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Travel Associated Malaria among Migrant Workers in Rural Murshidabad, West Bengal, India: A Retrospective Epidemiological Study

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Research Article

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Abstract

Background

Malaria is an important public health concern in India, and migration of the population is an important challenge to malaria elimination as it facilitates the introduction of malaria parasites from endemic to receptive areas. In West Bengal, Kolkata contributes majorly to urban malaria, while Hosnabad Health Sub-Centre (HSC) under Bhagabangolla-II Block in Murshidabad district reported persistent rural malaria transmission despite ongoing control efforts. This study aims to assess the epidemiological characteristics and population demography details to find out the reasons for persistent malaria at Hosnabad HSC.

Methods

A retrospective assessment of routine malaria surveillance data from 2017 to 2024 was conducted utilizing records from Hosnabad HSC. Demographic characteristics, *Plasmodium (P)* species, and documented travel histories of laboratory confirmed malaria cases were extracted from surveillance registers. Cases were accessed according to their reported travel history and timing of symptoms onset to determine the likely origin of infection.

Results

Among 7,273 fever individuals screened, 233 (3.2%) were diagnosed with malaria. Most cases occurred among adult male (98.7%, mean age of 24.6 ± 8.0). The majority were migrant worker 230 (98.7%) predominantly engaged in construction work 219 (93.1%), followed by plumbing 11 (4.7%) and domestic work 2 (0.9%). *P. vivax* was the predominant species 209 (89.7%), followed by *P. falciparum* 15 (6.4%) and mixed infection 9 (3.9%). A documented travel history was available for 95.7% patients, of whom 87.1% had travelled to Kolkata, followed by Mumbai (3.5%) and Odisha (2.1%). Among cases with travel history, 66.1% returned with fever while 20.6% developed symptoms within two weeks of return, supporting a predominantly imported origin of infection.

Conclusion

Malaria cases reported at Hosnabad HSC was predominantly *P. vivax*, associated with population movement, particularly migration between Kolkata and the rural catchment area. These findings highlight the importance of integrating migrant sensitive surveillance into malaria elimination strategies, including systematic documentation of travel history, prompt diagnosis and treatment, and radical cure of *P. vivax* infections to prevent relapse and onward transmission. However, inter-district and inter-state cross-

notification is important to improve surveillance and response between urban infection source and rural receiving areas to prevent re-establishment and support India's malaria elimination goal.

1. Background

Malaria remains a major public health challenge in India despite remarkable progress achieved through strengthened surveillance, improved diagnosis, effective case management, and large-scale vector control interventions. India reported 161,753 malaria cases and 90 malaria-attributed deaths in 2021, while 255,500 cases and 86 deaths were reported in 2024, indicating that sustaining elimination gains remains challenging [1]. The complexity of malaria transmission in India is largely driven by its diverse ecological and socio-demographic landscapes. Malaria persists across a wide range of settings, including rural villages, urban centres, forested regions, tribal areas, industrial zones, and migrant populations, each presenting unique challenges for disease control and elimination [2–8]. In addition to environmental factors, the epidemiology of malaria is influenced by human activities such as unplanned urbanisation, population migration, and conversion of forest to agricultural land [9–10]. Previous studies have demonstrated that population movement contributes to malaria redistribution, particularly in elimination settings [11–15]. As India moves closer towards malaria elimination, understanding the role of human movement has become one of the important concerns. Migration can facilitate the movement of malaria parasites from high transmission areas to regions where local transmission has declined but permissive vectors are still present. Such imported infections may sustain malaria transmission in receptive areas and create challenges for achieving and sustaining elimination [16, 17]. Therefore, identifying the contribution of population migration to persistent malaria is essential for designing targeted surveillance and control strategies. West Bengal (WB), an eastern Indian state, which holds the second highest population density in the country and significantly contributed to the national malaria burden. Between 2017 and 2024, the state accounted for 4–23% of India's reported malaria cases, with annual case numbers ranging from 14,049 to 40,595 [1]. The tropical climate and diverse geography of state support vector survival and parasite development, facilitating sustained malaria transmission. Malaria in WB is predominantly urban, with Kolkata Municipal Corporation (KMC) consistently reporting the highest number of cases and contributing 46.7–90% malaria burden of state during 2017–2024. This substantial urban contribution underscores the persistent challenges of malaria control in densely populated, highly heterogeneous and operationally complex urban settings [unpublished annual report, Health Department of WB from 2017–2024]. Besides this, malaria transmission remains an important concern in rural areas as well, where several districts continue to report sustained transmission even with continued interventions. Murshidabad is one of such districts, contributing the second highest malaria burden in WB with 1,459-1,686 cases annually during 2017–2024, accounting for 4.6–7.5% of the state's malaria burden, [unpublished M4 data of NVBDCP, Murshidabad district]. Although the district experienced an overall decline of malaria cases from 2009 to 2024, the Bhagabangola-II block remained a persistent focus, consistently reporting an Annual Parasite Incidence (API) above 1 and contributing approximately 15% of the district's malaria burden from 2017 to 2024. In micro-stratification, it was observed that the Hosnabad Health Sub-Centre (HSC) within this block has been a persistent hotspot,

with malaria incidence remaining stable over time with API values ranging from 1.45 to 5.28 between 2017 and 2024 [unpublished report of Nashipur Block Primary Health Centre (BPHC)].

In spite of sustained control efforts, the continued occurrence of malaria cases in Hosnabad HSC raises an important epidemiological concern, whether these cases reflect sustained local transmission or repeated introduction of infections through population movement. Hosnabad HSC has a large migrant workforce with frequent movement to malaria endemic urban and peri-urban regions, including Kolkata, where malaria transmission remains substantial [18]. However, the contribution of such migration associated infections to persistent rural malaria transmission remains poorly characterized. To address this knowledge gap, we conducted a retrospective epidemiological analysis using routine malaria surveillance records from Hosnabad HSC between 2017 and 2024. The study aimed to characterize the demographic and parasitological profile of malaria cases, investigate travel and migration histories, and assess the potential contribution of imported infections to persistent malaria within this rural setting.

