ASSESSMENT OF THE IMPACT OF IGNP IRRIGATION AND SOME ENVIRONMENTAL FACTORS ON MALARIA CASES IN THE NORTHWESTERN RAJASTHAN

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ABSTRACT
The present study aims at examining the probable impact of Indira Gandhi Nahar Pariyojna (IGNP) irrigation and related environmental factors on malaria incidence in Hanumangarh District of Rajasthan covering three divisions over a period of 15 years (1996-2010). Data have been reviewed to examine whether the incidence of malaria is related to irrigated agriculture and related factors like paddy area, rainfall and water logging. The study area shows an increase in water-related diseases, such as malaria because the infrastructure in irrigation schemes has been found to create or enhance ecological environments that are favourable for the transmission of malaria. Trend of malaria cases due to both \textit{P. vivax} and \textit{P. falciparum} are discussed in relation to agricultural practices and rainfall. Environmental factors like rainfall and irrigation practices are both found to be contributing to increasing malaria cases in the area.

INTRODUCTION
Irrigated agriculture has been the backbone of increased food production and improved quality of life for millions over the past 50 years (Amerasinghe and Boelee 2004). Irrigation has numerous potential benefits, most important of which is that it may contribute considerably to food security and economic progress, which in turn provide improved health care delivery services and education to rural population (Keiser et al. 2005). Planning for the development of water resources for agricultural production is of paramount importance to sustainably utilize water resources with minimum effects on human health. In the past, irrigation projects did not fully address environmental impacts and, as a result, human health deteriorated a great deal owing mainly to increase in water-borne, water-related and water-oriented diseases (Rushomesa and Ndondo 2002). Irrigation and drainage canals, and the various ancillary hydraulic structures in irrigation systems, can become important foci of vector breeding if they provide the right ecological conditions (Keiser et al. 2005). The infrastructure in irrigation schemes has been found to create or enhance ecological environments that are favourable for the transmission of malaria and other vector-borne diseases (Senzanje et al. 2002).

With the progression of canal-irrigation work of the Indira Gandhi Nahar Pariyojna (IGNP), the command area has experienced rise in malaria epidemics. Before the initiation of canalised irrigation, only Anopheles stephensi was prevalent transmitting malaria at low level. Since the 1980s, extensive irrigation with water from three different canal systems has altered the desert physiography and triggered the emergence of \textit{Plasmodium falciparum}-dominated malaria in Thar Desert. In the area \textit{Plasmodium falciparum}-dominated malaria, transmitted both by \textit{Anopheles stephensi} and \textit{Anopheles culicifacies}, was particularly extensive in the upper reaches of the desert currently under extensive irrigation by the Indira Gandhi Nahar Pariyojna (Tyagi et al. 2002).

One of the most important agricultural modifications associated with mosquito-borne diseases is the paddy cultivation. These shallow bodies of water are ideal habitats for the development of many mosquito species. Mosquito-borne diseases are often associated with activities like deforestation, water management that directly alter environmental conditions in favour of mosquitoes. Mosquitoes prefer warm, shallow water suggesting that sedimentation is an ideal process for creating suitable mosquito habitat. Agricultural development may also alter local climate such that an apparently minute change in local temperatures may be enough to alter the vectorial capacity
of available vectors. Even small increases in temperature may increase the development time of mosquitoes, increase mosquito population densities and shorten the extrinsic incubation period of the pathogen resulting in enhanced transmission (Norris 2004).

Malaria is a major public health concern in India resulting in 2 million cases annually and about 1,000 deaths (Dash et al. 2008). In most parts of India, periodic epidemics of malaria occur every five to seven years. Malaria is a vector borne disease caused by Plasmodium species of protozoan parasite transmitted by Anopheline mosquitoes (Garg et al. 2009). There are about 400 species of Anopheles mosquitoes, but only about 10 species are responsible for transmitting malaria. Plasmodium vivax and P. falciparum are the two species of malarial parasite prevalent in India. P. vivax causes about 60% of malaria cases while P. falciparum about 40%. P. malariae is also encountered in tribal areas in India but with less than 1% prevalence (Garg et al. 2009).

