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Aerial application for control of public health pests

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Summary

The use of aircraft to control important vector borne disease outbreaks through the selective application of pesticides continues to play a vital role in preventing the spread of disease in many parts of the world. The deployment of aircraft allows health authorities to treat large areas rapidly to reduce the presence of invertebrate disease vectors such as mosquitoes, flies and molluscs that transmit important human and animal diseases. Application methods using very small particle sizes, typically in the range 10 – 30 µm, can selectively target flying insects over large distances whilst avoiding unnecessary contamination of waterways and other non-target areas using Ultra Low Volume (ULV) techniques to minimise spray volumes and dose rates. Recent developments in the use of rotary atomisers, high pressure hydraulic nozzles and twin fluid nozzles are discussed in relation to control of both adult mosquitoes and flies as well equipment requirements for the application of larvacides.

Key words: Aerial spraying, Vector borne disease, ULV, Rotary atomisers, Adulticiding

Introduction

Aerial spraying operations have been practised for a number of years to control important disease vectors such as flies, mosquitoes and snails. Important vector borne diseases include encephalitis, trypanosomiasis (sleeping sickness), dengue, dengue haemorrhagic fever (DHF), yellow fever, malaria, schistosomiasis and onchocerciasis (river blindness). More recently, outbreaks of Rift Valley Fever (RVF) in the Middle East (WHO 2001) and also the West Nile Virus (WNV) in Eastern and Southern US States have caused concern amongst health authorities. A series of control measures including large scale aerial spraying has been employed to reduce the mosquito populations that transmit these diseases. An outbreak of Rift Valley Fever (RVF) in Saudi Arabia during September 2000 required the deployment of some eight fixed wing Antonov AN 2 aircraft and six KA-26 helicopters to apply technical malathion over an area of some 10 million hectares during a three month control campaign. The disease, whose inter-mediate hosts are sheep and cattle, is transmitted by mosquitoes to humans. During the recent outbreak it was estimated to have caused over 400 deaths and debilitating to many thousands. West Nile Virus (WNV) is a potentially life threatening disease first recorded in the USA in New York State during 1998/9. In 1999 some 22 deaths in NY State were reported and many hundreds reported ill (Miller *et al*, 2001). The disease has since spread to the southern US with recent reports of suspected disease in Florida. The disease has been found in carrion birds, such as crows, which act as inter-mediate hosts, as far north as Manitoba in Canada. In many parts of the US, routine surveillance and control is undertaken to contain the spread of WNV as well as encephalitis and routine nuisance mosquito control.

Aerial spraying for vector disease control

Aircraft are particularly suited to large-scale emergency control operations where the speed and timeliness of aerial application can prevent or impede the spread of disease, particularly in areas difficult to access from the ground in the time scales required. For example, in 1968 following a hurricane that struck the lower Gulf Coast of the U.S., many thousands of residents had to be housed in temporary camps. Following reports of an upsurge in the incidence of western equine encephalitis transmitted by the mosquito *Culex tarsalis*, the authority's, fearing an outbreak of disease, initiated an emergency aerial control programme to treat some 1.4 million ha (Chow *et al*, 1977). Ultra Low Volume (ULV) application techniques are typically used for adult mosquito and tsetse fly control due to the need to use minimal spray volumes to treat large areas rapidly. The use of relatively non-volatile formulations also prevents loss of product through evaporation particularly as release heights are typically between 15 – 100 m above ground.

