluents. Nine toxicants were added to Pikes Peak Clay in two times higher concentration than to Insecticide Grade Pyrophyllite. Table 11 shows that, when used against *Drosophila,* the pyrophyllite was superior to clay when organophosphorous toxicants were added, but was no better than clay as a diluent for the other toxicants. With the German cockroach as the test insect, pyrophyllite was superior as a diluent for Dibrom, DDVP, and Dylox, but for no other toxicants. On the other hand, the clay proved to be more effective than the pyrophyllite as a diluent for Sevin.

In both tables 10 and 11, Sevin was more effective in sorptive than in nonsorptive diluents when used against cockroaches, whereas no significant differences were found between the two types of diluent when Sevin was used against *Drosophila.* This may result from the beneficial independent effect of the sorptive diluents, and adverse effect with the nonsorptive diluents, when the cockroach is used as the test insect (see table 9). However, in one experiment made independently of those depicted in tables 10 and 11, Sevin proved to be more effective in Pikes Peak Clay than in Insecticide Grade Pyrophyllite, both against *Drosophila* and against the German cockroach. At 2 per cent concentration in the clay, Sevin knocked down *Drosophila* in forty-six minutes; at 4 per cent in clay, forty minutes; and at 2 per cent in pyrophyllite, sixty-six minutes. The corresponding figures when the German cockroach was used as the test insect were eleven, ten, and eighteen, respectively. The temperature was 27° C., and the relative humidity was 32 per cent.

Comparison of Sorptive and Nonsorptive Diluents in Old Residues

An experiment was made to determine whether the superiority of the sorptive powders as diluents for organophosphorous toxicants continues with increasing age of the residues of the toxic dusts. Formulations of 1 per cent DDVP in Attaclay and in Insecticide Grade Pyrophyllite were prepared. *Drosophila* and German cockroaches were placed in 1 cc. of each of these formulations in four-ounce jelly jars, as in previous experiments. After each test, the insects were removed but the powders remained. Since there were only four sets of jars for each insect species, and the tests were made at weekly intervals, each jar had to be used twelve times during the experiment, which was begun on December 26, 1959, and completed on March 22, 1960. The experiment was made in a well-lighted room with a mean temperature of 23° C. and a mean relative humidity of 39 per cent.

The increase in period required for 100 per cent knockdown with increasing age of the toxic residues is shown in table 12.

DDVP showed a remarkable degree of persistence in pyrophyllite, in view of the brief period of residual activity generally displayed by this insecticide under ordinary conditions of usage. It was not possible to compare the performance of this toxicant in the two types of diluent over the entire three-month period, because with *Drosophila,* death by desiccation took place in the sorptive diluent before toxic action was apparent, even on the first day of the experiment. With cockroaches, the toxic action of the DDVP had decreased during the third month of the experiment to such an extent that again the insects were killed by desiccation before any toxic action was evident.

TABLE 12

INCREASE IN PERIOD REQUIRED FOR 100 PER CENT KNOCKDOWN OF *DROSOPHILA* AND MALE GERMAN COCKROACHES IN RESIDUES OF 1 PER CENT DDVP IN A SORPTIVE AND IN A NONSORPTIVE DILUENT OVER A PERIOD OF THREE MONTHS*

Insect	Diluent	Average period (minutes) for 100 per cent knockdown during:		
		First month	Second month	Third month
Drosophila	Attaclay	83†	79†	88†
	Pyrophyllite	3.8	5.2	7.8
German cockroach	Attaclay	34	92	187†
	Pyrophyllite	6.2	20.5	32.3

* The experiments lasted from December 26, 1959, to March 22, 1960. The mean temperature for that period was 23° C., and the mean relative humidity was 39 per cent.
† The insects died from desiccation, resulting from the adsorption of the lipid from their epicuticles by the diluents, before death by toxication could take place.

