# MALATHION AND NALED AS MOSQUITO ADULTICIDES IN ALASKA [1]

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ABSTRACT. Wild-caught *Aedes* mosquitoes and water striders (*Gerris buenoi*) were exposed in cages to low-volume fogs of malathion and naled. The cages were arrayed at two levels—on the ground and 6 feet above ground—from 100 feet to 500 feet from point of discharge. Mortality was consistently high at 100 feet for both insecticides when the cages were placed 6 feet above ground, but beyond that point mortality decreased in relation to increasing distance from point of discharge and in relation to the height and density of ground cover between each cage and the point of discharge. Malathion nonthermal fog and naled thermal fog penetrated dense ground cover much more readily and with greater insecticidal effect than naled nonthermal fog. In those cases where the fog readily reached the cages, naled produced a much higher percentage of knockdown (1-hour postspray) of both mosquitoes and water striders. Water striders were more susceptible to naled (40–61% mortality) than to malathion (13–21%). Malathion and naled as nonthermal fogs were both effective against adult mosquitoes, but malathion would be preferable where the target areas included dense underbrush and aquatic habitats.

INTRODUCTION. Adulticiding as a technique of mosquito suppression was extensively tested in Alaska about 25 years ago (Jackowski and Schultz 1948, Blanton *et al.* 1950, Hedeen and Keegan 1952, Wilson 1951). Three organochlorine adulticides (DDT, dieldrin and lindane) were tested, but only DDT came into operational use. Those early tests demonstrated that the duration of effective protection from mosquito attack was related to either frequency of treatment (in the case of ground application) or size of the treated area (in the case of aerial application).

A ground-based system, consisting of generators to dispense DDT in an aerosol form (Wilson 1950), was developed as one approach to the major mosquito problem of Alaska: How to protect small enclaves of people surrounded by vast regions highly productive of mosquitoes. This system provided effective protection from mosquitoes (also from blackflies, Berg 1951) so long as it was in operation and for a short period thereafter. Frequent applications of DDT were required to maintain an acceptable level of protection, and the equipment required careful attention to keep it in operating condition.

Ground-based methods aimed at adult mosquito suppression were largely abandoned in favor of aerial techniques. Reinvasion of treated areas still occurred, but the aerial techniques permitted treatment of much larger target areas. Treatment of a 4 $mi^2$ area with DDT provided protection for about 48 hours; 24–30 $mi^2$, 5–7 days; 100 $mi^2$, 3 days; and 100 $mi^2$, 14 days (Blanton *et al.* 1949, Wilson 1951). Such treatments kill a large part of the mosquitoes in the target area; but the duration of relief from further attack seems to depend on the population dynamics of the mosquitoes peripheral to the treated area.

From 1950 until 1965, Fairbanks and the major military installations were sprayed with DDT at least once each summer by military aircraft. Bush pilots did some contract spraying with small aircraft in Anchorage during this period. With the exception of one experimental application in 1967 (Mount *et al.* 1969), DDT was last used as a mosquito adulticide in Alaska in 1965. Malathion was used thereafter for that purpose in all

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localities (except Ft. Greeley) where adult mosquito suppression was attempted. At Ft. Greeley naled was used routinely in a ULV system from 1967 to 1972.

From 1966 to 1969 the Special Aerial Spray Flight of Langley Air Force Base, Virginia, made one trip each summer to Alaska to apply adulticidal malathion to those military reservations requiring treatment. Since 1969 aerial applications of malathion have been done only by bush pilots working under private contracts to spray certain residential districts of Anchorage. Except for these occasional operations by bush pilots, all adult mosquito suppression in Alaska, since 1970, has been done with ground equipment.

Tests were conducted in 1967 to compare the effectiveness of malathion and DDT as adulticides applied from the ground as nonthermal fogs, and to demonstrate the effectiveness of malathion applied with an aerial ULV system (Mount *et al.* 1969). Analysis of soil samples collected before and after this series of tests indicated that malathion and one of its degradation products, malaoxon, persisted in the soil for various lengths of time ranging up to one year (Holty 1970).

TEST POPULATIONS. Fifteen species of mosquitoes, all females, were included in the test populations, but most of these species comprised less than 1 percent of the total (main species: *Aedes intrudens,* 49%; *Ae. fitchii,* 14%; *Ae. communis,* 10%; *Ae. punctor,* 9%). All mosquitoes and water striders used in these tests were collected within the limits of Eielson Air Force Base.

The water striders (*Gerris buenoi*), all taken from one pond, were chosen for use in these tests because they were abundant and readily available and because they are usually associated with unpolluted aquatic environments. Their presence at the air-water interface makes them probable, if inadvertent, targets of air-borne insecticides.

