

## Invited Presentation Articles

### Aspects to Consider for Vector Control

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#### Abstract

The aerial application of mosquito adulticides is an important part of many mosquito control programs' IPM approach. For some it is the only effective method for dealing with large migratory populations of mosquitoes. Mosquito adulticides are applied as aerosols over large areas of 10,000 to 50,000 acres with diverse habitats, with the intent of drifting through these target zones. Much research has been conducted for these adulticides, primarily in laboratory wind tunnels and small scale field trials, and all indicate 5 to 30 microns as the optimum droplet size range. Mosquito adulticides are applied as space sprays to treat the air column in which mosquitoes are active, not deposit sprays treating surfaces on which they might feed or alight. As space sprays, drift of these drops is desirable since it keeps the pesticide available to contact actively flying mosquitoes, whereas deposit of the drops is undesirable as it removes the pesticide from impacting the mosquitoes. There is no standard, or guidance on labels, for many of the operational parameters in aerial adulticiding applications such as spray altitude or swath width. This results in an extremely wide variation in peak deposits and spray cloud concentrations that could reasonably be expected to result from different aerial adulticide applications. Due to the nature of the application and the reliance on local meteorology to disperse the spray cloud, significant off-target drift could be expected. Much research on optimum droplet size, efficacy and long distance drift and deposit from operational aerial applications remains to be completed.

#### Introduction

One of the most familiar statements included in any introduction to mosquitoes goes something like "It has been estimated that mosquito-borne diseases have resulted in more human deaths than all the wars in the history of the world". Whether this is true or not, the modern picture of malaria certainly supports the medical importance of mosquitoes: It has been estimated that there were 489 million cases of malaria worldwide in 1986, of which 2.3 million were fatal (Sturchler 1989).

Early mosquito control programs in the US originated as true vector control programs, with a goal of reducing or eliminating mosquito-borne diseases as well as providing relief from biting mosquitoes. Most, but not all, have since become primarily "nuisance" mosquito control rather than "vector" mosquito control as the incidence of mosquito-borne diseases in the US diminished rapidly from the 1930's to the late 1990's. The appearance of West Nile Virus in New York City in 1999, followed by its rapid spread throughout the US by 2004 has resulted in a much greater public interest, both positive and negative, in vector control programs and methodology. Despite this, existing programs in areas such as Florida still conduct the bulk of their operations against nuisance species, primarily the black salt marsh mosquito, *Ochlerotatus taeniorhynchus* and the pasture mosquito, *Psorophora columbiae*. It has been argued that these mosquitoes, although not direct vectors of disease agents, can occur in such huge numbers that they are responsible for infected sores and ulcers that occur when individuals scratch in response to hundreds of bites. As such they are considered a public health concern.

Modern residents of previously "uninhabitable" mosquito infested areas, such as coastal Florida counties, demand a high level of mosquito control. Most programs use a true IPM approach, utilizing source reduction, public education, biological control, larviciding and adulticiding. But for many, a high emphasis is placed on adulticiding as the only practical control method for particular species in certain areas at certain times. For instance, Collier County in Southwest Florida borders upon and includes parts of the Everglades National Park. This park, encompassing much of the southern tip of Florida, contains tens of thousands of acres of mosquito breeding habitat that cannot practically be treated through larviciding even if the federal government allowed it. The resultant broods of mosquitoes migrate up to 50 miles into the affluent city of Naples. The only control method available to minimize the impact of

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swarms of biting adult mosquitoes is large area (10,000-50,000 acre) aerial adulticiding over inhabited areas of the county during the early morning hours. This may have to be conducted on three, four or even five nights in a week due to the continuous migration of mosquitoes from the Everglades National Park. Failure to do so would result in biting counts in excess of 50 mosquitoes per minute, both day and night, in the heavily populated downtown areas.

