

Seasonal Distribution and Trend Analysis of Urban Malaria Prevalence in a Malaria Clinic, South Delhi, India, between 2012 and 2019

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Abstract. It is important to study the recent malaria incidence trends in urban areas resulting from rapid urbanization that can lead to changes in environmental conditions for malaria. This retrospective study assessed trends in malaria patients, their distribution according to parasite species, patient demographics, and weather data for the past 8 years at a malaria clinic in the National Institute of Malaria Research, New Delhi, India. We overlaid the effects of environmental factors such as rainfall, relative humidity, and temperature on malaria incidence. The malaria data were digitized for a period spanning 2012 to 2019, during which 36,892 patients with fever attended the clinic. Of these, 865 (2.3%) were diagnosed with malaria microscopically. *Plasmodium vivax* was predominant (96.2%), and very few patients were of *Plasmodium falciparum* (3.5%) or mixed infections (0.3%). The patients with malaria were within a 10-km radius of the clinic. Males (70.9%) were more commonly affected than females (29.1%). Of the total malaria patients, a majority (~78%) belonged to the > 15-year age group. A total of 593 malaria patients (68.6%) received primaquine. These patients were most commonly diagnosed in April through October. Furthermore, there was a lag of 1 month between the rainfall peak and the malaria case peak. The peak in malaria cases corresponded to a mean temperature of 25 to 30°C and a relative humidity of 60% to 80%. This analysis will be useful for policymakers in evaluating current interventions and in accelerating malaria control further in urban areas of India.

INTRODUCTION

Malaria, a vector-borne disease, is a public health problem in developing countries, predominantly affecting the African and Asian regions.¹ In South Asia, India has witnessed a decreasing trend in malaria in the past few decades.¹ However, it still contributes significantly to morbidity and mortality in parts of India (<https://nvbdcp.gov.in/>), where ~80% of reported malaria patients are from hilly, tribal, and difficult-to-access areas.^{3,4} In 2019, ~340,000 cases of malaria were reported in the country.² In India, malaria is commonly caused by either *Plasmodium falciparum* or *Plasmodium vivax*, and other species involved can be *Plasmodium malariae*, *Plasmodium knowlesi*, and *Plasmodium ovale*.⁵ In 2019, 63.1% of malaria cases were the result of *P. falciparum* and 36.9% were the result of *P. vivax*.²

It is important to study recent malaria trends in urban areas of India because the country is targeting elimination by 2030 and different timelines are set for each state based on the epidemiological situation and level of malaria transmission. Under the National Framework for Malaria Elimination, National Center for Vector Borne Disease Control (NCVBDC) guidelines, Delhi being a low malaria transmission area, falls under category 1 states/union territories, and the target was to eliminate malaria by 2022.² In the National Institute of Malaria Research, a malaria clinic has been in operation since 2010 where walk-in febrile patients are tested for malaria by microscopy using thin and thick blood smears. After setting up the clinic, home visits and fever surveillance was done in surrounding areas so that the local population become aware of the clinic. The details of the patients with positive malaria infection are sent through e-mail to the district malaria officer. Furthermore, the patients testing positive for malaria are provided treatment

per the national drug policy issued by the NCVBDC for malaria. We analyzed clinic data for 2012 to 2019. Our analysis will be useful for policymakers in accelerating further the elimination efforts to combat malaria in urban areas.

METHODS

Study area and design. The study was conducted at the malaria clinic located in the National Institute of Malaria Research, Dwarka, New Delhi, in northern India. The target population comprised malaria-suspected participants attending the clinic from 2012 to 2019. The clinic was attended primarily by patients from nearby areas. Also, patients referred from nearby hospitals attended the clinic for confirmation of malaria diagnosis.

