The focus of malaria field work was on the tribal settlements in forests, epidemiology of malaria in tribal areas, bioenvironmental malaria control in tribal settlements and field trials with the insecticide-treated bednets in prevention from mosquito bites. Special mention may be made of the following research contributions that attracted global attention.

- Malaria in pregnancy: There was high morbidity and mortality in pregnant women. Even today, main reliance in the treatment of malaria remains on the local herbs/indigenous remedies. This work led to special programme on malaria in pregnancy.

- Malaria vaccine is under development in the Indian laboratories, and many other foreign laboratories. India offers various ecological settings, good infrastructure and strong technical manpower for testing malaria vaccines. Site has been prepared in Mandla district for undertaking malaria vaccine trials. This work has produced a wealth of epidemiological data on malaria transmission dynamics.

- During epidemiological investigations a variant of *P. vivax* malaria like parasite was discovered. In the last two decades malaria parasite formula has changed in favour of *P. falciparum*. The problem of mono- and multi-drug resistance is becoming acute in certain pockets of the state.

### Background

Forest malaria is an important paradigm of malaria in India (Singh & Khare, 1999). Large part of Madhya Pradesh is forested and is highly endemic for malaria since long, which necessitated in-depth studies on malaria in tribal population in Jabalpur. Therefore, a unit of Integrated Disease Vector Control (IDVC) project was established in Jabalpur in 1986 to find out transmission dynamics of malaria in tribal/forested population, to study socio-cultural practices for implementation of intervention measures and evaluate effective control measures. Before the launch of field unit, API in Mandla district where the field work was initiated ranged from 9.52 in 1980 to 1.98 in 1985. *Pf* was found increasing from 19.16 in 1980 to 44.1 in 1985.

### Activities, Progress and Achievements

#### Bioenvironmental control of malaria

A feasibility study on bioenvironmental control of mosquito breeding and malaria was launched in more than 100 tribal villages of Bizadandi PHC, Mandla district in 1986. Encouraging results were obtained and the strategy has been handed over to the state government for its implementation in other similar ecological hilly-forested undulating terrain of the state. As a result, this strategy is being implemented in 18 out of 47 districts of Madhya Pradesh with the assistance of the World Bank (Singh *et al.*, 1989; 1993). It is worth-while to mention that 19% population of these districts of the state contributes 53% malaria and 71.5% *P. falciparum* cases.
Initially malaria prevalence was high with a predominance of *P. falciparum*. Results at the end of five years are summarised in Table 1. About 50–60% reduction in the number of malaria cases was maintained, but there was an increase in API from 105 in 1988 to 134 in 1989. The increase might have been due to better case detection and excessive rains during 1989 when a majority of villages were cut-off. Another reason could be the resettlement of people from the submerged areas as a result of construction of Bargi dam. Infant and child parasite rates in some index villages showed a drastic reduction in SPR in the experimental villages as compared to those in the control villages which were being regularly sprayed by NVBDCP and where patients were administered antimalarials by the staff of the district malaria office (Table 2). The entomological evaluation mainly focused on indoor resting collection of adults to estimate man hour density. This parameter showed a gradual decline (Table 3).

### Table 1: Results of active surveillance* to detect malaria cases

<table>
<thead>
<tr>
<th>Year</th>
<th>BSC</th>
<th>(+)ve</th>
<th>Pv</th>
<th>Pf</th>
<th>Mixed</th>
<th>ABER</th>
<th>API</th>
<th>% Reduction</th>
</tr>
</thead>
<tbody>
<tr>
<td>1987</td>
<td>29,443</td>
<td>4,586</td>
<td>2,690</td>
<td>1,877</td>
<td>19</td>
<td>73.60</td>
<td>114.65</td>
<td>114.65</td>
</tr>
<tr>
<td>1988</td>
<td>30,711</td>
<td>5,320</td>
<td>3,005</td>
<td>2,291</td>
<td>24</td>
<td>60.81</td>
<td>105.35</td>
<td>8.11</td>
</tr>
<tr>
<td>1989</td>
<td>29,401</td>
<td>6,900</td>
<td>3,514</td>
<td>3,369</td>
<td>17</td>
<td>57.08</td>
<td>133.98</td>
<td>16.86</td>
</tr>
<tr>
<td>1990</td>
<td>21,797</td>
<td>3,294</td>
<td>2,022</td>
<td>1,255</td>
<td>17</td>
<td>42.68</td>
<td>36.96</td>
<td>44.21</td>
</tr>
<tr>
<td>1991</td>
<td>17,330</td>
<td>2,919</td>
<td>1,582</td>
<td>1,324</td>
<td>13</td>
<td>33.65</td>
<td>56.68</td>
<td>50.58</td>
</tr>
</tbody>
</table>

