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EXTERNAL APPLICATION OF PROPOXUR IN VILLAGE TRIALS AGAINST ANOPHELES ALBIMANUS IN EL SALVADOR, CENTRAL AMERICA

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A single application of propoxur at the rate of approximately 2 g/m² to the eaves and the entire outside wall surfaces of houses of open or loose construction in the coastal areas of El Salvador drastically reduced the number of intradomiciliary bites by A. albimanus and the number of early-morning resting mosquitoes for 3 to 4 weeks.

Although the second treatment was applied to the same house several weeks after the first treatment had lost most of its effectiveness, the data suggest some additive effect from the second application. This additive effect appears to be sufficient to warrant further studies of this technique, with the subsequent insecticide applications being more closely timed to coincide with the loss of an acceptable level of effectiveness from each previous treatment applied.

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EXTERNAL APPLICATION OF PROPOXUR IN VILLAGE TRIALS AGAINST *ANOPHELES ALBIMANUS* IN EL SALVADOR, CENTRAL AMERICA [1]

JOSEPH R. AUSTIN [2]

INTRODUCTION

Alternate insecticides as substitutes for DDT for use in antimalaria programs are being sought, but few compounds have reached the stage of field testing in problem areas. The Central America Malaria Research Station (CAMRS) in San Salvador, El Salvador, Central America, has tested several materials for use as residual applications to wall surfaces in villages where malaria is a problem.

Normally, residual-type insecticides are applied inside houses. DDT has been utilized in this manner for more than 20 years, but anopheline resistance to DDT has precluded its use in some areas of the world including much of Central America. Three insecticides thought to have promise against *Anopheles albimanus* were tested by CAMRS in village trials in El Salvador starting in 1969. Although carbaryl,[3] fenitrothion [4] and propoxur [5] were tested, only propoxur was judged under the conditions of the studies to be effective against *A. albimanus*.

Carbaryl applied at the rate of 2 g/m^2 prepared from an 85 percent water dispersible powder (WDP) formulation was applied twice to all inside wall surfaces in the southeastern coastal village of El Progreso. Treatments were made in June and October 1969, utilizing hand compression sprayers. No effect on the number of *A. albimanus* entering the treated houses nor on the biting rate was noted. There was only 42 percent mortality of mosquitoes in the treated houses one week after the first treatment but 100 percent mortality was observed the first week after the second treatment. However, residual effectiveness disappeared rapidly (down to 13 percent after 6 weeks) with naturally entering and departing *A. albimanus*. Hence, carbaryl was found not to be useful for the residual spraying of houses for malaria eradication in the coastal, DDT-resistant problem area of El Salvador.

Fenitrothion was tested in the coastal village of El Zapotal, also in southeastern El Salvador, in June 1969. The fenitrothion, prepared as a suspension from 50 percent WDP formulation, was applied at a target dosage of 2 g/m^2 of technical material. Four weeks after treatment *A. albimanus* morning resting densities in the treated houses equalled or exceeded pretreatment levels, and by the fifth week there was a marked decline in mortalities of mosquitoes found in the houses. Some indication of resistance of *A. albimanus* to fenitrothion was noted and a second application was not made. It was concluded that fenitrothion would not be useful for residual spraying of houses as an antimalaria measure in this coastal problem area of El Salvador.

Propoxur also was studied, utilizing exterior house treatment rather than the conventional interior treatment. An earlier study of the effectiveness of spraying of

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[1] From the Central America Malaria Research Station, San Salvador, El Salvador, Malaria Program, Center for Disease Control, Health Services and Mental Health Administration, Public Health Service, U. S. Department of Health, Education, and Welfare, Atlanta, Georgia 30333. This work was supported by the Agency for International Development, U. S. Department of State.

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[3] Carbaryl (OMS-29) = 1-naphthyl methylcarbamate.

[4] Fenitrothion (OMS-43) = o,o-dimethyl o-(4-nitro-m-tolyl) phosphorothioate.

[5] Propoxur (OMS-33) = o-isopropoxyphenyl methylcarbamate.

houses in Sabah, East Malaysia, had indicated that external spraying of walls with DDT at 4 g/m² appreciably reduced inside contact between man and the malaria vector of that area, *Anopheles balabacensis* (Cheng, 1968). In late 1969 a preliminary study therefore was made in El Salvador of the effectiveness of exterior house treatments with target dosages of 4 g/m² of DDT and 2 g/m² of propoxur. Based on all-night biting rates and early-morning house captures, there was no measurable effect with the DDT treatment. In two open-type houses built with vertical pole walls treated exteriorly with propoxur at 2 g/m² there was a 30 percent to 89 percent reduction of inside biting by *A. albimanus* during 5 weeks and 86 percent to 100 percent reduction in one closed house for a period of 8 weeks.

