Bull. Org. mond. Santé
Bull. Wld Hlth Org. } 1964, 31, 399-409

Assessment of the Kill of *Anopheles gambiae* by the Fumigant Insecticide Dichlorvos in Experimental Huts *

A. SMITH, P. O. PARK & K. S. HOCKING

As part of the World Health Organization's programme for the evaluation and testing of new insecticides, different types of dichlorvos dispenser were installed in experimental huts in Tanganyika for study of their effectiveness in killing Anopheles gambiae. *It was found that satisfactorily high mosquito mortalities of 75% or more were maintained for one to two months after installation of a dispenser. Mortalities were about 10% higher in huts with grass roofs than in those with mud-lined roofs. The vapour toxicity was similar in the two types of hut, but the results of bio-assay tests on different types of surface showed that there was a residual contact effect of the insecticide as well as the fumigant effect; the lower mortalities in the mud-roofed huts may be due in part to removal or decomposition of the dichlorvos by the mud surface.*

Measurements of blood pseudo-cholinesterase levels in persons who slept in the experimental huts gave no indication that the dichlorvos had any harmful effect on them.

The insecticide dichlorvos (*O,O*-dimethyl *O*-2,2-dichlorovinyl-phosphate) has been studied in experimental huts at the Magugu outstation of the Tropical Pesticides Research Institute as part of the World Health Organization's programme of testing and developing new insecticidal compounds. The mode of action of dichlorvos is novel compared with that of the contact residual insecticides, since it is brought into contact with mosquitos as a vapour that diffuses from a dispenser. The studies have thus required several kinds of investigation to determine the fumigant as well as the incidental surface effects of the insecticide. The results presented in this paper are of trials made between February 1961 and May 1962.

METHODS

Three principal types of dispenser were used. The first and second types have the insecticide dissolved in solid matrices. The first, furnished by the US Public Health Service Technical Development Laboratories, Savannah, Ga., is a 200-g wax cylinder, 15 cm × 4 cm in diameter, of the following composition: 25% dichlorvos, 56% montan wax and 19% dibutyl phthalate. The second, produced by the Shell Chemical Company, USA, is an annular cylinder 14 cm long × 3.5 cm containing 30% dichlorvos in polyvinyl chloride plus plasticizer. From each of these two types, the dichlorvos diffuses out of solid solution from the wall of the cylinder.

In the third type, from Ciba Limited, Basel, Switzerland, the insecticide in plasticizer solution is contained in a plastic tube and diffuses through the walls of the tube. Three individual modifications of this type were used: A1 with a discharge tube 10 cm × 1.5 cm diameter, B2 with a shorter tube (5 cm × 1.5 cm) and C3 with a long tube (10 cm × 1.5 cm) and containing a modified liquid composition of 70% dichlorvos, 20% epoxy stabilizers and 10% dibutyl phthalate. (Some physical determinations have been made on five other models of this dispenser resembling the C3 modification but differing in the quality of the polyvinyl chloride discharge tube, its wall thickness and the shape of its section.) All these dispensers were produced on an experimental basis.

The experimental huts have been described by Rapley (1961), the volume of air-space within each being approximately 500 cubic feet (14 m³). One dispenser was hung in each hut in a central position and half-way with respect to height between the

* From the Tropical Pesticides Research Institute, Arusha, Tanganyika.

eaves and ridge of the roof. In one hut (No. 20) three Savannah dispensers were equidistantly spaced across the width of the room at the same height as in the other huts, so that the decrease in vapour concentration occurring with age of dispensers could be studied more fully.

The kills of naturally entering *Anopheles gambiae* were calculated from the daily counts of dead mosquitos on the floor plus the numbers in the window traps that died within 24 hours. The catching techniques have been described by Hocking, Armstrong & Downing (1960). Since nearly all *A. gambiae* that enter experimental huts at Magugu rest on the roof (Smith, 1962) and the nature of this substrate greatly affects contact toxicity (Smith & Hocking, 1962), mortalities were assessed in experimental huts with roofs lined with sorptive mud as well as in huts with grass roofs.

Biological assessments were made of the distribution of the fumigant effect of dichlorvos on mosquitos contained in 22 small cages ($3 \times 3 \times 6$ inches; $7.5 \times 7.5 \times 15$ cm) placed within the huts, as indicated in Table 4, and in the window traps. A wind vane and an anemometer, near the huts, gave records of wind direction and speed during the fumigation tests. The toxicity by contact with surfaces of the huts was also studied. Pieces of palm-mat, one foot (30 cm) square, and discs of sorptive mud were suspended in four experimental huts at eave level, and removed once a week to an insecticide-free building for bio-assay tests. The mosquitos used for fumigation and bio-assay tests were blood-fed *A. gambiae* caught in local houses.