Table 1 Productivity of various vector control operations – adulticiding

Equipment	**Possible daily Coverage (ha)**
Twin Engine aircraft e.g. C47, BN Islander	6000
Small single engine aircraft or helicopter	2000
Vehicle mounted cold fogger	225
Motorised ULV Knapsack blower	30
Hand carried thermal fogger	5
Hand carried indoor ULV generator	5 ha or 250 houses

(after Chow *et al* 1977)

Mosquito Control

Many of the world's most important vector borne diseases are transmitted by mosquitoes. *Aedes aegypti*, for example, is responsible for transmission of dengue and yellow fever in South and Central America as well as outbreaks of dengue haemorrhagic fever in South East Asia. These diseases are often debilitating, affecting many organs of the body and can be fatal. In areas of rapid urbanisation, poor sanitation or temporary encampments the mosquito can breed rapidly. This species is often to be found resting in dwellings in and around residential homes. In 1962 8,000 cases were reported in Bangkok during an outbreak (Self, 1974). Similarly in Thailand, Vietnam, Burma, Indonesia and the Philippines there were some 170,935 cases of DHF reported in the years 1968 – 1976 (Miles 1978). A related disease to the dengue viruses is Chikungunya prevalent in Africa and Asia. Some 380,000 cases of this disease were reported in Madras in 1963 from a then population of 1.8 million (Davidson, 1976). Malaria is also transmitted by mosquitoes, the principle vector being the *Anopheles* species and is the single largest cause of death by vector borne disease throughout the world, e.g. over 4 million cases world-wide were reported in 1975 with some 300,000 deaths (Davidson 1976). Control measures vary from residual spray applications in dwellings, personal protection through use of repellents or bed nets or source reduction (involving drainage of potential breeding sites) to large scale spraying. Mosquitoes are also routinely sprayed to reduce populations of biting insects that are a nuisance to local inhabitants. Pesticides can be applied to water as larvicides or as airborne space sprays (adulticides) to control flying adults. Most aerial spraying involves the use of pesticides, preferably with quick knockdown and limited environmental persistence. Spray is targeted to deliver pesticide directly to the adult insect or in close proximity to resting sites or other harbourages. Often sprays require to be applied in the early morning or the evening when many mosquito species are most active. The spray particles require to be applied in vary small discrete droplets typically in the range of 10 – 30 µm in order that particles remain airborne for as long as possible and carried by prevailing winds over large distances. The objective is very different from traditional agricultural spray applications in that the intention is to avoid the pesticide actually depositing on the ground. Aerial adulticides for mosquito control are applied at extremely low dosage and volume rates, typically as little as a few grams active (5.0 – 50 g a.i. ha^{-1}) at volumes as low as 50 – 200ml ha^{-1}. Products commonly used are the organophosphates naled (dibrom), malathion and fenthion and the pyrethroids resmethrin and permethrin.

Aerial larviciding with liquid sprays is not yet widely practised and involves much smaller areas. Larvicides need to be delivered directly onto water and frequently granule application with helicopters is preferred due the requirement for penetration of material through dense vegetative cover and the small areas treated. Products include *Bacillus thuringensis israelensis* (Bti), napthenic oil, isosteayrl oils and other monomolecular surface films, diflubenzuron and s-methoprene (insect growth regulators) and the organophosphate, temephos. Liquid sprays have been applied to open expansive waterways such as tidal flats using larger spray particles typically 150 – 300µm in size as a placement spray with narrow spray swaths (e.g. 50m).

Tsetse fly control

The tsetse fly (G*lossina species)* is an important vector of sleeping sickness (*trypanosomiasis*) that afflicts many people in Eastern and Southern Africa and Latin America. The disease affects both people and livestock. Chow (1977) has reported near destruction of cattle stocks in Zambia during tsetse fly outbreaks, the causative organism being a protozoan parasite. The policy in the past to control this disease has been to eradicate the tsetse fly from known breeding areas by aerial spraying over forests. This strategy was first developed in the late 1950’s by the Tropical Pest Research Unit (TPRU) in Arusha, Tanzania. The technique developed was to utilise Ultra Low Volume (ULV) spray techniques to apply endosulphan and latterly the pyrethroid Deltamethrin, using rotary atomisers to achieve even sized spray particles in the range 30 – 60 µm released above the forest canopy at night under inversion conditions. The optimal particle size to control adult tsetse flies is around 10 – 30 µm, hence the product formulation contains a volatile solvent carrier to reduce particle size through evaporation of solvent (FAO 1977). A number of successful eradication programmes have been undertaken in Somalia, Ethiopia, Chad, Tanzania, Zambia and Botswana (Lofgren 1970, Kendrick and Alsop 1974, Lee *et al* 1975) where typically five consecutive applications were made at three week intervals. Alternative control strategies have since been developed using impregnated black sheets and Octonol (an attractant) positioned every 1 km^2 within the forest to lure and kill tsetse flies. However, as fly numbers increased in recent years due to extensive flooding preventing deployment of treated ground targets, an aerial eradication policy has been re-adopted in some countries e.g. Botswana where over 1 million ha of forest will be treated over the next few years using ULV formulations of deltemethrin and Micronair AU4000 rotary atomisers (Alsop *pers comm*).

