ARTICLES

THE OPERATION AND PHYSICAL EVALUATION OF ROUTINE APPLICATIONS OF DDT LARVICIDES BY AIRPLANE *

H. STIERLI
Senior Assistant Engineer

AND

W. R. SCHMITZ
Formerly Assistant Engineer, United States Public Health Service (Resigned Sept. 3, 1947)

Introduction

Experimental studies were conducted at the Savannah Wildlife Refuge during 1946,[1, 2] to determine the effects on wildlife of routine applications of DDT larvicides by airplane as spray and as exhaust aerosol. This paper deals with the operational factors and the physical evaluation of the distribution and recovery of DDT on the water surface.

Dispersal Equipment

Two Army-type PT-17 airplanes were used for the distribution of DDT in the form of spray and of exhaust aerosol. Krusé and Metcalf[3] and others[4] have described the basic equipment for these aircraft. Each airplane was furnished by the Tennessee Valley Authority with essentially the following equipment: a 33-gallon-capacity solution tank mounted in the rear cockpit, a propeller-driven pump unit mounted on the footwalk of the lower left wing, a relief valve with pressure adjustment screw to regulate solution pressure, five hollow cone atomizing nozzles (Spraying Systems Co. Nozzle No. ¼ LN12) for wing sprays, an exhaust pipe extension with venturi containing two flat atomizing nozzles (Spraying Systems Co. Nozzle No. ¼ T8006) which sprayed the larvicide into the throat section for aerosol dispersal, and shut-off valves controllable from front cockpit for the spray and aerosol systems.

In order to obtain accurate quantitative data on solution output for short test runs, a flow meter which registered to 0.02 gallons was installed on one of the airplanes. The meter, Hersey Model GB ⅝" size, was of the wobble plate type normally used for measurement of fuels and water. Installation was on the discharge line of the solution pump with mounting behind the pump on the footwalk of the lower left wing. A 70 x 80 mesh screen strainer was also connected in the discharge line between the meter and the spray nozzles. The tap for pressure gauge was installed downstream in order to obtain as nearly as practicable the true nozzle pressures. A metal gauging stick readable to 0.1 gallon was calibrated to serve as a check on the meter. To protect the fuselage interior from spillage of spray solutions, an aluminum sheet metal cover was installed on the rear cockpit. The rear windshield was removed and the filler neck extended through the cover. The cover facilitated cleaning and tended to streamline the fuselage.

By a series of test flights it was found that the normal cruising speeds of the two airplanes were both about 90 miles per hour. Based on 100 ft. swath widths, an area of approximately 18.2 acres was treated per minute of discharge. A 20 per cent (by weight) solution of technical DDT in *Velsicol NR-70* * was employed

* From Communicable Disease Center, Technical Development Division (Savannah, Georgia).

* *Velsicol NR-70*, a polymethylated naphthalene, is a solvent produced by the Velsicol Corp., Chicago, Ill.

in all of the treatments. Each gallon of solution contained approximately 1.85 lbs. DDT. Since an output of 0.1 lb. DDT per acre was desired for the experiments, the solution discharge rate of one gallon per minute was used for calibration of nozzle output.

The exhaust venturi as originally designed for the PT-17 airplane was of 4-inch diameter with 2-inch throat diameter and 22½-inch long discharge section. Following later recommendations from the Tennessee Valley Authority, the discharge section of the venturi was reduced in length to 10 inches. No significant change in performance was observed.

An attempt was made to obtain a more uniform distribution of spray drops by use of different nozzles and nozzle arrangements. There was no apparent improvement; therefore, the five Spraying Systems No. ¼ LN12 Nozzles were used for all of the spray treatments described in this paper.

METEOROLOGICAL OBSERVATIONS

A portable weather tower 6½ feet tall was constructed to facilitate accurate measurement of essential meteorological variables during tests. Air temperatures were observed at 6 feet and 1 foot above ground level using paired mercury thermometers shielded from the direct radiation of the sun. Average wind velocities were secured over one minute periods with a 4-inch diameter pinwheel anemometer at the 6 foot level. A sensitive vane with removable pivot was mounted on the top of the tower for observation of wind direction. The difference in temperature of the air at 6 feet and 1 foot above ground was an indication of vertical thermal air movement. Downward air movement occurred during a condition known as "inversion" (T_6–T_1, a plus value). Thermal upward movement of air normally occurred during a condition of "lapse" (T_6–T_1, a negative value). It is generally accepted that best deposition of small spray or aerosol drops is obtained during conditions of "inversion."