The daily rate of loss of weight from the various dispensers, which was mainly due to the loss of dichlorvos, was determined in the laboratory of Arusha and in experimental huts. The air in the experimental huts was sampled at intervals to determine the concentration of vapour. This air was drawn through a pair of spined bubblers (Neal & Perry, 1959), standing at the mid-point of the floor and joined in series by a spherical joint, at 10 litres per minute using the pump and control equipment described by Johnstone.[1] In the experiment in hut No. 20 with three dispensers, air was sampled at two points: (1) middle of the floor, about one foot (30 cm) above the surface as above, and (2) approximately 5 feet (1.5 m) above the centre of the floor and 2 feet (60 cm) below the dispensers. In order to minimize loss of vapour from solution in the 25 ml of water placed in each bubbler, the bubblers were cooled in ice-water and carry-over from the first to the second bubbler was then restricted to about 20%. The dichlorvos in solution was determined by the resorcinol method developed by Ciba Ltd (Geiger & Furer, 1960) and some samples were also examined by the cholinesterase method of Michel (1949).

Two people slept in each hut for five nights each week from 9 p.m. to about 6.30 a.m. They were thus exposed to the insecticide for approximately 48 hours per week. The blood enzyme levels of the sleepers were checked over a period of six months by means of a portable testing kit in which the pseudocholinesterase level was measured by the change in pH when a drop of blood was mixed with acetylcholine perchlorate (shown by the colour of an indicator) (Edson, 1955).

RESULTS

Mortalities of naturally entering mosquitos

The monthly mortalities produced in naturally entering *A. gambiae* were calculated by the method of Hocking, Armstrong & Downing (1960) and are summarized in Table 1. In huts with grass roofs, all dispensers gave satisfactorily high kills in the first month, but only the two Ciba dispensers with long discharge tubes (A1 and C3) gave high kills during the second month of operation. There was no indication that the type of wall surface alone—plywood, non-sorptive mud or sorptive mud—influenced the kills in the huts with grass roofs. Mortalities were, however, lower in the huts with roofs lined with sorptive mud, and only the Savannah type of dispenser gave a satisfactorily high kill during the first month. The lower mortalities caused by the Ciba dispensers during the first month of operation, compared with the Shell and Savannah types, were due to the Ciba dispensers not becoming fully operative until after they had been opened for a week, whereas the others were immediately operative after removal of their plastic covers. There were, as is usual in field studies, great differences between the totals of mosquitos caught in individual huts, but, in addition, the various studies reported in this paper extended over two mosquito seasons with different and changing mosquito populations and thus the hut totals in the different studies are not comparable.

[1] Johnstone, D. R. (1961) TPRI/Porton Report No. 186 (unpublished document of the Tropical Pesticides Research Institute, Porton, Wilts., England).

TABLE 1

MORTALITIES IN *A. GAMBIAE* ENTERING EXPERIMENTAL HUTS WITH DICHLORVOS DISPENSERS

Type of dispenser	No. of huts examined	Percentage 24-hour mortality [a]		
		Months after treatment		
		0-1	1-2	2-3
Single dispenser: Grass roofs				
Ciba (A1)	4	72 (2 312)	77 (1 619)	53 (657)
Ciba (B2)	4	74 (785)	62 (554)	—
Ciba (C3)	1	83 (341)	72 (352)	—
Savannah	3	85 (1 328)	39 (1 437)	—
Shell	1	85 (732)	41 (1 419)	—
Control	2	27 (801)	13 (1 311)	9 (161)
Single dispenser: Mud roofs				
Ciba (A1)	2	62 (803)	53 (898)	—
Ciba (C3)	1	66 (2 036)	56 (3 319)	—
Savannah	1	75 (1 077)	40 (1 509)	—
Control	1	23 (450)	16 (1 002)	—
Three dispensers: Grass roof				
Savannah	1	93 (204)	84 (139)	55 (93)

[a] The numbers of *A. gambiae* caught are shown in parentheses.

Table 2 shows the weekly and Table 3 the two-monthly mortalities given by different types of dichlorvos dispenser in huts with grass and mud-lined roofs. The three types of Ciba dispenser gave lower mortalities during the first week than the Savannah and Shell types. With a number of exceptions, such as in huts with Shell dispensers, the general indication was that a higher proportion of the total catch of dead mosquitos occurred in the window traps and a lower proportion on the floor of huts with mud roofs, even in instances, such as with Savannah dispensers (see Table 3), where there were similar mortalities in the two types of hut.

