# THE EFFICACY OF CARBARYL, PROPOXUR, ABATE AND METHOXYCHLOR AS LARVICIDES AGAINST FIELD INFESTATIONS OF *AEDES AEGYPTI*[1]

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To provide new or improved insecticides to the Aedes aegypti Eradication Program[2] for control of the larvae of *Aedes aegypti* breeding in tin cans, rubber tires and other small containers, an evaluation system of three phases was established. The initial phase at Savannah, Georgia, consisted of laboratory determinations of the LC-95 levels and the residual activity of the toxicant, followed by the assessment of the life of deposits in tin cans and tire sections exposed to full weathering conditions (Brooks *et al.*, 1967; Schoof and Jakob, 1964; Taylor, 1968). All of these tests were conducted with laboratory reared specimens of resistant strains. The compounds of greatest promise were then subjected to field evaluation at either Perrine, Florida, or in Puerto Rico. All such assessments were based on controlling natural field infestations of *Ae. aegypti* in small containers and tires. Compounds that offered the maximum potential for operational purposes were then subjected to a large-scale evaluation under field conditions in Puerto Rico.

The present paper describes field tests in Perrine, Florida, on carbaryl, propoxur, Abate[3] and methoxychlor.

PROCEDURES. A treatment area of 95 blocks was selected as the source of the study sites for the experimental insecticides. Each compound was sprayed in 5 to 7 blocks, but the blocks treated with any one insecticide were noncontiguous and scattered throughout the treatment area. Within a given block, the insecticide was applied to all premises that had 10 containers or more. The objective with the application of each chemical was to treat a minimum of 5,000 containers. Within the test area 10 blocks interspersed among the insecticide treated blocks were sprayed with an inert formulation and used as untreated blocks to measure the normal prevalence of *Ae. aegypti* larvae. All applications were made with a power sprayer at a pressure of 125 p.s.i. using a fixed pistol grip nozzle and a number 4 cone spray disc.

The evaluation technique was to inspect the containers on each treated premises and on the untreated control premises for the absence or presence of *Ae. aegypti* larvae. To insure that a container recorded as treated when found on a treated premises had been sprayed, each container was marked with paint before the insecticide was applied. Since all containers on the various premises were examined, all unmarked and untreated containers within a treated block served as a parallel set of controls with the containers present in the 10 untreated blocks.

One variable in the appraisal procedure arose from the fact that numerous containers were dry which made it impossible to determine whether or not the container was infested. Consequently, the major emphasis in the assessment was based on the larval indices in wet treated containers, wet untreated containers in treated blocks, and wet containers in the untreated blocks.

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[2] This Program was terminated as of July 1, 1969.

[3] Use of trade names is for identification purposes only and does not constitute endorsement by the Public Health Service or the U.S. Department of Health, Education, and Welfare.

TABLE 1.—Comparative effectiveness of outdoor premises treatments of Abate (0.25 percent), propoxur (0.5, 1.25, 2.5 percent), carbaryl (0.5, 1.25, 2.5 percent), methoxychlor (0.5, 1.25, 2.5 percent) and malathion (2.5 percent) suspensions as measured by percentage of wet containers[a] infested with larvae of *Ae. aegypti*, Perrine, Florida.