*Surveillance organised at weekly intervals.*

### Table 2: Infant and child parasite rates in Mandla district

<table>
<thead>
<tr>
<th>Year</th>
<th>BSC</th>
<th>Pv</th>
<th>Pf</th>
<th>Mix</th>
<th>(+)ve</th>
<th>IPR</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Infant</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1987</td>
<td>E</td>
<td>718</td>
<td>14</td>
<td>9</td>
<td>–</td>
<td>23</td>
</tr>
<tr>
<td></td>
<td>C</td>
<td>151</td>
<td>38</td>
<td>23</td>
<td>1</td>
<td>62</td>
</tr>
<tr>
<td>1988</td>
<td>E</td>
<td>606</td>
<td>17</td>
<td>11</td>
<td>–</td>
<td>28</td>
</tr>
<tr>
<td></td>
<td>C</td>
<td>295</td>
<td>61</td>
<td>56</td>
<td>1</td>
<td>118</td>
</tr>
<tr>
<td>1989</td>
<td>E</td>
<td>424</td>
<td>16</td>
<td>10</td>
<td>–</td>
<td>26</td>
</tr>
<tr>
<td></td>
<td>C</td>
<td>250</td>
<td>28</td>
<td>34</td>
<td>–</td>
<td>62</td>
</tr>
<tr>
<td>1990</td>
<td>E</td>
<td>252</td>
<td>15</td>
<td>1</td>
<td>–</td>
<td>16</td>
</tr>
<tr>
<td></td>
<td>C</td>
<td>141</td>
<td>27</td>
<td>6</td>
<td>–</td>
<td>33</td>
</tr>
<tr>
<td>1991</td>
<td>E</td>
<td>316</td>
<td>21</td>
<td>4</td>
<td>–</td>
<td>25</td>
</tr>
<tr>
<td></td>
<td>C</td>
<td>98</td>
<td>10</td>
<td>2</td>
<td>–</td>
<td>12</td>
</tr>
<tr>
<td><strong>Children</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1987</td>
<td>E</td>
<td>6,850</td>
<td>652</td>
<td>321</td>
<td>6</td>
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<td>1,071</td>
<td>288</td>
<td>373</td>
<td>17</td>
<td>678</td>
</tr>
<tr>
<td>1988</td>
<td>E</td>
<td>7,741</td>
<td>909</td>
<td>498</td>
<td>3</td>
<td>1,410</td>
</tr>
<tr>
<td></td>
<td>C</td>
<td>2,866</td>
<td>551</td>
<td>917</td>
<td>28</td>
<td>1,496</td>
</tr>
<tr>
<td>1989</td>
<td>E</td>
<td>7,203</td>
<td>1,020</td>
<td>820</td>
<td>–</td>
<td>1,840</td>
</tr>
<tr>
<td></td>
<td>C</td>
<td>1,914</td>
<td>227</td>
<td>533</td>
<td>–</td>
<td>760</td>
</tr>
<tr>
<td>1990</td>
<td>E</td>
<td>5,548</td>
<td>614</td>
<td>304</td>
<td>5</td>
<td>923</td>
</tr>
<tr>
<td></td>
<td>C</td>
<td>895</td>
<td>109</td>
<td>114</td>
<td>3</td>
<td>226</td>
</tr>
<tr>
<td>1991</td>
<td>E</td>
<td>4,553</td>
<td>505</td>
<td>321</td>
<td>3</td>
<td>829</td>
</tr>
<tr>
<td></td>
<td>C</td>
<td>588</td>
<td>41</td>
<td>93</td>
<td>1</td>
<td>135</td>
</tr>
</tbody>
</table>

*Intervention of strategies: E—Experimental : Biological control, source reduction and chemotherapy (MRC); C—Control : 4 rounds of insecticide (HCH) spray in 1987 and 1988 and 3 rounds from 1989 onwards and chemotherapy (NVBDCP).*
Strategy for Integrated control of malaria in Sagar district

In collaboration with WHO (WR-India), it was proposed to develop an integrated strategy for control of malaria in Sagar district where malaria constituted a public health problem. Current strategy of malaria control was based on indoor residual spraying of DDT as per NVBDCP schedule. The study in Sagar district was undertaken in partnership with Madhya Pradesh state antimalaria programme with the objectives to identify mosquito larval habitats by geographical reconnaissance to help implement an appropriate antilarval strategy, find out mosquitogenic conditions in the study areas and vector bionomics, formulate strategic integrated vector control measures and sensitise and build capacity of local health and non-health sectors for implementation of control measures. The study was initiated in the month of August 2002.

