TOXICITY OF INSECTICIDE RESIDUES TO *ANOPHELES QUADRIMACULATUS* AND EFFECTS ON RESTING BEHAVIOR[1]

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ABSTRACT. Laboratory tests were made to determine the toxicity of 28 insecticidal residues to *Anopheles quadrimaculatus* Say when the mosquitoes were free to leave the residues. Also, observations were made of the resting behavior of mosquitoes exposed to the residual deposits. When known numbers of female mosquitoes were released into screened cages each containing an untreated and an insecticide-treated box, only two —methoxychlor and Abate® (*O,O'*-(thiodi-*p*-phenylene)*O,O,O',O'*-tetramethyl phosphorothioate) —were ineffective. Three—DDT, carbaryl and Gardona® (2-chloro-1-(2,4,5-trichlorophenyl dimethyl phosphate)—were moderately effective. All other compounds killed a high percentage of the mosquitoes though the mosquitoes were not confined continuously on the residual deposits and could rest on untreated surfaces. Thus, repellency, irritability, or avoidance behavior did not prevent all or a high percentage of the mosquitoes from obtaining a lethal dose.

Our laboratory maintains a continuing program concerned with the development and evaluation of insecticides for use as residual treatments against female anopheline mosquitoes that can transmit malaria. Basically the program involves the testing of promising insecticides against laboratory-reared females from both a DDT-susceptible and a DDT-resistant colony of *Anopheles quadrimaculatus* Say and determining the length of time a given residual deposit remains highly effective. The long-lasting, more effective compounds are then tested against naturally occurring populations of *A. quadrimaculatus* in the Southeastern United States. Thus, in laboratory studies, the mosquitoes are confined for varying times on residual deposits; in the field studies, the mosquitoes can attempt to avoid or leave these deposits if they are repelled or irritated by them. [Studies of the repellency or irritability of DDT have been summarized by Muirhead-Thompson (1960).] We therefore arranged a series of tests in the laboratory with 28 promising insecticides in which we attempted to simulate more closely the actual field conditions. Our objective was to gain added information about the effectiveness in the field. We also hoped to learn the effect of these compounds on the resting behavior of this mosquito.

METHODS AND MATERIALS. Known numbers of blood-fed *A. quadrimaculatus* females (regular, insecticide-susceptible colony) were placed in large (55 cm square and 55 cm high) screen cages containing two plywood boxes (30 x 21 x 16 cm) with one end open to provide darker areas where the mosquitoes could rest away from the light. Fluorescent lights equipped with daylight bulbs and placed above the cages produced approximately 2000 ft-c at the test box level. Thus, when the room was darkened, the mosquitoes left the boxes and were present throughout the cage; when the lights were turned on, most mosquitoes sought resting areas within the boxes. Cotton pads saturated with a 10 percent sugar-water solution were placed in each cage. The temperature was maintained at 80±2° F; the relative humidity was held between 60 and 70 percent. The front of each large screen cage was covered with plexiglass to permit observation, but a polyethylene film curtain 7 feet wide extended the full length of the area to isolate the observer from the cages and prevent the mosquitoes from being attracted to a host.

The afternoon before the test, 100 blood-

[1] This paper reflects the results of research only. Mention of a pesticide in this paper does not constitute a recommendation of this product by the USDA.

fed *A. quadrimaculatus* females were placed in each of the five test cages, and all lights were turned off from then until 9:00 am the following morning. In the morning, one untreated box and one box treated with insecticide (2 g/m^2) were placed in each of four cages; two untreated boxes were placed in the remaining cage to serve as a control and to demonstrate the normal distribution of mosquitoes. The lights were then turned on, and the mosquitoes were observed. Since most of the mosquitoes soon sought shelter in the test boxes, the length of time the mosquitoes remained in a treated box depended on the effect produced by the chemical. When the residue became more irritating than the repellency of the outside light, the mosquitoes left the box, flew around in the cage for a brief period, and then either rested on the screen in the light or re-entered a box.

Counts were taken at 15-minute intervals during the first hour of the test and thereafter once an hour for 7 hours. Each count included the number of mosquitoes resting in each box, the number flying in each cage, the number knocked down in each box, and the total knockdown in the boxes and cage. Immediately after the completion of each count, the mosquitoes were driven out of all test boxes. The lights, which were connected to a time switch, remained on until 11:00 pm and were turned off until 9:00 am the following morning. A final count was made 15 minutes after the lights were again turned on.