### Major Points

For most agriculture and forestry pesticide applications, deposit (to the target surface) is considered “good” and drift is “bad”. Equipment, nozzles, tank mixes, drop-size and operational parameters are chosen to ensure high efficacy and efficiency in the target area while minimizing, managing or mitigating off target drift.

But aerial mosquito adulticiding, by its very nature, relies on the downwind drift of the aerosol spray cloud. Airborne aerosol spray particles impinge on **actively flying** adult mosquitoes (the “target”) causing mortality. Once the pesticide droplet deposits out, either through sedimentation to the soil surface or impingement upon vegetation, it is no longer available to affect a toxic response on flying adult mosquitoes. So, in this case drift is “good”, since it keeps the pesticide droplet available to contact the target (adult mosquitoes), and deposit is “bad”.

Mosquito adulticiding is a space spray, as opposed to a surface spray. The target area is not a single habitat or monoculture, such as a cotton field or a citrus grove, with definable edges. Rather it is the air or space above the ground in areas where people work, play or reside. These areas might be cities, towns, subdivisions or rural communities. These areas might consist primarily of houses, yards and public recreational areas, as you would expect in towns and cities, or they might be a patchwork of subdivisions, rural villages, farms and undeveloped wilderness. The latter is becoming an increasingly common situation in Florida.

Mosquito adulticide labels describe application rates in terms of “ounces per acre” or some other rate related to surface coverage. But as has already been mentioned, mosquito adulticiding is a “space spray” as opposed to a deposit spray. For ground based adulticiding many labels refer to the 300 feet effective swath assumed downwind from the truck. It has been suggested that this “effective swath” is based more on the width of a standard city block (16 blocks per mile, or 5280 feet) than the distance traveled by the spray drops before depositing out. This makes sense since spray trucks travel on city streets, and so rates were calculated based on the spray cloud providing mosquito mortality out to at least the next downwind street. However the aerial portion of an adulticide labels does not stipulate spray altitude or effective swath width, only maximum application rates as “ounces per acre”. It is up to the applicator to determine what altitude and what swath width to use. Altitudes used vary from 50 feet to greater than 300 feet AGL. Typical swath widths (or lane separations) vary from 300 feet to 2000 feet, although some operators have used 10,000 feet or greater. Thus spray cloud concentrations at emission can vary by a factor of 30 or more for the same formulation. These two factors, along with drop size and meteorology, will have a significant impact on the potential deposition peak and spray cloud concentration downwind of the aircraft flight line.

Effective droplet sizes for mosquito control adulticiding are generally considered to be between 5 and 30 microns in diameter, certainly less than 50 microns in diameter. Some very early work (Latta, 1947) investigated the combination of droplet size (mono-sized sprays from 1 to 20 microns) and wind speed (rather drop speed relative to a mosquito) on mosquito mortality in a wind tunnel using a DDT oil spray. They concluded that as long as the product of the droplet diameter squared (in microns) and the wind speed (in mph) exceeded 300, then the spray was “efficient”. For example, 10 micron drops in a 3 mph wind (relative to the mosquito) would be efficient ( $10 \times 10 \times 3 = 300$ ), but at 1 mph 10 micron drops would not be efficient. Later work (Weidhaas, 1970) investigated the relationship between drop size and lethal dose for mosquitoes for the 3 organophosphate adulticides. They calculated lethal drop sizes of 17.5 microns for Fenthion, 20 microns for Naled and 25 microns for Malathion. Still later work (Haile, 1982) using a low speed wind tunnel demonstrated the dose/mortality response of malathion on

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mosquitoes for different mono-sized drop sprays. They showed that the lowest LC50's (most efficient drop sizes) were obtained for droplets between 7 and 22 microns.