METHODS OF EVALUATING DEPOSITED DDT

For proper evaluation of airplane dispersal of DDT, it was necessary to know not only the amount of DDT put out by the airplane but also the amount of DDT deposited on the ground or water surface. Preliminary investigations on the distribution of DDT-oil droplets from the airplane were made by measuring the ground deposition at sampling points arranged at 20- or 25-foot intervals in two or three lines perpendicular to the line of flight. Each line of sampling stations was about 100 feet apart, and the values for the corresponding stations in each line were averaged. The mass median diameter of the oil droplets and the area dose of DDT deposited were determined by microscopic counting of the oil droplets collected on carbon-coated slides, which were placed horizontally on the ground at each sampling point.

All tests were made just after dawn when conditions of inversion were most prevalent. Flights were made at a height of 20 to 30 feet, and tests were made with the airplane flying both directly into the wind and perpendicular to the wind. Multiple swath flights were also made to determine the effect of overlapping of swaths.

During the routine dispersal of DDT at the Savannah Wildlife Refuge, the evaluation of the amount of DDT actually deposited on the water surface was determined by chemical analysis of DDT deposited on 3 x 12 inch glass panels. On each of the treated ponds, twelve stakes arranged at 30- or 40-foot intervals in a "horseshoe type" pattern were used as sampling stations. Two dikes along the ponds were also selected for sampling stations, and six stations at various intervals were placed on each dike. A 6 x 15-inch wood platform was nailed on top of each stake to hold the glass panel.

Initially, it was desired to use carbon-coated slides to sample the deposited DDT-oil droplets, with only an occasional check by actual chemical analysis of DDT. Because of the time required to place slides or glass panels on each of the four ponds and two dikes, it was necessary to place them on the stations the day before the actual airplane treatment, which occurred at dawn. Heavy dew or rain ruined many of the carbon-coated slides, and this method of analysis had to be abandoned in favor of quantitative chemical analysis of DDT. The analytical procedure used was a modification of the Schechter, et al.,[5] and the Bent [6] colorimetric methods of analysis for DDT. Acetone was used to wash the DDT from the panels into beakers, and the desired aliquot portion was taken for analysis. Considerable experience in judging the amount of oil-droplets on the glass panels was necessary in order to select the most convenient size portion for analysis of DDT. Special boxes, similar to a microscope slide box, were constructed to hold the 3- x 12-inch glass panels during transportation from the ponds to the laboratory.

DISTRIBUTION OF DDT

Factors which were of primary importance in affecting the distribution of DDT from the airplane were the size of oil-droplets, elevation of airplane, and meteorological conditions, especially wind velocity. With wind velocities of less than 2 miles per hour, it was quite common for the direction of the wind to change as much as 90 degrees in a few seconds. Under practical field conditions it was not feasible for the airplane to fly in any one direction in relation to the wind direction. Thus, the distribution of DDT was determined with the airplane flying both directly into the wind and perpendicular to the wind.

Typical single swath distributions of DDT from the airplane are presented in Figures 1 and 2. On the basis of a 100-foot swath width, a minimum dosage of 0.002 lb. DDT/acre was recovered from aerosol applications, with flights into the wind, and a minimum dosage of 0.003 lb.

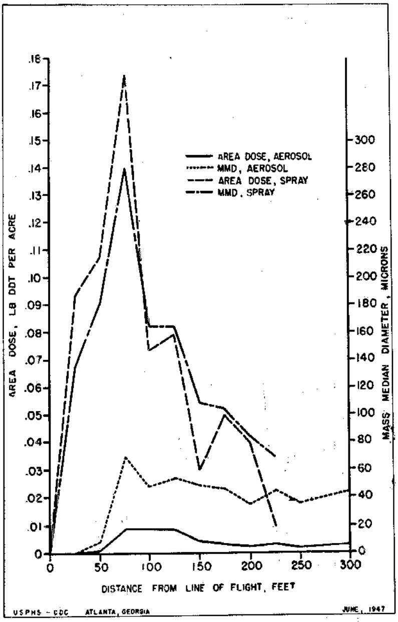

FIGURE 1. Typical distribution of DDT as thermal aerosol and spray by airplane which flew into a 2 mph wind.

