Original Article

MALARIA ELIMINATION AND OUTBREAKS: ARE WE LOSING THE BATTLE? A CASE STUDY OF MALARIA OUTBREAK IN SOLAR POWER PROJECT, TUMAKURU, KARNATAKA

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Date of submission : 5th Oct., 2020
Date of review : 5th Dec., 2020
Date of acceptance : 9th Dec., 2020

ABSTRACT

Background: Tumakuru in Karnataka, one of the malaria endemic districts, has shown high malaria morbidity during 1990-2000.

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Cite this article as:
Usha A, Manjushree R, Purushotham TN, Srivastava PK. Malaria elimination and outbreaks: a case study of malaria outbreak in solar power project, Tumakuru, Karnataka. J Med Arthropodol & Public Health 2021; 1(1): 93-112.

However, cases declined in next decade and recorded incidence rate of less than 1 per 1000 population in 2007 and onwards and, hence, the district was well on track to comply with the set goal, "Malaria Elimination by 2030."

However, a major outbreak of *Plasmodium vivax*-malaria occurred in the project site of solar power project in Pavagada, Tumakuru between October 2017 and March 2018. This project has witnessed immigration of labourers from different parts of the country who were vulnerable for many diseases as they lived in unsafe environment and unfit dwellings.

Methods: Standard formats and case definitions prescribed under NVBDCP were used for capturing and analyzing the data, and for surveillance, respectively. Malaria cases were confirmed through microscopy whose quality control was ensured through cross verification at higher levels of institutions. Malaria cases were administered with anti-malarial drugs as per the existing national drug policy. Vector control measures were implemented to contain the outbreak. Entomological studies were carried out to know the vector prevalence.

Results: Initial cluster of malaria cases were reported in labourers' colony in the project site, which then gradually percolated to the nearby villages. A total of 139 malaria cases reported during the episode with 138 *Plasmodium vivax* infections. Out of the total cases, 68% of infections were detected in migrant labourers and remaining 32% infections in locals. Among the local people infected with malaria, 40% of them were working at the project site as security guards. The drug compliance was 68% and 100% among migrant labourers and locals, respectively. *Anopheles culicifacies* was the vector collected in solar project site and in two index villages with Per Man Hour (PMH) density ranging from 0.125 to 2.0. Vector dissection revealed oocyst rate of 33%.

Conclusion: Outdoor transmission during this outbreak was suspected as majority of the persons infected with malaria showed

outdoor dusk hour and/or night activities and also outdoor sleeping behaviour. The analysis revealed that a provision of screening of migratory labourers must be made mandatory and, more importantly, health impact assessment studies need to be carried out as a prerequisite before start of the project. Outbreaks like this and sub-optimal drug compliance among migrant labourers would be huge hurdles in malaria elimination path.

Keywords: malaria outbreak, migrant labourers, drug compliance, health impact assessment.

INTRODUCTION

Malaria, one of the ancient diseases, still continues to affect 87 countries and territories around the world.[1] In 2018, 228 million cases and 405,000 deaths due to malaria occurred globally; three per cent of these cases occurred in India.[2] Large-scale malaria interventions resulted in considerable reduction in mortality and morbidity in endemic countries including India. Between the year 2000 and 2015, the rate of new malaria infections declined by 37% and death by 60% across the globe.[3] Encouraged by massive success, World Health Assembly in May 2015 resolved to eliminate malaria by the year 2030, and urged the member states to update their national strategies and operational plans to achieve the targets.[4] Conforming to this, India launched its National Framework for Malaria Elimination 2016-2030 on 11th February, 2016. National strategies and operational guidelines on malaria elimination were also framed and released. In context of malaria elimination, occurrence of outbreaks is alarming and becomes a hurdle in achieving the desired objectives. In general, though reasons for an outbreak could be multiple, yet a prompt effort was made to elicit the factors responsible for the outbreak and search a possible solution to contain outbreaks in future.