| | | Treated Zone | | | | |
|---|---|---|---|---|---|---|
| Toxicant | | Total[c] | Treated Containers | | New Containers[d] | |
| (Percent) | Month[b] | Containers | No. | % + | No. | % + |
| Malathion (2.5) | 0 | 1769 | 252 | 2.4 | ... | .... |
| | 1 | 808 | 117 | 3.4 | 14 | 35.7 |
| | 2 | 583 | 104 | 10.6 | 146 | 6.8 |
| | 3 | 415 | 148 | 19.6 | 438 | 11.4 |
| Propoxur (2.5) | 0 | 3156 | 655 | 6.9 | ... | .... |
| | 1 | 1160 | 194 | 1.0 | 225 | 5.3 |
| | 2 | 831 | 162 | 9.9 | 289 | 18.3 |
| (1.25) | 0 | 639 | 82 | 13.4 | ... | .... |
| | 1 | 1362 | 382 | 5.0 | ... | .... |
| | 2 | 1039 | 121 | 17.4 | 63 | 61.3 |
| (0.5) | 0 | 2473 | 350 | 10.3 | ... | .... |
| | 1 | 1858 | 515 | 2.3 | ... | .... |
| | 2 | 1353 | 233 | 18.9 | 196 | 25.5 |
| | 3 | 916 | 208 | 22.6 | 250 | 14.8 |
| Carbaryl (2.5) | 0 | 1083 | 135 | 3.0 | ... | .... |
| | 1 | 2244 | 300 | 1.7 | 150 | 11.3 |
| | 2 | 1469 | 233 | 14.2 | 259 | 23.9 |
| | 3 | 948 | 203 | 24.6 | 376 | 35.1 |
| (1.25) | 0 | 1195 | 177 | 5.1 | ... | .... |
| | 1 | 2123 | 365 | 5.2 | 34 | 2.9 |
| | 2 | 1081 | 147 | 22.5 | 165 | 18.8 |
| | 3 | 1033 | 264 | 29.2 | 460 | 15.6 |
| (0.5) | 0 | 1860 | 320 | 6.9 | ... | .... |
| | 1 | 2211 | 644 | 3.0 | ... | .... |
| | 2 | 1915 | 448 | 12.3 | 308 | 26.6 |
| | 3 | 1041 | 196 | 23.5 | 239 | 17.2 |
| Abate (0.25) | 0 | 2242 | 334 | 10.2 | ... | .... |
| | 1 | 1889 | 351 | 0.6 | 66 | 21.2 |
| | 2 | 1470 | 291 | 2.1 | 350 | 22.6 |
| | 3 | 882 | 201 | 10.4 | 400 | 21.5 |
| Methoxychlor (2.5) | 0 | 746 | 156 | 1.3 | ... | .... |
| | 1 | 1173 | 138 | 1.5 | 167 | 1.2 |
| | 2 | 802 | 146 | 2.1 | 184 | 8.7 |
| | 3 | 1052 | 227 | 8.4 | 373 | 19.5 |
| Methoxychlor (1.25) | 0 | 3102 | 483 | 4.6 | ... | .... |
| | 1 | 2059 | 550 | 0.4 | ... | .... |
| | 2 | 1627 | 197 | 4.1 | 217 | 9.7 |
| | 3 | 1689 | 379 | 7.7 | 644 | 18.6 |
| (0.5) | 0 | 1842 | 218 | 6.4 | ... | .... |
| | 1 | 2114 | 551 | 0.5 | ... | .... |
| | 2 | 2004 | 311 | 5.8 | 213 | 7.8 |
| | 3 | 1332 | 239 | 7.1 | 239 | 18.0 |
| Untreated Zone | 0 | 2715 | 468 | 10.3 | ... | .... |
| | 1 | 1548 | 298 | 8.1 | 73 | 17.8 |
| | 2 | 1388 | 172 | 18.0 | 274 | 24.1 |
| | 3 | 1460 | 283 | 33.6 | 516 | 27.9 |

[a] Containers with sufficient water for mosquito breeding.
[b] 0=before treatment; 1, 2 and 3=number of months after treatment.
[c] Includes all containers whether dry or wet.
[d] Containers that appeared on premises since treatment was applied, mostly new containers but possibly including some containers missed on the initial survey.

The test insecticides were carbaryl (1-naphthyl methylcarbamate), propoxur (*o*-Isopropoxyphenyl methylcarbamate), Abate (O,O,O′-thiodi-p-phenylene phosphorothioate) and methoxychlor [2,2-bis (p-methoxyphenyl)-1,1,1-trichloroethane]. Malathion and DDT served as standards. Carbaryl, propoxur and methoxychlor were applied at strengths of 0.5, 1.25 and 2.5 percent, malathion at 2.5 percent and Abate at 0.25 percent.

RESULTS. The data (Table 1) indicated that neither propoxur nor carbaryl was sufficiently effective after 2 months to be considered for use as a larvicide of extended killing power against *Ae. aegypti*. Propoxur at its maximum dosage (2.5 percent) was highly effective 1 month after treatment, but on the next inspection the index was above the pretreatment level. At concentrations of 1.25 and 0.5 percent the application also reduced the infestation levels at the time of the first month posttreatment inspection, but at month 2 the indices were greater than those before treatment.

Carbaryl showed a similar picture of efficacy and, paradoxically, reflected a higher effectiveness at the lowest concentration used. Despite the relatively poor performance of each of these carbamates, both were superior to malathion (2.5 percent). The latter had little effect on the infestation rate, which increased from 3.4 to 19.6 during the 3 posttreatment months.

