# PREHATCHING TREATMENTS FOR THE CONTROL OF *AEDES* IN ALASKA[1]

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A recent approach to the control of marsh-breeding mosquitoes has been the application of insecticides to breeding areas before the eggs hatch. The unusual stability of the new insecticides permits their application several weeks or months in advance of the mosquito-breeding season. This method, now known as the preflooding or prehatching treatment, may prove a useful adjunct to other control measures.

Favorable results with prehatching treatments of DDT have been reported against *Psorophora* in Florida (Wisecup and Deonier 1945) and in Arkansas (Wisecup *et al.* 1945, Horsfall 1946). Poor control of the salt-marsh mosquitoes *Aedes taeniorhynchus* (Wied.) and *A. sollicitans* (Walk.) was obtained in Florida with light applications of DDT (Wisecup *et al.* 1947), but good control of those species was obtained with heavy applications (Deonier *et al.* 1948). This method was also found effective against flood-water *Aedes* along the Columbia River in Oregon (Yates and Gjullin 1947). In New Jersey promising results against fresh-water swamp mosquitoes were obtained with DDT but not with benzene hexachloride (Hansens and Hart 1947). Perhaps the most effective use of prehatching treatments is indicated by applications to snow for *Aedes* control in Washington (Roth *et al.* 1947, Lindquist *et al.* 1948) and near Churchill, Canada (McDuffie *et al.* 1949). This paper will describe tests on a large series of plots in Alaska treated during the fall of 1947 and the spring of 1948.

Materials and Methods.—A total of 201 one-fourth and one-half acre plots were treated with rotary hand dusters and 3-gallon cylindrical pressure sprayers. Forty 5 to 10-acre plots were treated with either an L-5 or a UC-64 (Norseman) airplane.

The plots treated with hand equipment were in the vicinity of Anchorage, Gulkana, Tok, Tanacross, and Paxton, Alaska. Four or five replications were made of each treatment, one in each of several different mosquito-breeding environments —natural depressions and old roadways where sedge (*Carex*) was the predominant vegetation, and bogs with plant associations of *Myrica* (*M. gale*)-heath-*Sphagnum*, *Sphagnum*-heath, and *Sphagnum*-sedge-heath. The plots treated by airplane were in the following plant associations: deep grassy (*Calamagrostis canadensis*) depressions, *Sphagnum*-heath, *Sphagnum*-*Myrica*-birch (*Betula nana*) and *Sphagnum*-heath-sedge. These test areas were hummocky with accumulations of water between the hummocks, and all were known mosquito producers.

Half the plots were sprayed in August 1947. At this season there was little or no water in bogs having sedge or grass as the predominant vegetation, whereas in the other environments most of the depressions between the hummocks were filled with water. The remainder of the plots of each type were treated in March and April 1948, when the snow was 3 to 30 inches deep.

In the plots treated by hand DDT was applied in emulsions, fuel-oil solutions, dusts, and wettable powders. Chlordane,

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toxaphene, methoxychlor, TDE, and parathion were applied in fuel-oil solutions. Benzene hexachloride (12 per cent gamma) was applied both in fuel-oil solutions and in 50 per cent wettable powders. To each 5 gallons of fuel oil 1 quart of cyclohexanone was added to insure stable solutions during cool weather, and also, in the spring, 1 pint of alcohol to prevent moisture in the cans from freezing and stopping the spray nozzles. The dusts were diluted with pyrophyllite. All liquids were applied at the rate of 2.5 gallons per acre. The dusts were applied at 5 pounds per acre except for benzene hexachloride, which was applied at the rate of 8.4 pounds of dust per acre.

The airplane plots were treated with a 20 per cent DDT concentrate diluted with fuel oil to obtain different dosages. From 2 to 8 quarts of spray per acre were applied in the fall and from 1 to 2 pints in the spring. Red dye was added to the sprays, and white cards were placed at 25-foot intervals across the plots to determine whether the spray was well distributed.

All plots were dipped from 2 to 6 times to determine the effect of the various treatments. In most tests from 30 to 60 dips per plot were made at each observation in the hand-treated plots and from 30 to 100 in the airplane plots. A total of 22,823 dips were made in the hand-treated plots and 13,981 in the airplane plots.

