

## DDT RESIDUES ON VEGETATION AND GROUND LITTER FOR CONTROL OF ADULT SALT-MARSH MOSQUITOES

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The effectiveness of spray residue treatments containing DDT (1-trichloro-2,2-bis-(p-chlorophenyl)ethane) in buildings against the common malaria mosquito, *Anopheles quadrimaculatus* Say, under both laboratory and field conditions has been determined by Gahan *et al.* (1945a, b, c). The effect of such treatments on the incidence of malaria has not been determined, but it is reasonable to believe that a substantial reduction of the disease would result.

Since many species of pest and disease-carrying mosquitoes are known to have sylvatic resting places, an investigation on the efficiency of treating the vegetation in jungles with DDT appeared worthwhile. It was believed that the armed forces could utilize this method of control by spraying with ground equipment the vegetation in and around camps, airfields, and bivouac areas.

### *Experimental Methods and Conditions.*

—Tests were made near Cocoa Beach, Fla., during the summer of 1944 against adults of the salt-marsh species *Aedes taeniorhynchus* (Wied.) and *A. sollicitans* (Walk.), in a rather dense jungle growth containing a preponderance of cabbage palms and oak with an undergrowth of saw palmetto and low hammock shrubs.

Square plots, either  $\frac{1}{2}$  or 1 acre in size, were treated by applying the material to the foliage of the undergrowth and up to a height of about 5 feet on the tree trunks. Much of the spray also fell on the litter of dead leaves lying on the ground.

<sup>1</sup>This work was conducted under a transfer of funds, recommended by the Committee on Medical Research, from the Office of Scientific Research and Development to the Bureau of Entomology and Plant Quarantine.

The authors wish to acknowledge the able assistance of Charles Lewis and Charles Wood, Jr., in the conduct of these investigations.

Applications were made with 3-gallon, hand-operated, compressed-air sprayers. Nozzle disks having  $\frac{3}{64}$ -inch apertures discharged approximately 1 gallon of liquid in 8 minutes. Sprays were applied in swaths from 15 to 20 feet in width, back and forth across the plots to insure complete coverage. The objective, as in the treatments in buildings, was to establish a residue of DDT on all surfaces upon which the mosquitoes might rest. Dosages were determined on the basis of the number of gallons of spray per acre rather than on the number of milligrams of DDT per square foot, which was the basis for determining the dosage rate in buildings.

The results were evaluated by counting the mosquitoes on the front of a man's trousers at the end of a 1-minute exposure. A count of the landing rate provides an excellent index of the population density in any given area. At each observation period a number of these counts were made at random in the plots and in the surrounding untreated areas. In this way the percentage control or reduction resulting from the treatment at any given time was determined. Counts usually were made early in the afternoon.

Since the tests were conducted during the rainy season, the treatments were subjected to an abundance of rainfall. All treatments, however, were applied at least 12 hours before any rain fell. The official Weather Bureau record of precipitation for the period of the investigations, taken at the Merritt Island station, about 3 miles from the plots, is as follows: July 9.32, August 7.70, and September 6.53 inches.

In addition to the effect of rainfall, considerable new growth appeared in the plots and much untreated litter fell to the ground before the observations were terminated.

*Effect of Various Dosages and Concentrations of DDT Sprays and Emulsions.*—In the first experiment a solution consisting of 5 per cent of DDT<sup>2</sup> in No. 2 fuel oil was applied to three 1-acre plots at rates of 3, 5, and 10 gallons per acre. Some difficulty was experienced in obtaining complete coverage of an acre with 3 gallons of spray, and in the plot treated with 10 gallons the application was somewhat spotted owing to the dense undergrowth of palmettos. A landing rate in the plots of 200 mosquitoes per minute was recorded immediately before treatment, which was one of the highest counts of the season. In this and in subsequent experiments there was a marked reduction in the mosquito population shortly after the treatments were applied.

A record of mosquito reduction in the plots at approximately weekly observation periods is presented in table 1. Similar results were obtained in all the plots up to 17 days after treatment. Beyond that time reduction was usually less in the plot treated with 3 gallons per acre, although the difference was not always great enough to be considered significant. There was a definite drop in the effectiveness of the heavier dosages after 82 days, and general observations 102 days after treatment (not given in table) showed little or no reduction in any of the plots. The dosages of 5 and 10 gallons per acre were equally effective during the entire period.

To determine the duration of effectiveness of a relatively heavy dosage of DDT, a 5-acre plot was sprayed with 5 per cent of DDT in No. 2 fuel oil at the rate of 20 gallons per acre. One half of this plot was located in the jungle and the other half in an open, nearly treeless marsh. Landing-rate counts on the open marsh were made in the shelter of the few trees that were present, since the adults of these species generally remain in the shade during the daytime.

Counts were begun in this plot and the

<sup>2</sup> All concentrations of DDT are in terms of weight per volume.