Tumakuru, a known malarious district in Karnataka, had reported incidence rate of 10.66 per 1000 population in the year 2001 which had gradually decreased to less than 1 per 1000 in the year 2007 due to the concerted and continued efforts to track, test and treat malaria cases aligned with vector control measures. Since then the district has reported consistent and steady decrease of malaria infections and recorded incidence rate of 0.01 per 1000 population in 2017. The annual blood

examination rate (ABER), a surveillance indicator defined under National Vector Borne Disease Control Programme (NVBDCP), was always above the set national target of 10% indicating good surveillance system.[5] Majority of the cases reported in the district in recent past years were reported as sporadic cases.

The malaria outbreak occurred in Asia's biggest solar power project in Pavagada of Tumakuru district. The solar park is spread over a total area of 13,000 acres (53 km^2) which includes five revenue villages of Balasamudra, Tirumani, Kyataganacharlu, Vallur and Rayacharlu in Pavagada. The project was piloted in October 2016 in a confined area with a small number of labourers. The work was then expanded from June 2017 on large scale in a phased manner involving different areas of above mentioned villages.[6]

The outbreak occurred in phase I of the project with a total of 139 malaria cases, spread over six months between October 2017 and March 2018. Solar power project site and eight villages were affected in this incident, as the first malaria case was reported on 27th Oct 2017 in passive surveillance at Tirumani primary health centre (PHC) followed by two more cases on 30th Oct 2017 in passive surveillance at PHC Tirumani. All three infections were seen among migrant labourers. Subsequently contact screening was carried out and 45 labourers were screened, all were reported to be negative for malaria infection. However, after a gap of 23 days, five more cases reported on 20th November 2017 in active surveillance and hereafter malaria cases reported continuously. Surveillance and other control activities were geared up after the reporting of a cluster of cases.

MATERIAL AND METHODS

Data source

Malaria situation since 2011 in Tirumani PHC, which is the jurisdictional PHC for solar project site, was analyzed using NVBDCP data forms and registers. The line list of confirmed malaria cases of the outbreak was also verified for descriptive epidemiology.

Case finding

A case with current fever or history of fever in the past fifteen days was considered as suspected malaria case and a suspected case whose blood was

positive for malaria by microscopy and/or antigen based Rapid Diagnostic Test (RDT) was considered as confirmed malaria case.

Different firms functioning in the solar project were contacted to obtain the list of existing migratory labourers to ensure complete screening. Considering the solar project site as the epicenter of outbreak, eight villages surrounding the solar site were also selected for surveillance and implementation of other containment measures. Exclusive surveillance teams were constituted to screen labourers at project site and locals in villages for malaria by means of blood films. Each team was assigned with specific areas for their surveillance. These teams carried out a mass survey from 23rd November, 2017 to 30th November, 2017.

During the mass survey, blood films were collected from all labourers and from locals irrespective of presence or absence of symptoms. The surveillance was sustained in both solar power project site and villages after this one time mass survey. In subsequent surveillance, it was made mandatory to screen all the new migrant labourers, while the screening was restricted only to suspected cases amongst locals. In addition to this, tracking and screening of contacts of malaria positive cases and a follow up blood film on sixth day of treatment for confirmed malaria cases were also carried out by these teams.

The teams were provided with standard formats to collect demographic details, date of onset of fever, diagnostic results and treatment particulars of positive cases following national programme guidelines. These data were used to describe the epidemiology of the outbreak.

Laboratory investigation

Finger prick blood was collected during screening process. Both thick and thin smears were made and were stained using JSB stain, conforming to the guidelines of NVBDCP. Blood films were collected by well-trained and skilled paramedical staff, while the blood film staining and examination, using binocular microscope was carried out by designated teams of trained laboratory technicians. The examination results were communicated to both surveillance and treatment team. Quality control of blood film examination was ensured through cross-checking of positive blood films and randomly picked up negative blood films through district and state level malaria referral laboratories.