These results suggested further consideration of this method with propoxur and consequently a small village-scale trial was carried out in March 1970. Because of the difficulty of finding adequate populations of *A. albimanus* in El Salvador at this time of year for such a test, an area on the shores of Lake El Jocotal, with a high dry-season mosquito density, was chosen. In that area there are two small fishing villages, El Borbollón and La Curruncha, situated along the edge of El Jocotal. This lake is located in the southeastern part of El Salvador in a valley some 25 meters above sea level. The houses are small and the construction is mainly of the "open" type, e.g., vertical poles, thatch, palm.

The village of El Borbollón was selected for treatment while the nearby village of La Curruncha was left untreated as a control. The houses in both villages had previously been sprayed with DDT at 2 g/m² for several years as part of the National Malaria Eradication Program (Campaña Nacional Anti-Paludica, CNAP).

MATERIALS AND METHODS. For the first treatment with propoxur (March 1970) the locality of El Borbollón was divided into two parts. The exterior treatment of houses at one end of the village included only the eaves and the upper half of the walls (Area I) while treatment of the remaining (Area II) houses included the eaves and the entire walls. In the second treatment (May 1970) all of the houses in the El Borbollón study were treated alike, i.e., the eaves and all outside wall surfaces were sprayed. The evaluation, however, continued with the village divided into the designated Areas I and II to note any difference in results.

INSECTICIDE TREATMENT. The village was treated 5 March by four spraymen furnished by CNAP, using conventional hand-operated compression sprayers. The standard house-spraying technique had to be altered due to the open condition of the houses. The method of facing and spraying directly against the surface would have allowed considerable insecticide to penetrate into the houses, thus extensively contaminating the inside. The sprayman was trained to spray from an angle. The distances and speed remained the same as in conventional spraying but the sprayman directed the spray at an angle one way then returned in the opposite direction thus treating all outer portions of any round surface, such as poles, with a minimum of insecticide falling inside the house. Twenty-one houses were treated with one-half coverage and 35 with the total outside treatment, utilizing 37 sprayer charges and 11 working hours.

A second treatment was begun on 6 May with three spraymen from CNAP using the same equipment. This time all houses were treated equally and included all eaves and exterior surfaces of the walls. Fewer houses were treated for a total of 52, but only 19 charges were used, obviously resulting in a considerably lower applied dosage of insecticide than in the first test. Several houses in the study group were left unsprayed in this second test as they were in the process of being rebuilt. The spraying of 52 houses by the three men was completed in one 8-hour day.

The insecticide formulation utilized was 70 percent propoxur WDP, prepared

as a 5 percent suspension. The results of limited tests in three houses, in the second cycle, indicated variable deposits of 2 g/m^2 to 4 g/m^2 of propoxur being applied, when the target dosage was 2 g/m^2. With this outside spraying technique, occupants of the houses were requested only to turn over bed covers, to remove animals, and to remove food or cover it well. It was not necessary to remove household furniture. No complaints were received from the occupants and none reported illness in either test spraying. There was, however, in both treatments one sprayman who experienced nausea and had to rest. No further problems were reported.

ENTOMOLOGICAL EVALUATION OF EFFECTIVENESS. Evening and all-night captures from human bait were made weekly in two "fixed point" houses in the one-half treated area (Area I), two in the total treatment portion (Area II), and two in the untreated control village. The peridomiciliary captures began at 1800 hours and continued until 2000 hours when normally the majority of rural people go inside the houses. The door is usually closed and shortly thereafter they retire. The observer entered the house at 2000 hours and, with the door closed, remained inside until 0600 hours making the mosquito captures directly from his exposed legs. Supervision had to be close as to the starting hour and time of entering the house as well as during the long late hours.

EVENING FOUR-HOUR HUMAN BAIT CAPTURES. These weekly captures were made from 1800 to 2000 hours (peridomiciliary) and 2000 to 2200 hours (intradomiciliary) for two purposes: first as a check to see if a shorter period could be used to show density changes instead of the long, difficult, 12 hours of overnight observations, and secondly as a check against the 12-hour captures that were carried out during the same week.

In all human bait captures the "bait" was rotated among the test houses. The same two "fixed point" houses in the villages were utilized as in the 12-hour captures. The 4-hour captures were made during the first test only.

