Effect of construction of an irrigation canal on malaria situation in two primary health centres of Dhenkanal district of Orissa, India

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Abstract. To assess the impact of irrigation canals on malaria transmission, a study was conducted in Dhenkanal district of Orissa, India. The district is situated in the central part of Orissa and hyperendemic area for malaria. A canal system is being constructed for irrigation in the district, which passes through Parjang and Analabereni Primary Health Centres (PHC), endemic for malaria. The water has been released only up to Parjang (Canal with water -CWW) area during the end of 2004 and construction work is still going on in Analabereni PHC (Canal under construction-CUC). Retrospective clinical data (2001–2008) collected from health services from two study sites showed average Slide Positivity Rate (SPR) before release of water (2001-2004) was 9.25% and 18.04% in CWW and CUC areas, respectively. After release of water (2005-2008) the SPR was 5.77% and 10.19%, in CWW and CUC areas, respectively. The average Annual Parasite Incidence (API) was 7.66 and 22.67 in CWW and CUC areas before the release of water and 5.32 and 12.28 after release of water, respectively. A point fever survey was conducted in 2009 which revealed the presence of Plasmodium falciparum (Pf) and P. vivax (Pv) in both study areas. The survey found SPR of 18.82% and 24.54%, and Pf percentages of 75% and 85%, in CWW and CUC areas, respectively. The present study revealed the presence of two malaria vectors, Anopheles culicifacies and Anopheles annularis in the area. Vector Per Man Hour Density was 2.38 in CWW and 2.69 in CUC for An. culicifacies and 1.46 and 1.54 for An. annularis respectively. The sporozoites rates were found to be 3.6 and 3.8 for CWW and CUC, respectively. The present study reveals that, the construction of canal system did not increase the malaria prevalence during post water release period – implying that the malaria control programme was effective although still more intensive situation specific vectors control programme need to be continued simultaneously so that malaria transmission can be curtailed.

INTRODUCTION

Development of irrigation schemes is widely recognized as a key for promoting economic growth, ensuring food security and alleviating poverty in most developing countries (Kibret et al., 2010). Irrigation projects may result in the development and maintenance of mosquito-borne disease (Ameresinghe & Indrajit, 1994; Tyagi & Chaudhury, 1997). Especially in areas where malaria is unstable, irrigation may alter the malaria transmission pattern from seasonal to annual. However, the relationship between irrigation and malaria is not straightforward (Kibret et al., 2010). Due to large-scale water development projects in Sri Lanka, malaria became prevalent in areas where it was nearly eradicated (Ramasamy et al., 1992). High incidence of malaria has been found to be positively correlated with canal irrigation system. High mosquitogenic and malariogenic condition in Bargi Dam area...
of Madhya Pradesh has been documented by Singh & Mishra, (2000) in India. The distribution of Plasmodium falciparum-dominated malaria in the Thar desert is more or less synchronous with the spread of Indira Gandhi Nahar Pariyojana related irrigated agriculture and Anopheles culicifacies vector (Tyagi, 2004). A study in Gujarat, India showed the importance of irrigation water release in maintaining high An. culicifacies adult abundance during the dry season (Konradsen et al., 1998).

Malaria is the foremost public health problem of Orissa state of India contributing 23% of malaria cases, 40% of P. falciparum cases and 50% of malaria deaths in the country. An. culicifacies, Anopheles flaviatilis and Anopheles annularis are the three major vectors of the state. In the state lots of irrigational development activities are going on which might have influenced the epidemiology of malaria. Very few studies are available in this regard. Therefore, this study was conducted to find out the effect of irrigation canal system during construction and after release of water on malaria, in Dhenkanal district of Orissa.

