A COMPARISON OF TEFLON® SLIDES AND THE ARMY INSECTICIDE MEASURING SYSTEM FOR SAMPLING AEROSOL CLOUDS[1]

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ABSTRACT. The effects of method of droplet analysis, reader of Teflon® slides and distance on mass median diameter of a Cythion® aerosol cloud were examined in the calibration of an Army Insecticide Measuring System (AIMS). There were no significant differences in results among readers and between the AIMS and readers. There were slight but statistically significant differences between readers of Teflon slides and between the methods of analysis. Data supports the manufacturer's recommendation that, for the AIMS, the distance at which an aerosol generator air blast is between 3 and 7 m^3 s^{-1} must be determined.

INTRODUCTION

Characteristics desirable in a field technique for collecting aerosol droplets produced by ultralow volume (ULV) generators have been amply described (Peterson et al. 1978). For the past 2 decades at least, waving of Teflon® slides by hand or by rotating impingers have been the principal techniques used by field workers, since those techniques are simple and inexpensive. However, repeatability of data from field sites by workers using a variety of microscopes, spread factors, different insecticide lots and low sample size (typically 100–200 drops) has been a matter of concern. Although more sophisticated technologies for droplet collection and analysis are available, the mosquito control community at large has been reluctant to utilize and accept such instrumentation due to either initial costs or a general lack of formal endorsement by labeling authorities. Teflon slide waving technique need not be the only acceptable technique for aerosol cloud analysis. Also a better understanding of regulations governing aerosol droplet analysis, according to chemical labels, is an issue needing attention.

This current paper is a brief summary of results obtained using one such instrument based on hot wire instrumentation (Army Insecticide Measurement System (AIMS), KLD Laboratories, Inc., Huntington Station, NY) compared with Teflon-coated slides. Although current costs of the AIMS is high relative to that of the equipment needed for analyzing slides, it is relatively inexpensive compared with a variety of laser particle analysis systems. The AIMS probe is relatively delicate, but no careful alignment is necessary. The main advantages of the AIMS is that it is relatively easy to use, can count and analyze up to 10,000 drops (collection time approximately 100 seconds), and the analysis is done in real time in the field (allowing immediate adjustments to the aerosol generator).

MATERIALS AND METHODS

A stationary LECO® 1600 HD (Lowndes Engineering, Inc., Valdosta, GA) was used as the aerosol generator. The machine was calibrated with Cythion® (malathion) to 8.6 fl oz min^{-1} (maximum labeled flow rate for mosquito control) prior to the test. The blower pressure was adjusted to 5 psi. Samples were collected under the following conditions: RH 85%, wind speed 3 km h^{-1} and ambient temperature 20.5°C. Aerosol droplets were collected on Teflon-coated glass slides mounted on a 1.5 m dowel rod with a standard alligator clip and in a stationary settling chamber. The slides were swung with a "baseball swing" into and upward through the aerosol cloud. The test included 3 replications (1 slide and 1 AIMS reading = 1 replication) at 1.5 m and 7.6 m with slides, 1.5 and 4.6 m with the AIMS and at 4.6 m alone with the settling chamber. Three slides were waved in the same fashion as the test slides but upwind of the aerosol generator to serve as controls. All slides were sealed in a slide box after sampling and read within 3 hours. One hundred randomly selected droplets were measured on each slide with 3 separate microscopes by 3 individual readers in turn. Droplets ≤1 micron were not included in the count. Eyepiece divisions were

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[1] The opinions and assertions contained herein are the private ones of the writers and are not to be construed as official or reflecting the views of the Navy Department, the Naval Service at large, Florida A & M University, the City of Vero Beach, FL, or the USDA-ARS.

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calibrated for each microscope and the label spread factor of 0.69 was used in the calculations. Settings selected on the AIMS were "insecticide" and "100 seconds." Three "hot-wire wands" (Mahler 1987) were tested with each of the 3 AIMS devices with one reading taken with each wand. These readings were then averaged. The 3 AIMS devices were individually calibrated at the KLD Associates laboratory immediately prior to use in this test. Wands were taped onto stands 1.5 m in height and placed at distances at which the air flow from the aerosol generator was between 3 and 7 m^3 sec^{-1} (average approximately 5 m^3 sec^{-1}). This varied due to effects of a slight breeze and normal surges in the aerosol generator (variables difficult to control). All measurements were analyzed by a ULVDROPS Software Program (Haile et al. 1987), VECTEC Droplet Analysis Program (VECTEC, Orlando, FL), and a hand-held Hewlett Packard calculator (Model HP 41CVX). The first 2 procedures utilized interpolation as the method of analysis and the third linear regression. The corresponding mass median diameters (MMD) for slides and the AIMS readings were subjected to analysis of variance (SAS Institute 1982) and the means separated by Duncan's multiple range test (SAS Institute 1982).

