ECONOMIC ENTOMOLOGY.—*The effect of particle size and velocity of movement of DDT aerosols in a wind tunnel on the mortality of mosquitoes.*[1] RANDALL LATTA, LAUREN D. ANDERSON, and E. E. ROGERS, U. S. Bureau of Entomology and Plant Quarantine, and V. K. LAMER, S. HOCHBERG, H. LAUTERBACH, and I. JOHNSON, Columbia University. (Communicated by C. F. W. MUESEBECK.)

This paper reports a continuation of the cooperative work between the Bureau of Entomology and Plant Quarantine and the Central Aerosol Laboratory of Columbia University on the influence of the size of uniform particle size oil aerosols of DDT upon mosquitoes. In the first paper[2] the mosquitoes and the aerosols were maintained in chambers so that an essentially static atmosphere prevailed. In the present paper this restriction is removed by subjecting the test insects to an aerosol moving in a wind tunnel at carefully defined speeds of motion.

It was recognized that aerosols applied in the open as large clouds, and drifted across an area to be treated, might be governed by somewhat different factors than were those applied in confined atmospheres. In the open, movement by drifting would far exceed gravitational fall. Furthermore, in drifting by wind movement, all particles could be assumed to have the same velocity regardless of size, within the range of sizes capable of remaining airborne for any length of time.

The apparatus for the generation of these homogeneous aerosols and the optical instruments and methods of measuring their particle size which had been developed by LaMer, Sinclair, Hochberg, and others in the Central Aerosol Laboratory in previous studies relating to various types of smokes were utilized in this study. A detailed description is given in O.S.R.D. Reports Nos. 119 and 1668, and N.D.R.C. Div. B Report No. 57.

In the previous work on confined atmospheres, exposures of 10 to 30 minutes in aerosol concentrations of around 100 micrograms per liter, of oil containing 8 percent of DDT were necessary to cause high mortalities when particles of 1 micron or less in diameter were used. On the other hand, exposures of ½ to 2 minutes in aerosol concentrations of around 25 micrograms per liter produced high mortality when particles were 5 to 16 microns in diameter. When *Ct* (concentration × time of exposure) values which produced 50 per cent mortality of females were plotted against particle size, the toxicity was shown to be increased 250-fold when the diameter of the particle was increased from 0.33 to 11 microns. It was shown also that this curve corresponds to a curve in which the time necessary for an aerosol to settle out of 1 cc is plotted against particle size, as calculated according to Stokes's law. This finding indicated that the mortality of resting insects caused by aerosols in confined atmospheres resulted from deposition of the particles on the insects as a result of gravitational settling, and could be directly correlated with Stokes's law; i.e., the toxicity was proportional to the square of the diameter of the particle up to about 16 microns diameter, the concentration of DDT and the exposure time being held constant.

Shortly after the completion of the work on confined atmospheres, a theoretical treatment of the extent of deposition of wind-borne aerosols upon objects of various

[1] This work was conducted under transfers of funds, recommended (1) by the Committee on Medical Research, from the Office of Scientific Research and Development to the Bureau of Entomology and Plant Quarantine, and (2) by the National Defense Research Committee, from the Office of Scientific Research and Development to Columbia University under Contract OEMsr 1388. It is based upon Report No. 5566 of the O.S.R.D. dated July 30, 1945. This report is on file with the Insect Control Committee of the National Research Council and is available for reference upon application to that agency. Received June 2, 1947.

[2] LAMER, V. K., S. HOCHBERG, et al. *The influence of the particle size of homogeneous insecticidal aerosols on the mortality of mosquitoes in confined atmospheres.* (In press.) This paper is based upon O.S.R.D. Report No. 4447, to which the reader is referred for more details of execution and of history of subject.

geometrical shapes by Winsche[3] based upon Sell's[4] original studies became available. This study indicated to us that the deposition upon insects, and hence the toxicity of a moving mass of aerosol, might likewise be expected to be dependent upon the square of the radius (or diameter) of the particle and in addition upon the first power of the velocity of the wind propelling the aerosol.

The series of experiments reported in this communication were therefore undertaken to test this conclusion by direct measurements in a wind tunnel. This study was performed at the Bureau laboratories, Agricultural Research Center, Beltsville, Md., between January 10 and May 2, 1945. The Central Aerosol Laboratory at Columbia University was responsible for all the physical and chemical phases of the program and the Bureau for all biological phases, as well as quarters and all permanent installations. Evaluation of results was done jointly.

[3] WINSCHE, WARREN E. *The deposition of non-volatile aerosol clouds in open and forested areas.* N.D.R.C. Report No. 10.4–55. 1944.

[4] SELL, W. [*Spray precipitation in an uncombined body and in an air filter.*] Ver. Deutsche Ingen. Forschungsarb., V.D.I Verlag, 347. Berlin, 1931.

TECHNIQUE

Aerosols uniform in particle diameter were introduced into the mouth of a small wind tunnel (Fig. 1) in which a known air flow was maintained. Adult mosquitoes in cages were exposed in the tunnel to measured quantities of the aerosol and observed for mortality.