Seven tests, each consisting of 4 selected compounds and an untreated check, were made in this way. Each test was duplicated on another day. The positions of the treated and untreated boxes were reversed between the first to the second trials.

The chemical names of those test compounds that do not have accepted common names are listed below.

RESULTS AND DISCUSSION. The $LT_{50's}$ and $LT_{95's}$ and slopes of regressions of mortality versus time are summarized in Table 1. The first 20 compounds were highly effective in killing the mosquitoes (95–100 percent mortality in 24 hours) though the mosquitoes could leave the residual deposits in the treated boxes and rest either in an untreated box or in the cage. Three other materials—UC-8454, Cidial, and Mobam—gave 92, 93, and 86 percent mortality in 24 hours. DDT, carbaryl, methoxychlor, Gardona, and Abate were much less effective (5–66 percent mortality). This procedure required that mosquitoes be driven out of the boxes after each count was made. Thus, mosquitoes were disturbed and forced from the boxes a total of 8 times during the first 7 hours

A13—No.	Designation	Chemical name
	Boots 14991	*o*-Isopropylphenyl butyrymethylcarbamate
27127	Chevron RE-5353	*m*-(1-Methylbutyl)phenyl methylcarbamate
27699	Plant Protection PP-511	*O*-[2-(dimethylamino)-6-methyl-4-pyrimidinyl] *O,O*-dimethyl phosphorothioate
25780	Hooker HRS-1422	3,5-Diisopropylphenyl methylcarbamate
27524	BAY 85032	1,1-Dimethyl-4-indanyl-methylcarbamate
27408	CIBA C-9491	*O*-(2,5-dichloro-4-iodophenyl) *O,O*-dimethyl phosphorothioate
27213	BAY 38799	*o*-Cyclopentylphenyl methylcarbamate
27177	BAY 46650	*S*-(*o*-Chlorophenyl) *O,O*-dimethyl phosphorodithioate
27253	Union Carbide UC-8454	5,6,7,8-Tetrahydro-1-napthyl methylcarbamate
27165	Abate	*O,O'*-(Thiodi-*p*-phenylene) *O,O,O',O'*-tetramethyl phosphorothioate
25841	Gardona	2-Chloro-1-(2,4,5-trichlorophenyl)vinyl dimethyl phosphate
27386	Cidial®	Ethyl mercaptophenylacetate *S-ester* with *O,O*-dimethyl phosphorodithioate
25843	Shell SD-8530	3,4,5-Trimethylphenyl methylcarbamate
27041	Mobam®	Benzo[*b*]thien-4-yl methylcarbamate

TABLE 1.—Summary of mortality data obtained in cage tests with blood-fed female *A. quadrimaculatus*. (All treatments at 2 g/m² with 2 tests of 100 females each.)

Compound	LT_{50} (hr)	LT_{95} (hr)	Slope
Propoxur	0.6	1.6	2.2
Boots 14991	0.9	2.4	3.7
Chevron RE-5353	0.4	2.9	2.0
Shell SD-8530	0.8	3.1	2.9
Plant Protection P-511	2.3	4.8	5.2
Promecarb	0.8	5.7	1.9
Dichlorvos	0.9	5.7	2.0
Phoxim	2.0	5.9	3.5
Fenthion	3.5	6.4	6.2
Carbanolate	2.6	8.7	3.1
Malathion	2.8	10.2	2.9
Hooker HRS-1422	3.2	11.0	3.1
Dicapthon	4.3	12.0	3.7
BAY 85032	4.3	13.0	3.4
Fenitrothion	3.3	13.0	2.7
Bromophos	4.3	14.0	3.2
Chlorphoxim	5.0	14.9	3.5
CIBA C-9491	7.9	20.0	4.1
BAY 38799	4.4	21.4	2.4
BAY 46650	6.3	23.0	2.9
Union Carbide UC-8454	5.5	26.0	2.4
Cidial	4.0	28.2	1.9
Mobam	8.3	<28.0	2.2
Gardona	8.3	<28.0	2.2
Carbaryl	16.4	<28.0	2.7
DDT	29.0	<28.0	1.8
Methoxychlor	>24	<28.0	...
Abate	>24	<28.0	...

of exposure. After each disturbance, they were driven out by light to seek shelter again. Thus twenty compounds did not cause sufficient repellency, irritancy, or an avoidance reaction to prevent 95–100 percent of the mosquitoes from obtaining a lethal dose.

In addition to the information on the comparative toxicity of the insecticides when mosquitoes were free to leave the residual deposits, we hoped to learn something of the effect of the chemicals on resting behavior.

