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Identification of risk factors for malaria control by focused interventions in Ranchi district, Jharkhand, India

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ABSTRACT

Background & objectives: Ranchi, the capital of Jharkhand state is endemic for malaria, particularly the Bundu Primary Health Centre (PHC) is the worst affected. Therefore, a study was initiated during 2009 using remote sensing (RS) and geographical information system (GIS) to identify risk factors responsible for high endemicity in this PHC.

Methods: Bundu and Angara in Ranchi district were identified as high and low malaria endemic PHCs based on epidemiological data of three years (2007–09). The habitation, streams, other water body, landform, PHC and village boundary thematic maps were prepared using IRS-P6/LISS III-IV imageries and macro level breeding sites were identified. Digital elevation model (DEM) of the PHCs was generated using Cartosat Stereo Pair images and from DEM, slope map was derived to calculate flat area. From slope, aspect map was derived to indicate direction of water flow. Length of perennial streams, area under rocky terrain and buffer zones of 250, 500 and 750 m were constructed around streams. High resolution remote sensing imageries were used to identify micro level breeding sites. Based on macro-micro breeding sites, six villages from each PHC were selected randomly having combination of different parameters representing all ecotypes. Entomological data were collected during 2010–11 in pre- and post-monsoon seasons following standard techniques and analyzed statistically. Differential analysis was attempted to comprehend socioeconomic and other determinants associated with malaria transmission.

Results: The study identified eight risk factors responsible for higher malaria endemicity in Bundu in comparison to Angara PHC based on ecological, entomological, socioeconomic and other local parameters.

Conclusion: Focused interventions in integrated vector management (IVM) mode are required to be carried out in the district for better management and control of disease.

Key words DEM; GIS; malaria risk factors; remote sensing; slope; stone quarries

INTRODUCTION

During last decade, a number of studies related to mapping malaria risk along with identification of risk factors have been published using modern data acquisition tools like remote sensing (RS) and global positioning system (GPS) and sophisticated analysis by means of geographical information system (GIS)[1–5]. Assessment of risk factors at local scale is crucial for focused and cost-effective control of disease. Socioeconomic and other attribute data contribute to detailed understanding of the disease etiology. Identification of risk factors ensures that if a localized spurt of the disease occurs, it can be associated rapidly with a likely cause, a specific vector and a probable human source so that appropriate preventive actions can be taken to arrest any rising trend[6].

Ranchi, the capital of Jharkhand state is endemic for malaria with *Plasmodium falciparum (Pf)* accounting for 50% of cases. Ranchi is situated between 22°52' to 23°43' N latitude and 84°56' to 85°54' E longitude covering an area of 5231 km^2 under 14 PHCs. The temperature in the district ranges from 5.3°C in winter to 41.2°C during summer and annual rainfall is 153 cm, most of which occur during monsoon months from June to September. Entire terrain of the district is full of high and lowlands. The district is characterized by large network of streams and other water bodies which provide innumerable breeding sites for malaria vectors throughout the year. These breeding sites may be diverse and species-specific as per terrain profile. Malaria transmission risk of a location may be attributed to the presence of the breeding sites and appropriate vectors at that location. *Anopheles culicifacies,* *An. fluviatilis* and *An. annularis* (Diptera: Culicidae) are vectors in Ranchi district[7]. *Anopheles culicifacies* breeds mainly in pools formed in streams and riverbeds, the most productive breeding sites of *An. fluviatilis* are slow moving streams located in foothills and undulating areas while *An. annularis* breeds in margins of ponds, rivers and streams with abundant vegetation[8].

This paper identifies risk factors responsible for malaria in a highly endemic Bundu PHC of Ranchi district using ecological, entomological, socioeconomic and other local parameters. Identification of risk factors at PHC level is crucial to improve planning of control strategies.

MATERIAL & METHODS

Study site

PHC-wise annual parasite incidence (API) data were collected from 2007–09 from the State Health Department of Ranchi district. These data were processed and classified. Average API indicated Bundu as highly malaria endemic PHC while Angara was found to be low endemic. Bundu is situated about 70 km south and Angara is about 21 km north of Ranchi City. Bundu covers an area of 264 km^2 consisting of 0.062 million population and Angara covers an area of 445 km^2 with population being 0.11 million[9].