The wind tunnel was constructed of composition board and was 1 foot square in cross section by 32 feet in length. The air movement was provided by a suction blower attached to the end of the tunnel. The air flow was adjusted by a slide damper placed just ahead of the blower and measured by determining the pressure drop across an orifice placed in the tunnel ahead of the damper. The pressure drop was read by means of an inclined manometer. This arrangement allowed air flows ranging from 1 to 16 m.p.h. to be determined with accuracy. The calibrations of the velocity of air flow in respect to the

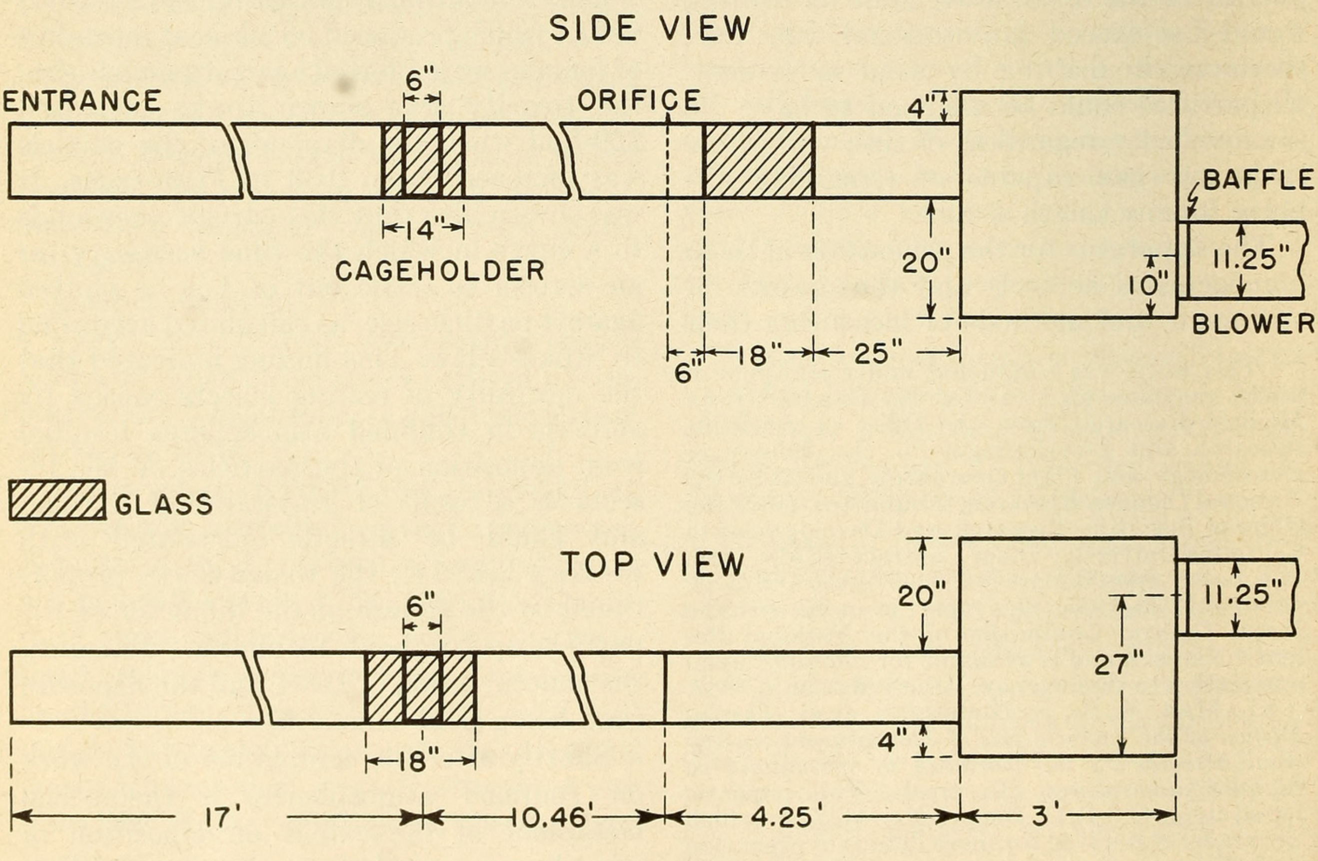

FIG. 1.—Diagram of wind tunnel used in these experiments.

radial distribution of flow in the tunnel, as well as adjustments of the orifice diameter and pressure, were performed by K. C. Hodges and J. C. Rowell, of the Central Aerosol Laboratory. Their findings, which proved to be in good agreement with the predictions of air flow theory, are fully discussed in O.S.R.D. Report No. 5566. This report should be consulted by those interested in the details of constructing wind tunnels.

At a point 17 feet from the mouth of the tunnel, a cage holder (Fig. 2) into which a cage holding mosquitoes could be inserted, was placed in the tunnel. The cages were cylindrical, 6 inches in diameter and 6 inches long, with both ends removable. The side walls of the cages were lined with 20-mesh wire cloth. The covers were made of 16-mesh wire cloth. The holder, which occupied the entire cross section of the tunnel, was covered front and back with 16-mesh wire cloth in order to equalize resistance across the tunnel. Glass windows were inserted on all sides of the tunnel at the location of the cage, so that observations could be made during treatment. Access to the tunnel was through a removable panel in the top.

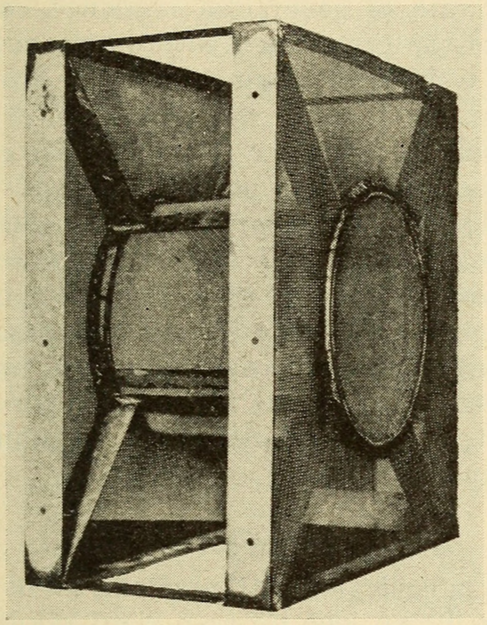

Fig. 2.—Square frame placed across the wind tunnel to hold the insect exposure cage in the exact center. The cage is in place.

