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# Impact of DDT spraying on malaria transmission in Bareilly District, Uttar Pradesh, India

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*Background & objectives:* Impact of indoor residual spraying of DDT on malaria transmission and vector density was evaluated in six villages of Shergarh PHC, Bareilly district, Uttar Pradesh under the operational condition of National Vector Borne Disease Control Programme (NVBDCP) from July 2001 to March 2002 (one transmission season only).

*Methods:* Two rounds of DDT (50% WDP) spraying @ 1 g/m$^2$ were done both in the experimental and control villages by the state health authorities. The spraying in experimental villages was supervised by Malaria Research Centre (MRC) whereas the district health authorities supervised the operation in control villages. Mass blood surveys were made three times—before the first round, in between the first and second rounds and after the second round of spraying. The blood smears were examined by the trained microscopists of MRC, Haldwani. From the above examinations epidemiological indicators such as slide positivity rate (SPR), slide falciparum rate (SFR) and infant parasite rate (IPR) were calculated. All malaria positive cases were given radical treatment as per NVBDCP schedule. Entomological parameters such as per man hour mosquito density, parity rate, gonotrophic condition and adult susceptibility status of *Anopheles culicifacies* to diagnostic dosages of DDT (4%) were monitored as per the standard techniques.

*Results:* A total of 988.5 kg of DDT was consumed during two rounds of spray. The house coverage varied from 87 to 95.3%. Parasitological evaluation revealed significant reduction in malaria cases ($p < 0.0005$) and infant parasite rate declined from 2.9 to 0%. Entomological observations revealed considerable reduction in the density of malaria vector *An. culicifacies* despite of its 21.4% mortality against DDT test papers.

*Interpretation & conclusion:* The overall results of the study revealed that DDT is still a viable insecticide in indoor residual spraying owing to its effectivity in well supervised spray operation and high excito-repellency factor.

**Key words** *An. culicifacies* – DDT – impact – spray – susceptibility

Insecticide-based indoor residual spraying is the main strategy for vector control programme in rural areas where 60–70% of the total malaria cases throughout the country are transmitted by *An. culicifacies* Giles (Diptera : Culicidae)[1]. Currently DDT, malathion and to some extent synthetic pyrethroids are being used for controlling the malaria vectors under the National Vector Borne Disease Control Programme (NVBDCP), the erstwhile National Anti Malaria Programme (NAMP). Continuous usage of insecticides either in the public health programme or in agriculture has resulted in the development of resistance in the major malaria vector species to different insecticides[2]. The efficacy of a given insecticide depends not only on the intrinsic chemical nature and properties of the molecule but also on certain technical factors such as susceptibility of the target vector species to the insecticide, the quality of spraying, dose dispensation and coverage, residual efficacy and also on human intervention. Any of these factors would affect the vector control in particular and disease control in general.

Earlier workers[3,4] provided sufficient proof of the usefulness of DDT in areas where *An. culicifacies* was resistant to DDT or HCH but spray coverage of 50 to 90% and application of correct dosages of insecticides provided desired efficacy. Observations made in South America[5] revealed that when large number of houses were sprayed with DDT malaria rates declined and when fewer houses were sprayed malaria rates increased. In spite of its proven efficacy DDT is an exempted insecticide being the persistent organic pollutant (POP) and is to be used with caution[6,7]. The fundamental problem is the lack of affordable alternative to DDT. For the large-scale disease vector control programme like that of India's NVBDCP there is a need to continue the use of existing insecticides. DDT is still the cheapest insecticide when compared to both malathion and synthetic pyrethroids. Therefore, for evaluating the efficacy of DDT a multicentric study was carried out by ICMR in different districts in different states and Bareilly in Uttar Pradesh. Malaria Research Centre coordinated the study to evaluate the efficacy of DDT indoor residual spray in malaria vector control; to know the susceptibility status of malaria vector to DDT; and to understand the quality of spray coverage and influence of human interference (mud plastering, painting, etc.) on the efficacy of residual spraying.

The evaluation was done through different entomological and parasitological indices from July 2001 to March 2002 (one transmission season only). The results of the study are communicated in this paper.

## Material & Methods

*Study area:* As suggested by the district health authorities a cluster of six villages—Vasudharan Jageer, Sedha Gautia, Aklabad, Nirbhua, Gautia and Sunder Gautia of Shergarh PHC, Bareilly district was taken for DDT spray. The total population of the above villages is 7534. They are located about 45 km north of Bareilly on the Nainital–Bareilly highway. Two villages—Takia and Paharpur situated about 4–5 km away from the experimental villages were taken as control. Most of the houses are made of bricks and cement while cattlesheds are with mud plastered walls and thatched roofings. The cattlesheds are situated either adjacent to the human dwellings or separated by a courtyard.

