The IR-4 Project
Pest Management Solutions for Specialty Crops and Minor Uses

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Controlling Adult Mosquitoes with Pesticides Part II: Toxicant Efficacy & Effectiveness

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Very large-scale aerial application of mosquito adulticide. Photo courtesy of Armed Forces Pest Management Board.

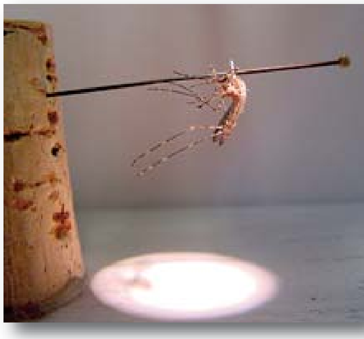
Controlling adult mosquitoes with pesticides is a standard activity for public health programs in many areas where mosquito-borne pathogenic diseases are common, or where the abundance of adult mosquitoes causes a substantial nuisance.
Since this is often performed with public funds, and because the use of pesticides poses some risks, it is important to understand how the effects of these programs are evaluated.

This article continues a series which started with a review of how chemicals are used to help control mosquitoes and mosquito-borne diseases, and which continued with an introduction to some programs that develop mosquitocides and other public health pesticides, including the IR-4 Project. In this segment, we use the linked concepts of pesticide efficacy and effectiveness to explore the benefits of killing adult mosquitoes with aerosol pesticides, and how these benefits are measured. Other chemical interventions, including indoor residual sprays, repellent use, barrier sprays, and attractant-baited traps will be discussed in a later article in the series.

The ultimate goal of any mosquito control program is to protect public health and comfort, and killing adult mosquitoes is a common means towards that end, because dead mosquitoes, obviously, cannot bite.

Hand-held thermal fogging for adult mosquitoes (courtesy Manatee County, FL, MAD)

Many materials are toxic to adult mosquitoes ("toxicants"), and those that are registered for area-wide mosquito control are generally called adulticides. Mosquito eradication (killing all the mosquitoes in an area for an extended period of time) has never been demonstrated, using adulticides alone or in combination with



Dead adult mosquito - no longer a threat! Courtesy AFPMB.

any other tool. Therefore, the key to evaluating the benefits of adulticide use is determining whether the reduction in mosquito population that can be achieved is enough to significantly reduce disease risk and/or nuisance value. In other words, if mosquito numbers are reduced but not enough to protect public health, then adulticide use may not be worth the cost and risk. Insecticides are sold and used because they kill insects, and "efficacy" is used to characterize the toxicity of pesticides to the target pests. Generally, laboratory studies are conducted to determine the doses required to kill 50% and 95% of mosquito populations for a range of species. Pesticide labels are written and risk assessments conducted for application rates that should generally result in 95% mortality under good conditions; this rate has traditionally been considered ideal both for achieving good control and for minimizing the risk of resistance. Field efficacy tests are used to verify the extent to which lab results can be achieved with real-world application equipment, and to determine if adequate control is locally possible given the mosquito fauna and specific weather conditions in an area.

Screening for adulticide efficacy in the lab. Courtesy of Sierra Research.

Mosquito bioassay cage to field test adulticide efficacy. Courtesy AFPMB.

Additionally, field efficacy monitoring is critical to catch control failures, which may result from old or poorly stored pesticide, poor spray equipment calibration or other problems with application methods, or the development of pesticide resistance in local mosquito populations.

