EVALUATION OF SMOKE FROM INSECTICIDAL COILS AGAINST MOSQUITOES

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Smoke from burning various dry materials has been used since early times to deter insects, especially mosquitoes. Howard (1911) in discussing mosquito control stated, "The burning of pyrethrum powder in a room at night is common practice—often the powder is moistened and molded roughly into small cones, and after drying it burns readily and perhaps with less waste than does the dry powder." More recently there has been widespread use of insecticidal sticks and coils to prevent mosquitoes from biting, particularly during the night, in Southeast Asia, Japan, Africa, Australia, and South America (Maciver, 1963). The results of toxicity and repellency tests against mosquitoes with smoke from various coils are given in this paper.

MATERIALS AND METHODS. Some of the coils tested, commercially available in Japan and Africa, contained 0.5 percent allethrin and 0.5 percent pyrethrins respectively. Also tested were other experimental coils prepared by a United States manufacturer by soaking blank Philippine coils

TABLE 1.—Results of toxicity tests with smokes from insecticidal coils against free-flying *Culex pipiens pipiens* mosquitoes. (Average no. of insects per test was 72 and the sex ratio was 49% males and 51% females).

Insecticide in coil	Concentration (%)	Coil burned (g.)	Exposure (min.)	Percent knockdown in minutes									Percent killed in 1 day		
				5	10	15	20	30	45	60	90	120	Total insects	Male	Female
None [a]	...	...	45	0	0	0	0	0	0	..	..	..	0	0	0
None [a]	...	0.32	15	0	0	0	..	..	..	..	..	..	1	2	0
None	...	0.32	15	0	0	0	..	..	..	..	..	..	0	0	0
None	...	8.0	120	..	..	..	..	0	..	0	4	..	1	3	0
Pyrethrins	0.5	0.9	30	..	40	..	62	75	..	..	..	..	22	24	14
Pyrethrins	0.5	4.0	60	..	0	0	0	0	32	90	..	..	9	50	6
Pyrethrins	0.5	8.0	60	..	..	10	..	14	49	100	..	..	35	39	29
Pyrethrins	0.5	8.0	120	..	..	..	..	49	..	65	76	100	19	28	9
Pyrethrins	0.5	8.0	120 [a]	..	..	..	..	..	..	..	..	100	8	12	0
Allethrin	0.5	8.0	120	..	..	..	..	..	..	..	..	100	15	12	7

[a] Caged insects.

TABLE 2.—Results of repellency tests with smokes from insecticidal coils against *Culex pipiens pipiens* mosquitoes.

Percent concentration of ingredients in coils					Coils burned g.	Number of		Ratio male to female	% mosquitoes repelled		
Pyrethrins	Allethrin	MGK–264	MGK–874	Amcid		tests	insects		Total insects	Male	Female
Blanks											
...	...	....	...	....	....	2	86	70–30	1	1	0
...	...	....	...	....	0.25	1	58	71–29	9	12	0
...	...	....	...	....	0.50	1	148	44–56	9	12	7
...	...	....	...	....	1.25	11	129	60–40	24	26	22
0.5	...	....	...	....	0.25	3	72	72–28	42	43	42
0.1	...	....	1.0	....	0.25	1	88	70–30	3	3	4
0.1	...	....	1.0	....	1.25	2	86	74–26	32	33	28
...	0.5	....	...	....	0.25	2	104	68–32	4	6	1
...	0.5	....	...	....	0.50	3	90	46–54	27	34	19
...	0.5	....	...	....	1.00	1	69	75–25	58	54	71
...	0.1	....	1.0	....	1.25	2	94	50–50	26	30	23
...	0.1	0.25	...	....	1.25	3	105	52–48	31	30	33
...	0.1	0.25	1.0	....	0.96	1	104	66–34	28	30	23
...	0.1	0.25	1.0	....	1.25	6	87	65–35	32	33	32
...	0.1	0.25	...	0.25	1.25	2	119	57–43	28	24	32
...	...	....	1.0	....	0.25	1	64	77–23	3	4	0
...	...	....	1.0	....	0.99	1	87	60–40	5	6	3
...	...	....	1.0	....	1.25	3	95	75–25	24	25	16
...	...	....	2.0	....	1.25	1	77	71–29	23	20	32