Intervention measures

Multi-pronged measures were undertaken to contain the outbreak. Series of meetings were held with all solar project firms, at various levels to set right the issues like non-cooperation by the firms for surveillance activities; very poorly maintained labour registry; provision of proper shelters to labourers; and provision for screening of labourers soon after their arrival. Prompt and complete treatment was attempted for all the confirmed cases by a designated treatment team. The drugs were administered strictly according to the national drug policy. Vector control activities like space spraying; indoor residual spray, release of larvivorous fishes in water sources like ponds, step wells, tanks, and distribution of long lasting insecticidal nets (LLIN) to both labourers and locals were carried out to contain the outbreak.

Entomological investigation

Entomological investigation was carried out during November-December-2017 and February-2018 during the outbreak period, in solar project site and in the two index villages of Rayacharlu and Achammanahalli which reported relatively more number of malaria cases in this outbreak as compared to the other neighboring villages. These two villages were selected as they were located about 1.5-2.0 km from the project site and additionally, village Achammanahalli was covered by solar sites on three directions and thus was more vulnerable for penetration of outbreak from solar site. Entomological studies were also conducted post outbreak from April-2019 to March-2020 in the above mentioned two villages for all the three climatic seasons. Investigation was conducted to know the breeding sources, vector prevalence, vector density and vector infectivity rate. Water bodies like puddles, pools, tanks and step wells in and around the project site and villages were surveyed. Temporary dwellings of labourers and outdoor spots in solar project site were selected for vector collection. Similarly human dwellings, mixed dwellings and cattle sheds were selected for vector collection in villages.

RESULTS

Data analysis

The PHC Tirumani had reported malaria incidence at 2.18 per 1000 population in 2011. However, cases were reduced to 0.10 per 1000 population in 2012 and in

the subsequent years, too. In 2016, the year previous to outbreak, the PHC had reported 0.24 malaria cases per 1000 population and more importantly, in 2017 it had reported zero malaria cases till the first reported case in solar power project.

Descriptive Epidemiology

A total of 139 confirmed malaria cases were reported in the outbreak in PHC Tirumani, Pavagada taluk between October 2017 and March 2018. Out of these cases, 138 (99.3%) were *Plasmodium vivax* (*Pv*) malaria and 1 (0.7%) was *P. falciparum* (*Pf*) malaria. The analysis revealed median age was 24 years, and mode was 20 years with the age range of 1.3 - 78 years. It also revealed that, out of total cases, 129 (92.8%) were males. The age distribution of cases showed that 59 (42.4%) cases were in the age group of 21 – 30 years followed by 34 (24.5%) cases in 11 – 20 years age group and notably, 5 (3.6%) cases reported in the age group of 1-10. To be more precise 3 (2.2%) cases were in the high risk age group of 1-5 and presented with trophozoite and gametocyte stages (Table 1).

Table 1. Age distribution of malaria cases during an outbreak in Solar power project, Tumakuru, Karnataka (N = 139)

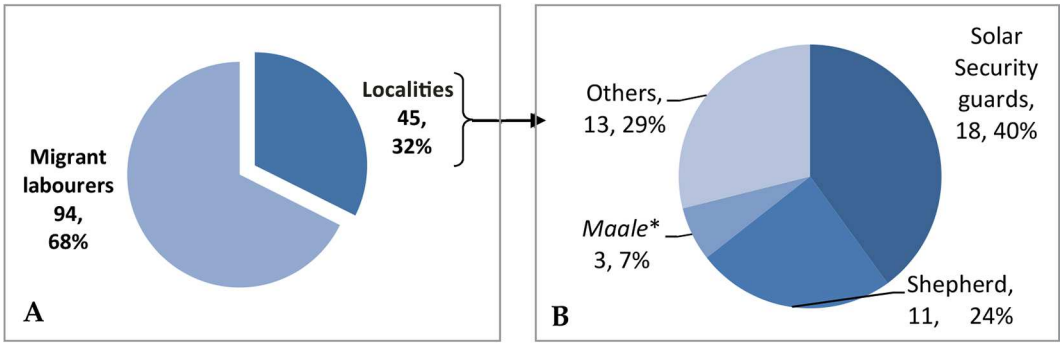
Age group	N	%
less than 1 year	0	0
01 - 10 years	5	3.6
11 - 20 years	34	24.5
21 - 30 years	59	42.4
31 - 40 years	22	15.8
41 - 50 years	15	10.8
51 - 60 years	1	0.7
Above 60 years	3	2.2