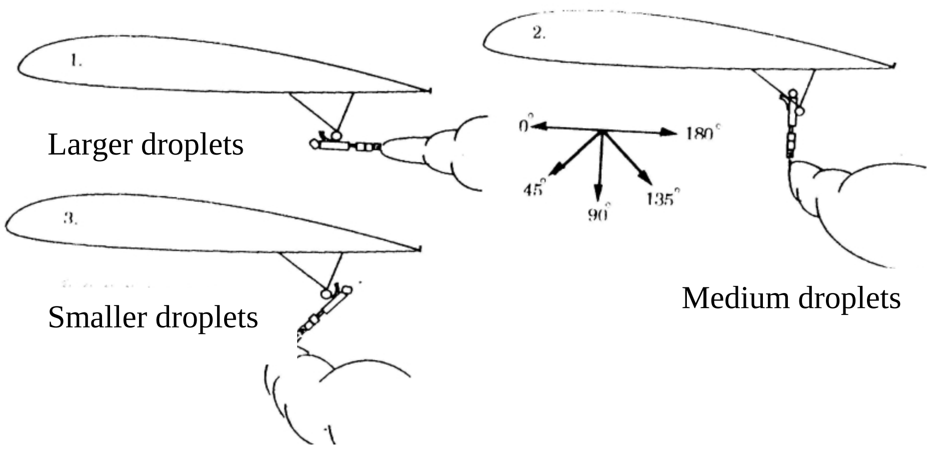
Flies

House flies and other *Diptera* are also responsible for disease transmission, for example gastro-enteritis in humans. They thrive in areas where refuse and organic waste collects and can pose a serious health problem in both temperate and tropical environments. One example of a successful aerial spraying campaign against flies was carried out during 1974 and 1975 in Saudi Arabia. Fly populations had exploded around the holy cities of Mecca and Medina during the Haj religious festival where sheep are ritually slaughtered by many millions of pilgrims and the waste and effluent provide fertile breeding sites for flies. Two Pilatus Porter aircraft equipped with Micronair rotary atomisers producing drop sizes of around 40 – 80um (larger than those used in mosquito control) sprayed some 325,000 ha. This spray operation has been continued in subsequent years using twin-engine Piper Aztec and Cessna 310 aircraft.