The water striders proved to be very tractable experimental subjects. Once captured, they assumed a quiescent disposition which made them very easy to count and transfer to cages. They were kept in an insulated chest on water from their pond until time for transfer to cages. If the high rate of survival of the controls was any indication, then the loss of contact with water upon transfer to the cages was not notably detrimental.

TEST PROCEDURES. The basic test procedure, described elsewhere (Gorham 1972), called for an array of cages (see Rathburn *et al.* 1969 for cage description) at intervals of 100, 200, and 300 feet from the point of insecticidal discharge. The tests were done in June 1970 and June, July and August 1971, some in an open area of close-cropped lawn, others in areas of natural vegetation. Variations of the basic procedure are described under the appropriate sections below. No testing was attempted when wind speeds exceeded 10 mph. Extremes of temperature and relative humidity, during the entire series of tests, were 56–81 F (average, 67 F) and 34–53% (average, 42%). Routine operational formulations and procedures were used for both insecticides: malathion in No. 2 fuel oil, 40 gallons per hour, 6% at 5 miles per hour or 12% at 10 miles per hour; naled in No. 2 fuel oil, 40 gallons per hour, 0.7% at 5 miles per hour. Runs past the experimental target areas were merely detours from the usual fogging pattern. Abbott's formula was applied where control mortalities exceeded 5%.

TESTS WITH NONTHERMAL FOGS AT 100 TO 300 FEET. Malathion and naled produced very high and essentially equal mortalities among the mosquitoes; the water striders appeared to be much more susceptible to naled than to malathion (Table 1).

TESTS WITH NONTHERMAL FOGS AT 100 TO 500 FEET. These tests were conducted in two natural areas where the predominant plants were horsetails and willows. The willows, standing about 5 feet tall, formed a dense cover over much of the target area. At 6 feet above ground, the caged mosquitoes were in the direct line

Table 1. Mortality caused by nonthermal fogs.

| Insect [a] | Insecticide | Feet from point of discharge 100 | 200 | 300 | Controls |
|---|---|---|---|---|---|
| Mosquitoes | Malathion | 96:23 [b] | 80:21 | 75:19 | 10:20 |
| | Naled | 99:15 | 86:13 | 66:10 | 6:15 |
| Water striders | Malathion | 21:11 | 14:9 | 13:7 | 6:10 |
| | Naled | 46:9 | 40:7 | 61:6 | 4:3 |

[a] Wild-caught specimens in cages suspended six feet above ground. Average number of specimens per replicate: mosquitoes, 26; water striders, 22.
[b] Percent mortality (24 hours after treatment): Number of replicates.

of drift, but the dense undergrowth obstructed much of the intervening space between the point of discharge and the cages (Table 2). Both adulticides were effective to the 200-foot level; malathion was effective, with 83% mortality, to the 500-foot level.

Cages on Ground and Six Feet Above Ground. The same brush-covered locations were used for these tests as for those just described. The attenuated effect of naled, which was apparent in the aboveground tests and which may presumably be attributed to the dense undercover, was even more pronounced in the ground-level tests (Table 2). Although the performance of malathion was superior under these conditions, its effectiveness dropped sharply beyond the 200-foot level.

Tests with Naled Thermal Fog. The poor penetration of the underbrush by the nonthermal naled fog prompted further testing with a thermal fog. This was generated by a portable fogger (Dyna-Fog 150B, FSN 3740–682–5286). One gallon of 0.7% naled was dispersed over the test area. The thermal fog penetrated the brush barrier much more effectively than the nonthermal fog (Table 3).

Survival of Mosquitoes in Treated Areas. These areas of dense willow underbrush normally support a large population of resident mosquitoes. I noted that mosquitoes were present in such areas shortly after treatment with nonthermal fogs even though the caged mosquitoes had sustained high mortalities. I was not able to thoroughly explore the question of survival in treated areas, but the very limited results available (Table 4) suggest that malathion had greater impact on the resident mosquitoes than naled. This conclusion is strengthened by the results of the ground-level tests on caged mosquitoes (Table 2). Reinvasion of the treated area by unaffected mosquitoes certainly occurs, but this could not account for 100% survival following naled treatments and 41% survival after malathion treatments. Survival levels approximating those of the

Table 2. Effects of nonthermal fogs on mosquitoes.[a]

| Cage location | Insecticide | Feet from point of discharge 100 | 200 | 300 | 400 | 500 | Controls |
|---|---|---|---|---|---|---|---|
| Six feet above ground | Malathion | 100:6 [b] | 89:6 | 95:6 | 93:6 | 83:6 | 17:6 |
| | Naled | 100:2 | 100:2 | 44:2 | 53:2 | 15:2 | 5:2 |
| On ground | Malathion | 100:2 | 100:2 | 48:2 | 19:2 | 24:2 | 0:2 |
| | Naled | 65:2 | 18:2 | 4:2 | 2:2 | 0:2 | 0:2 |

[a] 24 hours after treatment. Wild-caught specimens. Average number per replicate, 30.
[b] Percent mortality: Number of replicates.