Results revealed that 47% breeding sites were positive for anopheline larvae and pupae. The highest larval density per dip was observed in nullahs (stream) and rivers (>5). The per man hour density of anopheline mosquitoes was highest (77.3) in the month of September, of that An. subpictus was the dominant species (41.6), followed by An. culicifacies (32.1). However in November, February and March collections, the density of An. culicifacies was high. A total of 12 anopheline species were recorded, of those An. culicifacies, An. fluviatilis and An. stephensi were the malaria vector species. In light-trap collections, the mean per trap per night anopheline catch was 13.9 indoors and 27 outdoors. Out of six anopheline species trapped, An. culicifacies was the dominant species both indoors and outdoors.

Malaria incidence in the study villages of both the PHCs was very low during our surveys. The study was conducted by involving antimalaria staff of respective PHCs to strengthen the capacity of the staff in doing geographical reconnaissance, entomological monitoring and planning at local level. Four training and two dissemination workshops were organised during the study. The strategy suggested included use of larvivorous fishes, minor engineering intervention at village-level, community participation, improvement in surveillance and treatment, judicious use of IRS, involvement of non-health sectors like Panchayat, fisheries, forest, irrigation departments, NGOs, etc.

Dynamics of malaria transmission in forest and deforested regions of Mandla

A longitudinal study carried out in two adjacent ecological zones in forested and deforested villages revealed interesting information not recorded earlier. The prevalence of Anopheles species varied widely between the two ecological settings. In the villages in forest, An. culicifacies and An. fluviatilis were mainly exophilic, whereas in the deforested villages An. culicifacies was predominantly endophilic and An. fluviatilis was equally prevalent both indoors and outdoors. The seasonal patterns of malaria transmission were also different between the two zones. P. falciparum was the dominant parasite species in the villages in forest, whereas malaria infection was mainly due to P. vivax in the deforested villages. The annual parasite incidence was high in the villages in forest (Fig. 1). The failure to control malaria in forested areas is rooted in the terrain and a variety of poorly understood sociological factors (Singh et al., 1996).

Patterns of rainfall and malaria in Madhya Pradesh

Some recent outbreaks of P. falciparum malaria have been attributed, at least in part, to increase in the intensity and duration of rainfall caused by the El Nino southern oscillation, a periodic phenomenon. Since it takes time for unusually heavy rainfall to translate into unusually high densities of the vector mosquitoes, it has been suggested that data on recent rainfall might
be used to predict climate-related epidemics of malaria. This possibility was explored by comparing the patterns in the incidence of malaria in Dungaria, a highly malarious village in Mandla district and in Mandla district as a whole for the periods 1986–2000 and respectively with data on rainfall for the same areas and periods. No clear association was observed between rainfall and malaria incidence, although a major development project to improve water resources in the study areas (which resulted in local villages being partially or completely submerged in water) may have masked any significant association (Fig. 2). A useful method for predicting which years are going to be high- or low-risk years for malaria epidemics, in the present and other epidemiological settings, remains a future goal (Singh and Sharma, 2002).

**Evaluation of use of insecticide-treated bednets vs DDT indoor residual spraying for malaria control**

This study was carried out from 1995–98 in rural population of Bhamni PHC of District Mandla (central India) to evaluate the impact of insecticide-treated bednets (ITN) in comparison with indoor residual spraying of DDT carried out on selective basis with proper coverage.

Nylon bednets impregnated with cyfluthrin (Solfac EW050, 50 mg/m²) were distributed in May 1996 in three villages (pop. 4200). For impact assessment, two groups of villages were kept as control. In one group (three villages, pop. 4500), indoor residual spraying of DDT was carried out on selective basis (DDT-S) under supervision of staff of the Malaria Research Centre, while in other group (four villages, pop. 4000), routine DDT spray (DDT-R) was carried out under the National Anti Malaria Programme. Monitoring of entomological data revealed that after distribution of impregnated bednets, a sharp reduction in number of mosquitoes was recorded in ITN villages. Per man hour density of *An. culicifacies* was much less in ITN villages as compared to that of in DDT-S (p<0.025) and DDT-R (p<0.025) villages.