MATERIALS AND METHODS

Study area
Dhenkanal district is centrally located between the longitude of 85° 58'-86°2'E and latitude of 20° 29' to 21°11'N with an average elevation of 80 meters from the sea level. The district has 13 Primary Health Centres (PHC). The economy of the district is predominantly agrarian. Over seventy percent of the population depends on agriculture. The present cultivable area in the district is 1,49,755 hectare. The irrigated area is less than 24% of the total cultivable area which is much less than the state average of 35%. Therefore, to increase the cultivable area, construction of a new irrigation canal system named Rengali Left Bank Canal, of 141 km long has been planned during 1996, which would provide irrigation facilities of 51,522 Ha to the district. (District Statistical Handbook, 2001). Till now only 71 km of the canal has been constructed covering Parjang (0-30 km) and Analabereni (31-71 km) PHC areas. The water has been released up to 30 km of the canal in Parjang area (canal with water-CWW) and in Analabereni PHC (31-71 km), the canal is under construction and water has not been released (canal under construction-CUC) (Dept. of Water Resource Department, 2008). Both the PHCs were highly endemic for malaria. Four villages were selected from each of the above two study area for epidemiological and entomological survey. Study villages are within 1km buffer zone of the canal command area. Villages in CWW area have irrigation throughout the year due to the water availability in the canal system and the villages of the CUC area are basically dry foothill villages (cultivation depends upon rain i.e. from July to September).

Epidemiological and Entomological Surveys

Epidemiological and entomological surveys were conducted in the study area during high transmission season (November-February 2009). Monthly epidemiological data of both the study area were collected from Department of Health Services, Government of Orissa. Different parameters such as annual parasite incidence (API), slide positivity rate (SPR) and P. falciparum percentage (PF%) were calculated and analyzed to assess the malaria situation. Towards the end of 2004, the water was released to the canal in the CWW area. Therefore, the malaria data between 2001 and 2004 was taken as pre release of water period and between 2005 and 2008 as post release of water period. The above mentioned parameters were calculated by the following methods:

Annual Parasite Incidence (API) = \( \frac{\text{Total slides found positive}}{\text{Total Population}} \times 1000 \)

Slide Positive Rate (SPR) = \( \frac{\text{Total positive slides}}{\text{Total Blood slide Examined}} \times 100 \)
Information on various malaria control measures taken by the government were collected from Department of Health Services, Govt. of Orissa as well as from National Vector Borne Disease Control Programme (NVBDCP).

One point fever survey was carried out to evaluate the current malaria situation in the study area. All the fever cases were screened in both the area (CWW and CUC) by door-to-door visit in the studied villages by blood slide collection. Numbers of *Plasmodium falciparum* malaria cases found were recorded.

Entomological survey comprising only adult mosquito collection was conducted in four villages from each study area, following standard method (WHO, 1975). The survey was carried out between November 2008 and February 2009. Indoor resting adult mosquitoes were collected from 6 am to 9 am from 10% of the households of the study villages using sucking tube. The mosquitoes were identified following the key (Christophers, 1933) and Per Man Hour Density (PMHD) of each species of mosquito were calculated as follows.

\[ PMHD = \frac{\text{Total no. of mosquitoes collected}}{\text{No. of person} \times \text{Time spent in hours}} \]

**Sporozoite detection**
All the collected samples of *An. culicifacies*, *An. annularis* and *Anopheles subpictus* were kept in individual vial for detection of sporozoite by following nested PCR technique (Mahapatra *et al.*, 2006).

**DNA template preparation**
Total DNA from individual mosquitoes was extracted following a modified method proposed by Collins *et al.* (1987). Briefly, the mosquitoes were homogenized in 100 µL of extraction buffer (pH 9.1) containing 0.1M NaCl, 0.2 M sucrose, 0.1 M Tris-HCl, 0.05 M EDTA, followed by Phenol chloroform isoamyl extraction. Finally, the DNA was precipitated using ethanol and dissolved in 50 µl of deionized water.

