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THE RESIDUAL TOXICITY OF SIX INSECTICIDES TO MOSQUITOES IN WINDOW TRAP HUTS AT MAGUGU, TANZANIA, AND AT TAVETA, KENYA

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INTRODUCTION

Since 1960 the Tropical Pesticides Research Institute has been one of the centres carrying out Stage IV experimental hut screening of new compounds against wild mosquitoes as part of the World Health Organization's Evaluation Scheme for Insecticides. The progress of this scheme, which was started primarily to evaluate alternative insecticides for use against resistant insect vectors, has recently been reviewed (Wright, 1971).

This paper reports the screening of three new organophosphate insecticides: OMS–1170 (also known as phoxim or Bayer 77488), OMS–1197 (also known as chlorphoxim or Bayer 78182), and OMS–1211 (also known as Iodofenphos or Ciba C9491); and three new carbamates: OMS–708 (also known as Mobam or MCA600), OMS–1028 (also known as Bayer 38799), and OMS–1202 (also known as U.C. 8454). Results of a trial of lindane are also included as a standard. The work was carried out during four seasons between March 1967 and July 1970.

STUDY AREAS. The trials were carried out at two outstations of the Tropical Pesticides Research Institute at Magugu, Tanzania, and Taveta, Kenya. The Taveta area has been described by Smith and Draper (1959) and the Magugu area by Smith (1964a). Both stations are in the East African Savannah Zone, and both have an annual rainfall of 600–700 mm, falling mainly in two seasons, from late October to early December, and mid-March to mid-May.

Anopheles gambiae species A and B

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have both been recorded at Taveta but only Species B has been recorded at Magugu. The numbers of *A. gambiae* entering the huts allowed insecticide screening to be carried out at Magugu from December of one year to July the next year, and at Taveta from March to August each year. Sufficient *Anopheles funestus* Giles and *Culex pipiens fatigans* Wied. usually entered the huts at Taveta from May to August to give adequate evaluations of the insecticides.

Anopheles gambiae and *A. funestus* adults at Taveta and Magugu were susceptible to DDT, dieldrin, lindane and malathion. *Culex p. fatigans* adults were resistant to dieldrin and DDT, and had an LC50 of about 1 percent of malathion. The houses in the Taveta area were sprayed with six cycles of dieldrin between 1955 and 1958 (East Africa High Commission, 1960). The houses at Magugu have never been sprayed on an organised basis.

MATERIALS AND METHODS. The window trap huts used were essentially the same as described by Rapley (1961). The huts were 8 ft square (2.42 m.) with walls of burnt brick lined with mud plaster. The mud used to make the plaster was of two kinds, a more sorptive red and a less sorptive black. The sorptive capacity of dried pellets of these muds was compared on the basis of the proportions of their own weight (percent) of carbon tetrachloride vapour which they absorbed in 24 hours at 25° C, using the method of Hadaway and Barlow (1955). The results were as follows:

1967: Taveta red mud: 9.7% ± 2.0 (31 pellets)

Taveta black mud: 6.9% ± 0.3 (21 pellets)

1969: Magugu ("Babati") red mud: 10.25% ± 0.81 (20 pellets)

Magugu black mud: 3.12% ± 0.31 (28 pellets).

The roofs were of split sisal pole frames thatched with grass. The roofs of some huts were also lined with a layer of mud plaster. In most of the experiments reported here the grass-roofed huts had walls lined with black mud and the mud-roofed huts had both roofs and walls lined with red mud, in order to test the insecticides under the best and worst conditions. Some huts had corrugated iron ("tin") roofs on metal slotted angle frames. The sprays tended to run off or bounce off the metal, and during the heat of the day the roof temperature rose to 50° C and few mosquitoes rested there, (Smith, Obudho and Esozed, 1967).

Chemical names of the insecticides are given in Table 1. All were supplied as water dispersable powder (w.d.p.) formulations, and were sprayed at dosages of 2.0 g/m^2 active ingredient, except for the lindane which was applied at 1.0 g/m^2. All spraying was done with an Oxford precision sprayer fitted with an Allman 00 jet at a lance pressure of 2.8 kg/cm^2. The quantities of powder necessary to give the required dosages for each hut were mixed with 1500 ml of water. The first sample of OMS–1170 received, which was sprayed at Taveta on 16.3.68., was unsatisfactory because some of the active ingredient, a liquid, separated out as an immiscible layer which stuck to the sides of the sprayer and the mixing vessel. The sample used the following year at Magugu was better. The other samples could all be sprayed satisfactorily.