Monitoring of epidemiological data in 1996–97 revealed that annual parasite incidence was only 10 in ITN villages as against 20 in DDT-S villages and 51 in DDT-R villages. During 1997–98 also malaria cases were significantly less in ITN villages as compared to those in DDT-S villages (p<0.001) and DDT-R villages (p<0.0001) (Figs. 3 a, b, c and d). Spleen examination of children revealed that spleen rate in ITN villages was significantly less than that of in DDT-S (p<0.05) and DDT-R villages (p<0.001).
Fig. 2: Correlation between malaria and rainfall

Fig. 3a: Epidemiological indices in ITN used villages

Fig. 3b: Epidemiological indices in DDT selective spray villages

Fig. 3c: Epidemiological indices in DDT routine spray villages

Fig. 3d: Spleen examination in children (aged 2–9 yr) in study villages
Bioassays carried out between three and six months of bednet use against *An. culicifacies* gave 100% mortality within 15–30 min exposure. Occasional night cross-checks revealed that in 1996 on an average approximately 60% people were using bednets, while in 1997 as a result of health education this percentage increased to 75%. About 40% people were willing to buy bednets if supplied on subsidised rates (Sharma et al., 1996; Singh et al., 1993).

On the contrary, in forest villages of Bizadandi PHC of District Mandla, the usefulness of these bednets is limited because of prevailing sociocultural and economic practices—majority of people (83%) sleep on the floor hence it was difficult to use bed nets, during winter people sleep around fire and bednet can not be used near fire, some people even found it convenient as ‘net’ for catching fish from the ponds/streams, besides regular movement in jungle for collection of forest produce (*Mahua* for liquor, *Tendue* leaves for country cigarettes, herb collection and hunting wild animals). Although the site of anopheline infection in forest villages was obscure, the villagers frequently spent the night in the open, presumably providing a source of infection to the anophelines prevalent outdoors (Singh et al., 1994). Thus in tribal areas bednets are effective only in stable tribal population who do not depend on forest-based economy.

**Population dynamics of *An. culicifacies* and malaria**

Longitudinal study on malaria was carried out during 1993–94 in typical forest-fringe tribal village to obtain baseline data on malaria transmission to elucidate the factors responsible for persistent malaria and thereby to help in formulating an improved malaria control programme. The study revealed that the transmission period was from May to November. Analysis of malaria cases revealed hyper-endemic malaria with *P. falciparum*, the predominant species. The prevalence of *P. vivax* was mainly in the summer and that of *P. falciparum* in autumn. Infective *An. culicifacies* were found mainly in the months of May, August and November. All infective *An. culicifacies* were found from human dwelling collections, which indicated that malaria was transmitted within the village. One epidemiologically important finding was that more than 50% of host seeking female *An. culicifacies* had already fed once. No infective *An. fluviatilis* was found. The presence of *An. fluviatilis* in human dwellings, though in small numbers, raises the question of whether it plays any role in malaria transmission. The study suggested that a number of factors were responsible for the continuous malaria transmission in the village (Singh et al., 1999).

**Influence of moonlight on light-trap catches of *An. culicifacies***

The study was carried out in a forested belt of Madhya Pradesh, inhabited by tribal people. Breeding habitats of *An. culicifacies* are shown in Fig. 4. A significant effect of moon phase on light-trap catches of *Anopheles* species was observed. However, moon phase does not seem to have any effect on the proportion of adult *An. culicifacies* in the total catch, or the parity rate in this species, which is the vector responsible for perennial transmission of malaria in the area (Singh et al., 1993, 1996; Singh & Mishra, 1997).

**KABP studies related to malaria**

In central India, malaria control programme in tribal belts failed to make any dent as the perceptions of the tribals regarding control and treatment of malaria and Government strategies are at variance. Therefore, knowledge, attitude, belief and practices (KABP) study was undertaken among Gond tribes of Mandla district to assess their knowledge related to malaria transmission and its control. Surveys revealed that the tribals call this ‘fever with shivering and rigour’ as *Attrala* and they did not appreciate the presence of malaria control programmes in the first place. About 98% tribals believed that malaria was transmitted by drinking or bathing in contaminated water. First line of treatment is through ‘guniyas’, the village traditional healers, failing which injections were given by unqualified practitioners (quacks) in the market place. Primary health care system is their last resort. Tribals did have knowledge about mosquito breeding in stagnant water (43%) yet all efforts were made to store rain water around their houses and in agricultural fields. Further, they did not understand the relevance of DDT spray for control of mosquito/malaria. Therefore, there is an urgent need to build up information, education and communication (IEC) programmes for greater acceptance of the malaria control programme (Singh et al., 1998).

