# EVALUATION OF BENDIOCARB AS AN ULV COLD AEROSOL AGAINST CAGED MOSQUITOES[1,2]

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ABSTRACT. Bendiocarb was evaluated as an ULV cold aerosol against two species of caged mosquitoes, *Anopheles quadrimaculatus* and *Aedes taeniorhynchus*. Evaluations were made at flow rates of 60 ml/min and 120 ml/min at a vehicle speed of 16 kph, and 120 ml/min at a vehicle speed of 8 kph (equivalent to 240 ml/min at 16 kph). Good control was obtained at 5.6 and 11.2 g AI/ha at the highest treatment rate. Calculated effective dosages (ED) showed that as the flow rates increased the amount of active ingredient per hectare required for an ED-95 decreased. Mosquitoes maintained in the exposure cages had higher mortalities than those transferred to clean holding cages (our standard procedure) soon after exposure to the aerosol, reconfirming the necessity for routine transfer to prevent bias in results due to the effect of the residue in the exposure cages.

## INTRODUCTION

The results of initial laboratory studies with bendiocarb, a carbamate insecticide, as a mosquito adulticide indicated that additional evaluation under field conditions were warranted. Compared to the malathion standard in our wind tunnel aerosol tests against the salt marsh mosquito, *Aedes taeniorhynchus* (Wiedemann), bendiocarb was about 2.5× more effective at the $LC_{50}$ level and 5× more effective at the $LC_{90}$ level. The potential effectiveness of bendiocarb as an adulticide has also been demonstrated by Tapley et al. (1980) in field aerosol studies and by Eshghy et al. (1980) in field residue studies. The present paper reports field studies conducted in 1982 to evaluate bendiocarb as an ULV cold aerosol against caged mosquitoes under field conditions.

## MATERIALS AND METHODS

The tests were conducted in a fairly level open field near Gainesville, Florida, during April and May 1982. Applications were made between 1900 and 2200 hr during favorable weather. Temperatures were measured at ground elevations of 1.8 m and 9.1m and wind speed at 1.8 m. Tests were not conducted when the wind velocity was less than 3.2 kph, greater than 16 kph, or wind directions varied more than 30° from perpendicular to the spray line.

A Leco Model HD Cold Aerosol Generator with a blower pressure of 27.6 KPa was used to disperse the adulticide, which was delivered to the nozzle by a positive displacement pump at either 60 or 120 ml/min. The formulation of bendiocarb[3] as a suspension in oil containing 238 g AI/liter (2 lbs AI/gallon) was used. The formulation was diluted in Klearol®[4] to obtain the concentrations necessary for treatment at the desired rate (AI/hectare), based on a 91 m (300 ft) swath and truck speed of either 8 or 16 kph (5 or 10 mph).

Laboratory-reared, insecticide-susceptible strains of *Aedes taeniorhynchus* and *Anopheles quadrimaculatus* Say were exposed in modified WHO insect test kits (Roberts 1982, 1983; Haile et al. 1982). The test insects were immobilized on a cold table (Barry et al. 1978) for handling and counting. Twenty-five adult female mosquitoes (4–6 days old) were placed in each 16 × 16 mesh cage. Four cages of each species were suspended 1.2 m above ground on stakes 46 m and 91 m downwind in two rows spaced 30.5 m apart perpendicular to the line of travel of the truck-mounted ULV aerosol generator. After each aerosol had drifted through the test plot (ca. 5 min), the exposure containers were collected and the insects were transferred to the plastic holding tubes lined with clean paper. The cages containing the test insects were held in chilled insulated chests containing moist cotton for transportation between the laboratory and the test site. During the 12-hr holding period prior to mortality counts, the test insects were

[1] This paper reports the results of research only. Mention of a pesticide in this paper does not constitute a recommendation for use by the U.S. Department of Agriculture nor does it imply registration under FIFRA as amended. Also, mention of a commercial or proprietary product does not constitute an endorsement of this product by the USDA.

[2] This research was conducted as a cooperative effort between the Agricultural Research Service, USDA, and the State Agricultural Experiment Stations of Arkansas, California, Louisiana, Mississippi, and Texas as part of a USDA/CSRS Southern Regional Project (S-122) on the Biology, Ecology and Management of Riceland Mosquitoes in the Southern Region.

[3] Supplied by BFC Chemicals, Inc., P. O. Box 2867, Wilmington, DE 19805.

[4] Witco Chemical Corporation, Sonneborn Division, 277 Park Avenue, New York, NY 10017.

held at room temperature (24°C) and supplied with 10% sugar water on cotton pads. Cages of test insects not exposed to the insecticide but handled in the same manner were used as controls. Droplet size measurements were made by the hand wave method (Mount and Pierce 1972).