Fumigation bio-assay tests

Average mortalities of 31% and 37% were obtained with 2-hour exposures in fumigation tests in three grass-roofed and three mud-roofed huts, indicating that the vapour toxicities were similar in both types of hut. The result of 16 fumigation tests are summarized in Table 4 and show that there was a great variation in kill in different parts of the hut. The highest mortality was inflicted level with the dispenser and the lowest kill was in the window trap during the first month. In the second month of operation the lowest kill was at floor level, thereby showing that dichlorvos vapour was not reaching the floor in more than very small concentrations.

The kill in the huts appeared to be influenced by the strength of the wind, there being in general higher mortalities when the strength of the wind outdoors was less than about 4 feet (1.2 m) per second (Table 5). The results of certain tests indicated also that wind direction affected the mortality in different parts of the hut.

Bio-assays on different types of surface

The average mortalities from bio-assays on pieces of palm-mat and mud plaques previously suspended in four huts containing dichlorvos dispensers are summarized in Table 6. The results show that the palm-mat and mud plaques acquired toxicity and that there was thus a residual contact effect in a hut containing a dichlorvos dispenser. The results also indicate that the matting was more toxic than the mud plaques, thereby suggesting either that the palm-mats absorbed more dichlorvos than the mud plaques or that the mud plaques were able to

TABLE 2

EFFECT OF DIFFERENT TYPES OF DICHLORVOS DISPENSER ON THE WEEKLY KILLS IN EXPERIMENTAL HUTS

Type of dispenser		Grass roofs								Mud roofs							
		Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7	Week 8	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7	Week 8
Ciba (A1)	Window trap Alive	30	9	0	3	12	4	22	24	100	16	32	66	46	87	162	81
	Window trap Dead	26	10	6	1	2	1	3	9	41	57	26	32	7	31	155	44
	Floor	51	64	22	28	104	53	54	61	29	70	43	31	27	44	67	44
	Total	107	83	28	32	118	58	79	94	170	143	101	129	80	162	384	169
	Mortality (%)	72	89	100	91	90	93	72	74	41	89	68	49	43	46	58	52
Ciba (B2)	Window trap Alive	61	15	14	23	22	15	33	54								
	Window trap Dead	91	49	8	14	6	5	35	19								
	Floor	0	81	58	44	79	89	27	16								
	Total	152	145	80	81	107	109	95	89								
	Mortality (%)	60	90	83	72	79	86	65	39								
Ciba (C3)	Window trap Alive	32	6	3	16	2	8	26	50	310	49	83	148	134	164	364	802
	Window trap Dead	54	8	7	18	3	1	8	29	365	143	119	548	114	45	305	963
	Floor	0	53	51	93	27	35	84	79	0	85	89	97	35	101	140	152
	Total	86	67	61	127	32	44	118	158	675	277	291	793	283	310	809	1 917
	Mortality (%)	63	91	95	87	94	82	78	68	54	80	71	81	53	47	55	58
Savannah	Window trap Alive	10	12	57	84	85	69	191	493	23	13	46	186	92	129	362	317
	Window trap Dead	60	152	86	84	22	8	87	240	61	54	101	359	107	17	92	346
	Floor	135	100	88	102	37	16	41	61	102	56	19	57	8	15	20	2
	Total	205	264	231	270	144	93	319	794	186	123	166	602	207	161	474	665
	Mortality (%)	95	95	75	69	41	26	40	38	88	89	72	69	56	20	24	52
Shell	Window trap Alive	0	35	41	37	163	523	123	34	3	62	21	11	28	82	74	12
	Window trap Dead	3	79	28	34	67	244	66	4	7	37	19	2	2	17	45	4
	Floor	124	203	49	99	58	64	66	7	25	57	23	33	26	26	3	2
	Total	127	317	118	170	288	831	255	45	35	156	63	46	56	125	122	18
	Mortality (%)	100	89	65	78	43	37	52	24	91	60	67	76	50	34	39	53
Control	Window trap Alive	73	37	108	122	258	140	77	89	105	74	70	96	199	188	208	249
	Window trap Dead	5	33	12	15	13	5	3	23	28	14	25	38	18	28	32	80
	Floor	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Total	78	70	120	137	271	145	80	112	133	88	95	134	217	216	240	329
	Mortality (%)	6	47	10	11	5	3	4	21	21	16	26	28	8	13	13	24

