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A Field Measurement Device for the Aerosols Used in Mosquito Control

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Abstract. *Field droplet sizing is particularly difficult in mosquito control. The droplets produced have a low collection efficiency often leading to inaccurate measurements of the droplet size spectra. An attempt has been made here to find a simple field method that will return a reliable droplet size spectrum for machine calibration and adjustment. Comparisons were made between laser diffraction particle sizers in the laboratory and rotary impingers in the field. This field method is also to be used on an experimental basis to characterize aerosol movement and fate.*

Miscalculations of droplet spectrum statistics ($Dv_{0.1}$, $Dv_{0.5}$, and $Dv_{0.9}$) occur in the field because the whole droplet size spectrum is rarely sampled due to collection inefficiencies with most samplers. In an attempt to sample a more representative fraction of the spectrum, a rotating impinger has been developed. The sampler has a different size and velocity of collection surface which provides a significant improvement to conventional equipment. Results showed that there was still an underestimation of the smaller droplets due to their low collection efficiency, so a correction factor is still required. This new sampler which operates at 5.6 m/s with a width of 3 mm consistently measured spectra comparable to the laser systems if the Yeomans correction is applied. This sampler could become very useful for measurement of the poly-disperse aerosol used in mosquito control.

Keywords. Mosquito Control, Sampler Development, Droplet Statistics, Laser Measurement, Field Techniques and Aerial Application.

Introduction

Laser diffraction particle size analyzers are often used to characterize the droplet size spectrum from a nozzle system. However, field techniques are still required to ensure that atomizers are working operationally. Field droplet sizing for equipment verification is particularly difficult; it requires that the emitted droplets be collected onto a surface for analysis. The likelihood of collecting a droplet depends on the size of that droplet, its velocity in relation to the target and the size of that collector. As the droplet size and velocity increases, the likelihood of droplet capture also increases. However, as the collector size increases, the likelihood of droplet capture decreases.

The droplets produced for mosquito control are in a size range (1-150µm) where capture efficiency can be low. Smaller drops have lower capture efficiencies so overestimation of the average size of the droplets in the air is likely. The average droplet size is computed as volume median diameter ($Dv_{0.5}$) where half the spray volume is in droplets larger than the computed diameter and half in droplets smaller than the computed diameter. The $Dv_{0.1}$ and $Dv_{0.9}$ are additional measures included to show the range of the droplet size spectrum and describe the proportion of the spray volume (10% and 90%, respectively) contained in droplets of the specified size or less.

The collection efficiency of drops <10-15 µm is low because of the low impaction efficiency of these drops (Rathburn, 1970; Cooper, et al., 1996). Therefore, the droplet size spectrum used in mosquito control would be overestimated. A method that compensates for higher critical impingement velocities of smaller drops is used to calculate the $Dv_{0.50}$ (Yeomans, 1945). This method considers that the collection efficacy of droplets on slides increases directly with the square of the droplet diameter (D^2). Even though volume is proportional to D^3 to compensate for the decrease in the rate of collection as the droplet size decreases, the $Dv_{0.5}$ is calculated on the basis of droplet diameter D^3/D^2 or D (Yeomans, 1945). The slide wave method with this correction factor does work comparably well for aerosols with narrow droplet spectrums like those from ground based cold foggers (Brown, et al., 1990). This is because these sprays are in the range of 5-25µm; hence, the collection efficiency of droplets is directly proportional to D^2 (Yeomans, 1945). Research has confirmed that the slide wave for cold foggers is a respectable test producing results comparable to the Army Insecticide Measurement System or AIMS, a hot-wire device (Brown, et al., 1993).

The conventional rotating slides used for measurement of aerial sprays, however, completely miscalculate the median volume of sprays with wider drop size spectrums (Rathburn, 1970). For aerial sprays, using D instead of D^3 as a cumulative volume calculation is inappropriate. Significant underestimation of the $Dv_{0.5}$ (Fig. 1) occurred due to the fact that the sprays produced by the old flat fan system were poly-disperse; and the effect of larger droplets on the cumulative volume fraction is lost when D is calculated alone (Yeomans, 1945; Mount, et al., 1996). The figure below shows to what extent the $Dv_{0.5}$ was under estimated using a rotating impinger and the Yeomans correction for flat fan nozzles.

