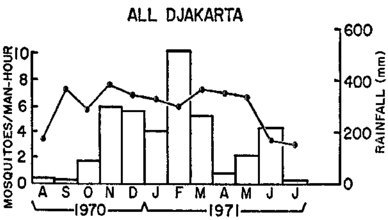

FIG. 2.—Monthly abundance of female *Aedes aegypti,* all areas combined, Djakarta. Bars show monthly rainfall. Measured by number collected per man-hour.

A further reason for the apparent lack of distinct seasonal patterns of abundance may be related to technics used. Inadequate length of time spent collecting biting mosquitoes, and attention only to indoor collections, may have biased collection data. However, collections were uniformly conducted throughout the year; and checks on peaks of man-biting activity were made periodically. It is therefore unlikely that important seasonal changes in densities were missed, particularly of sufficient magnitude to correlate with the seasonal changes in DHF morbidity in Djakarta.

Literature Cited

Halsted, S. B. 1966. Mosquito-borne haemorrhagic fevers of South and Southeast Asia. Bull. Wld Hlth Org. 35:3–15.

Kho, L. K., H. Wulur, A. Karsono and S. Thaib. 1969. Dengue haemorrhagic fever in Djakarta. J. Indonesian Med. Assoc. 19:417–437.

Russell, P. K., D. V. Quy, A. Nisalak, P. Simasathien, T. M. Yuill and D. J. Gould. 1969. Mosquito vectors of dengue viruses in South Vietnam. Amer. J. Trop. Med. Hyg. 18:455–459.

Scanlon, J. E. 1966. Bangkok haemorrhagic fever investigations: the 1962–63 mosquito collection. Bull. Wld Hlth Org. 35:82–83.

Tonn, R. J., P. M. Sheppard, W. W. MacDonald and Y. H. Bang. 1969. Replicate surveys of larval habitats of *Aedes aegypti* in relation to dengue haemorrhagic fever in Bangkok, Thailand. Bull. Wld Hlth Org. 40:819–829.

LABORATORY THERMAL AEROSOL TESTS OF NEW INSECTICIDES FOR THE CONTROL OF ADULT MOSQUITOES

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The West Florida Arthropod Research Laboratory conducts tests of candidate insecticides of low mammalian toxicity in a continuing program to develop new mosquito adulticides for the Florida mosquito control program. Those which show promise in laboratory tests and which are or will be commercially available are further tested in the field. The following report contains the results of laboratory thermal aerosol tests conducted with nine insecticides and compares their effectiveness to malathion as a standard.

METHODS. All tests were conducted using a laboratory thermal aerosol generator (Figure 1) developed at the West Florida Arthropod Research Laboratory (Rathburn, 1969). One-half milliliter of the insecticide solution, diluted to predetermined concentrations in Number 2 diesel oil or kerosene, was sprayed at 15 psi into a heater operated at a temperature of 850 ° F. The aerosol was drawn through the wind tunnel, which contained the 6-inch diameter screened test cages, at an air velocity of 3 mph. Check or control mosquitoes were exposed in the same manner to an aerosol of only diesel oil or kerosene.

Each test cage contained 25 female mosquitoes and each concentration of each insecticide, including the check, was