The collecting and counting routine for the huts was the same as described by Smith (1964b). Two paid volunteers slept in each hut for 5 nights per week. The mosquitoes entered the hut through the eaves. Mosquitoes were removed morning and evening from the single window trap in the east wall, and held for a further 24 hours before mortalities were recorded. The mortalities were calculated from the mosquitoes in the window traps plus the mosquitoes recovered dead from the floors, according to the formula of Smith (1963). The resting mosquitoes were not included in the calculation unless they died or entered the window traps. Any mosquitoes which left through the eaves escaped assessment.

Bioassays of treated surfaces using fed and gravid *A. gambiae* caught in local

TABLE 1.—Chemical names of compounds tested

OMS number	Chemical name	Formulation
OMS–708	4–benzothienyl N–methylcarbamate	50% w.d.p. (Taveta, 1967)
OMS–708	4–benzothienyl N–methylcarbamate	80% w.d.p. (Magugu, 1968)
OMS–1028	o–cyclopentylphenyl N–methylcarbamate	75% w.d.p.
OMS–1170	o,o–diethyl thiophosphoryl o–alpha–cyanobenzaldoxime	40% w.d.p.
OMS–1197	o,o–diethyl thiophosphoryl o–cyano–ortho–chlorobenzaldoxime	50% w.d.p.
OMS–1202	5,6,7,8–tetrahydro–1–napthyl N–methylcarbamate	50% w.d.p.
OMS–1211	o,o–dimethyl o–2,5–dichloro–4–iodophenyl phosphorothioate	50% w.d.p.
OMS–17 (lindane)	hexachlorocyclohexane gamma isomer	26% w.d.p.

houses were made by the method recommended by the WHO Expert Committee on Insecticides (1970). Control bioassays were carried out in untreated huts.

After each experiment the contaminated grass roofs and mud plaster linings were removed and replaced. The iron roofs were cleaned well with soap and water.

In a grass-roofed hut at Taveta during 1967–70 mean daily maximum temperatures were 25–32° C and daily minimum temperatures 17–23° C, while mean daily maximum relative humidities were 70–83 percent and mean daily minimum relative humidities 47–62 percent.

RESULTS

OVERALL MORTALITIES OF *Anopheles gambiae*. The mortalities of *Anopheles gambiae* females in all abdominal conditions are shown in Table 2. The mortalities in treated huts have been corrected for mortalities in their respective control huts by Abbot's formula. Mortalities in the control huts were 0–18 percent, consisting mainly of unfed female mosquitoes which died in the window traps. Where more than one hut of a particular type was used, the results have been combined. The mortalities due to two of the carbamates, OMS–708 and OMS–1202, and three of the organophosphates, OMS–1170, OMS–1197, and OMS–1211, are shown graphically in Fig. 1.

Using mortality of 70 percent as a criterion for effectiveness, in the grass-roofed huts, OMS–1211 was effective for at least 28 weeks, OMS–1197 for at least 24 weeks, OMS–1170 for 16–20 weeks, OMS–708 for more than 20 weeks in its first trial but only 8 weeks in its second, OMS–1028 for 16 weeks, and OMS–1202 for 8 weeks. Lindane was effective for 8–12 weeks.

In the mud-roofed huts, OMS–1170 was effective for 12 weeks at Taveta in 1968 but for only 4 weeks at Magugu in 1969. The other new compounds were effective for only 4 weeks or less, but lindane was effective for 20 weeks.

Five of the six new compounds were

TABLE 2.—Corrected mortalities of *Anopheles gambiae* females in treated window trap huts.