in solvents containing the toxicants. These contained allethrin plus the synergists MGK-264® (*N*-(2-ethylhexyl)-5-norbornene-2,3-dicarboximide); the MGK repellent 874® (2-(octylthio)ethanol), and the additive AMCID (Atlox® 3300, isopropylamine salt of dodecyl-benzenesulfonic acid.) A single coil contained pyrethrins and MKG repellent 874®. The formulas of the coils tested are shown in Tables 1 and 2. Except for the insecticide the Japanese and African coils were quite similar in composition. They contained ground leaves; wood powder; Tabu powder, which serves as a binder and is the powdered leaves or bark of the tree *Machilus thunbergii;* a fungistat; and coloring material (Nagasawa *et al.,* 1950), (Maciver, 1963). The African coils also contained pyrethrum powder, and as bulk pyrethrum marc, the residue left after pyrethrum flowers have been extracted. The composition of the Philippine coil was not known.

Maciver (1964) discussed mortality and repellency of *Aedes aegypti* mosquitoes caused by smoke from African pyrethrins coils burned in a 40-m^3 room. However, during these tests the insects were confined in lamp glasses. Similar tests in Brazil with smoke from burned pyrethrins against *Culex fatigans* mosquitoes were reported by Paulini and Ernest (1954). Kogan (1961), also in Brazil, used this same species and his tests with smoke from pyrethrins coils employed an olfactometer. Insecticidal coils have been tested extensively in Japan. Nagasawa *et al.* (1951) tested smoke from pyrethrins and allethrin coils against *Culex pipiens pallens* mosquitoes by the method devised by Nagasawa and Uruha (1950) in which the mosquitoes were confined in a glass cylinder 22 cm in diameter and 45 cm in height. The insects were exposed to the smoke from an 0.5-g piece of coil.

In the toxicity tests conducted at this laboratory, *Culex pipiens pipiens* mosquitoes reared in the laboratory from egg rafts collected in nature were released in a 28.3 m^3 room. Caged mosquitoes were also included in a few tests. The rate of burning of a given coil was determined. Then pieces of it, no greater than 1 g., that would deliver the desired dosage, were pierced by a straight pin and thus fastened to a large cork, which was placed on the floor of the test chamber where they were burned during the test (Fig. 1). The test chamber was outdoors and was located beneath an open shed (Fig. 2). Smoke from blank coils was also tested to determine any affect of the smoke alone. These were African coils and the pyrethrum marc used as part of the bulk was said to contain approximately 0.02 percent pyrethrins. At the end of the exposure period the ports were opened and the chamber vented. The insects that were knocked down and those still flying were collected and held in clean cages. Cotton moistened with sugar solution was provided for food and mortality counts were made the next day.

The same test chamber was employed for the repellency tests. The method worked out after some preliminary tests involved the use of two 51x56x25-cm wood and wire cages, one containing the mosquitoes inside the test chamber and the other covered with heavy paper on the outside of the chamber. The two cages were connected through the door of the test chamber by a large glass cylinder 21 cm in diameter and 38 cm in height (Fig. 3) and also covered with paper. The mosquitoes were thus free to leave the cage in the 28.3 m^3 chamber containing the smoke from the coils and go to the cage on the outside. Repellency was measured by the percent of mosquitoes that left the cage inside the test chamber following a 20-minute exposure to smoke from a coil. Blank coils of the same type as used in the toxicity tests were tested with each lot of daily tests.

RESULTS. There was a negligible toxicity to either caged or free-flying mosquitoes following 15- and 120-minute exposures to the smoke from 0.32 g or 8 g of blank coil, respectively (Table 1). An African coil containing 0.5 percent pyrethrins was tested at dosages of 0.9, 4, and 8 g with exposures varying from 30 to

