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# IMPACT OF RESIDUAL SPRAYING OF BENDIOCARB AGAINST THE MALARIA VECTOR *ANOPHELES CULICIFACIES* IN SELECTED VILLAGES OF THE GHAZIABAD DISTRICT, UTTAR PRADESH, INDIA

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ABSTRACT. A longitudinal study was carried out to evaluate the bioefficacy of indoor residual spraying of bendiocarb 80% wettable powder (WP) at 0.2 and 0.4 g/m$^2$ against *Anopheles culicifacies,* a principle malaria vector, and the impact of bendiocarb use on malaria incidence in selected villages of the Ghaziabad District, Uttar Pradesh, India. The control village was sprayed with malathion at 1 g/m$^2$ in 2001. Two rounds of bendiocarb spraying were carried out in each year from 1999 to 2001. Bendiocarb applications resulted in significant reduction in densities of adult *An. culicifacies* and other mosquito species in villages when compared to that of the control village ($P < 0.05$). Bioassay tests revealed that persistence of insecticide against *An. culicifacies* at 100% mortality was observed for about 10, 8, and 10 wk on mud, cement, and brick wall surfaces, respectively. Epidemiological evaluation revealed that malaria cases were significantly reduced after 1 year of spraying ($P < 0.05$) and by 2001, no *Plasmodium falciparum* was recorded in either of the bendiocarb-sprayed villages. The study revealed that indoor residual spraying of bendiocarb 80% WP at 0.2 g/m$^2$ produced effective control of resistant *An. culicifacies,* provided that >95% human-dwelling room coverage is achieved in both 1st and 2nd rounds of spraying at an interval of 10 wk in areas where malaria is a seasonal problem.

**KEY WORDS** *Anopheles culicifacies,* bendiocarb, indoor residual spraying, insecticide, malaria control, vector control

## INTRODUCTION

The strategy of malaria control in rural areas in India under the National Anti Malaria Programme (NAMP) is to carryout indoor residual spraying of insecticides in Primary Health Centres (PHCs) showing annual parasite incidence >2 (NAMP 2002). As per the National Insecticide Policy, dichlorodiphenyltrichloroethane (DDT), malathion, and pyrethroids are being selectively used to control *Anopheles culicifacies* Giles (Diptera: Culicidae) which is a principal vector of malaria in rural and peri-urban areas of the northern plains of the country (NAMP 2002). Malathion is sprayed in DDT-resistant areas and pyrethroids are used in multiple-resistant areas under the NAMP in India. Policy dictated that these insecticides were sprayed for several years, which likely precipitated selection of widespread resistance to DDT, hexachlorocyclohexane (HCH), and malathion in certain states and also to pyrethroids in Maharashtra and Gujarat states (Raghavendra et al. 1992, Pillai 1996, Anonymous 2001). Consequently, evaluation of alternative insecticides to control malaria is urgently needed, especially in locations where multiresistant *An. culicifacies* exists.

In consonance with this policy, efficacy of bendiocarb (2,2-dimethyl-1,3-benzodioxol-4-yl *N*-methylcarbamate), a wide-spectrum carbamate insecticide developed and recommended by the World Health Organization (WHO 1986) for the control of resistant vector species of mosquitoes was evaluated over a period of 3 years. Single (0.2 g/m$^2$) and double (0.4 g/m$^2$) doses of bendiocarb against *An. culicifacies* and the impact of bendiocarb use in controlling malaria incidence in certain selected villages were evaluated.

## MATERIALS AND METHODS

*Study sites:* The villages of Nahal (Dasna PHC) and Dehra and Dhaulana (Dhaulana PHC) in Ghaziabad District, Uttar Pradesh, India, were selected for evaluation of indoor residual spraying of bendiocarb. These villages are located in the command area of the upper Ganga canal at 70°30′N, 28°30′E. According to the 1991 census, the populations of Nahal and Dehra were 9,554 and 6,792, respectively, and these villages were chosen for bendiocarb spraying. Nahal has about 1,704 human dwellings and 1,116 cattle sheds and temporary structures (structures prepared with mud and bamboo for the purpose of storing grass, cow dung, and other items), as compared to 1,442 human dwellings and 837 cattle sheds and temporary structures in Dehra. The control village (Dhaulana) was located approximately 12 and 6 km away from Nahal and Dehra, respectively. Dhaulana has a population of 9,169 as per the 1991 census and 1,833 human dwellings and 712 cattle sheds and temporary structures. Experimental and control villages had more or less the same composition of mosquito fauna, vector species, and malaria endemicity. *Anopheles culicifacies* is the principal malaria vector and breeds profusely in irrigation channels in this area. The main profession of the inhabitants is farming, which relies on canal water for irrigation. The ratio of humans to cattle is about 1:2. Susceptibility tests carried out in 1990 revealed that *An. culicifacies* is resistant to both DDT and HCH; however, it was susceptible to deltamethrin (Ansari et al. 1990).