DISCUSSION

The choice of the diluents in the preparation of insecticide dusts has traditionally been influenced by the following factors: (1) chemical compatibility with the toxicant, (2) bulk density, (3) particle size and distribution, (4) flowability, (5) dustability, (6) abrasiveness, (7) adsorptivity, and (8) price and availability.

Adsorptivity has been considered in relation to the amount of toxicant that can be incorporated into the diluent. In the case of liquid toxicants, it is essential that the desired concentration of toxicant be adsorbed without impairing the flowability and dustability of the final product. In the present paper, it is shown that adsorptivity of the diluent is of importance not only in relation to formulation problems, but also in relation to its adverse effect on the insecticidal efficiency of dusts containing liquid toxicants. This effect becomes increasingly important with decreasing concentration of the toxicant in the dilute dust.

It is usually necessary to use highly sorptive diluents for the preparation of dust concentrates, for the quantity of toxicant in these concentrates may vary from 20–25 per cent up to 75 per cent by weight. However, it would appear that nonsorptive diluents could be used to advantage in diluting concentrates with liquid toxicant down to the percentage used in field application, because of the greater insecticidal efficiency of formulations containing such diluents. This presumes, of course, that the nonsorptive diluents would have the other desirable characteristics listed above, besides their nonsorptivity.

In view of the undesirable characteristic of sorptive diluents of preventing free access of the liquid toxicants to the insect cuticle, it would appear to be desirable whenever possible to spray such toxicants directly onto a nonsorptive diluent in the quantity used in the ultimate dust formulation. This would appear to be particularly desirable with toxicants on which sorptive diluents have an especially adverse effect, such as Dibrom, DDVP, and Dylox. On the other hand, it appears that most toxicants that are solid in the pure or technical state are affected little, if any, by the degree of sorptiveness of the diluent; the effectiveness of Sevin against cockroaches is actually *increased* by the use of a highly sorptive diluent.

The writers are aware that the pH of the diluent may have some influence on the insecticidal effectiveness of a toxicant. The pH's of the various powders used in this investigation are given in table 1. This table shows that there was a wide range of pH among both sorptive and nonsorptive powders, yet this did not prevent their acting as a class, with regard to their effect on toxicants, when they were used as diluents.

SUMMARY

When adult *Drosophila pseudoobscura* were placed on "sorptive" powders (Olancha Clay, Pikes Peak Clay, and Santocel C) before being placed in a 2 per cent Dibrom dust, the period required to bring about their "knockdown" was 3.3 times longer than when they were placed in "nonsorptive" powders—walnut-shell flour, Mississippi Diluent (treated), and blue talc—or when they were not "pretreated."

With German and brown-banded cockroaches, pretreatment with sorptive powders had an effect that was directly opposite to that obtained with *Drosophila*. A ten-minute pretreatment with the sorptive powders caused the German cockroaches to be knocked down in 60.6 per cent less time, and the brown-banded cockroaches in 66.7 per cent less time, than when they were pretreated with nonsorptive powders.

In the pretreatment experiments with drywood termites, results were similar to those obtained with cockroaches.

Regardless of the independent effect of the sorptive powders on the susceptibility of the insects to Dibrom, as indicated by the pretreatment experiments, they were much less effective than the nonsorptive powders as diluents for Dibrom when effectiveness was based on the period required for paralysis or knockdown. This was the case with all insect species tested: two species of cockroaches and termites and one species of *Drosophila*. The reason appears to be that the sorptive powders, when used as diluents, adsorb the toxicant so effectively that it cannot be adsorbed by the insect cuticle in quantities adequate for rapid toxication.

In the case of the two species of termites, when sorptive powders were used as diluents for Dibrom, toxication was retarded to such an extent that the insects died of desiccation before signs of paralysis became apparent. They died no more rapidly than did the termites treated with the same powders without the addition of Dibrom. On the other hand, when nonsorptive powders were used as diluents, paralysis occurred rapidly. However, the period required for death to occur was greater than when the sorptive powders were used as diluents, for the latter killed the insects by desiccation. Desiccation resulted in the death of termites more rapidly than toxication.

