Application Considerations for Mosquito Control

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Abstract

Mosquito control aerial adulticiding sprays rely on the drift of aerosol spray clouds with drop sizes less than 50 microns in diameter. These sprays by their very nature will drift for a long distance. In order to minimize biologically significant off-target drift, careful planning derived from a good understanding of all aspects influencing spray cloud dispersal is essential. Three phases of vertical spray cloud dispersal occur between emission at the aircraft nozzle and depositing out at ground level: entrainment within the descending aircraft vortices, general atmospheric turbulence and sedimentation. These three phases of movement are influenced by four major factors (assuming aircraft type, speed and weight are constant): Droplet size, Spray altitude, horizontal wind speed and atmospheric stability. For the small drop sizes effective against adult mosquitoes, sedimentation velocity is very small and so sedimentation plays a minimal role in their vertical transport from aircraft to ground level. But it may be important in regards to the larger droplet fraction produced by inefficient “conventional” spray systems which produce a spray cloud with a VMD between 50 and 100 microns. There is a paucity of research data describing spray cloud movement in mosquito control aerial adulticiding. Advancements in research equipment such as LIDAR and SODAR may provide the technology to better understand the spray cloud movement and the meteorology in which it occurs. Future research on these subjects must be supported by the mosquito control industry, chemical/equipment manufacturers and the government.

Introduction

Mosquito Control adulticide applications rely on drift, or large scale meteorological dispersion, for efficacy. The aerosol drops must stay airborne and disperse throughout the target area to be effective in impacting flying adult mosquitoes. In this case the target area is the column of air above the ground in areas where people live, work and play. An adulticide application is a space spray, relying on the longevity of small airborne particles to achieve efficacy, as opposed to a deposit or surface spray. The target area is not a single uniform habitat with definable edges, such as a cotton field or citrus grove, but may consist of a mosaic of habitats such as residential subdivisions, parks and recreational areas, agricultural lands and natural forest/swamp areas. The term “drift”, when used in the context of adulticide applications needs to be understood, since it is usually used with negative connotations when discussing agricultural pesticide applications utilizing deposit sprays. “Good drift” is essential in dispersing the spray cloud throughout the target area in sufficient concentrations to be efficacious on adult mosquitoes. “Bad drift” would be that portion of the spray cloud drifting outside of the target area in sufficient concentration to be biologically significant to sensitive non-target organisms.

As discussed in a previous presentation, research has shown the most efficacious drop sizes for killing adult mosquitoes in the target zone are between 5 and 30 microns in diameter (Latta, 1947), (Weidhaas, 1970), (Haile, 1982). These are highly driftable particles with very low sedimentation velocities (0.2 feet/minute to 5.3 feet per minute). Due to the very nature of these adulticide applications, off-target drift is next to impossible to totally eliminate. But biologically significant off-target drift may be managed or minimized with effective planning coupled with a good understanding of all the relevant factors.

Significant long distance drift outside the target area can be minimized or managed by applying the aerosol cloud directly to the lower atmospheric layer (0 to 30 feet above the ground) where the mosquitoes are active. This is commonly achieved by utilizing truck based application equipment on residential streets. Most commercially available truck mounted Ultra Low Volume (ULV) equipment is capable of producing a spray cloud with drops in the optimum range of 5-30 microns diameter, with a VMD of between 12 and 20 microns. But trucks are limited to driving where roads allow access. They are usually only effective where a good street grid exists and streets are separated by a maximum of

500-600 feet. Heavily wooded neighborhoods significantly impede spray cloud dispersion and hence the effectiveness of truck sprays. Also, areas upwind of the most upwind street in a treatment area remain untreated, allowing for rapid re-infestation if harboring large populations of adult mosquitoes.

Unlike ground adulticiding applications, aerial applications are not limited by street access, nor are flight line separations (operational swath widths) limited by street separation. Also, aerial applications are capable of covering much larger areas, typically as much as 25,000 to 50,000 acres in a 4-hour mission as compared to the 1,000 to 2,000 acres treated by a truck in an urban setting. Theoretically and ideally, an aerial application can be planned such that swath width, flow rate and spray altitude under the prevailing meteorological conditions will result in an efficient and efficacious operation. By the same token, it is theoretically possible to plan the mission to minimize significant off-target drift into adjacent areas where this might pose a problem, such as environmentally sensitive areas or organic farms.

