THE EFFECTIVENESS OF PREHATCHING TREATMENTS FOR THE CONTROL OF ARCTIC MOSQUITOES [1]

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Recent reports by a number of workers have shown that good control of certain species of mosquitoes may be obtained by applying DDT to the breeding areas before they are flooded. Such treatments were found effective against *Psorophora* by Wisecup and Deonier (1945), Wisecup *et al.* (1945), and Horsfall (1946), and against salt-marsh *Aedes* by Deonier *et al.* (1948). Prehatching treatments were also found to be effective against floodwater *Aedes* by Yates and Gjullin (1947) and against mountain snow-pool breeding species by Roth *et al.* (1947).

In view of these promising results, preliminary studies on small plots with several insecticides were undertaken at Churchill, Manitoba, Canada, during the spring of 1947 to determine whether treatments applied to the snow and ice covering breeding areas would control breeding of arctic and subarctic species of *Aedes*. Owing to the difficulty attending movement by vehicle or on foot after the spring thaw, and the short season of larval development, it was thought that this method might be an easier and more effective means of achieving control under arctic conditions than conventional larvicide applications.

Promising results were obtained from the initial tests at Churchill in 1947, especially with DDT. Further studies in 1948 included comparative tests with DDT and several other new insecticides on small plots, and applications of DDT by airplane on large areas. The airplane tests were designed to determine the optimum concentration, volume of solution, and dosage of DDT per acre for control of mosquitoes on a practical scale. These tests also afforded an opportunity to study the feasibility of aerial spray operations under arctic winter conditions. The results of the studies during the 2 years are presented in this paper.

Test Conditions and Methods. *Hand Applications.*—In 1947 the first prehatching treatments were applied on May 24 to terrain that was frozen and covered with about 2 feet of packed snow. The last treatments were applied on June 4 to plots partly free of snow and containing partly thawed pools and grassy depressions. During this period daily temperatures ranged from near zero at night to a maximum of 28° F. during the day. By June 8 many areas were free of snow, and newly hatched larvae were present in scattered pools and flooded, grassy depressions. By June 15 the greater part of the open tundra was free of snow and ice and the larval population was at a peak.

In 1948 the small plots were treated during late April and early May, when the terrain was frozen and covered with snow and ice to a depth of 6 inches to 3 feet or more. Daily temperatures were comparable with those in 1947. An early thaw occurred in 1948, and by May 15 very little snow remained on the open

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tundra. Most of the pools contained larvae. Cold weather during the latter part of May retarded hatching and larval development, but by early June the entire terrain was free of snow and the larval population was at a peak.

Most of the small plots were located on the open, marshy tundra flats; the remainder were in open pool areas. Of 48 plots treated in 1947, 30 were 2 acres in size, and the remainder were from 0.5 to 1 acre. In 1948 all the plots were 1 acre in size.

In 1947 four insecticides were applied at dosages ranging from 0.1 to 1 pound per acre. DDT was tested in a fuel-oil solution, in a xylene-Triton X-100 [6] emulsion, as a 50 per cent wettable powder, and as a 10 per cent dust. Chlordane and toxaphene were used in fuel-oil solution and as wettable powders. The chlordane powder contained 50 per cent of active ingredient and the toxaphene powder 25 per cent. Benzene hexachloride (20 per cent gamma) was applied only in a fuel-oil solution. Spray materials were applied at 2.5 gallons per acre with hand-pressure equipment and with a power unit mounted on a "weasel" (cargo carrier, M-29). The percentage of toxicant was varied to provide the desired dosages. DDT dusts were applied with rotary hand dusters. Swath intervals of 25 feet were maintained in all tests.

In 1948 tests on small plots were made with DDT, TDE, methoxychlor, heptachlor, and parathion. Parathion was applied as a 15 per cent wettable powder and the other materials as oil solutions. The experimental dosages were applied in 1 gallon of water or oil per acre with hand-pressure sprayers. Swath intervals of about 25 feet were maintained in treating each plot.