Although the numbers of larvae taken during the preliminary observations are reported, the per cent control is based on the final observation and includes both larvae and pupae.

Results. *Hand-treated Plots.*—The data for the hand-treated plots, as summarized in table 1, are averages for all plots given the same treatment. Complete control was obtained only with DDT applied at the rate of 2 pounds per acre as an emulsion. A 90 per cent or higher control was shown in plots treated with DDT in the fall at the following rates per acre: 2 pounds in fuel-oil solution, emulsion, and wettable powder; 0.5 pound in fuel oil and wettable powder; and 0.1 pound in an emulsion. Of the spring treatments, only the 0.1 pound dosage of DDT in fuel oil and the 0.5 pound dosage of TDE gave more than 90 per cent control. The following applications gave 70 to 89 per cent control: Fall applications of DDT at 1 and 0.1 pound in fuel oil, 1 and 0.5 pound in emulsions, 2 pounds in dust, and of benzene hexachloride wettable powder at 0.5 pound of the gamma isomer; spring applications of 0.5 pound of DDT in fuel oil and in emulsion. All other treatments gave less than 70 per cent control. Parathion and methoxychlor were ineffective as prehatching treatments.

It was observed during the dipping that newly hatched larvae were being killed by some of the treatments. This observation is confirmed by the low counts in the preliminary observations of plots in which the treatments were effective. During the early observations it was common to find only first-instar larvae in treated plots, whereas in untreated plots other instars were present.

There was little evidence of a delayed kill. Dead larvae were rarely seen in the treated plots. In 16 of the 39 treatments the larval population was not significantly lower at the final observation than during the preliminary observations. In the remaining treatments the final observation showed higher populations.

In a number of plots receiving various DDT treatments no larvae were taken during the entire study period. The effectiveness of treatments in these plots was confirmed by the death of larvae that were transferred to pools in these plots. Conversely, introduced larvae survived in plots where the insecticides appeared non-effective.

The degree of variation in populations in these studies is illustrated in table 2, which gives data for the moss-heath plots treated with DDT-fuel oil solutions. All the variations may not be due to the chemical, as similar variations are noted in the check plots. It is evident, however,

Table 1. Effectiveness of various prehatching treatments when applied with hand equipment for control of *Aedes* mosquitoes.

| Insecticide | Formulation | Dosage (pounds per acre) | Season applied | Average number of immature forms per dip: Preliminary observations [1] | Average number of immature forms per dip: Final observations | Per cent control |
|---|---|---|---|---|---|---|
| DDT | Fuel-oil solution | 2 | Fall | 0.06 (1/5) | 0.05 | 98 |
| | | 1 | " | .11 (2/5) | .35 | 83 |
| | | 0.5 | " | .40 | .08 | 96 |
| | | | Spring | .64 | .50 | 76 |
| | | .1 | Fall | 1.26 | .54 | 74 |
| | | | Spring | .23 | .05 | 98 |
| | | .05 | " | 1.29 | .95 | 54 |
| | | .01 | " | 1.00 | 1.81 | 12 |
| | Emulsion | 2 | Fall | <.01 (1/4) | 0 | 100 |
| | | 1 | " | .47 (2/5) | .33 | 84 |
| | | .5 | " | .52 | .47 | 77 |
| | | | Spring | .22 | .25 | 88 |
| | | .1 | Fall | .09 | .05 | 98 |
| | | | Spring | .65 | .94 | 54 |
| | Dust | 2 | Fall | .44 (3/4) | .44 | 79 |
| | | 1 | " | .42 | .85 | 59 |
| | | .5 | " | 1.20 | 1.80 | 13 |
| | | | Spring | 1.78 | 1.05 | 49 |
| | | .1 | Fall | 2.38 | 2.41 | Increase |
| | | | Spring | 3.33 | 4.78 | " |
| | | .05 | " | 6.16 | 4.26 | " |
| | | .01 | " | 2.30 | 1.35 | 34 |
| | Wettable powder | 2 | Fall | .13 (2/4) | .05 | 98 |
| | | 1 | " | .21 | 1.79 | 13 |
| | | .5 | " | .04 | .19 | 91 |
| | | | Spring | .11 | .90 | 56 |
| | | .1 | Fall | .12 | .89 | 57 |
| | | | Spring | .63 | 7.30 | Increase |
| Parathion | Fuel-oil solution | .1 | " | 3.18 | 10.89 | " |
| | | .05 | " | 4.18 | 2.33 | " |
| | | .01 | " | 3.28 | 3.72 | " |
| TDE | " | .5 | " | <.01 | .11 | 95 |
| | | .1 | " | 1.85 | 3.07 | Increase |
| Methoxychlor | " | .5 | " | 1.24 | 3.43 | " |
| | | .1 | " | 1.77 | 3.82 | " |
| Chlordane | " | 1.0 | Fall | .72 | .71 | 66 |
| Toxaphene | " | 1.0 | " | 1.05 | 1.11 | 46 |
| Benzene hexachloride: | | | | | | |
| 12% gamma | " | 1.0 | " | .92 | 1.78 | 14 |
| 6% gamma (wettable powder) | " | 2.5 | " | .03 | .23 | 89 |
| Check (untreated) | — | — | — | 2.31 | 2.06 | — |