Compound, station, date of spraying, type of hut	Overall mortality percent — Weeks after treatment 1–4	5–8	9–12	13–16	17–20	21–24	25–28
OMS–708							
Taveta, 28.3.67							
two grass-roofed	90(311)*	85(1011)	90(207)	79(95)	14/16**	.....	.....
two mud-roofed	75(390)	38(1464)	45(552)	19(180)	2/23	.....	.....
two iron-roofed	67(756)	64(3832)	56(1207)	52(139)	65(132)	.....	.....
Magugu, 5.1.68							
one grass-roofed	76(58)	69(52)	50(219)	60(779)	39(430)	43(77)	.....
one iron-roofed	53(143)	43(43)	21(492)	14(1648)	.....	.....	.....
OMS–1028							
Magugu, 5.1.68							
one grass-roofed	100(54)	76(67)	83(215)	68(509)	50(254)	55(54)	.....
one mud-roofed	37(135)	17(103)	.....	.....	.....	.....	.....
OMS–1211							
Magugu, 5.1.68							
one grass-roofed	100(40)	100(38)	83(164)	72(587)	76(346)	79(87)	89(27)
one mud-roofed	57(91)	54(54)	34(223)	.....	.....	.....	.....
one iron-roofed	84(76)	80(70)	48(291)	37(944)	.....	.....	.....
OMS–1170							
Taveta, 16.3.68							
one grass-roofed	98(2226)	89(4308)	89(1085)	74(409)	41(349)	47(58)	.....
one mud-roofed	88(1742)	76(2448)	69(749)	44(278)	19(72)	5/14	.....
Magugu, 31.1.69							
two grass-roofed	99(226)	96(204)	87(110)	92(83)	81(86)	2/6	.....
two mud-roofed	81(140)	37(220)	9(63)	.....	.....	.....	.....
one iron-roofed	96(126)	50(128)	30(106)	9(64)	5(63)	.....	.....
OMS–1197							
Taveta, 16.3.68							
one grass-roofed	99(1518)	98(3229)	98(1330)	98(444)	98(191)	100(73)	.....
one mud-roofed	45(1732)	22(3592)	25(1356)	17(861)	19(155)	8(38)	.....
Magugu, 31.1.69							
two grass-roofed	90(152)	88(134)	87(109)	86(106)	71(73)	14/15	.....
one mud-roofed	62(32)	11(44)	.....	.....	.....	.....	.....
one iron-roofed	86(251)	59(236)	56(89)	26(27)	0(35)	.....	.....
OMS–1202							
Magugu, 27.12.69							
two grass-roofed	86(110)	72(403)	50(474)	35(210)	34(288)	22(181)	.....
two mud-roofed	3/10	33(61)	7(164)	5(167)	7(260)	5(140)	.....
one iron-roofed	90(39)	40(67)	30(108)	8(128)	22(202)	17(81)	.....
Lindane (standard)							
Magugu, 27.12.69							
one grass-roofed	100(43)	91(78)	69(84)	30(36)	47(150)	30(77)	.....
one mud-roofed	17/17	21/24	83(60)	71(65)	77(148)	56(132)	.....

* The numbers of mosquitoes upon which each mortality is based are shown in parentheses.
** Mortalities based on catches of less than 25 mosquitoes are expressed as fractions of the total.