TABLE 3. Effects of naled thermal fog on mosquitoes.[a]

| Cage location | Effect | Feet from point of discharge 100 | 200 | Controls |
|---|---|---|---|---|
| Cages six feet above ground | Knockdown [b] | 100:6[d] | 99:4 | .. |
| | Mortality [c] | 100:6 | 100:4 | 4:1 |
| Cages on ground | Knockdown | 89:5 | 23:4 | .. |
| | Mortality | 100:4 | 97:4 | 16:1 |

[a] Wild-caught specimens. Average of 31 mosquitoes per replicate.
[b] One hour after treatment.
[c] 24 hours after treatment.
[d] Percent (mortality or knockdown): Number of replicates.

controls would be expected in both instances if reinvasion were taken as the explanation of these results.

KNOCKDOWN EFFECTS. As nonthermal aerosols, both adulticides produced readily-observable deleterious effects on mosquitoes at 1-hour post-treatment (Table 5). Naled produced effects of much greater magnitude than malathion, but those effects were markedly diminished when the target cages were at ground level and somewhat protected by a dense layer of shrubby vegetation. This moderation of the knockdown effect also occurred in the naled thermal fog tests (Table 3).

The waterstriders appeared to be much more susceptible to the immediate effects of naled than of malathion. However, no knockdown at 1-hour post-treatment was not necessarily followed by complete survival at 24 hours; neither did a low knockdown rate predispose a low mortality rate. Except for the ground-level tests with naled reported in Table 5, Tables 1 and 5 are essentially comparable, that is, the knockdown reported in Table 5 may be compared with the mortality reported in Table 1. For example, even though water strider knockdown by malathion was zero, mortality eventually amounted to 13 and 14% at 24 hours.

DISCUSSION. Adult mosquito suppression in Alaska was first achieved by ground-based techniques (Wilson 1951). This approach was quickly dropped in favor of aerial techniques, which dominated the scene for about 20 years. Now with the current renewed emphasis on ground-based techniques, the evolution of adulticidal techniques has come full circle. Ground-based adulticiding techniques have proved

TABLE 4. Survival of mosquitoes in treated areas.

| Nonthermal fogs | Number of replicates | Percent survival in Control area [a] | Treated area [b] |
|---|---|---|---|
| Malathion | 2 | 81 | 41 |
| Naled | 2 | 97 | 100 |

[a] Wild-caught specimens collected before treatment.
[b] Wild-caught specimens collected in the middle of the target area approximately one hour after treatment.

TABLE 5. Knockdown effects of nonthermal fogs.[a]

| Insect | Insecticide | Feet from point of discharge 100 | 200 | 300 |
|---|---|---|---|---|
| Mosquitoes [e] | Malathion [b] | 64:26[d] | 40:25 | 33:23 |
| | Naled [b] | 92:17 | 83:13 | 64:10 |
| | Naled [c] | 25:4 | 0:2 | 0:2 |
| Water striders [f] | Malathion [b] | 1:11 | 0:9 | 0:7 |
| | Naled [b] | 29:9 | 18:7 | 14:6 |

[a] One hour after fogging. Dead mosquitoes, as well as those debilitated and dying, were counted.
[b] Cages suspended six feet above ground.
[c] Cages located at ground level and surrounded by dense underbrush about five feet tall.
[d] Percent knockdown: Number of replicates.
[e] Average number per replicate, 27.
[f] Average number per replicate, 21.

to be generally more compatible with Alaskan conditions than aerial techniques, but there are doubtless circumstances where aerial methods would be more advantageous.

Both malathion and naled nonthermal fogs are effective mosquito adulticides, and both have been used successfully in routine mosquito suppression programs in Alaska. Malathion or its toxic derivatives may persist in some Alaskan soils for prolonged periods, in contrast to its demonstrated lability in other parts of the world, but there is no evidence that this small residual is environmentally dangerous. The behavior of naled in Alaskan soils has not been investigated.

Both adulticides performed well in an open area where the path of insecticidal drift was unobstructed. In areas of dense, shrubby undergrowth, both malathion nonthermol fog and naled thermal fog produced satisfactory levels of mortality in caged mosquitoes (malathion thermal fog was not tested). In those instances where aquatic habitats would be included in the target area, the results of these tests suggest that, of the two adulticides tested, malathion should be the insecticide of choice.

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## NOTICE

The Bishop Museum in Hawaii should be added to the list of cooperators in the National Mosquito Identification Service. They will identify mosquitoes from the Pacific Basin and Southwest Pacific, including New Guinea. Requests should be sent to Dr. Wallace A. Steffan, Bernice P. Bishop Museum, Box 6037, Honolulu, Hawaii 96818.