Keeping this in view, the present study was taken to examine whether the incidence of malaria in three divisions of Hanumangarh district is related to irrigation, paddy cultivation, rainfall and water logging.

**MATERIALS AND METHODS**

**Study area**

The study area, which comprises of Hanumangarh district (previously incorporated in the Sriganganagar district), is located in the northernmost part of Rajasthan, India. It is situated between 75° 30’ to 74° 33’ East longitude and 28° 58’ to 29° 20’ North latitude, and is surrounded by Sriganganagar district in the west, Bikaner and Churu districts towards south west and south, Sirsa district of Haryana in the east and Firojpur district of Punjab in the north.

The climate of the district is marked with large variations in temperature, extreme dryness and scanty rainfall, which are characteristic of a desert climate. Intense heat along with very strong winds is experienced in the area during summer, when very high temperatures up to 45 to 50 degree Celsius are observed. The coldest month is January when average minimum temperature is 6 degree Celsius. The rainy season lasts for a very short spell between mid - July to first week of September. About 82% of the annual rainfall in the district is received during the months June to September. July and August are the rainiest. In the pre-monsoon period the relative humidity in the afternoon can reach values as low as 5%, creating conditions which cause very high potential evaporation rates and large plant water requirements (Ramkrishna and Rao 1991). The main soil types of the study area are deep and calcareous flood plain soils, aeolian sand deposits and sand dunes. Groundwater is generally saline in most parts of the study area.

The sub-soil water is 50-150 ft below the ground level and is highly brackish. Its salinity stunts the growth of all vegetation. Bajra, jowar, moth and moong are the crops of the rainy season. Rainfall being scanty in most parts, canal is the only source of water for agriculture. Main crops are wheat, bajra, barley, rice, gram, sugarcane and cotton; amongst them wheat has been the most important cereal crop and gram is the most important pulse. The growth of the rice crop has been made possible only with the help of artificial irrigation from canal-waters in the semi arid tracts of the district. Availability of irrigation water in the area facilitates the cultivation of fodder and forage crops of jowar, guar, lusan, chari macca, chari jowar and bareaen etc.

**Data collection and analysis**

The study was based on secondary data related to the malaria cases, total irrigated area, area under paddy cultivation and annual rainfall in Hanumangarh district, Rajasthan. Secondary data over the years 1996-2010 were collected from various sources i.e. Health department, Command Area Development (CAD) and Groundwater Department, IGNP, Bikaner, Rajasthan. Data on annual rainfall in the study area for the study period were obtained from the Meteorology Department, Hanumangarh, Rajasthan.

The trends in incidences of malaria cases over a period of last 15 years were analysed in all the three irrigation-impacted divisions of Hanumangarh districts, viz., Hanumangarh, Sangria and Nohar. Seven tehsils of Hanumangarh districts have been divided into these three divisions. Hanumangarh and Pilibanga tehsils are covered in Hanumangarh division. Sangria and Tibbi tehsils are covered in Sangria division. Nohar, Bhadra and Rawatsar tehsils are covered in Nohar division.

Malaria cases in these divisions were examined and assessed in relation to irrigation, paddy crop and rainfall to know the contribution of these factors on the disease incidence in the Hanumangarh district in post IGNP period. Various aspects of complex life cycle of vectors are known to be affected by different ecological factors like rainfall, temperature, humidity, water quality, vegetation and socio-economic conditions of the affected regions. Both spatial and temporal changes in
environmental conditions are important determinants of vector borne disease transmission (Jeganathan et al. 2001). The present study was planned to identify the environmental and anthropogenic factors influencing occurrence of malaria in the desert environment of Hanumangarh, Rajasthan particularly, in relation to IGNP.

The identification of specific risk factors can play an important role in improving the control of malaria.

