Assessment of the Residual Toxicity to *Anopheles gambiae* of the Insecticides UC-10584 and Bayer 39007*

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The insecticides 3-isopropylphenyl N-methylcarbamate (UC-10584) and 2-isopropoxyphenyl-N-methylcarbamate (Bayer 39007) received study in the form of bio-assays and trials in experimental huts at the Magugu Outstation of the Tropical Pesticides Research Institute, Arusha, Tanganyika, as part of the World Health Organization's programme of testing and developing new insecticidal compounds. The results presented in this paper are largely of trials made between November 1961 and March 1962.

Experimental methods

The first formulation (UC-10584) was a water-dispersible powder made by Union Carbide Co. Ltd, containing 50% w/w technical 3-isopropylphenyl N-methylcarbamate; the other (Bayer 39007) was also a water-dispersible powder made by Farbenfabriken Bayer A.G. with 50% w/w technical 2-isopropoxyphenyl-N-methylcarbamate. The insecticides were applied on mud panels at Arusha at nominal dosages of 2 g/m² by means of the Poulton Precision Sprayer.[a] Bio-assays were done using the technique recommended by the WHO Expert Committee on Insecticides.[b] The test insects were confined on different substrates, under plastic funnels (9 cm in diameter and 6 cm high) provided by WHO. The decline in toxicity was assessed by increasing the duration of time that the test insects were exposed to the mud panels from half an hour to eight hours as mortalities fell below 75%.

Three experimental huts were treated throughout by an Oxford Precision Sprayer[c] at a nominal dosage of 1.5 g/m². The dosages applied to the huts were determined colorimetrically by means of a dye, kiton red, which was dissolved in the water that was applied with the insecticide. The kills of naturally entering *Anopheles gambiae* were calculated from the daily counts of dead mosquitos on the floor plus the numbers captured in the window-traps that died within 24 hours. The catching techniques are described by Hocking et al.[d] In view of the roof-resting habits of *A. gambiae* in the experimental huts,[e] the residual toxicity of each insecticide was assessed in an experimental hut with a roof lined with sorptive mud, as well as in two huts with grass roofs. In bio-assays on the surfaces of the experimental huts decline in toxicities of the roof and wall deposits was assessed by increasing the exposure of the test insects from five minutes to eight hours. Short initial exposure times were used in bio-assays in the experimental huts as earlier tests with organophosphorus insecticides had indicated that a more direct relationship between bio-assays and the overall mortalities in these huts might be apparent with exposure periods of less than half an hour than with longer periods.[f]

The insects tested were blood-fed *Anopheles gambiae* from the laboratory colony for tests on the Arusha panels; and locally caught *A. gambiae* for bio-assays in the experimental huts. All tests were duplicated, the average of both tests being used to express the percentage mortalities after 24 hours.

Results

Bio-assays. The toxicity of UC-10584 on a panel of sorptive mud declined from 100% mortality after half an hour's exposure, two weeks after application, to 48% mortality after four hours' exposure 14 weeks after application. Mortalities of 100%, or nearly 100%, persisted for a year at eight hours' exposure. On non-sorptive mud the insecticide showed great promise by maintaining nearly 100% mortality for a year at only half an hour's exposure.

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[a] Poulton, G. F. (1960) *Miscellaneous report No. 272*, Arusha, Colonial Pesticides Research Unit (unpublished).

[b] World Health Organization, Expert Committee on Insecticides (1960) *Wld Hlth Org. techn. Rep. Ser.*, **191.**

[c] Fryer, J. D. (1956) In: *Proceedings of the Third British Weed Control Conference*, London, p. 585.

[d] Hocking, K. S., Armstrong, J. A. & Downing, F. S. (1960) *Bull. ent. Res.*, **22**, 757.

[e] Smith, A. (1962) *E. Afr. med. J.*, **39**, 15.

[f] Smith, A. & Hocking, K. S. (1962) *Bull. Wld Hlth Org.*, **27**, 231.