The habitation, streams and other water body, land form, PHC and village boundary thematic maps were prepared for Bundu and Angara PHCs using IRS-P6/LISS III imageries of 2009 (23.5 m spatial resolution), survey of India topo sheets and cadastral map in collaboration with Jharkhand Space Application Centre (JSAC), Ranchi. These maps were further updated by JSAC using IRS-P6/LISS IV (5.0 m spatial resolution) imageries of 2009. All the thematic layers were geo-referenced in GIS environment in the Universal Transverse Mercator (WGS-84) projection.

Digital elevation model (DEM) was generated using Cartosat Stereo Pair images of the study area by JSAC. From DEM, slope map was generated following standard GIS routines and it was divided into six categories as per standard classification-gentle (flat area), moderate, moderate high, high, steep and very high. Slope measures the rate of change of elevation at surface location. Area was calculated for different classified categories of slope. Aspect map was derived from slope which indicated direction of water flow. Habitation map was overlaid on slope map and number of hamlets in flat areas was identified.

Habitation map of the study area indicated sporadic pattern of population settlement and tendency to settle in hamlets consisting of about 10–25 houses. Each hamlet was identified as a polygon for analysis purpose. Length of the perennial streams in both the PHCs was calculated using GIS analysis. From landform map, rocky terrain landform was extracted. Rocky terrain is an eroded land structure which leads to formation of seasonal pools of water. Area under rocky terrain in both the PHCs was calculated. Buffer zones of 250, 500 and 750 m were constructed around streams in both the PHCs and habitation map was overlaid. Number of hamlets settled within each buffer zone was calculated using GIS analysis.

Thematic layers related to streams and other water bodies, rocky terrain and village map were overlaid in ArcGIS 9.3 software and macro level breeding sites were identified. Selected PHCs were also screened through high resolution remote sensing imageries of 2008–09 (<1 m spatial resolution) and micro level breeding sites were identified. For rural areas, suitable high resolution satellite imageries are generally not available for the period of field sampling of breeding sites. However, using satellite imageries taken at different times than the larval samplings helps address the general utility of satellite images for identifying larval habitats across different seasons and years[10].

Based on identified macro-micro breeding sites, six villages from each PHC were selected randomly having combination of different parameters representing all ecotypes. From Bundu PHC—Humta, Taimara, Jareya, Reladih, Gutuhatu and Baruhatu villages were included. From Angara PHC—Rupru, Kuchu, Pirtaul, Getalsud, Ambajhariya and Sataki villages were included.

Two surveys were undertaken in both the PHCs during April–May 2010 (pre-monsoon) and October 2011 (post-monsoon). Anopheline larvae and adults were collected following standard techniques. The identified macro and micro breeding sites in the selected villages were matched in the field using Garmin handheld Montana 650 GPS during field data collection.

Total catch was performed to identify mosquito species resting inside the houses and cattlesheds. All the exits were covered, a white cotton sheet was placed on the floor and a pyrethrum-based insecticide was sprayed. Fifteen minutes following the spraying, the mosquitoes were collected and identified simultaneously and species-wise recording was done. Four houses and two covered cattlesheds from each selected village were covered under total catch. Differences in collected vectors in both the PHCs during pre- and post-monsoon seasons were tested by using Student's *t*-test. Per room vector density