[1] All plots showed breeding except as indicated—e.g., (1/5) indicates that 1 out of 5 plots was breeding.

TABLE 2. Variation in numbers of larvae per dip at different observations in moss-heath plots treated by hand with DDT in fuel-oil solution.

| Dosage (pounds per acre) | Season of application | April 12 | April 21 | April 27 | May 4 | May 10 | June 1 |
|---|---|---|---|---|---|---|---|
| 2 | Fall | 0 | 0.60 | 0 | 0.01 | 0.07 | 0.25 |
| 1 | " | .18 | .57 | .03 | .02 | 0 | .02 |
| 0.5 | " | 0 | .90 | .52 | .18 | 2.67 | .22 |
| | Spring | 0 | 1.50 | 3.14 | .56 | .73 | 1.39 |
| .1 | Fall | .02 | 1.87 | .48 | .51 | .23 | .22 |
| | Spring | 0 | .23 | 1.57 | .20 | .06 | .06 |
| .05 | " | 0 | 1.90 | 1.76 | .85 | 1.17 | .38 |
| .01 | " | .05 | 6.13 | 1.50 | .22 | .17 | 1.04 |
| Check (untreated) | — | .05 | 5.10 | 4.67 | 1.62 | 3.00 | 3.48 |

that even the 0.01-pound dosage affected the larval population, as the average count at the final observation was never higher than the highest count during the preliminary observations.

In table 3 the data from all final observations on comparable dosages of DDT are averaged to show the effect of different environments, formulations, and seasons of application. The fall treatments were least effective in the moss-heath association and most effective in the sedge depressions, road tracks and moss-heath-sedge associations showing intermediate effectiveness. The spring treatments were least effective in the moss-heath association and most effective in the moss-heath-sedge association, the sedge depressions and road tracks showing intermediate effectiveness. In the spring fuel-oil solutions and emulsions were more effective than dusts and wettable powders. In the fall the dust was the least effective, but there was little difference between the other formulations. The variation between treatments within each association

TABLE 3. Influence of breeding environment and season of application on effectiveness of DDT treatments applied by hand, as shown by average numbers of larvae per dip at final observation.

| Dosage of DDT (pounds per acre) | Formulation | Sedge depressions | Road tracks | Moss-heath | Moss-heath-sedge | Average all environments |
|---|---|---|---|---|---|---|
| | | Fall applications | | | | |
| 0.5 and 0.1 | Fuel oil | 0.28 | 0.30 | 0.22 | 0.45 | 0.31 |
| | Emulsion | 0 | .97 | .09 | .04 | .28 |
| | Dust | .51 | 1.62 | 4.24 | 2.06 | 2.11 |
| | Wettable powder | 0 | 0 | .80 | .37 | .29 |
| | Average | .20 | .72 | 1.34 | .73 | .75 |
| 2 and 1 | Fuel oil | 0 | 0 | 0.89 | 0.12 | 0.25 |
| | Emulsion | .01 | 0 | 0 | .66 | .17 |
| | Dust | .05 | 0 | 2.06 | .50 | .65 |
| | Wettable powder | 0 | .08 | 3.33 | .15 | .89 |
| | Average | .02 | .02 | 1.57 | .36 | .49 |
| | | Spring applications | | | | |
| 0.5 and 0.1 | Fuel oil | .40 | .01 | .73 | <.01 | .29 |
| | Emulsion | 2.67 | .02 | 1.04 | 0 | .93 |
| | Dust | .03 | 5.02 | 5.19 | 1.15 | 2.84 |
| | Wettable powder | 3.24 | .01 | 6.95 | .57 | 2.69 |
| | Average | 1.58 | 1.26 | 3.47 | .43 | 1.69 |
| Check (untreated) | | .93 | 2.77 | 3.48 | 1.60 | 1.90 |