The toxicity of Bayer 39007 on a panel of sorptive mud declined from 100% mortality after half an hour's exposure, three days after application, to 44% mortality after 12 hours' exposure eight weeks after application. On non-sorptive mud the insecticide maintained nearly 100% mortality for a year at eight hours' exposure.

The results of bio-assays in the experimental huts are given in Table 1 and show that UC-10584 was persistent on all surfaces. Toxicity persisted longer on the grass roofs than on the mud walls, and there was considerably greater persistence on the non-sorptive than on the sorptive mud. For example, in the sixth month the grass roofs gave a mortality of 100% after one hour's exposure, and a non-sorptive mud wall 100% mortality after two hours whereas a sorptive mud wall gave 100% mortality only after eight hours' exposure.

The insecticide Bayer 39007 was highly persistent on plywood and grass but poor on mud. For example, in the sixth month a plywood wall gave a mortality of 100% after 10 minutes' exposure, and a grass roof 100% mortality after one hour's exposure, compared with a non-sorptive mud wall which at three months gave 100% mortality after two hours' exposure, and a sorptive mud roof which at one month gave no more than 40% mortality after four hours' exposure.

Mortality of naturally entering mosquitos. The results, summarized in Table 2, show that high over-all mortalities to UC-10584 persisted for four months in the two huts with grass roofs. The over-all mortalities in the two experimental huts with grass roofs were very similar although one had walls lined with non-sorptive mud and the other walls with sorptive mud. High toxicity persisted for two months in the hut with the roof lined with sorptive mud, but in the third month the over-all mortality dropped to 40%.

High over-all mortalities to Bayer 39007 persisted for seven months in the hut with a grass roof and plywood walls, but for only two months in the hut with a grass roof and walls lined with non-sorptive mud. A low toxicity occurred even in the first month in the hut with the roof lined with sorptive mud.

Control mortalities were high in this series of trials possibly owing to the rather high temperatures in the field laboratory to which the mosquitos, retained for records for mortalities after 24 hours, were subjected during the short dry season. Generally, the unfed mosquito was least able to survive adverse temperatures, and high control mortalities usually occurred when there was a high proportion of unfed mosquitos in the window-trap. Table 3 shows that the distributions of mortalities between the hut and the window-trap for hut 11, treated with UC-10584, and the control hut were quite different and that the percentage of unfed mosquitos in the total catch was very high in the window-trap of the control hut during the first month of observations.

Discussion

The results of bio-assays on the Arusha panels and in the experimental huts have shown that UC-10584 has a long-lasting toxicity, not only on impervious surfaces such as grass, but also on non-sorptive mud. Its persistence on sorptive mud, while being much shorter than on non-sorptive mud, is also appreciably longer than that of the organophosphorus insecticides malathion and fenthion.[f] Bayer 39007 was effective for a long period on impervious surfaces but its persistence on mud was even shorter than that of malathion and fenthion. The effects of the different types of surface on the persistence of toxicity of the two carbamate insecticides were, however, similar in kind, if not degree, to those of malathion and fenthion [f, g] and the chlorinated hydrocarbon insecticides DDT and dieldrin.[h, i, j]

Over-all mortalities among naturally entering *A. gambiae* have shown UC-10584 to have an effective residual toxicity for five to seven months in experimental huts with grass roofs. The high over-all mortality during the second month in the hut with a roof lined with sorptive mud is most significant and suggests that the compound may be a useful insecticide even in areas where houses are built with sorptive mud. Bayer 39007 maintained high over-all mortalities for three months in an experimental hut with a grass roof and walls lined with non-sorptive mud compared with five months for UC-10584, thereby indicating that the latter insecticide was also more persistent on impervious substrates. High kills for seven months in a hut with a grass roof and walls lined with plywood indicate, however, that Bayer

[g] Rao, A. M., Press, J., Caprari, P. & Regamey, J. (1960) Unpublished working document WHO/Mal/274; WHO/Insecticides/115.