**PCR amplification**
Amplification of genus and species specific *Plasmodium* was done by using the primers: rPLU5, PLU6, rFAL1, rFAL2, rVIV1 & rVIV2. Each 20 µl reaction mixture for nest-1 amplifications contained 12 µl of template DNA, 250 nM of each primer (rPLU5 & rPLU6), 4 mM MgCl₂ PCR buffer (50 mM KCl, 10mMTris-HCl), 200 µM of each dNTPs and 0.4 units of Taq DNA Polymerase. The PCR conditions (nest-1) were as follows: step-1: 94°C for 4 min; 94°C for 30 sec, 55°C for one min; Extension at 72°C for one min; 35 cycles and final extension at 72°C for 4 min. About 8 µl of the nest-1-amplification products served as the DNA template for each of the 20 µl of second PCR (nest 2) amplification. The concentration of the nest 2 primers and other constituents were identical to nest 1 amplification, except that 0.3 unit of Taq DNA Polymerase was used. The second PCR (nest 2) amplification conditions were identical to those of first PCR (nest-1) except that the annealing temperature was 58°C for the species-specific primer. PCR amplified products (10µl) were subjected to gel electrophoresis on a 2% agarose gel, stained with ethidium bromide, and visualized in an Alphalmager gel documentation system.

**Statistical analysis**
Statistical analysis was done by using the software Graphpad Prism (Version 5). t-test and \( \chi^2 \) test has been used for the analysis of epidemiological data and entomological data respectively.

**RESULTS**

**Epidemiological data**
Epidemiological data collected between 2001 and 2008 are presented in Table 1. The average API, SPR and Pf percentage was 7.66, 9.25% and 97.3% in CWW area before release of canal water and 5.32, 5.77% and
97.62%, respectively, after release of the canal water.

In CUC area, the average API, SPR and Pf percentage was 22.67, 18.04%, and 94.06%, respectively, before release of canal water (2001-2004). All these parameters showed declining trend during the period coinciding with the post release period (2005-2008).

The API before and after release of canal water indicates no significant changes in the CWW area (t=0.6387, df=1 P>0.05) even though it showed a lower value after water release. However, the API during the two periods showed significant decline in CUC area (t=35.5365, df=1 P<0.001).

During one point fever survey, a total of 333 fever cases were screened for malaria infection in two study areas by door-to-door visit. The result revealed that the SPR was 18.82% and 24.54% in CWW and CUC areas, respectively. The Pf infection contributes around 75% and 85% respectively in the two study areas (Table 2).

**Adult mosquito collection**

A total of 478 mosquitoes belonging to two genera (Anopheles=356 and Culex=122) were collected from both the study areas.

Four anopheline species i.e. *An. culicifacies*, *An. annularis*, *An. subpictus* and *Anopheles vagus* along with three culcines viz. *Culex quinquefasciatus*, *Culex vishnui* and *Culex whitmorei* were found in both the study areas (Table 3). *Anopheles subpictus* was the most prevalent species.

**Table 1. The malarialogenic situation in areas with Canal Water (CWW) and Canal under construction (CUC) before canal water release period (2001-04) and after canal water release (2005-08) in Dhenkanal district of Orissa, India**

<table>
<thead>
<tr>
<th>Year</th>
<th>CWW area</th>
<th>CUC area</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>SPR</td>
<td>Pf%</td>
</tr>
<tr>
<td>2001</td>
<td>13.9</td>
<td>92.8</td>
</tr>
<tr>
<td>2002</td>
<td>8.7</td>
<td>98.4</td>
</tr>
<tr>
<td>2003</td>
<td>9.3</td>
<td>98.2</td>
</tr>
<tr>
<td>2004</td>
<td>5.1</td>
<td>99.8</td>
</tr>
<tr>
<td><strong>Mean</strong></td>
<td><strong>9.3</strong></td>
<td><strong>97.3</strong></td>
</tr>
<tr>
<td></td>
<td>Release of water</td>
<td>No water release</td>
</tr>
<tr>
<td>2005</td>
<td>1.8</td>
<td>100.0</td>
</tr>
<tr>
<td>2006</td>
<td>4.4</td>
<td>97.1</td>
</tr>
<tr>
<td>2007</td>
<td>9.3</td>
<td>96.5</td>
</tr>
<tr>
<td>2008</td>
<td>7.6</td>
<td>96.8</td>
</tr>
<tr>
<td><strong>Mean</strong></td>
<td><strong>5.8</strong></td>
<td><strong>97.6</strong></td>
</tr>
</tbody>
</table>