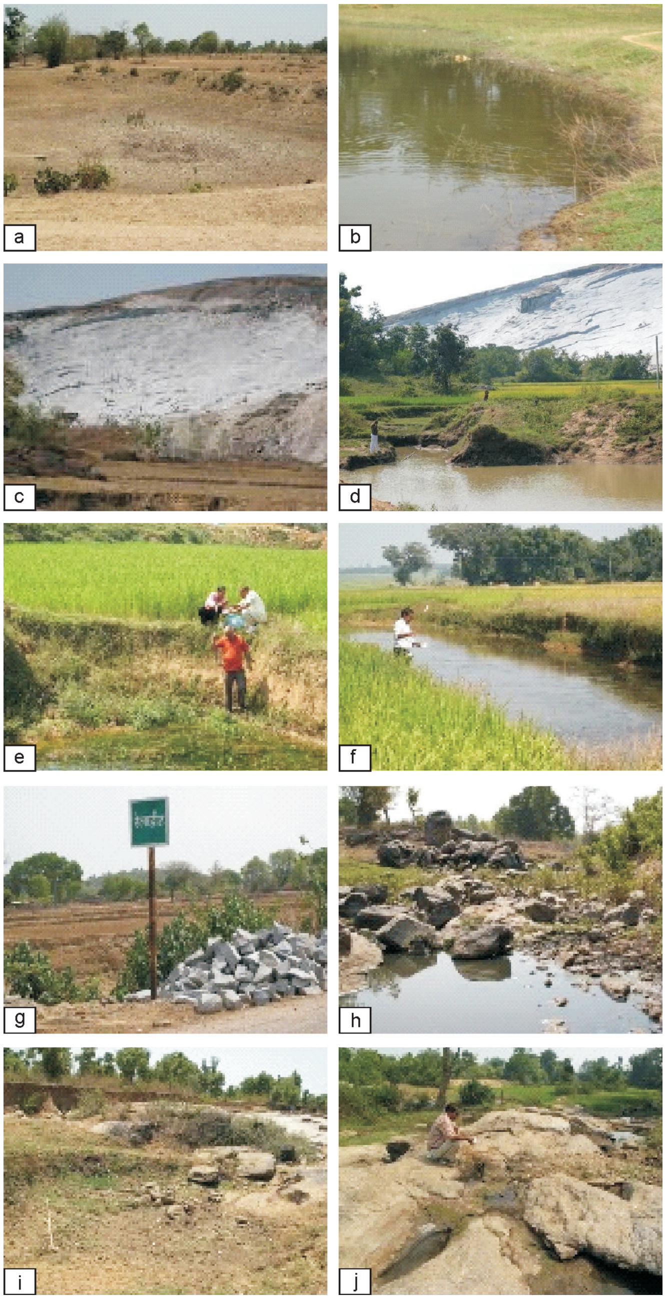

Fig. 1 (a–j): Breeding sites during pre- and post-monsoon seasons in PHCs of Ranchi district, Jharkhand [(a) Dry small pond during pre-monsoon; (b) Same pond during post-monsoon; (c) Pit below stone quarry during pre-monsoon; (d) Same pit during post-monsoon; (e) Pit left after brick kilning during pre-monsoon; (f) Same pit during post-monsoon; (g) Pit due to earth work during pre-monsoon; (h) Pit during post-monsoon; (i) Rocky terrain pits during pre-monsoon; and (j) Rocky terrain pits during post-monsoon].

was also calculated in both the PHCs during pre- and post-monsoon seasons.

Around 200 questionnaires were filled from each PHC in order to collect socioeconomic and other attribute data. The parameters investigated were education level, occupation, monthly income, type of houses, sleeping habits, *etc*. Other attribute data collected through survey was—local/migratory labour settlement around brick kilns and stone quarries, knowledge about malaria and its breeding sites, use of repellents/traditional methods to protect from mosquito bites and use of insecticide treated nets (ITNs) by the population. Ethical clearance was not required for this data collection. Differential analysis was attempted to comprehend socioeconomic and other determinants associated with malaria transmission.

RESULTS

Overlaying of habitation map over aspect map indicated 37% of the hamlets affected due to water logging during rains in Bundu PHC and 32% hamlets in Angara. Flat area (gentle slope) with respect to total area, calculated from slope map was found to be 71% in Bundu PHC and 56% in Angara. Total length of perennial streams as calculated using GIS routines was 0.95 km/km^2 area in Bundu PHC and 0.80 km/km^2 area in Angara. In Bundu PHC, the area under rocky terrain landform was 24.68 km^2 while in Angara, it was 20.86 km^2.

