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COMPARATIVE TESTS OF FOG OILS AND DIESEL OIL AS THERMAL AEROSOLS FOR CONTROL OF ADULT MOSQUITOES

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The possible effects of the use of oils of high viscosity in thermal aerosol formulations have been realized for some time. Peterson (1952) using fuel oil, SAE 10 and SAE 50 motor oils in a thermal aerosol generator found that at the same discharge rate an oil of lower viscosity would produce a smaller particle size. In tests conducted by Brown and Watson (1953) with a TIFA aerosol generator, a solution of 5 percent DDT in fuel oil (viscosity 38.7 SSU at 70° F.) produced a smaller particle size (17 μ mmd) than a solution of 30 percent DDT in methylated aromatics (viscosity 44.6 SSU at 70° F.) (26 μ mmd). There was, however, no difference in the biological effectiveness between the two solutions when applied at the same dosage of DDT.

Results of research by Brown and Morrison (1955) show that a formulation of 5 percent DDT in kerosene emitted from a Dyna-Fog Jr. produced a smaller particle size (8.9 μ mmd) than a formulation of 5 percent DDT in fuel oil (18.5 μ mmd), the fuel oil being of higher viscosity than the kerosene. No comparative tests of the biological effectiveness were conducted. Morrill and Wesley (1955) comparing several fog formulations applied by non-thermal and thermal generators demonstrated an increase in particle size when 20 percent SAE 50

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motor oil was added to diesel oil applied as a thermal aerosol.

Edmunds, *et. al.*, (1958) found that 18 to 20 percent of SAE 50 motor oil was necessary to cause any significant retardation of evaporation of the atomized particles at distances of 300 feet from the machine. When less than 10 percent SAE 50 motor oil was used there was no measurable effect on evaporation. He states that the reduction in particle size due to evaporation of diesel oil is not considered serious enough to warrant the addition of the more costly SAE 50 motor oil. These studies, however, were conducted with non-thermal aerosol generators and evaporation may be considerably greater with thermal aerosol generators. Schechter, *et. al.*, (1960) showed that the non-volatile content of an aerosol formulation is not of much importance as long as the droplets do not exceed the aerosol range. These tests were conducted with flies in 1000 cu. ft. rooms using formulations of a non-volatile content ranging from 0.5 to 15 percent. The results, therefore, may not be applicable to field research.

Most of the preceding research is concerned with the addition of a quantity of an oil of high viscosity to one of a lower viscosity for the purpose of reducing evaporation and increasing particle size and thereby, it is believed, increasing the volume of material depositing on insects. The same possible effect may also be accomplished by the use of a single oil of medium viscosity. Recently, single oils of medium viscosity, called fog oils, have been used in mosquito control operations in Florida. In appearance these fog oils produce a much denser fog than that produced by diesel or fuel oils. The use of fog oils, although more expensive than diesel oil, was prompted by this spectacular visual difference and certain physical factors such as insecticide solubility and viscosity. However, adequate comparisons of biological effectiveness were lacking. Therefore, tests were conducted during 1964 to compare the effectiveness of No. 2 diesel oil and fog oil in insecticidal thermal aerosols against adult mosquitoes. Fog oil was also compared with one grade of diesel oil in a laboratory formulation test. This is a report of the results of these tests.

Methods. The testing methods used were similar to those reported by Rogers, *et. al.*, (1957). All tests were conducted in the early evening hours after dark on level, open areas having little or no underbrush. Two species of mosquitoes, *Aedes taeniorhynchus* Wied. and *Culex nigripalpus* Theobald, were exposed in each test. At each station, one cage of each species, containing approximately 25 females per cage, was attached to a stake at 6 feet and another at 2 feet above the ground. In certain tests a third cage was placed on the bare ground at the foot of the stake, and a fourth cage was placed a few feet away in grass about one foot in height. These sets of 4 or 8 cages of mosquitoes were placed at 660 feet and 1320 feet or 660 feet and 990 feet downwind from and perpendicular to the line of travel of the fogging vehicle. Each test consisted of the cages in three lines of stations placed a block (approximately 300 feet) apart or a total of 12 or 24 cages for each species.