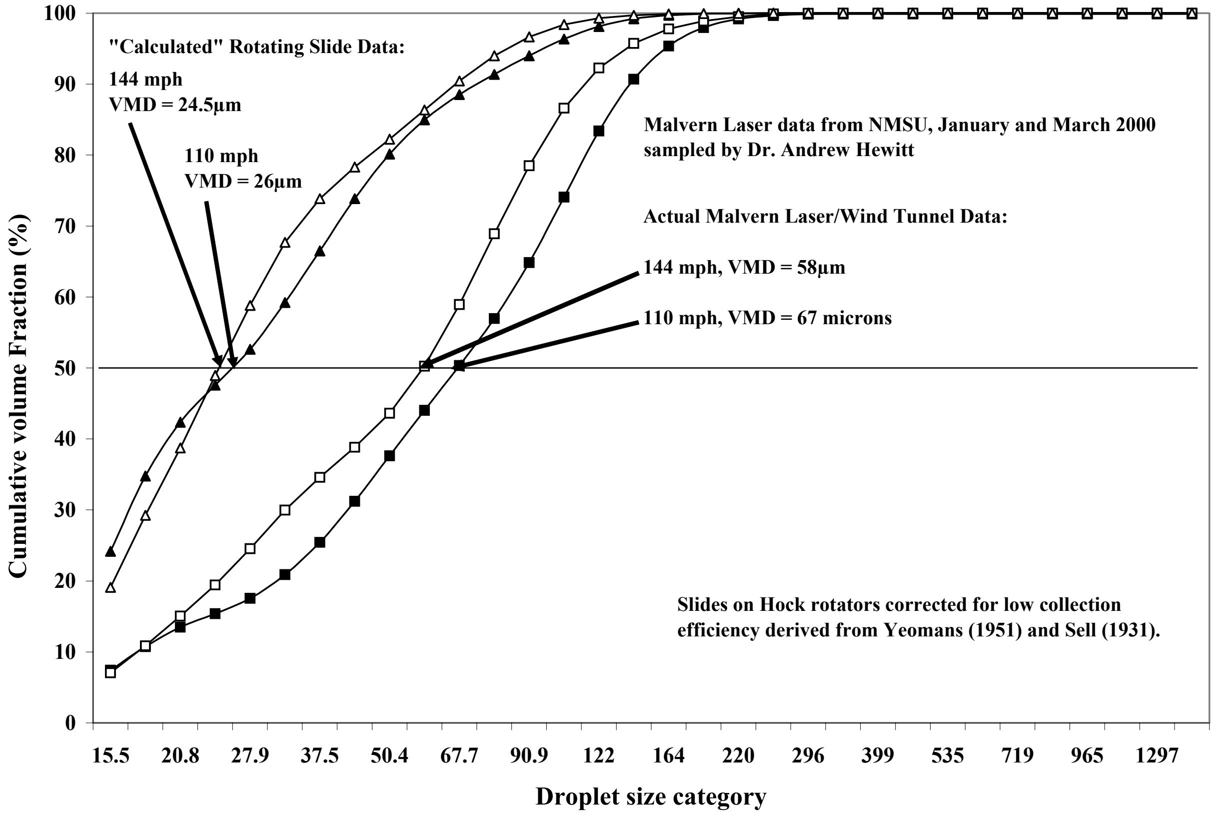

Figure 1. Droplet size distributions measured using a Hock impinger with data corrected using the Yeomans D conversion compared to actual droplet size distributions measured with a Malvern laser system; 8001Flat Fan Nozzle, ULV Oil, 70 psi, 135 degrees (45 degrees into air stream), 110 mph and 144 mph airspeed.

Research has shown that aerosols with a smaller droplet size distribution than the old flat fan system decreased ground contamination and significantly increased mosquito mortality down wind (Dukes, et al., 2004). A Malvern laser system was installed in Florida to isolate nozzle systems that could better provide the droplet distributions we required. The impingers used to collect droplets in the previous studies were Hock impingers rotating the 2.5-cm wide slide at 3 m/s. It was postulated that if the rotational speed was increased and the slide size reduced then a slightly more accurate sample of droplet size distribution would be taken. A number of rotational speeds and slide sizes for the new sampler were investigated. Then a variety of mathematical conversions were applied to try to best correlate results with laser diffraction measurements of drop size distribution for the same nozzle setups. The sampler and correction factor found best suited to measure aerosols where 90% of the droplets are within the 5-50 µm diameter range, hence specific to mosquito control, is presented.