The effectiveness of prehatching treatments on small plots was determined by comparing larval counts in the treated areas with counts in adjacent untreated check areas. Plots were dipped for larvae as soon as water appeared, and at 4- or 5-day intervals thereafter until only mature larvae or pupae remained in untreated areas. The dipping was done by two to four men, and from 100 to 200 dips were taken at random in each plot.

Aerial applications.—The aerial sprays were applied from April 29 to May 7, 1948, on lightly forested tundra areas that were covered with 3 to 8 feet or more of snow. The forest cover consisted of light to moderate stands of spruce and larch, averaging about 25 feet in height, interspersed with light to moderate densities of dwarf willow and birch. Virtually all of the latter growth was covered with snow at the time of treatment. Several of the plots were barren except for dwarf willow and birch. Each test plot was 1 mile long and ½ mile wide, and each was separated by an area of similar size, which later served as a check.

The C-47 plane used in the tests was equipped with a standard U. S. Air Force spray unit consisting of a cargo tank (capacity 670 gallons) which emptied by means of gravity through a single discharge pipe. Several interchangeable pipes calibrated to deliver from 13.5 to 32 gallons per minute were available. Sprays were applied from altitudes of 75 to 100 feet, at a plane speed of 160 mph. Flights were made primarily with or against the wind, which ranged from 6 to 10 mph during the spraying. Air temperatures ranged from 22° to 31° F. A swath interval of 300 feet was maintained in the six basic comparative tests, whereas in others it was varied from 225 to 600 feet.

In the aerial spray tests 5-, 10-, and 20-per cent DDT-oil solutions were compared. Standard airplane spray solution (20 per cent of DDT, 40 per cent of Velsicol AR-50,[7] and 40 per cent of fuel oil) was used, undiluted and diluted appropriately with fuel oil to give 10 and 5 per cent solutions. Single plots were treated in 300-foot swaths with 1.1 and 1.8 pints

[6] An aralkyl polyether alcohol.

[7] Chiefly mono- and dimethylnaphthalenes.

per acre of each strength of solution, to give dosages of DDT ranging from approximately 0.05 to 0.33 pound per acre. One plot was treated with 0.5 pint of 20 per cent solution at swath intervals of 600 feet. Two other plots were treated with 3.3 and 6.7 pints per acre of 5 per cent solution at swath intervals of 225 feet. The higher dosage was obtained by traversing the area twice at 225-foot intervals.

The plots were dipped first early in June, when hatching was complete and most of the larvae in the check areas were in the second or third instar. A second check was made 1 week later, when all the larvae were mature or had pupated. Dipping counts were made by two to four men traversing the center half of each plot. Five dips in each of at least 50 pools or other dipping stations was established as the standard sample for each observer. This standard was met or exceeded in all except two plots where breeding spots were few and widely scattered.

The per cent control was calculated by comparing the larval counts in the treated plot with those in the check plot, and also by comparing the number of dipping stations where larvae were found in the treated and check plots.

Results. *Hand Applications.*—The results of small-plot tests in 1947 and 1948 are summarized in table 1. In the 1947 small-plot tests, DDT as a wettable powder and an emulsion gave complete control of larvae at the lowest dosage tested—0.1 pound per acre. A fuel-oil solution at 0.25 pound per acre and a dust at 0.4 pound gave nearly complete control. On the basis of results with fuel-oil solutions, DDT was the most effective of the four materials tested.

Chlordane in oil provided excellent control at dosages of 0.25 to 0.5 pound per acre. The wettable powder was also effective, except at 0.25 pound per acre. Toxaphene and benzene hexachloride (20 per cent gamma) in fuel-oil solution appeared inferior to the other compounds, but as a wettable powder toxaphene provided complete control at 0.1 pound or more per acre. When compared on the basis of the gamma isomer, the benzene hexachloride was equal to DDT in fuel oil.

In the 1948 tests DDT, TDE, and

TABLE 1. Per cent control of *Aedes* mosquito larvae obtained with various formulations of DDT and other insecticides applied by hand as prehatching treatments at various dosages per acre.