[h] Hadaway, A. B. & Barlow, F. (1952) *Bull. ent. Res.*, **43**, 281.

[i] Barlow, F. & Hadaway, A. B. (1959) *Bull. ent. Res.*, **49**, 315.

[j] Armstrong, J. A. & Bransby-Williams, W. R. (1960) *Mosquito News*, **20**, 297.

TABLE 1

RESULTS OF BIO-ASSAYS ON THE WALLS AND ROOFS OF EXPERIMENTAL HUTS

Huts treated with UC-10584

Hut No.	Substrate	Dosage (g/m²)		Age of deposit (months) 1	2	3	4	5	6	7	8
			Walls								
3	Non-sorptive mud	1.52	Exposure time (min.)	5	10	120	120	120	120	—	—
			% mortality	*91*	*23*	*100*	*100*	*86*	*100*	—	—
11	Sorptive mud	1.31	Exposure time (min.)	5	10	—	—	—	—	—	—
			% mortality	*100*	*36*	—	—	—	—	—	—
16	Sorptive mud	1.16	Exposure time (min.)	5	10	120	480	480	480	480	480
			% mortality	*33*	*21*	*7*	*97*	*62*	*100*	*51*	*69*
			Roofs								
3	Grass	2.94	Exposure time (min.)	5	10	60	60	60	60	—	—
			% mortality	*91*	*6*	*100*	*78*	*41*	*100*	—	—
11	Sorptive mud	2.00	Exposure time (min.)	5	10	—	—	—	—	—	—
			% mortality	*100*	*5*	—	—	—	—	—	—
16	Grass	2.41	Exposure time (min.)	5	10	60	60	60	60	60	60
			% mortality	*100*	*59*	*97*	*92*	*97*	*100*	*97*	*97*

Huts treated with Bayer 39007

Hut No.	Substrate	Dosage (g/m²)		Age of deposit (months) 1	2	3	4	5	6	7	8
			Walls								
18	Plywood	1.8	Exposure time (min.)	5	5	10	10	10	10	20	40
			% mortality	*100*	*89*	*98*	*100*	*93*	*100*	*100*	*76*
10	Sorptive mud	1.5	Exposure time (min.)	240	—	—	—	—	—	—	—
			% mortality	*14*	—	—	—	—	—	—	—
2	Non-sorptive mud	1.13	Exposure time (min.)	5	10	120					
			% mortality	*43*	*16*	*100*					
			Roofs								
18	Grass	2.47	Exposure time (min.)	5	10	60	60	60	60	60	120
			% mortality	*100*	*26*	*100*	*97*	*38*	*100*	*40*	*46*
10	Sorptive mud	1.5	Exposure time (min.)	240	—	—	—	—	—	—	—
			% mortality	*40*	—	—	—	—	—	—	—
2	Grass	1.67	Exposure time (min.)	5	10	60	—	—	—	—	—
			% mortality	*96*	*20*	*100*	—	—	—	—	—

Control hut

Hut No.	Substrate	Dosage (g/m²)		Age of deposit (months) 1	2	3	4	5	6	7	8
			Wall								
1	Non-sorptive mud	—	Exposure time (min.)	5	10	120	480	480	480	480	480
			% mortality	*0*	*0*	*3*	*2*	*3*	*0*	*0*	*2*
			Roof								
1	Grass	—	Exposure time (min.)	5	10	60	60	60	60	60	120
			% mortality	*0*	*3*	*10*	*5*	*23*	*0*	*0*	*9*