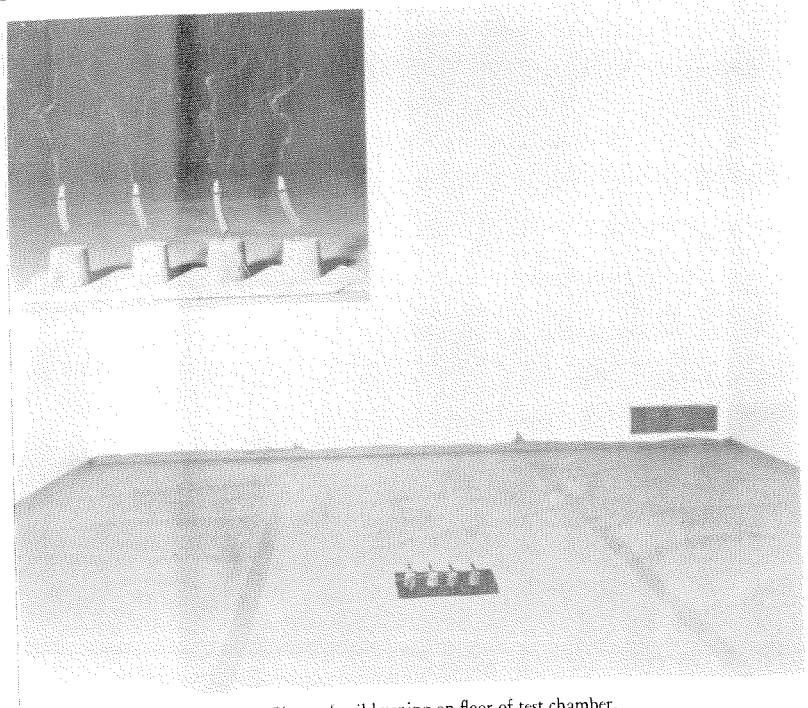

FIG. 1.—Pieces of coil burning on floor of test chamber.

120 minutes. A 60-minute exposure to the smoke from 8 g was required to obtain 100 percent knockdown. There were marked recoveries in these tests and the highest kill obtained was 35 percent. The smoke from 8 g of a Japanese 0.5 percent allethrin coil caused 100 percent knockdown in 120 minutes and a kill of only 15 percent. In all of these tests male mosquitoes were more susceptible than females.

FIG. 2.—Chamber used for testing coils.

The smoke from the 0.25, 0.5, and 1.25 g pieces of the blank coil caused repellencies of 9 percent, 9 percent, and 24 percent respectively (Table 2). This repellency was probably due to the pyrethrum marc (0.02 percent pyrethrins) used as part of the bulk in the blank coils. In a test without any smoke only 1 percent of the mosquitoes passed to the outside cage. The 0.5 percent pyrethrins coil at a dosage of 0.25 g caused a repellency of 42 percent. At this same dosage the 0.1 percent pyrethrins-1 percent MGK-874 coil was ineffective but at five times this dosage it repelled 32 percent. The 0.5 percent allethrin coil was ineffective at the

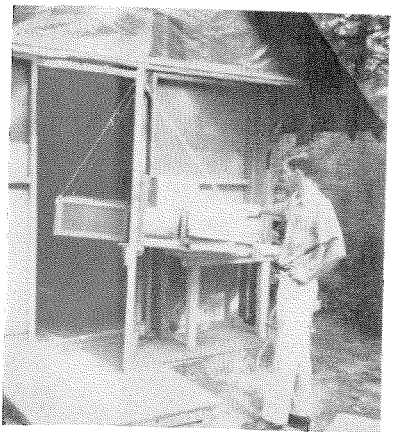

FIG. 3.—View of cages on inside and outside of test chamber connected thru hinged entrance door by glass cylinder used in evaluating smoke from insecticidal coils as mosquito repellents.

0.25 g dosage. However, four times this dosage caused repellency slightly better than that obtained with 0.25 g of the 0.5 percent pyrethrins coil. The coil containing the low concentration of 0.1 percent allethrin plus the various additives required five times the dosage of the 0.5 percent pyrethrins coil to obtain repellency only about two-thirds that of the pyrethrins coil. The value of the additives in the allethrin coils was not determinable. The coils containing 1 percent or 2 percent alone of MGK-874 repelled 24 percent and 23 percent respectively at the 1.25 g dosage.