2. Materials and Methods

2.1. Study Site

Murshidabad district is located in the eastern part of WB, between 23º43'N-24º52'N latitude and 87º49'E-88º44'E longitude, has 26 administrative blocks and 8 Municipalities. Bhagabangola-II block is one of the highly endemic blocks in the district as mentioned before (Fig. 1). It is a predominantly agrarian district with a population of approximately 7.1 million, a literacy rate of 63.8%, and a population density of 1,334 persons/km². The district shares a 125.35 km international border with Bangladesh, including both land and riverine boundaries, spanning 11 administrative blocks. In Murshidabad district a significant portion of the rural population seasonally migrates to urban centres such as Kolkata and other states, including Odisha, Karnataka, and Maharashtra, for livelihood opportunities [18, 19]. Hosnabad HSC, located under Bhagabangola-II Block, was selected as the study site because it represented a persistent malaria despite an overall decline in malaria burden at the district level. Hosnabad HSC covers two villages, Hosnabad and Barianagar. According to the HSC family register, as of 2018 Hosnabad has a population of approximately 4200 individual (1113 households), and Barinagar has 5000 individuals (1349 households). On the basis of high API of Bhagabangolla-II block, data was further analysed up to the sub-centre level, and the study site was selected as Hosnabad HSC, which is one of the endemic HSCs, reporting persistent API (Fig. 2).

2.2. Data Collection and Investigations:

A retrospective analysis was carried out using routinely collected malaria surveillance data from January 2017 to December 2024. Data were obtained from malaria surveillance registers and case investigation records maintained at Hosnabad HSC, Nashipur BPHC, and where applicable from KMC. All laboratory confirmed malaria cases recorded in the Hosnabad HSC malaria surveillance register during the study period were considered for inclusion. Data were extracted on demographic characteristics (age and sex),

occupation, *Plasmodium* species, diagnostic findings, treatment and follow-up, travel history, and reactive case detection (RCD) activities. Particular emphasis was placed on documented travel history, including the place of travel and timing of travel in relation to onset of fever to assess the likelihood of imported infection. Information from RCD activities was reviewed to assess evidence of local transmission and the epidemiological context of identified cases. The data were systematically collected using a structured data extraction format (Supplementary Annexure 1).

2.3. Malaria diagnosis

All suspected malaria cases presenting with fever were investigated with RDTs and microscopy as part of routine surveillance. Peripheral blood samples were collected at Nashipur BPHC or Hosnabad HSC. Malaria diagnosis was performed by microscopic examination of Giemsa stained thick and thin blood films following the SOP of NCVBDC [1]. Thick and thin smears were examined under 100× oil immersion visual fields (1000× magnification). Microscopy reviewed 100 high power fields of the thick blood smear were examined before the sample was considered parasite negative. RDTs were used according to manufactures instructions and used as additional diagnostic methods.

2.4. Treatment

All confirmed malaria cases were treated at Nashipur BPHC as part of the district case management system according to National Centre for Vector Borne Disease Control (NCVBDC) guidelines. Following each malaria cases, active screening within a 500 meters radius of patient's residence was conducted within 2 weeks of case reporting to screen additional infections and evaluate evidence of local transmission.

2.5. Data Validation

To validate the data recorded in the HSC register, regular monitoring was conducted by block and district level officials. Positive cases from 2017–2024 were cross verified through field visits and direct interviews with patients and their family members. The investigations were carried out by the Regional Office for Health & Family Welfare team and district level surveillance team for verification of demographic details, travel history, occupational migration patterns, and epidemiological links.

2.5. Data Analysis

Data were analysed using Microsoft Excel, Origin Pro 8.5, and R statistical software (R-4.6.1). Descriptive analyses were performed to summarize demographic characteristics, malaria species distribution, seasonal trends, travel patterns, and epidemiological classification of cases. Continuous variables were summarized using mean ± standard deviation or median with interquartile range (IQR), wherever appropriate. Categorical variables were presented as frequencies and percentages. Spatial and temporal patterns of malaria occurrence were visualized using appropriate graphical methods.

3. Results

3.1. Malaria Surveillance Indicators of Hosnabad HSC

Malaria surveillance indicators remained consistent at Hosnabad HSC throughout the study period (2017–2024), with the Annual Blood Examination Rate (ABER) exceeding 10% in each year (Fig. 3). Even with sustained surveillance, malaria cases continued with the API remaining above 2 in all years. The API increased from 3.60 in 2017 to 5.28 in 2018, followed by a decline to 3.00 in 2019 and 2.48 in 2020. It subsequently increased to 2.79 in 2021 and 3.42 in 2022, then declined to 2.43 in 2023 and increased slightly to 2.61 in 2024 (Fig. 3).

3.2. Demographic, Occupational, Parasitological & Clinical characteristics of the study population

A total of 7273 fever incidences were investigated for malaria using antigen based rapid diagnostic tests (RDTs) and microscopy from January 2017 to December 2024. Among these, 233 cases (3.2%) were confirmed for malaria infections. The majority of malaria cases were reported among males (230/233; 98.7%), while only three cases (1.3%) occurred among females (Table 1). The mean age of malaria positive individuals was 24.6 ± 8.0 years, with a median age of 23 years (IQR: 18–29 years) and the age range of 3–54 years. Among the confirmed malaria cases 230 (98.7%) were migrant labour, and remaining 3 (1.3%) had different occupation (Table 1).

Among confirmed malaria cases, *P. vivax* was the predominant parasite species, accounting for 209 cases (89.7%), followed by *P. falciparum* (15 cases; 6.4%) and mixed infections (9 cases; 3.9%) (Table 1). All malaria positive individuals presented with fever. The median interval between fever onset and diagnosis was 5 days (IQR: 3–6 days). The mean time interval between fever onset and diagnosis was 5.37 ± 2.90 days (range: 1–28 days). All confirmed cases of malaria were treated on the day of diagnosis. Overall, 61.4% of cases were diagnosed within five days, 85.8% within seven days, and 98.7% within fourteen days of fever onset (Table 2).

Table 1
Demographic, occupational, parasitological, and clinical characteristics of malaria cases identified in Hosnabad HSC (2017–2024).

