AGENCY FOR INTERNATIONAL DEVELOPMENT
WASHINGTON, D. C. 20523
BIBLIOGRAPHIC INPUT SHEET

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Batch 69

1. SUBJECT CLASSIFICATION	A. PRIMARY Health	NS00-0000-G324
	B. SECONDARY Tropical diseases	

2. TITLE AND SUBTITLE
Studies with dichlorvos residual fumigant as a malaria eradication technique in Haiti, 1: operational studies

3. AUTHOR(S)
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4. DOCUMENT DATE	5. NUMBER OF PAGES	6. ARC NUMBER
1966	10p.	ARC

7. REFERENCE ORGANIZATION NAME AND ADDRESS
HEW/PHS/CDC

8. SUPPLEMENTARY NOTES (Sponsoring Organization, Publishers, Availability)
(In Am.j.of tropical medicine and hygiene,v.15,no.5,p.661-669)

9. ABSTRACT

10. CONTROL NUMBER	11. PRICE OF DOCUMENT
PN-AAE-301	

12. DESCRIPTORS	13. PROJECT NUMBER
Field tests Haiti Fumigation Malaria	14. CONTRACT NUMBER PASA 5903-7 Res. 15. TYPE OF DOCUMENT

AID 590-1 (4-74)

REPRINT NUMBER PASA 5903-7 R00
PASA 5903-7
76 PN-AAL-501
HEW/PHS/CDC

American Journal of Tropical Medicine and Hygiene
Vol. 15, No. 5

STUDIES WITH DICHLORVOS RESIDUAL FUMIGANT AS A MALARIA ERADICATION TECHNIQUE IN HAITI

I. Operational Studies

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Field trials of the dichlorvos-wax residual fumigant in the Republic of Upper Volta demonstrated that the technique gave effective kills of caged *Anopheles gambiae* and/or *Aedes aegypti* for approximately 3 months in adobe huts with minimum ventilation.[1] From the same studies, Quarterman *et al.* reported that the parasite rates were reduced 38 to 55% in the treated village as compared to that in the untreated vilage.[2] To test the effect of the technique on another malaria vector and on disease transmission under housing conditions with greater ventilation, a 2-year study was initiated in Haiti in June 1962. This investigation was a cooperative endeavor of the Communicable Disease Center (CDC), Pan American Health Organization (PAHO), Agency for International Development (AID), and the Goverment of Haiti (GH). The findings are summarized in three parts: I. Operational studies; II. Epidemiological studies; and III. Toxicological studies.

The selection of Haiti as a test site was based on (1) the absence of insecticide house treatments since 1959, (2) the occurrence of adequate malaria incidence, (3) suitable native dwellings of uniform construction, and (4) the availability of laboratory facilities and experimental field areas.

STUDY AREA

The Commune of Arcahaie extends over a coastal plain approximately 30 miles to the north of Port-au-Prince, Haiti (18°30'N and 72°30'W). The topography varies with mountains rising a few miles inland (Fig. 1). This coastal plain was divided into two test zones, a dichlorvos-treated zone that ranged from sea level to 60 meters and a DDT-treated zone that ranged from sea level to 300 meters.‖

The dichlorvos test zone is extensively criss-crossed with narrow irrigation canals with the flow towards an area below a level of 20 meters in which extensive rice cultivation is practiced. The land is divided into small parcels (2 to 10 acres) which are planted and watered at irregular intervals throughout the year, thus providing adequate water for continuous breeding of *Anopheles albimanus*. The average annual rainfall in this area over a 34-year period has been 36 inches, most of which falls between the months of May and October. Maximum temperatures range between 87° and 94°F, the warmest period being June through August; night-time minimum temperatures normally are 17° to 20°F below the maximum.

In the adjacent DDT-treated zone there are no irrigation canals and only a small area of rice culture. Rice seedlings are planted in terraces from June to September, the period in which there is sufficient rainfall, and harvested in December. Rarely is there sufficient rainfall to result in standing water over the area as the soil is quite porous except for that in the rice fields.