**Use of neem oil and cream as mosquito repellent**

The study was carried out to evaluate the mosquito repellent action of neem (*Azadirachta indica*) oil and cream in villages of Mandla district. Various concen-
trations of neem oil and cream mixed in coconut oil were applied to the exposed parts of human body (Figs. 5 a and b). Results revealed 81 to 91% protection during 12 h period of observation from the bites of anopheline mosquitoes (Mishra et al., 1995; Singh et al., 1996).

**Ecological succession of mosquitoes in rice-fields**

Studies on ecological succession of anophelines and the malaria vectors were carried out in rice-fields located in two ecologically different terrains—plains and forested hills in Jabalpur district during monsoon (July–October 1995). In the plain and forested hill villages, 9 and 15 anopheline species were found breeding in the rice fields respectively. *An. culicifacies* and *An. subpictus* were dominant species. The percentage emergence of adults of *An. annularis*, *An. nigerri-mus* and *An. pallidus* was higher in plain area villages, while the percentage of *An. theobaldi*, *An. fluviatilis* and *An. jeyporiensis* was higher in forested hill area villages. Among malaria vectors, three species were found breeding in rice fields of hilly terrain—*An. culicifacies*, *An. fluviatilis* and *An. stephensi* and in rice-fields of plains, *An. culicifacies* and *An. fluviatilis* were
recorded (Singh et al., 1989; Mishra & Singh, 1997).

**Anopheline ecology and malaria transmission at a new irrigation project area**

Anopheline ecology and malaria transmission were studied in a newly irrigated area of the Bargi project in Jabalpur. Observations were made for two years in 10 villages along the Bargi irrigation canal that are situated 44 km (head end of canal) and 78 km (tail end of canal) from the dam site. *An. annularis* was the predominant species in head end villages and its abundance was directly related to the opening of the canal, whereas *An. culicifacies* was the most abundant species in tail end villages, where irrigation was limited. Malaria infection was due to *P. vivax* and *P. falciparum*. The API in children and adults was significantly higher in head end villages as compared to that in tail end villages. However, seasonal trends in the prevalence of *P. falciparum* and *P. vivax* were the same in each group, with some fluctuations (Singh et al., 1997; Singh & Mishra, 2000).

**Malaria and Narmada river development in India: a case study of the Bargi dam**

The largest river-valley development to be proposed in India is in the Narmada valley. The building of the Bargi dam, a multi-purpose irrigation and hydroelectric project in Jabalpur in central India, formed part of the first phase of the development of this valley (1974–88). Many villages and several hectares of land in three districts were submerged as the water rose behind the dam, the worst-affected area being the catchment area of the primary health centre (PHC) at Narayanganj, in Mandla district. Until recently, cases of malaria were relatively rare in Narayanganj. However, an epidemic of malaria in late 1996 claimed hundreds of lives in the area and the outbreak spread during 1997 to new villages in the region. A review of the records collected by the National Anti Malaria Programme (NAMP) not only indicated that the number of malaria cases in Narayanganj increased from 184 to over 2400 (>13-fold) between 1979 and 1999 but also that the number of *Pf* cases increased from 14 to over 1400 (>100-fold) over the same period (Fig. 6). The NAMP data available for Mandla district as a whole indicated that the number of malaria cases increased from 8900 to 41000 (>4 fold) and number of *P. falciparum* cases increased from 3400 to over 11000 (>3 fold) between 1979 and 99. There is no evidence that a new species of vector has established since 1979. In fact, indoor-resting densities of anophelines and of the most established vector, *An. culicifacies*, have fallen since the dam was built, but densities of another vector, *An. fluviatilis* have increased.

![Fig. 6: Malaria incidence in Narayanganj, District Mandla](image-url)
Investigation revealed that with the completion of the dam, there was about 20–30% increase in the existing population of some villages because of resettlement of villages from the completely submerged areas, consequent to which there was formation of new hamlets along with import of different strains of parasite with people of different endemicity. These new hamlets were not in the records of NAMP for spray operations and surveillance. There was no attempt made to increase the number of local medical personnel or to increase drug supplies to meet the needs of the resettled.

The problem is further compounded by the fact that agriculture is rainfed and a single crop is raised. In some villages which are under complete submergence, people have not left the villages despite receiving compensation/dues from the government in lieu of their land/houses, because of the availability of naturally fertile, irrigated soil (when the water recedes after rain), which produces maximum profit with minimum of labour. Moreover, because of the dam, the general water level in wells, streams and its tributaries has also raised, thereby increasing the breeding potential of vectors manifold. The fishing community naturally prefers to live close to the reservoir and the abundance of fish has also attracted many migrants. The remoteness of the villages, the low population density and the mobility of the population make surveillance, insecticide spraying and treatment difficult, and increase the risk of a malaria epidemics among the local, highly vulnerable communities of non-immune, poverty-stricken individuals (Singh et al., 1999).