Dosage-mortality data were analyzed with a log-probit program written for a Hewlett-Packard Model 9810-A Programmable Calculator based on procedures given by Finney (1971). Based on the regression line established by the data, the probable effective dosages (ED), together with their 95% confidence limits, for 50 and 95% control were calculated.

In the evaluation of the aerosol, a study was included to determine if the residues left on the exposure cages were sufficient to have an additional effect on those mosquitoes that had received a sublethal exposure to the aerosol. Three replicates of additional cages were exposed to aerosols at two selected treatment rates of 5.6 and 2.8 g/ha, delivered with a flow rate of 120 ml/min and a vehicle speed of 16 kph. The mosquitoes in these cages were retained in the exposure cages and maintained in the same manner as those that were transferred to clean holding cages prior to mortality counts.

## RESULTS AND DISCUSSION

The data on the efficacy of bendiocarb at the various rates of application are presented in Table 1. Droplet size measurements of the bendiocarb formulation showed a volume median diameter (VMD) of 15 μm at the 60 ml/min and 17 μm at the 120 ml/min flow rates.

The data in Table 1 reveal some interesting relationships between treatment rates per hectare, rate of delivery and formulation strength. For example, with the 0.12 kg AI/1 formulation, the treatment rate increases (2.8-5.6-11.2 g AI/h) as the delivery rate increases. Mortality of *Aedes taeniorhynchus* also increased over this range from 56–80–94%. However, the amount of active ingredient per particle remained the same so the increase in mortality was due to the increase in the number of particles per unit volume that increased the probability of delivering a toxic dose to the mosquito targets. Examining the same treatment rate, for example, 2.8 g AI/h, the formulation strength decreases (0.12, 0.06 and 0.03 kg AI/1) as the release rate increases thus decreasing the amount of active ingredient per particle and requiring an increased number of particles to impact on the target insect for a toxic dose.

Since the number of particles appears to be an important factor in the level of control, some additional speculation would appear to be in order. In a spray aerosol particles range in size from about 0.1 to 100 μ in diameter. At the upper end, particles >30 μ are usually <3% of the particles measured. While a percentage curve can be calculated for particles at each size in the distribution pattern, as is done in determining the volume median diameter (VMD), it is more convenient for discussion to assume all particles are one size. If all the particles from 60 ml were 15 μ, then there would be $3.39 \times 10^{10}$ particles while at 10 μ, there would be $1.15 \times 10^{11}$ particles. These numbers would double at 120 ml and double again at 240 ml to $1.35 \times 10^{11}$ for 15 μ particles and $4.6 \times 10^{11}$ for 10 μ particles. If all the 15 μ particles from 60 ml were equally distributed over 1 acre to a depth of 9.144 m (30 ft), the enclosed volume would

Table 1. Efficacy of bendiocarb as an ULV ground aerosol against caged adult female mosquitoes[a] (number of replications in parentheses).

| Treatment rate g AI/ha | Formulation ml/min | Formulation kg AI/1 | Vehicle speed (kph) | Average 12 hr mortality (%) *Aedes taeniorhynchus* | Average 12 hr mortality (%) *Anopheles quadrimaculatus* |
|---|---|---|---|---|---|
| | | | | $\bar{x}$ ± S.E. | $\bar{x}$ ± S.E. |
| 5.6 | 60 | 0.24 | 16 | 57 ± 8 (6) | 61 ± 8 (7) |
| 2.8 | 60 | .12 | 16 | 56 ± 7 (7) | 45 ± 6 (7) |
| 1.4 | 60 | .06 | 16 | 29 ± 7 (7) | 23 ± 5 (7) |
| 11.2 | 120 | .24 | 16 | 81 ± 4 (7) | 86 ± 3 (7) |
| 5.6 | 120 | .12 | 16 | 80 ± 7 (7) | 85 ± 7 (7) |
| 2.8 | 120 | .06 | 16 | 57 ± 6 (7) | 51 ± 7 (7) |
| 1.4 | 120 | .03 | 16 | 41 ± 8 (5) | 39 ± 5 (7) |
| 11.2 | 120 | .12 | 8 | 94 ± 3 (5) | 94 ± 3 (5) |
| 5.6 | 120 | .06 | 8 | 81 ± 6 (5) | 86 ± 6 (5) |
| 2.8 | 120 | .03 | 8 | 72 ± 4 (5) | 57 ± 7 (5) |
| Control | | | | 3 ± 0.9 (7) | 2 ± 0.6 (7) |

[a] Caged mosquitoes at 1.2 m elevation 46 and 91 m downwind.

be 37,004 $m^3$ and there would be $9.16 \times 10^5$ particles/$m^3$ or $9.16 \times 10^2$ particles/l. There would be, likewise, $1.83 \times 10^3$/l of 10 μ particles. At a 60 ml rate of discharge there would be 0.9, 1.8 at 120 ml and 3.6 at 240 ml of 15 μ particles per cubic centimeter.