In a separate test, the air blast was measured at the 8-m Cythion label distance for a Leco HD, Micro-Gen G4 (Micro-Gen Equipment Corp., San Antonio, TX), Leco P1, London Fog Eliminator (London Fog Inc., Long Lake, MN), and a Thermo Fogger 3901 (Thermo Fogger Co., Libertyville, IL). A distance was also determined at which each machine air blast was between 3 and 7 m^3 s^{-1} (= "preferred distance," Table 3, AIMS manufacturer's recommendation). Impingement of droplets on the wire requires an air blast exceeding 3 m^3 s^{-1} but an air blast greater than 7 m s^{-1} frequently damages the instrument (= broken wire). The high flow rate setting was used with all machines except the Leco HD. Four AIMS readings were taken, averaged, and compared with a MMD obtained from a Teflon slide waved through an aerosol cloud generated by each machine. The Teflon slides were processed as described above.

RESULTS AND DISCUSSION

Tables 1, 2 and 3 show the variation in MMD among the 3 methods of analysis, 3 readers of slides, 2 distances and 3 AIMS devices. The statistical models accounted for 99 and 93%, respectively, of the variation in the observed data.

Although there was a significant difference ($P \leq 0.0001$) with respect to MMD between methods of analysis, the spread in means was very small (0.4 microns) and could not be used to justify the recommendation of one analysis program over another (Tables 1 and 2).

There was a significant difference ($P \leq 0.0001$) between readers with respect to MMD when averaged over distances and methods of analysis. Overall, the difference in means between Readers A and B was 3.3 microns (total droplets measured = 2,700) (Tables 1 and 2). When compared with the range of mass median diameters permitted on some insecticide labels (i.e., Scourge®, ground application = 5–30 mi-

Table 1. Comparison of mass median diameters by method of analysis, slide reader and distance.

Comparison of MMD by method of analysis[1]		
Method of analysis	*n*	Mean (±SD)
HP 41CVX	27	17.1 ± 2.7a[2]
ULVDROPS	27	16.8 ± 2.9ab
Vectec Droplet Program	27	16.7 ± 2.7b
Comparison of MMD by reader[3]		
Reader	*n*	Mean (±SD)
B	27	18.9 ± 3.3a
C	27	16.2 1.4b
A	27	15.6 ± 1.6b
Comparison of MMD by distance[4]		
Distance	*n*	Mean (±SD)
25 (settling chamber)	27	17.7 ± 4.0a
25	27	17.4 ± 1.3a
5	27	15.6 ± 1.6a

[1] Averaged over reader and distance.
[2] Means followed by the same letter are not significantly different ($P \leq 0.05$) according to Duncan's (SAS Institute 1982) multiple range test.
[3] Averaged over method of analysis and distance.
[4] Averaged over method of analysis and reader.

Table 2. Analysis of variance and comparison of readers of Teflon slides and the Army Insecticide Measuring System.

Comparison of readers and the AIMS		
Method	*n*	Mean MMD (u)
Reader B	3[1]	16.7 ± 0.2a[1]
AIMS No. 3	6[3]	15.9 ± 2.2a
AIMS No. 2	6	15.7 ± 0.7a
AIMS No. 1	6	15.2 ± 2.7a
Reader C	3	14.9 ± 0.2a
Reader A	3	14.8 ± 0.1a
Control (blank slides)	3	0b

[1] ULVDROPS method of analysis at 5 ft only.
[2] Means followed by the same letter are not significantly different ($P \leq 0.05$) according to Duncan's (SAS Institute 1982) multiple range test.
[3] ULVDROPS method of analysis at 5 and 15 ft.

Table 3. Comparison of mass median diameters as measured by the Army Insecticide Measuring System (AIMS) and Teflon slides at selected distances.[1]

Machine	Flow rate (ml/min)	Distance (m)[2]	AIMS MMD (μ) Preferred dist.	AIMS MMD (μ) Label dist.	Slide MMD (μ) Preferred dist.	Slide MMD (μ) Label dist.
Leco HD	90	1.5	7.9 ± 1.8	<1.0	11.1	13.9
Micro-Gen-G4	90	0.7	15.6 ± 3.1	<1.0	12.4	16.3
Leco P1	178[3]	0.9	25.9 ± 2.9	<1.0	33.7	25.3
Eliminator (thermo-fogger)	—	0.6	1.8 ± 0.4	<1.0	21.5	20.0
Thermo-Fogger 3901	1000	0.9	12.7 ± 2.2	<1.0	26.9	20.4

[1] 4 replications with the AIMS, 1 slide (100 drops/slide).