However, in order to plan aerial adulticide applications to achieve efficacy within the target zone while minimizing non-target impacts and off-target drift, we must develop a better understanding of all the dynamic factors that influence the drift and deposit of the spray cloud. Some may be known, such as critical threshold deposit levels for sensitive organisms utilized during regulatory assessments. But much is not, necessitating research projects to investigate all the applicable factors. We have an obligation to both applicators and sensitive parties to provide accurate guidance for efficacious applications while minimizing the potential for non-target impacts.

Major Points

In order to understand many of the factors involved in drift and deposition of aerially applied mosquito adulticides we need to look at the movement of an aerosol spray cloud from emission at the aircraft nozzle to depositing on the ground.

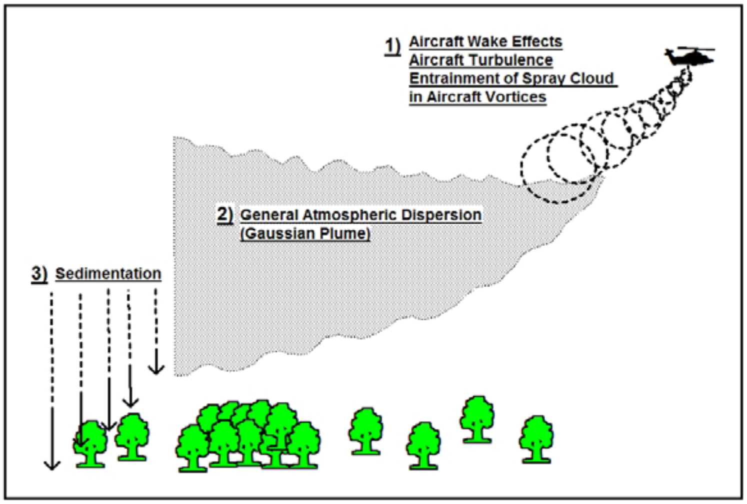


Figure 1 – Diagrammatical representation of phases of spray cloud movement from aircraft to ground level.

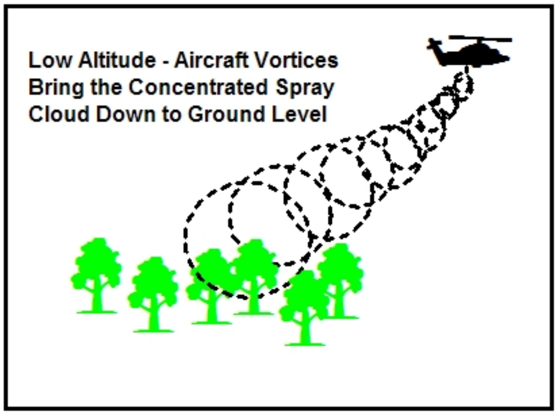
Soon after emission from the aircraft nozzle, the spray cloud is caught up in the aircraft wake turbulence and entrained within the aircraft vortices. The strength of the aircraft vortices are governed by the aircraft type, weight and planform area. The vortices from the upwind and downwind wing tips behave differently, but a discussion of this is beyond the scope of this presentation (Mickle, 1994). The energy of the vortices slowly dissipates until the spray cloud is effectively released into the general prevailing atmospheric movement or turbulence. Sedimentation also becomes a factor after the spray is released from the energy of the aircraft vortices. Whether sedimentation or atmospheric turbulence dominates the further vertical dispersion of spray drops is governed primarily by the drop size (which determines the sedimentation velocity) and the prevailing level of atmospheric turbulence. “Small drops” are those whose sedimentation velocity is about 3 times smaller than the friction velocity (an indication of atmospheric turbulence), whereas “big drops” are those whose sedimentation velocity is about 3 times larger than the friction velocity (Cramer, 1976). Mosquito adulticide aerosols (droplet diameters between 5 and 30 microns) would be considered “small drops” under almost all circumstances. An excellent basic description of this subject is covered in the chapter “Dynamics of Droplet and Particulate Dispersal” in the book “Aviation in Crop Protection, Pollution and Insect Control” (Quantick, 1985).