Laboratory Methods

Two nozzles were evaluated in this study: a rotary cage atomizer representing the upper end of droplet sizes used in mosquito control and an impaction nozzle representing the lower end of droplet sizes used in mosquito control. A Malvern 2600c laser diffraction particle sizer was used to characterize the drop size spectra from the rotary cage nozzle (AU4000, Micron Sprayers

Ltd., Bromyard, UK). Measurements were made with a 600 mm focal length lens measuring droplets of size 3 to 1128 µm. The first size class of the instrument measured droplets with diameters 3 to 11.6 µm, and successive size classes extend in wider size class separations to 1128 µm. Results were obtained using model independent analysis. The AU4000 was operating at a wind speed of 64.8 m/sec (145 mph), a loaded rotational speed of 10,000 rpm at 43° blade pitch, and a flow rate of 1.5 and 3.4 L/min (51 and 115 oz/min). A Malvern SprayTec laser diffraction particle sizer was used to characterize the drop size spectra from the high pressure impinger nozzles. The laser emits at 670 nm with a 1 cm beam width and is focused by a 450 mm lens. The overall droplet measurement range extends from 0.5 µm to 850 µm. The PJ12 high pressure impinger nozzle (Bete nozzles, Thomas Agency, Winter Park, FL) was operating at a wind speed of 69.2 m/sec (155mph) spray pressure of 19.3 MPa (2808 psi), and a flow rate of 0.47 L/min (16 oz/min).

Field Methods

Two Micronair AU4000 nozzles were fitted to a DC3 with a forward speed of 67.1 m/s (150 mph), a loaded rotational speed of 10,000 rpm at a 43° blade pitch and applying 2.3 L/min (80 oz/min). Two PJ12 impinger nozzles (Bete nozzles, Thomas Agency, Winter Park, FL) were placed on another DC3 aircraft flown at 69.2 m/s (155mph). The spray pressure was 19.3 MPa (2808 psi) and the flow rate was 0.47 L/min (16 oz/min). Both aircraft (DC3's) were atomizing Dibrom Concentrate (naled). All spray tests were run at dawn with wind speeds of 0-1 mph. The aircraft flew over the samplers at 12-15 m (40-50 ft) to minimize the loss of the ultra fines. A low emission height, flying into the wind, and an appropriate spread of replicate samplers considering the nozzle positioning is required for proper droplet sizing. Both atomization systems were mounted on a tail boom; samplers were placed 20 ft apart in line with the direction of flight.

3 mm slides were fabricated from extruded acrylic bars (McMaster-Carr, Atlanta, GA) and coated with FEP (Teflon®) tape (McMaster-Carr, Atlanta, GA) rather than cutting Teflon coated glass. The fabricated slides were positioned 18 cm apart on threaded nylon rod. Holes were drilled for the slides and nylon nuts screwed in on the outer edge to hold the slides in position. A third hole was drilled in the center to attach the rod arm to the motor. The DC motor rotated at 590 rpm generating 5.6 m/s at the slide.

Two samplers were used in each replication, which consisted of one spray pass. Each nozzle setup was evaluated three times. Once the aircraft had completed its pass, samplers were left running for up to 15 mins. Slides were collected and placed in sealed plastic containers. Once all the samples were collected they were taken back to the laboratory for microscopic assessment. Droplet counts had to be completed within 2-3 hours due to dibrom volatility. One hundred droplets were counted on each slide giving an approximate total of 600 drops per nozzle type.

Results and Discussion

Malvern measurements of the AU4000 are presented as $Dv_{0.5}$ alone. The D^3 calculation was run for $Dv_{0.5}$ but still presented a much higher median volume than all other measurement methods indicating that the sample still did not truly represent the smaller droplet sizes even using a faster rotational speed and smaller sampler size. The correction D^2 (n x d) however produced a $Dv_{0.5}$ comparable to that of the laser systems. Results from the high pressure impinger nozzle are presented as $Dv_{0.1}$, $Dv_{0.5}$, and $Dv_{0.9.}$ The D^3 again severely over estimated the droplet size spectrum again. For both nozzle systems the D calculation along with 5.6 m/s, 3 mm sampler returned droplet size distributions very close to that of the laser measurements (Table 1). Figure 2 shows the cumulative volume fraction for the AU400 and the PJ12 nozzles using the new sampler.