In the dichlorvos-treated zone there were 34 localities and in the DDT-treated zone 29. The total population in the Arcahaie commune was somewhat over 20,000, with an average of about 3.5 people per house. Almost all of the houses were rectangular in shape (8 ft. wide by 18 to 20 ft. long) with the walls of whitewashed mud and the roofs of thatch (Fig. 2). Generally the houses had two rooms, four doors, and two or more shuttered windows in varying combinations. It was common

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‖ The original selection of the zone to be treated with dichlorvos versus that treated with DDT was based on the information from local sources that the two zones were approximate in their disease and *A. albimanus* levels. Subsequent study showed that the dichlorvos-treated zone had a much higher potential for anopheline breeding, principally because of the rice culture therein.

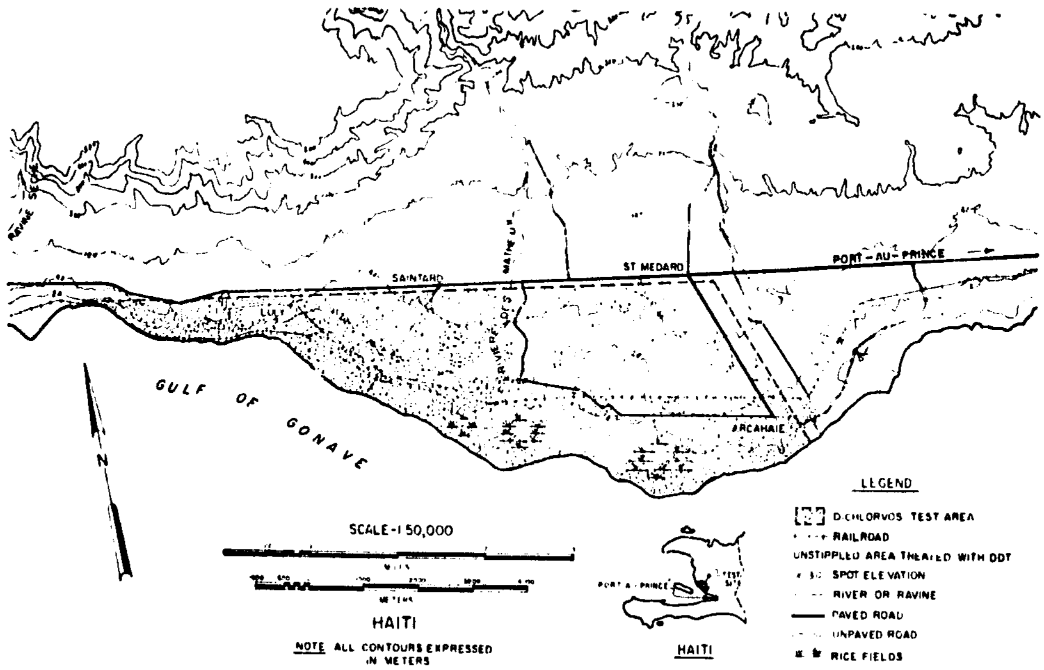

FIGURE 1. Topography of areas treated with dichlorvos and DDT.

practice to shut the doors and windows at night and frequently during the day. Cooking and nearly all other activities from rising to going to sleep were done outdoors, under a kitchen shelter, a front porch, or some other type of canopy.

MATERIALS AND METHODS

Insecticide Treatment

The dichlorvos dispensers[3] were composed of 25% dichlorvos in a base of dibutyl phthalate (25%) and Montan wax (75%). Each dispenser (6.0 in. long with a diameter of 1.5 in.) weighed approximately 200 g, and each was installed encased in a plastic mesh cage (Fig. 3). For dispenser protection and suspension, the plastic cage was closed at the top by a wire (18 gauge) that was attached to the roof or to other similar elevated supports.

Previous tests at Savannah, Georgia, indicated that a treatment rate of 1 dispenser per 165 cubic feet was effective for [illegible]ks against dieldrin-resistant *Anopheles quadrimaculatus* in mud-thatch houses.[4] A pilot run made at the same treatment rate in a few huts in Arcahaie prior to the over-all treatment of the test area confirmed that this dosage was effective for more than 8 weeks.

FIGURE 2. Typical house in rural Haiti.

Two brigades of 5 men each were used to install the dispensers.* Since it was necessary to know the cubic capacity of each dwelling, a "rule of thumb" table was prepared. After pacing off the width and length of a dwelling, the men consulted this table which indicated the number of dispensers to be used for the various size huts. With this general guide the rate of treatment ranged between 1 unit per 165 cubic feet to 1 unit per 300 cubic feet. Most of the dwellings received 4 to 6 dispensers. A complete tabulation of the quantities

* On one of the six treatment cycles four brigades were used.