The mouth of the tunnel was equipped with a flared metal collar and a mixing baffle. The distance from the mouth to the position of the cage was sufficient to allow the aerosol to be distributed uniformly across the tunnel. The uniformity of distribution of the aerosol in the cylindrical cage was confirmed by observing, through the windows, the flow of a screening smoke.

The aerosols were prepared in a LaMer-Sinclair homogeneous aerosol generator, similar to the one used in the previous studies relative to aerosols in confined atmospheres except for some modifications for preparing more homogeneous aerosols in the large particle range. In this generator DDT, dissolved in an oil having a narrow boiling-point range and a vapor pressure comparable to that of DDT, was vaporized in glass vessels, and mixed with known amounts of air and with a controllable number of nuclei. The diluted vapor was allowed to cool and condense upon these nuclei under carefully regulated conditions. The particle size was controlled by regulating the vapor pressure by adjusting the temperature and the number of nuclei. The nuclei were produced by heating sodium chloride deposited upon electrically heated nichrome wire.

Two methods were used to determine the average particle diameter of an aerosol, rate of settling and impingement on a waved slide. In the first method the average time for 10 particles to settle 0.5 cm in quiet air was determined, and the particle diameter calculated from this figure. In the second method a slide was waved in the aerosol stream at the mouth of the tunnel, and a sample of at least 200 particles measured. The average diameter of the particles was calculated on the basis that the probability that a particle in the aerosol will adhere to the slide is in proportion to the square of its diameter. The aerosols were uniform in size. Generally 90 percent of the mass would fall in a range ± 10 percent from the average.

The output of the generator was constant, once it was properly adjusted for a desired particle size. Prior to a series of treatments the aerosol was drawn through a weighed glass-wool filter for a measured period of about 10 minutes. The filter was reweighed and the amount of aerosol generated per minute computed. The aerosol deposited on the filter was analyzed for DDT content. The content of DDT in the aerosol was usually somewhat different from the content in the unvaporized oil, owing to an unavoidable slight difference in vapor pressure. Different dosages of aerosol could be applied by varying the time during which the aerosol was introduced into the tunnel. The rate of generation was usually between 5 and 15 mg of oil-DDT aerosol per minute. The generator was placed above the mouth of the tunnel, with the outlet in the center of the tunnel opening.

Adult *Aedes aegypti* mosquitoes[5] ranging 4 to 7 days old were used in all tests. The mosquitoes were kept in a small insectary well removed from the wind tunnel. For individual tests mosquitoes were transferred from stock cages into one of the cylindrical cages used in the wind tunnel. The test cage was then transported to the tunnel in a closed fibreboard box and immediately placed in position in the tunnel. At the end of the treatment the cage was transported back to the insectary in the same manner, and the mosquitoes were immediately emptied into a clean cage for observation of mortality. Adequate control samples were handled in the same manner as treated ones, except for exposure to the aerosol.

In each series one control sample was exposed to air flow in the tunnel for a period equal to or greater than the most rigorous exposure in the treated series. When there was no wind the mosquitoes flew about the cage, but once air flow was started through the tunnel there was little or no activity. At low velocities they tended to congregate on the front screen of the cage, but at 16 m.p.h. they were blown against the rear screen and held there by the air flow. The control experiments showed that mosquitoes were not injured by air speeds of 16 m.p.h.

Mortality counts were made the day following treatment. The mortality of males was invariably greater than that of females, but only data on female mortality were used in the final evaluation of the results.

Every precaution was taken to prevent contamination of the cages and the insectary with DDT. The test cages were washed with acetone, and the holding cages thoroughly scrubbed with water after each using.

[5] The mosquitoes were supplied by Abby Casanges and associates in the Bureau of Entomology and Plant Quarantine.

RESULTS

Fifteen series of tests were made with homogeneous aerosols. The particle diameter of these aerosols ranged from 1.12 to 20.4 microns. Since the particle size and the rate of generation remained constant once the generator was properly adjusted, all tests with a given particle size were made as a group when possible. A group usually consisted of four exposures each at velocities of 2, 4, 8, and 16 m.p.h.

The mortality produced by each particle size is given in table 1. The amount of aerosol is in terms of the total amount admitted to the tunnel. Since it all passed the point where the cage of insects was exposed, it represents the amount per square foot, as the cross section of the tunnel was 1 square foot.

DISCUSSION

For each particle diameter a set of curves was drawn, one for each wind velocity, relating the percent mortality of females to the number of milligrams of aerosol passed through the tunnel. From each curve a figure for the amount of aerosol required to kill 50 percent of the females was obtained by interpolation. Since the DDT content was determined for each run, the amount of DDT for 50 percent mortality of females can be derived from these figures. Such data for 14 particle sizes are given in table 2.

The curves fall into three types. Small particles yield curves similar to Fig. 3, large particles curves similar to Fig. 4, and intermediate sizes curves similar to Fig. 5. In the first case the amount of aerosol required to pass through the tunnel to kill any given fraction of the females is inversely proportional to the wind velocity; in the second case it is independent of the wind velocity, and in the third case it is inversely proportional to the wind velocity for low