TABLE 3
EFFECT OF DIFFERENT TYPES OF DICHLORVOS DISPENSER ON KILLS AT TWO MONTHS IN EXPERIMENTAL HUTS

Type of dispenser		Grass roofs		Mud roofs	
		Total (less week 1)	%	Total (less week 1)	%
Ciba (A1)	Window trap Alive	74	15	490	42
	Window trap Dead	32	7	352	30
	Floor	386	78	326	28
	Total	492	100	1 168	100
	Mortality (%)		85		58
Ciba (B2)	Window trap Alive	176	25		
	Window trap Dead	136	19		
	Floor	394	56		
	Total	706	100		
	Mortality (%)		75		
Ciba (C3)	Window trap Alive	111	18	1 744	37
	Window trap Dead	74	12	2 237	48
	Floor	422	70	699	15
	Total	607	100	4 680	100
	Mortality (%)		82		63
Savannah	Window trap Alive	991	47	1 145	48
	Window trap Dead	679	32	1 078	45
	Floor	445	21	177	7
	Total	2 115	100	2 400	100
	Mortality		53		52
Shell	Window trap Alive	956	47	290	49
	Window trap Dead	522	26	126	22
	Floor	546	27	170	29
	Total	2 024	100	586	100
	Mortality (%)		53		51
Control	Window trap Alive	904	89	1 084	82
	Window trap Dead	109	11	235	18
	Floor	0	0	0	0
	Total	1 013	100	1 319	100
	Mortality (%)		11		18

decompose the absorbed insecticide, thus reducing its activity, or that both factors were operating.

Daily weight loss of dispensers

The daily losses in weight of the various dispensers (L_t g) tend to decrease with the age of the dispensers and by fitting, by eye, a best line to the experimental points relations describing these trends were obtained.

For example, with the Ciba C3 dispenser the

TABLE 4
EFFECT OF SITE OF CAGED MOSQUITOS IN EXPERIMENTAL HUTS ON KILLS INFLICTED BY DICHLORVOS AFTER TWO HOURS' EXPOSURE

Site of caged mosquitos	Percentage mortality	
	1 month	2 months
Ridge level	54	27
Level with dispenser	93	53
Eaves	71	41
Just below window trap level	80	40
Floor	80	22
In window trap	52	28

following alternative formulae were obtained from the laboratory results:

$L_t = 0.655\text{-}0.340 \log_{10} t$, where $t = 10\text{-}70$ days, or
$\log_{10} L_t = 0.941\text{-}1.221 \log_{10} t$, where $t = 20\text{-}150$ days.

Table 7 shows some laboratory experimental figures for the daily loss in weight of dispensers and Fig. 1 shows all the data for the C3 dispenser fitted to the two alternative lines. Some dispensers show a best fit when the loss is related to the logarithm of the time, particularly in the early part of their life, while later on a logarithm of loss against logarithm of time relation is better.

All dispensers are sensitive to marked changes in temperature and humidity, the solid Savannah and Shell types being more so than the Ciba. At higher temperatures and drier atmospheres greater losses were observed than on cool humid days, possibly because moisture was absorbed by the dispenser owing to the highly hygroscopic dimethyl phosphate which is a break-down product of dichlorvos. The mean monthly temperatures at Arusha during the period (September 1960 to June 1961) when the losses were measured varied between 18°C and 21°C.

Vapour concentrations

The vapour concentrations found in the various huts are given in Tables 8 and 9, and those from hut No. 20 (three dispensers) show a tendency to decrease with time. These concentrations (from hut No. 20) have been plotted in Fig. 2 and a line which satisfies the equation

$$\log_{10} C_t = -0.703\text{-}0.549 \log_{10} t$$

has been fitted by eye (C_t is the concentration after t days, in μg dichlorvos per litre of air).

