Sampling and Optimization in Mosquito Control

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Abstract

Attempts are being made to improve the methods used to characterize the drifting spray cloud used in mosquito control. Much work done in this field has relied on equipment inherited yet again from agricultural drift assessments. We however are concerned with smaller droplet size spectrums. Much work in agriculture is dealing with much larger volumes of chemical and a large proportion of the drift is significantly larger. Agriculture considers anything under 100µm to be a drift threat we consider anything above 50µm to be a deposition threat. At the time of application the meteorology is often not ideal for production of an effective adulticidal cloud, nor good collection efficiency due to low wind speeds. We have had to spend a great deal of time over the last two years working on improving our methodologies. I will introduce some of the most important changes made so far.

Introduction

For all pesticide applications there will be a specific set of methods most applicable to assess application efficiency. Methods often are a trade off between gathering an appropriate sample number and returning the most precise data. In many cases the natural target is the most appropriate object to sample. For mosquito control that would be the flying mosquito or the air within which the chemical is directed to impact upon the flying mosquito. Our approach has been to develop methods which return information on the volume of chemical moving through a sample area and that depositing to the ground. The droplet size distribution of the spray cloud is also measured. In addition an indicative measure via cage bioassay of the effects of this cloud on the target species is returned. It is widely understood that the primary parameter affecting drift is the size of the droplet. The secondary parameter is meteorology; many other factors are involved, but it is toward these two that we are concentrating our measurements to attempt to return explanatory information on pesticide application efficiency.

Recent information on the nocturnal boundary layer indicates that although the static stability tends to deepen during the night, the presence of wave phenomena and low level jets may lead to sporadic breakdowns in the stability. This is due to the significant wind shear with height. This shear will eventually erode into turbulence that may propagate downward through the boundary layer. This “upside down” turbulence is in addition to turbulence that is initiated mechanically at the top of the canopy and reaches upwards. Spraying in strongly stable conditions means that the spray will drift or be advected to extreme distances. Neutral or slightly stable conditions are more likely to occur in overcast skies and there would be more mixing of the spray in these cases. But there are likely other times in an otherwise very stable night when other events can cause the rapid mixing of the spray down to the near ground level targets. Even if the spray reaches the canopy top efficiently, there is then the need to penetrate the canopy without losing much of the spray to deposition in vegetation. The correct droplet spectrum is essential here but meteorology plays an important role too. Stability in many dense canopies is opposite to that outside of the canopy, whereas in a more open canopy, the stability is closer to that outside. Therefore, when spraying heterogeneous canopies at night, any spray that does penetrate may encounter anything from very unstable to very stable conditions. Added to this is the possible presence of bursts or sweeps which cause large penetrations or ejections of air into or out of the canopy.

The proper instrumentation and sampling is needed to understand this panoply of nocturnal events which influence the mosquito adulticide spray. Any such information garnered can reinforce the theoretical basis and applicability of present and future models.

Cloud Characterisation

The most popular field method for evaluating droplet spectra in mosquito control was the glass slide wave for ground ULV applications and rotating slides (impingers) for aerial ULV. The collection efficiency for drops <10µm (Rathburn, C. B. 1970) <10-15µm (Cooper, et al, 1996) is low because of the low impaction efficiency of these drops. A method developed by Yeomans that compensated for higher critical impingement velocities of smaller drops is used to calculate the VMD (Yeomans, A. H. 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 their spray is in the range of 5-25µm, a range within which the collection efficiency of droplets on waved glass slides is directly proportional to D2 for diameters. Much research has confirmed that the slide wave is a respectable test producing results comparable to the AIMS hot-wire field measuring device (Brown, et al 1993). The rotating slides used for measurement of aerial sprays however, completely miscalculate the volume of sprays with wider drop size spectrums. In this instance using D instead of D3 as a cumulative volume calculation significantly underestimates the volume contribution of drops with a diameter larger than 50 microns and hence the spray clouds' true VMD (Mount, et al 1996 and Yeomans, A. H. 1945).

The impingers used to collect droplets in the past were hock impingers rotating the 2.5cm slide at 3m/s. It was postulated that if the rotational speed was increased and the slide size reduced then a slightly more accurate sample of the smaller droplet sizes within the spray distribution, those that constitute the majority of the drifting cloud, would be taken. A number of rotational speeds and slide sizes were investigated. Then a variety of mathematical conversions were applied to try to best imitate results from laser diffraction measurements of drop size distribution for the same nozzle set ups.