Data collection. Malaria diagnosis was done as per WHO protocol using microscopic examination of peripheral blood smear slides. The variables included in the study were the date of the patient visit, method of diagnosis, species of parasite, age, gender, glucose-6-phosphate dehydrogenase (G6PD) assessment, and treatment received. The data were collected and entered by trained personnel, including a WHO level 1 certified malaria microscopist. Standard operating procedures for sample collection, smear preparation, and examination of slides were followed.⁶ At the study site, a blood smear was considered positive if one or more malaria parasites were seen, and negative if none were found in 200 fields. After blood examination, any individuals found positive for malaria were provided treatment according to national guidelines. Furthermore, on the day of positive diagnosis, G6PD testing was done using the dichlorophenol indophenol dye decolorization (semiquantitative) method.⁷ G6PD testing was not done in children younger than 5 years, nor was it done if patients were unwilling to undergo G6PD testing. Patients with a normal G6PD level were provided primaquine in a dose of 0.25 mg/kg in a follow-up visit on the third day. Primaquine was given as a single dose (0.75 mg/kg body weight) for *P. falciparum*, and a 14-day course (0.25 mg/kg/day) was

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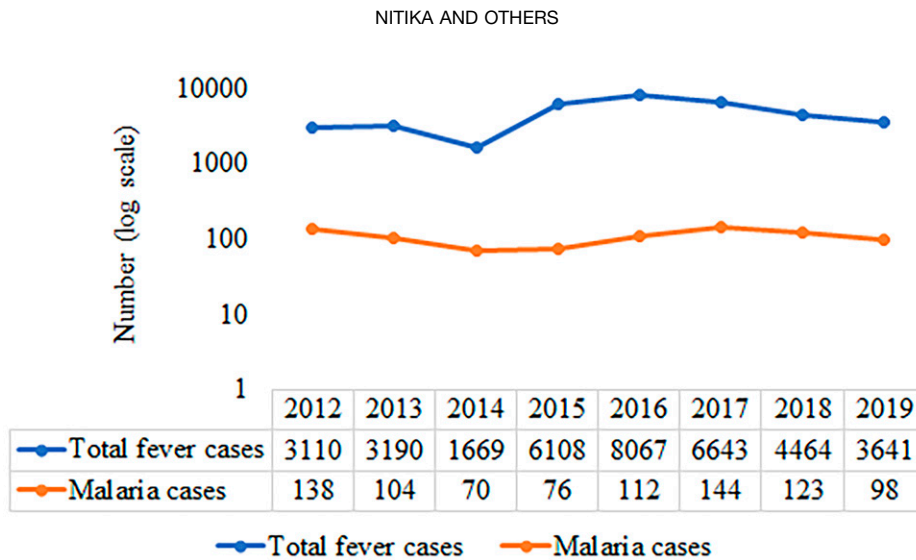


FIGURE 1. Annual trend in total fever and malaria patients from 2012 to 2019. This figure appears in color at www.ajtmh.org.

prescribed for *P. vivax* infection. Patients were counseled regarding the importance of completing the course of primaquine. The medication was not changed for the patients who were taking medications from outside or those attending the clinic for malaria confirmation only.

Rainfall data were acquired from the Ministry of Earth Sciences, India Meteorological Department released under the National Data Sharing and Accessibility Policy. The humidity and temperature data were obtained from the National Aeronautics and Space Administration Langley Research Center Prediction of Worldwide Energy Resource Project funded through the NASA Earth Science/Applied Science Program.

Data analysis. After entering the data in Microsoft Office Excel worksheets (version 16.65 Microsoft Corp., Redmond, WA), data analysis was done using the same software. Descriptive statistics for showing the trends according to year, gender, species, and season were used. Line graphs were used to depict the trend over the years. Seasons were categorized as summer (March, April, and May), monsoon

(June, July, August, and September), and winter (October, November, December, January, and February).