DISCUSSION

The studies have shown that the fumigant insecticide dichlorvos is toxic to *A. gambiae* entering experimental huts. In grass-roofed huts a satisfactory mortality of over 75% was not maintained for more than about two months with a single dispenser or with three dispensers, and in huts with mud-lined roofs average mortalities never exceeded 75% after the first month. Chemical findings from the hut with three Savannah dispensers showed that there was a great initial loss of dichlorvos from these dispensers, followed by low vapour concentrations in the hut for a long period but these were not sufficiently toxic to maintain high mortalities after two months. If the weekly percentage mortalities of freely entering mosquitos in this hut are plotted on log probit paper against weekly mean vapour concentration as obtained from the relationship expressed under "Vapour concentrations" above

TABLE 5
MEAN PERCENTAGE MORTALITIES AFTER TWO HOURS' EXPOSURE IN FUMIGATION BIO-ASSAY TESTS COMPARED WITH THE WIND SPEED OUTDOORS

	Age of dispenser (days)															
	2	7	8	9	14	16	22	30	33	34	36	38	44	45	51	52
Wind speed <4 feet (1-2 m) per second	0	2.8	2.9		2.1			3.1							0	0
Mortality (%)	97	69	89		83			73							58	69
Wind speed >4 feet (1-2 m) per second				4.6		4.4	5.4		5.4	4.6	4.6	4.1	4.5	7.3		
Mortality (%)				80		27	68		29	15	50	14	44	54		

TABLE 6
PERCENTAGE MORTALITIES IN BIO-ASSAYS ON PIECES OF PALM-MAT AND MUD PLAQUES PREVIOUSLY SUSPENDED IN HUTS WITH DICHLORVOS DISPENSERS

Hut	Age of dispenser (days)					
	18	24	32	42	51	57
Palm-mats						
Huts with dispensers:						
Exposure time (hours)	2	2	2	2	4	4
Mortality (%)	73	76	79	19	40	61
Control hut:						
Exposure time (hours)	2	2	2	2	4	4
Mortality (%)	9	0	0	0	0	0
Mud plaques						
Huts with dispensers:						
Exposure time (hours)	2	2	2	2	4	4
Mortality (%)	55	29	54	18	19	19
Control hut:						
Exposure time (hours)	2	2	2	2	4	4
Mortality (%)	0	16	0	0	0	0

(see Table 8), an approximately linear dose-response curve is obtained with the LC_{50} at 0.02 μg/litre and the LC_{95} at 0.04 μg/litre (LC_{50} and LC_{95} denote lethal concentrations of dichlorvos in the air of the hut for 50% and 95% mortalities). A significant feature of this line is its steep slope, which indicates that small variations in the vapour concentration caused large differences in mosquito mortality.

In other hut experiments it has not been possible to devise similar relationships between concentration and mortality because of the extremely narrow limits of the effective range of the insecticide concentration and the limited amount of chemical sampling. Nevertheless, the higher ranges of mortalities occurred between limits of 0.03 and 0.02 μg/litre of air, and the lower ranges of mortalities between 0.02 and 0.01 μg/litre of air. It should be made clear that the actual values of the vapour concentration found by sampling at only two points in the hut may be different from the mean effective concentration in the hut.

The weight losses for Ciba-type dispensers placed in the experimental huts follow the same curve as that determined more sensitively in the Arusha

TABLE 7
DAILY LOSS IN WEIGHT OF DISPENSERS AT MEAN MONTHLY TEMPERATURES BETWEEN 18°C and 21°C

Type of dispenser	Daily weight loss (mg) at indicated time after opening									
	1 day	10 days	15 days	20 days	30 days	40 days	60 days	80 days	100 days	150 days
Ciba (A1)	—	—	576	199	195	142	63	38	27	—
Ciba (B2)	—	111	112	85	65	37	34	42	—	—
Ciba (C3)	—	212	221	214	161	113	48	37	32	36
	—	182	217	205	160	127	48	38	34	
Ciba IV	—	280	260	190	80	96	89	56	21	—
Ciba V	—	225	248	185	85	105	68	52	23	—
Ciba VI	—	231	261	198	86	110	69	51	23	—
Ciba VII	—	184	196	135	48	66	59	51	23	—
Ciba VIII	—	185	201	137	52	74	64	50	23	—
Savannah	150	110	80	60	90	40	36	30	30	15
Shell	548	111	—	70	78	89	30	96	130	53