Aerial application equipment and techniques

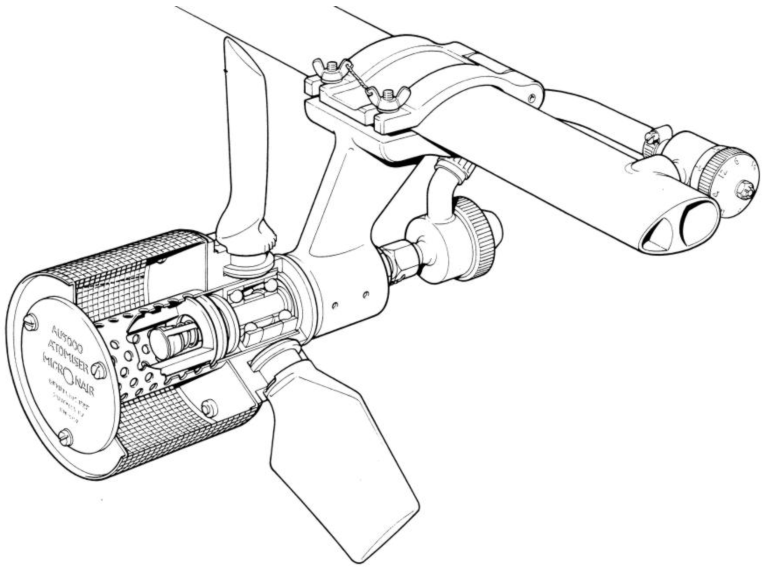
There are a variety of spray systems used in aerial adulticiding. Thermal fogs have and are still used to some extent where pesticide is emitted into the hot gasses of the engine exhaust. Malathion has for many years been routinely applied as a thermal fog using converted DC 3 twin engine aircraft. Particle size is small but hot exhaust gasses can adversely affect some pesticide formulations and the use of thermal fogs is declining for both aerial and ground application. Flat fan nozzles are also commonly used, typically Spraying Systems 8002 or 8004 types, although hollow cone nozzles are also used in some mosquito control operations. Nozzles are orientated into the air stream at 45^0 to maximise air shear to produce as small a droplet as possible. Recent particle size measurements using a Malvern particle size analyser in a wind tunnel has indicated typical drop sizes of 70 – 90 µm VMD depending on nozzle type and airspeed - the higher the airspeed the smaller the average droplet size. Traditionally, particle size measurements have been made using rotating teflon coated slides sampling spray moving horizontally on the ground. This technique tends to selectively sample droplets in the 10 – 30 µm range and gives poor agreement with more recently introduced sampling methods in a wind tunnel (Hewitt and Zhai, 2001).

Figure 1 Orientation of Hollow Cone nozzles for aerial adulticiding – 45^0 into airflow



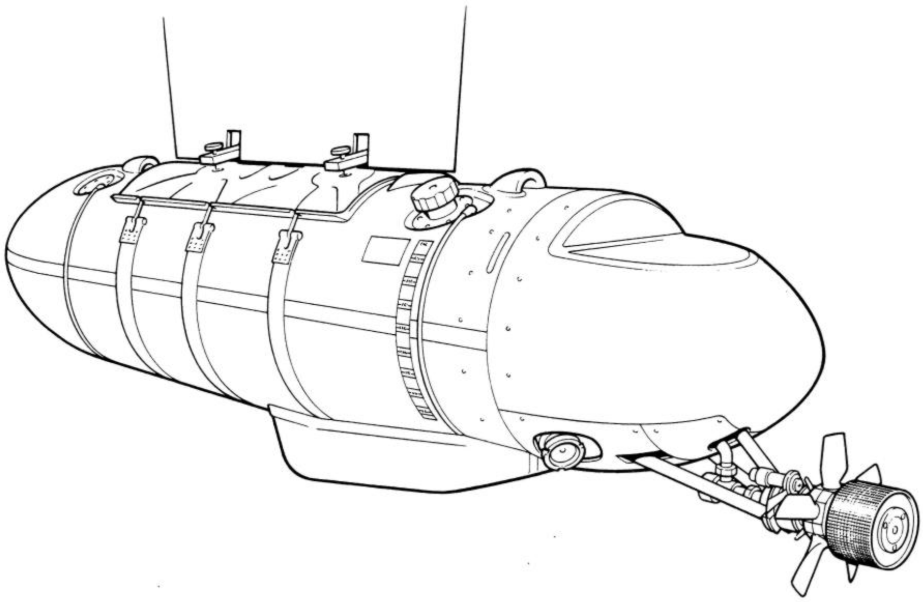
Rotary atomisers have been used for many years for both mosquito and tsetse fly adulticiding particularly throughout Africa and Asia and more recently increasingly used in North America. Rotary atomisers are able to produce a narrower droplet size spectrum avoiding large droplets over 60 µm that fall out as ground deposits and are therefore wasteful and potentially contaminating. Furthermore as frequently control operations have to be undertaken over urban areas spotting of cars has become a problem with certain products if inappropriately applied with equipment producing droplets larger than about 50 µm. The Micronair AU4000 and more recently the Micronair AU5000 rotary cage atomisers have been widely used for tsetse, fly and mosquito control operations. The AU4000 atomiser is typically operated at around 9 – 10,000 rpm at low flow rates of around 2 – 4 litres per minute with spray particle sizes of between 30 – 45 µm VMD (Vliet and Picot, 1987). The smaller diameter AU5000 rotating at similar speeds gives slightly larger spray particle size typically 35 – 55 µm VMD at the point of emission. Depending on the volatility of the formulation, the mature particle size will decrease with time with evaporation of volatile components.