[2] Distance where actual blast ranged between 3 to 7 m^3 s^{-1}. Air blast at 8-m label recommendation was <1 m s^{-1} for all machines.

[3] Flow rate setting no. 3.

Table 4. Percent malathion aerosol droplets in each "bin" as generated by a Leco HD and measured by the Army Insecticide Measuring System (AIMS).[1,2]

Bin	Distance (m) 1.5	2.4	4.6
1.0	44.5 ± 1.5	42.7 ± 2.7	44.3 ± 3.3
1.5	23.3 ± 1.3	25.3 ± 2.2	25.9 ± 2.5
2.5	12.7 ± 0.6	13.9 ± 1.2	14.5 ± 1.5
6.5	7.9 ± 0.6	8.1 ± 0.4	7.7 ± 0.8
12.5	6.7 ± 0.9	5.8 ± 1.2	4.8 ± 0.9
22.0	3.9 ± 0.5	3.4 ± 0.8	1.9 ± 0.5
31.5	1.0 ± 0.2	0.9 ± 0.3	0.6 ± 0.4
40.0	0.1 ± 0.1	0.2 ± 0.1	0.1 ± 0.1
90.0	0.03 ± 0.02	0.03 ± 0.02	

[1] The droplets, once measured, are assigned by the AIMS micropressor to one of 11 bins; each bin containing a range of droplet sizes whose diameters are close to 1.0, 2.5, 6.5, 12.5, 22.0, 31.5, 40.0, 90.0, 170.0 or 200.0 microns.

[2] Four replications at each distance.

crons), this difference may be a small matter. Additionally, when the data for readers was analyzed at 8 m only (label recommendation), there was no significant difference (A = 17.1, C = 17.3, B = 18.9, $P > 0.05$). The level of consistency shown by these three independent readers, using 3 independently calibrated microscopes, indicates that a high degree of confidence may be placed in the currently labeled "Teflon® slide technique" being utilized by many workers. There was no significant effect of distance with respect to MMD (Tables 1 and 2).

No significant difference with respect to MMD was shown when readers at 1.5 m were compared with the AIMS at 1.5 and 4.6 m. Only the ULVDROPS program was used for that analysis. The range of MMDs for slides and the AIMS was 1.9 microns (Table 2).

Preliminary to a "hot-wire" device being accepted by the mosquito control community, it must be found to measure the droplet spectra of an aerosol cloud accurately, be inexpensive and be simple to use (Swartzell 1991). Hot-wire data should correlate acceptably with the labeled method in current and popular use. The data presented here suggest that there was no statistical difference between a newly calibrated AIMS and Teflon slide data regarding MMD when the air blast was between the recommended levels. Also, for commercial concerns or research stations frequently calibrating a large number of aerosol generators, the use of an AIMS may be cost effective when the time required to read and evaluate a Teflon slide (10–25 minutes) is considered.

These data show that there is a difference in MMD measurements between Teflon slide readings and the AIMS when using aerosol generators having "air blast" less than a heavy duty generator such as the Leco 1600 HD (Table 4). In this test the air blast was less than 1 m^3 s^{-1} at the Cythion label distance for all machines. The AIMS registered MMDs < 1.0 at the Cythion label distance for all machines and at the "preferred distance" for both thermofoggers. Clearly, if an AIMS is to be used to determine a MMD for cold aerosol generators, the distance at which the air blast is between 3 and 7 m^3 must be predetermined for each machine tested.

These data indicate a high degree of reliability using the slide waving method, different individuals reading slides and various types of aerosol generators. The Teflon slide technique is currently Environmental Protection Agency labeled and the insecticide industry is in no hurry to initiate label changes concerning droplet analysis of aerosol clouds. Even though these data show a high degree of correlation in MMD between AIMS and slide wave methods it also shows variation between distances and aerosol generators with the AIMS alone (Table 3). There is no doubt that the slide waving method is selective for large droplets and AIMS selective for smaller droplets (Table 3). Approximately

90% of all droplets counted with the AIMS were smaller than any observed on a Teflon coated slide (Table 4). These data further demonstrate differences between the Teflon slide method and the AIMS for thermo-foggers (Table 3). The Teflon slide method indicates larger MMDs than those indicated by the AIMS for the foggers at both distances. A possible explanation might be coalescence of droplets as they impinge onto a slide and that interpreted as a larger drop. That possibility needs investigation.

If the purpose of monitoring aerosol droplets is to compare equipment or the efficacy and dispersion of droplets for mosquito control, then it would appear that modern technologies need to be incorporated in the labeling of insecticides. But if the primary intent is to monitor larger droplets that may have a damaging effect on non-targets or automobile paint surfaces, the Teflon slide method has proven repeatable over time.

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