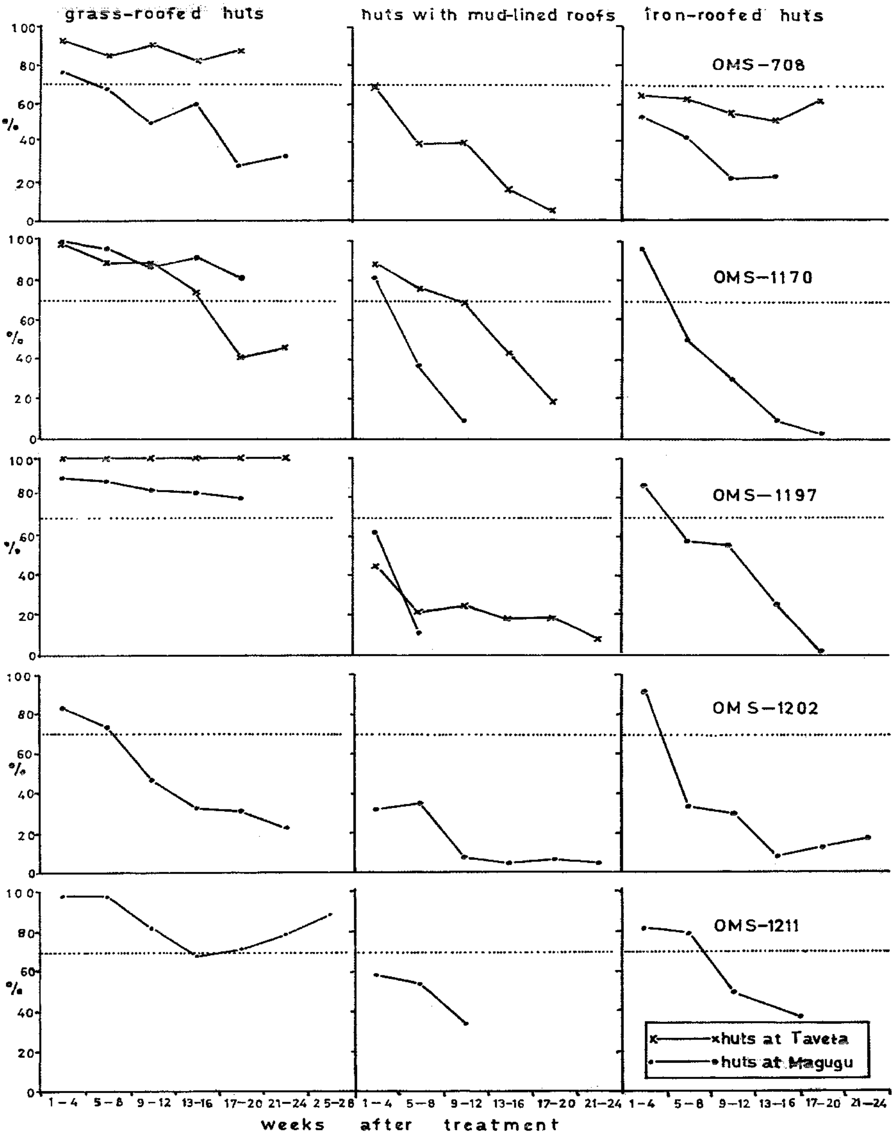

FIG. 1.—Mortalities of *A. gambiae* in window trap huts treated with different insecticides.

also tried in iron-roofed huts. The results were generally slightly better than in mud-roofed huts but not as good as in grass-roofed huts. OMS–1211 was effective in these huts for 8 weeks, while OMS–1170, OMS–1197, and OMS–1202 were effective for 4 weeks each. In the two iron-roofed huts treated with OMS–708 on 28.3.67, the overall mortality never reached 70 percent but remained at 52–67 percent during a 20-week observation period. This may have been because the roofs of these huts were supported by a rather bulky wooden frame which offered an extensive mosquito resting area of treated, non-sorptive material. The sample tested at Magugu in 1968 in a hut with an all-metal roof was less effective.

Mortalities of *Anopheles funestus and Culex p. fatigans* at Taveta. The corrected mortalities of *A. funestus* and *C. p. fatigans* females in huts at Taveta treated with OMS–708, OMS–1170, and OMS–1197 are shown in Table 3. Control hut mortalities of *A. funestus* were 0–23 percent and of *C. p. fatigans* 0–10 percent.

Against *A. funestus* in grass-roofed huts OMS–1197 was effective for at least 24 weeks, OMS–1170 was effective for 20 weeks, and OMS–708 was effective for at least 20 weeks. In mud-roofed huts OMS–1170 was effective for 12 weeks, OMS–1197 for 8 weeks and OMS–708 for 4 weeks. In the two huts with iron roofs on wooden frames OMS–708 was effective for 12 weeks.

Against *C. p. fatigans* in grass-roofed huts OMS–1197 was effective for at least 24 weeks and OMS–708 for at least 16 weeks, but OMS–1170 was effective for only 8 weeks. In mud-roofed huts OMS–1170 was effective for 8 weeks, OMS–1197 for 4 weeks and OMS–708 for less than 4 weeks. In the two huts with iron roofs

Table 3.—Mortalities of *Anopheles funestus* and *Culex p. fatigans* females in window trap huts at Taveta.