Characteristic	Overall (N = 233)
Demographic Profile	
Number of patients	233
Age, mean ± SD, years	24.6 ± 8.0
Age, median (IQR), years	23.0 (18.0–29.0)
Age range, years	3–54
Male, n (%)	230 (98.7%)
Female, n (%)	3 (1.3%)
Occupational Details	
Migrant Labor, n (%)	230 (98.7%)
House wife n (%)	1 (0.42%)
Student n (%)	1 (0.42%)
Child / NA n (%)	1 (0.42%)
Parasitological Profile	
P. falciparum (Pf), n (%)	15 (6.4%)
P. vivax (Pv), n (%)	209 (89.7%)
Mixed infection, n (%)	9 (3.9%)
Diagnosis & Treatment	
Fever onset to diagnosis days	Median (IQR) = 5 (3–6), Mean ± SD = 5.37 ± 2.90, Range = 1–28
Fever onset to treatment initiation days	Median (IQR) = 5 (3–6), Mean ± SD = 5.37 ± 2.90, Range = 1–28
Treatment initiated on diagnosis day, n (%)	233 (100.0%)

Table 2
Time threshold between fever onset, malaria diagnosis, and treatment initiation.

Time threshold	Diagnosed, n (%)	Treatment initiated, n (%)
≤ 3 days	60 (25.8%)	60 (25.8%)
≤ 5 days	143 (61.4%)	143 (61.4%)
≤ 7 days	200 (85.8%)	200 (85.8%)
≤ 10 days	217 (93.1%)	217 (93.1%)
≤ 14 days	230 (98.7%)	230 (98.7%)
> 14 days	3 (1.3%)	3 (1.3%)

3.3. Travel history and Migration pattern of the malaria cases of Hosnabad HSC from 2017-24

A detailed epidemiological investigation confirmed that 223 out of 233 (95.7%) malaria cases had documented travel history outside the Hosnabad HSC before diagnosis. Kolkata was the most frequently reported travel destination, with 203 cases (87.1%), followed by Mumbai (8 cases, 3.4%) and Odisha (5 cases, 2.1%) (Fig. 4). Only 10 cases (4.3%) had no documented travel history and diagnosed with *P. vivax* infection. The temporal relationship between travel and fever onset was analysed among malaria cases with documented travel history. Among all malaria cases, 154 (66.1%) returned from their workplace with fever, whereas 40 (17.2%) developed fever within one week after returning. Subsequently a few cases developed symptoms during the second week (8 cases, 3.4%), third week (2 cases, 0.9%), and fourth week (7 cases, 3.0%) after returning from migration sites. A small proportion developed fever one to three months after return (12 cases, 5.1%) (Fig. 5). Seven *P. vivax* cases without documented travel history were migrant labour by occupation frequently moving to malaria endemic areas, particularly Kolkata and Odisha. These cases may represent relapse associated infections or repeated exposure during previous migration related travel. Three epidemiologically linked cases without travel history were identified from family linked imported *P. vivax* infections, indicated limited potential for secondary local transmission (Table 1).

3.4. Recurrent Malaria Episodes among Migrant Workers

During 2017–2024, total 28 individuals experienced more than one documented malaria episode. All 28 individuals were migrant workers and had travel histories associated with their recurrent episodes. Twenty-five individuals experienced two episodes, one experienced three episodes, and two experienced four episodes during the study period. The occurrence of repeated malaria episodes among individuals with continued population mobility suggests that recurrent exposure or repeated infection in the same population group may have contributed to the continued detection of malaria at Hosnabad HSC.

3.5 Evidence of Local Transmission and Reactive Case Detection

Among malaria cases without a travel history, epidemiological investigations identified three cases with potential household level epidemiological links to previously imported infections. One case occurred in a three-year-old child in 2017, while two cases were identified in 2020 in households with documented imported *P. vivax* infections. Following malaria case detection, RCD activities were undertaken around the residences of affected individuals. Over the entire study period, these activities cumulatively screened 2,959 individuals using RDTs and blood smear microscopy. No malaria cases were identified during these community based follow-up investigations. The absence of additional cases detected through RCD provided limited evidence for sustained secondary transmission within the investigated households and surrounding communities during the study period.

3.6 Comparison of Malaria Species Composition and Monthly Malaria Trend between the Hosnabad HSC and Kolkata

Since, Kolkata was the most frequently reported travel destination among malaria cases from Hosnabad, parasite species distribution was compared between the two locations to assess epidemiological similarity. In Hosnabad HSC, *P. vivax* constituted 89.7% of malaria infections, followed by *P. falciparum* (6.4%) and mixed infections (3.9%) (Figure S1). In KMC, approximately 86% of reported malaria cases were attributed to *P. vivax* and 14% to *P. falciparum* during the study period (Figure S1). Mixed infections were not separately reported in the available KMC secondary dataset and were included under *P. falciparum* classification, Therefore, direct comparison of mixed infections between Hosnabad and Kolkata could not be done The comparable predominance of *P. vivax* infections in both locations supports the epidemiological association between the two settings, though parasite origin could not be confirmed without molecular characterization.

Monthly trends of malaria showed similar seasonal patterns in Hosnabad HSC and KMC. In both locations, malaria cases increased during and after the monsoon period, with a peak during the post-monsoon months (Fig. 6). Similar seasonal distribution of both sites reflects similar ecological conditions influencing malaria transmission and provides additional epidemiological context for the observed travel associated malaria patter

Discussion

The present study provides epidemiological evidence that persistent malaria transmission in Hosnabad HSC, Murshidabad, WB is strongly associated with population migration, particularly among individuals with occupational travel to malaria endemic urban areas. Through analysis of eight years of routine surveillance data (2017–2024), we observed that malaria cases in this rural setting occurred despite sustained surveillance activity and vector control interventions, and was characterized by a

predominance of *P. vivax* infections among young male adults with documented travel histories. A key observation of this study was the continuous malaria case report even with effective surveillance procedures. ABER was consistently above 10% throughout the study period, indicating strong surveillance activities in accordance with the NCVBDC guidelines. However, the API remained continuously high, ranging from 2.43 to 5.28 between 2017 and 2024. This pattern suggests that the persistence of malaria in Hosnabad HSC cannot be attributed to inadequate surveillance or missed diagnoses. The demographic profile of malaria cases strongly supports the association with occupational mobility. Almost all malaria cases were male (98.7%) with median age of 23 years, which is the working age population. This distribution pattern is unusual for a community wide malaria pattern and correlates with the known migration pattern of the Hosnabad HSC population, in which approximately 40% of the residents migrate seasonally for employment [18]. Thus, the frequency of malaria cases among young adult males provides an epidemiological clue to the association of malaria occurrence with migrant populations. These findings align with previous findings indicating that adult males are disproportionately affected in areas of Gujarat, Rameswaram and Delhi with high labour related migration [11–15].