TABLE 2

OVER-ALL MORTALITIES OF *A. GAMBIAE* ENTERING EXPERIMENTAL HUTS

Hut No.	Roof		Walls		Average hut dosage	% 24-hour mortality at indicated time after treatment [a]							
	Substrate	Dosage (g/m²)	Substrate	Dosage (g/m²)		0-1 month	1-2 months	2-3 months	3-4 months	4-5 months	5-6 months	6-7 months	7-8 months
					UC-10584								
11	Sorptive mud	2.00	Sorptive mud	1.31	1.58	96 (985)	74 (1 101)	40 (540)	— —	— —	— —	— —	— —
3	Grass	2.94	Non-sorptive mud	1.52	2.10	100 (417)	95 (564)	80 (174)	80 (142)	66 (266)	58 (210)	—	—
16	Grass	2.41	Sorptive mud	1.16	1.68	99 (342)	99 (485)	84 (200)	94 (226)	89 (229)	77 (154)	75 (57)	40 (20)
					Bayer 39007								
10	Sorptive mud	1.5	Sorptive mud	1.5	1.5	52 (40)	19 (108)	—	—	—	—	—	—
2	Grass	1.13	Non-sorptive mud	1.67	1.32	99 (628)	82 (569)	69 (296)	—	—	—	—	—
18	Grass	1.8	Plywood	2.47	2.07	100 (597)	99 (434)	97 (240)	95 (296)	95 (186)	95 (250)	91 (65)	64 (25)
					Control								
1	Grass	—	Non-sorptive mud	—	—	37 (396)	18 (703)	31 (250)	27 (436)	14 (182)	14 (118)	24 (63)	16 (37)

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

TABLE 3
THE MORTALITIES AND PROPORTION OF UNFED MOSQUITOS IN A TREATED (UC-10584) AND AN UNTREATED HUT

Month	Percentage of total catch					
	Treated hut (No. 11)			Untreated hut (No. 1)		
	Dead on floor	Dead in window-trap	Unfed	Dead on floor	Dead in window-trap	Unfed
1	82	14	39	0	37	66
2	57	17	48	0	18	58
3	16	24	54	0	27	41

39007 would be an effective residual insecticide in areas where houses are built almost entirely with wood or grasses.

The present trials with these two carbamate insecticides provide a subtle illustration of how the resting habits of *A. gambiae* at Magugu affect over-all mortalities in huts. Well over 90% of *A. gambiae* rest on the roofs of experimental huts, but when the walls are lined with plywood at least 10% more mosquitos rest on the wall by day or night.[k] The high mortalities in hut 18 are thus not only due to the high toxic surface of the treated plywood, but also to its greater use as a resting-place.

Results have again shown that bio-assay exposure times have no simple relationship with the times that naturally entering mosquitos spend resting in a hut. For example, on the grass roof of hut 3, treated with UC-10584, bio-assay mortalities of 100% were still being inflicted after six months with exposure periods of only one hour's duration, while the over-all mortality to naturally entering mosquitos was only 58%.

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[k] Tropical Pesticides Research Unit, *Progress report No. 28*, Arusha (unpublished).

Assessment of the Residual Toxicity to *Anopheles gambiae* of the Insecticides Sevin and Sumithion *

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The insecticides alpha-naphthyl-N-methylcarbamate (Sevin) and O,O-dimethyl-O-(3-methyl-4-nitrophenyl) phosphorothionate (Sumithion) received study in the form of bio-assays and trials in experimental huts at the Magugu Outstation of the Tropical Pesticides Research Institute, Arusha, Tanganyika, as part of the World Health Organization's programme of testing and developing new insecticidal compounds. The results presented in this paper are of trials made between March and July 1962.

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Experimental methods

Two formulations of Sevin were studied, both made by Union Carbide Co. Ltd. The one contained 50% w/w technical product and the other, Sevin 85W, was an air-milled, microfine (2-10 μ), wettable powder containing 85% actual Sevin. Sumithion was also a water-dispersible powder, made by Farbenfabriken Bayer A.G., with 50% of the technical product. Five experimental huts were treated throughout by an Oxford Precision Sprayer at a nominal dosage of 2 g/m² and two at a nominal dosage of 4 g/m². The dosages applied to the huts were determined by chemical analysis of treated sample papers and ranged from 1.6 to 2.2 g/m² for the five huts and were 3.8 and 4.9 g/m² for the two treated