In topical application tests with bendiocarb on *Ae. taeniorhynchus,* the $LD_{50}$ was 7.8 ng and the $LD_{95}$ was 23.5 ng. A 15 μ particle from a 0.24 kg/l formulation contains 0.4 ng of active ingredient. Thus, at the $LD_{95}$ dose, at least 55 particles must impact for a toxic dose. Obviously, the more particles per unit volume, the greater the probability of a toxic dose. However, too many particles result in overtreatment and therefore a waste of insecticide. One way to decrease waste is to decrease the amount of active ingredient. The optimum number of particles and the amount needed for a toxic dose will vary depending on the insecticide used.

In order to make a proper comparison between treatments, log-probit regression analyses were made for each treatment. The calculated effective dosages (ED) presented in Table 2 indicate a relationship to the flow rates and vehicle speed. The ED-95 values were the greatest at 60 ml/min and a vehicle speed of 16 kph. At this treatment rate ca. 3 × more bendiocarb than malathion would be needed for 95% control. As the flow rate increases, the amount of bendiocarb needed for comparable control decreases. The amount of active ingredient needed for the treatment rate of 120 ml/min and 16 kph was ca. 0.4× and at 120 ml/min and 8 kph was ca. 0.2× the amount needed for 95% control at the 60 ml/min and 16 kph treatment rate. Thus, by increasing the number of aerosol droplets per unit volume and thereby increasing the probability of droplet contact with the insects, the amount of active ingredient in g/ha needed for an ED-95 was reduced.

The bendiocarb formulation contains 238 g AI/liter (2 lbs AI/gallon). This concentration was not sufficient to attain the *Ae. taeniorhynchus* ED-95 control level of 14.2 g/ha at either the 60 or 120 ml/min flow rates at a vehicle speed of 16 kph, but it was attained at 120 ml/min at a vehicle speed of 8 kph. Under field usage against mosquitoes of unknown insecticide susceptibility, flow rates of 180 ml/min or higher may be required for adequate control. At 180 ml/min and a vehicle speed of 16 kph, a formulation of 198 g AI/liter (1.67 lbs. AI/gal) would be needed to achieve a rate of 14.5 g AI/ha (0.0129 lb AI/acre). The greatest treatment rate with the 238 g AI/liter formulation is 17 g AI/ha (0.015 lb. AI/acre) at 180 ml/min and 16 kph.

Mosquitoes retained in the exposure cages had higher mortalities than those transferred to clean holding cages. The comparable 3-replication average mortalities at the treatment rate of 5.6 g/ha for retained and transferred *Ae. taeniorhynchus,* respectively, were 99 and 73%, for *An. quadrimaculatus*, 97 and 84%. At 2.8 g/ha, the mortalities for *Ae. taeniorhynchus* were 76 and 57%, respectively, and for *An. quadrimaculatus,* 100 and 47%. These data reconfirm the advisability of transferring the mosquitoes to clean holding cages as soon as possible in order to adequately evaluate the aerosol exposure.

In summary, bendiocarb was effective as a mosquito aerosol adulticide, but usage of this formulation under field conditions will probably require flow rates of 180 to 240 ml/min at a vehicle speed of 16 kph to achieve satisfactory control.

Table 2. Calculated effective dosages (ED) in g/ha for 50 and 95% control of caged adult female mosquitoes with ULV ground aerosols of bendiocarb.

| | | *Aedes taeniorhynchus* | | | *Anopheles quadrimaculatus* | | |
|---|---|---|---|---|---|---|---|
| Ml/min | kph | ED-50 | ED-95 | Slope | ED-50 | ED-95 | Slope |
| Bendiocarb | | | | | | | |
| 60 | 16 | 3.2 | 73.4 | 0.5236 | 3.6 | 45.3 | 0.6481 |
| | | (2.8–3.6)[1] | (40.7–181.0) | | (3.2–4.0) | (30.0–81.0) | |
| 120 | 16 | 2.0 | 31.8 | .5914 | 2.2 | 19.9 | 0.7519 |
| | | (1.7–2.2) | (23.7–46.8) | | (2.0–2.5) | (16.3–25.6) | |
| 120 | 8 | 1.3 | 14.2 | .6811 | 2.3 | 11.0 | 1.0483 |
| | | (0.8–1.7) | (11.2–20.5) | | (2.0–2.6) | (9.5–13.5) | |
| Malathion[2] | | | | | | | |
| 60 | 16 | 6.6 | 22.3 | 1.3420 | 4.6 | 14.8 | 1.4081 |
| | | (5.9–7.2) | (19.3–27.0) | | (4.0–5.1) | (12.9–17.9) | |

[1] 95% fiducial limits in parentheses.
[2] Data from Roberts 1983.

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