ARTICLES

ANALYSIS OF CONTROLLED VARIABLES AS THEY AFFECT ULV DROPLET DISTRIBUTION[1]

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ABSTRACT. Droplets of 95% malathion from a ULV aerosol generator were collected on silicone-coated slides, using the hand wave technique, by 3 researchers at 3 fixed distances. All combinations of 3 insecticide temperatures and 3 machine pressures were utilized for each distance. The droplet distribution of the aerosol was characterized by calculating 2 parameters: the volume median diameter (VMD) and the percentage of spray volume (PSV) in droplets less than 18μ. Using normal operating procedures, it was found that sampling distance and machine operating pressure significantly affected the droplet distribution, while neither the sampler nor the insecticide temperature were significant factors. There were no significant interactions between the 4 test variables indicating independence of each.

Techniques for sampling insecticide droplets produced by ultra low volume (ULV) ground equipment have received considerable interest in recent years: Mount et al. (1968); Mount et al. (1970); Mount and Pierce (1972a); Mount and Pierce (1972b); Mount et al. (1975); and Himel and McDaniel (unpublished). The 3 techniques which are available for the collection of aerosols are hand wave, settling chamber, and impaction. In comparing these techniques, Mount and Pierce (1972b) found that different computation methods for mass median diameter (MMD) determination would result in only a slight difference between the 3 techniques.

The hand wave technique is most commonly used to collect droplets produced by ULV equipment in the field. To determine whether a machine is atomizing the insecticide properly, the collected droplets are analyzed based on the calculated volume median diameter (VMD= MMD). Analysis of machine performance with hand wave collected droplets has been difficult since variables such as sampling distance, liquid temperature, operating pressure, and the sampler may influence the VMD.

The distance from the nozzle that the samples are taken by the hand wave method has been reported as being 25 ft. by Mount et al. (1968) and Mount et al. (1970) as well as 3–6 ft. by Mount and Pierce (1972a) and (1972b).

There appears to be no published information concerning what effect insecticide temperature has on the expected droplet spectrum, although Thompson (1973) reported that flow rates of a viscous liquid must be measured throughout the operating temperature range of a ULV machine as the chemical may be more viscous and difficult to atomize at low temperatures.

It is well documented that the operating pressure of the machine significantly affects droplet size, Mount and Pierce (1972a) and Mount et al. (1975). Insecticide tank pressures for application of 95% malathion are recommended to be

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not less than 2 psi or greater than 6 psi, Anonymous (1972).

The sampler may unintentionally bias VMD's by particular waving styles. It is even possible that different samplers may wave slides at varying velocities through the aerosol. Himel and McDaniel (unpublished) have shown that spread diameters of droplets collected on M_gO and Teflon® slides were unaffected when impinged at velocities up to 15 mph. Yeomans (1949) stated that deposition by impingement may be accomplished by moving the slide through the spray cloud or by moving the spray cloud past a slide in a fixed position.

Thus, of the 4 main variables (sampling distance, liquid temperature, operating pressure and the sampler), only the influence of operating pressure on the VMD is well-documented in the literature. This paper presents an analysis of the actions and interactions of these 4 variables on the droplet spectrum produced by a ULV machine.

MATERIALS AND METHODS. A LECO ULV HD cold aerosol generator, atomizing 95% malathion as an ultra low volume aerosol, was operated during this experiment at 3 pressures: 4.5, 5.0 and 6.0 psi. The insecticide temperature was regulated so tests could be run at liquid temperatures of 75° F (73° F–77° F), 85° F (83° F–87° F), and 95° F (93° F–97° F). To obtain the higher liquid temperatures, it was necessary to heat the insecticide tank externally. The temperature of the insecticide at the nozzle was found to be essentially the same, within 2° F, of that being simultaneously recorded on the flow meter console. For each test series of operating temperatures and pressures, the machine was precisely calibrated for a flow rate of 4.0 fl. oz/min. All samples were collected in the morning with the following meteorological conditions in effect: ambient temperature 75° F to 84° F, relative humidity 59% to 76%, and wind speed 3 mph with gusts to 8 mph. The nozzle was pointed down wind.