MORNING HOUSE RESTING DENSITIES. House checks were made weekly for live and dead anophelines in 10 "fixed point" houses in Area I, 10 in Area II of the treated village, and 10 in the control village. There were two men to each group making the captures with aspirator and flashlight. They spent approximately 15 minutes per house. The female *A. albimanus* encountered were grouped into bloodfeds, gravids, and nonfeds. The live specimens were held with sugar-water soaked cotton pads for 24-hour mortality observations. The men making the searches were rotated among the houses being examined.

OUTSIDE FUMIGANT TESTS. In an attempt to ascertain if a correlation existed between the fumigant action of the insecticide and the results of the human bait captures, one "fixed point" house in Area I and one in Area II were used for special outside fumigant tests. Small round wire cages 10 cm by 7 cm were placed approximately 14 cm above the ground level and 10 cm from the wall surface and in the eaves area approximately 10 cm from the surfaces. There were two cages to a side, one in the eaves the other near the ground. Ten to 15 blood-fed females captured in the nearby cattle corral were placed in each wire cage. The *A. albimanus* utilized were captured as blood-fed females the night of the test and taken to the village to be placed around the test houses. The exposure began at approximately 2000 hours and continued for 3 hours if there was not 100 percent mortality earlier in all cages. The final mortalities were recorded at the end of the 3-hour period. Survivors were not held for 24-hour mortalities. Two cages were held in the vehicle as controls.

BIOASSAYS OF OUTSIDE WALL SURFACES. Bioassays were made once prior to treatment and on weeks 2 and 6 during the first test, and only once on week 1 during the second test. The bioassays were made on wood, thatch, mud, tile and poles in

houses in each treated area and in the untreated village. The pole tests were divided into "high" and "low," as the higher portion under the eaves was better protected and the insecticide deposits might last longer than in the lower areas near the ground. A specially designed chamber for such round surfaces was utilized in these tests, two being used in each wall—one high and one low—for a total of eight chambers per house. Ten to 15 blood-fed females from the El Jocotal corral were used in each chamber. Because the tests were done at 0600 hours, i.e., after daylight, the chambers were covered with brown paper toweling to reduce the admission of light which would stimulate the escape mechanism so apparent among *A. albimanus* at this time of day. At the end of the 30-minute exposure period the test mosquitoes were removed from the chambers using CO_2 gas anesthesia, and were held for 24 hours for mortality readings.

RESULTS

EVENING/ALL NIGHT HUMAN BAIT CAPTURES. The results for both peridomiciliary and intradomiciliary biting rates in the first and second test are summarized in Table 1. There were four weekly observations made prior to treatment which indicated a very high density in the three parts of the overall study area. The control village and Area II (total treatment) had approximately the same density with average intradomiciliary captures, respectively, of 427 and 478 total *A. albimanus*, while Area I (partial treatment) had less with 293.

Following the treatment it was noted that in the houses in which only one-half of the outer walls were treated (Area I), a marked reduction of intradomiciliary biting occurred only on week 1. In the houses with complete outside spraying there was a notable reduction of intradomiciliary biting for 3 to 4 weeks before returning to pretreatment levels.

In the second test, in which the exterior of houses in both Areas I and II were treated completely, there were good reductions for 4 or 5 weeks, respectively.

EVENING FOUR-HOUR HUMAN BAIT CAPTURES. These captures, made only in the

TABLE 1.—Average number of *A. albimanus* bites/hour from 1800 to 0600 hours in and around two houses in each area. Treatments with propoxur 2 g/m², El Borbollón, 1970.

		Area I		Area II		Control no treatment	
Date	Week	Peri.*	Intra.**	Peri.*	Intra.**	Peri.*	Intra.**
15 Jan.	−7	20.7	17.4	49.7	39.5	47.7	44.6
29 Jan.	−5	51.7	43.2	96.7	94.3	89.7	57.3
12 Feb.	−3	105.2	25.4	93.0	40.3	41.5	34.1
26 Feb.	−1	49.0	31.4	34.5	17.1	54.5	34.8
5 Mar.	0	Partial Outside Treatment		Total Outside Treatment			
12 Mar.	1	11.7	2.1	65.2	5.9	72.7	98.1
19 Mar.	2	29.7	18.6	50.0	7.3	65.0	93.0
24 Mar.	3	36.7	30.6	21.0	8.4	72.2	124.0
2 Apr.	4	48.7	28.2	51.0	25.7	79.0	120.1
9 Apr.	5	92.0	40.5	120.0	72.2	67.0	70.1
21 Apr.	−2	63.0	30.6	26.2	26.2	16.7	48.6
29 Apr.	−1	68.5	38.1	48.0	12.5	35.7	60.4
6 May	0	Total Outside Treatment		Total Outside Treatment			
14 May	1	10.0	.6	11.2	1.2	5.7	14.2
21 May	2	15.5	3.4	36.5	1.8	21.2	11.5
2–3 Jun.	4	99.0	9.6	159.7	12.5	111.5	59.4
9–10 Jun.	5	50.0	21.8	64.5	13.7	89.0	42.6