Abate (0.25 percent) satisfactorily reduced the indices for 2 posttreatment months, although there was an increase from 0.6 to 2.1 between months 1 and 2. Methoxychlor (2.5 percent) was less effective than Abate but did produce low indices for the second posttreatment month during a period when the index in the untreated containers in the same area rose to 8.7. At the lower concentrations, methoxychlor was not effective after 1 month. However, because *Ae. aegypti* populations in the Florida area have a varying and sometimes high level of resistance to DDT (Flynn and Schoof, 1965), the efficacy of methoxychlor, a closely-related compound, was encouraging.

The results with methoxychlor suggested that this compound should be compared directly to DDT, particularly since DDT was the standard chemical used in the Aedes aegypti Eradication Program in the United States. In addition, the use of DDT had been the subject of much criticism by wildlife and environmental groups, which generally consider methoxychlor a more desirable compound because of its tendency to degrade under natural conditions.

The data for the comparative tests of the two compounds on premises are given in Table 2.[5] Results for posttreatment month 2 are omitted because the dry weather precluded the occurrence of enough wet containers upon which to obtain a reliable index. The findings indicate that methoxychlor at the 1.25 or 2.5 percent concentrations gave results superior to those achieved by the DDT (1.25 percent) applications. The number of wet containers occurring in the methoxychlor zone treated with 2.5 percent was low but this same deficiency did not exist in the zone treated with the lower dose of methoxychlor. Here the number of wet containers and the pretreatment index were similar to those for the DDT-treated area. Based on the index for the new containers in the treated blocks versus that for the treated containers, 1.25 percent methoxychlor and 1.25 percent DDT gave 96 and 81 percent control, respectively, at the third month of inspection.

DISCUSSION. The poor results with propoxur and carbaryl were not unexpected inasmuch as carbamates as a group normally do not display high toxicity to mosquito larvae. These compounds were included because previous larvicidal studies revealed that three insecticides (Abate, Gardona, bromophos) were superior to

[5] Eight blocks each were involved in the application of the 1.25 percent concentration of both compounds; four blocks each in the 2.5 percent methoxychlor treatment and in the untreated zone.

TABLE 2.—Comparative effectiveness of outdoor premises treatments of DDT and methoxychlor suspensions as measured by percentage of wet containers[a] infested with larvae of *Ae. aegypti*, Perrine, Florida.

| Toxicant | | Total[c] | Treated Containers | | New Containers[d] | |
|---|---|---|---|---|---|---|
| (Percent) | Month[b] | Containers | No. | % + | No. | % + |
| Treated Zone | | | | | | |
| DDT (1.25) | 0 | 6795 | 1180 | 29.1 | ... | .... |
| | 1 | 2060 | 368 | 1.9 | 344 | 11.6 |
| | 3 | 1142 | 257 | 2.0 | 370 | 9.7 |
| Methoxychlor (1.25) | 0 | 5780 | 1202 | 42.8 | ... | .... |
| | 1 | 1763 | 434 | 0.7 | 370 | 21.3 |
| | 3 | 2126 | 415 | 0.5 | 619 | 11.6 |
| (2.5) | 0 | 2176 | 425 | 27.5 | ... | .... |
| | 1 | 655 | 84 | 1.1 | 558 | 15.8 |
| | 3 | 534 | 71 | 1.4 | 878 | 2.9 |
| Untreated Zone | 1 | 1664 | 264 | 21.9 | ... | .... |
| | 3 | 1783 | 67 | 47.0 | ... | .... |

[a] Containers with sufficient water for mosquito breeding.
[b] 0=before treatment; 1 and 3=number of months after treatment.
[c] Includes all containers whether dry or wet.
[d] Containers that appeared on premises since treatment was applied, mostly new containers but possibly including some containers missed on the initial survey.

malathion as a premises treatment against *Ae. aegypti*, and each was an organophosphorus compound. Since the possibility that resistance developing to any one of these insecticides might apply in general to the organophosphorus group, the evaluation of compounds of a wholly different chemical nature was considered justification for the trials with carbaryl and propoxur.

The trials showed that malathion, the standard treatment in use in Puerto Rico, was the poorest of the larvicides tested. Abate and methoxychlor gave the most favorable results, but neither (Table 1) provided 3 months of efficacy similar to that reported for Gardona, Abate and bromophos in earlier studies (Eliason *et al.*, unpublished manuscript).