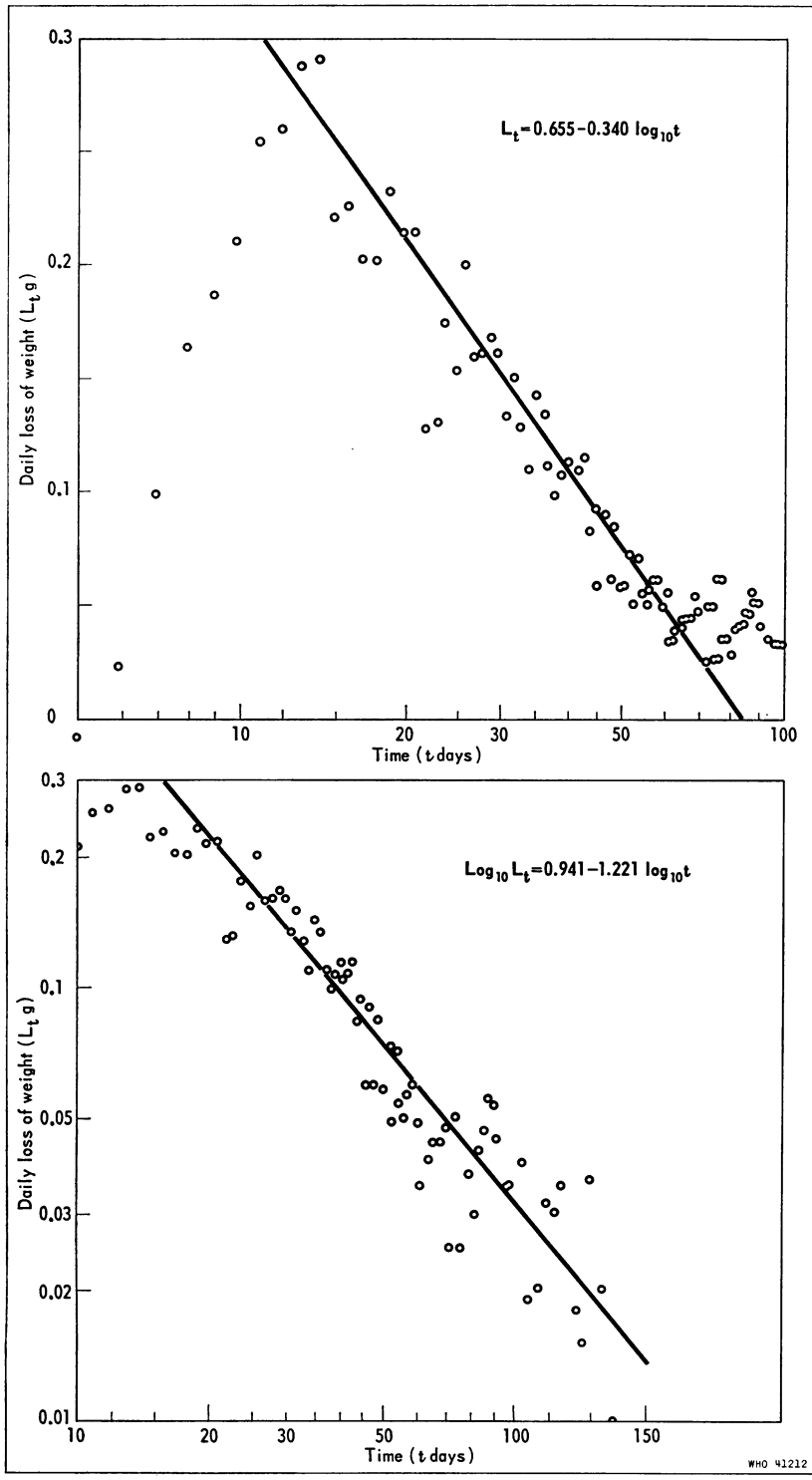

FIG. 1
RELATION OF DAILY WEIGHT LOSS OF CIBA C3 DICHLORVOS DISPENSER TO AGE OF DISPENSER [a]

[a] The upper graph relates the daily weight loss of the dispenser (L_t) to the logarithm of the time t. The lower graph relates the logarithm of the daily weight loss (L_t) to the logarithm of the time t.

TABLE 8. OVER-ALL PERCENTAGE MORTALITY IN HUT 20 CONTAINING 3 SAVANNAH DISPENSERS AND INTERPOLATED DICHLORVOS CONCENTRATION IN THE AIR DERIVED FROM DATA IN FIG. 2

Weeks after start	Mortality (%)	Interpolated vapour concentration at mid-week [a] (μg/litre)	Days after start	Vapour concentration (μg/litre)
			2	0.127
1	98	0.100		
			7	0.082
2	86	0.054	14	0.056
3	100	0.041	22	0.045
4	87	0.034	32	0.023
5	70	0.030		
6	95	0.027		
7	89	0.024	51	0.022
8	84	0.022	58	0.019
9	62	0.021		
10	66	0.020	72	0.020
11	35	0.019		
12	30	0.018	86	0.019
13	36	0.017		
14	9	0.0165		
15	44	0.016		
			113	0.010

[a] Derived from figures in last column *via* Fig. 2.