* Peridomiciliary counts made between 1800 and 2000 hours.
** Intradomiciliary counts made between 2000 and 0600 hours.

first test, showed a marked reduction in inside biting for Area I during the first week, followed by a steady rise; however, not until week 5 was the biting rate equal to pretreatment levels. A marked reduction of intradomiciliary biting occurred in Area II during a 4-week period with pretreatment levels being reached by the fifth week. In general, the results of the short, 4-hour observation period, appeared to confirm the results of the longer 12-hour captures (Table 1).

MORNING HOUSE-RESTING DENSITIES. The captures of live and dead mosquitoes inside the 10 "fixed" houses in the first test showed a reduction in the number of mosquitoes entering the treated houses for 3 weeks in both Areas I and II (Table 2). In the second test a reduction in the number of entering mosquitoes was again noted during a 4-week period (Table 2) while the mortalities in the two areas were about the same.

It is of interest that on week 4 of the second test, the average of the 10 "fixed point" treated houses in Area II was 0.7 live *A. albimanus* per house. In contrast one untreated house within the treated Area II yielded 29 and the houses in the untreated village gave an average of 26.9 live mosquitoes per house. On week 5, when the effectiveness of the insecticide had appeared to "break," there were 36 live mosquitoes in the same untreated house and the untreated village had an average of 32.1 mosquitoes per house. Although on week 5 the 10 "fixed" treated houses in Area II had an average of only 5.1 *A. albimanus* per house, in one of these houses 40 specimens were found.

The marked reduction of early morning house-resting densities of *A. albimanus* following each of the exterior treatments with propoxur generally paralleled the reduction in the human bait captures (Table 1). The early morning captures, therefore, in this locality are considered a reliable index of the effectiveness of an insecticide when applied as an exterior treatment.

OUTSIDE FUMIGANT TESTS. It will be noted in Table 3 that the decline in fumi-

TABLE 2. Average indoor resting densities of *A. albimanus* per house (ten "fixed point" houses in each area). Based on 30 minutes collection per house starting at 0600 hours. Treatments with propoxur 2 g/m², El Borbollon, 1970.

		Area I		Area II		Control No Treatment	
		Female *A. albimanus*		Female *A. albimanus*		Female *A. albimanus*	
Date	Week	Alive	Dead	Alive	Dead	Alive	Dead
14 Jan.	—7	7.7	0	7.7	0	11.2	0
27 Jan.	—5	11.5	0.4	18.1	0	4.3	0
10–11 Feb.	—3	16.6	1.4	13.5	0.7	15.6	1.9
5 Mar.	0	Partial Outside Treatment		Total Outside Treatment			
10 Mar.	1	0.1	7.0	0	6.6	17.8	0.1
17 Mar.	2	4.4	0.8	4.7	0.6	10.5	0.2
24 Mar.	3	1.7	0.7	0.1	2.6	8.9	0
31 Mar.	4	5.7	2.2	4.6	1.5	8.6	0.2
7 Apr.	5	33.8	0.5	13.0	0.6	18.7	0.3
24 Apr.	—2	66.6	0.2	21.6	0.5	15.3	0
6 May	0	Total Outside Treatment		Total Outside Treatment			
13 May	1	0	3.6	0	2.1	11.7	0.1
19 May	2	0	1.3	0	0.2	10.3	0.3
	3	No Capture					
2 Jun.	4	1.3	0.4	0.7	0.4	26.9	1.2
9 Jun.	5	6.7	2.0	5.1	0.4	32.1	1.3

Dead—Indicates number found dead in houses and mortalities after 24-hour period of those found resting inside houses.

TABLE 3.—Percentage mortality of *A. albimanus* from three hours of exposure to fumigant action of propoxur, applied to outside of dwellings, El Borbollón, 1970.

	AREA I						AREA II					
	Cages exposed in						Cages exposed in					
	High position			Low position			High position			Low position		
Hrs. of exposure:	1	2	3	1	2	3	1	2	3	1	2	3
Weeks after treatment												
0 (5 Mar.)	Partial Outside Treatment						Total Outside Treatment					
1	..	..	..	30	100	100	..	..	..	100	100	100
2	100	100	100	3	6	26	..	..	..	0	45	60
4	20	72	77	0	2	12	8	33	67	5	47	63
5	0	17	37	0	0	0	0	2	2	[illegible]	3	8
0 (6 May)	Total Outside Treatment						Total Outside Treatment					
2	75	100	100	33	67	75	40	93	100	75	85	100
4	8	70	97	3	3	5	0	30	100	5	38	62
5	23	43	50	2	2	5	5	30	65	0	0	1

TABLE 4.—Percentage mortality of field collected *A. albimanus* females 24 hours after exposure to propoxur residues on outside wall surfaces.* El Borbollón, 1970.