The strongest evidence of travel associated malaria was obtained from individual cases investigations. Among the 233 malaria cases, 223 (95.7%) had a documented history of travel outside the Hosnabad HSC. Kolkata was the most common travel destination, representing 87.1% of reported travel associated cases [19]. Moreover, this association was not based solely on residence or occupation but was supported by the temporal relationship between travel and disease onset. Two thirds of patients returned from migration sites with fever, and additional 17.2% developed fever within one week after returning. Considering the incubation period of *P. vivax*, these findings are epidemiologically consistent with infections acquired during migration and detected after returning to the native village [11–13]. The prevalence of *P. vivax* infection further supports the observed epidemiological pattern. In Hosnabad HSC, *P. vivax* contributed to 89.7% of infections. A similar parasite prevalence was observed in KMC, where approximately 86% of reported malaria cases were linked to *P. vivax*. These findings further support the hypothesis of reverse malaria transmission, from urban to rural areas, driven by labour migration. As mentioned, the parasite origin could not be confirmed without molecular characterization, the comparable species distribution between the primary travel destinations and receiving rural area provides supportive epidemiological evidence for a shared transmission context.

Seasonal analysis provided additional support for this association. Both Hosnabad HSC and KMC showed increased malaria incidence during and after the monsoon period, with a post monsoon peak. The similar seasonal patterns suggest that both areas have overlapping ecological conditions that contributed to malaria transmission. However, seasonality alone cannot establish the direction of parasite movement, and these findings should be interpreted together with the strong travel history observed among Hosnabad HSC cases. In addition, our findings suggest limited evidence of sustained local transmission within Hosnabad HSC during the study period. Only 10 cases (4.3%) had no documented recent travel history, and all were *P. vivax* infections. Seven of these individuals reported frequent occupational travel to malaria endemic areas, suggesting possible relapse associated

infections, repeated exposure, or undocumented travel [20]. Three additional cases had epidemiological links with imported infections, including one child in 2017 and two household associated cases during 2020. However, extensive reactive case detection involving 2,959 community screenings did not identify any additional infections amongst the indigenous population. Overall, these findings indicate that sustained transmission chains are likely to be limited, although secondary local sporadic transmission may occur.

The findings have important implications for malaria elimination strategies. In elimination settings, malaria control approaches must consider population movement as an epidemiological driver. Traditional interventions focused on strengthening local surveillance system and vector control strategy may be insufficient in areas repeatedly receiving infected individuals from endemic locations. The study highlights a reverse transmission pattern of urban to rural posing significant challenges to malaria elimination in receptive areas like Hosnabad HSC. It underscores the urgent need for targeted interventions among migrant populations and enhanced surveillance systems incorporating migration data in the infection source station by systematic cross-notification. In Hosnabad HSC, strengthening migrant focused surveillance, improving communication between urban source areas and rural receiving areas, and ensuring early diagnosis and complete treatment of returning migrants may help prevent repeated parasite introduction. This study has few limitations, being a retrospective study. First, imported malaria classification was based mostly on documented travel history and investigations in selected cases, rather than on genomic studies to confirm parasite origin. Therefore, travel associated infections should not be interpreted as genetically confirmed importation events. Also, the reactive case detection involving community screenings did not involve more sensitive molecular techniques, thereby characterizing the sub-microscopic burden and their possible roles in local transmission could not be explored and the entomological studies could not be performed during the study period and for vector incrimination, which again set the limitation in deciphering the extent of local transmission. Nonetheless, the presence of travel history in almost all cases warrants a strong role of urban to rural migration for malaria.

Conclusion

Overall, study highlights the reported malaria cases in Hosnabad HSC of Murshidabad district is mainly due to *P. vivax* infection and majority of the cases are imported through migrant workers from urban to rural setting, particularly from the metropolitan city of Kolkata. Identifying the source and movement patterns of infections is critical for preventing reintroduction and sustaining malaria elimination efforts. The study highlights the importance of strong surveillance system, including detailed travel and migration histories, ensuring early diagnosis and maintaining complete treatment adherence can limit the secondary infection even in a receptive ecology. The surveillance framework applied in this study provides valuable epidemiological insights and may be adapted to other area of low persistent transmission, where human mobility and migration continue to influence malaria epidemiology. Additionally, the findings underscore the need of regular inter-district and inter-state cross notification of

malaria cases including active surveillance and vector management in source of origin for achieving the national malaria elimination goal.

Abbreviations

HSC
Health Sub-Centre
KMC
Kolkata Municipal Corporation
RCD
Reactive Case Detection
RDT
Rapid Diagnostic Tests
IQR
Interquartile Range
ABER
Annual Blood Examination Rate
API
Annual Parasitic Index
NCVBDC
National Centre for Vector Borne Disease Control
P
Plasmodium

Declarations

Ethical Approval:

The survey was conducted with the District Health Department, with the official letter of permission (Ref. No- 3 – 1/RHO/2005/NVBDCP-FIL (GEN)-(2)/0994 & Ref. No. 3 – 1/3 – 1/RHO/2005/NVBDCP-FIL (GEN)/0136). This study used standard diagnostic and treatment procedures carried out by trained health staff at Nashipur BPHC and Hosnabad HSC, following the Government of West Bengal guidelines and NCVBDC, Ministry of H&FW, GoI. No new methods were introduced. Additional information was collected from patients with prior verbal consent for analysis. As all activities were subjected to routine monitoring, hence ethical approval was not required. The authors have declared no conflict of interest. All authors have read and agreed to the published version of the manuscript.

Consent for publication:

All authors have read and agreed to the publication of the submitted version of the research work. Consent from the study sample was not applicable, as it was a part of the program monitoring activity of

the Department of Health and Family Welfare of West Bengal and the ROHFW, Kolkata, Gov. of India. Office order no. has been provided in the ethical details.