The attack rate for the outbreak was 1.1% and among the eight malaria reporting villages, Achammanahalli village reported highest attack rate of 2.1% (Table 2). Out of 139 cases, 94 (68%) were detected among migrant labourers and 45 (32%) were detected among locals. It is noteworthy that, of these local 45 malaria cases, 32 (71%) cases had evidence of direct or indirect contact with solar project site including 18 (40%) persons who were serving as security guards in different solar firms (Fig. 1**)**.

Table 2. Attack rate of malaria by village for an outbreak in Solar power project, Tumakuru, Karnataka (N = 139)

Village	Cases	Attack rate (%)
Achammanahalli	21	15.10
Annadanapura	1	0.71
Husenpura	2	1.43
Nagenahalli Thanda	4	2.87
Nagenahalli	5	3.59
Rayacharlu	4	2.87
Tirumani	7	5.03
Valluru	1	0.71
Solar project site*	94	67.62

* project site had floating population



*A religious custom where the men wear holy clothes, prepare their own food and prefer to sleep in temples during a particular month/s of the year.

Fig. 1. (A) Distribution of cases by migrant labourers and Localites, and (B) Distribution of local cases by their profession for a malaria outbreak in solar power project, Tumakuru, Karnataka (N = 139)

Day-wise distribution of malaria cases showed that, first three cases were reported between 27th October 2017 and 30th October 2017 in solar project site and the next case on 20th November 2017 after a gap of 23 days. Clustering of cases then started from 20th November 2017 with a peak on 24th November 2017. Cases started declining from 1st December 2017, however, the fluctuation with small

upsurge was again noticed from mid of December, with reports of few positive cases from villages of the area which continued thereafter. Continuity of cases was seen in November and December months (Fig. 2).

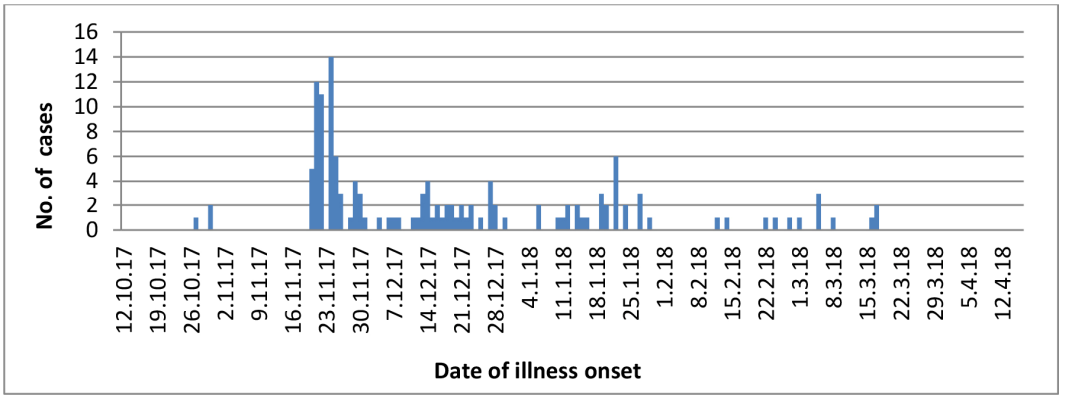


Fig. 2. Cases by date of onset of illness during a malaria outbreak in solar power project, Tumakuru, Karnataka (N = 139)

Case finding

A total of 10002 blood films were collected during the entire screening process between 1st October 2017 and 31st March 2018 including the mass survey, contact survey and routine survey. Of which, 6381 (64%) were from villages and 3621 (34%) from solar project site (Table 3**)**. Further, a total of 124 contacts were traced and screened, out of which 3 were found positive for malaria.