A sample of the aerosol at each operating pressure for each insecticide temperature was collected by waving a standard, flat microscope slide through the cloud. The microscope slides were coated with a 10% solution of "Dri-Film," a silicone compound in a diluent of acetone. The siliconized slide was then secured to the end of a wand with a spring-type paper clip and swung horizontally toward the machine through the aerosol cloud. Samples were collected at 3 distances (15, 20 and 25 ft) from the machine by 3 individuals.

After the sample was taken, a spacer was placed on the slide to prevent droplet compression, and an untreated cover slide was added. The 2 slides were then taped together to reduce the possibility of evaporation and prevent movement during transport. Slide analysis was accomplished within 1 week of collection. Anderson and Schulte (1971) found no detectable reduction in size of malathion droplets left exposed in an air conditioned room for 4 days.

A total of 81 aerosol samples (slides) were collected: 3 pressures, 3 temperatures, 3 distances, and 3 individuals (replicates). The 81 slides were analyzed to determine the droplet size distribution of the sampled aerosol cloud by measuring the diameters of 200 insecticide droplets per slide under a microscope. A modified technique developed by Yeomans (1949) was utilized to compute the spread factor in order to avoid the error introduced by using a fixed spread factor (i.e., 0.4 or 0.5). The correction factors were calculated for each slide by averaging the focal distance divided by the diameter of the particle for 10 droplets per slide.

The droplet distribution of the aerosol was characterized by calculating two parameters: the volume median diameter (VMD) and the percentage of the spray volume (PSV) in droplets less than 18 μ in diameter. The VMD is defined as the droplet size where 50% of the spray volume is located in droplets smaller than the VMD.

The VMD's and PSV's for the 81 slides were analyzed as a 3x3x3 factorial experiment with 3 replicates from each test block.

RESULTS AND DISCUSSION. The VMD's and PSV's were analyzed for the 3 machine pressures, 3 insecticide temperatures, 3 sampling distances from the machine and 3 samplers (replicates) for each test block. Table 1 presents the analysis of

Table 1. F-Values computed from VMD and PSV data.

Source	df	VMD	PSV
Samplers	2	.77	.37
Distance A	2	4.38*	8.21**
Temperature B	2	.23	2.87
Pressure C	2	29.9**	45.4**
AB	4	2.52	2.51
AC	4	.49	.99
BC	4	1.72	2.54
ABC	8	.55	.48

* Significant at 95% level.
** Significant at 99% level.

variance computed from VHD and VMD data. The F-values indicate whether the various effects significantly influence the droplet distribution. There was no significant difference in observed droplet distribution among any of the 3 individual samplers. The mean VMD calculated for each person taking the sample ranged from 15.3 μ to 15.8 μ. Mean PSV's ranged from 65.0% to 66.9%.

The insecticide temperature does not significantly affect the droplet distribution of the aerosol sample. Because the flow rate was adjusted to 4.0 fl. oz/min throughout the experiment as each temperature and/or machine pressure was changed, the lack of a temperature influence indicates that a change in insecticide viscosity does not affect atomization of 95% malathion when the machine is operated between 73° F. and 97° F. The mean VMD for each temperature ranged from 15.4 μ to 15.7 μ while the mean PSV ranged from 64.1% to 69.3%.

The data indicate that the machine pressure significantly affects the droplet distribution. Table 2 presents the mean VMD and PSV for each machine pressure. The mean VMD decreased from 16.8 μ to 14.0 μ as the machine pressure was increased from 4.5 to 6.0 psi. The mean PSV increased from 57% to 78.5% as the pressure was increased from 4.5 to 6.0 psi. The optimal VMD for malathion, as described by Lofgren et al. (1973) and Mount et al. (1968) is between 2 and 16 μ.