CWW - Canal With Water, CUC - Canal Under Construction

**Table 2. Results of prevalence of malaria infection among the fever cases in villages around the Left Bank Canal system of Dhenkanal District during February 2009**

<table>
<thead>
<tr>
<th>Study area</th>
<th>Villages</th>
<th>No. of reported fever cases</th>
<th>Pf +ve (%)</th>
<th>Pv +ve</th>
<th>Total +ve</th>
<th>% of total +ve</th>
</tr>
</thead>
<tbody>
<tr>
<td>CWW area</td>
<td>Kumusi</td>
<td>87</td>
<td>12 (75)</td>
<td>4</td>
<td>16</td>
<td>18.39</td>
</tr>
<tr>
<td></td>
<td>Dharmasal Kany Ashram</td>
<td>2</td>
<td>1 (100)</td>
<td>0</td>
<td>1</td>
<td>50</td>
</tr>
<tr>
<td></td>
<td>Tandimunda</td>
<td>45</td>
<td>5 (62.5)</td>
<td>3</td>
<td>8</td>
<td>17.78</td>
</tr>
<tr>
<td></td>
<td>Arakhapal</td>
<td>36</td>
<td>6 (85.7)</td>
<td>1</td>
<td>7</td>
<td>19.44</td>
</tr>
<tr>
<td></td>
<td><strong>Total</strong></td>
<td><strong>170</strong></td>
<td><strong>24 (75)</strong></td>
<td><strong>8</strong></td>
<td><strong>32</strong></td>
<td><strong>18.82</strong></td>
</tr>
<tr>
<td>CUC area</td>
<td>Analabereni</td>
<td>37</td>
<td>7 (100)</td>
<td>0</td>
<td>7</td>
<td>18.92</td>
</tr>
<tr>
<td></td>
<td>Guneabili</td>
<td>36</td>
<td>12 (70.6)</td>
<td>5</td>
<td>17</td>
<td>47.22</td>
</tr>
<tr>
<td></td>
<td>Amba baula</td>
<td>47</td>
<td>7 (87.5)</td>
<td>1</td>
<td>8</td>
<td>17.02</td>
</tr>
<tr>
<td></td>
<td>Kantaikateni</td>
<td>43</td>
<td>8 (100)</td>
<td>0</td>
<td>8</td>
<td>18.6</td>
</tr>
<tr>
<td></td>
<td><strong>Total</strong></td>
<td><strong>163</strong></td>
<td><strong>34 (85)</strong></td>
<td><strong>6</strong></td>
<td><strong>40</strong></td>
<td><strong>24.54</strong></td>
</tr>
</tbody>
</table>

Pf +ve- *Plasmodium falciparum* positive, Pv +ve- *Plasmodium vivax* positive, Total +ve*-(Pf+Pv)

Numbers in parentheses shows percentage of total

CWW - Canal With Water, CUC - Canal Under Construction
dominant species (41.56% and 44.55%) followed by An. vagus (29.22% and 27.23%), An. culicifacies (18.18% and 18.32%) and An. annularis (11.04% and 9.90%) in CWW and CUC areas, respectively. The PMHD of the two vectors were high in CUC area (An. culicifacies - 2.69, An. annularis - 1.54) as compared to CWW area (An. culicifacies - 2.38, An. annularis - 1.46). The percentage composition of these species did not show any significant difference ($\chi^2= 0.222$, df=3, $P>0.05$) between the two areas.

Mosquitoes were processed for detection of sporozoites by molecular method. Only P. falciparum sporozoites were found and none of the mosquitoes were positive for Plasmodium vivax (Pv). Only one An. culicifacies was found positive for sporozoites in CWW area (sporozoite rate (SR) =3.57%) where as sporozoites were detected in one An. culicifacies (SR =2.7) and in one An. annularis (SR =5) in CUC area (Table 4).