Table 3. Screening data by area during a malaria outbreak in solar power project, Tumakuru, Karnataka (N = 10002)

Description	Solar project site	Villages	Total
Total blood films collected between 1st October 2017 and 31st March 2018	3621	6381	10002
Blood films collected during mass survey alone between 23rd November 2017 and 30th November 2017	1610	5085	6695
Blood films positive for malaria (N=10002)	94	45	139
Positivity rate (%)	**2.60**	**0.70**	**1.39**

Lab results

A total of 10,002 blood films were examined out of which, 139 were declared as positive for malaria with a positivity rate of 1.39%. Further, a follow up blood films on day 6th of start of drug administration were collected from 112 malaria patients and all of them were confirmed for absence of malaria parasite. Remaining 27 persons were not available for follow up blood films as they left the project site. The cross check results of all 139 positive blood films and randomly picked negative blood films were in concordance with the initial results declared by the PHC.

Outcome of intervention measures

Outcome of administrative intervention: Series of meetings with solar park administration resulted in cooperation for surveillance activities at their end; maintenance of labourers' register by each of the firm; notification of entry of new to the health authority; and construction of decent dwellings for labourers (Fig. 3).

Fig. 3. Conditions of the labour dwellings: (A) Before intervention, and (B) After intervention, during a malaria outbreak in solar power project, Tumakuru, Karnataka.

Outcome of treatment: Designated treatment teams could administer radical treatment (RT) to 136 cases out of 139 notified cases. However, the team was able to administer complete dose of drugs only to 109 (78.4%) cases and could not do so for 27 (19.4%) cases whose treatment remained partial and for remaining 3 (2.2%) cases the team was unable to administer even a single dose. Among 109 cases, which were administered with complete dose of drugs, 45 were local cases and 64 were migrant labours amounting to100% drug compliance in locals with only 68% in case of migrants (Table 4). Amongst partial treatment, number of days of drug administration varied from 1 day to 11 days. Bifurcation of malaria cases on number of days of treatment taken is depicted in Fig. 4.

Table 4. Treatment data by complete vs. incomplete and local vs. migrant for a malaria outbreak in solar power project, Tumakuru, Karnataka

Total malaria cases	139
No. administered with complete dose of drug	109 (78%)
No. administered with incomplete/nil dose of drug	30 (22%)
No. of malaria cases among local residents	45
No. of local malaria patients administered with complete dose of drug	45 (100%)
No. of malaria cases among migrants	94
No. of migrant patients administered with complete dose of drug	64 (68%)
No. of migrant patients who were not administered with complete dose of drug	27 (29%)
No. of migrant patients who were not administered with any drug	3 (3%)

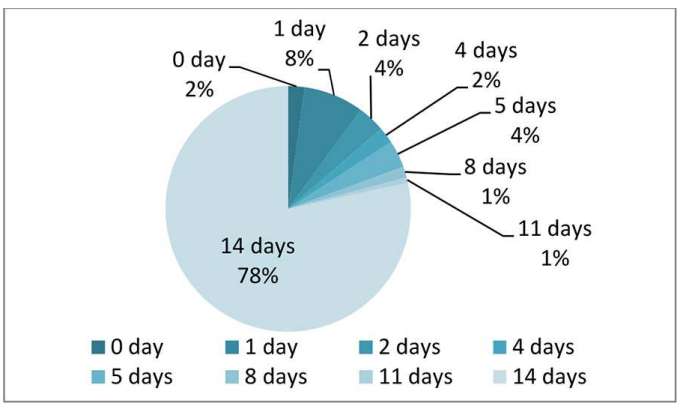


Fig. 4. Bifurcation of cases based on number of days of treatment administered during a malaria outbreak in solar power project, Tumakuru, Karnataka, India