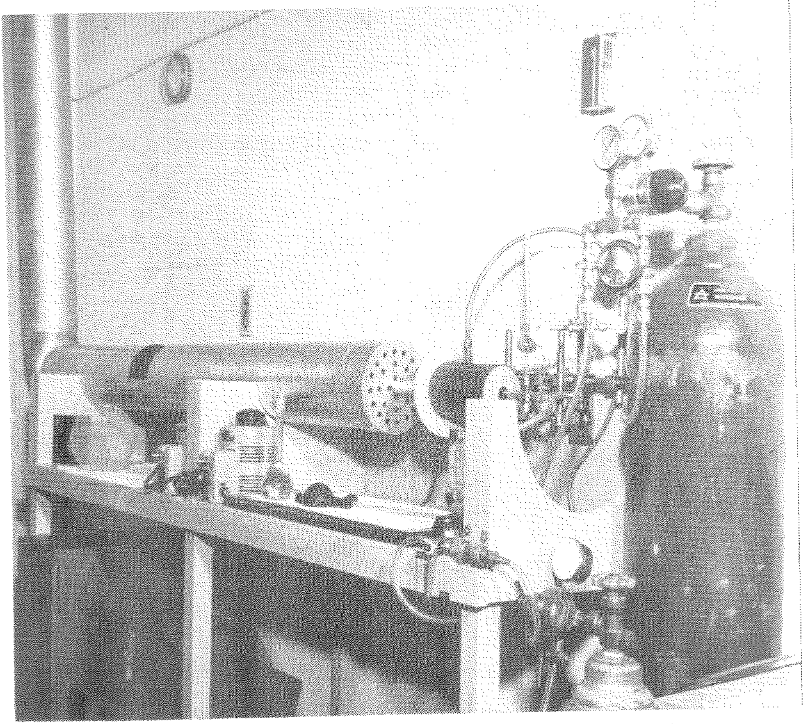

Fig. 1.—The laboratory thermal aerosol generator and wind tunnel.

replicated 5 to 29 times. LC_{50} and LC_{90} dosages were determined from dosage mortality curves of 3 to 5 concentrations of each insecticide. The mosquitoes used in the tests were from laboratory colonies and were 2 to 8 days old at the time of testing. Two species of mosquitoes, *Aedes taeniorhynchus* and *Culex nigripalpus* were used in all tests since it had been previously determined that these two species usually are not equally susceptible to a particular insecticide. Treated mosquitoes were changed to clean cages and held for 24 hours with access to sugar water.

The insecticides tested were C–9491 (Ciba Agrochemical Company), Dowco 214 and Dursban (Dow Chemical Company), EL–400 (Eli Lilly and Company), fenthion (Chemagro Corporation), malathion (American Cyanamid Company), naled (Chevron Chemical Company), SBP–1382 (S. B. Penick and Company), Sevin (Union Carbide Corporation), and TH–3461 (Thompson-Hayward Chemical Company). The chemical composition of the coded experimental insecticides are shown in Table 1. Thiosperse at 0.5 percent was used in all dilutions of malathion in diesel oil and Ortho Additive at 1 percent in all dilutions of naled in diesel oil to control the formation of sludge.

Results. Results of the thermal aerosol tests are shown in Table 2. All treatment mortalities were corrected by Abbott's formula for check mortalities which averaged 1.1 percent for 207 replications with *A. taeniorhynchus* and 1.2 percent for 215 replications with *C. nigripalpus*.

Initially, No. 2 diesel oil was used as the diluent in all tests, but because of erratic results possibly due to variations

TABLE 1.—Chemical composition of coded experimental insecticides.

Insecticide	Chemical Composition
C–9491	o,o-dimethyl o-(2,5-dichloro-4-iodophenyl) phosphorothioate
Dowco 214	o,o-dimethyl o-(3,5,6-trichloro-2-pyridyl) phosphorothioate
EL–400	o-(4-bromo-2, 5-dichlorophenyl) o, o-dimethyl phorothioate
SBP–1382	(5-benzyl-3-furyl) methyl 2,2-dimethyl-3-(2 methylpropenyl) cyclopropanecarboxylate.
TH–3461	ethyl o,o-dimethyldithiophosphoryl 1-phenylacetate

between different lots of diesel oil, the diluent was changed to kerosene in later tests. In general the insecticides diluted in kerosene were more toxic to the adult mosquitoes than when diluted in diesel oil. Although diesel oil is preferred in actual control operations because of its lower cost, kerosene appears better suited for comparative laboratory testing because of its uniformity between lots.