**Malaria Control measures in the study area**

In the study area, intensive malaria control programme was running by Government of Orissa in collaboration with National Vector Borne Disease Control Programme (NVBDCP), Govt. of India since 2001. The programme includes early diagnosis and prompt treatment, vector control measures, emphasis on information, education and communication (IEC) to promote community participation and promotion of personal prophylactic measures including use of insecticide impregnated nets etc.

Since Health Impact Assessment was not implemented at the preparatory stage of the canal system, considering the endemicity of malaria and situation prevalent in this newly constructed canal command area, Malaria Mitigation Measures was undertaken in the area by Govt. of Orissa. The programme has been commenced from 2006 in both the study areas. The malaria mitigation programme includes establishment of Microscopic Centers, Disrupting the transmission of infection chain (e.g. vector control measure), IEC activities and capacity building.

**DISCUSSION**

The epidemiological data of the present study areas has demonstrated the decline
Table 4. Sporozoite rate of Anopheles mosquitoes sampled in areas with canal water (CWW) and canal under construction (CUC) processed by PCR method, in Dhenkanal district of Orissa, India

<table>
<thead>
<tr>
<th>Study area</th>
<th>Species</th>
<th>No. mosquitoes processed</th>
<th>No. positive for sporozoite</th>
</tr>
</thead>
<tbody>
<tr>
<td>CWW</td>
<td>An. culicifacies</td>
<td>28</td>
<td>1 (3.57)</td>
</tr>
<tr>
<td></td>
<td>An. annularis</td>
<td>17</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>An. subpictus</td>
<td>64</td>
<td>0</td>
</tr>
<tr>
<td>CUC</td>
<td>An. culicifacies</td>
<td>37</td>
<td>1 (2.7)</td>
</tr>
<tr>
<td></td>
<td>An. annularis</td>
<td>20</td>
<td>1 (5)</td>
</tr>
<tr>
<td></td>
<td>An. subpictus</td>
<td>90</td>
<td>0</td>
</tr>
</tbody>
</table>

Numbers in parentheses shows percentage
CWW – Canal With Water, CUC – Canal Under Construction

![Annual Parasite Incidence of CWW and CUC area during 2001-2008](image)

Figure 1. Annual Parasite Incidence (API) in areas with canal water (CWW) and canals under construction (CUC) area from 2001-2008 in Dhenkanal district of Orissa, India (2004 is the year of release of canal water to the irrigation canals in CWW area.)

trend of average malaria incidence in CWW area from 7.66 to 5.32 after the release of canal water. Sharma et al. (2008) had also observed the same phenomenon in Sundergarh district of Orissa, India, where they found API came down to 230 from 650 after four years of construction of the dam. In contrast to this, in India, after the construction of Bargi dam in Jabalpur, Madhya Pradesh, a 2.4-fold increase in malaria cases and more than four fold in annual parasite incidence among children were recorded in villages closer to dams compared with more distant villages confirming the high transmission (Singh et al., 1999).

The observed decrease in mean API in both the areas during 2005-08 was may be due to the combined effect of NVBDCP control programme and Malaria Mitigation Measures.

The data of the present study reveals that, in CWW area the API showed a declining trend from 2004 to 2006. The API was 4.05, 1.51 and 2.69 during 2004, 2005 and 2006 respectively. An extensive
control programme taken by the Govt. before the release of water in 2004, might have resulted in reduction of API in the area. Thus, the API came down to 1.51 in 2005 and 2.69 in 2006. As per the NVBDCP guidelines, indoor residual spray (IRS) for the vector control must be done where API was more than 2 for last three consecutive years. Since the API during the year 2005 decreased to <2 the IRS had not been undertaken in the area which affected the increase of API to 2.69 during 2006 and sudden increase of a very high API of 9.42 in 2007 that lead to undertake IRS in the area and the malaria situation was maintained with the API lower than the baseline level.