Malaria epidemic investigations

The field unit is also involved in epidemic investigations in the districts of Chhindwara, Betul, Hoshangabad and Panna in M.P. and Korea in Chhattisgarh, which are areas of different ecological terrain and under different malarious conditions. In-depth investigations revealed the inadequate surveillance and supply of chloroquine, presence of high level of chloroquine resistance of *P. falciparum* and movement of population to a nearby development project site (Tava project) or for collection of forest produce. On the basis of investigation appropriate suggestions were given to contain outbreaks (Singh et al., 1995; 1989; 2003; 2004; Ghosh et al., 1989; Singh and Shukla, 1990).

Seasonality of *P. vivax* and *P. falciparum*

Microscopic examination of blood film produced from samples collected over a decade (1986–2000), from the inhabitants of five tribal villages of Mandla district, M.P. revealed that malaria was highly endemic and probably transmitted perennially. Both *P. vivax* and *P. falciparum* were prevalent in all age groups but their prevalence was highly seasonal. Longitudinal studies showed an autumn peak (October–November) for *P. falciparum* and a summer peak (April–May) for *P. vivax*. However, both the incidence and prevalence of infection with each *Plasmodium* species showed inter-village variations. Analysis of the malarometric parameters revealed that there had been no improvement in the malaria situation over the study period, and that since 1992 there had been a shift in the predominant parasite species, from *P. vivax* to *P. falciparum*, in each village. *P. vivax* predominated over *P. falciparum* between 1986 and 1991, however, from 1992 to 1995, *P. falciparum* became the predominant species, accounting for more than 60% of all malaria infections. Further analysis in 1999 revealed that malaria showed more or less stable malaria conditions with steady increase in number of *P. falciparum* (93%) (Singh et al., 2000, 2004) (Figs. 7 and 8).

Evaluation of rapid diagnostic tests

The evaluation of new diagnostic tests for *falciparum* malaria in India was carried out in different tribal areas of M.P. Immunochromatographic test (ICT) and Dipstick test (ParaSight™-F) are being marketed now as a result of successful demonstration in the field. More recently, other diagnostic kits—Determine™ malaria * Pf*, OptiMal®, Paracheck® and ParaHit-F have been evaluated on the request of the Drug Controller of India. These diagnostic kits are very essential for hardcore tribal areas of Madhya Pradesh to diagnose malaria in inaccessible forest villages. The Govt. of Madhya Pradesh has introduced the Paracheck® and ParaHit-F rapid test in 22 districts under EMCP where speed and precision of diagnosis are essential (Singh et al., 1997, 2000, 2002, 2003, 2004; Valecha et al., 2003).

Monitoring of insecticide resistance

Monitoring of insecticide resistance in different parts of Madhya Pradesh and Chhattisgarh states revealed that corrected mortality of *An. culicifacies* against DDT (4%) was only 5 to 20% in Mandla, Dindori, Betul, Chhindwara, Sagara, Damoh, Khandwa and Raigarh districts (Chhattisgarh). These results have a direct implication for the programme as in these districts DDT is replaced by synthetic pyrethroids (except Raigarh).
The corrected percent mortality with malathion (5%) was 41 to 89% and it was 100% with deltamethrin (0.05%), propoxure (0.1%) and bendiocarb (0.1%).

**Situation analysis of malaria**

On the request of NVBDCP, situation analysis of malaria was carried out in the year 2002 in Mandla, Dindori, Sagar and Damoh districts. During the extensive surveys, it was observed that the trend of malaria incidence in Mandla and Dindori was increasing, whereas in Sagar and Damoh it was in decreasing trend since last three years. These analyses were done for assessment of insecticide spray quality, as-
sistance in planning insecticidal spray schedule, epidemiological situation, entomological activities and working of microscopy laboratory and DDC/FTD.