Compound, Type of hut.	Corrected Mortalities Percent — Weeks after treatment 1–4	5–8	9–12	13–16	17–20	21–24
Anopheles funestus						
OMS–708						
28.3.67 Two grass-roofed huts	94(31)	97(116)	99(93)	90(69)	91(58)	......
28.3.67 Two mud-roofed huts	23/24	63(94)	46(172)	7(173)	12(119)	......
28.3.67 Two iron-roofed huts	93(27)	95(82)	84(119)	64(56)	62(26)	......
OMS–1170						
16.3.68 One grass-roofed hut	100(290)	92(478)	96(247)	89(133)	68(77)	56(45)
16.3.68 One mud-roofed hut	100(267)	85(428)	81(178)	60(109)	28(39)	4/21
OMS–1197						
16.3.68 One grass-roofed hut	99(231)	99(358)	98(316)	95(138)	100(52)	100(50)
16.3.68 One mud-roofed hut	94(192)	78(319)	47(227)	22(117)	24(51)	15(52)
Culex p. fatigans						
OMS–708						
28.3.67 Two grass-roofed huts	..(0)	64(33)	98(111)	76(114)	84(74)	......
28.3.67 Two mud-roofed huts	0/1	10/23	29(148)	8(188)	10(92)	......
28.3.67 Two iron-roofed huts	12/24	90(137)	31(109)	17(104)	45(52)	......
OMS–1170						
16.3.68 One grass-roofed hut	94(181)	83(655)	60(290)	61(184)	16(409)	14(495)
16.3.68 One mud-roofed hut	96(125)	79(301)	60(153)	59(74)	22(98)	32(194)
OMS–1197						
16.3.68 One grass-roofed hut	98(174)	93(475)	92(307)	95(187)	95(293)	95(615)
16.3.68 One mud-roofed hut	67(105)	39(345)	54(314)	11(93)	18(172)	22(276)

on wooden frames OMS–708 was effective for 8 weeks.

BIOASSAYS OF TREATED SURFACES. The results of bioassays of treated surfaces at Magugu are shown in Table 4 and Fig. 2. The results from treated huts have been corrected, by Abbot's formula, for the mortalities of mosquitoes exposed to the same substrates in the control huts. In the control huts bioassay mortalities on grass were 0–3 percent, on mud plaster 0–13 percent, and on corrugated iron 0–7 percent.

The criterion for effectiveness has been taken as 70 percent mortality after an exposure period of 1 hour plus a holding period of 24 hours.

On grass both OMS–708 and OMS–1197 remained effective for at least 24 weeks, OMS–1028 and OMS–1211 were effective for 22–24 weeks, OMS–1170 was effective for 14 weeks and OMS–1202 was effective for 8–10 weeks.

On the other substrates the results were inconsistent and in some cases no conclusions could be drawn. There was often a striking increase in mortality after 5–6 weeks and again after 11–12 weeks. This was a result of changing the positions of the cones every 6 weeks since it was found that the surfaces became damaged by accidental abrasion. In future trials it would be preferable not to move all the cones at the same time but to move a few on each week to fresh positions.

Nevertheless it is noteworthy that the deposits on grass were still toxic enough to cause consistently high kills in spite of any abrasion which may have occurred. None of the new compounds was as persistent on red mud, black mud, or iron as it was on grass. Lindane, however, was effective for more than 22 weeks on red mud and for 14–16 weeks on black mud, but for only 10 weeks on grass.

When the deposits no longer gave high kills after one hour's exposure, the bioassays were continued with longer exposure times. In some cases these longer exposures did produce higher mortalities but the results were inconsistent and are not shown here.

DISCUSSION

The results for OMS–1170, OMS–1197, and OMS–1211 compare well with those for malathion, which was one of the first organophosphates to be evaluated at Stage IV at Arusha (Smith and Hocking, 1962), and was later shown to be capable of interrupting malaria transmission in a large scale field trial, in Uganda (Najera *et al.*, 1967). The results for OMS–708 are as good as those for propoxur (also known as Baygon, Bayer 39007, and OMS–33) which was evaluated at Stage IV at Magugu (Smith and Hocking, 1963) and has now proved its effectiveness in Stage VI area scale trials (Wright *et al.*, 1969).