FIGURE 3. Dichlorvos dispenser attached to roof of thatched house.

of dispensers used for each of the 6 treatment cycles is given in Table 1. In the first 3 treatments only occupied houses were treated. In treatments 4, 5, and 6 practically all existing structures were treated, thus increasing the coverage to approximately 90%. Only 85% of the treated dwellings were occupied regularly, the unoccupied structures representing storerooms, kitchens, churches, schools, and "voodoo" spirit houses.

Each new dispenser was encased in a sealed aluminum container* that was removed by workers at the warehouse during each treatment cycle. These workers also placed the dispensers in the plastic cages for field use. Impoverished dispensers removed from the dwellings were buried under a 2-foot ground cover.

An analysis of operations during the first treatment cycle shows 2,820 manhours of labor for installation of 23,248 dispensers in 4,618 houses plus 564 manhours of supervision by two brigade chiefs. Each man averaged about 17 houses and 85 dispenser installations per 8-hour day. The average installation times varied little throughout the course of the experiment except that a slight increase in the number of houses and dispensers per 8-hour day occurred in the latter treatments when the brigades became more familiar with the area and with the technique and it was only necessary to take down the old dispensers and replace them with new ones. Since it was not necessary for the inhabitants to move any of their belongings outside during the treatments, they were pleased with dispenser installation.

* Chemical analyses of such sealed dispensers stored for periods up to 12 months indicated that decomposition of the dichlorvos was less than 4 percent.

TABLE 1

Dispenser installation rates for six treatment cycles, 1962–1964

Treatment cycle	No. buildings treated	Dispensers used	Avg. dispensers/treated construction
1. 7/19/62 8/29/62	4,618	23,248	5.0
2. 12/4/62 1/18/63	4,650	22,760	4.9
3. 4/16/63 5/2/63	5,062	24,941	4.9
4. 8/26/63	5,581*	40,190	7.2*
5. 12/11/63 1/29/64	5,760*	37,710	6.5*
6. 4/6/64 5/15/64	5,316*	37,313	7.0*
Total	30,987	186,162	6.0

* Includes any building with walls, roof, and doors.

The dwellings in the DDT-treated area received the standard application of 2 g DDT/square meter that was then used for house treatment throughout Haiti on the National Malaria Eradication Program (SNEM). This spraying was done by the spray brigades of Zone 2, and the applications were at 6-month intervals beginning in September 1962.

EVALUATION

Insecticidal

Caged adult female *A. albimanus* (100/cage, 3-day-old, sugar-fed) were used to evaluate the efficacy of the dichlorvos treatment. Two cages per house were suspended at the 2-ft. and 6-ft. levels for a period of approximately 12 hours (1900–0700 hours). All exposed specimens were held for 24 hours with food and water before the mortality was determined. Initially, the specimens were laboratory-reared DDT-susceptible *A. albimanus* derived from a colony at Savannah, Georgia, and from eggs from Guatemala. In October 1963 a native strain which was colonized the previous year replaced the original culture for subsequent tests. This strain was also susceptible to DDT, as was true of *A. albimanus* throughout Haiti.

During the period from August to October 1962, 19 houses were used as evaluation sites. Subsequently, the number ranged from 25 to 42 for the remainder of the first treatment. The number of evaluation sites remained in the range of 20 to 50 for the 2nd and 3rd treatment cycles, but during the last three treatment cycles the number was reduced considerably. Essentially the same houses were used throughout the experiment although the interval between successive tests in the different houses varied. Inspections also were made in other houses selected at random to confirm the reliability of data obtained from the sample huts. Several untreated houses in each locality served for check purposes.

The original criterion for retreatment was established as that time interval when 50% of the evaluation stations showed unsatisfactory kills (average mortality of less than 70%). However, the time required to complete the treatment of the entire area (approximately 6 weeks), coupled with the difficulties of maintaining inspection and treatment schedules because of local conditions made it necessary after the 3rd installation cycle to adopt 3 to 3.5 months as the routine period by which to schedule retreatment.

Biological

In the fall of 1963 the entomological evaluation was extended to measurements of adult and larval densities and to observations on the adult behavior.