Macro-level breeding sites identified were — streams, reservoir, river, ponds, rocky, terrain, *etc* and micro-level breeding sites identified were — small ponds, rocky river beds and margins, seepage and escape water from reservoir, other pits due to earth work, pits left after brick kilning, stone quarry sites, *etc*. Anopheline larvae were collected from all these identified macro- and micro-breeding sites. During both the seasons, maximum numbers of larvae were collected from streams. Five breeding sites, namely small ponds, pits below stone quarries, pits left after brick kilning, other pits due to earth work and rocky terrain based pits were full of water during post-monsoon season (Fig. 1 a–j).

Buffer zone analysis indicated that the maximum number of hamlets (60%) was settled within 500 m distance of streams in both the PHCs.

Entomological data were analyzed and are presented in Tables 1 and 2. *Anopheles fluviatilis* was collected from breeding sites located in hilly and undulating areas as identified through DEM. Room vector density was found 36 (pre-monsoon) and 78 (post-monsoon) in Bundu PHC and 19 (pre-monsoon) and 31 (post-monsoon) in Angara PHC. The collected vector species in Bundu PHC were significantly higher in comparison to Angara (p <0.05) during transmission season.

As given in Table 3, socioeconomic data were found

Table 1. Total catch from houses and cattlesheds in Angara PHC

S.No.	Village	*An. annularis*	*An. culicifacies*	*An. fluviatilis*	Total
April–May 2010 (Pre-monsoon)					
1.	Rupru	18	146	0	164
2.	Kuchu	17	202	24	243
3.	Getalsud	48	73	0	121
4.	Pirtaul	93	15	0	108
5.	Ambajhariya	7	12	1	20
6.	Sataki	10	22	0	32
	Total	193	470	25	688
October 2011 (Post-monsoon)					
1.	Rupru	44	212	106	362
2.	Kuchu	70	65	105	240
3.	Getalsud	38	147	25	210
4.	Pirtaul	113	18	11	142
5.	Ambajhariya	47	51	0	98
6.	Sataki	28	41	0	69
	Total	340	534	247	1121

Room vector density: Pre-monsoon–19; and Post-monsoon–31.

Table 2. Total catch from houses and cattle sheds in Bundu PHC

S.No.	Village	*An. annularis*	*An. culicifacies*	*An. fluviatilis*	Total
April–May 2010 (Pre-monsoon)					
1.	Humta	193	7	261	461
2.	Taimara	34	69	0	103
3..	Jareya	31	6	49	86
4.	Reladih	213	280	2	495
5.	Gutuhatu	26	11	0	37
6.	Baruhatu	80	19	0	99
	Total	577	392	312	1281
October 2011 (Post-monsoon)					
1.	Humta	225	269	365	859
2.	Taimara	57	139	252	448
3.	Jareya	56	354	48	458
4.	Reladih	247	292	43	582
5.	Gutuhatu	203	19	10	232
6.	Baruhatu	197	23	6	226
	Total	985	1096	724	2805

Room vector density: Pre-monsoon–36; and Post-monsoon–78.

Table 3. Socioeconomic and other attribute data collected from Angara and Bundu PHCs

S.No.	Features	Angara	Bundu
1.	Total population*	0.11 million	0.062 million
2.	Population density*	253	233
3.	Education level (illiterate population)	>50%	>50%
4.	Occupation	Labour and farmer (90%)	Labour and farmer (90%)
5.	Monthly income	₹ 2000–3000 (80%)	₹ 2000–3000 (80%)
6.	Type of houses	Poorly constructed (Mud and thatched roof) – 50%	Poorly constructed (Mud and thatched roof) – 80%
7.	Sleeping habits	Indoor (98%)	Indoor (97%)
8.	Brick kilns	Many	Few
9.	Stone quarries (earth work)	Many	Few
10.	Stone quarries (hills)	–	Many
11.	Labour engaged in brick kilns, stone quarries (earth work and hills)	Local villagers	Migratory population
12.	Knowledge about malaria and its breeding sites as per conducted interviews	Unaware (100%)	Unaware (100%)
13.	Use of repellents/traditional methods to protect from mosquito bites as per conducted interviews	None (100%)	None (100%)
14.	Use of insecticide-treated bednets (ITNs) as per conducted interviews	53%	48%