Competing interests:

The authors declare no competing interests in this research work.

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Author Contribution

Conceptualisation, S.R.J., R.B., and I.P.B.; methodology S.R.J., R.B., S.S., and I.P.B.; Software, S.R.J., A.K.K., and U.G.; validation, S.R.J., I.P.B., A.K.K., R.B.; investigation, S.R.J., R.B. SA.S., S.B. and S.C.; original draft preparation, S.R.J.; writing review and editing, S.R.J., A.K.K., I.P.B.,K.B., R.B., S.C., P.P.G., S.S, S.B., P.A., and S.S.; Visualisation, I.P.B., A.K.K., U.G. and S.R.J.; supervision, R.B., K.B., S.S., P.P.G., and S.S.; data curation, S.R.J.; project administration, S.R.J., S.S and P.P.G.

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Availability of data and materials:

All the data have been provided in the main text of the manuscript. Any further information about the study population can be provided by the corresponding authors on request,

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Figures

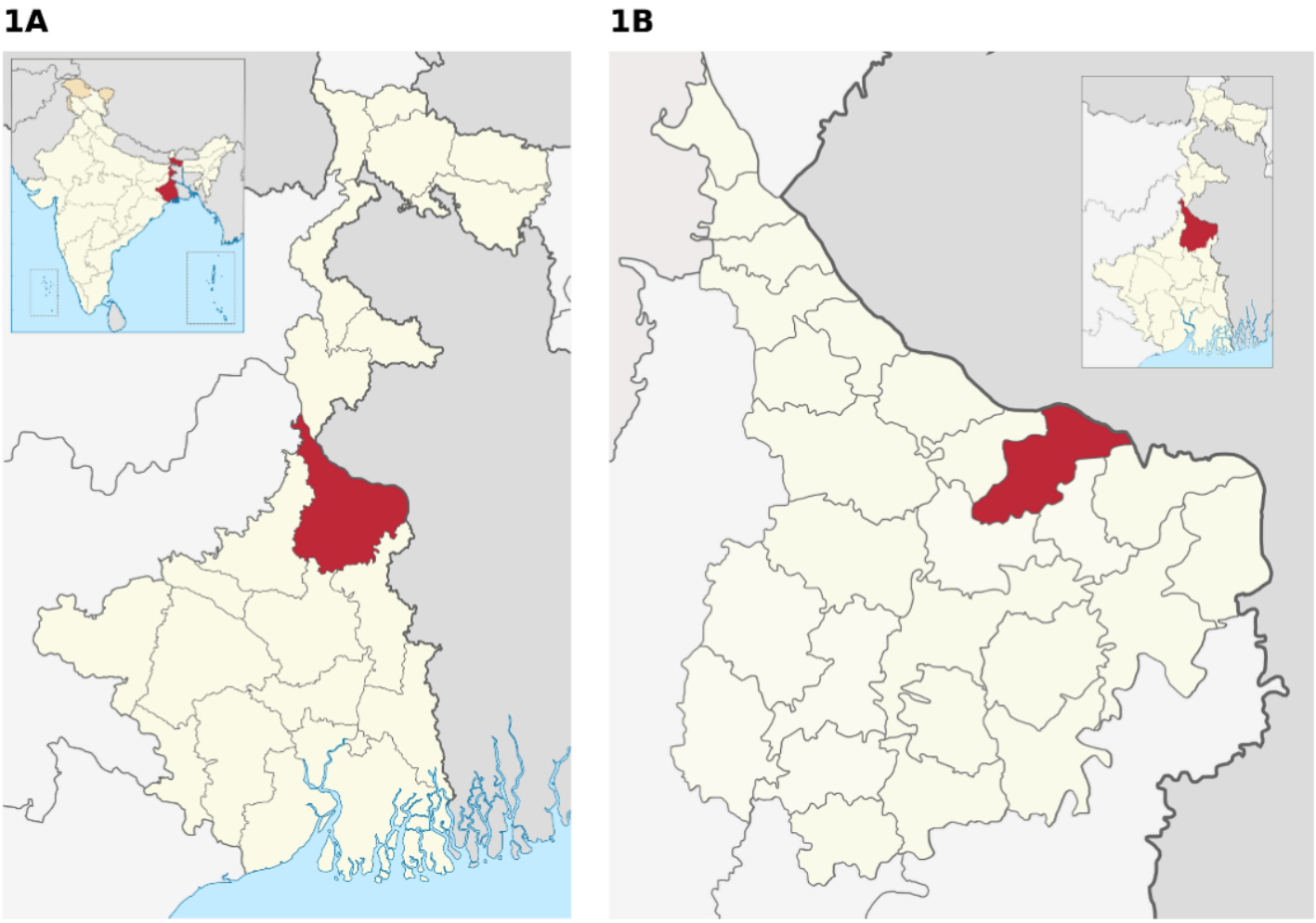


Figure 1

Murshidabad district within West Bengal (**1A**). Bhagbangola-II block within Murshidabad district (highlighted polygon) (**1B**).