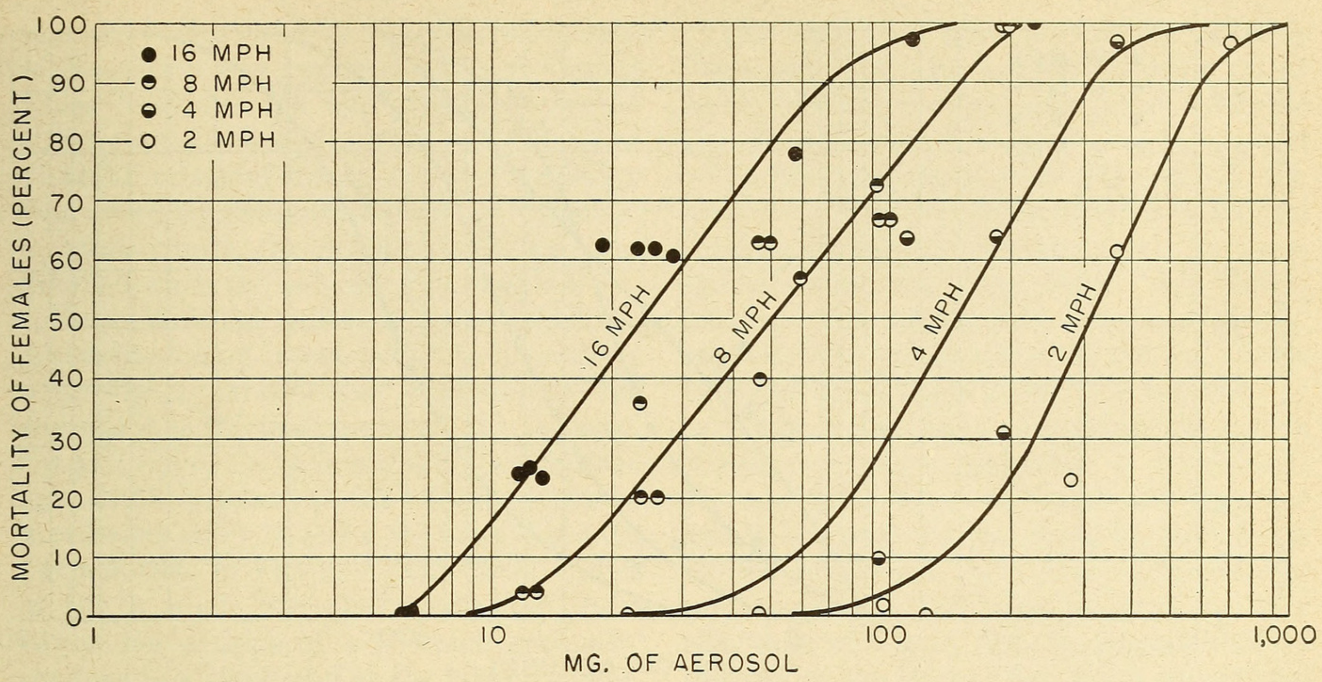

FIG. 3.—Dosage-mortality curves for a homogeneous aerosol of 2.5 microns particle diameter, moving at velocities of 2,4,8, and 16 m.p.h.

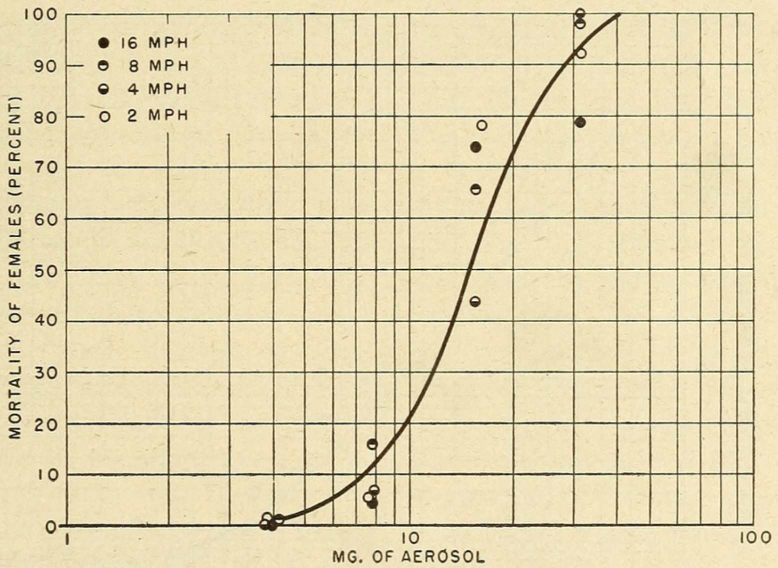

FIG. 4.—Dosage-mortality curve for a homogeneous aerosol of 20.4 microns particle diameter, moving at velocities of 2, 4, 8, and 16 m.p.h.

wind velocities and independent of wind velocity for high wind velocities.

The differences in mortality produced by aerosols with different particle size at a constant rate of motion, or by different rates of motion with an aerosol of constant size, were ascribed to differences in the rate of deposition of the particles on the insects induced by the above variations. In other words, the differences were due to a change in the percentage of particles which adhered to the insects in their paths, as a result of a change in size or velocity of the particle. It is easily observed that a reduction in particle size tends to reduce deposition. Smoke or fog, consisting of very fine particles, tends to follow the air streamlines around a body, and only a small fraction actually strikes the body. On the other hand, larger particles, as illustrated by rain, practically all strike bodies in their paths. It has been demonstrated also that an increase in the velocity of particles also increases the rate of deposition. In fact, it