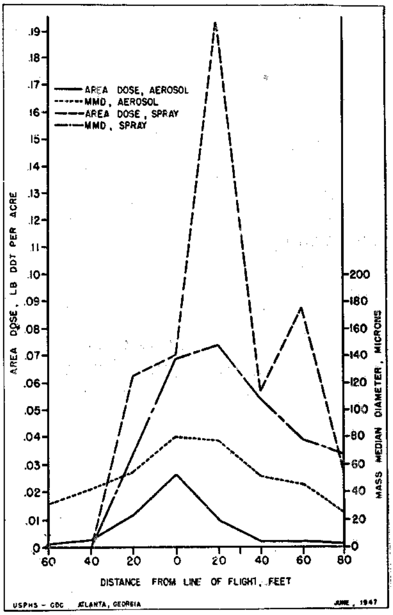

FIGURE 2. Typical distribution of DDT as thermal aerosol and spray by airplane which flew perpendicular to a 5 mph wind.

DDT/acre for flights perpendicular to the wind. The maximum recovered dosage from the aerosol was about three times greater for flights into the wind than for flights perpendicular to the wind direction. However, on flights perpendicular to the wind direction, a dosage of 0.002 lb. DDT/acre was maintained for about 250 feet. The mass median diameter of the oil-droplets from the aerosol ranged from about 40 microns to 80 microns. On the basis of a 100-foot swath width the spray produced a minimum recovered dosage of 0.03 lb. DDT/acre for flights into the wind, and a minimum recovered dosage of 0.07 lb. DDT/acre for flights perpendicular to the wind. The distribution of DDT from the spray was quite similar for both flights into the wind and perpendicular to the wind. Very large maximum dosages of from 0.17 to 0.19 lb. DDT/acre were obtained in each case. The mass median diameter of the oil-droplets from the spray ranged from about 60 microns to 280 microns. A very close correlation between the mass median diameter and the area dose was obtained for both sprays and aerosol.

Typical multiple swath distribution of DDT with the airplane flying perpendicular to the wind direction is presented in Figure 3. The airplane made four parallel swaths at 100-foot intervals, as indicated by the diagram in Figure 3. In such flights, the swaths are started at the downwind side, in order that succeeding swaths may be made without flying into the oil-droplets from previous swaths. At the end of a swath, the airplane turns slightly downwind to make the turn for the next swath. Such a flight pattern prevents the airplane and pilot from becoming contaminated with the insecticide being dispersed. The sampling station at 325 feet received the greatest dosage of DDT, as it was the point of maximum deposit from swath No. 1, and material from the other three swaths added to the total deposit. The 100-foot width which had the maximum deposit of DDT occurred at points which received driftage of DDT from 2 to 3 succeeding swaths. In this 100-foot width, the spray had a minimum recovered dosage of 0.08 lb. DDT/acre and the aerosol had a minimum recovered dosage of 0.012 lb. DDT/acre. The spray generally showed a peak deposition of DDT at 25 feet downwind from the lines of flight and a marked reduction in deposition of DDT at 75 or 100 feet from the lines of flight. The aerosol did not have as large a variation in deposition of DDT as the spray, but the recovered dosage was much smaller for the aerosol than the spray.

TREATMENT OF THE SAVANNAH WILDLIFE REFUGE

Weekly treatment of four Savannah Wildlife Refuge pools for studies on the effects of DDT on aquatic and terrestrial forms of life was begun on May 1, 1946. In order to treat the pools with spray under similar conditions, two airplanes were used until mid-season. One airplane

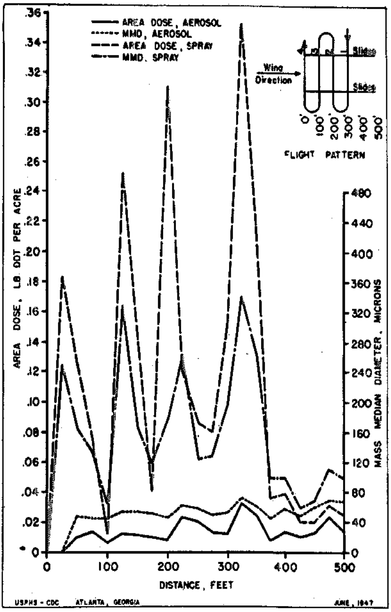

FIGURE 3. Typical multiple-swath distribution of DDT as thermal aerosol and spray by airplane which flew perpendicular to a 5 mph wind.

applied spray to pool 6 (270 acres) * and pool 2 (185 acres) while the other dispersed the exhaust aerosol to pool 3A (120 acres) and pool 3 (240 acres). As one of the airplanes with pilot was transferred to another project during the latter portion of July, it was necessary to make the last six weekly treatments with one airplane. The following procedure was then employed: starting at dawn treat pools 3 and 3A with aerosol, return to airport for metering and refilling of solution tanks, and then spray pools 2 and 6.