RESULTS AND DISCUSSION

Temporal and spatial variations in malaria incidence

Data have been studied from 1996 to 2010 to know the trend in *P. vivax* and *P. falciparum* infections in Hanumangarh district. Number of cases due to both *P. vivax* and *P. falciparum* in all the three divisions of Hanumangarh district during last 15 years (1996 to 2010) have been shown in Fig. 1. Number of cases due to *P. vivax* is higher than *P. falciparum*. As a whole Hanumangarh district had 2611 cases of malaria due to *P. vivax* (96% of total malaria cases) and *P. falciparum* contributed only 4% (95 cases) in 1996. It was found that Nohar division showed the highest number of cases of malaria due to both *P. vivax* and *P. falciparum* among the three divisions in most of the time during the study period. It had a share about 55% of malaria cases alone in 1996 and 40% in 2010.

A perusal of Fig. 1 (a & b) shows that in the Hanumangarh division the cases of *P. vivax* showed decreasing trend during 1996-2002, but increased slightly after 2003 for 3 years. The number of cases increased distinctly in 2006-2009. In Sangria and Nohar, malaria cases were high in 1996 but declined thereafter till 2002. During 2003-05 cases were medium in number while increased sharply during 2006-09. Cases due to *P. falciparum* were much less and did not show a specific trend. Sudden rise in the cases happened in the year 2003 in Nohar.

Agricultural practices like total irrigated area and area under paddy cultivation are considered important in influencing the occurrence of water related diseases like malaria. Figure 2-4 represent the relation between number of malaria cases and three factors viz. irrigation, rice cultivation and rainfall.

Relation with total irrigated area

Annual incidences of malaria cases were examined in relation to the irrigated area in each division. It has observed that irrigated area did not fluctuate very much individually in the three divisions during the study period, but varied amongst the three divisions. Hanumangarh had maximum irrigated area (217 to 276 Th ha), followed by Sangria (163 to 199 Th ha) and it was the minimum (122 to 181 Th ha) in Nohar. On comparing the data on total irrigated area in each division with the number of malaria cases, it was observed that Nohar with maximum number of malaria cases had minimum irrigated area. Thus total area under irrigation could not be identified as a sole factor influencing malaria. This could be due to the fact that Geographical area of Nohar subdivision was the largest (almost 3 times) and had much larger population than Hanumangarh and Sangria divisions. Thus these factors could also be important in determining the number of total malaria cases in the division (Fig. 2 a & b).
Malaria was found to be almost similar. During 2006-2009 number of cases of malaria due to *P. vivax* was very high i.e. almost 3.8 times, 1.8 times and 1.6 times than previous year respectively which corresponded well with increase in total irrigated area. A remarkable decline in *P. vivax* cases of just 19 in 2002 as compared to 219-1400 cases in previous five years was observed. In this year, both irrigated and non irrigated area declined sharply for all the crops like cotton, paddy, bajra and guar. *P. falciparum* induced malaria cases were relatively much less and it was mainly in Nohar division in the years 1996 and 2003 when 75-80 cases were recorded. Moderate number of cases (20-35) was recorded in this division in 1997, 2001 and 2004-2006. However, the cases did not show much relation with total irrigated land area.

This indicates that in the same area, with other conditions alike, even slightly changing irrigation pattern can play an important role in occurrence of malaria but when different areas are considered, there seem to be other factors as well, which influence the occurrence of the disease. Values of regression coefficients ($R^2 = 0.456, 0.344, 0.418$, df = 13, $p>0.05$), between total irrigated area and malaria cases showed some direct dependence of malaria cases on irrigated area.

Malaria is considered to be one of the major tropical diseases associated with irrigation schemes. It has often been assumed that high numbers of malaria vector Anopheles mosquitoes result from irrigation schemes and lead inevitably to increased malaria in local communities (Jumba et al. 2001). Irrigation schemes create conditions that enhance mosquito breeding and hence contribute to the transmission of malaria (Senzanje et al. 2002). Irrigation networks often result in seepage from canals, thus creating a source of still water for vectors breeding (Garg et al. 2009). However, the present study shows that besides total irrigated area, other factors should also be considered while evaluating malaria cases.