DISCUSSION AND CONCLUSIONS. The tests against the free-flying mosquitoes demonstrated that a 1-hour exposure to smoke from the burning of 8 g of an insecticidal coil containing 0.5 percent pyrethrins caused complete knockdown, but there was a high recovery by the next day. Reducing the dosage reduced knockdown and kill. Increasing the exposure to 2 hours did not increase the mortality. The smoke from the 0.5 percent allethrin coil with a 2-hour exposure gave approximately the same kill as the 0.5 percent pyrethrins coil. Since smoke from the same dosage of a blank coil caused negligible knockdown and mortality, it was concluded that under the conditions of these tests in a tightly enclosed room, both the allethrin and pyrethrins coils could be expected to give good knockdown of mosquitoes but low mortalities. Nagasawa, *et al.* (1951) found with the use of the glass cylinder test method that the smoke from an allethrin coil was more effective in knockdown of *Culex pipiens pallens* than from the same dosage of a pyrethrins coil. Maciver, (1964) in tests against *Aedes aegypti* mosquitoes by a lamp glass test method found the KD_{50} of pyrethrins was 2.2 times that of allethrin.

The data obtained from the tests designed to show repellency indicated that the method used was adequate to show differences between coil samples. Although neither the 0.5 percent pyrethrins nor 0.5 percent allethrin coils caused high repellency it was shown that pyrethrins were more effective than allethrin at similar dosages. The coils containing 0.1 percent allethrin and the additives were all less effective than the 0.5 percent allethrin coil. Kogan (1961) in olfactometer tests found that using pyrethrins in the coil increased the repellency of the smoke to *Culex pipiens fatigans* mosquitoes. Paulini and Ricciardi (1954) reported that smoke from a burned cord containing 0.48 percent pyrethrins repelled 57 percent of *Culex fatigans* while cords containing 0.97 percent and 2 percent pyrethrins were less effective due to knocking down the mosquitoes instead of repelling them.

For repellency it appears that the successful coil formula would be one that does not rapidly paralyze the mosquitoes so that they can fly out of the treated area. Maciver (1964) found that very dilute concentrations of pyrethins vapour repelled *Aedes aegypti* mosquitoes. He also stated that, "The optimum concentration of pyrethrins in coils is between 0.35 percent and 0.5 percent w/w, beyond which little further action on mosquitoes is observed." Smith and Obudho (1967) found that smoke from pyrethrins coils was highly repellent to *Anopheles gam-*

biae in practical tests using a 17.6 m^3 verandah-trap hut.

Coil performance could be expected to be best in tightly enclosed spaces. However, their greatest use is in areas such as partially open living spaces or porches with minimum of air movement for continuous periods. Coils with pyrethrins content of 0.3 percent for use on porches when there is no breeze have been accepted for registration by the Pesticides Regulation Division.

Literature Cited

HOWARD, L. O. 1911. Remedies and preventives against mosquitoes. U.S.D.A. Farmers' Bul. 444, 15 pp.

KOGAN, M. 1961. Teste para á determinaçao do grau de repelencia do piretro. Revista Brasileira de Biologia 21(1):17–36.

MACIVER, D. R. 1963. Mosquito coils. Part I. General description of coils, their formulation and manufacture. Pyrethrum Post 7(2):22–27.

MACIVER, D. R. 1964. Mosquito coils. Part II. Studies on the action of mosquito coil smoke on mosquitoes. Pyrethrum Post 7(3):7–14.

NAGASAWA, S., KATSUDA, Y., OKAMOTO, A., and OHONO, M. 1951. On the knockdown effect of so-called pyrethrins and allethrin coating mosquitocide incense to adults of the common house mosquito (*Culex pipiens* var. *pallens* Coquillett). Studies on the biological assay of insecticides. XVII. Botyu-Kagaku 16(3):176–181.

NAGASAWA, S., SUMITA, S., and HIRAW, S. 1950. On the inspection of mosquitocide incense. Studies on the biological assay of insecticides. X. Botyu-Kagaku 15(4):206–217.

NAGASAWA, S., and URUHA, C. 1949. On the knock-down effects of the mosquitocide incense made of pyrethrum mixed with benzophenone against the adult of the common house fly (*Musca domestica* L.). Studies of the biological assay of insecticides. VII. Botyu-Kagaku 14:31–41.

PAULINI, E., and RICCIARDI, I. 1954. The repellent effect of pyrethrin vapour to *Culex fatigans*. Trans. Roy. Soc. Trop. Med. and Hygiene 48(3):276–7.

SMITH, A., and OBUDHO, W. O. 1967. Trials with pyrethrum mosquito coils against *Anopheles gambiae* entering a verandah-trap hut. Pyrethrum Post 9(2):15–17.