The output dosage for both spray and aerosol was 0.1 lb. DDT per acre, employing the solution containing 20 per cent (by weight) DDT in *Velsicol NR-70*. Applications were made at an elevation of about 30 feet wherever possible, and roughly 20 feet above trees and other obstructions. Uniformly spaced and parallel swaths of 100-foot width were obtained by using existing landmarks and twenty-five 4- x 4-feet yellow markers strategically placed for guidance of the pilot. The markers were installed at 500-foot intervals perpendicular to the line of flight. The pilot flew over a marker for his first, sixth, eleventh, etc., swath with satisfactory spacing of intermediate swaths. To minimize flight hazards, it was necessary to remove several tall dead trees from pools 6 and 3A.

The usual treatment time for pools 6 and 2 was about 27 minutes each or a total of approximately 55 minutes. Pools 3 and 3A were treated as a unit and normally required 45 to 50 minutes for application.

The thermal condition of "inversion" (T_6–T_1 a plus value) occurred only 30 to 40 minutes following sunrise. A portion of the treatment was applied with thermal upward movement of air. Furthermore, the wind velocity increased from about 2 mph to 3 mph during period of treatment. These conditions were considered good for general treatment. It was sometimes necessary to apply the sprays and aerosols with severe conditions of lapse and wind velocities up to 6 mph.

Pools 3 and 3A each received 15 aerosol applications for a total output dosage of 1.60 pounds DDT per acre. Pool 2 was sprayed 16 times and pool 6 received 17 spray treatments for total output dosages of 1.54 and 1.64 pounds DDT per acre, respectively. The average output dosages per treatment were therefore 0.107 pounds DDT per acre for the aerosol pools and 0.093 pounds DDT per acre for the spray pools.

RECOVERY OF DDT AT THE WATER SURFACE

The recovery of DDT from both the thermal aerosol and the spray at twelve sampling stations in each treated pool at the Savannah Wildlife Refuge furnished data that could be subjected to analysis of variance.

Both pools 3 and 3A, which were treated with the thermal aerosol, showed variation of the mean recovered dosage of DDT from week to week which far exceeded the 1 per cent level of significance. The recovered dosage from week to week varied from 0.008 to 0.030 pounds DDT per acre on pool 3 and from 0.005 to 0.032 pounds DDT per acre on pool 3A. Since the recovered dosage of DDT was quite low, ranging from 5 per cent to 25 per cent of the applied dosage, the magnitude of the variation from week to week was small, but the variation was much greater than the random sampling error. The mean recovered dosage at twelve sampling stations varied from 0.008 to 0.017 pounds DDT per acre on pool 3 and from 0.006 to 0.017 pounds DDT per acre on pool 3A, but the variation was not significantly greater than the random sampling error. Thus, the distribution of DDT deposited on the water surface from the thermal aerosol was quite uniform, but the different meteorological conditions encountered caused a significant change in the mean

* Treatment area included the pool area plus a strip approximately 100 feet wide around the pool.

recovered dosage of DDT from week to week.

On the pools which were treated with the spray, the mean recovered dosage of DDT from week to week varied from 0.038 to 0.096 pounds DDT per acre on pool 6 and from 0.037 to 0.091 pounds DDT per acre on pool 2. Although the range of variation was practically the same, only on pool 6 was the variation equal to the 1 per cent level of significance. The mean recovered dosage for the spray was quite high, ranging from 37 per cent to 96 per cent of the applied dosage. The mean recovered dosage of DDT at twelve sampling stations varied from 0.031 to 0.078 pounds DDT per acre on pool 6 and from 0.041 to 0.124 pounds DDT per acre on pool 2. The variation between stations on pool 2 almost reached the 5 per cent level of significance, while on pool 6, the variation between stations was not significantly greater than the random sampling error. The random sampling error for pool 2 was very large and prevented the large variation between weeks and between stations from being statistically significant. Probably the physical characteristics of the two pools influenced the variation of recovered dosages of DDT considerably. Pool 2 had a large amount of "saw-grass" over the entire area but was otherwise free from trees and other obstructions. Pool 6 was practically open water but was bordered by a dike which had high trees at several places. The data for pool 2 on July 9, 1946 offers an example of the wide range in the amount of DDT deposited on the water surface by the spray for a single treatment. The extreme variation between stations, which were 30 or 40 feet apart, was more than 20 fold. The distribution of DDT on the water surface was spotty, i.e., a heavy dosage of DDT was deposited in one place, and 40 feet or more away, a very light dosage of DDT was deposited.