For field evaluation of operational equipment, it is necessary to see the insecticide cloud to insure the impingement of droplets on the waved slide. Observations indicate that cloud disintegration begins to occur at approximately 20 ft. from the machine. Thus, a sampler should stand no more than 20 ft from the machine. But as the data indicate in Table 2, the distance a sampler stands from the nozzle of the ULV generator significantly influences the observed droplet distribution. The mean VMD decreased from 16.2 to 15.0 μ as the distance was increased from 15 to 25 ft. The mean PSV also increased from 61.4% to 70.9% as the distance increased.

Mount et al. (1975) stated that the malathion label requires sampling at 25

Table 2. Mean VMD's and PSV's of ULV aerosols, observed as pressure and sampling distance from machine nozzle were varied.

Pressure	Distance from machine nozzle							
	15 ft		20 ft		25 ft		Mean ft	
psi	VMD (μ)	PSV (%)	VMD (μ)	PSV (%)	VMD (μ)	PSV (%)	VMD (μ)	PSV (%)
4.5	17.4	53.1	16.6	58.2	16.3	59.7	16.8	57.0
5.0	16.4	58.8	15.6	63.8	15.6	66.0	15.9	62.8
6.0	14.6	72.4	14.2	76.0	13.0	87.0	14.0	78.5
Mean	16.2	61.4	15.5	66.0	15.0	70.9	....	....

ft which allows larger droplets to settle out of the cloud resulting in a lower VMD for certain ULV generators. The data demonstrate no significant interactions (AB, AC, BC, or ABC) between the main effects (distance, pressure, and temperature). The main effects are therefore independent variables and do not affect each other. If the hypothesis that larger droplets may settle out is correct, there would be a significant interaction between distance and pressure (AC); the data indicate no significant interactions. We hypothesize that collected droplets tend to coalesce on the slide as the sampling distance decreases because the insecticide cloud is denser closer to the machine. Thus it appears that larger droplets tend to be more frequently collected closer to the machine when in reality, if the hypothesis is correct, this tendency is the result of coalescence.

References cited

Anderson, C. H. and Schulte, W. 1971. Teflon ® as a surface for deposition of aerosol droplets. Mosquito News 31(4):499–504.

Anonymous. 1972. Modern mosquito control. American Cyanamid Company. 3rd Edition, 30 p.

Lofgren, C. S., Anthony, D. W. and Mount, G. A. 1973. Size of aerosol droplets impinging on mosquitoes as determined with a scanning electron microscope. J. Econ. Entomol. 66(5): 1085–1088.

Mount, G. A. and Pierce, N. W. 1972a. Adult mosquito kill and droplet size of ultra-low-volume ground aerosols of insecticides. Mosquito News 32(3):354–357.

Mount, G. A. and Pierce, N. W. 1972b. Droplet size of ultra-low-volume ground aerosols as determined by three collection methods. Mosquito News 32(4):586–589.

Mount, G. A., Lofgren, C. S., Pierce, N. W. and Husman, C. N. 1968. Ultra-low-volume non-thermal aerosols of malathion and naled for adult mosquito control. Mosquito News 28(1): 99–103.

Mount, G. A., Pierce, N. W. and Baldwin, K. F. 1975. Droplet size of aerosols dispersed by portable and truck-mounted generators. Mosquito News 35(2):195–198.

Mount, G. A., Pierce, N. W., Lofgren, C. S. and Gahan, J. B. 1970. A new ultra-low-volume cold aerosol nozzle for dispersal of insecticides against adult mosquitoes. Mosquito News 30(1):56–59.

Thompson, G. A. 1973. Some errors inherent in ULV operations. Mosquito News 33(3):364–367.

Yeomans, A. H. 1949. Directions for determining particle size of aerosols and fine sprays. USDA Bur. Entomol. Pl. Quar. ET-267.