The relative effects of each of the three basic phases of spray cloud movements illustrated in figure 1 are governed primarily by four factors (assuming aircraft type, speed and weight are constant); droplet size, spray altitude, horizontal wind speed and atmospheric stability.

Droplet Size: Droplet size will determine how long each drop stays entrained within the aircraft vortices. Small drops will stay entrained until the vortices’ energy has dissipated to almost zero, whereas large drops will exit the vortices much earlier. Ideally, mosquito adulticides are aerosols or very small drops and so are influenced by the movement of the vortices until they decay to almost zero. The drops then come under the influence of general atmospheric turbulence and their own sedimentation velocities. Again, the very small drops making up the optimum mosquito adulticide sprays (5 to 30 microns drop diameters) have extremely low sedimentation velocities and so are strongly influenced by atmospheric turbulent dispersal. But it must be remembered that the old “conventional” flat fan spray systems still used by many operators produce an “inefficient” mosquito adulticiding spray with a VMD of 50 to 100 microns. As such many of the “inefficient” sized drops greater than 50 microns will have sedimentation velocities that may be significant when compared to the low atmospheric turbulence energies in the strongly stable conditions that often exist during the nighttime hours. (A 60 micron drop has a sedimentation velocity of almost 20 feet per minute, as compared to the 2 feet per minute for a 20 micron drop). These “big” drops, making up more than 50% of the volume of sprays from many “conventional” systems, will deposit out quickly within the target area. As such they are not airborne (available to impact adult mosquitoes) for very long and may actually deposit out in high enough concentrations to be damaging to non-target organisms (Zhong, 2003).

Spray Altitude: Spray altitude will determine how widely dispersed the spray cloud will become before reaching the target area close to the ground (0 to 30 feet above the ground). After emission from the nozzles, the spray becomes entrained within the aircraft vortices which bring the bulk of the material down towards the ground as a fairly concentrated cloud. The descent distance (out of ground effect) and the vortex life should be relatively constant for a given meteorological stability regime, assuming aircraft type, speed and weight are constants. Once the vortex encounters ground effect (typically assumed to be within one wingspan, or rotor diameter of the ground), the decay rate becomes more rapid, typically four times that expected out of ground effect (1.25 mph IGE as compared to 0.34 mph OGE), (Teske, 2002a). Typical vortices descent distances for mosquito control aircraft vary between 40 and 80 feet, with a life to decay of 100 to 300 seconds (in a neutral atmosphere), (Teske, 2002a). Larger aircraft tend to have longer-lived vortices whereas helicopters tend to generate the greatest downward “push” and descent distances, some upwards of 150 feet.

Once the vortices have decayed the spray cloud is released from entrainment and disperses more widely as a result of the existing atmospheric turbulence. The degree of spray cloud dispersal that occurs will depend on how close to ground level (or canopy top) the vortex phase “hands off” to the general atmospheric dispersion phase. Low spray altitudes (below 100 feet) will usually result in the aircraft vortices bringing the spray cloud almost to the ground as a concentrated cloud (Figure 2). This may limit off-target drift, but could result in deposit levels potentially damaging to non-target organisms. High spray altitudes (above 250 feet) will usually result in significant atmospheric dispersion occurring, diluting the spray cloud considerably before reaching the ground level “target zone” (Figure 3). High altitude sprays will certainly increase the potential for off-target drift, but the spray cloud should be significantly diluted so as to pose little threat to non-target organisms.



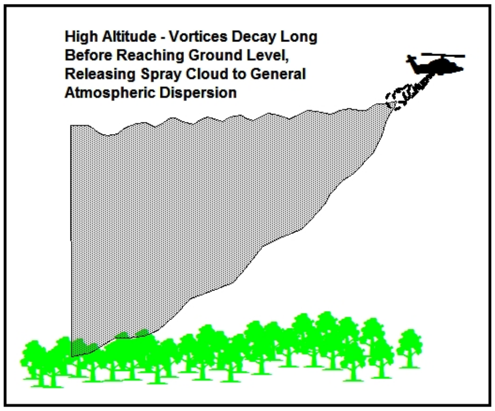


Figure 2 – Low Altitude Spray **Figure 3 – High Altitude Spray**

Horizontal Wind Speed: Horizontal wind speed is going to most significantly effect the downwind dispersion and dilution of the spray cloud. In light winds there is the possibility of high deposit levels close to the aircraft flight line, whereas high winds may cause significant, although dilute off-target drift. High winds may also cause increased decay of the vortices due to wind shear (Mickle, 1994). When spraying above forest canopies, the mechanical turbulence created by the friction of the horizontal wind speed on the rough surface layer will move the spray vertically in eddies (Miller, 1995). High winds in a neutral atmosphere create strong eddies that will bring the spray cloud down through the canopy. Low winds in a stable atmosphere with weak to non-existent eddies may result in the spray cloud drifting in a thin layer with little penetration through the canopy top.