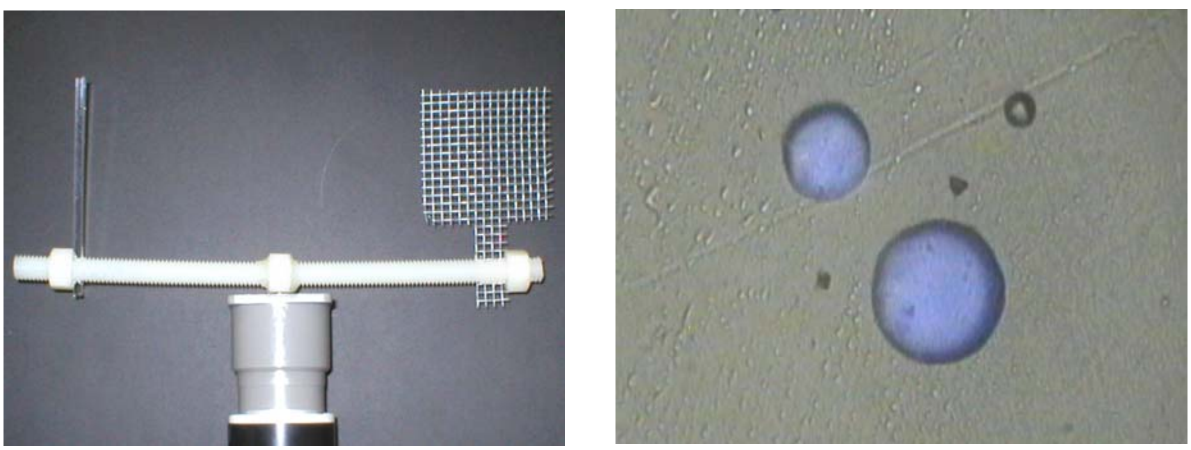

Figure 1 Left: Photograph of the spinner holding a 3mm slide on one side and a welded wire mesh on the other rod arm length to sampler 18cm rotational speed 5.2m/s Right: Three droplets to which fluorsece hence are pesticide one that does not, this could be sap

Volume measurements were taken from a wire mesh held on the opposite side of the rod arm to the slide. Wire mesh was chosen because the thin wire would have high collection efficiency, and the mesh design would provide increased surface area and strength.

Meteorological Measurement

Time of Application is predicated on the behaviour of the target – mosquitoes which tend to host seek after sunset and before sunrise. An efficient droplet spectrum has many small droplets which are not greatly subject to gravity but are susceptible to turbulent air movements Applications are primarily made at night – in a nocturnal boundary layer. There are normally low winds and a surface inversion begins to grow. Applications are made in variable boundary layer depths and inversion heights. Under conditions of strong static stability, the surface layer may decouple from the upper layer. Other phenomena such as intermittency, waves and low level jets may complicate the predictability of conditions. Other problems are heterogeneous canopies and complex land-sea interactions. It is therefore extremely important to have detailed information on meteorology if we are to be confident in our understanding of the effects of one spray to the next.

Equipment and Analysis

Standard anemometry such as propeller anemometers is not suitable for our work due to inertia and high starting thresholds. Sonic anemometry is sensitive with rapid acquisition rates meaning fluxes as well as length and time scales can be found. We currently posses two, 3 dimensional sonic anemometers, for measurements of wind speed within canopy structures. The 3D is essential because important air movements in the canopy at night are vertical. Canopy measurements are important because mosquitoes predominantly reside within the more humid air of the canopy. A sonic detection and ranging device (SODAR) is the next sensor on our list; it reads wind and temperature fluctuations, in 2 dimensions. We have sigma and theta software for vertical and horizontal wind speed measurements respectively. Importantly we have also requested automatic inversion software which will provide real time detection of the inversion. This could show us exactly where and how strong the inversion is allowing us to respond appropriately. We collaborate with districts that have Kitoon weather stations, allowing us to measure wind speed and direction at application altitude. Over a hundred ibuttons have been purchased which are strung up within the canopy to provide temperature profiles and also on the tether of the kitoon for further temperature profiles. A meteorological montage, no less.