Table 1. Record of indoor residual spraying of bendiocarb 80% wettable powder and percent coverage of different structures in Nahal and Dehra villages, Ghaziabad District, Uttar Pradesh, India.[1]

| | | Number of structures sprayed | | | | % coverage | | | |
|---|---|---|---|---|---|---|---|---|---|
| Spray round | Spraying date | HD | RS | CS | TS | HD | RS | CS | TS |
| Nahal (0.2 g/m²) | | | | | | | | | |
| I | Aug. 8–Sept. 13, 1999 | 1,662 | 7,533 | 504 | 319 | 99.7 | 99.7 | 100.0 | 100 |
| II | Nov. 1–15, 1999 | 1,665 | 7,440 | 504 | 319 | 98.5 | 97.2 | 99.2 | 100 |
| III | July 11–27, 2000 | 1,670 | 7,629 | 832 | 199 | 98.5 | 98.9 | 86.6 | 100 |
| IV | Sept. 19–1 Dec., 2000 | 1,672 | 7,635 | 834 | 200 | 98.5 | 98.8 | 87.1 | 100 |
| V | July 4–29, 2001 | 1,703 | 7,800 | 870 | 244 | 97.5 | 98.2 | 94.4 | 100 |
| VI | Sept. 4–24, 2001 | 1,704 | 7,808 | 870 | 246 | 97.1 | 97.1 | 100.0 | 81.3 |
| Dehra (0.4 g/m²) | | | | | | | | | |
| I | Sept. 9–30, 1999 | 1,409 | 6,156 | 323 | 224 | 99.1 | 99.4 | 100.0 | 100 |
| II | Nov. 16–28, 1999 | 1,415 | 6,536 | 460 | 220 | 89.3 | 90.5 | 100.0 | 100 |
| III | July 28–Aug. 8, 2000 | 1,420 | 6,576 | 604 | 228 | 98.4 | 98.8 | 99.8 | 100 |
| IV | Oct. 3–15, 2000 | 1,421 | 6,578 | 605 | 230 | 98.5 | 99.7 | 100.0 | 100 |
| V | July 4–28, 2001 | 1,440 | 6,653 | 618 | 212 | 96.5 | 94.7 | 100.0 | 100 |
| VI | Sept. 4–24, 2001 | 1,442 | 6,661 | 618 | 214 | 97.1 | 97.9 | 100.0 | 100 |

[1] HD, human dwelling; RS, rooms; CS, cattle shed; TS, temporary structure.

*Insecticide applications:* A preliminary survey was carried out in different villages to select experimental and control villages with more or less the same malaria incidence, topography, and mosquito density. Bendiocarb 80% wettable powder was supplied by the sponsoring agency Aventis Environmental Science (Aventis Crop Science India Ltd., Mumbai, India). Indoor residual spraying with single (0.2 g/m²) and double (0.4 g/m²) doses was carried out in Nahal and Dehra, respectively. Spraying was carried out with stirrup pumps attached to calibrated flat-type nozzles that discharged 780 ml of insecticide suspension. Two rounds of spray were carried out with bendiocarb in these villages commencing from September in 1999 and from July during 2000 and 2001. The control village was sprayed with DDT at 1 g/m² as per NAMP schedule. Man-hour density (MHD) was monitored in both cattle sheds and human dwellings before and after the spray in both control and experimental villages. The parity rate of randomly collected females from bendiocarb-sprayed and DDT-sprayed villages was calculated by dissecting females. Bioassay tests were performed by using standard WHO cones (WHO 1981) on different surfaces in separate houses and villages after obtaining the consent of the inhabitants that they would not whitewash or mud-plaster the walls. Door-to-door active surveillance on weekly basis was carried out in all the villages and presumptive treatment was given to all patients with fevers, whereas radical treatment was given to patients of confirmed positive cases as per NAMP schedule.

Slide positivity rate (SPR), cases per 1,000, and *Plasmodium falciparum* (*Pf*) per 1,000 population were calculated according to standard procedures. Percent reduction of vector densities and epidemiological indices were calculated by using the following formula described by Mulla (1971):

$$\% \text{ reduction} = 100 - \frac{C_1}{T_1} \times \frac{T_2}{C_2} \times 100,$$

where $C_1$ = pretreatment density in control, $C_2$ = posttreatment density in control, $T_1$ = pretreatment density in experimental, and $T_2$ = posttreatment density in experimental.