RESULTS

From 2012 to 2019, 36,892 patients with fever attended the clinic, of whom 865 (2.3%) were diagnosed microscopically as malaria positive, and all patients were reported from localities falling within the 10-km radius of the Institute and are thus Delhi patients. During the past decade, there was significant variation in the annual number of malaria patients reported, with 70 being the minimum in 2014 and 144 being the maximum reported in 2017 (Figure 1). *Plasmodium vivax* was predominant ($n = 832$), with very few cases ($n = 30$) reported of *P. falciparum* (Figure 2) and three cases of mixed infections, one each in 2012, 2015, and 2017. Of 865 patients with malaria, G6PD assessment was done in 808 patients (93.4%) using dichlorophenol indophenol, a semiquantitative method, and six male patients were found to be G6PD deficient (0.7%).

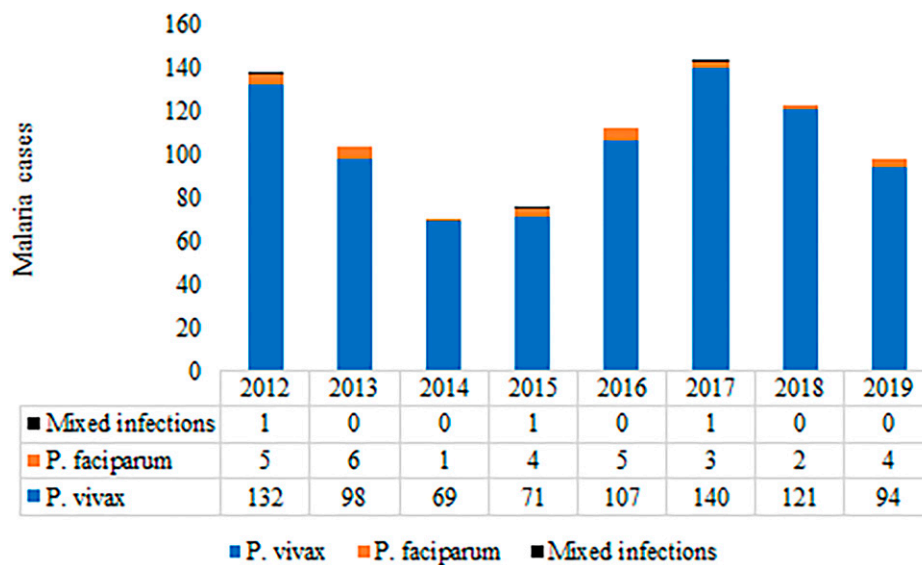


FIGURE 2. Species trends from 2012 to 2019. *P.* = *Plasmodium*. This figure appears in color at www.ajtmh.org.

TABLE 1
Distribution of malaria positivity by age and gender

Age group, years	Male		Female		Total, n
	n	%	n	%	
< 5	32	57.1	26	42.9	58
5–15	75	57.3	56	42.7	131
> 15	506	74.8	170	25.2	676

Per the malaria clinic record review, males (70.9%) were found to be infected with malaria more commonly than females (29.1%) (Table 1). Of the total malaria patients, a majority (~78%) belonged to the > 15-year age group. The prevalence was 6.7%, and 15.1% among those younger than 5 years and 5 to 15 years respectively.

Overall, primaquine was given to 593 patients with malaria (68.6%): a 14-day course to 574 patients (68.9%) with *P. vivax* infection and to two patients (67%) with mixed infection; a single dose was given to 17 patients (56.7%) with *P. falciparum* infection. Primaquine was not prescribed to 38 patients (4.4%) because 14 were pregnant, 17 were anemic, 6 were G6PD deficient, and 1 woman was lactating. A total of 234 patients (27.0%) did not return for follow-up visits for primaquine despite contacting them by phone. For patients with *P. vivax* infection ($n = 832$), chloroquine was prescribed to the majority of them ($n = 809$), two were given artemisinin-based combination therapy, nine were referred to the hospital, and information on treatment was not available for 13 patients. For patients with *P. falciparum* infection ($n = 30$), artemisinin-based combination therapy was prescribed to the majority of them (24 patients were given artesunate–sulfadoxine–pyrimethamine, and three patients were provided with artemether–lumefantrine), and information on treatment was not available for 3 patients.