Table 1 Droplet size spectrum measured by the field sampler (using D Yeomans correction) and Malvern for the two nozzle types

	PJ12 Field	PJ12 Malvern	AU4000 Field	AU4000 Malvern
Dv $_{0.1}$	3	3	6	24
Dv $_{0.5}$	11	12	23	
Dv $_{0.9}$	26	30	43	

As mentioned previously the D^3 calculation for cumulative volume fraction provided a significant over estimation of the droplet size distribution. The new nozzle systems investigated here produce a much smaller and narrower spectrum compared to the old flat fan system. The narrower spectrum (<10% of the drops over 50 μm) and therefore the collection efficiency of the majority of droplets on slides more closely correlates with the square of the droplet diameter (D^2). Hence the Yeomans correction factor taking the measure of D rather the D^3 can now be applied to the nozzles used for aerial applications. Therefore counts were analyzed as number multiplied by diameter alone (n x d) following the Yeomans correction for reduced collection efficiency.

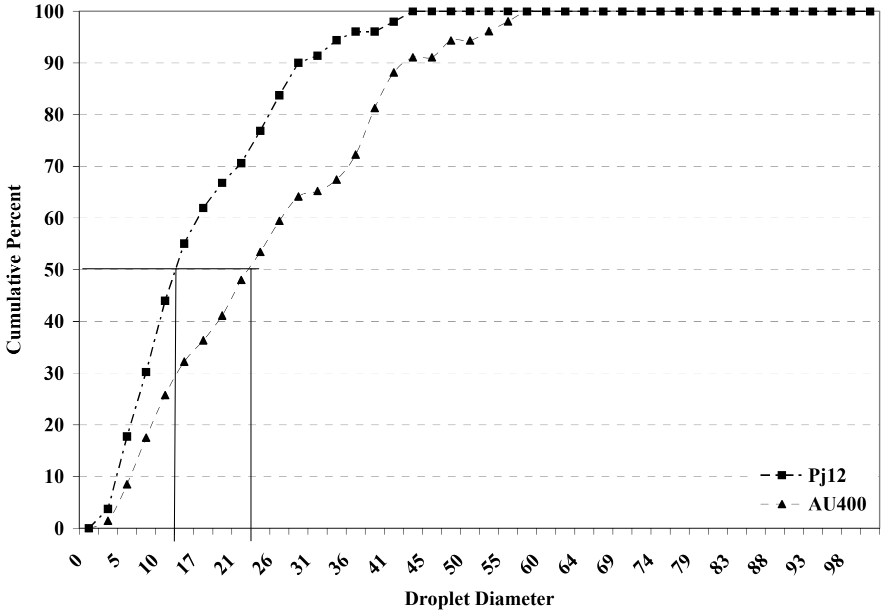

Figure 2 Cumulative volume percent using D rather than D^3, as measured by the new rotating impinger for the two nozzle systems

Conclusions

A field sampler has been developed for mosquito control which provides a representative measure of the spray cloud. The motor and battery system for this sampler is simple and inexpensive, so more likely to be implemented. Applicators can build their own for approximately $30, which is much more reasonable than off the shelf products. This device/technique is only relevant to those applicators that have moved to smaller emission spectra ($DV_{0.5}$'s of 12-30 μm) by using high pressure systems, air assist nozzles, high speed rotary atomizers or other atomizers. As more aerial applicators move towards smaller droplet producing systems this device in conjunction with the Yeomans correction should be recommended as a field measuring system. But in the meantime the message must be emphasized this sampler is not applicable for measuring "conventional spray systems" sprays with $DV_{0.5}$'s in excess of 50 μm.

In addition this sampler can be used by researchers to characterize the aerosol flux, to advance our understanding of pesticide movement and improve upon our application techniques. Preliminary studies have shown that using an active sampler rather than a passive sampler, for measurement of our drifting aerosol, negates the effect of wind speed change from site to site. Previously results were confounded with passive samplers because their collection efficacy was highly dependant on changing wind speed from sample site to site.

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