*Statistical analysis:* A *t*-test was performed to determine homogenous composition of mosquito vector species, for significant reduction in vector densities, and for incidence of malaria in experimental and control villages.

## RESULTS

Dates of application and spray coverage in human dwellings and cattle sheds are presented in Table 1. The spraying coverage in both the villages was achieved through enthusiastic response from the inhabitants because of collateral benefits and no inhabitants of both villages refused spraying. The slight decline in spraying coverage in target villages was due to peak cultivation time of the wheat crop, and percent coverage in cattle sheds, particularly in Nahal, declined due to storage of fodder in cattle sheds.

### Entomological evaluation

Percent reduction in MHD of *An. culicifacies* and total mosquitoes of Nahal (treated with bendiocarb at 0.2 g/m²) and Dehra (treated with bendiocarb at 0.4 g/m²) are presented in Table 2. The spraying of bendiocarb at 0.2 g/m² in 1999 resulted in significant reduction in adult densities of *An. culicifacies* and other mosquitoes. At the low dose, >82% reduction was observed in *An. culicifacies* in the 1st year of spraying and >88% reduction occurred in other mosquitoes. At the higher dose, >78% and

Table 2. Impact of bendiocarb spraying on reduction of mosquito density and malaria incidence.

| | Entomological evaluation[1] | | | | Epidemiological impact[1] | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | *Anopheles culicifacies* | | Other mosquitoes | | SPR[2] | | Cases per 1,000 | | *Pf* per 1,000 | |
| Year | 0.2 g/m² | 0.4 g/m² | 0.2 g/m² | 0.4 g/m² | 0.2 g/m² | 0.4 g/m² | 0.2 g/m² | 0.4 g/m² | 0.2 g/m² | 0.4 g/m² |
| 1999 | 82.2 ± 1.5 | 78.2 ± 3.5 | 88.7 ± 3.5 | 89.1 ± 7.8 | 75.2 ± 8.5 | 78.2 ± 5 | 6.1 ± 1 | 50.5 ± 0.5 | 90 ± 0 | 81.1 ± 0 |
| 2000 | 92 ± 1.5 | 82 ± 1 | 93.9 ± 4.5 | 91.1 ± 3.5 | 92 ± 8.5 | 82 ± 11 | 92 ± 1 | 83.3 ± 1.5 | 100 ± 0 | 97.4 ± 0 |
| 2001 | 98.5 ± 1 | 86.1 ± 2 | 95.7 ± 7.5 | 90.4 ± 6.5 | 89.5 ± 11 | 86.1 ± 1 | 80.5 ± 1 | 84.5 ± 1 | 100 ± 0 | 100 ± 0 |

T-test

| | MHD[3] of *An. culicifacies* | MHD of other mosquitoes | SPR | Cases per 1,000 |
|---|---|---|---|---|
| Control and 0.2 g/m² | 4.18* | 3.85* | 2.82* | 2.12* |
| Control and 0.4 g/m² | 3.78* | 3.5* | 2.71* | 2.1* |
| 0.2 g/m² and 0.4 g/m² | 2.0 (ns) | 2.06* | 2.15* | 1.5 (ns) |

[1] The values depict percent reduction over control.
[2] SPR, slide positive rate.
[3] MHD, man-hour density.
* $P < 0.05$ (significant); ns, nonsignificant.

>89% reduction were observed in *An. culicifacies* and total mosquito density, respectively. In subsequent years, both doses of bendiocarb showed enhanced impact in reduction of mosquito density (Table 2).

The impact of bendiocarb spraying also was observed on nontarget species of mosquitoes, because a substantial reduction in total mosquito density occurred in experimental villages in the 1st year of spraying. Subsequent spraying of bendiocarb during 2000 and 2001 provided enhanced impact on vector species as well as nontarget species of mosquitoes ($P < 0.05$).

## Bioassay tests

Results of bioassay tests carried out on different surfaces are given in Figs. 1–3. The bendiocarb insecticide persists for several weeks on mud, cement, and brick wall surfaces. However, marginal variations were observed with each surface and species tested. The persistence of bendiocarb against *An. culicifacies* was indicated by the 100% mortality up to 10, 8, and 10 wk on mud, cement, and brick wall surfaces, respectively. Residual efficacy of bendiocarb was observed up to 8 wk for *Culex quinquefasciatus* Say (Diptera: Culicidae) on different surfaces. Of the 3 surfaces tested, maximum persistence was observed on mud walls, followed by brick and cement walls.