OMS–708, OMS–1170 and OMS–1197 all gave better results at Taveta than they did at Magugu. The reasons for this are not known but could include differences between the first and second samples of each compound, differences in the susceptibility of the mosquitoes at Taveta and Magugu, and the fact that the spraying at Taveta was done later in the season than at Magugu.

In houses where the inside surfaces are of non-sorptive materials such as grass, thatch, wood, or palm matting, OMS–1197 and OMS–1211 at 2.0 gm/m^2 could be expected to give good control of *A. gambiae* for 6 months, OMS–1170 for 4 months, OMS–708 and OMS–1028 for 3 months and OMS–1202 for 2 months.

In houses with mud walls and iron roofs, OMS–1197 and OMS–1211 would be unlikely to give effective control of *A. gambiae* for more than 2 months and the other compounds would be less effective than these.

The good results for OMS–708 and OMS–1197 at Taveta against DDT- and dieldrin-resistant *C. p. fatigans* suggest that these compounds would be suitable for use as adulticides where larviciding is impracticable.

All the new compounds were applied at the standard dosage of 2.0 g/m^2 but this is not necessarily the most economical one. It would be well worth repeat-

TABLE 4.—Results of bioassays of treated surfaces at Magugu using wild caught, fed and gravid *Anopheles gambiae*.

OMS Number	Substrate	Corrected Mortality, Percent, 24 Hours After One Hour's Exposure — Weeks After Treatment: 1–2	3–4	5–6	7–8	9–10	11–12	13–14	15–16	17–18	19–20	21–22	23–24	Conclusion: Number of Weeks Effective
708	Grass	100	100	100	100	100	100	100	100	100	100	100	100	>24
	Red mud	66	19	16	85	0	..	..	..	..	..	..	..	NC *
	Black mud	100	87	57	100	32	..	..	..	..	..	..	..	NC
	Iron	100	64	37	13	20	..	..	..	..	..	..	..	2–4
1028	Grass	100	100	100	100	97	100	100	100	94	87	100	50	22–24
	Red mud	3	22	17	100	1	..	..	..	..	..	..	..	NC
	Black mud	100	65	17	86	99	87	17	16	..	..	..	..	NC
1170	Grass	100	100	100	100	99	96	92	64	6	..	..	..	14
	Red mud	100	33	7	..	..	..	..	..	..	..	..	..	2–4
	Black mud	100	92	75	98	34	20	32	30	2	..	..	..	8–10
	Iron	100	100	27	..	..	..	..	..	..	..	..	..	4–6
1197	Grass	100	100	100	100	100	100	98	100	100	100	100	100	>24
	Red mud	100	52	37	75	53	7	1	..	..	..	..	..	8
	Black mud	100	73	76	72	47	65	1	..	..	..	..	..	8
	Iron	100	100	8	..	..	..	..	..	..	..	..	..	4–6
1202	Grass	100	100	100	92	48	..	..	..	..	..	..	..	NC
	Red mud	52	8	2	26	..	..	..	..	..	..	..	..	<2
	Black mud	100	68	67	65	68	..	..	..	..	..	..	..	>10
	Iron	100	100	55	80	21	..	..	..	..	..	..	..	8–10
1211	Grass	98	100	100	98	100	85	97	100	86	82	100	42	22–24
	Red mud	82	44	68	8	17	..	..	..	..	..	..	..	6
	Black mud	95	80	70	68	71	30	76	4	..	..	..	..	>14
	Iron	90	65	1	46	40	..	..	..	..	..	..	..	4
17 (Lindane)	Grass	..	100	73	12	73	19	..	..	..	..	..	..	NC
	Red mud	..	100	100	100	100	99	100	100	100	86	83	..	>22
	Black mud	..	100	78	100	89	100	100	56	36	..	..	..	14–16

* NC = No conclusions.