Date	Week	Area	Wood	Thatch	Mud	Tile	Poles High	Poles Low
5 Mar.	0	I	0	..	0	3	6	2
		II	3	0	0	0	4	2
5 Mar.	0	Locality Treated						
18 Mar.	2	I	100	..	38	100	100	46
		II	100	85	63	59	100	79
14 Apr.	6	I	66	..	0	36	65	21
		II	84	16	0	31	26	11
6 May	0	Locality Treated						
12 May	1	I	100	..	88	92	100	100
		II	97	100	93	84	100	100

* The exposure period in these tests was 30 minutes and the number of *A. albimanus* used ranged from 34 to 90 per test.

gant activity occurred more rapidly in the "low" cage positions. By week 4 there was an appreciable decline in mortality, especially in the "low" positions and on week 5 reduced mortalities were obtained in all positions. The loss in fumigant activity appeared to be closely correlated with the overall effectiveness of the treatments in reducing the number of mosquitoes entering the houses and in killing those which did enter.

BIOASSAY OF OUTSIDE WALL SURFACES. The results of the bioassays as shown in Table 4 tended also to indicate that by 6 weeks after application the effectiveness of the insecticide had decreased to a low level. These tests appeared to complement the data from the other types of evaluation procedures presented previously. During the post-treatment period untreated control houses showed mortalities similar to that in the pre-treatment.

CONCLUSIONS

A single application of propoxur at the rate of approximately 2 g/m^2 to the eaves and the entire outside wall surfaces of houses of open or loose construction in the coastal areas of El Salvador drastically reduced the number of intradomiciliary bites by *A. albimanus* and the number of early-morning resting mosquitoes for 3 to 4 weeks.

Although the second treatment was applied to the same house several weeks after the first treatment had lost most of its effectiveness, the data suggest some additive effect from the second application. This additive effect appears to be sufficient to warrant further studies of this technique, with the subsequent insecticide applications being more closely timed to coincide with the loss of an acceptable level of effectiveness from each previous treatment applied.

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VILLAGE TRIAL OF FENITROTHION AGAINST ANOPHELES ALBIMANUS IN EL SALVADOR, CENTRAL AMERICA[1]

by

Joseph R. Austin[2]

ABSTRACT

Fenitrothion, formulated as a 50% water-dispersible powder, applied as a residual treatment at the rate of 2 g/m^2 to houses in El Salvador, Central America, controlled DDT-resistant Anopheles albimanus adults for approximately four weeks on wood, thatch, pole, and tile surfaces. However, this period of residual activity was judged to be too short to test this material further in antimalaria programmes in the coastal problem areas of El Salvador.

Fenitrothion, (O, O-dimethyl O-(4 nitro-m-tolyl) phosphorothioate, OMS-43), is an organophosphorus insecticide which has undergone considerable study as a possible replacement for DDT in residual house spraying antimalaria programmes. In a village trial during 1963 with fenitrothion in Nigeria, Africa, Bar-Zeev and Bracha (1965) reported anopheline densities decreased to almost nil inside the treated village for the first six months after spraying. Mortality of anophelines captured in window traps in fenitrothion treated huts was high for seven months after treatment.

In El Salvador where vector resistance to DDT has caused serious problems for malaria eradication, a substitute insecticide for DDT has been sought for many years. In 1969, an entomological evaluation of fenitrothion was carried out in the village of El Zapotal, which is located in the eastern part of the country. The village is situated in a valley 65 metres above sea level near the foot of a low range of hills. The main Anopheles albimanus breeding source is south of the village and in very close proximity to the dwellings. It is of the "rainy-season" type, and for the most part is dry during the dry season. The rainy season in this area is usually from May to November with a range of 1725 to 2570 mm of rain during the year and a temperature range of 19.3°C to 37.2°C. There is extensive cotton-growing in the vicinity of El Zapotal.

Approximately five kilometres south in the same valley at an altitude of 62 metres another village, Playa Grande, was selected as a comparison village, although it was under routine DDT residual spraying. An untreated village was not available as the country has been under insecticide treatment for over 10 years.