Figure 2 Micronair AU5000 Rotary Atomiser



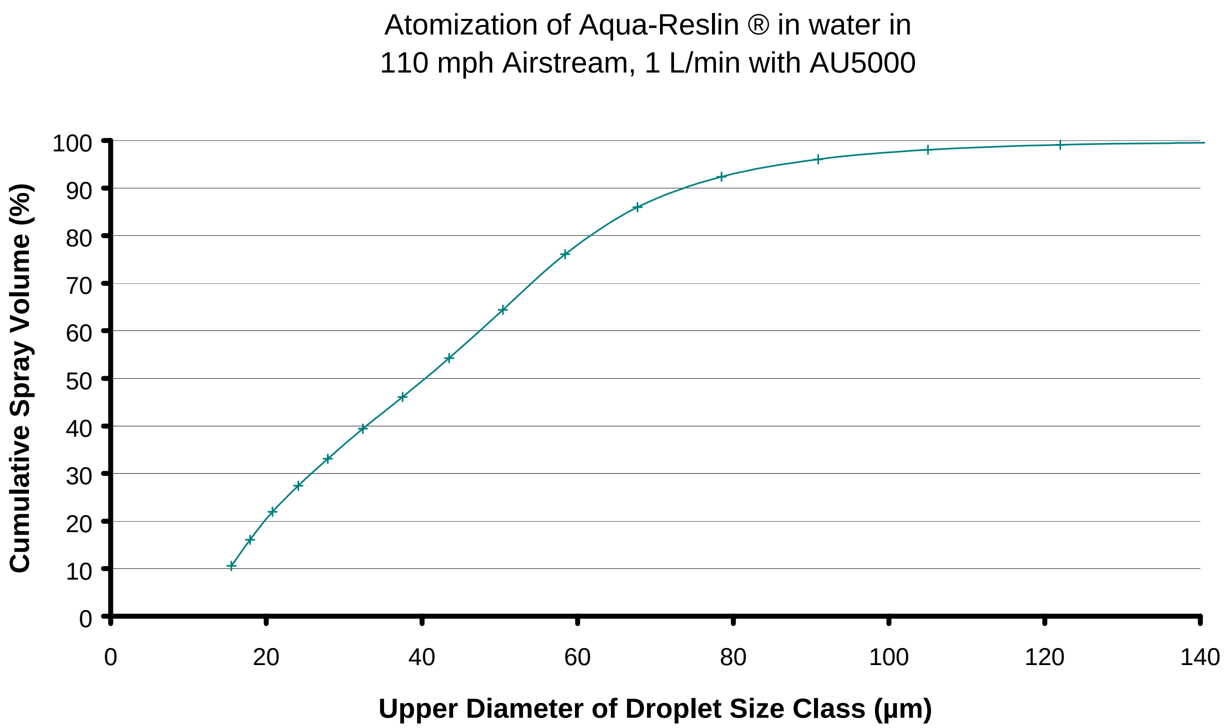
The Micronair AU4000 atomiser is incorporated on the Micronair Spray Pod, recently introduced into North America and elsewhere for mosquito control operations. The Pod consists of a 210 litre spray tank with integral 24 V DC centrifugal pump, flowmeter turbine, diaphragm check valve and atomiser. Two Pods are mounted on the underside of a high wing aircraft, such as BN Islander, Pilatus PC-7 or PC-9, De Havilland DH-2 Beaver, Dornier DO-228, Partenavia P-68 or similar high-wing types. A control panel is installed in the aircraft cockpit. This incorporates controls for the pumps and electro-magnetic atomiser brakes as well as Application Monitors to display flow, volume application rate, atomiser rpm and other parameters. Application monitors have been integrated with agricultural GPS (Global Positioning System) track guidance systems to record application parameters for use within GIS software packages. Recently, two systems have been fitted to the BN Islander aircraft to replace ageing DC3 aircraft and operating costs have been reduced from $650 per hour to $250 per hour (E.Fussel, *pers comm*). The system is advantageous in that the spray tanks are external to the aircraft fuselage, thus improving pilot safety. Also, the Pods can be easily removed so that the aircraft can be utilised for other activities.