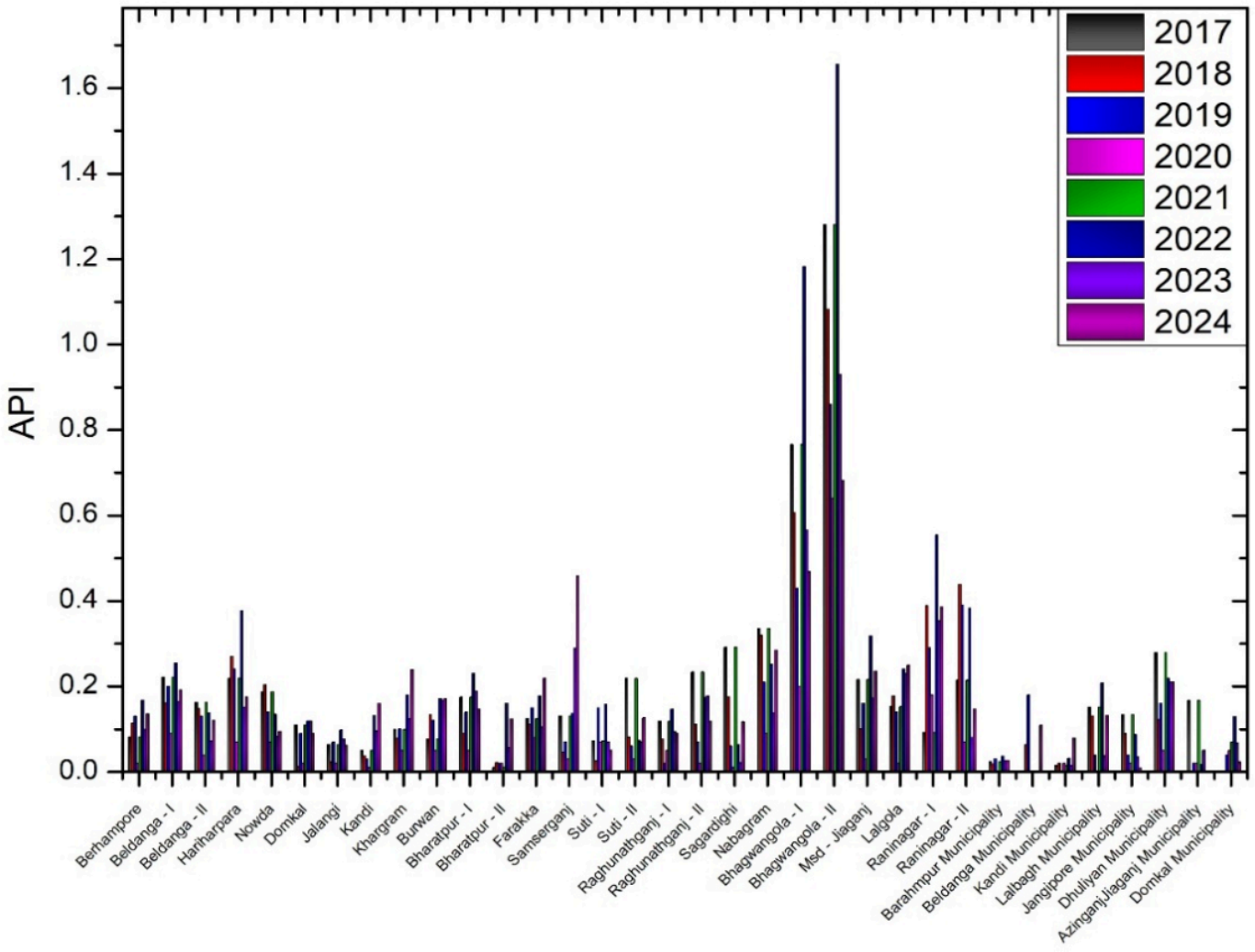


Figure 2

Block-wise API of Murshidabad District from the year 2017 to 2024.

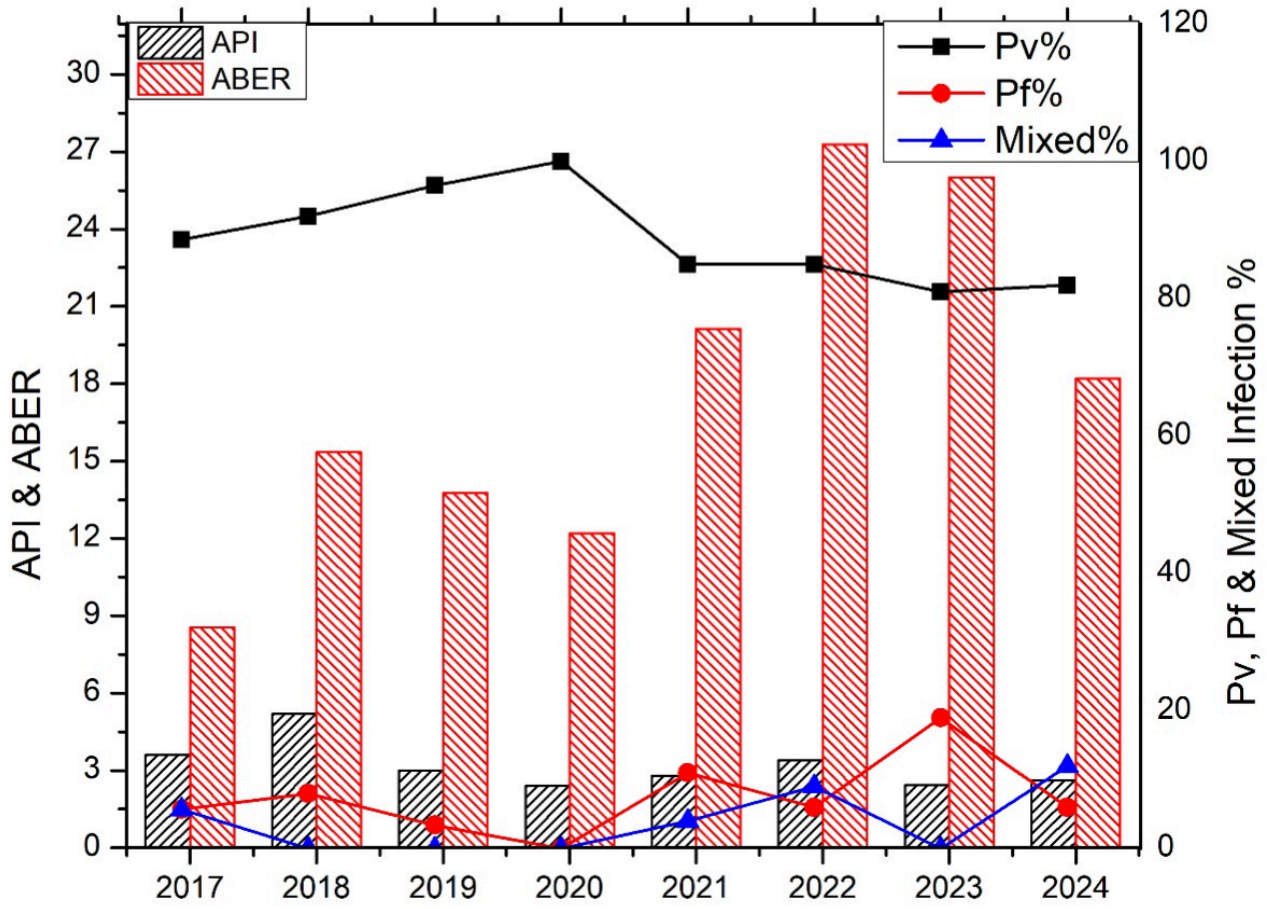


Figure 3

Malaria Surveillance Indicators of Hosnabad HSC from the year 2017 to 2024.