There are two primary ways to judge how well adulticides kill mosquitoes in the field – by subjecting caged mosquitoes to the spray drift and observing the mortality, and by estimating the local mosquito population before and after the pesticide application. It seems obvious that measuring the reduction in mosquito populations in the treatment area would be the best way to determine the effects of spraying that area with adulticides, but this is surprisingly difficult to do with any precision. Adult mosquito populations are typically estimated by sampling the populations with baited traps, and the fraction of local mosquitoes that are captured in these traps is highly sensitive to wind and other environmental variables. In other words, big changes in trap counts are common from night to night even when there is no spray activity and populations are relatively steady. Thus, estimating adulticide efficacy from trap data requires many traps, both in the spray zone and in an untreated control zone, at considerable cost. Therefore, proxy methods are used to estimate adult mosquito abundance, such as public complaint calls, and caged mosquitoes are frequently placed in the spray zone to ensure that spraying has the intended effect. Reviews of many studies have shown that a 90% mortality in caged mosquitoes and a 50-80% reduction in local adult mosquito population can generally be expected with modern adulticides and spray equipment, good weather, and relatively open habitat. However, the rate can be considerably lower in less favorable conditions.

All of the methods and studies described so far generate entomological data, such as adult mosquito abundance, but if our ultimate concern is human health and well-being, these data are not enough to allow evaluation of the epidemiological effectiveness of mosquito control. We really want to know how much specific mosquito control practices protect public health, and there are two general ways to approach this question. First, we can conduct direct studies comparing disease rates or other measures in areas with and without mosquito control; while relatively uncommon, these studies have consistently shown significant benefits of mosquito control during major outbreaks of mosquito-borne diseases (see, for example, Carney et al, 2008).

However, studies with epidemiological outcomes, and in particular, controlled prospective studies, are rare because of their expense. In addition, even high quality retrospective studies are relatively uncommon because of the difficulty of identifying sites that are similar in all other relevant variables but that differ in the extent of mosquito control that is performed. Finally, there could also be ethical challenges in denying mosquito control to a community during a disease outbreak solely to conduct this research. For all these reasons, most studies supporting the use of adulticides have used indirect methods that relate entomological outcomes to health outcomes.

Methods that link entomological efficacy to epidemiological effectiveness of mosquito and other vector-control programs have traditionally been more practical than theoretically driven. Simply put, many scientists and public health workers have observed that once the population of mosquitoes or other vectors is driven below some threshold, disease transmission drops substantially or human activities are again undertaken without undue nuisance. In addition, numerical models have been created that help define the relationships between vector population and age structure and vector-borne disease, especially for malaria. Developing reliable models for other disease systems seems to be a fruitful area for research in coming years. A key finding of these models has been theoretical support for the common observation that even short-term reductions in adult mosquito populations can have major impacts on human disease, if the adulticide kills older adult mosquitoes that are more likely to be infected with pathogens. Thus, even if mosquito populations rebound quickly after adulticide use, the new mosquitoes are young and generally uninfected and, hence, should pose lower risk to people than those that were killed. Thus, both empirical data and models help us understand how and to what extent mosquito adulticides protect public health.

Air Force C-123 cargo plane applying malathion over Dallas during 1966 outbreak of St. Louis Encephalitis (courtesy AFPMB).

For Further Reading:

EPA Product Performance Test Guidelines OPPTS 810.3400: Mosquito, Black Fly, and Biting Midge (Sand Fly) Treatments (March 1998) [www.epa.gov/opptsfrs/publications/OPPTS_Harmonized/810_Product_Performance_Test_Guidelines/Series/810-3400.pdf]

CDC (2003). "Epidemic/Epizootic West Nile Virus in the United States: Guidelines for Surveillance, Prevention, and Control." 77pp. www.cdc.gov/ncidod/ dvbid/westnile/resources/wnv-guidelines-aug-2003.pdf

Carney, Ryan M., et al. (2008) "Efficacy of Aerial Spraying of Mosquito Adulticide in Reducing Incidence of West Nile Virus, California, 2005." Emerging Infectious Diseases www.cdc.gov/eid, 14(5): 747-754.

Fritz, Bradley, et al. (2010) "Filtration Effects due to Bioassay Cage Design and Screen Type." J American Mosquito Control Association 26(4):411–421.

Mount, Gary, et al. (1996). AA Review of Ultralow-Volume Aerial Sprays of Insecticide for Mosquito Control.@ J American Mosquito Control Association 12(4): 601-618.