Fig 3. Micronair Spray Pod with AU4000 atomiser



Recently. a high pressure hollow cone nozzle system has been developed in the U.S for use with helicopters and fixed wing aircraft (Robinson, 2001 and Latham, 2001). This system uses a high pressure pump delivering around 2,500 psi to atomise liquids through small orifice stainless steel nozzles. Particle size is very small (typically around 20 – 30µm VMD at the point of emission). This system has been developed to reduce spray particle size to ensure droplets remain airborne when released over the target area. Other operators in Florida have developed twin fluid systems using air to atomise liquid at the nozzle. The air supply is bleed air from turbine engines cooled in a heat exchanger. These systems have been fitted to both Hughes 500 helicopters and Shorts Skyvan twin engine fixed wing aircraft (Collier Mosquito County, Florida *pers comm*). There is increasing use of high speed rotary atomisers, twin fluid or high pressure systems to produce smaller particle sizes to improve efficacy and productivity, reduce dose rates and avoid deposits onto waterways. Figure 4 illustrates a typical droplet spectrum for the Micronair AU 5000.

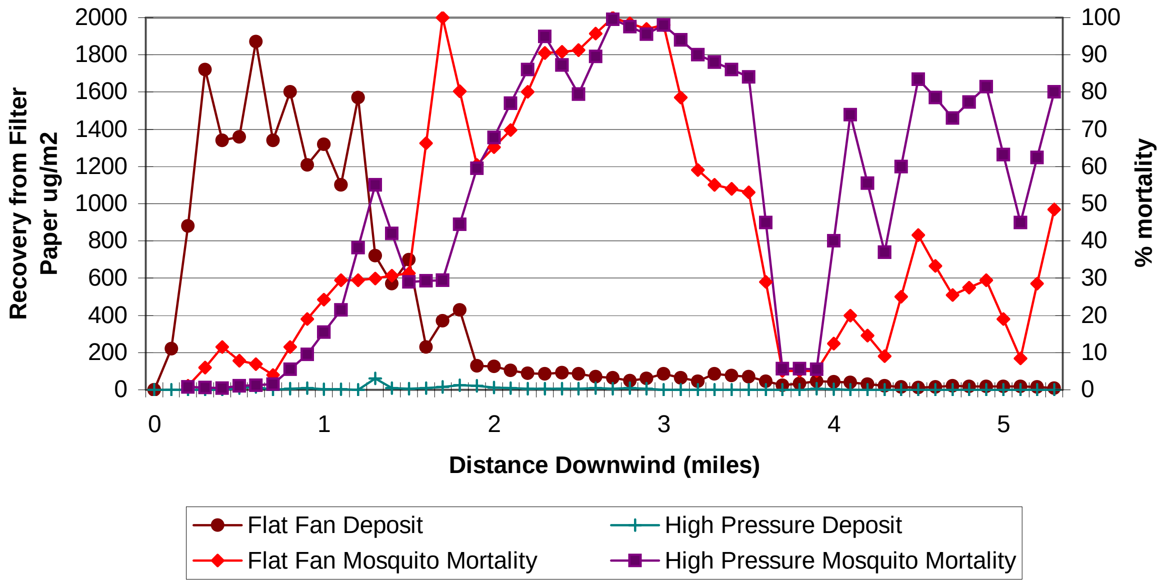
Figure 4 Cumulative droplet size by volume – Micronair AU5000 @ 9000rpm