Malaria in pregnancy and infants

One of the most important thrust areas identified by the field unit is “Malaria in pregnancy and infancy”. Women having malaria during their pregnancy are at great risk particularly during first pregnancy as it may cause cerebral malaria, abortion, still births, anaemia, maternal death and neonatal death. Mean parasite densities were significantly higher in pregnant women as compared with non-pregnant women for both \( P. falciparum \) and \( P. vivax \). Pregnant women with \( falciparum \) or \( vivax \) malaria were significantly more anaemic than non-infected pregnant women or infected non-pregnant women. Pregnant women are screened regularly, advised for various risk factors and preventive measures. Congenital malaria was also recorded. Malaria infection was seen in 218 infants and >30% of the infants examined at two months of age showed both \( P. vivax \) and \( P. falciparum \) (Fig. 9). The overall malaria prevalence in infants was 50% with \( P. vivax \) (25%) and \( P. falciparum \) (75%). Follow-up revealed that three infants with \( falciparum \) died in the study cohort (Singh et al., 1995, 1996, 1997, 1998, 1999, 2001, 2002 and 2004).

Another prospective study of 208 pregnant women at delivery was undertaken during transmission season at district hospital, Mandla to document the prevalence of malaria during pregnancy in an area where both \( P. vivax \) and \( P. falciparum \) co-exist. The results revealed that at delivery, the maternal peripheral blood parasitaemia was 12%, placental parasitaemia 26% and umbilical cord blood parasitaemia was 12%. Both \( P. vivax \) and \( falciparum \) were recorded from placenta and umbilical cord blood. The mean birth weight of 51 babies born to mothers with infected placentas was significantly low (p<0.0001) as compared to 150 babies born to mothers without infection. Moreover, a large number of asymptomatic pregnant women of all parity groups had subpatent parasitaemia with \( P. falciparum \). The findings of the study have important practical implications for the development of an effective intervention strategy and programme to reduce the impact of malaria in pregnant women (Singh et al., 1995, 2003).

Control of malaria in Betul district

Betul is a forested district (pop. 13,95,175; 45% ethnic tribes) accounting for 10% of all malaria cases in Madhya Pradesh, although it has less than 1% of the state’s population. The reported annual incidence of malaria in Betul district as per NVBDCP had dramatically increased from 0.43 per 1,000 in 1990 to 11.37 per 1,000 in 2000. The disease was not responding to control measures by NVBDCP showing steady increase indicating the need for change in control strategies and better intervention tools. On the request of the Govt. of Madhya Pradesh, malaria situation was investigated in 40 villages of three worst-affected primary health centres between October and December 2000 and 2,467 blood smears were collected from fever cases, of which 1,300 were positive for malaria (SPR>50%, SFR and \( Pf% >90% \)).

The age-specific data on malaria prevalence revealed that SPR was 39% among infants, 56% in children aged 1–4 yr, 59% in children aged 4–8 yr and 58% in children aged 8–14 yr and 52% among adults (>14 yr). Similarly, SFR in these age groups was 34, 50, 55, 54 and 49.5%. Out of 700 children (2–9 yr) examined, over 500 (>70%) were found with enlarged spleen.

\( An. culicifacies \) and \( An. fluviatilis \) are the two potential vector species prevalent in this area. Insecticide sus-

![Fig. 9: Malaria prevalence during infancy](image-url)
ceptibility tests showed only 10% *An. culicifacies* susceptible to DDT. In view of very high prevalence of falciparum malaria and large number of deaths, certain recommendations were given by us which were implemented by the Government. The recommendations were—DDT should be replaced by an effective insecticide such as synthetic pyrethroid, prompt treatment of all fever cases preferably with SP, frequent health camps and use of rapid diagnostic test in inaccessible villages for prompt diagnosis and treatment, spraying of watch huts in agricultural field and use of personal protection measures—treated nets, repellents, etc. These recommendations were implemented by the Govt. of M.P.

Post-intervention follow-up revealed a steady decline in overall malaria situation (Fig. 10). There was 54, 62, 98 and 100% reduction in SPR and 67, 81, 99 and 100% reduction in SFR in 2001, 2002, 2003 and 2004 respectively (all age groups combined). Spleen rate also showed decline—21, 65 and 83% reduction in 2001, 2002 and 2003 respectively as compared to 2000 (Fig. 11). Further, monitoring of entomological results revealed a sharp reduction in anopheline density by 67, 96 and 88% in 2002, 2003 and 2004 respectively as compared to 2000 (Fig. 12). NVBDCP data revealed that in 2001 Betul was contributing 10% malaria and 12% *P. falciparum* cases in M.P., while in 2003, malaria and *P. falciparum* contribution by Betul was reduced to 1.4 and 0.8% respectively.