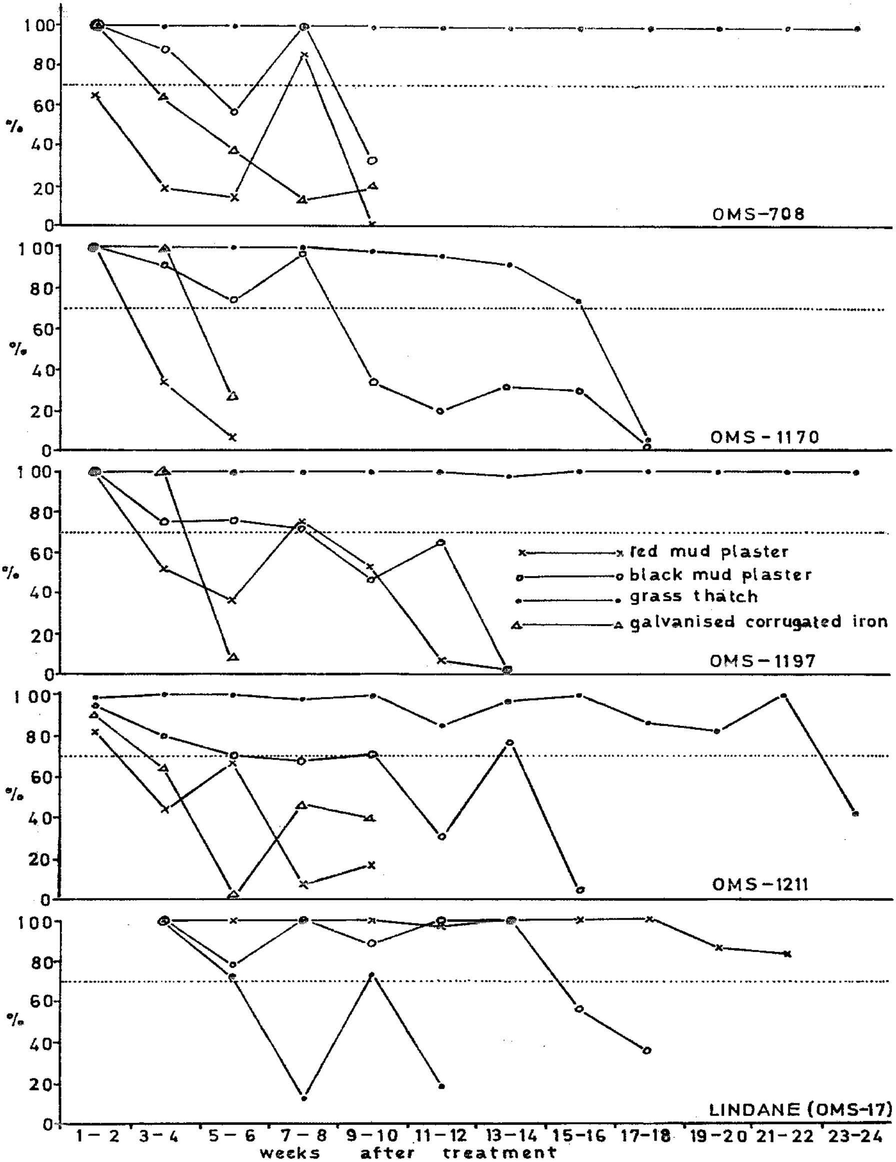

FIG. 2.—Mortalities of *A. gambiae* in bioassays of treated surfaces. Exposure time one hour.

ing the trials of the most effective compounds at lower dosages before proceeding to larger scale trials.

SUMMARY

Three organophosphate insecticides, OMS–1170, OMS–1197, and OMS–1211, and three carbamates, OMS–708, OMS–1028, and OMS–1202, were given WHO stage IV evaluations against adult *Anopheles gambiae* in experimental huts at Magugu, Tanzania and at Taveta, Kenya, during 1967–70. Results for one of the carbamates and two of the organophosphates against *A. funestus* and *Culex p. fatigans* are also given. All compounds were wettable powders sprayed at 2.0 g/m^2 active ingredient. Results for lindane at 1.0 g/m^2 against *A. gambiae* are included for comparison.

Mortality and bioassay results suggest that the best of the organophosphates, OMS–1197 and OMS–1211, would give effective control of *A. gambiae* in mud-and-thatch houses for 6 months, and in houses with mud walls and corrugated iron roofs for 2 months. The best of the carbamates, OMS–708, would give effective control of *A. gambiae* in mud-and-thatch houses for 4 months and in houses with mud walls and iron roofs for less than 2 months.

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