(data kindly supplied by Aventis Environmental Science, Montvale, NJ 07645, USA)
Aqua-Reslin® is a registered trademark of the Aventis Group

A recent study (Robinson *et al* 2001)has highlighted the importance of particle size (figure 5). Comparisons were made between aerial applications using typical flat fan spray nozzles and a novel high pressure hydraulic nozzle system to examine spray deposits sedimenting on the ground as well as mosquito mortality in cages suspended near ground. Assessments of spray deposits and cage mortality were made at distances of up to 5 miles downwind from the point of release. From Figure 5 it is apparent that although the recovered spray deposit on the ground was extremely small with the high pressure system the cage mortality was much higher than that with the flat fan nozzle. The flat fan nozzle had much higher ground deposits up to 2 miles downwind but poorer cage mortality overall. The graph illustrates the importance of particle size control to minimise ground deposits and potential water contamination. This is important to avoid destruction of non target aquatic fauna (e.g. fiddler crabs in Florida). For aerial adulticiding the objective is that the spray moves through an area rather than deposits within it. The target area was actually the first 1.5 miles downwind from the last spray pass (8 in total) and illustrates the quantity of material and level of control occurring outside the target area. The one anomaly indicated on the graph is at a distance of 3.5 miles, where both ground deposits and cage mortality declined rapidly due to the positioning of ground collectors and cages within a densely forested area that acted as an efficient natural spray filter. Mickle, (2001) has developed a number of computer models to simulate spray deposits with different particle sizes when released from aircraft. Mickle (2001) advocates that spray applications should be optimised to take into account spray spectrum, formulation characteristics and wind and meteorological conditions to maximise spray delivery within the target zone. Typically 500 – 1500 metre offsets upwind of the target area are required when sprays are released from heights of 30 – 100 metres. It has been proposed that a series of spray runs on the same flight path are required rather than conventional sequential parallel swathes. Mickle (2001) has also reported that the type of vegetative cover strongly influences the success of penetration of spray for the purposes of larviciding, suggesting up to 60 – 85% of spray can be filtered out by the vegetative canopy.

Figure 5 Comparison of deposition and mosquito mortality from two aerial spray applications (windspeed 1-5 mph)



For larviciding, helicopters are frequently employed due to their higher manoeuvrability making them better suited to treatment of discrete water surfaces. Granules are often used to maximise penetration of foliage. Typical application systems use two ‘saddle tank’ hoppers with pneumatically operated outlet gates and either rotating discs or pneumatic speaders to dispense material. Liquid applications may be made with Micronair type rotary atomisers operating at low rotational speeds (typically around 2000 – 3000 rpm) to produce drop sizes in the range 100 – 300 µm (e.g Micronair AU6539 electric drive atomisers for helicopters).

Conclusions

For aerial adult mosquito and tsetse fly control the ideal particle size should approach 10 – 30μm at the point of contact with the insect. The rationale for this is not only to improve probability of contact by producing more numerous spray particles, but also to minimise fallout and ground deposition of spray particles which is not only wasteful but can also lead to contamination of waterways. New advanced application techniques together with selective pesticides allow for improved targeting of sprays for control of flying insects. Aerial spraying plays an essential strategic role in the prevention of disease for many health authorities world-wide as seen with their recent deployment to control the spread of West Nile Virus in the USA and Rift Valley Fever in the Middle East.

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