**Migration malaria associated with forest economy**

An investigation on malaria was undertaken following reports of high prevalence of fever cases and deaths in Jabalpur during dry hot weather. Inquiries revealed that 39 people from 14 families had gone to forest of Panna for mahua collection, of which two had died. Examination of 37 migrants revealed 84% *Pf* infection in them, of whom one died. Investigation on the site of occupational activities of these migrants in Panna revealed 77% *P. falciparum* in rapid fever surveys (Singh *et al.*, 2004).

**Asymptomatic *P. falciparum* during dry season**

The study was performed in the 18 villages of Biza-dandi PHC located in the forest area in 35 km radius, District Mandla during February and March 2001. Overall, 140 of 573 (24.4%) schoolchildren tested were found to be malaria positive. Of those found infected, 126 (21.9%) had only *P. falciparum* infection,
11 (1.9%) had *P. vivax* and 3 (0.5%) had mixed infections of *P. vivax* and *P. falciparum*. Out of 126 cases, only 10% had gametocytes of *P. falciparum* with asexual stages. In addition, three were found with only gametocytes of *P. falciparum*. From a transmission perspective, these asymptomatic carriers form a reservoir of infection in the community but are also likely to suffer continued morbidity due to persistent infection (Singh et al., 2002, 2004).

**Clinical trials of antimalarials**

Following drug trials were undertaken:

1. A phase-III clinical trial of $\alpha$–$\beta$ arteether in uncomplicated *P. falciparum* malaria was carried out in Medical College, Jabalpur in collaboration with Central Drug Research Institute, Lucknow during 1996–97. A total 46 patients (25 males and 21 females) of *P. falciparum* malaria were enrolled in the study. They were administered 150 mg of $\alpha$–$\beta$ arteether intra-muscular daily for three days. All patients completed 28 days follow-up. There was no adverse reaction reported during the course of trial and follow-up period. The parasite clearance time was 30 h and recrudescence rate was 6.7% within 28 days of follow-up period. Study showed that arteether is a fast acting and potent schizontocidal antimalarial drug with minimal adverse reactions.

2. A double blind randomised clinical trial of chloroquine vs azithromycin in *P. vivax* malaria was carried out in medicine wards of Medical College, Jabalpur during 2000–01. A total of 52 cases of *P. vivax* malaria were enrolled in the study. They were administered either tab chloroquine 1500 mg or tab azithromycin 1 g daily for three days. All the...
cases completed 28-days follow-up. Fever clearance time ranged from 24 to 36 h and PCT ranged from 48 to 72 h. There was no recrudescence reported in the patients who completed follow-up.

3. An open label clinical trial of azithromycin and chloroquine combination in uncomplicated cases of *P. falciparum* malaria was carried out in the medicine ward of Medical College, Jabalpur in the year 2002. A total of 8 patients were enrolled in the study who were administered 1500 mg of tab chloroquine and 3 g of tab azithromycin in divided doses over three days. There was no serious adverse reaction reported in enrolled cases. The PCT ranged between 24 and 48 h and FCT ranged between 32 and 72 h. There was no recrudescence reported during the course of follow-up.

4. A clinical trial of artesunate combination either with chloroquine or sulphadoxine-pyrimethamine versus mono therapy of chloroquine or sulphadoxine-pyrimethamine was carried out in uncomplicated cases of *P. falciparum* malaria during 2001–02. A total of 34 cases of uncomplicated *P. falciparum* malaria were enrolled in the study. Eighteen patients were enrolled in the combination therapy group (9 cases each in both combinations) and 16 cases enrolled in the mono therapy group (8 cases each in CQ & SP mono therapy). Both the combinations were tolerated very well without any adverse reaction. The PCT ranged between 18 and 24 h in combination groups and 48 to 72 h in mono therapy groups. This study showed better parasite and symptom clearance in artesunate combinations than monotherapy of CQ or SP.

**Workshops/Trainings organised**

The following international, national, state-level workshops and training programmes were conducted successfully by the Field unit.

1. International training workshop on “Rapid assessment tools for malaria in pregnancy” for southeast Asia from 26–29 April 2004 at IDVC Field unit, Jabalpur. Delegates from WHO, CDC, Atlanta, KEMRI, MRC & RMRC attended the workshop as resource persons. Participants were from India, Bangladesh, Indonesia and Myanmar (Fig. 13).

2. Indo-US workshop on “Cerebral malaria associated neurological disorders” at IDVC Field unit, Jabalpur from 3–5 October 2004. All scientists working on cerebral malaria were invited (Fig.14).

3. A national level workshop on “Clinical management of malaria during pregnancy” was conducted by NVBDCP from 1–3 March 2005 in which 11 doctors/medical officers participated.