*Census 2011.

more or less same in both the PHCs. Poorly constructed-mud and thatched roof houses were recorded 80% in Bundu and 50% in Angara PHC. Brick kilns and stone quarries (earth work) engaging local labours were the features in Angara PHC while in Bundu, stone quarries from hills were observed and migratory population from nearby endemic areas were found settled around them. Knowledge about malaria and its breeding sites and use of repellents/traditional methods to protect from mosquito bites was found negligible in both the PHCs as per conducted survey. This may be due to low education level recorded from both the PHCs. In Bundu, 48% and in Angara 53% of the respondents ascerted the use of insecticide treated bed nets (ITNs).

Eight risk factors were found to be responsible for higher malaria endemicity in Bundu in comparison to

Angara PHC : (i) More number of hamlets affected due to water logging in low lying area and availability of more flat area capable of forming stagnant water pools during rains; (ii) Higher length of perennial streams; (iii) More area under rocky terrain leading to formation of water pools during rains; (iv) Abundance of poorly constructed houses; (v) Higher room vector density; (vi) Significant higher collection of vector species during transmission season; (vii) Migratory population settlement from endemic areas around stone quarries; and (viii) Less ITN coverage in comparison to Angara PHC.

DISCUSSION

Remote sensing technology is well established for identification, characterization, monitoring and surveillance of malaria vector breeding habitats[11]. Low and high resolution satellite data were used for identification of macro- and micro-level breeding sites in this study. With improvement in resolution and cut-down in data cost, in future more useful applications of this technology are envisaged. However, there is problem in getting latest high resolution imageries of rural areas as only scenes for limited time period are available. As development is low in rural areas, using archived data is considered a good option for detailed screening of the study area.

This study clearly identified role of ecological, entomological, socioeconomic and other local parameters in propagating malaria in Bundu PHC. Some of the risk factors identified were similar as found in other studies carried out in other parts of the world[12–17].

In a study done in western Kenya highlands, topographic wetness index (TWI) was derived from DEM using GIS for predicting areas of high malaria risk[18]. In the present study, DEM helped derive slope and aspect maps indicated availability of more flat area capable of forming stagnant water pools and identification of number of hamlets affected due to water logging in low lying areas.

As per NVBDCP guidelines, every year two rounds of indoor space spraying (IRS) using insecticides are done following blanket coverage. From 2008, World Bank assisted malaria control project became operational in Ranchi district and stratified approach of IRS has been recommended[19]. Therefore, covering households within 500 m of streams will lead to cost-effective control. Another low cost measure suggested is the use of water management for control of vector breeding[20].

The population in the PHCs was not found using either repellants or personal protection methods to protect from mosquito bites. The reason may be low literacy rate and complete unawareness regarding malaria caused by mosquito bites. This is in contrast to the study carried out in Sri Lanka where people living close to the streams used more preventive measures especially traditional fumigants[12]. The requirement to conduct intensive information, education and communication (IEC) activities among people of PHC comes from the fact that none of the 400 people interviewed knew about malaria and its breeding sites.

The study identified limited use of ITNs in Bundu PHC which were distributed as per the existing practices in vector control. During indepth review carried out by National Vector Borne Disease Control Programme (NVBDCP) during 2006, the use of ITNs was observed to be inadequate due to multiple factors, such as social, cultural and operational problems to re-impregnate the nets. In World Bank assisted malaria control project, emphasis is on the introduction of long-lasting insecticidal nets (LLINs). Since, 60% of the population was found settled within 500 m buffer of streams, covering of this population by LLINs on priority basis will yield useful results.

Meteorological data could not be incorporated in this study as the data were not available at PHC level. However, in future with the help of HOBO temperature-relative humidity data loggers and rain gauge, this data can be generated and analyzed to identify more risk factors[21–22].

CONCLUSION

This is the first study of its kind carried out in Ranchi district using GIS and RS to identify risk factors for high malaria endemicity. Focused interventions in integrated vector management (IVM) mode are required to be carried out in the district for better management and control of disease.

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Conflicts of interest

The authors declare that they don't have any conflict of interest.

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