laboratory (see " Daily weight loss of dispensers " above). No relationship has been found between weight losses and the vapour concentrations determined, again probably because of insufficient data. It has been possible to derive from plots of log daily loss (from Table 9) against probit over-all mortalities (from Table 2) the values of LL_{50} and LL_{95} (daily weight loss for 50% and 95% mortalities). From the mean daily weight losses shown for huts 5 and 20 in Table 9 it will be seen that the rates of dispensing for the two huts are similar, yet the LL_{50} and LL_{95} (as determined above) for hut 5 (about 50 mg/day and 200 mg/day respectively) with the mud roof are higher than the corresponding figures of about 40 mg/day and 100 mg/day for hut 20 with the grass roof. With other pairs of huts containing the other types of dispenser similar results were obtained, and the over-all mortalities in the huts with mud-lined roofs were some 10% lower than in huts with grass roofs. The results of bio-assay tests suggest that the lower over-all mortalities in huts with mud roofs may be in part due to some sorption of the insecticide by the mud surface. A possible explanation of the higher proportion of dead mosquitos in the window traps of the huts with mud-lined roofs than in huts with grass roofs is that mosquito behaviour was affected by the dichlorvos. The results of studies on this subject confirm the

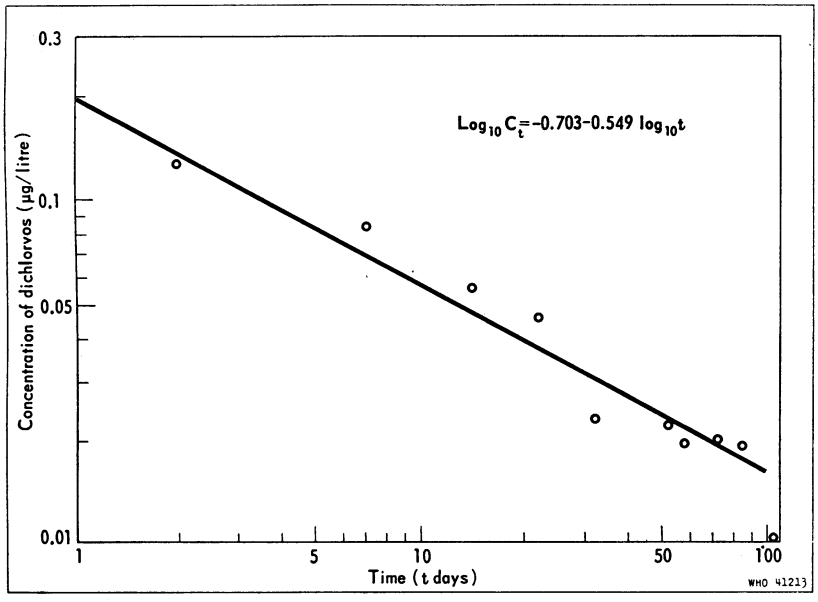

FIG. 2

RELATION OF CONCENTRATION OF DICHLORVOS FROM 3 SAVANNAH DISPENSERS IN HUT 20 TO AGE OF DISPENSERS

TABLE 9

CONCENTRATION OF DICHLORVOS VAPOUR AND MEAN DAILY LOSS IN WEIGHT OF DISPENSERS COMPARED WITH MORTALITIES IN FUMIGATION TESTS

Date of observation	Hut No. and type	Type of dispenser	Age of dispenser (days)	Dichlorvos (μg/litre air)	Mean daily weight loss (g)	Fumigation tests	
						Mortality (%)	Exposure (hours)
	No. 20						
4.12.61	Grass/sorptive	Ciba (C3)	7	0.010			
13.12.61			16	0.014	0.107		
21.12.61			24	0.011	0.078		
10. 1.62			44	0.013	0.072	44	2
22. 1.62			56	0.011	0.056	10	2
	No. 5						
4.12.61	Sorptive/sorptive	Ciba (C3)	7	0.021			
13.12.61			16	0.015	0.102		
21.12.61			24	0.016	0.090		
10. 1.62			44	0.021	0.070		
22. 1.62			56	0.015	0.067	73	2
	No. 4						
6.12.61	Sorptive/sorptive	Savannah	9	0.021			
15.12.61			18	0.009			
3. 1.62			37	0.017		19	4
16. 1.62			50	0.013			
24. 1.62			58	0.012			
	No. 7						
6.12.61	Grass-sorptive	Savannah	9	0.029		80	2
15.12.61			18	0.016			
3. 1.62			37	0.029			
24. 1.62			58	0.014			

suggestion and are described in a separate paper (Smith, 1963).