TABLE 1. Reduction of Adult Salt-Marsh Mosquitoes in 1-acre Jungle Plots Sprayed with 5 per cent of DDT in No. 2 Fuel Oil at Various Dosages.

Time After Treatment	Reduction at Indicated Dosages Per Acre		
	3 Gallons	5 Gallons	10 Gallons
<i>Days</i>	<i>Per Cent</i>	<i>Per Cent</i>	<i>Per Cent</i>
2	99	97	95
9	90	89	98
17	91	87	86
27	67	92	92
34	64	79	72
40	55	67	72
47	41	62	65
54	59	66	65
75	64	63	59
82	28	76	67
91	26	50	40

surrounding untreated area 3 days after the spraying and were continued at intervals of approximately 1 week until 76 days after the treatment, when the natural reduction in mosquitoes terminated the test. A high reduction was maintained throughout the test period (table 2), but the total time over which such a heavy deposit would have been effective was not fully determined. Undoubtedly it would have been effective several weeks longer. It should be pointed out, however, that the application of 20 gallons of spray per acre with hand equipment under jungle conditions represents an extremely laborious task.

TABLE 2. Reduction of Adult Salt-Marsh Mosquitoes in a 5-acre Plot Sprayed with 5 per cent of DDT in No. 2 Fuel Oil at the Rate of 20 Gallons per Acre.

Time After Treatment	Reduction in—	
	Jungle Area	Open Marsh
<i>Days</i>	<i>Per Cent</i>	<i>Per Cent</i>
3	99.8	93
9	97	95
15	96	94
23	88	96
30	85	83
39	91	94
51	88	86
56	86	77
65	92	80
76	86	80

An aqueous emulsion and a fuel-oil solution containing 5 per cent of DDT were compared by spraying two adjoining 1-acre plots at the rate of 5 gallons per acre. The results presented in table 3 indicate that DDT was slightly more persistent when applied in an emulsion than in a solution.

TABLE 3. Reduction of Adult Salt-Marsh Mosquitoes in 1-acre Plots Sprayed with a Fuel-Oil Solution and an Aqueous Emulsion Containing 5 per cent of DDT at the Rate of 5 Gallons per Acre.

Time After Treatment	Reduction in Plot Treated With—	
	Solution	Emulsion
Days	Per Cent	Per Cent
2	96	98
5	84	95
9	82	88
15	52	79
22	62	57
26	78	89
33	60	55
40	44	62
61	64	34
77	48	80

In another experiment three adjoining ½-acre plots were treated at various rates with a fuel-oil solution containing DDT, one plot with 5 and two plots with 20 per cent DDT. An additional ½-acre plot was treated with an aqueous emulsion containing 5 per cent of DDT. Results given in table 4 show that the differences between

treatments were too slight to be considered significant. However, random samples of foliage and ground litter were collected in each of the plots 50 days after treatment, and aged houseflies (*Musca domestica* L.) were exposed to these samples for 6 hours in the laboratory. The emulsion killed all the flies in 1 hour and the 5-gallon dosage of the 20 per cent DDT-fuel oil solution killed them all in 6 hours. At the end of the 6 hours the mortality was 8 per cent from the 10-gallon application of 5 per cent DDT and 17 per cent from the 2½-gallon application of 20 per cent DDT. This indicates that the residue retained a high degree of toxicity over the longest period in the plot treated with the emulsion.

*Effect of a Barrier Treatment.*—To determine the protective value of a treated barrier surrounding an untreated area, a 100-foot strip around an untreated ½-acre plot was sprayed with 5 per cent of DDT in No. 2 fuel oil at the rate of 10 gallons per acre. Since adult mosquitoes present in the untreated inner plot were killed with a liquefied-gas pyrethrum aerosol when the barrier strip was treated, those subsequently found there probably had crossed the treated barrier. It appeared possible that adults crossing the barrier would make this flight in short stages, and thereby rest on the treated foliage long enough to obtain a lethal dose.

The results of this experiment are given

TABLE 4. Reduction of Adult Salt-Marsh Mosquitoes in Four ½-Acre Plots Treated with DDT Solutions and an Emulsion at Various Concentrations and Dosages

Time After Treatment	Reduction at Indicated Concentrations and Dosages per Acre				
	Fuel-Oil Solutions				Emulsion
	5 per cent DDT 10 gallons	20 per cent DDT		5 per cent DDT 5 gallons	
Days	Per Cent	Per Cent	Per Cent	Per Cent	
2	97	99	91	89	
9	95	86	88	90	
16	93	93	80	75	
23	87	92	47	58	
32	73	89	89	92	
43	76	56	61	56	
50	48	82	47	48	
59	69	61	81	72	

in table 5. A fairly satisfactory reduction was maintained in the untreated plot up to 27 days after treatment of the barrier, and there was good reduction in the barrier up to 85 days. This leads to the conclusion that, in dealing with species having a shorter flight range than salt-marsh mosquitoes, particularly if a barrier wider than 100 feet is used, a satisfactory degree of protection might be obtained for a reasonable length of time by the use of this method.