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Most houses in both villages have grass-thatch or tile roofs with pole or other "open" type wall construction. Pole wall surfaces were found to be predominant in both villages.

Both villages had been routinely treated for several years previously by the Campaña Nacional Anti-Palúdica (CNAP) (National Malaria Eradication Programme) with DDT at 2 g/m^2. During the study period the control village was again treated with DDT when the six-monthly cycle came due, 2 June 1969. Prior studies had already indicated that there was no apparent effectiveness from DDT spraying when measured with present entomological evaluation techniques.

MATERIALS AND METHODS

Insecticide treatments - The test village (El Zapotal) was treated with fenitrothion 25 June by six spraymen furnished by the CNAP, utilizing conventional hand operated compression sprayers. Fenitrothion as a 50% water-dispersible powder (WDP) was applied to 83 houses by inside total coverage at a target dosage of 2 g/m^2 of the technical material. A total of 83 houses were treated using 87 kg of fenitrothion WDP.

It was noted that the insecticide at the time of spraying had an unpleasant odour. Several female occupants of the treated houses complained of a dizzy feeling and one complained of nausea and headache. In a toxicological study carried out in Southern Nigeria during 1963, Vandekar reported that fenitrothion was safe enough for extended field trials, providing precautionary measures including use of protective clothing and masks, washing after exposure and avoidance of treated surfaces contact by inhabitants be observed.

ENTOMOLOGICAL EVALUATION

Early morning resting densities - Ten "fixed point" houses selected throughout each village were searched bi-weekly by two men to a house using aspirators and flash-lights. The time spent was approximately 15 minutes to a house beginning at 0600 hours. The female A. albimanus specimens found were grouped into blood-feds, gravids, and unfeds. Counts were made of dead anophelines found in the houses and those females found alive were held for 24-hour mortality observations.

Exit trap densities and mortalities - Collapsible exit traps made of marquisette and metal frames were placed over the open wall spaces of a pole-type house in each village. They were fixed into position by 1800 hours and left in place all night. The following morning at 0600 hours the traps and the house were searched for live and dead anophelines. The live specimens were held for 24-hour mortality observations.

Fumigant tests - Due to the possibility of a fumigant action from the insecticide affecting the exit trap captures, special round wire cages (10 x 7 cm) containing 15 blood-fed A. albimanus each were placed inside the exit traps to measure any fumigant activity. One such cage was placed on each side of the house. Following the overnight exposures, the surviving mosquitos were transferred to clean cages and held for 24-hour mortality determinations.

Bio-assays of inside surfaces - Bi-weekly bio-assays of the main indoor surfaces were made using the World Health Organization (WHO, 1963) method with modifications. The removal of the mosquitos from the surface being tested was done by the use of CO_2 gas anaesthesia. There were 10 to 15 blood-fed females per testing chamber and the exposure period was 60 minutes. A special testing chamber was developed for the testing of the curved pole and tile roof surfaces. Two houses were selected for each type of surface to be tested and three testing chambers used per surface type. The main surfaces were wood, thatch, roofing tile, pole and adobe. The A. albimanus used were from corrals in the locality, or from one in nearby El Jocotal where there was a constant supply of A. albimanus known to be resistant to DDT. The test mosquitos were caught blood-fed the night prior to the bio-assay tests and held with cotton pads soaked in sugar water. The bio-assay tests were made starting at 0600 hours on the morning following the captures.

Susceptibility tests - In an effort to determine at least one of the causes of the poor results obtained with fenitrothion in the village spraying, susceptibility tests were conducted to evaluate the possible role of A. albimanus resistance to the insecticide. Before the arrival of the special fenitrothion impregnated papers supplied by WHO, an expedient technique was utilized for the susceptibility tests of A. albimanus in the study area. Plywood panels of 30 x 30 cm covered with kraft paper were sprayed with calculated dosages of the insecticide. The day following treatment the panels were bio-assayed with the WHO testing chamber. Three "cones" were used for each concentration, with from 10 to 15 blood-fed females per chamber, using a 60-minute exposure period. The exposed A. albimanus were removed from the testing chambers with the use of CO_2 and held for 24-hour mortality observations.

After the arrival of the fenitrothion impregnated papers from WHO, tests were done with the local El Zapotal A. albimanus strain from the corral. Similar checks were made with the DDT-resistant colony maintained at the Central America Malaria Research Station in San Salvador and a strain collected from an additional corral (Hacienda Nueva) where there has been little or no agricultural insecticide usage. The exposure period in all tests was 60 minutes.

DDT susceptibility tests, using the WHO procedure, were done employing four tubes with WHO 4% DDT impregnated papers and a control, using an exposure period of 60 minutes. The mortality reading was made at 24 hours in all tests.