The mathematical relationship for the daily rate of loss of dichlorvos from the dispensers given on page 404 can be used, when related to a satisfactory level of over-all mosquito mortality, to predict the useful life of new dispensers under the same conditions. A 75% over-all mortality can be regarded as such a satisfactory level and from the experiment using huts 5 and 20 a value for the LL_{75} of about 70 mg/day can be derived. The predicted lives for various dispensers are tabulated in Table 10, together with the experimental values abstracted from Table 2. The agreement is sufficiently close to give confidence in the predicted values for the five dispensers Ciba IV-VIII.

The results of fumigation tests show that the dichlorvos vapour is unevenly distributed in a hut. It would seem that at low wind speeds the vapour is less stratified than when there is a calm, but it is still in sufficient concentrations to inflict high mortalities. At higher wind speed the over-all concentration of the vapour was possibly reduced below the lethal level in a larger section of the hut. The results

TABLE 10
THE USEFUL LIVES OF DISPENSERS AS PREDICTED AND AS OBSERVED

Type of dispenser	Predicted life (days)	Experimental life to 75 % mortality in grass-roofed huts (days)
Ciba (A1)	55	50
Ciba (B2)	25-30	40
Ciba (C3)	50	50
Savannah	25	25
Shell	40	30
Ciba IV	60	
Ciba V	50	
Ciba VI	50	
Ciba VII	40	
Ciba VIII	40	

of fumigation bio-assay tests also show that exposure periods of two hours give mortalities which provide a fair indication of the magnitude of over-all mortalities in an experimental hut, and indeed the values of LL_{50} and LL_{95} from hut No. 20 mentioned above are similar to corresponding figures derived from fumigation test data.

No deleterious effect of the dichlorvos vapour on the sleepers in the huts were detected, as indicated by blood pseudo-cholinesterase levels.

Finally, it is concluded that dichlorvos is lethal to naturally entering mosquitos, both as a vapour, and by contact with surfaces in the hut. The importance of the fumigant effect is difficult to assess because it varies in different parts of the hut. Contact toxicity is equally difficult to assess because it is not known to what degree toxicity is augmented by sorption or to what degree different types of substrates physically remove the insecticide from the surface or chemically decompose it.

ACKNOWLEDGEMENTS

We wish to thank Field Officer Mr W. O. Obudho for careful supervision of mosquito collection in experimenta huts, Mr E. T. Mesmer and Mr C. E. McKone for their unremitting assistance with the chemical determinations and Dr D. J. Webley for valuable discussions.

RÉSUMÉ

Des essais sur le terrain ont été effectués au Tanganyika afin d'évaluer l'efficacité de plusieurs modèles d'évaporateurs de dichlorvos pour la destruction d'*Anopheles gambiae*. Deux types de huttes ont servi aux expériences: le premier à toiture uniquement végétale, le second à toiture recouverte intérieurement de boue séchée.

Avec les divers appareils, on a obtenu un taux de mortalité des anophèles satisfaisant, atteignant au moins 75% pendant une période de un à deux mois après la mise en place des évaporateurs. Les meilleurs résultats ont cependant été observés dans les huttes à couverture exclusivement végétale.

On a pu démontrer que le pouvoir toxique des vapeurs de dichlorvos était identique dans les deux cas, mais que l'action insecticide par contact était moins marquée dans le second type de hutte, peut-être par absorption moindre ou décomposition chimique du produit au niveau des surfaces recouvertes de boue séchée.

Aucun effet toxique n'a été constaté chez les personnes ayant séjourné la nuit dans les habitations servant aux essais.

REFERENCES

Edson, E. F. (1955) *Brit. med. J.*, **1**, 841, 1218
Geiger, M. & Furer, R. (1960) *Z. anal. Chem.*, **174**, 401
Hocking, K. S., Armstrong, J. A. & Downing, F. S. (1960) *Bull. ent. Res.*, **22**, 757
Michel, H. O. (1949) *J. Lab. clin. Med.*, **34**, 1504
Neal, E. & Perry, B. J. (1959) *Analyst*, **84**, 226
Rapley, R. E. (1961) *Bull. Wld Hlth Org.*, **24**, 659
Smith, A. (1962) *E. Afr. med. J.*, **39**, 15
Smith, A. (1963) *Indian J. Malar.*, **17**, 131
Smith, A. & Hocking, K. S. (1962) *Bull. Wld Hlth Org.*, **27**, 231