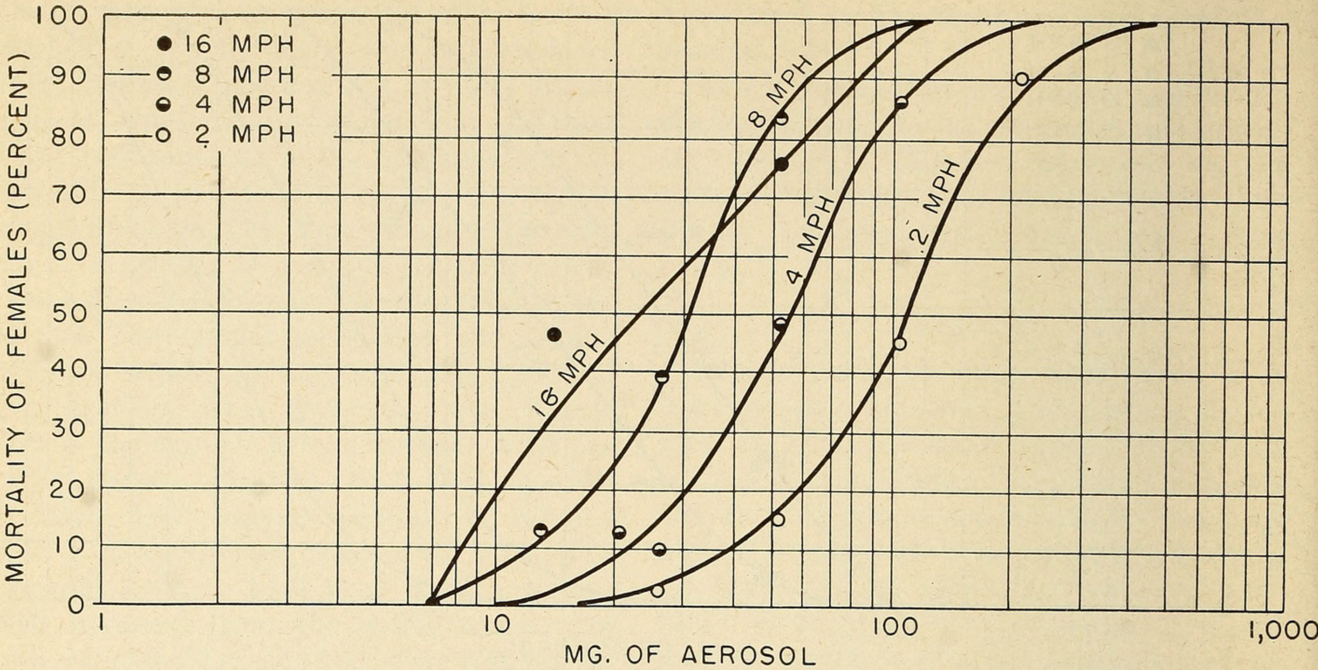

Fig. 5.—Dosage-mortality curves for a homogeneous aerosol of 5 microns particle diameter, moving at velocities of 2, 4, 8, and 16 m.p.h.

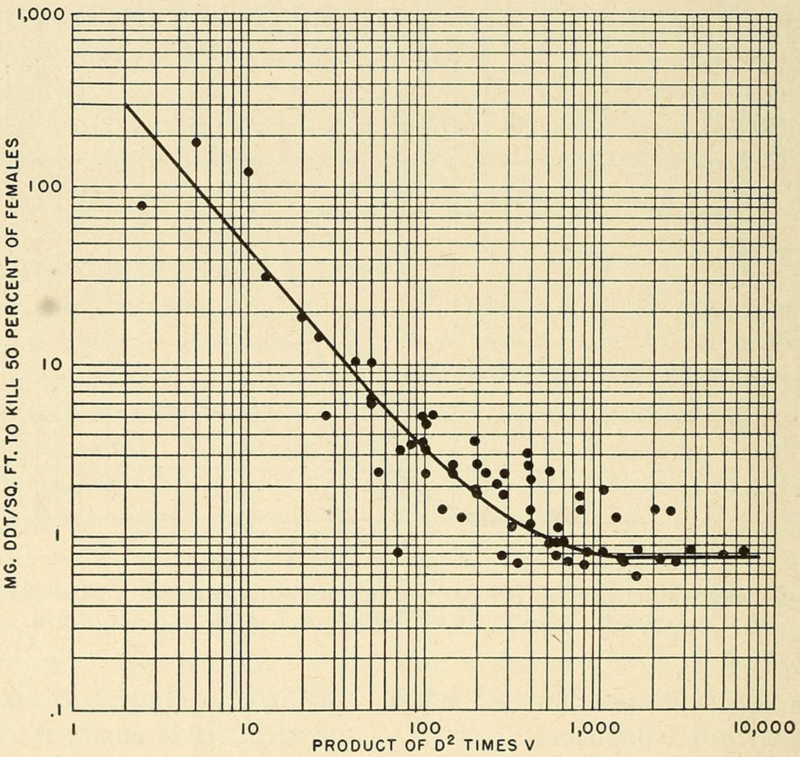

Fig. 6.—The effect of the product of D^2v on the amount of DDT required to produce 50 percent mortality of females.

is possible to remove practically all the particles of an aerosol by impingement against a surface with sufficient velocity.

In the range of the smaller particle sizes that were tested, the mortality with a given amount of DDT was dependent upon the particle size and velocity, i.e., proportional to the square of the diameter and the first power of the velocity. In the range of the largest particle sizes that were tested, the mortality with a given amount of DDT was not affected by a change in particle size or velocity. This condition was considered to be above the point where the maximum rate of deposition occurred. The influence of particle size and velocity upon mortality decreased as the maximum rate of deposition was approached. In the range where particle size and velocity exerted their greatest effect on mortality, the amount of DDT required for 50 percent mortality was inversely proportional to the velocity; in other words, the rate of deposition was doubled when the velocity was doubled.

Since Winsche (1944) indicated that the deposition on an insect might be dependent upon the square of the diameter of the particle and the first power of the velocity, the amount of DDT in milligrams is plotted against the product of D^2v (D is measured in microns and v in miles per hour) for each particle size, in Fig. 6. At the lower values of D^2v, a single line plotted through these values has a slope of -1, which gradually changes to a slope of 0 at the higher values. This signifies that further changes in velocity or particle size do not affect the mortality.