TABLE 4. Effectiveness of DDT sprays as a mosquito-prehatching treatment when applied by airplane in different dosages and seasons.

| Dosage per acre | | | Average number of immature forms per dip | | |
|---|---|---|---|---|---|
| DDT (pounds) | Solution | Season of treatment | Preliminary observations [1] | Final observations | Per cent control |
| 2 | 8 qt. | Fall | 0.11 (4/5) | 0.51 | 88 |
| 1 | 4 qt. | " | .06 (3/5) | .15 | 96 |
| 0.5 | 2 qt. | " | .16 (4/5) | .48 | 88 |
| .2 | 2 qt. | Spring | .45 | .74 | 56 |
| | 1 pt. | " | .19 | .78 | 81 |
| .1 | 1 qt. | Fall | .60 | .99 | 76 |
| | | Spring | 1.64 | 1.32 | 22 |
| | 1 pt. | " | .15 | .49 | 29 |
| Checks (untreated): | | | | | |
| Fall | | — | — | 4.2 | — |
| Spring | | — | — | 1.7 | — |

[1] All plots showed breeding except as indicated—e.g., (4/5) indicates that 4 out of 5 plots were breeding.

was so great that the average per dip for the fall treatments was not significantly lower than for the spring treatments.

Thirty-nine of the hand-treated plots were abandoned and the data omitted in this summary, as they were in a flood-water drainage area.

*Plots Treated by Airplane.*—The results from plots treated with airplane equipment are presented in table 4. From 88 to 96 per cent control was obtained with dosages of 0.5, 1, and 2 pounds of DDT per acre, and from 22 to 81 per cent with 0.2 and 0.1 pound per acre. The average number of larvae per dip was higher at the final observation than in the preliminary count in all plots except those treated in the spring with 0.1 pound of DDT per acre. No significant difference could be noted between spring and fall treatments of 0.1 pound or between the 1-pint and 1-quart applications.

In table 5 all final observations on comparable dosages are averaged to show the effect of different environments on the effectiveness of DDT as a prehatching treatment. Few or no larvae developed in plots that were located in grass depressions or moss-heath-birch, moss-heath, and moss-heath-sedge associations. The treatments were least effective in marshes containing *Myrica gale,* which occur commonly in seepage areas next to the hills and moraines on coastal flats and river flood plains. Conventional larvicide treatments likewise were least effective in this environment.

TABLE 5. Influence of breeding environment, season of application, and dosage on the effectiveness of DDT treatments applied by airplane, as shown by average numbers of larvae per dip at the final observation.

| | Fall treatments | | | Spring treatments | | |
|---|---|---|---|---|---|---|
| Breeding environment | 2 pounds | 1 pound | 0.5 pound | 0.2 pound | 0.1 pound | Average |
| Grass depressions | 0 | 0 | 0 | — | — | 0 |
| Moss-heath | .03 | 0 | 0 | .02 | .04 | .02 |
| Moss-heath-birch | 0 | 0 | 0 | — | — | 0 |
| Moss-heath-sedge | — | — | — | .22 | .42 | .32 |
| *Myrica-Calamagrostis* | 0 | .73 | 1.20 | — | — | .64 |
| *Myrica*-moss-heath | 2.50 | 0 | 1.22 | 1.19 | 2.62 | 1.51 |
| *Myrica*-moss-heath-birch | — | — | — | 1.62 | .54 | 1.08 |

Five of the plots treated with airplane equipment were inadvertently placed in an area that failed to hold water this season, although the marsh produced many mosquitoes in 1947. These plots were abandoned and the data are not included in this summary.