All mosquitoes used in the tests were between 2 and 8 days old and had been fed only sugar water. After exposure to the fog, the mosquitoes were transferred to clean cages and a fresh pad of cotton saturated with sugar water was placed on the top of each cage. Mortality counts, of female mosquitoes only, were made 12 hours after treatment.

The diesel oil was a number 2 grade oil[2] purchased locally. The fog oil[3] was a high viscosity oil (SUS 108 @ 100° F.) with a high specific gravity (0.918 @ 60° F.). Several tests were also conducted with a horticultural spray oil[4]. This oil also was a high viscosity oil (105/115 @ 100° F.). The malathion formulations of fog and diesel oils

[2] Standard Oil Co.
[3] Fog oil X-light, Sun Oil Co.
[4] 345 Spray oil, Standard Oil Co.

were prepared from technical malathion to which 0.25 percent Thiosperse[5] was added to retard the formation of precipitates. Malathion formulations of the spray oil were also prepared from technical malathion but without Thiosperse.

For the formulation tests the malathion formulations were prepared as for the field tests above. The Dibrom (naled) was prepared from an oil soluble concentrate containing 14 pounds per gallon. Ortho Additive[6] was used where indicated as a sludge inhibitor. The Baytex (fenthion) used in the formulation tests was formulated from an oil soluble concentrate containing 8 pounds per gallon and Thiosperse was added where indicated as a sludge inhibitor.

All tests at 40 gallons per hour were conducted with a Leco 80 thermal generator. The generator was operated at a burner temperature of 850° F. and at a formulation pressure necessary to give a discharge of 40 gallons per hour, which was 13 p.s.i. for the formulations with diesel oil and 17 p.s.i. for the formulations with the fog oil and spray oil.

The tests at 20 gallons per hour were conducted with a TIFA 40E thermal aerosol generator, which was operated at a burner temperature of 1000° F. and a formulation pressure of 25 p.s.i. The fogging vehicle was driven at 5 miles per hour for all tests. The operation of the machines was checked constantly during the tests and the volume discharged was measured accurately before and after each test. Tests in which the output varied more than 6 percent were discarded. At least one test with each oil was run on each night so that the results between the oils are comparative. The fog coverage at each station was visually checked and if poor coverage was noted the test was discarded. The wind velocities and temperatures at 6 feet during the tests were between 1 and 5 miles per hour and 60 and 79° F., respectively.

[5] American Cyanamid Co.
[6] California Chemical Co.

Results. The field tests were designed to compare the effectiveness of formulations of fog oil and diesel oil: (1) in wider swaths than the usual 330 feet; (2) at less than the usual dosage levels; (3) at different discharge rates, and (4) with respect to the location of mosquitoes, especially at ground level, on bare ground, and in grass.

The laboratory formulation test was designed to evaluate the solubility of insecticides in the two types of oil, with and without the addition of sludge inhibitors.

Presented in Tables 1 and 2 are data from tests with malathion at 6 oz. and 8 oz. per gallon respectively in fog oil and diesel oil. This series of tests was designed to demonstrate if fog oils could be used at reduced dosages or at increased swaths. It is evident from the data that no difference in mosquito kill between the two oils was obtained either at increased distances or at reduced dosages of malathion. Although the increased dosage resulted in a slightly higher kill with each oil, it did not demonstrate a superiority of either.

In the same tests reported in Table 2, cages were placed at ground level in the open and in the grass to show if the fog oil stays closer to the ground than the diesel oil and therefore results in better coverage and better mosquito kill at ground level. The results, shown in Table 3, indicate that there was no difference in kill between the two oils at ground level either in the open street or in the grass. Neither oil produced a satisfactory kill of caged mosquitoes on the ground.