Outcome of entomological investigation

Anopheles (An) culicifacies, a known vector of malaria, was collected from solar project site and from Achammanahalli village. But Rayacharlu village did not show the presence of any of the malaria vectors during the study. Prevalence of vector was noticed during post monsoon period. Per man hour density (PMHD) of vector varied from 0.125 to 2.0. Village wise and month wise density of *Anopheles culicifacies* studied during the outbreak and post outbreak is illustrated in Fig. 5. *Anopheles culicifacies* collected from the labourers' tents in solar project site during November 2017 was 1.7 PMHD and during this period malaria peak occurred. These vectors were subjected to dissection which revealed oocyst rate of 33%. However, no gland infection with sporozoite could be detected. Water sources surveyed showed the presence of anopheline breeding however, no malaria vector species was noticed on their emergence. Other mosquito species viz., *An. subpictus, An. vagus, An. barbirostris, An. annularis, An. pallidus, An. culiciformis, An. roperi, An. nigerrimus, An. barianensis, An. karwari, An. crawfordi, Cx. quinquefasciatus, Cx. vishnui, Ae. aegypti, Ae. vittatus* and *Armigeres* spp. were also collected during the study (Fig 5).

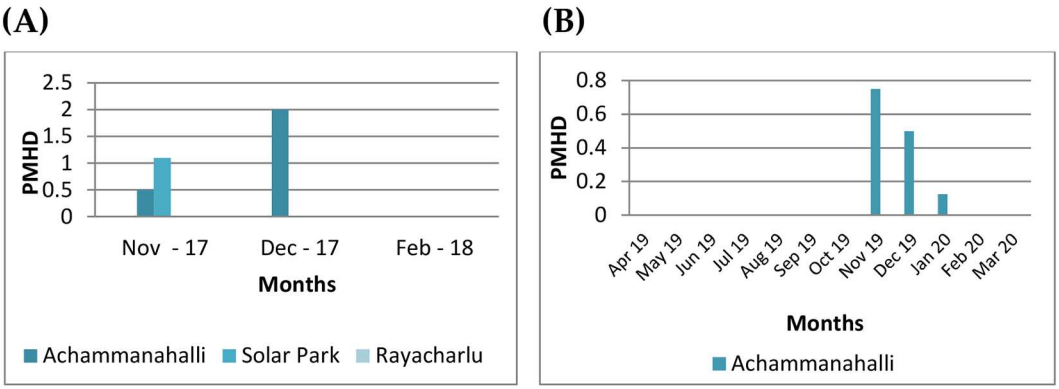


Fig. 5. Prevalence of vector *Anopheles culicifacies* by village: (A) vector density during an outbreak, and (B) vector density during post-outbreak studied during all three climatic seasons for outbreak in Solar power project, Tumakuru, Karnataka

Effect of vector control measures was estimated in terms of effect of IRS and decrease in vector density as well as in malaria cases in village Achammanahalli (Fig. 6).

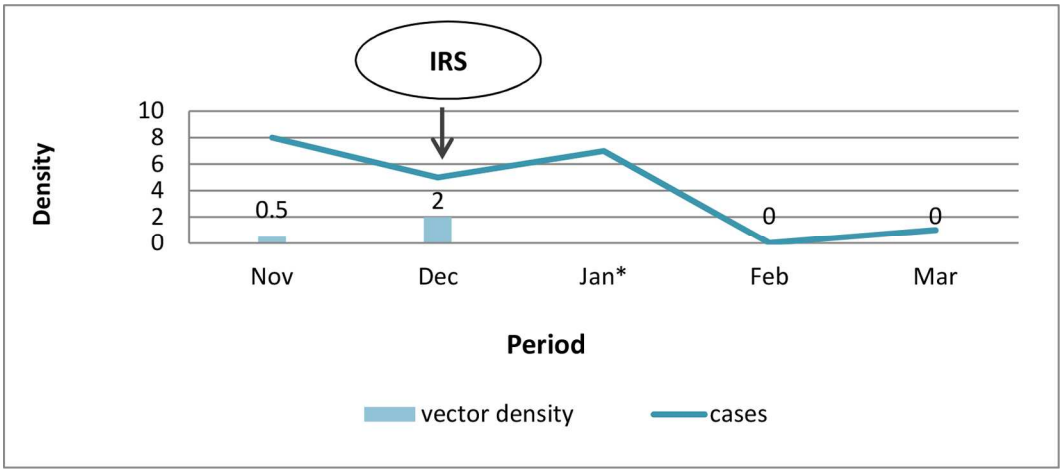


Fig. 6. Effect of IRS in terms of decrease in vector density and malaria cases in village Achammanahalli during a malaria outbreak in solar power project, Tumakuru, Karnataka.