The results with the untreated controls demonstrated the expected distribution of mosquitoes at the test conditions when insecticides were not present. With this system, the control mosquitoes distributed themselves about equally between the 2 boxes and the cage. Also, after 7 hours of disturbing the mosquitoes, the number resting in the cage increased slightly, that is, not all of them entered the boxes. Thus, in the absence of insecticide, we could anticipate that the numbers could be about the same in each box and that the number in the cage would be equal to the number in either box.

Propoxur, Boots 14991, and Chevron RE-5353 had killed over 90 percent of the females by the 2-hour observation. Indeed, at 15 minutes, the number of mosquitoes resting in these treated boxes was reduced. Whether this behavior resulted from repellency, irritability, or avoidance following contact with the insecticide was thus impossible to determine. Indeed, many insecticides were so rapid in their toxic action that behavior could not be differentiated. However, the mosquitoes contacted the insecticides sufficiently to obtain a lethal dose. Avoidance seemed to be more associated with some irritating effects of contact with the insecticide than with repellency or avoidance since the mosquitoes did enter the boxes.

The 17 other compounds that were also highly effective required longer to achieve 95 percent kill (3 to 23 hours) as shown in Table 1. With these compounds, the reduced numbers of mosquitoes found in the treated boxes (increased numbers in the untreated boxes or cages) seemed mostly to be associated with irritancy or avoidance following contact with the insecticide. For example, the ratio of the number of mosquitoes in treated boxes to untreated boxes generally decreased with time while the ratio of numbers in the cage to the untreated box generally increased with time. However, five of these compounds—carbanolate, Hooker HRS-1422, dicapthon, bromophos, and CIBA 9491—produced a distribution of mosquitoes at the 15-minute observation that differed little from that in the control indication that these chemicals had little or no initial repellency.

Union Carbide UC-8454, Cidial, Mobam, Gardona, carbaryl, and DDT all caused initial low ratios of numbers of mosquitoes in treated boxes to the numbers in untreated boxes. Also, all of these com-

pounds except UC-8454 and Gardona caused increased ratios of the numbers of mosquitoes in the cage to those in the untreated boxes during the first 7 hours of observation, another indication of an irritating effect produced by contact with the chemicals.

Methoxychlor and Abate were not effective in killing mosquitoes in these tests, and Abate also had little or no effect on the resting behavior of the mosquitoes. Methoxychlor reduced the number of mosquitoes in the treated boxes and increased the number found in the cage.

Of the 28 materials studied, only 2—methoxychlor and Abate—were ineffective in killing adult mosquitoes. However, three others—DDT, carbaryl, and Gardona—were only moderately effective. The other compounds killed a high percentage of mosquitoes though the mosquitoes were not confined directly on the deposits and could fly to and rest in either an untreated box or the cage. Repellency, irritability or avoidance behavior did not prevent all or high percentages of mosquitoes from obtaining a lethal dose of the highly effective materials.

Literature Cited

Muirhead-Thompson, R. C. 1960. The significance of irritability, behavioristic avoidance and allied phenomena in malaria eradication. Bull. Wld. Hlth. Org. 22:721–734.

PRELIMINARY EVALUATION OF THE EFFECTIVENESS OF MOSQUITO BEATER®, A GRANULAR REPELLENT, AGAINST MOSQUITOES AND BLACKFLIES[1]

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ABSTRACT. Mosquito Beater® containing naphthalene and polymethylated naphthalenes performed satisfactorily as a repellent against mosquitoes and blackflies. In a limited area, the material was effective for a 24-hour period.

In recent years there has been a trend by the suburban homeowner toward increased outdoor activity, such as gardening, outdoor meals and backyard sports. There has also become decreasing tolerance of nuisance insects, particularly biting flies such as mosquitoes (Culicidae), blackflies (Simuliidae) and punkies (Ceratopogonidae).

Many devices and materials are available in hardware, farm and garden, sporting goods and even drug and grocery stores to better enable the homeowner to protect himself from these pests. Among these is a granular area mosquito repellent marketed by Bonide Chemical Company of Utica, N. Y. under the tradename, Mosquito Beater.[2] Because there have been a substantial number of inquiries regarding this product, it was tested during the summer of 1972 for its effectiveness in repelling mosquitoes and, to a lesser extent, blackflies, from small treated areas.

MATERIAL TESTED. Mosquito Beater is

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[2] This paper reflects the results of research only. Use of the trade name Mosquito Beater does not constitute a recommendation or endorsement by the N.Y. State Museum & Science Service.