One of the controversial aspects of the procedures used in the eradication program concerns the period of time for which a given treatment remains effective. From the viewpoint of operational efficiency, the greatest residual action should require fewer applications and thus free the crews for extending the operational area to be covered. Although this concept in theory is quite logical, it fails to take into consideration the fact that new and untreated containers are added daily to the urban premises. With Abate (Table 1) the index in the treated containers was 0.6 percent, but that for the "new" containers was 21.2. This same type of differential is reflected in the majority of treatments.

One possible reason for the greater percentage of positive sites in the "new" containers could be that the treated containers were somewhat repellent to the ovipositing females, thus forcing them to seek the "new" containers. The validity of this premise is purely conjectural. Yet it has been observed that anopheline mosquitoes do not always enter insecticide treated dwellings as readily as those that are untreated (Mathis and Schoof, 1968).

The results with DDT and methoxychlor suggest strongly that the latter could be substituted for DDT without materially affecting the biological effectiveness of the treatment. However, the cost of DDT is only one-third to one-fourth that of methoxychlor; consequently, a program would have to spend three to four times its present amount for chemicals or would have to reduce the size of the project area accordingly.

From the standpoint of potential harm to nontarget organisms, methoxychlor would be the insecticide of choice because it is biodegradable and thus less objectionable than DDT to groups concerned with birds and other forms of wildlife. However, despite 4 years of use of DDT on the Aedes aegypti Eradication Program in certain states as a premises treatment, there has not been any confirmed evidence that it has adversely affected the bird or fish life in those areas. Whether this condition would have continued will always be a moot question since the Federal program was terminated in the United States in October 1969.

*References*

Brooks, G. D., Smith, E. A. and Schoof, H. F. 1967. Residual effectiveness of eleven insecticides under weathering conditions against *Aedes aegypti*. Mosq. News 27(1):93–99.

Flynn, A. D. and Schoof, H. F. 1965. Susceptibility of *Aedes aegypti* (L.) from Florida and Texas to DDT, dieldrin and malathion. Mosq. News 25(4):411–414.

Mathis, W. and Schoof, H. F. 1968. Effectiveness of some new insecticides on various types of surfaces and in clay-lined experimental huts against *Anopheles quadrimaculatus*. Mosq. News 28(1): 16–20.

Schoof, H. F. and Jacob, W. L. 1964. Insecticides for use against *Aedes aegypti*. Mosq. News 24 (3):309–311.

Taylor, R. T. 1968. Simulated field evaluation of promising insecticides for use against *Aedes aegypti*. Mosq. News 28(1):12–16.

# RESISTANCE TO AGING AND RAIN OF REPELLENT-TREATED NETTING USED AGAINST SALT-MARSH MOSQUITOES IN THE FIELD

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ABSTRACT. In 1967, 1968, and 1969, 4-mesh-per-inch tied cotton netting was treated with 27 individual compounds and one mixture applied at a rate of 0.5 gram (g) chemical to 1 g of net; 45 individual compounds and the same mixture applied at a rate of 0.25 g of chemical to 1 g net; and 22 individual compounds applied at a rate of 0.5 g of chemical to 1 g net. Twenty-four compounds gave 90 percent protection for more than 87 days against the salt-marsh mosquito, *Aedes taeniorhynchus* Wiedemann, and three of the 24 were still 90 percent effective after 287 days when they were applied at a rate of 0.5 g of chemical to 1 g net. Also, 28 compounds gave 90 percent protection for more than 60 days when they were applied at a rate of 0.25 g chemical to 1 g net, and 7 of the 28 were still 90 percent effective after 141 days. Two compounds were 90 percent effective after being exposed to 4.13 inches rainfall, and 6 compounds were 90 percent effective after being exposed to 2.69 inches rainfall.

INTRODUCTION. Netting treated with repellents against biting insects might be used as head nets, bed nets, and nets to cover windows or entrances where more air movement and visibility are desired or where standard screens do not deter small insects (Gouck *et al.*, 1967a). Screening tests have therefore been conducted at the Insects Affecting Man Investigations Laboratory at Gainesville, Florida, to find chemicals effective in preventing mosquito penetration through wide-mesh netting and preliminary field tests have been made with the promising compounds (Gouck *et al.*, 1967b). During 1967, 1968, and 1969, further field studies were made with 70 individual compounds and one mixture against salt-marsh mosquitoes, *Aedes taeniorhynchus* Wiedemann to find other promising compounds for more practical