Vector density. At three stations* in the dichlorvos zone and at one in the DDT zone, larval surveys, biting collections, and light trap collections were made. On the surveys of each breeding site, each of three collectors took 100 dips at random during each weekly visit. Biting collections from four human baits of approximately the same age and weight were made by two collectors one night each week in each of the four sampling localities. Each of the baits was located between a breeding site and a group of houses for each observation. Collections were made from 10 minutes before sundown until 50 minutes after sundown.

For light trap collections the battery-operated CDC miniature light trap[5] was used. Each trap was hung at about 3 feet above the ground and run from sundown until 0100 hours.

Activity periods. To establish the periods of activity of *A. albimanus*, all-night biting collections were made at the 4 stations described previously. Four human baits of approximately the same age and weight were placed outdoors between the breeding site and a group of houses. The same number of baits were placed indoors in one house in the same area. Two collectors were used outdoors and two indoors. All collections were grouped by the time intervals of 1730–1900, 1900–2100, 2100–2300, 2300–0100 and 0100–0700 hours. Nineteen replications were made using the same house at each of the 4 stations. Light traps were run at the same stations 1 night a week. These collections were processed for the same time intervals as indicated above.

Biting and resting behavior. To estimate the relative numbers of *A. albimanus* biting outdoors and indoors, four human baits of approximately the same age and weight were placed outdoors between the breeding sites and a group of houses, four were placed indoors in a dichlorvos-treated house, and four were placed in an untreated house. Outdoors two collectors were used to capture biting mosquitoes. Indoors two collectors were used to record the mosquitoes that fed on the baits and then flew to a resting place; this was done simultaneously in one treated and one untreated house. A third collector in each of the houses continuously surveyed the walls and captured the resting mosquitoes. These collections were made during the peak period of biting activity, 10 minutes before sundown until 50 minutes after sundown. The same situations were used for all observations that were done at 2, 4, 8, and 10 weeks after installation of dichlorvos dispensers.

Early morning (0500–0600 hours) indoor captures were accomplished in a random sample of houses in the two treated zones (DDT and dichlorvos). The floor of each house was covered with white cloth, and the dwelling sprayed with a pyrethrin mixture. Dead mosquitoes were collected from the floor and counted.

* A locality having 1 to 3 groups of 5 to 10 houses within 60 feet of a permanent breeding site of 300 to 500 acres.

TABLE 2

Summary of results obtained with 12-hour exposure of caged female Anopheles albimanus *in dichlorvos-treated houses during the first three treatments—Haiti, 1962–63*

Dispenser age in weeks	No. houses tested			Avg. female mortality			% houses with kills less than 70%			% houses with kills less than 90%		
	Treatment			Treatment			Treatment					
	1	2	3	1	2	3	1	2	3	1	2	3
9	19	50	22	90	96	97	10	6	5	10	10	14
10	20	30	28	86	94	93	15	7	8	25	17	21
11	31	33	18	91	80	89	6	33	11	29	55	33
12	38	29	—	92	89	—	5	10	—	34	55	—
13	25	14	26	81	80	72	24	0	42	52	22	70
14	34	15	—	79	84	—	29	13	—	50	80	—
15	42	—	27	58	83	40	55	—	85	76	—	85
16	42	26	23	61	70	20	57	31	95	83	69	100

Response of A. albimanus *to dichlorvos.* To determine the mortality of free flying mosquitoes and to see if dichlorvos vapors had any repellent effect on *A. albimanus*, tests were conducted in houses in which all openings were sealed with paper and tape except for an egress window trap. White cloth was placed on the floor so that any mosquitoes which were killed could be collected. Approximately 500, 3-day-old, sugar-fed male and female *A. albimanus* were released in each house at approximately 1800 hours. After exposure times of 1.25 hours to 4 hours, the dead mosquitoes were removed from the floors and window traps, and the houses were sprayed with pyrethrins. After the spraying, the dead mosquitoes were picked up and counted. The specimens were then sexed, and the mortality based on the females. These tests were accomplished in houses with 5- and 9-week-old dispensers.

Tests also were made to measure the relation between exposure time and mortality. Twelve cages were placed in each of four houses, 6 at the 2-ft. level and 6 at the 6-ft. level. In three houses the dichlorvos treatment was 12 weeks old; the fourth house was untreated. One cage of mosquitoes was removed from each level at 2-hour intervals over a 12-hour test period (1830–0630). Mortality counts were made after 24 hours.