RESULTS

Early morning resting densities - A series of three of these early morning captures were made prior to treatment, with a mean capture varying between 2.5 to 4.4 live A. albimanus per house (Table 1). The first week after the fenitrothion treatment no live mosquitos were found but an average of 1.4 dead females per house were encountered. By week 2, an average of 5.8 females were found per sprayed house, with 4.0 of these dead. The captures on post-treatment week 4 gave 3.9 live and 2.8 dead mosquitos per house. Beginning with week 4 the A. albimanus morning resting densities equalled or exceeded pretreatment levels, and by week 5 there was a marked decline in the mortalities obtained.

Similar captures were made in 10 "fixed point" houses of the comparison village, Playa Grande (Table 2). The mosquito densities appeared higher in Playa Grande from the outset and during the nine-week period covered in the study the house-resting densities averaged 3.8 to 10.6 A. albimanus females per house. Only in week 4 were any dead females found in any of the houses.

Indoor and outdoor night-biting counts and corral counts were made in both villages to determine general overall population trends during the test period. These counts indicated a general population increase during the first two weeks after the fenitrothion treatment, a subsequent decline to about pretreatment levels, and another increase on week 9.

Exit trap densities and mortalities - The only post-treatment capture of this type that gave 100% mortality was at the end of one week. The others on weeks 4, 6, and 8 gave 33, 50, and 40% mortalities, respectively. From 85 to 100% of the total female mosquitos encountered after treatment inside the house and in the traps were collected in the traps (Table 3).

During the post-treatment weeks 1, 2, 5 and 8 in the DDT sprayed Playa Grande, like captures in house 34A gave lower mortalities of 0 to 12% but with similarly high numbers (73 to 100%) escaping into the traps (Table 4).

Fumigant tests - The fumigant action of fenitrothion was relatively low - only 18% mortality of the caged mosquitos exposed overnight in the exit traps at the end of the first post-treatment week (Table 3), and no mortality on subsequent exposures.

Bio-assays of inside surfaces - With a one-hour exposure period on week 3, when the first post-treatment tests were done in El Zapotal (Table 5), satisfactory 24-hour mortalities were obtained with fenitrothion only on wood (80%), thatch (92%), and roof tile (77%). By the fifth week all test mortalities were between 0 and 32% and subsequent tests showed a further decline in mortalities.

All bio-assay tests done on the DDT-treated surfaces in the comparison village of Playa Grande indicated 25% mortality on wood and less on all other surfaces tested.

Susceptibility tests - The WHO susceptibility tests indicated a high DDT-resistant strain of A. albimanus present in the study area and comparison area (and also in the vicinity of El Jocotal, which served as a collection site for some of the mosquitos used in the bio-assay tests). This resistance (mortality less than 5% in all cases) accounted for the lack of effectiveness of the DDT spraying in Playa Grande.

In the preliminary susceptibility tests with the emergency technique using fenitrothion, one-hour exposures of the mosquitos collected from the Zapotal corral to dosages as high as 0.031 g/m^2 produced no mortality. Additional tests using higher concentrations produced the following 24-hour mortalities: 29% with residues of 0.062 g/m^2, 73% with 0.125 g/m^2, 97% with 0.25 g/m^2 and 100% with 0.5 g/m^2.

On receipt of the special fenitrothion-impregnated papers from WHO several comparison tests were made with A. albimanus from Zapotal, the DDT-resistant colony in San Salvador, and a non-agricultural zone of the country (Hacienda Nueva). The results are summarized in Table 6.

The results of these tests indicated that the Hacienda Nueva and the DDT-resistant colony strains were more susceptible to fenitrothion than A. albimanus from El Zapotal. A mortality of 90 and 100%, respectively, was obtained in the Hacienda Nueva and colony mosquitos with the 1.6% concentration which resulted in only 8 and 30% mortalities in two tests with the El Zapotal strain. The indicated resistance to fenitrothion in the mosquitos from El Zapotal may be due to the long years of usage of various different classes of insecticides in the nearby cotton fields. Methyl parathion, with a molecule similar to fenitrothion, is widely used in cotton-growing areas of the country.

CONCLUSIONS

Considering the rapid decline in the mortalities in the residue bio-assay tests, the quick return by week 4 of the house-resting densities, the low mortalities in the house and exit-trap captures, and the indicated resistance to fenitrothion in the susceptibility tests, it was concluded that this insecticide would not be useful for residual spraying of houses as an antimalaria measure in the coastal problem area of El Salvador.