After a certain value of D^2v is reached, the amount of insecticide required becomes independent of the velocity and diameter, but it is evident from statistical considerations[6] that eventually a point will be reached in particle size where a decrease in effectiveness will begin to occur. This is a consequence of the laws of probability, which come into prominence when a point is reached where a small number of particles are sufficient to kill an insect. When large numbers of particles are necessary each insect receives substantially the same number of particles and only the susceptibility of the insect determines the median lethal dose. On the other hand, when the particle number is small a small variation in number of particles represents a large percentage variation in toxic dosage. This effect, superimposed upon the susceptibility of the insect, tends to increase the median lethal dose.

Aside from the statistical considerations, it is evident that if a particle contains more than a lethal dose all the excess DDT in each particle is wasted. This factor will increase the apparent median lethal dose as determined experimentally and can become very significant.

[6] RODEBUSH, W. H. *Statistical considerations in the use of DDT aerosols.* O.S.R.D. Report No. 4757.

The optimum particle size for aerosols dispersed from the ground depends on at least two factors—(1) the most effective size in relation to deposit on the insect when the particle reaches it, and (2) the loss of aerosol by deposit on foliage and settling on its way to the insect. In these studies only the first factor was determined. However, certain known effects of particle size on the travel of aerosol clouds through vegetation permit an estimate to be made of the limits of particle size within which economical operation is feasible. If the aerosol cloud is to travel any distance at all, the particle size must be held down to one which will carry this distance. For maximum effect it must be held up to a size that will give the maximum rate of deposit on the insect. For *Aedes aegypti* the upper limits can be indicated by reference to Fig. 6. These limits would be at a point where D^2v is 300 to 1,000 (for example, 13 micron diameter at 5 m.p.h., or 10 micron diameter at 8 m.p.h., etc.). particles larger than this would not increase the efficiency of the aerosol when it reaches the insect, as a smaller percentage of such particles would carry to the insect.

Since the amount of DDT introduced into the tunnel was known, an approximate toxic dose of 0.03 microgram for a female of median susceptibility could be calculated from the data. For this purpose the area of a mosquito was assumed to be 0.03 cm^2, and the quantity of DDT to be 0.8 mg per square foot for large particles and high velocities where practically all particles would impinge on the insect. This quantity is contained in a single spherical particle of pure DDT (density 1.4) of a volume of 2.14×10^{-8} cm^3 or of a diameter of 34.4 microns. With a 10 percent solution of DDT, a 30×10^{-8} cm^3 droplet is required, which would be contained in a particle 83 microns in diameter.

The mortality curves obtained in these tests showed the amount of DDT causing 95 percent mortality to be between two and four times that for 50 percent mortality. Therefore, the approximate dose for 95 percent mortality would be between 6×10^{-5} and 12×10^{-5} mg; i.e., 0.06 to 0.12 microgram per insect. This would be a maximum amount, because in these calculations the deposition of aerosol on the wire screen of the insect cage and the amounts deposited on the walls of the tunnel have not been considered. Neither of these quantities was measured. That deposited on the walls of the tunnel was minimized by the elimination of depressions and rough areas. It is estimated from Stokes's law that the error due to settling would be greatest with the largest particles and lowest wind velocities and would amount to less than 20 percent at 2 m.p.h. or less than 3 percent at 16 m.p.h. Deposition on the wire screen would be less than 35 percent, since the wires of the mesh occupy approximately 35 percent of the area of the screen.

The median lethal doses, as given in table 2, fall within a range of 0.5 to 2 times the central tendency as shown in Fig. 6. It is therefore considered that the total experimental error, including the variation in susceptibility of the mosquitoes from day to day, is within these limits.

CONCLUSIONS AND ANALYSIS

The following conclusions on the effect of particle size and the speed of motion were reached by comparing the mortalities produced by particles varying between 1.12 and 20.4 microns in diameter, under various speeds between 2 and 16 m.p.h. The first four conclusions are associated exclusively with physical factors, and would apply to any insect and any insecticide.

1. The rate of deposition of an aerosol upon an insect, as evidenced by the mortality, is affected by the particle diameter and the velocity.

2. Under conditions where only a small fraction of the particles deposit on insects in their path (small particles and low wind velocity), the amount of aerosol required is inversely proportional to the product of the square of the diameter and the wind velocity.

3. The increase in effectiveness with increase in particle size and velocity continues until practically all particles are deposited on an insect in their path. Thereafter, further increase in particle size or velocity is ineffective.

4. The mortalities caused by different velocities, or different particle sizes, depend on the product of the velocity and the square of the particle diameter. Doubling the particle diameter has the same effect on mortality as quadrupling the velocity.

5. Total deposition of the aerosol on *Aedes aegypti* females is approached when D^2v (D is measured in microns and v in miles per hour) exceeds 1,000. However, there is little difference in doses for D^2v values of 300 to 1,000. (For instance, where $D=1$ micron and $v=5$ m.p.h., $D^2v=5$ and incomplete deposition resulted. Where $D=25$ microns and $v=2$ m.p.h., $D^2v=1{,}250$ and practically complete deposition resulted, as evidenced by the mortality obtained.)

6. The approximate amount of DDT that should be deposited on an *Aedes aegypti* female of median susceptibility to cause mortality was determined to be 0.03 microgram. This quantity is contained in a droplet of 10 percent DDT solution 83 microns in diameter.

SUMMARY

In order to determine the influence of wind velocity and particle size on the toxicity of an oil aerosol bearing DDT to adult insects, cages of *Aedes aegypti* mosquitoes were exposed, in a wind tunnel, to aerosols of uniform and known particle size at wind speeds of 2, 4, 8, and 16 m.p.h. The diameter of the aerosol droplets ranged from 1.12 to 20.4 microns.