RESULTS

Insecticide evaluation. Evaluation of the first treatment (7/19–8/29/62) was begun in the 19 huts 1 week after treatment. The average hut mortalities of the caged mosquitoes ranged from 91% to 100% during the first 8 weeks, and the results of subsequent weekly tests are given in Table 2.

Average mortalities for weeks 9 through 12 ranged from 86% to 92% which is only slightly lower than that obtained during the first 8 weeks. During the 9- to 12-week period the percentage of test huts with less than 70% kills was at or below 15, but the percentage of huts with kills below 90% gradually increased. On week 15, 76% of the huts had mortalities less than 90%, 55% less than 70% mortality. On weeks 15 and 16 the average mortality had dropped to about 60%.

During the second treatment cycle the average mortality for the first 8 weeks ranged from 96% to 100% with complete kills being obtained for the first 3 weeks. Table 2 gives results for weeks 9 through 16. The average mortalities were similar to those obtained for the first cycle, but more than 30% and 50% of the huts had mortalities less than 70% and 90%, respectively, by week 11. On week 13 only 0 and 22% of the huts had mortalities less than 70% and 90%, respectively, but this was caused by the treatment of one locality which had contained several of the evaluation huts that showed the low kills on week 11.

Following the third treatment no tests were made until week 6 when the 49 huts inspected gave an average mortality of the caged mosquitoes of 97%. Results for tests in weeks 9 through 16 are given in Table 2. The average mortalities gradually decreased during weeks 9, 10, and 11 (97%, 93%, 89%), and the percentage of huts with kills below 70% and 90% reached 11 and

TABLE 3

Comparison of average larval and adult Anopheles albimanus *densities in dichlorvos- and DDT-treated areas with the rainfall recorded during study period*

Date	Dichlorvos treatment area			DDT treatment area			Rainfall (mm) 1963–4
	Larvae/dip	Bites/hour	Females/trap night	Larvae/dip	Bites/hour	Females/trap night	
Nov. 1963							
Dec.	3.2	14.6	6.5	3.0	9.5	14.0	65.1
Jan. 1964	2.1	18.7	0.5	3.2	2.0	0.0	43.2
Feb.	2.2	58.5	21.9	1.1	15.7	16.7	5.8
Mar.	10.2	11.7	26.3	2.2	1.2	0.7	25.1
Apr.	3.3	18.8	41.5	2.1	0.7	0.0	8.6
May	2.3	31.5	13.4	8.3	6.0	2.5	150.6
June	5.9	22.8	12.0	10.0	8.0	4.6	74.6
Average	4.2	25.2	17.8	4.3	6.2	5.5	117.4

33, respectively, by week 11. On week 13 the average kill dropped to 72% with 70% of the huts having mortalities below 90%.

A summation of the evaluation of the first 3 treatments shows that the results were similar through week 9, with average mortalities of 90% or greater and no more than 10% and 14% of the individual huts with kills below the 70% and 90% levels, respectively. During weeks 10, 11, and 12 the results were more erratic, and after week 12 the efficiency of the treatments decreased rapidly.* A criterion for retreatment based on 80% average mortality level or on a level of 50% of the huts inspected having less than 90% kills appears to be better than a criterion based on 50% of the huts with kills below the 70% level.

On the basis of the data for the first three cycles subsequent inspections were reduced considerably and a 3-month retreatment schedule adopted. Tests were continued in approximately 12 huts from different areas on alternate weeks. Results from the fourth treatment were similar to those of the first three treatments, but in the fifth treatment the average mortality never fell below 93% during the 16 weeks of testing. During the last cycle only a limited number of houses were tested, but in each complete kills were obtained through week 8, and the average kills remained above 90% through week 12.

* Concentrations of dichlorvos were determined as 0.01 μg/l in 11 of 12 air samples taken in 6 houses containing dispensers 4 months old. This level approximates the concentration of dichlorvos considered to be effective threshold, 0.015 μg/l.

Vector density. Results of the 7-month (December 1963–June 1964) study of larval abundance, biting records, and light trap collections in the dichlorvos- and DDT-treated zones are given in Table 3. Data indicate that: (1) average larvae per dip were the same in two zones; (2) bites/manhour were higher for each month in the dichlorvos zone, with the average for the period in the dichlorvos-treated zone being 25 as versus 6 in the DDT-treated zone; (3) average densities per light trap collection were three times as great in the dichlorvos zone.