TABLE 5. Reduction of Adult Salt-Marsh Mosquitoes in a Barrier Treated with 5 per cent of DDT in No. 2 Fuel Oil at the Rate of 10 Gallons per Acre, and in the Untreated  $\frac{1}{2}$ -Acre Plot Surrounded by the Barrier.

Time After Treatment	Reduction in	
	Treated Barrier	Untreated Inner Plot
Days	Per Cent	Per Cent
3	....	78
11	95	59
19	87	49
27	92	57
33	91	26
41	83	21
48	80	0
57	89	49
69	56	34
76	47	0
85	76	22
96	28	0

#### Comparison of Methods of Application.

—An experiment was made to determine whether it is necessary to apply the spray to both the foliage and the ground litter, or is sufficient simply to spray the litter alone. Two adjoining 1-acre plots were treated with 5 per cent of DDT in No. 2 fuel oil at the rate of 10 gallons per acre. In one plot the spray was applied to the foliage and tree trunks in the manner previously described, and in the other it was applied to the ground litter only. No appreciable difference in effectiveness between the two methods was recorded up to the end of the experiment, 73 days after treatment (table 6). Thus it is apparent that to obtain a reduction of adult salt-marsh mosquitoes it is only necessary to spray the ground litter under which

they rest during the daytime. This emphasizes the need of a knowledge of the resting habits of the species involved in determining the most efficient method of applying the residue treatment, since it is unnecessary to treat surfaces other than those on which the mosquitoes will rest.

TABLE 6. Comparative Reduction of Adult Salt-Marsh Mosquitoes in 1-acre Plots Treated with 5 per cent of DDT in No. 2 Fuel Oil, Applied to Ground Litter and Foliage or to Ground Litter Only, at the Rate of 10 Gallons per Acre.

Time After Treatment	Reduction with Solution Applied to—	
	Ground Litter Only	Ground Litter and Foliage
Days	Per Cent	Per Cent
1	98	97
3	96	96
9	99	92
16	83	89
21	90	90
28	87	71
35	74	82
44	56	82
56	64	64
63	57	53
72	75	75

*Summary and Conclusions.*—Investigations were undertaken near Cocoa Beach, Fla., during the summer of 1944 to determine the effect of residue from DDT spray treatments on the abundance of adults of the salt-marsh species *Aedes taeniorhynchus* (Wied.) and *A. sollicitans* (Walk.) when applied to jungle areas. In the majority of tests 5 per cent of DDT in No. 2 fuel oil was applied to 1-acre plots at the rate of 3 to 10 gallons per acre, although some studies were made of higher concentrations at  $2\frac{1}{2}$  to 5 gallons per acre and of the 5 per cent concentration at 20 gallons per acre. A 5 per cent DDT aqueous emulsion also was tested.

The results show that 5 gallons per acre of 5 per cent DDT constitutes a satisfactory dosage, and that the emulsion is slightly more effective than the solution. Good reduction of adult mosquitoes was maintained in some plots for as long as  $2\frac{1}{2}$  months after application of the spray. Tests of a barrier treatment indicate that

this method could be used successfully against species less active than salt-marsh mosquitoes. Comparative tests of methods of application show that against these species it is sufficient to spray the ground litter alone. Thus the importance of a knowledge of the resting habits of the species involved is apparent, since obviously it is unnecessary to treat surfaces other than those on which the mosquitoes will rest.

The results of this work show that the residue from DDT spray treatments in jungle areas affords a promising means

of controlling adult mosquitoes possessing sylvatic resting habits.

#### Literature Cited

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## DEATH NOTICE

John Harrison Spackman, for the last nine years a Supervisor of the Delaware County Mosquito Extermination Commission in Pennsylvania, died on April 5, 1945, at his home, 105 Morton Avenue, Rutledge, Pennsylvania, which is near Swarthmore.

Mr. Spackman had been in poor health for several months, but had been apparently feeling better for a considerable period prior to his death. He died of a heart attack. Mr. Spackman was a graduate of Lafayette College and the University of Pennsylvania Law School. He had been a member of the Government Engineering Staff which surveyed the boundaries of Yellowstone Park before the turn of the century. From 1897 to 1920 he was Claim Agent for the Pennsylvania Railroad. His wife, Helen B. Spackman, survives.

Mr. Spackman, who had been a familiar figure at the meetings of the New Jersey Mosquito Extermination Commission at Atlantic City for many years, had been interested in Entomology and had read widely in this field. He had shown a great deal of interest in the trapping and identification of mosquitoes since his connection with the Delaware County Mosquito Extermination Commission in 1936. He had been a member of the American Mosquito Control Association and was known and liked by the many members who had come in contact with him.

Mr. Spackman had taken a special interest in the recent work which he had done in the schools of Delaware County, lecturing and showing films on mosquito control in many of the high schools and elementary schools of the county. He was engaged in this work up until the day before his death.

R.W.G.