## Parity rate of *An. culicifacies*

Studies were carried out to determine the parity rate of vector species in experimental and control areas to substantiate the impact of vector reduction on transmission of the disease. Parity rate of *An. culicifacies* ranged between 75.6 and 76.7 before bendiocarb spraying in Nahal and Dehra, respectively. However, the parity rate in the control village was 94.3%. After bendiocarb spraying, the parity rate was considerably reduced and ranged from 7.1 to 14.2 in Nahal and 5.8 to 7.1 in Dehra. No change in parity rate was recorded in the control village. One round of malathion focal spraying in the control village did not provide a desired impact, either on the reduction of vector density or on the parity rate. It has failed to interrupt malaria transmission, because a 0.4% sporozoite rate was still detected in 2000.

## Epidemiological impact

Percent reductions in SPR, cases per 1,000, and *Pf* per 1,000 in experimental villages compared to the control village are shown in Table 2. Bendiocarb indoor residual spraying produced >75% reduction in SPR in the village sprayed with bendiocarb at 0.2 g/m² and 78% reduction in the village sprayed with bendiocarb at 0.4 g/m² in the 1st year. The reduction in the SPR was further enhanced in

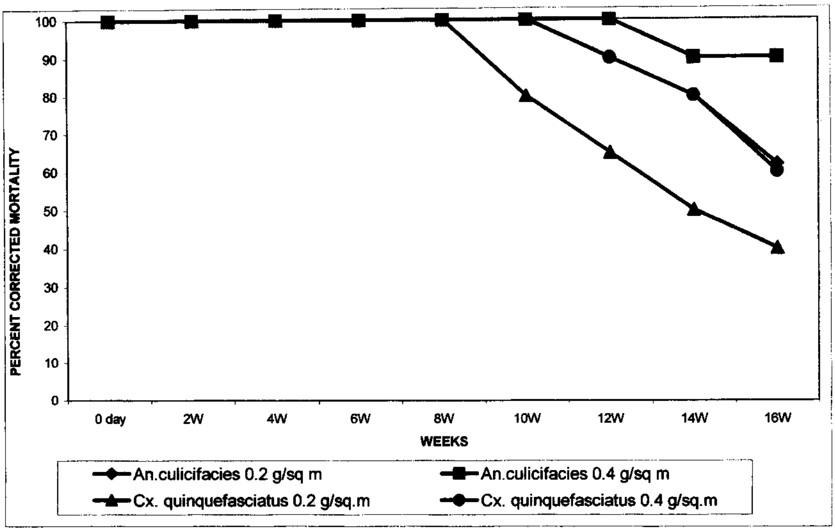


Fig. 1. Persistence of bendiocarb on mud wall surfaces and percent corrected mortality of *Anopheles culicifacies* and *Culex quinquefasciatus.*

subsequent years. Reduction in *Pf* per 1,000 also was observed in study villages.

## DISCUSSION

Insecticide resistance and cross-resistance among mosquito vector species, particularly malaria vectors, are well-known problems hampering sustainability and cost-effectiveness of vector control in several tropical and subtropical countries. Therefore, there is an urgent need to search for alternative insecticides that could be used selectively in multiresistant areas to tackle malaria outbreaks, which are reported periodically, particularly in the northeastern states of India.

Our study revealed that the spraying of bendiocarb at 0.2 and 0.4 g/m$^2$ was operationally feasible because >95% room coverage in houses was obtained continuously for 3 years because of enthusiastic response from inhabitants. Social acceptance of the use of bendiocarb was achieved because it does not stain the sprayed surface and was free from any unpleasant odor. The spraying also was found to be safe to humans because strict WHO safety standards were practiced throughout the spraying periods (WHO 1986). The oral median lethal dose of bendiocarb is 55 g/kg body weight (Chavasse and Yap 1997) and excessive exposure is known to induce papillary contraction when protective clothing and other safety measures are not