The similarity of larval collections in the two zones and the great difference in bites and number of adults collected reflect the large breeding areas in the dichlorvos-treated zone.

Activity periods. Collections of *A. albimanus* biting indoors and outdoors during the periods of 1730–1900, 1900–2100, 2100–2300, 2300–0100, and 0100–0700 hours were replicated between December 1963 and June 1964. The results (Table 4) showed that the same general trend of biting activity was followed indoors and outdoors for each period and that 50% of the biting occurred during the 1730–1900 hour period for each location. The biting activity decreased progressively for each period and was only 3% to 4% between 0100–0700 hours. Seventy-three percent of all biting mosquitoes (1,355) were recovered outside of the houses, and the percentage of outdoor biting for the different time periods ranged from 65 to 90.

Results for light traps operated each night

TABLE 4

Record of biting activity of A. albimanus *inside and outside of huts during the period of 1730–0700 hours, using human bait*

Loc tion	Percent of mosquitoes collected during time intervals below				
	1730–1900	1900–2100	2100–2300	2300–0100	0100–0700
Indoors	51 (185)*	27 (99)	15 (54)	4 (15)	3 (12)
Outdoors	48 (475)	19 (183)	16 (163)	13 (131)	4 (38)
Percent collected outdoors	72	65	75	90	76

* Numbers in parentheses represent number of mosquitoes collected during each interval.

TABLE 5

Recovery of A. albimanus *(approximately 250 ♀) released in dichlorvos-treated and untreated houses equipped with a window trap*

Houses	Exposure time (hrs)	Window traps		Rooms		Average	
		Total mosq.	% mort.	Total mosq.	% mort.	Total mosq.	% mort.
5-wk-old treat	1.25	64 (22)*	11	228	79	292	64
Control	1.25	56 (18)	0	249	2	305	2
9-wk-old treat	1.50	28 (21)	0	103	39	131	31
Control	1.50	23 (12)	0	169	4	192	4
9-wk-old treat	4.00	52 (36)	27	93	58	145	47
Control	4.00	26 (12)	34	195	3	221	5

* Number in parentheses represents the percent of total mosquitoes collected which were in window traps.

during the same time periods were entirely different. A total of 565 mosquitoes was collected in the traps during the 19 tests. The percentage recovered during each of the 5 successive time periods was 1, 13, 25, 44, and 18, respectively; maximum numbers were recovered between 2300-0100 hours. These data suggest that the primary activity soon after sunset concerns movement to obtain a blood meal; later in evening and during the night this biting activity is reduced. Whether the increase in numbers in light traps reflects the decline in feeding or the fact that other artificial lights in competition with those of the traps were extinguished later in the evening is an unresolved question.

Biting and resting behavior. Twelve replications of outdoor-indoor captures of *A. albimanus* females in dichlorvos-treated and in untreated houses in the period from 2 to 10 weeks after treatment indicated: (1) that approximately 80% of the 430 bites observed occurred outside; (2) that equal numbers of bites occurred in treated and untreated houses; (3) that slightly more mosquitoes rested on walls in untreated houses, 57% versus 43%.

Countrywide studies in the DDT-treated zone during this same time period have indicated that approximately 75% of the biting occurs outdoors and about 50% of the mosquitoes that feed inside will rest on the walls.[6] Few mosquitoes were found indoors in the early morning hours as shown by indoor captures between 0500 and 0600 hours with the aid of pyrethrin sprays.

Response to dichlorvos. In the untreated houses 12% to 18% of the approximately 250 female mosquitoes released in each house were taken in the window trap (Table 5), while in the treated houses, the percentage recovered in window traps ranged from 21 to 36. These figures suggest some irritability or repellency since in each test more mosquitoes left the treated houses than was true for the untreated control. This difference was

TABLE 6

Response of caged A. albimanus *when exposed for 2 to 12 hours to vapors from 11-week-old dispensers in three houses*

House no.	Percent mortalities after hours of exposure					
	2	4	6	8	10	12
1	44	55	61	69	87	83
2	49	83	83	79	99	94
3	58	71	49	28	61	64
Control	2	4	0	1	4	1

most apparent with the longest exposure time.

