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

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

[4] Fenitrothion (OMS-43) = 0,0-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/m^2 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/m^2 of DDT and 2 g/m^2 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/m^2 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/m^2 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	0	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	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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Reference

Cheng, F. Y. 1968. Responses of *Anopheles balabacensis* to various patterns of DDT-spraying of shelters in Sabah, East Malaysia. Bull. Wld. Hlth. Org. 38:469-477.