The vector density was studied in village Achammanahalli during outbreak period in the months of November - December 2017 and February 2018. Vectors were found only during first two months of the study. The IRS was carried out in the villages during 3rd week of December 2017. The vector density after three days of IRS was 2.0 PMHD which, however was reduced to zero in the subsequent month. Further, the malaria cases in the village had also declined from 2nd half of January 2018. Out of total 21 malaria cases reported from the village, 16 reported between 24th November and 12th January 2018 and remaining 5 cases between 13th January 2018 and 1st March 2018.

DISCUSSION AND CONCLUSION

Malaria primarily a tropical disease, though spread over large regions of the world is referred to as 'focal' disease. Its distribution is influenced by multiple factors related to human host, vector mosquito, parasite and the local environment.[7] Malaria distribution in India is as diverse as its topography. Malaria in the country exists under five epidemiological paradigms, viz., tribal, rural, urban, industrial and border.[8] The current outbreak can be grouped under industrial malaria.

Malaria data analyzed for Tirumani PHC is indicative of prevalence of malaria in the PHC**,** but with low transmission intensity**.** There are 33 villages under this PHC but cases in the past were reported from only three villages that are located away from the current solar project site and no malaria cases were reported from rest of the villages since 2012. Solar power project activities have led to an influx of labourers on large scale from all parts of the country including the areas known for high malaria morbidity. Migration of populations is a major public health concern as it usually increases the spread of diseases and it is well established in case of malaria transmission.[9-11] Here, in this instance, large number of migrant labourers arrived to work in solar project. However, majority of the solar firms functioning in the project did not make any arrangements for their stay. This forced the labourers to build their own tents in vacant open fields in the project site. Materials like cloth, wood, carton box, metal sheets etc. were used to raise the tents and were very unsafe for living. Clusters of tents, few hundred meters apart from each other was a common feature in the project site. These factors collectively led to the emergence of factors such as introduction of pathogen, availability of susceptible population, creation of vector breeding sources, easy biting opportunities to vectors etc. and these factors collectively put migrants and local communities in vulnerable situations.[12] It is therefore important that accessibility to basic health services to migrant workers be made available to prevent work related diseases as per the resolutions of the sixtieth World Health Assembly.[13]

The health authority both at local and district levels were not notified about the expansion of solar project and its subsequent activities. The screening and surveillance of migratory workers was thus significantly compromised in initial stages. The screening was started from later part of August 2017, although as per records it started from the month of October 2017. Three index malaria cases reported in October were among the migrant labourers, who were stationed in the solar project site for more than a month. This was followed by reporting of cluster of cases after a gap of 23 days from the date of report of the first case. Though the labourers' migration started from June, screening was initiated only in October. Further, there was no fixed tenure for these labourers, the crew changed every now and then. The period of their stay in the project site ranged from one day to six months. These factors might have resulted in possible missing of initial malaria case/s and would have led to autochthonous transmission leading to an outbreak as per Begoa Monge-Maillo *et al*.[14] Detection of gametocyte stage during outbreak

investigation indicates that some of the migrant labourers were gametocyte carriers which might have facilitated transmission as trophozoites were also seen during microscopic examination of blood smears. The absence of malaria cases in the area during last five years further substantiates that the recent outbreak was due to the presence of gametocyte carriers amongst labourers. This justifies the need for initial screening of migratory population.[15]