With both cockroaches and termites, the independent effect of the sorptive powders was to increase the rate of toxic action of the subsequently applied

Dibrom, yet these powders proved to be the least effective diluents because they tended to retard the release of the toxicant to the insect cuticle.

When 2 per cent Dibrom was added to powders of carborundum and iron oxide (both nonsorptive) and subsequently removed by air elutriation, the remaining powder was far more toxic to *Drosophila* than an unelutriated dust of 2 per cent Dibrom in activated carbon (highly sorptive).

When formulations of 10 per cent Dibrom in powders of various degrees of adsorptiveness were diluted progressively down to 0.2 per cent, those in the three least sorptive powders decreased only 20 per cent, whereas those in the three most sorptive powders decreased 18-fold, in rate of toxic action against *Drosophila.*

Following the experiments with Dibrom as the test toxicant, a comparative study of various toxicants was made. Using *Drosophila* as the test insect, pretreatment with sorptive powders decreased the rate of toxic action of the organophosphorous compounds, but increased the rate of toxic action of lindane and Sevin. When the German cockroach was used as the test insect, pretreatment with sorptive powders increased the rate of toxic action of all toxicants.

When used as diluents, the sorptive powders decreased the rate of toxic action of all organophosphorous compounds against both *Drosophila* and the German cockroach. However, there was no difference in the effect of sorptive and nonsorptive diluents when lindane was used as the toxicant. With Sevin, the sorptive diluents increased the rate of toxic action against the German cockroach, but were not significantly different from the nonsorptive diluents against *Drosophila.* Chlordane and dieldrin could not be tested in this respect against German cockroaches because the sorptive diluents resulted in their death by desiccation before toxication could take place. When used against *Drosophila,* they resulted in knockdown more rapidly when diluted with the nonsorptive diluents.

As might be expected, the sorptive diluents had the most deleterious effect when used with toxicants that were liquid in the pure or technical state, which included all the organophosphorous toxicants used in the experiments. However, among the organophosphorous compounds, Dibrom, DDVP, and Dylox were far more adversely affected than were parathion and malathion. The ratios of periods (minutes) required for 100 per cent knockdown with sorptive diluents compared with nonsorptive diluents were as follows: with 2 per cent Dibrom against *Drosophila,* 9.4 to 1, and against the German cockroach, 8.2 to 1; with 1 per cent DDVP against *Drosophila,* 52 to 1, and against the German cockroach, 13.3 to 1; with 5 per cent Dylox against *Drosophila,* 8.9 to 1, and against the German cockroach, over 2.6 to 1 (the sorptive diluents caused death by desiccation).

In one experiment, Dibrom was used at 2 per cent concentration by weight in Insecticide Grade Pyrophyllite and 4 per cent in Pikes Peak Clay, so as to provide equal quantities of toxicant per unit volume, for the pyrophyllite has twice the bulk density of the clay. Under these conditions, the pyrophyllite mixture was still superior as an insecticide when the organophosphorous toxicants were used.

Residues of 2 per cent dust concentrations of DDVP in Insecticide Grade

Pyrophyllite and in Pikes Peak Clay were allowed to age indoors for a period of three months. The period required for 100 per cent knockdown of *Drosophila* with the DDVP-pyrophyllite dust increased from 3.8 to 7.8 minutes during that period, while with the DDVP-clay dust, death by desiccation took place before the paralyzing effect of the toxicant was evident. The period for 100 per cent knockdown of the German cockroach with the DDVP-pyrophyllite dust increased from 6.2 to 32.3 minutes during the three months of the experiment, while with the DDVP-clay dust, it increased from 34 to 187 minutes. The latter figure was not significantly different from the period required to knock down cockroaches by means of the clay without toxicant. There was no longer sufficient toxicant present to cause a paralysis of the insect before desiccation resulting from the action of the sorptive diluent.

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