The mortality in the houses can be correlated to dispenser age and exposure time. With the treatment 5 weeks old and a 1.25-hour exposure, the mortality was 64%, whereas at 9 weeks and 1.5-hour exposure, the mortality was only 31%. When the exposure time was increased to 4 hours, the mortality increased to 47%.

In exposure time-mortality tests in three occupied houses where the dispensers were 11 weeks old, 44% to 58% of the caged test specimens succumbed in 2 hours (Table 6). The maximum kill was reached in two houses at 10 hours' exposure, but in the third house this level occurred at 4 hours. In two houses, essentially the same mortalities were recorded with 12 hours' exposure as with 4 hours. There were no consistent differences in mortalities observed in the cages suspended at the 2- and 6-foot levels. Other tests in houses with 7-week-old dispensers gave from 94% to 100% mortality with a 2-hour exposure. Complete kills were obtained with a 4-hour exposure.

DISCUSSION

The results obtained with caged female mosquitoes indicated that treatment of Haitian homes with dispensers at rates in the range of one dispenser per 165-300 cubic feet will produce average kills of approximately 90% for 12 weeks. These periods of effectiveness are contingent upon a 12-hour exposure period. Obviously a shorter exposure time, as the data in Tables 5 and 6 indicate, reduces the percentage kill. The figures in the two tables also suggest that higher kills may occur among caged as versus free flying mosquitoes.

The potential of the residual fumigant technique to arrest malaria transmission depends on: (1) intradomiciliary malaria transmission, and (2) blood-fed mosquitoes resting in homes a sufficient length of time for the lethal action of the insecticide to occur. If either or both of these conditions are missing, neither the residual fumigant technique nor treatment with a residual insecticide can be expected to achieve malaria eradication as the biological observations in Haiti indicate. The maximum biting activity has been shown to occur in the evening when the population is outside of the houses. (Approximately 75% to 80% of the bites were recorded outdoors with 50% of the feeding occurring between 1730 and 1930 hours.) In addition, observations indicate that *A. albimanus* have a tendency to leave houses after short periods (2 to 8 hours) of indoor resting.

Obviously the behavior of *A. albimanus* in Haiti is not conducive to successful eradication by the application of an insecticide as a residual spray or residual fumigant. This view is substantiated by the failure of both the DDT deposits and dichlorvos vapor to interrupt malaria transmission in Haiti.[7] The findings substantiate the current belief that new or modified approaches will be needed to achieve malaria eradication in problem sites such as Haiti and Central America. With the failure of indoor treatments, malariologists are forced to look towards the methods of general outdoor vector reduction by chemical and nonchemical methods and towards the use of drug therapy. As a further development, the obsolete tendency to rely on one method, to the exclusion of other techniques, for attacking this disease problem must be discarded in favor of a multiple facet approach in which combinations of various control tools are blended together to produce maximum vector elimination.

SUMMARY

A 2-year study was conducted in Haiti to determine the effect of the residual fumigant technique on *Anopheles albimanus* and on malaria transmission.

From 4,618 to 5,760 houses in the Commune of Arcahaie were treated with dichlorvos-wax dispensers at 3- to 4-month intervals and at a rate of one unit per 165 to 300 cubic feet of space. Twelve-hour exposure tests with caged *A. albimanus* females showed that the treatment gave average kills of 90 percent for approximately 12 weeks. Although malaria incidence declined,

transmission was not interrupted, a result considered to reflect the tendency of *A. albimanus* to bite out-of-doors.

Behavior studies indicated that 75 to 80 percent of the human biting occurred outside of the house. Half of this feeding was between 5:30 and 7:30 p.m. during a period when the human population normally was outside of the house. These habits of *A. albimanus* also preclude the successful use of other types of residual house treatments in interrupting transmission. This study was a cooperative endeavor of the Agency for International Development, Pan American Health Organization, Communicable Disease Center, and the Government of Haiti.

ACKNOWLEDGMENT

These studies were accomplished as part of a contractual agreement between the Communicable Disease Center and the Agency for International Development.

The authors express their sincere appreciation to Mr. A. Villereal, Pan American Health Organization, for his valuable assistance in conducting the dispenser treatments. Credit also goes to Mr. Marc Solis, National Malaria Eradication Service, Haiti, who aided considerably in the behavior studies.

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