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TABLE 1. EARLY MORNING CAPTURES OF A. ALBIMANUS INSIDE 10 HOUSES TREATED WITH FENITROTHION (EL ZAPOTAL, 1969)

Date	Week	Houses positive	A. albimanus females			
			Total		Total	
			Alive	Dead	Alive	Dead
29 May	-4	8	27	0	2.7	0
5 June	-3	8	44	0	4.4	0
25 June	0	9	25	0	2.5	0
25 June	0	Houses treated with fenitrothion at 2 g/m^2				
1 July	1	5	0	14	0	1.4
8 July	2	9	18	40	1.8	4.0
23 July	4	9*	35	25	3.9	2.8
29 July	5	6	22	2	2.2	0.2
12 August	7	9*	41	8	4.5	0.9
26 August	9	7	64	1	6.4	0.1

* Nine houses searched
Alive = survived 24 hours after capture
Dead = found dead or captured alive and died within 24 hours.

TABLE 2. EARLY MORNING CAPTURES OF A. ALBIMANUS INSIDE 10 "UNTREATED" HOUSES (PLAYA GRANDE, 1969)

Date	Week	No. houses positive	A. albimanus females			
			Total		Total	
			Alive	Dead	Alive	Dead
27 May	-1	7	64	0	6.4	-
2 June	0	Locality treated with DDT at 2 g/m^2				
4 June	0	8	78	0	7.8	-
1 July	4	9	102	12	10.2	1.2
7 July	5	8	106	0	10.6	-
31 July	8	10	73	0	7.3	-
14 August	10	10	73	0	7.3	-
28 August	12	10	38	0	3.8	-

Alive = survived 24 hours after capture
Dead = found dead, or captured alive and died within 24 hours.

TABLE 3. EARLY MORNING CAPTURES OF A. ALBIMANUS INSIDE A TREATED HOUSE AND IN EXIT TRAPS (EL ZAPOTAL, 1969)

Date	Week	House No.	A. albimanus females			% mortality in fumigant test
			Total	% mort.	% in traps	
18 June	-1	259 A	147	10	82	-
25 June	0	Locality treated with fenitrothion				
1 July	1	259 A*	56	100	91	18
23 July	4	317	9	33	89	0
5 August	6	262	22	50	100	0
19 August	8	262	20	40	85	-

* House abandoned by occupants following this test, requiring a change in houses for further evaluation.

TABLE 4. EARLY MORNING CAPTURES OF A. ALBIMANUS INSIDE AN "UNTREATED HOUSE" AND IN EXIT TRAPS (PLAYA GRANDE, 1969)

Date	Week	A. albimanus females		
		Total	% mort.	% in trap
2 June	0	Locality treated with DDT		
2 July	4	95	3	73
9 July	5	125	1	84
31 July	8	26	0	100
21 August	11	25	12	96

TABLE 5. PERCENTAGE MORTALITY OF FIELD COLLECTED A. ALBIMANUS 24 HOURS AFTER EXPOSURE TO FENITROTHION AND DDT RESIDUES (EL ZAPOTAL (FENITROTHION) AND PLAYA GRANDE (DDT), 1969)

Week after fenitrothion	Insecticide	Surface							
		Wood	Thatch	Poles	Mud	Tile	Adobe	Palm	Control
0*	Fenitrothion	17	2	2	-	5	4	-	0
	DDT	8	3	4	3	1	-	3	1
3	Fenitrothion	80	92	51	-	77	1	-	0
	DDT	-	-	-	-	-	-	-	-
5	Fenitrothion	26	17	32	-	28	0	-	0
	DDT	25	3	4	5	3	-	7	1
7	Fenitrothion	22	9	5	-	17	10	-	2
	DDT	17	7	5	6	4	-	18	2
9	Fenitrothion	23	3	1	-	6	1	-	0
	DDT	3	2	1	6	0	-	8	1

* DDT - resistant colony strain used in 0-week tests.

TABLE 6. PERCENTAGE MORTALITY OF A. ALBIMANUS FEMALES 24 HOURS AFTER EXPOSURE* TO WHO FENITROTHION-IMPREGNATED PAPERS, 1969

Date	Mosquito source	Concentration				
		.025%	.1%	.4%	1.6%	Control
25 July	Zapotal	7** (100)	2(75)	1(100)	30(100)	9(75)
21 July	Colony	0** (50)	0(45)	68(50)	100(66)	13(45)
5 August	Zapotal	--	--	0(100)	8(100)	0(50)
5 August	Hcda. Nueva	--	--	9(77)	90(80)	0(50)

* Following a 60-minute exposure to impregnated papers.

** Corrected mortalities.

() Number of A. albimanus used.