Discussion.—The results of these prehatching treatments are difficult to interpret. The newly hatched larvae are killed so rapidly that it is not possible to make accurate estimates of control on a basis of larval reduction within the treated plots. Moreover, the larval populations are so variable that control calculated on the basis of populations in untreated areas may not reflect the true effectiveness of the treatments. Hatching occurred over a period of several weeks in both treated and untreated areas. During this period larvae of all sizes were taken in the untreated areas, whereas in the treated plots only newly hatched larvae were present. This difference, as well as the difference in total populations, indicates that the larvae were being killed in the treated area shortly after hatching.

The data indicated that prehatching treatments could be relied upon to give satisfactory control except in *Myrica* marshes. The reasons for the lack of effectiveness in this type of breeding area were not determined. However, the fact that treatments both in the fall, when *Myrica* marshes were relatively dry, and in the spring, when they were covered with snow, were ineffective suggests that soil or water conditions in such areas may inactivate the DDT.

The practicability of prehatching treatments as a routine control method in much of this region is questionable. Further studies, however, may show this method to have a wider application than the present data indicate. Owing to the long flight range of Alaskan *Aedes* and the many square miles of breeding area adjacent to inhabited communities, it is likely that better mosquito control could be obtained with the same total amount of material applied by other methods. For example, at least 0.5 pound of DDT per acre was necessary in the prehatching treatment, whereas 0.1 pound was sufficient for conventional larvicidal treatments or for control of adults.

The prehatching method of control may be practicable in localities where mosquitoes are produced on localized breeding areas, such as exist in much of the Anchorage area. Many of these locations have little run-off, so that heavy dosages can be applied without danger to wildlife. It will be especially important to continue observations on the areas where the amount of DDT applied during the year totals 0.5 pound or more per acre. It is not unreasonable to expect a general reduction in mosquito breeding in such areas.

Summary.—The relative effectiveness of several of the new insecticides as prehatching treatments was determined from 201 plots treated with hand equipment and 40 plots treated by airplane. The plots were located in five different mosquito-breeding environments. Half the plots were treated in August 1947 and half in March and April 1948 when the snow was 3 to 30 inches deep.

In the plots treated with hand equipment in the fall, complete control was obtained only with 2 pounds of DDT per acre as an emulsion, but 90 per cent or higher control resulted from the same dosage of DDT as a fuel-oil solution, emulsion, and wettable powder, and from 0.5 pound in fuel oil and wettable powder, and 0.1 pound as an emulsion. Plots treated in the fall by airplane with 1 pound of DDT per acre averaged more than 90 per cent control. In the spring treatments only the 0.1 pound dosage of DDT in fuel oil and 0.5 pound of TDE gave as much as 90 per cent control when applied with hand equipment.

From 70 to 89 per cent control was obtained with fall applications of a minimum of 0.1 pound of DDT in fuel oil, 0.5 pound in an emulsion, and 2 pounds in a dust, with 0.5 pound of the gamma isomer of benzene hexachloride applied as a wettable powder (6 per cent gamma), when applied with hand equipment. Similar control was obtained with 0.5 pound of DDT in fuel oil and in emulsion, when applied by airplane in the spring. DDT was more effective in fuel-oil solution and in emulsions than in dusts or wettable powders. There was no significant difference between fall and spring treatments, but there was a large difference in effectiveness in the various environments. The treatments were least effective in marshes containing the shrub *Myrica,* and most effective in grassy depressions.

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# A METHOD FOR ARTIFICIALLY FEEDING MOSQUITOES

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There are several reasons for feeding mosquitoes and other blood-sucking insects on whole blood or other fluids off the host. Bishop and Gilchrist (1) used the artificial feeding technique to obtain malaria sporozoites in a medium of known composition. The author, following Woke (2), has used the method to determine food factors essential for oviposition by *Aedes aegypti.*

One of the fundamental considerations in any artificial feeding tehnique is to attract the insects to the proffered fluid. It is well known that some mosquitoes are positively thermotropic and this phenomenon can be used to attract them to the fluid which is offered. To do this, a warming apparatus was designed employing electrically heated resistance wires as a source of heat. The apparatus was made to accommodate six lantern globe cages, each having its own heating element to warm the feeding tube.

The heating element (Figure 1) consisted of 28-gauge nichrome wire strung between two asbestos rings which were held 50 mm. apart by three brass rods. Nuts on these rods allowed for tightening the wire after it had been strung. The inside diameter of the asbestos rings was