The quantity of DDT which must pass through a given cross-sectional area of the tunnel to kill 50 percent of the females is a simple function of D^2v, the product of the square of the diameter D of the droplets and the wind velocity. For small values of D^2v the quantity required is inversely proportional to D^2v; for large values it is independent of D^2v.

The results are analyzed on the basis that differences in mortality are produced by differences in rates of deposition of the aerosol, and on this basis a figure was obtained for the median lethal dose for females of 3×10^{-5} mg of DDT. This is contained in a single particle of a 10 percent solution 83 microns in diameter, or of 100 percent DDT 34 microns in diameter.

Table 1.—Mortality Caused by Particle Sizes of Aerosol Ranging in Diameter from 1.12 to 20.4 Microns, at Velocities of 2, 4, 8, and 16 M.p.h.

Particle diameter	Velocity	Total amount of aerosol	Content of DDT	Amount of DDT	Female mosquitoes	Mortality
Microns	*M.p.h.*	*Mg.*	*Per-cent*	*Mg.*	*Number*	*Per-cent*
1.12	16	48.2	11.55	5.6	24	8
		96.4	11.55	11.1	70	27
		114	10.42	11.9	64	8
		193	11.55	22.3	74	60
		223	12.4	27.6	72	92
		386	11.55	44.6	127	95
	8	193	11.55	22.3	12	0
		223	12.4	27.6	65	5
		386	11.55	44.6	103	9
		698	10.78	75.2	53	25
		750	10.42	78.2	121	19
	4	223	12.4	27.6	82	2
		386	11.55	44.6	117	2
		750	10.42	78.2	141	5
		771	11.55	89.0	10	10
		1308	10.78	141.0	56	39
	2	223	12.4	27.6	60	0
		386	11.55	44.6	55	11
		750	10.42	78.2	129	100
		771	11.25	86.7	60	60
		1308	10.78	141.0	52	100
	16	None	—	—	94	0
					81	0
					41	0
2.5	16	6.5	11.15	.72	62	0
		13	11.15	1.45	54	24
		14.6	12.55	1.83	73	25
		19.2	10.1	1.94	119	63
		26	11.15	2.9	47	62
		29.2	12.55	3.66	124	60
		58.4	12.55	7.33	110	78
		116.8	12.55	14.66	97	98
		233.2	12.55	29.27	75	100
	8	13	11.15	1.45	102	4
		23.2	9.25	2.15	33	36
		26	11.15	2.9	40	20
		46.4	9.25	4.29	79	41
		52	11.15	5.8	30	63
		60	10.1	6.06	53	57
		91.8	9.25	8.49	59	73
		104	11.15	11.60	54	67
		208	11.15	23.19	37	100
	4	23.2	9.25	2.15	107	0
		46.4	9.25	4.29	54	0
		91.8	9.25	8.49	115	10
		185.6	9.25	17.2	47	64
		192	10.1	19.39	58	31
		371.2	9.25	34.34	58	97
	2	96.0	10.1	9.7	62	2
		197.2	9.25	18.24	17	0
		288	10.1	29.09	52	31
		371.2	9.25	34.34	23	61
		720	10.1	72.72	91	97
	16	None	—	—	48	0
					111	0
					132	0
3.72	16	92.8	2.42	2.24	114	48
		185.6		4.49	42	86
		371.2		8.98	60	100
	8	185.6		4.49	75	44
		371.2		8.98	49	96
		742.4		17.96	84	100
	4	185.6		4.49	36	21
	2	371.2		8.98	20	5
4.48	16	4.78	9.17	.44	8	0
		9.55		.88	45	36
		19.1		1.75	62	79
		38.2		3.50	27	85
	8	9.55		.88	17	18
		19.1		1.75	99	68
		38.2		3.50	39	85
		76.4		7.0	140	93
	4	9.55		.88	31	3
		19.1		1.75	16	25
		38.2		3.50	48	52
		86.0		7.89	113	75
	2	19.1		1.75	16	0
		38.2		3.50	47	0
		76.4		7.0	92	24
		152.8		14.0	18	83
	16	None			68	0
					12	0
5.0	16	6.5	5.8	.38	53	0
		13		.75	124	46
		26		1.51	59	39
		52		3.02	24	75
	8	6.5		.38	49	0
		13		.75	76	13
		26		1.51	62	39
		52		3.02	29	83
	4	19.5		1.13	61	13
		26		1.51	61	10
		52		3.02	99	48
		104		6.03	29	86
	2	26		1.51	74	3
		52		3.02	52	15
		104		6.03	49	45
		208		12.1	29	90
		None	—	—	45	0
6.0	16	8	9.22	.74	23	39
		32		2.95	59	98
		64		5.9	29	100
	8	8		.74	53	4
		16		1.48	64	22
		32		2.95	104	71
		64		5.9	5	60

Table 1.—(*continued*)