Fig 2 From left to right the is 1) the 3D sonic anemometer from Campbell Scientific 2) the 2D sonic from Gill, 3) the open field base station and 4) the kitoon at flight altitude. On the Kitoon tether flagged at the bottom of the picture is one of our ibuttons there top provide a temperature profile.

Techniques such as spectrum analysis which displays the information on turbulent eddies in a well ordered manner and wavelet analysis which returns both time and frequency information may be needed.

Another technique is conditional analysis which describes the contribution of energy from large coherent structures in the form of sweeps and bursts. These events are very intermittent with typically half of the stress being delivered in less than one tenth of the time.

Results and Implications

- Results returned from the field evaluation have shown us that the rotating impinger is a sound device for comparative measurements from one test to the next. Improved collection efficiency compared to the old hock samplers was achieved with a 5.2m/s and 3mm slide size. For the droplet size range produced in mosquito control this sampler provides an improved droplet size distribution.

- Collection efficiency for this rotating impinger was calculated using the Stokes number and the data was converted appropriately. This did not bring our data in line with Malvern laser data. This is likely due to the fact that the spinner is rotating and the mesh is present, some form of computational fluid dynamics would be require to try to calculate the Reynolds number for this impinger and hence get a better grasp of the collection efficiency. The Yeomans correction, when applied, bought our data almost perfectly in line with Malvern laser data. This might just be serendipity, or there could be a sound mathematical explanation which again can only be answered with further detailed research

- Using an active sampler negates to a degree differences in wind speed from one sample site to the next. Previous passive samplers in our situation have therefore been made obsolete seeing as the data returned buffers the change in collection efficiency from one site to the next due to habitat (hence wind speed) change.

- The rotating impingers low cost have meant that hundreds can be deployed and effectively assessed for any one experiment. The volume collected due to the samplers active nature has also allowed us to move over from Gas Chromatography (a limit on sample number) to Fluorimetry. Fluorimetry is a faster less expensive analytical technique.

- Using fluorimetry enables us to rapidly run our samples increasing the number of samples possible in any one test. It also allows us to discriminate between pesticide droplets and foreign liquids collecting on the slide. The presence of the foreign droplets seriously puts into question any previous Teflon slide data used in similar studies which don’t have a discriminating fluorescent tracer in the pesticide.

- Small wind tunnel tests showed that wire size was not in this instance of major import instead a high openness fraction was required so that air movement was not inhibited too much around the individual wires.

- What we have created is a sampler that presently gives us good comparative data. The collection efficacies and inefficiencies will be properly investigated using a wind tunnel and laser facility along with computational fluid dynamics. Our research into the collection efficiency of this rotating impinger is ongoing. Collaboration with Florida A&M and Florida State engineering departments will physically test and computationally model our spinner

- Small wind tunnel tests have shown that for most experimentation the caged mosquito bioassay can only be used as an indicator of mortality. The wind tunnel tests working with an LC 50 and LC 25 for *Ochlerotatus taeniorhynchus* showed that after 20mins cage holding hence, exposure to secondary pick up of pesticide, there is a significant increase in mortality. These bioassays are still good however as an indicative measure that a fatal dose moved through the area. They are also useful to compare tolerances and or resistance levels from one species to the next.

- The sonic anemometers have provided detailed and reliable information by which we can make assured conclusions about effect due to knowledge of the prevailing atmospheric conditions at the time of application.

- The SODAR although not available as yet will allow us to visualise conditions aloft. The information returned will allow experimentation to follow the dynamic of atmospheric change rather than using standard altitudes treatment parameters.

Conclusions and Impacts

Models for the prediction of the fate of sprayed material are presently not designed for the nocturnal, non-uniform conditions within which we apply our compounds. Transport of momentum and scalars including pollutants or small spectrum sprays is dominated in the horizontal by the mean wind and in the vertical by turbulence. Higher order models may be needed and such models may require variances which are measures of turbulence intensity and co-variances which are measures of flux or stress. At present we work with AgDisp and possibly in the future there will be a combination of AgDisp and an air pollution model called Calpuff. Nevertheless what is created will require validation. It is with the development of these sampling techniques that we will be able to provide more reliable data for the modellers. This validation will not just help the modellers, but also operators who harbour a certain amount of mistrust in the use of smaller droplet sprays, greater distances for offsets and new spray optimization techniques. It is hoped that the data collection and analysis from these field measurement techniques will either confirm or dismiss their fears.

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