Insecticide	Formulation	1.0 lb.	0.5 lb.	0.25 lb.	0.1 lb.	0.05 lb.
	1947 Tests					
DDT	Fuel oil	100	100	99	79	—
	Wettable powder	100	100	100	100	—
	Emulsion	—	100	100	100	—
	Dust	—	95 [1]	68	—	—
Chlordane	Fuel oil	96	100	92	58	—
	Wettable powder	100	96	67	100	—
Toxaphene	Fuel oil	100	74	33	33	—
	Wettable powder	100	100	—	100	—
Benzene hexachloride (20% gamma)	Fuel oil	—	78	79	—	—
	1948 Tests					
DDT	Fuel oil [2]	—	—	97	76	79
TDE	"	—	—	96	85	71
Heptachlor	"	—	—	—	79	76
Methoxychlor	"	—	—	85	59	50
Parathion	Wettable powder	—	—	—	—	0

[1] Dosage 0.4 pound per acre.

[2] Fuel oil alone gave 34 per cent control at 1 gallon per acre, and 31 per cent at 2.5 gallons per acre.

heptachlor appeared about equally effective. Fuel-oil solutions of these materials applied at 0.05 and 0.1 pound per acre failed to give satisfactory control. At 0.25 pound per acre DDT and TDE gave 97 and 96 per cent control. Methoxychlor was markedly less effective than DDT, TDE, and heptachlor. Parathion at 0.05 pound per acre proved totally ineffective as a prehatching treatment, although in subsequent tests against mature larvae this material proved slightly more toxic than DDT.

Aerial Applications.—The results of the aerial treatments are given in table 2. Four of the five treatments in forested areas gave 85 to 95 per cent control. A fifth forested plot treated at an extended swath interval of 600 feet showed only 71 per cent control. The pattern of breeding in this plot clearly showed that the swath interval was too great for complete coverage. The results from these five tests in typical lightly forested terrain indicated that a dosage as low as 0.05 pound per acre, applied at a swath interval of 300 feet, would provide good, but not complete, control of larval breeding.

On open, eroded tundra and on areas partly forested and partly open tundra, higher dosages were required. Satisfactory control was obtained in only one of four plots treated at 0.09 to 0.35 pound per acre. The disparity in the results from the different areas may be attributed, at least in part, to the differences in speed of drainage and in the seasonal development of mosquito larvae. In forested areas melting of the snow was gradual, drainage relatively slow, and the predominant species of mosquito, *Aedes communis* (Deg.), hatched almost immediately in the mossy pools and grassy marshes and so was exposed to the highest concentration of insecticide. In open, eroded tundra, conditions favored rapid melting and run off, probably resulting in loss of insecticide before hatching was completed. Good control of the early hatching species, such as *Aedes nigripes* (Zett.) and *A. punctor* (Kby.), was indicated, but not of the late-hatching species, *A. campestris* (D. and K.). In one open area, where the control was 74 per cent, virtually all the surviving larvae were *A. campestris,* while in check areas at least three species were present. These results indicate the need for heavier dosages of DDT on open areas. They also suggest that treatments applied before snow fall might be more effective.

In general, these studies do not show that the prehatching method of control is superior to conventional larvicide treatments. However, they do indicate that effective control can be obtained under certain conditions and that in some areas prehatching treatments may be more convenient.

Summary.—The effectiveness of prehatching treatments for the control of arctic mosquitoes was studied in 1947 and 1948 at Churchill, Manitoba, Canada. These treatments were applied before the spring thaw, to snow and ice covering potential breeding areas. Comparative tests on small plots were made with DDT and seven other promising new insecticides applied by hand equipment. DDT was also applied by a C-47 airplane to determine the practical possibilities of controlling mosquitoes over large areas.