Against *A. taeniorhynchus,* only Sevin, C–9491, SBP–1382, and EL–400 were shown to be less toxic than malathion, while fenthion, naled, and TH–4361, were considerably more toxic than malathion. Against *C. nigripalpus* SBP–1382, fenthion, naled, TH–3461 and Dursban were considerably more toxic than the malathion standard. The differences in insecticide susceptibility between the two species, shown in the last column of Table 2, is very noticeable. While malathion, fenthion, Dowco 214, Sevin, and TH–3461 were more effective against *A. taeniorhynchus* than *C. nigripalpus,* the reverse was true with naled, SBP–1382, EL–400, and C–9491. When compared to malathion, SBP–1382 was extremely toxic to *C. nigripalpus* but considerably less toxic than malathion to *A. taeniorhynchus.*

STABILITY OF FORMULATIONS. The stability of insecticide solutions stored in clear glass volumetric flasks at room tem-

TABLE 2.—Toxicity of insecticides applied as thermal aerosols in the laboratory to caged adult *Aedes taeniorhynchus* (Wied.) and *Culex nigripalpus* Theob.

	Milligrams a.i. per milliliter						Reciprocal LC_{90} ratio to malathion		LC_{90} ratio of *Culex* to *Aedes*
	Aedes			*Culex*					
Insecticide	Reps	LC_{50}	LC_{90}	Reps	LC_{50}	LC_{90}	*Aedes*	*Culex*	
In kerosene									
fenthion	17	0.34	0.70	19	0.85	1.33	7.00	21.93	1.90
naled	14	0.53	0.80	10	0.48	0.78	6.13	37.40	0.98
TH–3461	10	0.95	1.27	10	1.59	2.55	3.86	11.44	2.01
Dowco 214	18	1.44	2.80	20	3.88	11.50	1.75	2.54	4.11
Dursban	14	1.37	2.88	15	2.01	4.17	1.70	7.00	1.45
malathion	16	3.50	4.90	28	16.34	29.17	1.00	1.00	5.95
C–9491	14	4.50	9.40	14	3.70	6.60	0.52	4.42	0.70
SBP–1382	12	4.90	15.00	16	0.25	0.88	0.33	33.15	0.06
In diesel oil									
naled	16	1.93	2.77	12	1.34	2.10	2.36	18.34	0.76
Dursban	10	1.73	3.24	9	1.73	3.24	2.02	11.89	1.00
TH–3461	5	2.86	3.92	5	4.14	6.89	1.67	5.59	1.76
malathion	29	4.43	6.53	25	17.50	38.51	1.00	1.00	5.90
Sevin	13	5.27	11.03	13	5.27	12.46	0.59	3.09	1.13
C–9491	15	7.10	17.50	10	5.90	12.50	0.37	3.08	0.71
EL–400	12	25.50	84.00	8	16.25	40.50	0.08	0.95	0.48

TABLE 3.—Reduction in toxicity of formulations of naled in kerosene to adult *Culex nigripalpus* with increasing age of formulation.

Formulation age in days	Reps.	Average percent mortality at indicated miligrams a.i./milliliter kerosene: 0.50	0.67	0.83	1.25	LC_{50}	LC_{90}
0	10	51.8	80.4	90.6	99.2	0.48	0.80
1	12	2.0	5.7	30.4	94.0	0.92	1.20
2	13	2.0	2.3	16.9	82.9	1.02	1.33
3–8	10	0.3	1.8	20.6	76.0	1.03	1.40
10	10	0	0.4	5.6	71.4	1.13	1.43

perature was not a problem with any of the insecticides used, with exception of naled. As shown in Table 3, there was almost a two-fold reduction in toxicity of naled solutions in kerosene after 10 days, and a reduction in toxicity was noticed even with 1-day-old solutions. As a result, all dilutions of naled used in obtaining the data presented in Table 2 were prepared immediately prior to use. Test solutions of TH–3461, fenthion, Dursban, Dowco 214, EL–400, Sevin, C–9491, and milathion, were used up to a maximum age of 2 days, 1, 2, 3, 4, 5, and 8 weeks respectively with no indication of a reduction in mosquito mortality. Dilutions of SBP–1382 were prepared just prior to use as instructed in the manufacturer's technical bulletin; therefore, no data on the stability of this insecticide were obtained.

Of importance in the laboratory testing of insecticides for future field use is the conversion of laboratory dosages to effective field dosages. In Table 4 currently recommended rates of fenthion, malathion, and naled for use as thermal aerosols in Florida were obtained from field research with various dosages of these insecticides. From dosage-mortality curves of these data the LC_{90} field dosages shown in column 2 were calculated. Comparing the recommended field dosage to the LC_{90} field dosage results in a ratio of 1.1 to 1 for all insecticides against both mosquito species.