The overall annual parasite incidence (API)—the number of malaria cases/000 population/year of these villages was reported to be 8.6 during the year 2000. The other malariometric indices—annual blood examination rate (ABER) and SPR were recorded to be 5.1 and 17.1% during the above year respectively. No *P. falciparum* incidence was reported by the state health authorities during the same period.

To combat malaria two rounds of DDT (50% WDP) spray was carried out @ 1 g/m$^2$ both in the experimental and control areas by the state health authorities during the year. It is to point out that the comparative area was not entirely unsprayed. In experimental villages spraying of DDT as well as entomological and parasitological evaluations were carried out by MRC, while the district health personnel supervised spray in the control villages.

*Parasitological evaluation:* To know the possible impact of spray mass blood surveys were carried out in the study villages by selecting every fourth house. The surveys were made three times in July–August, October–November 2001 and March 2002. The target of covering 25% population was achieved during the first survey. But the same could not be achieved during the second and third surveys due to less cooperation from the inhabitants. The blood smears collected from the field were stained with JSB stain[8] and examined by microscopists of MRC, Haldwani. At the time of blood smear collections 600 mg of chloroquine base to adults and proportionate dosages to other age groups were provided as presumtive treatment. Thereafter radical treatment as per NVBDCP schedule was administered to malaria positive cases by the state health authorities.

*Entomological evaluation:* Information on entomological aspects such as density of malaria vector and other anophelines, parity rates in vector mosquito based on tracheolar skeins in ovaries and adult susceptibility staus of *An. culicifacies* to DDT were collected as per the WHO techniques[9,10]. Following the study protocol we examined the tracheolar skeins only for parity rates (nulliparous/parous). The Polovodova's method which is undoubtedly useful for examination of the ovariole dilatations was not used in this study.

Hand collections of indoor resting malaria vector *An. culicifacies* and other mosquitoes were carried out using suction tube and torch-light before and after each round of spray. From these collections species-wise per man hour density (MHD) of mosquitoes was calculated as per the fomula given below:

$$\text{MHD} = \text{N} \times 60/\text{T} \times \text{P}$$

Where, N = No. of mosquitoes collected; T = Time spent in min; P = No. of persons involved in collections.

In addition to the above mentioned activites a random survey to assess the extent of mud plastering/white washing of the sprayed surfaces was carried out. The mosquito breeding sites were seepage water from irrigation canals, drains, nallahs, ponds, unused wells, rice fields and low-lying marshy land.

## Results & Discussion

*DDT spray:* Details of DDT spray coverage and insecticide consumed are given in Table 1. Room coverage were 90.5 and 81.2% in the first and second rounds of spray respectively.

It is worthwhile to point out that the spray schedules were not devised properly. First round should have been commenced in mid-June instead of August as observed in the present investigations. *An. culicifacies* which is the major malaria vector in this area usually builds-up fairly high densities immediately after the first monsoon shower during June. Therefore, to interrupt malaria transmission chain, spray should have been synchronised accordingly.

The second round spray clashed with the Deepawali festival during which majority of the inhabitants white-washed or mud plastered their houses. Due to this reason the refusal rate increased. Despite of our efforts to motivate the people there were refusals of spray in both the rounds.

*Parasitological evaluation:* To evaluate the overall impact on the disease prevalence mass blood surveys were conducted thrice in the experimental villages.

**Table 1. Records of DDT spraying coverage in experimental villages, Bareilly district, Uttar Pradesh**

| Spray round | Date of spray | Houses targeted | Houses sprayed (%) | Refusals/Locked houses (%) | Rooms targeted | Rooms sprayed (%) | DDT consumed (kg) |
|---|---|---|---|---|---|---|---|
| First | 20 Aug– 7 Sep 2001 | 1436 | 1368 (95.3) | 68 (4.7) | 4782 | 4328 (90.5) | 513.5 |
| Second | 9 Nov– 5 Dec 2001 | 1416 | 1232 (87) | 184 (12.99) | 4357 | 3537 (81.2) | 475 |

**Table 2. Parasitological results of mass blood surveys in study villages of Bareilly district, Uttar Pradesh**

| Survey period | Population | No. of blood smears examined | *P. vivax* | *P. falciparum* | Total +ve | Blood examination rate | Parasite incidence rate | SPR | SFR |
|---|---|---|---|---|---|---|---|---|---|
| Jul–Aug 2001 | 7534 | 1818 | 63 | 75 | 138 | 24.1 | 18.3 | 7.6 | 4.1 |
| Oct–Nov 2001 | -do- | 1634 | 24 | 32 | 56 | 21.7 | 7.4 | 3.4 | 2 |
| March 2002 | -do- | 827 | 12 | 1 | 13 | 11 | 1.7 | 1.6 | 0.1 |