Particle diameter	Velocity	Total amount of aerosol	Content of DDT	Amount of DDT	Female mosquitoes	Mortality
Microns	*M.p.h.*	*Mg.*	*Per-cent*	*Mg.*	*Num-ber*	*Per-cent*
	4	8		.74	43	0
		16		1.48	35	29
		32		2.95	47	53
		64		5.9	7	71
	2	8		.74	47	0
		16		1.48	49	6
		32		2.95	31	48
		64		5.9	8	75
		None			33	0
7.0	16	8.1	7.64	.62	31	13
		16.2		1.24	47	43
		32.4		2.47	21	72
		64.8		4.95	38	79
	8	8.1		.62	58	0
		16.2		1.24	40	20
		32.4		2.47	56	50
		64.8		4.95	46	80
	4	8.1		.62	65	0
		16.2		1.24	57	12
		32.4		2.47	79	66
		64.8		4.95	25	72
	2	8.1		.62	72	0
		16.2		1.24	75	1
		32.4		2.47	58	29
		64.8		4.95	91	81
		None			87	0
7.1	16	.45	9.5	.04	30	0
		.91		.09	66	0
		1.81		.17	114	1
		3.63		.34	90	1
		7.26		.69	91	7
	8	.91		.09	41	0
		1.81		.17	31	0
		3.63		.34	88	0
		7.26		.69	93	9
		14.51		1.38	83	42
	4	3.63		.34	52	0
		7.26		.69	92	1
		14.51		1.38	102	54
		29.02		2.76	75	61
		58.04		5.51	77	78
	2	7.26		.69	30	0
		14.51		1.38	45	33
		29.02		2.76	196	62
		58.04		5.51	10	10
		116.08		11.03	141	87
		None			27	0
8.0	16	4.16	7.62	.32	84	0
		8.33		.63	99	47
		16.66		1.27	80	50
		33.32		2.54	44	84
		66.64		5.08	73	96
	8	4.16		.32	76	0
		8.33		.63	34	29
		16.66		1.27	51	71
		33.32		2.54	71	78
		66.64		5.08	80	92
	4	4.16		.32	33	0
		8.33		.63	40	12
		16.66		1.27	29	45
		33.32		2.54	20	75
		66.64		5.08	68	100
	2	4.16		.32	60	0
		8.33		.63	27	11
		16.66		1.27	36	44
		33.32		2.54	45	71
		66.64		5.08	122	90
		None			80	0
10.0	16	9.6	5.0	.48	74	31
		19.3		.96	93	85
		38.5		1.92	62	94
	8	9.6		.48	54	22
		19.3		.96	64	69
		38.5		1.92	38	92
	4	9.6		.48	157	0
		19.3		.96	104	16
		38.5		1.92	82	89
	2	9.6		.48	110	0
		19.3		.96	130	11
		38.5		1.92	130	63
		None			102	0
11.4	16	10.1	6.67	.67	80	0
		20.2		1.35	50	66
		40.5		2.70	68	69
		60.8		4.06	48	81
		60.8		4.06	50	82
	8	10.1		.67	97	0
		20.2		1.35	96	27
		40.5		2.70	70	60
		60.8		4.06	53	42
	4	10.1		.67	103	0
		20.2		1.35	235	4
		40.5		2.70	127	54
		60.8		4.06	59	46
	2	10.1		.67	115	1
		20.2		1.35	114	0
		40.5		2.70	100	0
		60.8		4.06	69	80
		None			97	0

Table 1.—(*continued*)

Particle diameter	Velocity	Total amount of aerosol	Content of DDT	Amount of DDT	Female mosquitoes	Mortality
Microns	*M.p.h.*	*Mg.*	*Per-cent*	*Mg.*	*Num-ber*	*Per-cent*
11.9	16	13.8	4.8	.66	127	54
		19.3		.93	107	75
		22.1		1.06	222	79
	8	5.5		.26	99	23
		22.1		1.06	125	82
	4	5.5		.26	65	3
		13.8		.66	148	53
		27.6		1.32	141	93
	2	5.5		.26	112	1
		13.8		.66	198	70
		22.1		1.06	152	89
		None			87	2
13.0	16	5.1	3.0	.15	80	0
		10.2		.31	65	17
		20.4		.61	58	47
		40.8		1.22	78	64
	8	5.1		.15	67	3
		10.2		.31	65	23
		20.4		.61	52	58
		40.8		1.22	41	76
	4	5.1		.15	151	0
		10.2		.31	88	5
		20.4		.61	69	35
		40.8		1.22	42	57
	2	5.1		.15	45	0
		10.2		.31	62	2
		20.4		.61	71	46
		40.8		1.22	86	91
		None			84	1
17.8	16	12.6	3.45	.43	21	24
		25.3		.87	117	54
		50.5		1.74	72	72
	8	12.6		.43	51	0
		25.3		.87	46	17
		50.5		1.74	48	56
	4	12.6		.43	68	1
		25.3		.87	45	4
		50.5		1.74	42	67
	2	12.6		.43	51	0
		25.3		.87	39	38
		50.5		1.74	34	88
		None			38	5
20.4	16	3.9	5.8	.23	68	0
		7.8		.45	20	5
		15.6		.90	42	74
		31.2		1.81	29	79
	8	3.9		.23	49	0
		7.8		.45	58	16
		15.6		.90	83	66
		31.2		1.81	41	98
	4	3.9		.23	39	0
		7.8		.45	32	6
		15.6		.90	18	44
		31.2		1.81	42	100
	2	3.9		.23	127	1
		7.8		.45	31	6
		16.9		.98	67	78
		31.2		1.81	28	93
		None			45	0

Table 2.—Milligrams of DDT Producing 50 Percent Mortality of Female Mosquitoes as Determined by Mortality Curves Plotted from Percentages Given in Table 1

Particle diameter	Milligrams of DDT required at speeds of			
	16 M.p.h.	8 M.p.h.	4 M.p.h.	2 M.p.h.
Microns				
1.12	18.4	126.0	184.0	80.5
2.50	2.35	5.90	14.2	32.0
3.72	2.4	5.03	—	—
4.48	1.15	1.29	3.45	10.3
5.0	1.45	1.74	3.24	6.38
6.0	1.15	2.30	2.67	3.13
7.0	1.44	2.2	1.9	3.49
7.1	—	—	1.50	1.80
8.0	.836	.912	1.44	1.6
10.0	.59	.70	1.20	1.75
11.4	1.44	1.94	2.48	2.08
11.9	.62	.62	.62	.62
13.0	.705	.705	.705	.705
17.8	.83	1.41	1.31	.99
20.4	.87	.87	.87	.87