The recovered dosage of DDT was less along the dikes than on the water surface for both the spray and the thermal aerosol. The mean recovered dosage of DDT along the dike of pool 6, which was treated with the spray, was 0.046 pound DDT per acre or 49 per cent recovery of the applied dosage. The mean recovered dosage of DDT along the dike of pools 3 and 3A, which was treated with the thermal aerosol, was 0.008 pounds DDT per acre or 8 per cent recovery of the applied dosage.

The recovered dosage from the spray was significantly greater than the recovered dosage from the thermal aerosol. The magnitude of the variation at twelve sampling stations was greater for the spray than for the aerosol, but the variation between stations did not reach the 5 per cent level of significance for either the spray or the thermal aerosol. The marked difference in recovery of DDT on the water surface from the spray and from the thermal aerosol is shown in Figure 4.

Summary

Routine application by airplane of DDT larvicides in the form of spray and exhaust aerosol was made for experimental studies on the effect of DDT on wildlife. The equipment and operational procedure for airplane dispersal of DDT are described.

Examples of typical distribution of DDT as both spray and exhaust aerosol are graphically shown.

The recovery of DDT at the water surface of pools at the Savannah Wildlife Refuge is summarized, and the results of analysis of variance are discussed. The distribution of DDT at the water surface was more uniform from the aerosol than from the spray; however, the average recovered dosage of DDT was about 4 to 6 times greater from the spray than from the aerosol.

Acknowledgments

The authors wish to express their appreciation to the following members of the Technical Development Division of the Communicable Disease Center, U. S. Public Health Service: J. W. Taylor and Leroy Johnson who piloted the airplanes;

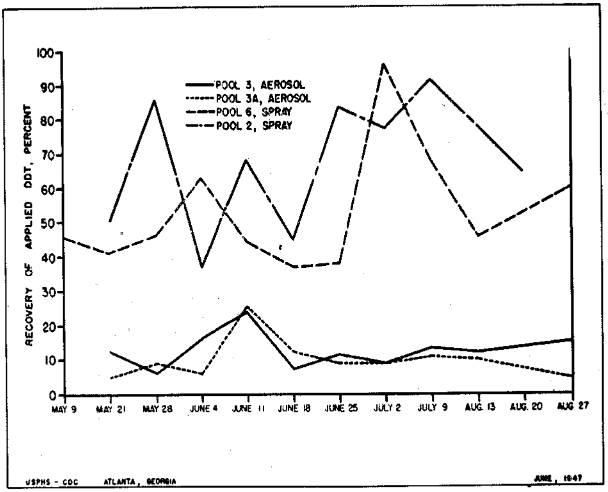

FIGURE 4. Average recovery of DDT at the water surface from the thermal aerosol and spray during the season.

M. B. Goette, S. B. Richter, and S. L. Resnick who aided in the chemical analysis for DDT; Dr. W. M. Upholt who was very helpful in the statistical analysis of the data; and especially Dr. S. W. Simmons whose direction and advice made these studies possible.

References

1. ERICKSON, A. B., Effects of DDT mosquito larviciding on wildlife. Part II. The effects of routine airplane larviciding on bird and mammal populations, Public Health Reports, August 29, 1947, Vol. 63, No. 35.
2. BISHOP, E. L., Effects of DDT mosquito larviciding on wildlife, Part III. The effects on the Plankton population of routine larviciding with DDT. Public Health Reports, August 29, 1947, Vol. 63, No. 35.
3. KRUSÉ, C. W. AND METCALF, R. L., An analysis of the design and performance of airplane exhaust generators for the production of DDT aerosols for the control of *Anopheles quadrimaculatus,* Public Health Reports, August 9, 1946, Vol. 61, No. 32.
4. DDT and other insecticides and repellents developed for the armed forces, Miscellaneous Publication No. 606, United States Department of Agriculture.
5. SCHECHTER, M. S.; SOLOWAY, S. B.; HAYES, B. A.; AND HALLER, H. L., Colorimetric determination of DDT Ind. Eng. Chem., Anal. Ed., *17*, 704-9 (1945).
6. BENT, H. E., Private communication.