Atmospheric Stability: Atmospheric stability influences both the decay rate of the aircraft vortices and the level of vertical dispersion that occurs to the spray cloud once the vortices have decayed. In a strongly unstable atmospheric condition the vortex decay rate was estimated to be approximately 2.5 times that expected in a neutral atmosphere, resulting in shorter lived vortices. Moderately stable atmospheric conditions did not change the vortex decay rate significantly from the neutral atmospheric state (Teske, 2002b). In a more stable atmosphere the aircraft vortices are going to remain more tightly wound, thus the spray cloud more concentrated. They will also be longer lived, resulting in a greater descent distance and horizontal downwind displacement of the concentrated, vortex-entrained spray cloud for a given wind speed. Once the vortices have decayed, general atmospheric dispersion takes place. In a strongly unstable atmosphere, the vertical dispersion of the spray cloud is rapid and widespread, resulting in significant dilution of the spray cloud throughout the atmosphere. In a stable atmosphere, atmospheric turbulence is minimal and vertical dispersion is limited, resulting in a slower dispersing, more concentrated spray cloud layer.

Implications

Given an understanding of aircraft vortex behavior and atmospheric stability on spray cloud drift, descent and dispersion, it should be theoretically possible to plan aerial adulticiding missions to maximize the placement of the spray cloud into the target zone. Spray altitudes, swath widths and flow rates could be chosen to ensure that an efficacious spray cloud is placed uniformly into the area to be treated below 30 feet in height (if we assume that 0 to 30 feet in height is the zone of maximum mosquito activity). Ideally, the aircraft vortices would bring the concentrated spray cloud down close to the lower 30 foot “target zone”, but not to the ground, before dissipating. Prevailing atmospheric turbulence would then disperse the spray cloud sufficiently throughout the target area (figure 4). This would prevent excessive loss of the spray material at higher altitudes where the target mosquitoes are not active, but not allow a concentrated spray cloud to impact the ground level (and deposit out). The actual spray height could be chosen based on habitat/canopy height in the target area: higher spray altitudes could be chosen for areas with tall forest canopies, lower spray heights for open range land.

However, we do not live in an ideal world, and we do not have a full understanding of aircraft characteristics, vortex strength and descent distances, prevailing atmospheric stability measures, or access to equipment to measure them. Anecdotal reports from employees and the public illustrate the degree of difficulty we have in accurately predicting and planning our missions. There have been spray missions flown at 150 to 200 feet in altitude where no impact of the spray cloud was observed by employees on the ground stationed at various distances downwind from multiple flight lines. And there have been complaints from several members of the public at a recreational field when the aircraft flew at 200 to 250 feet and a strong, concentrated spray cloud descended rapidly to the ground causing respiratory distress and irritated eyes. In both these instances, timing (dusk/dark) and conditions (light wind, moderately stable) were similar.