Tyagi et al. (2001) reported that the crucial outbreak of malaria in villages situated close to the main Indira Gandhi canal near Ramgarh in Jaisalmer district, western Rajasthan was due to stagnation of water over a month’s period in the main canal as well as long standing rain water in the form of expansive lakes near these villages, which created breeding grounds for the vectors like Anopheles culicifacies, along with A. stephensi. According to a survey in the late 1993 in some IGBP villages showed that *P. vivax* cases were 11%,
P. falciparum 89% and in the non irrigated villages P. vivax 17%, P. falciparum 83% and higher blood-sporozoite rate (32.3%) in the irrigated than in the non irrigated villages (25.5%) (Tyagi et al. 2002).

Our study of Hanumangarh district shows the reverse pattern of malaria cases showing higher numbers due to P. vivax than due to P. falciparum. This indicates that environmental conditions like temperature, rainfall, humidity etc and ecological conditions are also important factors influencing the diseases.

Relation with paddy area

It was only after IGPN that paddy could be grown in the Hanumangarh district. Since paddy fields are characterized by waterlogged condition, we have studied the relation of malaria cases in the three divisions with paddy area as shown in Fig. 3 (a&b). Paddy area was found be minimum in Nohar division while it may be seen in Fig 3 (a&b) that malaria cases both due to P. vivax and P. falciparum were maximum in this division. In Nohar, hardly any correlation could be seen. In Hanumangarh and Sangria, the trend of malaria cases almost followed trends in total paddy area, particularly for P. falciparum. Regression coefficient between paddy area and malaria cases for Hanumangarh, Sangria and Nohar were found to be low, (R² = 0.338, 0.021, 0.118, df = 13, p>0.05), showing a weak correlation between these two variables.

From our observations, it was indicated that neither total irrigated area nor paddy area are responsible totally for incidences of malaria cases in the region. Though it has been reported that surface irrigation mainly used for the flooding of rice fields creates temporary shallow water bodies, which provided the breeding habitats for mosquitoes along with human-vector contacts due to ecological and demographic changes (Keiser et al. 2005). Sharma et al. (1994) has even reported that rice farming creates large areas of stagnant water that provide breeding habitats for twenty Anopheline species. It seems that yearly variation in paddy area in each division does not correlate significantly to total malaria cases. However, continuous application of water for irrigation without proper management practices and lack of drainage causes the water logging problem. Rawatsar tehsil in Nohar division became waterlogged in early stage of irrigation through IGPN. Thus most of the area of this division is wasted due to this problem. This is the main reason that area under major crops has decreased and irrigation is also very less in Nohar division. The crops grown in Nohar division are guar, bajra, moong and moth. These crops require less water and are mainly grown in unirrigated area.

So total land irrigated area during the study period is less, but nonetheless water logged conditions prevail in this division due to IGPN since earlier irrigations, which create conditions for the malarial parasite and its vector.

Relation with Rainfall

Rainfall helps in creating breeding habitats and increases relative humidity (RH) of the area, which helps in survival of adult mosquitoes. To determine whether rainfall is an important factor responsible for malaria incidence in the study area, data were analysed for annual rainfall and annual malaria incidence in the three divisions (Fig. 4 a&b).
division in 1996 and 2003 (78 to 82) while the rainfall was relatively less than that in some other years. From our observations it seems that rainfall influenced malaria cases only to a limited extent. Very low values of regression coefficients ($R^2 = 0.006, 0.292, 0.160, df = 13, p=0.05$) between annual rainfall and malaria cases showed little direct dependence of malaria cases on rainfall.

**Relation with Water logging**

Decadal (1997-2006) water level trends have been recorded for Pre and Post Monsoon period by the Central Ground Water Board (2007). On comparing water level data majority of monitoring stations falling in Nohar block showed rising trend ranging from 0.67m/yr to 1.159m/yr during pre-monsoon. During post-monsoon decadal trend, show rise in water level ranging from 0.21m/yr to 0.48m/yr in Bhadra and Nohar block and decline of 0.086 to 0.51m/yr has been observed in parts of Hanumangarh and Nohar block.