In the small-plot tests DDT in a wettable powder (50 per cent) and an emulsion gave complete control of larvae at 0.1 pound per acre. DDT in a fuel-oil solution gave nearly complete control at 0.25 pound per acre, and in a dust at 0.4 pound. Toxaphene in a wettable powder (25 per cent) provided complete control at 0.1 pound per acre. When applied in oil solution, DDT, TDE, and heptachlor were about equal in effectiveness. Chlordane and methoxychlor were slightly and toxaphene considerably less effective than DDT. Benzene hexachloride was equal to DDT when compared on the basis of the gamma isomer. Fuel oil alone, applied at 1 and 2.5 gallons per acre, was rela-

TABLE 2. Control of *Aedes* mosquito larvae with DDT-oil solutions applied by C-47 airplane to snow and ice as prehatching treatments.

Test. No.	Temperature (° F.)	Wind speed (mph)	Swath interval (feet)	Strength of solution (per cent)	Dosage of DDT (pounds per acre)	Number of dipping stations	Per cent of stations breeding	Average number of larvae per dip	Per cent control based on —	
									Dipping stations	Larval counts
Spruce-larch forest										
5	31	8	600	20	0.11	191	25	0.8	67	71
6	31	8	300	20	.22	197	5	.2	91	85
8	29	9	300	10	.11	243	12	.1	78	89
7	22	6	300	5	.05	299	17	.2	80	95
9	30	9	225[1]	5	.33	284	5	.4	94	90
Checks:										
No. 5	—	—	—	—	—	165	75	2.7	—	—
Nos. 6 & 8	—	—	—	—	—	133	56	1.2	—	—
Nos. 7 & 9	—	—	—	—	—	153	83	4.3	—	—
Mixed forest and open tundra										
1	31	8	300	10	.18	290	5	.04	93	98
3	22	6	300	5	.09	133	51	1.5	32	44
Check	—	—	—	—	—	165	75	2.7	—	—
Largely open, eroded tundra										
2	29	9	300	20	.35	207	20	.2	64	74
4	29	10	225	5	.17	196	66	1.3	0	0
Check	—	—	—	—	—	191	56	.8	—	—

[1] Area sprayed twice to obtain the desired dosage.

tively ineffective. Parathion in a wettable powder (15 per cent) was completely ineffective at 0.05 pound per acre, the highest dosage tested.

In the airplane tests treatments in forested areas with DDT-oil solutions at dosages of 0.05 to 0.22 pound of DDT per acre gave 85 to 95 per cent control, except in one plot treated in 600-foot swath intervals when 71 per cent control was obtained. In tests on open, eroded tundra and on mixed forest and open terrain, dosages of 0.09 to 0.35 pound per acre gave satisfactory control in only one of four plots.

The results obtained in these tests indicate that prehatching treatments, although not superior to conventional larvicide treatments, may be used for the control of arctic species of mosquitoes. The requirements for control, however, may differ greatly according to the type of terrain.

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ANOPHELES GAMBIAE MELAS CONTROL BY SWAMP DRAINAGE IN A COASTAL ZONE OF NIGERIA, BRITISH WEST AFRICA

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The modern trend of malaria control is so dominated by the success of residual insecticides that a paper dealing with mosquito control by swamp drainage seems to be out of date. Nevertheless its aim will be reached if it provides a proof that even to-day the engineering methods of mosquito control based on the knowledge of the bionomics of the species involved and on a naturalistic approach to the technique of control can be highly successful.

At the very outset of this paper it must be made clear that the highly effective method of control of *A. gambiae melas* in West Africa was initiated and carried out by Dr. Alan B. Gilroy, O.B.E., who started the Lagos reclamation scheme as a military expediency in 1942 and expanded it by 1947 to its present size.

The Lagos reclamation scheme originated when the capital of Nigeria became one of the nodal points of the Transcontinental Ferry Service of the Royal Air Force. This service was organized to keep up the steady supply of front line aircraft for the Middle East theatre of war when the Mediterranean route was blocked. Fighter planes for the Middle East were shipped from Britain to West Africa in crates. Takoradi (Gold Coast) and Lagos (Nigeria) served as main bases for the assembly and test flights of these single-engined aircraft. From these two bases planes were flown across Africa in "air-caravans" consisting of 6–8 fighter planes following the leader—a light bomber with navigational facilities. The air route was across Nigeria, French East Africa, Sudan and then up the Nile valley to Cairo.

In 1943 and 1944 the Transafrican air