Results of these surveys are presented in Table 2. A total of 1818 blood smears were collected and examined during the first survey carried out from July–August 2001. The number of malaria cases were 138 (63 *P. vivax* + 75 *P. falciparum)*. The SPR and SFR was 7.6 and 4.1% respectively. In second point prevalence survey carried out in October–November 2001 a total of 1634 blood smears were collected and examined which revealed 56 malaria positive cases. The positives constituted 24 *P. vivax* and 32 *P. falciparum*. This revealed 3.4% SPR and 2% SFR. The third survey was carried out in March 2002 during which only 13 malaria positive cases were detected out of 827 blood smears examined. The SPR and SFR were 1.6 and 0.1% respectively. The results of point prevalence surveys revealed a gradual decline in malaria incidences after DDT spray. The decline in overall malaria cases might be due to the cumulative effect of early diagnosis and prompt treatment (EDPT) and DDT spraying.

*Statistical analysis:* The observed differences in incidence of *P. vivax* in three surveys was significant [?$^{2}$ = 17.72 (df =2) and $p < 0.0005$]. While for *P. falciparum* the reduction was highly significant ??$^{2}$ =134.2 (df =2) and $p < 0.0005$].

In this study *P. falciparum* constituted 52.2% of the total malaria cases. Whereas the data collected by the state health authorities revealed no *P. falciparum* malaria from 1998 to 2001. The entire malaria cases reported by them constituted only *P. vivax*. Our results were fairly in accordance to those reported by Sharma *et al*[11] from Haryana and Uttar Pradesh in which they found surveillance under National Malaria Eradication Programme was recording a small number of malaria cases and was not sensitive enough to reveal the real effect of spraying.

*Infant parasite rate (IPR):* The infant parasite rate (IPR) is an important indicator for detection of active malaria transmission. Analysis of positive malaria cases collected by us revealed occurrence of 4 (2.9%), 1 (1.9%) and 0 (0%) cases of infant malaria during the first, second and third mass blood surveys respectively. These results revealed that malaria transmission which occurred from July–November was interrupted later on by EDPT measures and DDT spraying. Our findings resembled to those reported by other workers[12].

*Entomological evaluation:* Results of per man hour density (MHD) of adult mosquitoes before and after each spray round is given in Table 3. Results revealed prevalence of five anophelines—*An. culicifacies, An. subpictus, An. vagus, An. annularis* and *An. barbirostris* both in experimental and control areas before first round of DDT spray. The pre-spray densities of these mosquitoes in experimental area were 10, 86, 11, 7 and 3 per man hour respectively which declined to 0, 4, 1, 0 and 0 per man hour respectively after first round of DDT spray.

The pre-spray densities of above mosquitoes in the control area were 10, 62, 8, 7 and 1 per man hour respectively. The post-spray densities revealed 3, 5, 2,

**Table 3. Per man hour densities before and after first and second rounds of DDT spray in study villages of Bareilly district, Uttar Pradesh**

| Mosquito species | Per man hour density | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | First round spray | | | | Second round spray | | | |
| | Experimental | | Control | | Experimental | | Control | |
| | Pre-spray | Post-spray | Pre-spray | Post-spray | Pre-spray | Post-spray | Pre-spray | Post-spray |
| *An. culicifacies* | 10 | 0 | 10 | 3 | 0 | 0 | 3 | 46 |
| *An. fluviatilis* | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 |
| *An. aconitus* | 0 | 0 | 0 | 2 | 1 | 0 | 10 | 1 |
| *An. subpictus* | 86 | 4 | 62 | 5 | 3 | 2 | 13 | 7 |
| *An. vagus* | 11 | 1 | 8 | 2 | 0 | 1 | 1 | 0 |
| *An. annularis* | 7 | 0 | 7 | 7 | 1 | 0 | 10 | 23 |
| *An. nigerrimus* | 0 | 0 | 2 | 0 | 1 | 0 | 0 | 0 |
| *An. barbirostris* | 3 | 0 | 1 | 0 | 0 | 0 | 3 | 0 |

7 and 0 per man hour respectively in the latter area. In addition to the above mentioned anophelines two more species—*An. aconitus* and *An. nigerrimus* were also recorded in the control area. Their densities varied from 0 to 2 per man hour each. Before second round of DDT spray low densities of four anophelines—*An. aconitus, An. subpictus, An. annularis* and *An. nigerrimus* were recorded in the experimental area. Their densities further declined after the second round of spray. In contrast no such decline in control area occurred especially in the case of *An. culicifacies* whose densities increased from 3 (pre-spray) to 46 (post-spray) per man hour (Table 3).