One test was conducted comparing fog oil with diesel oil at 20 gallons per hour. Results of this test are shown in Table 4 and indicate neither of the oils gave a superior kill at this discharge rate. While only one test was conducted at this volume, results were so similar to those of the other tests on a comparative basis that additional testing would not reasonably be expected to yield significantly different results. Presented in Table 5 are the data from the comparative tests conducted with the spray oil and diesel oil. The

TABLE 1.—Comparative tests above the ground with 6 oz. per gallon of malathion in fog oil and diesel oil applied at 40 gallons per hour.[1]

Oil	Mosquito Species	Percent kill at indicated distances and cage position				
		660 feet		1320 feet		
		6 ft.	2 ft.	6 ft.	2 ft.	Overall Average
Fog oil	*Ae. taen.*	85	76	61	63	70
	Cu. nig.	21	22	3	14	16
Diesel oil	*Ae. taen.*	83	67	67	65	70
	Cu. nig.	27	21	19	10	18

[1] Average of 2 tests with *Aedes taeniorhynchus* and 2 tests with *Culex nigripalpus*, except only one test with *Culex nigripalpus* with fog oil.

TABLE 2.—Comparative tests above the ground with 8 oz. per gallon of malathion in fog oil and diesel oil applied at 40 gallons per hour.[1]

Oil	Mosquito Species	Percent kill at indicated distances and cage position				
		660 feet		1320 feet		
		6 ft.	2 ft.	6 ft.	2 ft.	Overall Average
Fog oil	*Ae. taen.*	92	80	83	79	84
	Cu. nig.	33	24	29	19	26
Diesel oil	*Ae. taen.*	91	78	73	59	75
	Cu. nig.	49	34	26	17	31

[1] Average of 4 tests with *Aedes taeniorhynchus* and 3 tests with *Culex nigripalpus.*

results of these tests are not significantly different from those obtained in the fog oil-diesel oil tests.

Results of the laboratory formulation test comparing fog oil with diesel oil are shown in Table 6. In this test the diesel oil resulted in formulations which were as stable as those of fog oil where no sludge inhibitors were used. However, batches of diesel oil may vary widely in specifications and it is entirely possible that results somewhat different from those shown here might be obtained with diesel oils of different specifications. The specifications reported for the fog oil used in these tests are admittedly much more uniform between batches than diesel oils in general. Therefore, fog oils may be expected to result in more consistent formulations.

Unfortunately the highest wind under which any of the comparative tests were

TABLE 3.—Comparative tests at ground level with 8 oz. per gallon of malathion in fog oil and diesel oil applied at 40 gallons per hour.[1]

Oil	Mosquito Species	Percent kill at indicated distances and cage position				
		660 feet		1320 feet		
		Bare ground	Grass	Bare ground	Grass	Overall Average
Fog oil	*Ae. taen.*	34	4	19	3	15
	Cu. nig.	5	4	1	0	3
Diesel oil	*Ae. taen.*	43	2	10	2	16
	Cu. nig.	5	2	2	1	2

[1] Averages of 4 tests with *Aedes taeniorhynchus* and 3 tests with *Culex nigripalpus.*

conducted was only 4 miles per hour at 6 feet above the ground. However, since one of the main effects of wind velocity is to reduce exposure time, it appears that a higher wind velocity would not affect the formulations with diesel oil to any greater extent than the formulations with fog oil. It was noted, however, that under conditions of little or no ground wind and unfavorable inversion conditions, aerosols of fog oil "layered out" as did aerosols of diesel oil. (Note: "layered out" means that the fog formed a stable cloud layer, the base of which was 5 to 25 feet from the ground.)