The result of all this work suggests that the ideal aerosol for mosquito adulticiding would be of a size that 1) has a high impact (or collection) efficiency on a mosquito, 2) remains airborne for a significant period of time to increase the probability of encountering a mosquito, and 3) does not contain much more than a single toxic dose. Many, if not most aerial applicators are currently using spray equipment designed and intended for "deposit" sprays. As such these are extremely inefficient at producing spray drops in the "ideal" drop size ranges below 30 microns. Amongst the most common are small orifice flat fan nozzles operating at 30 to 50 psi. These typically produce a spray cloud with a VMD in the 60 to 100 micron range. Some of the newer rotary atomizers are capable of producing sprays with a VMD in the 20 to 40 micron range, but they are not yet being widely used. There are also novel systems built in-house by several mosquito control programs that utilize either high pressure pumps (1000-3000 psi) or two fluid systems to produce sprays with a VMD in the 10 to 30 micron range.

In order for mosquito adulticides to be effective, they must be applied at the time mosquitoes are active, or rather be present in the target zone at this time. They should also be applied when meteorological conditions favor transport of the spray cloud into and through the target zone. For ground based sprays, this is usually not a problem, since the application equipment is operating within the target zone. But for aerial applications, usually at altitudes of 100 feet to 300 feet or more, there may be significant impediments preventing the spray cloud from reaching the target. These include atmospheric layering (spraying above an inversion layer), forest canopies and high stability (where vertical dispersion of the spray cloud may be strongly dampened). The ideal meteorology for dispersing the spray cloud throughout the target area would appear to be neutral to slightly unstable conditions with moderate winds creating good vertical mixing. These conditions however may actually inhibit mosquito activity. Many if not most species are primarily active in the light winds and high humidity associated with highly stable atmospheres, usually around the hours following dusk and preceding dawn. Under these more stable conditions, aerial applicators can make use of the longer lived aircraft vortices to bring the spray cloud close to the ground without having to rely on atmospheric dispersion. However, the spray cloud may stay strongly connected to the vortex structure, resulting in a concentrated pesticide cloud in one part of the target area but not sufficiently distributed throughout the intended "swath" to be effective against the widely dispersed mosquito populations.

### Implications

Because of the very nature of aerial applications to control mosquitoes, drift cannot be avoided. To be efficient and effective, equipment capable of producing aerosols in the 10-30 micron range should be used.

But these potentially efficient sprays are close to the size range of particles that become a health concern because of being respirable, that is within the PM10 and PM2.5 size classes. Since there is currently no operational equipment available that is capable of producing a more mono-sized spray in the 10-30 micron range, our sprays with a VMD less than 50 microns are going to contain both large, inefficient depositing drops and small PM10 and PM2.5 fractions. The question becomes which is of highest concern, a higher level of deposition that occurs by using a larger droplet size and lower altitudes to minimize excessive or extended off-target drift, or higher PM10 and PM2.5 concentrations that occurs when using smaller, theoretically more efficient sprays to minimize peak deposition. The answer is that they may both be of concern at certain levels or concentrations. We currently lack the detailed information and specialized equipment to produce a narrow drop-sized spray containing only optimum drop sizes for the specific application parameters.

Observations of fiddler crab mortality at Rookery Bay National Estuarine Reserve in Collier County, Florida were demonstrated to be caused by high deposition levels of the aerially applied mosquito adulticide fenthion. (Zhong, 2003). This led to the development and evaluation of a high pressure aerial application system capable of producing a smaller drop size spray (14 micron VMD as compared to 80

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micron VMD) than the conventional low pressure flat fan nozzle application systems. (Dukes, 2004). At the application rates used, both systems demonstrated adequate mosquito mortality in the target zone. In fact the high pressure system continued to cause significant mosquito mortality at much greater downwind distances than the conventional flat fan nozzle system. However, unlike the conventional larger drop size system, the high pressure system caused no fiddler crab mortality. This is directly attributable to the much lower ground deposition levels measured for the high pressure system applications. What was not investigated was the impact of the PM<sub>2.5</sub> fraction of the high pressure spray, estimated to be a little less than 10% of the total volume applied (the authors estimated the DV<sub>10</sub> to be approximately 3 microns).