It was observed that a corresponding decrease in the densities of *An. culicifacies* occurred in control after the first round of spray. This occurred due to the reason that the comparative area was not entirely unsprayed. Further, it may be due to excito-repellency of DDT. If the control area was held unsprayed the impact of DDT spraying would have been more pronounced. Similar results were found in earlier studies[3,4,13]. The micro-ecological variations in the breeding potentials and resting sites might have influenced the densities of *An. annularis* which remained static during the pre- and post-spray periods of first round. However, after second round of spraying populations of both *An. culicifacies* and *An. annularis* were halted in the experimental area.

It is pertinent to point out that better impact on vector density in experimental area was achieved by maximising DDT spray and effective supervision by our staff whereas the spray work in the control area was left entirely under the BSW command. The senior supervisory staff of the district health authorities never supervised the spraying operation due to their pre-occupied work of Polio Immunisation Programme being executed during the study period. The cumulative effect of these factors resulted less impact on the overall mosquito densities in the control area.

*Gonotrophic condition:* Collected female *An. culicifacies* were classified into unfed (UF), blood fed (BF), semigravid (SG) and gravid (G) based on Christopher's stages[9]. The results revealed proportion of

UF, BF, SG and G were 0, 16.7, 50 and 33.3% respectively in the experimental villages during the prespray of first round. During the subsequent surveys no population of *An. culicifacies* was found in the experimental area whereas in control villages vector population was recorded during both the spray rounds. The above proportion in the latter area varied from 0 –10, 0 – 33.3, 30.4 – 70 and 20 – 66.7% respectively.

The proportion of BF and SG in the control area was found almost equal after first and second rounds of spray. From this it may be inferred that DDT had least impact on the indoor resting population of malaria vector in the control area as a result of which the species exhibited endophilic tendency in the area[14].

*Parous rate:* Tracheolar skeins on ovaries were examined to record parous rate of *An. culicifacies* for the estimation of its longevity. The results revealed 34.4% nulliparous and 65.6% parous during the prespray of first round. But after first and second rounds of spray no vector population was found in the experimental area. In contrast to this vector population was recorded during both the spray rounds in the control area. The parous percentage of the vector species varied from 74.1 to cent percent in the control area which revealed higher longevity of the vector mosquito in the said area. Occurrence of high parous percentage in the vector mosquito in the control area revealed no impact on its longevity.

*Adult susceptibility test:* Freshly-fed field collected adults of *An. culicifacies* were tested against the diagnostic doses of DDT (4%) as per WHO standard techniques[10]. The tests were carried out on different dates at average temperature of 28.8°C and 76% relative humidity (RH). In the experimental area a total of 140 mosquitoes in six replicates and in control 70 in three replicates were tested. After 24 h of holding mortality in experimental and control areas were 21.4 and 2.8% respectively.

In our earlier observations mortality of *An. culicifacies* to DDT was recorded as low as 1.1% in Nainital district[15] and 42.5% in Moradabad district, Uttar Pradesh[16]. Resistance in the major rural malaria vector *An. culicifacies* was also reported from other parts of the country[2].

In this study the spray impact was observed both on the vector density and malaria cases despite of the less susceptibility of *An. culicifacies* against DDT. Other field studies revealed that with intensified spray operations under proper supervision the epidemiological impact could be obtained with DDT in areas where the vector was found resistant to the above insecticide by WHO susceptibility test method[17], A similar epidemiological impact was reported by Sharma *et al*[3,4] while assessing impact of DDT spraying on malaria transmission and on *An. culicifacies* resistant to DDT and HCH in villages of Haryana and Uttar Pradesh. Their results revealed marked reduction both in malaria incidences and vector densities in the above areas despite 10–40% mortality of *An. culicifacies* to DDT. The reasons for significant reduction in the vector density and malaria incidence were attributed to application of correct insecticidal dosages and maximising spray coverage by procedure of convincing villagers at all levels about the advantages of spraying. It has been noticed that failure to maintain control over malaria most likely resulted from failure in the function of intervention or from failure to make proper application of intervention[5]. It was suggested that DDT should be produced and distributed for governments to use in malaria control only. Use of this insecticide should not be abandoned unless its known detrimental health effects are greater than the effects of uncontrolled malaria on human health[7].

## Conclusion

The limited data generated during this study proved that DDT is still a viable insecticide in indoor residual spraying owing to its effectivity in well supervised spray operation and high excito-repellency factor. Thus, this insecticide still can be used as a candidate insecticide till a cost-effective alternate insecticide is available.

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