DISCUSSION. It should be noted that

TABLE 4.—Comparative tests above the ground and at ground level with 8 oz. per gallon of malathion in fog oil and diesel oil applied at 20 gallons per hour.[1]

		Percent kill at indicated distances and cage position								
		660 feet				1320 feet				
		Above ground		On ground		Above ground		On ground		
Oil	Mosquito Species	6 ft.	2 ft.	Bare	Grass	6 ft.	2 ft.	Bare	Grass	Over-all Avg.
Fog oil	*Ae. taen.*	88	60	11	10	64	27	4	0	33
	Cu. nig.	10	3	4	0	0	0	0	0	2
Diesel oil	*Ae. taen.*	95	93	14	2	73	43	3	3	39
	Cu. nig.	24	12	0	3	3	0	0	0	6

[1] Only one test with *Aedes taeniorhynchus* and one test with *Culex nigripalpus.*

TABLE 5.—Comparative tests above the ground with 4 oz. per gallon of malathion plus 3 percent Lethane 384 in spray oil and diesel oil applied at 40 gallons per hour.[1]

		Percent kill at indicated distances and cage position				
		660 feet		990 feet		
Oil	Mosquito Species	6 ft.	2 ft.	6 ft.	2 ft.	Overall Average
Spray oil 100%	*Ae. taen.*	47	41	55	43	46
Diesel oil	*Ae. taen.*	44	29	29	22	33
Spray oil 50%	*Ae. taen.*	47	49	45	45	47
Diesel oil	*Ae. taen.*	49	54	57	59	55

[1] Average of two tests with the 100 percent Spray oil-Diesel oil comparative test and only one test with the 50 percent Spray oil-Diesel oil comparative test.

TABLE 6.—Comparison of fog oil and diesel oil as diluents for malathion, Dibrom (naled), and Baytex (fenthion).

	Number of days before formation of sludge									
	Malathion				Dibrom				Baytex	
	6 oz./gal.		8 oz./gal.		1½ oz./gal.		1¾ oz./gal.		1¼ oz./gal.	
	+	−	+	−	+	−	+	−	+	−
Fog oil	>30	4	>30	4	>30	1	>30	1	>30	>30
Diesel oil	>30	10	>30	10	>30	1	>30	1	>30	>30

(+)=With sludge inhibitor.
(−)=Without sludge inhibitor.

poor results were obtained in all tests where caged mosquitoes were exposed at ground level. This has often been observed in previous tests. Although confirming data are not yet available, it is theorized that greatly reduced air currents prevail at ground level where there is a dense vegetative cover, as in a grass meadow. The higher air velocities above the grass carry the aerosol particles great distances horizontally, thus preventing their deposition at ground level. This could explain the poor kills of mosquitoes at ground level with thermal aerosols. Therefore, insecticidal aerosols, as outdoor space treatments, should be more effective at night when mosquitoes are in flight. This is especially true with mosquito species such as *Aedes taeniorhynchus* and *Culex nigripalpus*, both of which rest on the ground during daylight hours.

The only objective of these tests was to compare the effectiveness of diesel oil and fog oil as diluents in insecticidal aerosols in Florida. The relatively poor kills obtained with various insecticides and formulations used in these tests were expected because of the increased distance from the fog generator at which the caged mosquitoes were placed. These distances were two to four times the recommended swath for these formulations, which is 330 feet. This increased distance is also a factor in the apparent reduction in kill of *Culex nigripalpus* when compared to the kills obtained with *Aedes taeniorhynchus*. It has been previously determined (Rathburn, *et al.* 1964) that a higher dosage of Dibrom (naled) or malathion is required to kill *Cu. nigripalpus* than *Ae. taeniorhynchus*. Therefore, the increased distances at which these tests were conducted resulted in a reduction in dosage and consequently a greater reduction in kill of *Cu. nigripalpus*.

The reason for the increased visual density of the fog produced with the fog oil is not fully understood. There are many factors which might contribute to the denser appearance of aerosols of fog oil. Among these are particle size and number, the refractive index and the evaporation rate of the oil. However, the results of these tests show that thermal aerosols of insecticide formulations made with fog oils are not superior to similar formulations made with No. 2 diesel oil; therefore, the more spectacular appearance of the fog oil thermal aerosols is only of academic interest.

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