As compared to CWW area, in CUC area the API was very high i.e 22.24 (in 2004) but the combined effect of routine control programme run by the Govt. and implementation of mitigation measures undertaken in 2006 resulted in 47.1% reduction of API in 2008 (Table 1). The one point fever survey data also tallies with high prevalence of malaria in both the study areas (CWW-18.82% and CUC-24.54%).

In different ecological conditions the distribution of the Anophelines are known to be different. In our study, An. culicifacies and An. annularis were prevalent with high dominance of An. subpictus in both the areas. Yadav et al. (1989) had found the association of An. culicifacies with An. annularis in both canal irrigated and non-irrigated areas and also An. subpictus was the most predominant species (95% of the total collection) in Gujarat, India. The PMHD for An. culicifacies were 2.38 and 2.69 in CWW and CUC area respectively and for An. annularis it was 1.46 and 1.54 in CWW and CUC area respectively. Several studies had shown wide variation in the density of An. culicifacies (0.75-25.9 PMHD) and for An. annularis (0.75-43.96) in various malaria endemic region of the country (Joshi et al., 2006; Singh et al., 1999, 2004).

Anopheles culicifacies and An. annularis are the two major vectors of Orissa (Dash et al., 1982; Gunasekaran et al., 1989; Kumari et al., 2009). In CWW area, only one An. culicifacies species was found positive for sporozoites (sporozoites rate-3.57%). In CUC area both the vector An. culicifacies and An. annularis species were found to be positive for sporozoites with rate of 2.7 and 5% respectively. The sporozoites rate of 4.16% and 1.55% were observed in An. culicifacies and An. annularis respectively in Sri Lanka (Ramasamy et al., 1992). The sporozoites rate as low as 0.25% in An. culicifacies was observed in Bargi dam area, India (Singh et al., 2000) and the same was observed to be 3.4% in An. annularis in Keonjhar district of Orissa (Mahapatra et al., 2006). Sporozoite detection in An. culicifacies and An. annularis from both the areas confirms the report that these two are established vector of this region. Though An. subpictus was found to be a predominant species in various region of the country. Its role in malaria transmission was not known until 1982 in India. However, An. subpictus was incriminated as a vector in Baster, Madhya Pradesh (Kulkarni, 1983) and costal villages of Tamil Nadu (Paniker et al., 1984). Subsequently, the sporozoite was detected in An. subpictus (sporozoite rate-0.5%) in Angul district, Orissa by nested PCR (Kumari et al., 2009). Subsequent stabilization of the irrigation canals and and increase in natural and planted vegetation is likely to encourage this species as a significant vector of malaria (Tyagi & Chaudhury, 1997).

Shukla et al. (2001) had reported that integrated vector management or other control interventions to have a strong influence on the malaria transmission parameters. A study carried out in Uttaranchal, India comparing the parasitological indices in a dam area with those in forest or plain areas showed a prevalence and annual parasite incidence of 0 in the dam area (Shukla et al., 2001). He opined that elevated economic status, indoor residual spraying, and more awareness of malaria risk were reported to be the main factors accounting for the lack of malaria transmission at the dam site. Singh et al. (2000) opined that health issues seem to have been neglected in many development
project. Poor engineering design is difficult to correct after construction, and hence early planning is critical. Action is required to develop an effective health care programme based on local transmission involving multisectoral action and community participation to prevent the spread of disease in the whole region during construction. The findings also suggests a need for health education so that irrigators would invest in personal protection measures (e.g. protective clothing and repellents in the evening), rather than to rely on bed nets that are no longer very effective with mosquitoes biting earlier. Proper water management and canal maintenance for source reduction through environment management could help to reduce mosquito-breeding sites and thus, malaria transmission (Kibret et al., 2010).

The present study reveals that, this canal system did not increase the malaria prevalence during post water release period ,this shows the malaria control programme was effective but still more intense situation specific vectors control programme should be continued simultaneously so that malaria transmission can be curtailed.

Therefore, the study suggests that with the construction of irrigation canal, simultaneous intensified sustainable situation specific malaria control programme with monitoring and surveillance system should run so as to control the malaria transmission in the command area.

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