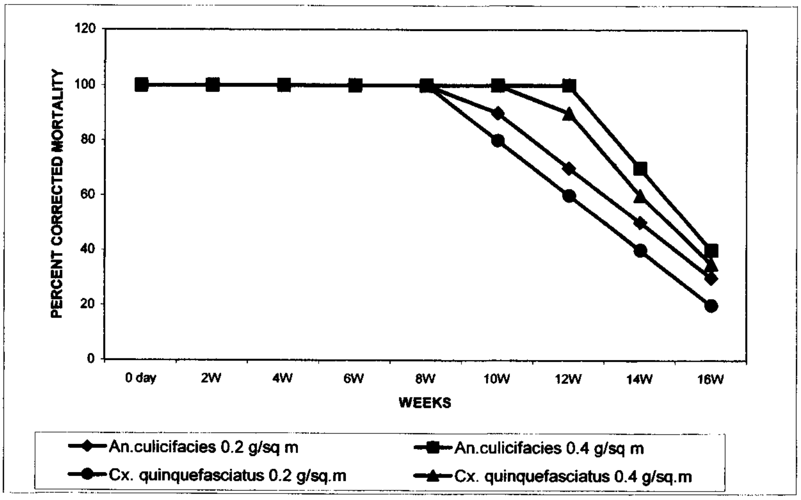


Fig. 2. Persistence of bendiocarb on cement wall surfaces and percent corrected mortality of *Anopheles culicifacies* and *Culex quinquefasciatus.*

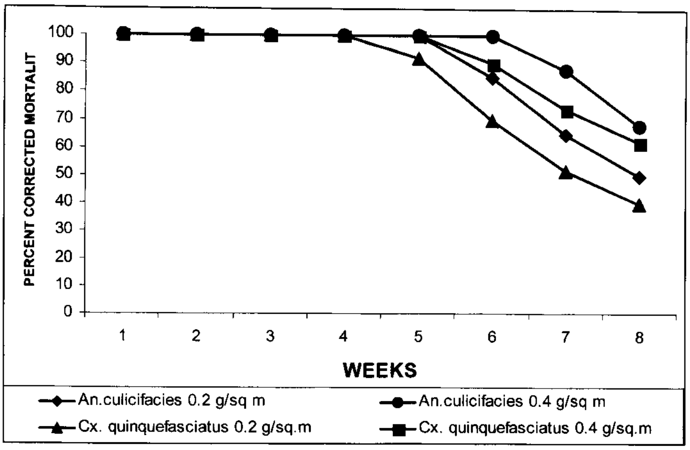


Fig. 3. Persistence of bendiocarb on brick wall surfaces and percent corrected mortality of *Anopheles culicifacies* and *Culex quinquefasciatus.*

used by spray applicators (Das et al. 1982). During the present study, no hazards were observed either to spray applicators or inhabitants. Our findings also are in agreement with those of earlier workers, particularly Motabar et al. (1981), who specifically studied the safety of bendiocarb to spray applicators and inhabitants during their field trial in Iran.

The residual efficacy of bendiocarb was demonstrated against target and nontarget species of mosquitoes at both single and double doses on different surfaces for several weeks. The persistence causing 100% adult mortality was observed for 10 wk on mud and brick wall surfaces at 0.2 g/m$^2$ against the malaria vector (*An. culicifacies*) and *Cx. quinquefasciatus,* suggesting that bendiocarb may be sprayed at an interval of 10 wk for the malaria control program. Similar supporting observations were made by Asinas et al. (1994) and Arredondo-Jiminez et al. (1993). The impact of bendiocarb spraying also was evident on adult densities of both target and nontarget species of mosquitoes during postspraying periods. Similar degree of reduction in vector densities with bendiocarb was observed against *Anopheles albimanus* and *Anopheles flavirostris* (Diptera: Culicidae) in Mexico and the Philippines (Eshghy et al. 1979, Del Rosario and Del Rosario 1984, Arredondo-Jiminez et al. 1992). The present study also demonstrated pronounced reduction in the parity rate of malaria vectors. Oocyst and sporozoite rates were zero in both the experimental villages, indicating interruption in malaria transmission.

Bendiocarb spraying also demonstrated a reduction in associated malaria incidence. Considerable reduction in cases per 1,000 and *Pf* per 1,000 during postspraying years, particularly in the 2nd and 3rd years, indicated the possibility of interruption of transmission in bendiocarb sprayed villages. This can be further substantiated by the fact that not even a single case of malaria caused by *Pf* was recorded in 2001. In view of these observations, it can be concluded that bendiocarb at 0.2g/m$^2$ could be used as a stock insecticide in multiresistant areas to prevent epidemics under the national program, provided that strict WHO safety measures are practiced. The cost of indoor residual spraying can be further reduced, particularly against *An. culicifacies,* which is basically a zoophilic species, by restricting the spraying only to human-dwelling rooms and by taking village annual parasite incidence as a unit as recommended earlier by Ansari et al. (1986, 1990). Results of this and other studies (Brown et al. 1987, Arredondo-Jiminez et al. 1993, Casas et al. 1998) have demonstrated that the low-volume insecticide technique is comparable to that using conventional stirrup pumps.

Long-term operational studies on relative efficacy of low-volume and conventional techniques are desired to evaluate efficacy, quality control, sustainability, and cost effectiveness before incorporation in the national program.

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