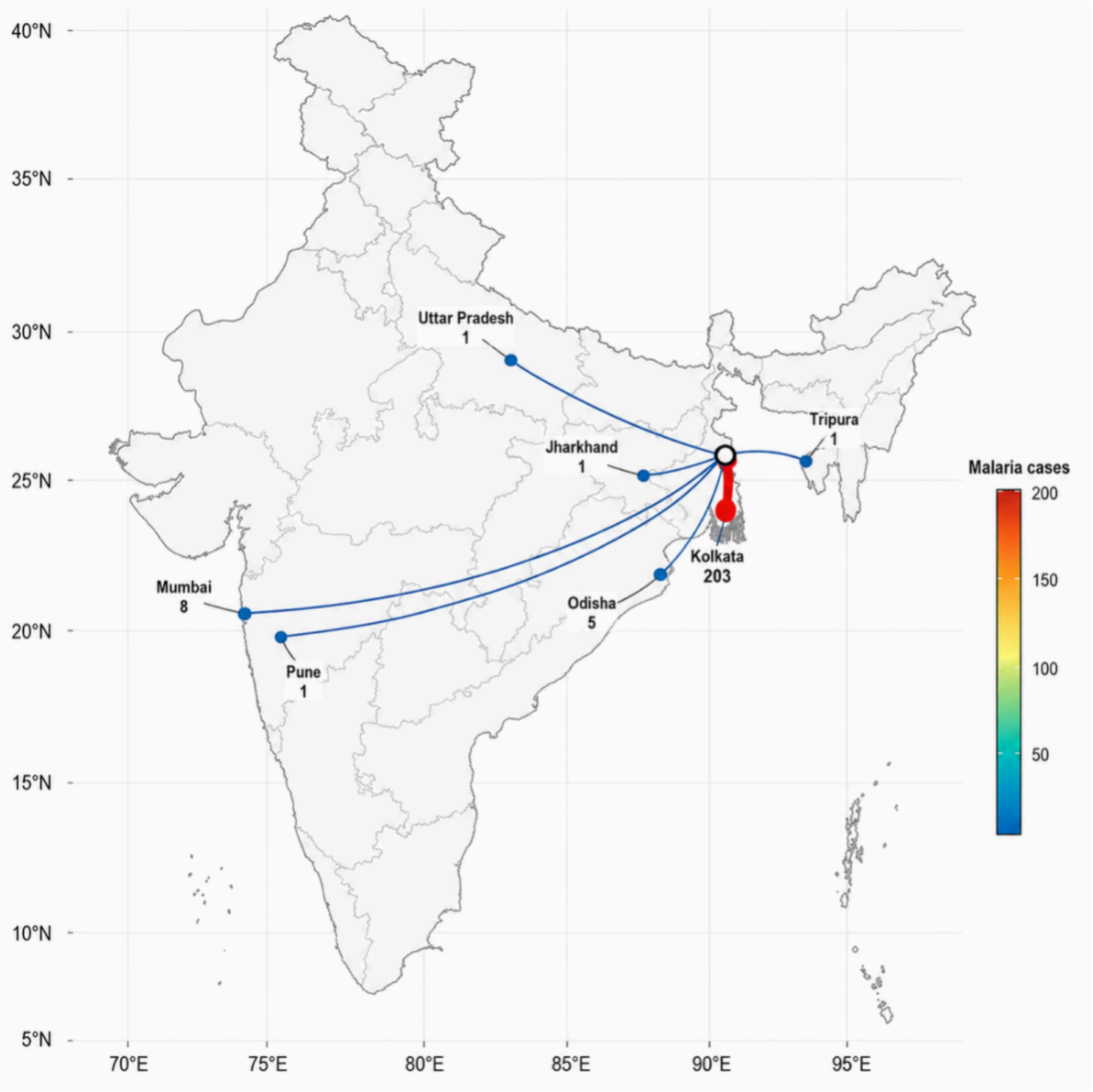


Figure 4

Cumulative external migration flows and geographic origins of migration linked malaria cases detected in Bhagbangola-II Block, Murshidabad District, West Bengal, India, during 2017–2024.