It is observed that during the study period, maximum water logging conditions persisted in Nohar division. While total area irrigated, paddy area and annual rainfall also seem to contribute partially to conditions favouring malaria outbreak, but water logged conditions seem to be very important. Since piezometric data on ground water level of all stations of these divisions for the study period were not available, we have only taken into account the data available on ground water rise / fall. Besides this temperature and relative humidity are also very crucial factors determining the outbreak and transmission of malaria. The minimum temperature required for transmission of $P. vivax$ parasite in anopheline mosquitoes is 14.5-16.5°C while that for $P. falciparum$ it is 16.5-19°C . The best conditions for development of malaria parasite are 24-26°C temperature and 60% RH. Fluctuations in temperature, rainfall, and relative humidity determine whether malaria transmission is seasonal (unstable malaria) or occurring throughout the year (stable malaria) (Garg et al. 2009). Temperature and relative humidity data from Gazetteer of Rajasthan shows that favourable temperature conditions for growth of malarial parasite are found in the study area during the months July to October, when the average daily temperature varied between 25°C - 33°C and the relative humidity reached more than 60%. In other months relative humidity remains low.

Annual rainfall, collection of water around Indira Gandhi Canal, forestation of shrubs around it and migration of labour, adaptation of Anopheles stephensi to desert climate and
favourable breeding of Anopheles mosquito under impact of irrigation; all seem have together helped in the outbreak of malaria in this region. The outbreak of malaria in Thar desert has revived charges that the canal has created ideal conditions for breeding of mosquitoes, the malarial vector, and spread of the disease. Importation of malaria has been considered to be the major cause of seasonal introduction of malaria in the desert (Kochhar et al. 1997, Joshi et al. 2006).

Since malaria is closely related to a number of environmental factors, a good monsoon and water logging from the Indira Gandhi Canal seem to be rather important. An understanding of the nature of malaria transmissibility response to climate variability can enhance the prediction of epidemics and the effects of longer-term climate change (Bombbies and Eltahir 2009). Therefore, sound epidemiological and entomological knowledge are needed before causing any environmental modifications for agricultural purposes and there should be regular monitoring to avoid any outbreak (Carnevale et al. 1999).

In the Thar Desert developmental activities of canal-based irrigation seem to have led to malaria becoming endemic because no malaria incidences were recorded earlier (Garg et al. 2009). After the initiation of irrigation activities since 1975, there has been a tremendous increase in the number of malaria cases. Continuous supply of canal water in the desert region has resulted in a rise of the water table, water-holding potential of the soil and plentiful growth of vegetation, particularly hydrophytic weeds. Such areas are extensive breeding grounds and the preferred sites for A. culicifacies, the most serious vector of malaria. All related actions that modify the environment affect the epidemiology of the disease. Due to demographic pressure and technological development, human involvement is becoming more frequent and aggressive, changing urbanization patterns, vegetal covering, surface water and affecting the conditions for vectors, intermediate hosts, and reservoirs (Mouchet and Carnevale 1997). Our observations also show that no single factor seems to explain the malaria incidences, while it is the combined environmental and ecological conditions along with changes like population immigration in the area that together have influenced malarial outbreak in the desert area after the IGNP irrigation.

CONCLUSION

Results obtained from the analysis revealed that during 1996-2010 period study area has been facing the malaria problem due to both P. vivax and P. falciparum, mainly due to the former. The study shows that the number of cases due to P. vivax is higher (2 to 2371) than P. falciparum (0 to 82) and Nohar division with the highest cases among all the three divisions had a major share. Malaria cases tended to follow the same trend as that of yearly changes in total irrigated area in each of the three divisions. However, the malaria cases when compared among the three divisions showed that beside irrigated area, other factors also seem to interact in influencing the occurrence of malaria. In this desert region, water logging caused already by IGNP seems to be a more important factor that contributes to malaria incidences. Canal irrigation has increased water logged areas, overall cropped area and growth of bushy vegetation, all of which together create favourable conditions for boosting mosquito population. Rainfall also known to be associated with epidemics of malaria, seems to partially explain the malaria cases in this desert region. This case study has indicated that major irrigation-project areas due to poor management of water, could aggravate adverse health impacts and increase the transmission of vector borne diseases such as malaria.

REFERENCES