Fenthion was omitted from the data for *C. nigripalpus,* because the maximum labeled dosage is not effective against this species; therefore, there is no recommended dosage of this insecticide against this species in Florida. Field LC_{90} data for malathion and naled against both mosquito species and for fenthion against *A. taeniorhynchus* were obtained from 2 to 4-point dosage-mortality lines.

Also shown in Table 4 are the field LC_{90} to laboratory LC_{90} ratios. In general, the LC_{90} field dosage is from 2 to 15 times more than the LC_{90} laboratory

TABLE 4.—A comparison of field and laboratory dosages of three insecticides, applied as thermal aerosols against adults of two species of mosquitoes.

	Field dosage—wt. oz. a.i. per gal.		Ratio of Recommended to LC_{90}	Lab. dosage—mg. a.i. per ml. of		Ratio of LC_{90} field dosage to LC_{90} lab. dosage	
Insecticide	Recommended	LC_{90}	field dosage	Diesel	Kerosene	Diesel	Kerosene
Aedes taeniorhynchus (Wied.)							
fenthion	1.25	1.10	1.1	....	0.70	...	11.7
naled	1.50	1.40	1.1	2.77	0.80	3.7	13.1
malathion	6.00	5.50	1.1	6.53	4.90	6.3	8.4
Culex nigripalpus Theob.							
naled	1.75	1.60	1.1	2.10	0.78	5.7	15.4
malathion	8.00	7.10	1.1	38.51	29.17	1.4	1.8

dosage, the ratio varying with the insecticide and being greater with the more toxic insecticides. The lower LC_{90} obtained in the laboratory is probably due to better coverage since all the aerosol produced must pass through the cage containing the mosquitoes.

SUMMARY. Against both mosquito species only fenthion, naled, and TH–3461 were appreciably more toxic than the malathion standard; and only Sevin, C–9491, SBP–1382, and EL–400 tested against *A. taeniorhynchus* were less toxic than malathion. SBP–1382, while extremely toxic to *C. nigripalpus,* was considerably less toxic than malathion to *A. taeniorhynchus.* Although not as pronounced as with SBP–1382, a difference in species susceptibility was also noticed with most of the other insecticides tested.

Almost a two-fold reduction in toxicity of naled solutions in kerosene was noted after 10 days. With the exception of dilutions of SBP–1382 which were only tested as freshly made solutions, none of the other insecticides tested showed any reduction in toxicity with increasing age.

Field to laboratory LC_{90} ratios vary with the insecticide, being greater with the more toxic insecticides. In the field, a 2 to 15 times higher concentration than that required in the laboratory is necessary for comparable kill.

Literature Cited

Rathburn, C. B. Jr. 1969. A laboratory thermal aerosol generator for the testing of insecticidal aerosols. Mosq. News 29(1):1–6.

ULTRA LOW VOLUME TESTS OF MALATHION APPLIED BY GROUND EQUIPMENT FOR THE CONTROL OF ADULT MOSQUITOES

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Insecticides applied as thermal aerosols for the control of adult mosquitoes have been widely used for many years. Although this method has given excellent results, it has several inherent disadvantages, the main one being the hazard to automobile traffic caused by the dense fog.

Mount, *et al.* (1968) reported on a technique for dispersing ultra low volumes (ULV) of undiluted insecticides as nonthermal aerosols, and showed that technical grade malathion applied at 0.68 gallon per hour (gph) was as effective against caged adult mosquitoes as dilute formulations applied as thermal aerosols dispersed at 40 gph. These results coupled with the commercial development of ULV application have produced considerable interest in this new technique for adult mosquito control. As with any new technique, however, many questions arise which must be answered before it can be successfully used in routine control operations. This paper deals with some of the more important aspects of the use of this technique, including accurate control of discharge rates and effective dosage of malathion against caged adults of two species of mosquitoes, *Aedes taeniorhynchus* and *Culex nigripalpus.*

METHODS. All tests were conducted in the early evening hours after sunset. Temperatures at test time ranged from