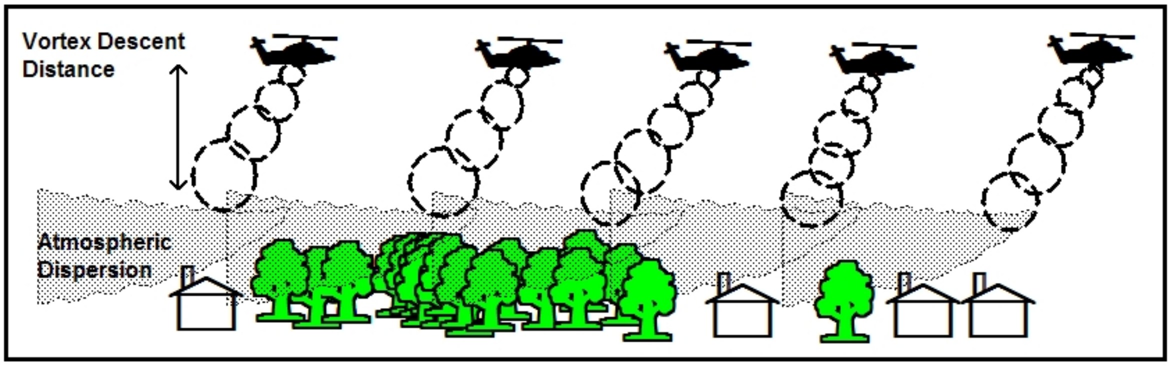


Figure 4 – A diagrammatic illustration of an ideal scenario: the aircraft vortices bring the spray cloud down to the 50-100 foot level (depending on habitat/canopy height) where general atmospheric turbulence takes over and disperses the drops throughout the target zone.

A second issue related to spray altitudes and timing is safety. Many, if not most aerial adulticiding applications are conducted during times of peak mosquito activity, that is at night. There are a couple of programs that utilize Night Vision Goggle (NVG) technology and have ex-military pilots well trained in their use. But the majority of programs do not, relying instead on GPS/moving map screens for flight guidance and obstacle avoidance. With the proliferation of communications towers, many up to 199 ft being constructed in a matter of days, low level nighttime flight has become increasingly dangerous. Two pilots tragically lost their lives this year in Florida providing relief spraying after one of the many hurricanes. Their aircraft hit a tower that was not lit due to storm related damage and power outages. As such, many applicators use spray altitudes of 300 feet or greater, well beyond the theoretically ideal altitude illustrated in figure 4.

The issue of droplet size is still unsolved. Many operators are still using old “conventional” flat fan spray systems producing spray clouds with a VMD between 50 and 100 microns. These are highly inefficient at producing the 5-30 micron drops proven efficacious for mosquito adulticiding by earlier research (Haile, 1982). The greater than 50% of the spray volume in wasted large drops is also potentially damaging when depositing out in high concentrations (Zhong, 2002). One problem is that language on many of the current labels allows these large droplet spectra. A compounding problem is that there are few commercially available aerial mosquito adulticiding spray systems capable of producing sprays close to the optimum size ranges. The “High Pressure Impingement Nozzle” systems and “Air Assist Nozzle” systems developed by several Florida programs are not likely to be commercially available as “off the shelf” systems. The liability involved in designing and manufacturing such aircraft based equipment make it not economically feasible for the limited mosquito control market.

Conclusions and Impacts

Much of the material discussed previously in regards to mosquito control aerial adulticiding operations is theoretical in nature, or derived from experimentation and observations from other aerial application techniques. Due to the nature of the operations, the widespread variability in habitats and meteorology encountered during applications, and the difficulty in isolating all parameters during high altitude spraying, there is a paucity of research or data available on the subject. The research conducted in Collier County, Florida in the late 1990's was important and introduced improved application possibilities for many operators, (Dukes,2004, a and b). It also introduced the use of LIDAR to record images of descending aerosol spray clouds emitted by aircraft that are otherwise invisible. This and other modern technologies (such as SODAR) offer the ability to measure, monitor and better understand the aerial application of mosquito adulticide spray clouds and the meteorology in which they occur, something this industry desperately needs. Research projects should be funded and supported by the mosquito control industry, the equipment and pesticide manufacturers and the government. The issue of off-target drift and deposit from aerial adulticides has not been clearly defined by the regulators, nor has sufficient operational guidance been provided by manufacturers/regulators on current labels. The range of perfectly legal (by label standards) operational techniques utilized by aerial mosquito adulticide applicators is enormous, resulting in some questionable practices. Support for appropriate research projects could lead to better guidance and more specific label language, benefiting both the applicators and the environment in general.

On the plus side, the introduction of new technologies to improve aerial adulticiding operations and guidance for pilots/applicators is occurring, all be it slowly. The recent introduction of a GPS/flight guidance system utilizing real-time weather data acquisition and computer spray model predictions offers the pilot "intelligent" guidance for more accurate flight line placement. This will lead to more efficient application of adulticides, more accurate flight line offsets, potentially lower application rates and a reduction in off-target drift. Improvements to and validation of these computer models will benefit the industry considerably.

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