Due to the paucity of guiding language on the aerial application portions of mosquito adulticide labels, the range of operational parameters utilized by mosquito control aerial applicators is huge, spanning small and large drop aerosols, 50 to 300 feet spray altitudes, 300 to 10,000 feet swaths, small to large aircraft and helicopters, daylight to nighttime operations, unstable to highly stable environments, etc. As a result, the potential range of spray cloud concentrations and pesticide deposit levels that could reasonably be expected from a mosquito adulticide aerial application is also very large.

Since mosquito adulticiding is a space spray and should be conducted during the times when mosquitoes are most active, many operations are conducted during nighttime hours. For aerial applications this becomes a significant concern regarding safe operations. Apart from the few operators using Night Vision Goggles (NVG's) in their operations, most spray flights are conducted at around 300 feet AGL in order to avoid the proliferation of unlit cell towers at 100 to 199 feet. At lower spray altitudes (50 to 150 feet) the entrainment of the spray cloud in the descending aircraft vortices will tend to bring the bulk of the spray quickly into the target zone (0 to 50 feet). However, at higher spray altitudes (200 to 300 feet) the dispersion of the spray cloud is governed primarily by prevailing atmospheric turbulence and movement, resulting in a significant probability of drift outside of the target zone.

Since drift cannot be totally avoided, and many applications occur over large target areas of 10,000 to 50,000 acres, the question of complying with some label language becomes an issue. "Do not apply when weather conditions favor drift from treated areas". In reality, the application of mosquito adulticide aerosols to favor good coverage and drift within the target area will also favor drift outside of the area. To avoid significant drift (enough to cause mosquito mortality) into neighboring environmentally sensitive areas could theoretically require buffer zones in excess of several miles. "Do not allow spray treatment to drift on pastureland, cropland, poultry ranges or water supplies". Should not the word "drift" in this statement be replaced with the word "deposit"? With the rapid urbanization of areas of Florida, many counties have become a mosaic of residential areas, agricultural areas and undeveloped wilderness or swamps. All of these areas become mosquito breeding habitats with the common flooding that occurs in the summer "rainy season". As such the treatment of a mosquito infested residential development in the suburban and rural areas will invariably result in the drift over "pastureland" (by simple definition "land used for livestock grazing..."), since many land owners and developers maintain undeveloped land in this way to qualify for the significantly reduced taxes on agricultural or "green belt" lands.

### Conclusions and Impacts:

Drift is the application method of choice, or the intent of mosquito control adulticiding operations. Ideally the spray produced from mosquito adulticiding equipment is 100% within the driftable fraction range of drop sizes. This makes the probability of drift outside the target area very high. The timing of sprays to correspond to both high mosquito activity and meteorology favoring transport throughout the target area is extremely important to ensure efficacy. As such, the option of timing spray operations for favorable meteorology to avoid or minimize off-target drift is usually not available.

Currently, the majority of "conventional" aerial adulticiding spray systems produce spray clouds with a VMD in the 60 to 100 micron range, well above the theoretically ideal range of 10 to 30 microns.

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Because of their inefficiency in producing ideal drop sizes, higher application rates are required and potentially damaging deposit peaks occur as a result of the larger droplets and higher rates. While some newer rotary atomizer designs and in-house built high pressure systems are capable of producing more ideal spray distributions, further research involving field evaluations of theoretically ideal drop sizes need to be conducted before the majority of aerial applicators will consider switching equipment.

There has been very little recent research measuring efficacy, long distance drift and deposit from aerial applications of mosquito control adulticides under operational conditions. Evaluations of aerial adulticides conducted during recent re-registrations of the products by US EPA were primarily based on information generated by computer models, not from actual field measurements. Current label language does not provide much guidance to the aerial applicator end-user. In order to improve our understanding and improve our efficacy while reducing potential non-target impacts, funding for significant research must be made available. Without a better understanding of all aspects of the aerial adulticiding process and access to efficient spray equipment we will be unable to effectively manage the spray drift we are producing.

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