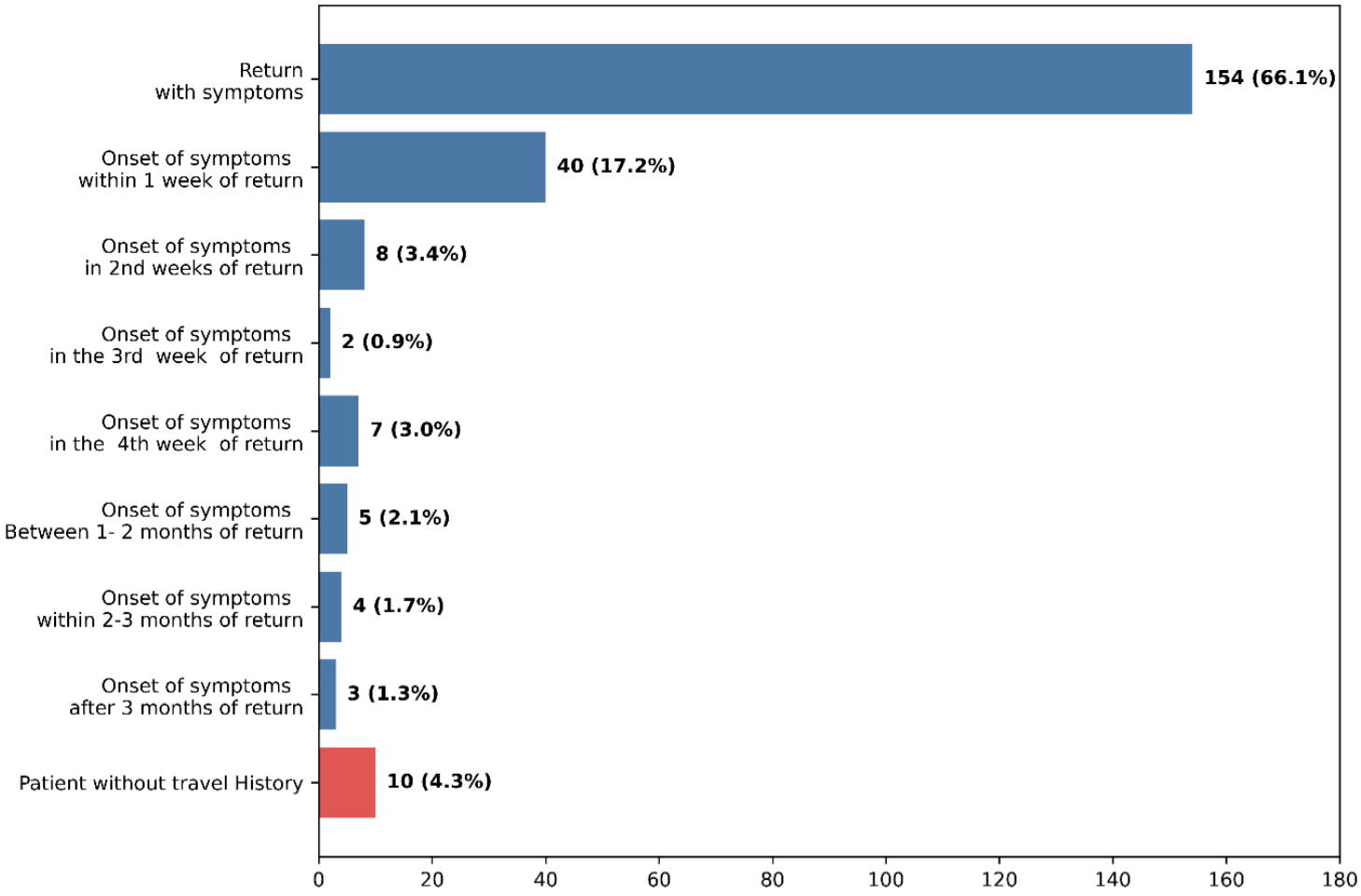


Figure 5

Malaria case distribution as per the symptom development

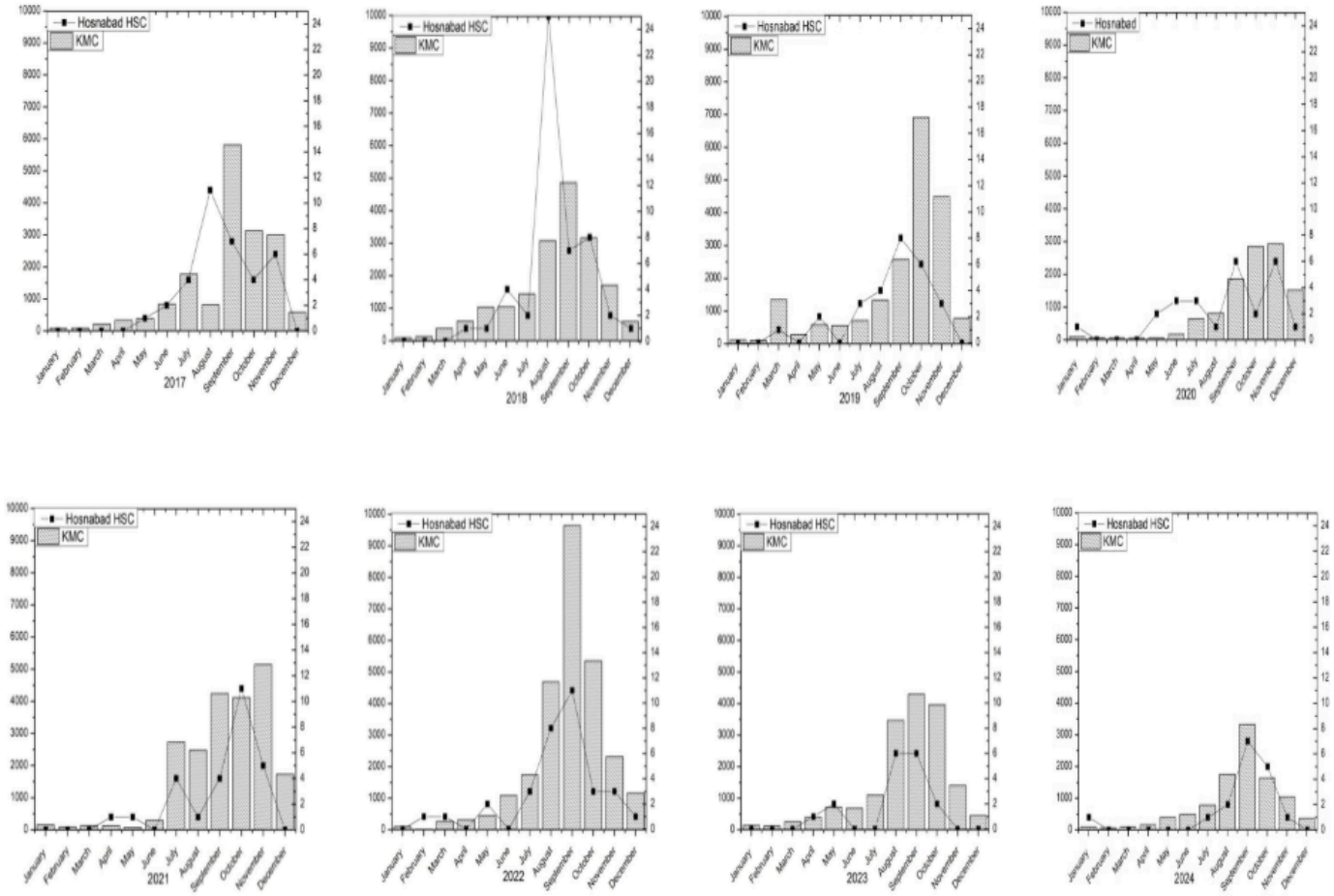


Figure 6

Monthly distribution of malaria cases in KMC and Hosnabad HSC (2017-2024). The transmission pattern represents a mostly similar trend for both the places.

Supplementary Files

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- SupplementaryFigure.docx