A development project will have both positive and negative impacts on the environment, health, social aspects and economy. Environmental impact assessment (EIA) and social impact assessment (SIA) are usually recommended to be carried out to assess the environment and social impacts of a development project. However, instances of health impact assessment (HIA) studies as a separate process are yet to gain priority in India. To name few projects where HIA was carried out are, vector-borne diseases in Sardar Sarovar Water Resources Development Project, Konkan Railway Project and Bargi Dam Project.[16] In spite of being a major project, HIA was not carried out in the solar project as it is not mandatory in India and this has resulted in major health issues in terms of malaria outbreak, and perhaps many other health issues which have gone unnoticed. Initially there was non-cooperation forthcoming from solar companies for surveillance; in fact, surveillance workers were denied entry inside the company premises and also information on the details about labourers until the issue was dealt at the highest authority of the district. It is thus important that information on development project be communicated to the health sector so as to make health sector as one of the stakeholders empowered to conduct HIA. It is therefore essential to make HIA a mandatory process in all the development projects as recommended.[17]

In this outbreak, as many as 94 migrant workers were infected with malaria parasite and majority of them were living in temporary open tents or shed-like structures (Fig. 3) and were forced to spend their time outdoors during dusk hours for various routine activities including cooking. Moreover, majority of them sleept outdoors which exposed them to all kinds of dangerous bites including mosquito bites. It is interesting to note that, out of 45 locals infected with malaria, 18 were security guards serving in different solar firms and attended night duties and spent their night outdoors; while 11 were shepherds who camped in the open grazing land adjacent to solar project site along with their flock continuously for 3-4 nights and 3 others were male individuals who were on a local religious custom, which entailed

them to sleep outdoors in the temple near the solar project site. Only remaining 13 local persons were found to have no direct contact with solar project. Further, the vectors collected from outdoor situation in solar park showed evidence of infection. Considering the fact that majority of the people infected with malaria had shown outdoor activities during dusk time and also shown outdoor sleeping behaviour, the outdoor transmission in this outbreak cannot be ruled out.[18-21] The strategies to control outdoor malaria transmission thus needs to be emphasized in malaria elimination period.

As stated in the result section, the drug compliance was only 78% which is a matter of concern in times of malaria elimination. Though good treatment strategy was in place, 100% drug compliance could not be achieved and the possible explanations could be (i) complete compliance to 14-days radical treatment for *Pv* malaria was difficult in outbreak situation on directly observed treatment (DoT) mode, (ii) tracing and follow-up for 14-day radical treatment to migrant labourers who contributed as much as 68% of the case load was a herculean task. (iii) many migrant patients left the project site abruptly without informing either the health authority or the project authority, due possibly to a melange of factors such as, for example, the fear of disease, new job exploration, living with family during sickness etc. It is noteworthy here that all 22% cases of non-compliance were amongst migrant workers alone, while the drug compliance among local patients was 100%.

There are well documented studies to show that, incomplete treatment or sub-optimal doses results in relapse or recurrence of vivax malaria.[22-26] Further, it is also established by various studies that, continuous exposure to malaria parasite results in asymptomatic infections.[27-29] And as per our field experience, self-medication for milder illness is a common practice among migrant labourers. Due to such practices many diseases in migratory labourers go undetected, untreated and unrecorded by the health system. As these migratory labourers take either no dose or sub-optimal dose of antimalarial drugs or sometime take irrelevant drug they are susceptible for relapses. Additionally, continuous exposure to malaria parasite may result in asymptomatic infection in these migrant labourers and they remain infective for longer period acting as silent reservoirs of transmission.[30-35] Hence there is likely chance that they transmit malaria along the way of their movement. The issues of malaria in migrant labourers, in particular non-drug compliance, therefore, needs to be dealt on top priority to achieve the goal of malaria elimination.

LIMITATIONS

Vector control measures and entomological parameters were not studied in depth due to limited infrastructure. Non-detection of salivary gland infection with sporozoites may be attributed to insufficient sample size.

ACKNOWLEDGEMENT

Our sincere thanks are due to the entire field staff involved in surveillance and control. Special thanks are due to Sri Ramesh and other paramedical staff of the PHC Tirumani. We also thank district health authorities for extending their cooperation.

Conflict of interest - None.

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