During the study period, there was a significant seasonal trend in the occurrence of malaria, and the maximum number of cases was reported during the monsoon season

(Figures 3 and 4). However, malaria cases were reported throughout the year and in other seasons as well. Figure 4 depicts the relation between rainfall and malaria cases. The peak in malaria cases followed the peak in rainfall, with a lag of almost 1 month. The variation in the occurrence of malaria corresponded to changes in relative humidity, and the peak in malaria cases corresponded to a mean temperature range of 25 to 30°C (Figure 4).

DISCUSSION

Over an 8-year study period, we were able to assess the epidemiological trends in the occurrence of malaria, and their distribution according to parasite species, patient demographics, and weather data. Overall, 36,892 blood slides were examined, and 865 malaria cases were reported, with a slide positivity rate of 2.34%. Despite the fluctuating trend in malaria cases, ~70 to 144 patients with patients were reported annually in this study. In 2014, the number of patients with malaria was the least, and this finding is reported in another study from Delhi as well.⁸ From 2015 to 2019, there was a significant number of patients with dengue in Delhi, reflected in the increased number of patients reporting fever.² *Plasmodium vivax* accounted for the majority of the patients (> 95%). In India, *P. vivax* is mainly responsible for urban malaria, and the percentage of cases attributed to *P. vivax* has increased in urban areas.⁹ The increase in malaria cases in urban areas is mainly attributed to uncontrolled urbanization, new construction sites, and a migratory population.^{10,11} Thus, it is important to target interventions for controlling the rise in *P. vivax* cases as this is also associated with severe malaria.^{12–14} Easier availability of rapid diagnostic test kits through pharmacies could aid in the early diagnosis of malaria and the timely initiation of treatment, thus preventing complications.¹⁵ However, it is prudent to confirm such patients with conventional microscopy to avoid false-positive results. Furthermore, different surveillance mechanisms per the transmission dynamics of malaria that cover high-risk populations such as migrants could accelerate

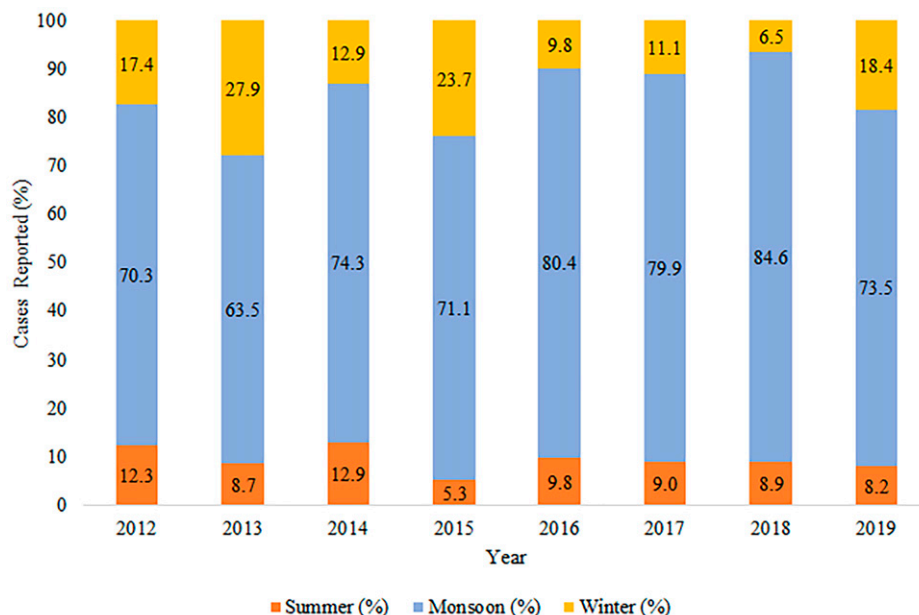


FIGURE 3. Seasonal distribution of malaria from 2012 to 2019. This figure appears in color at www.ajtmh.org.

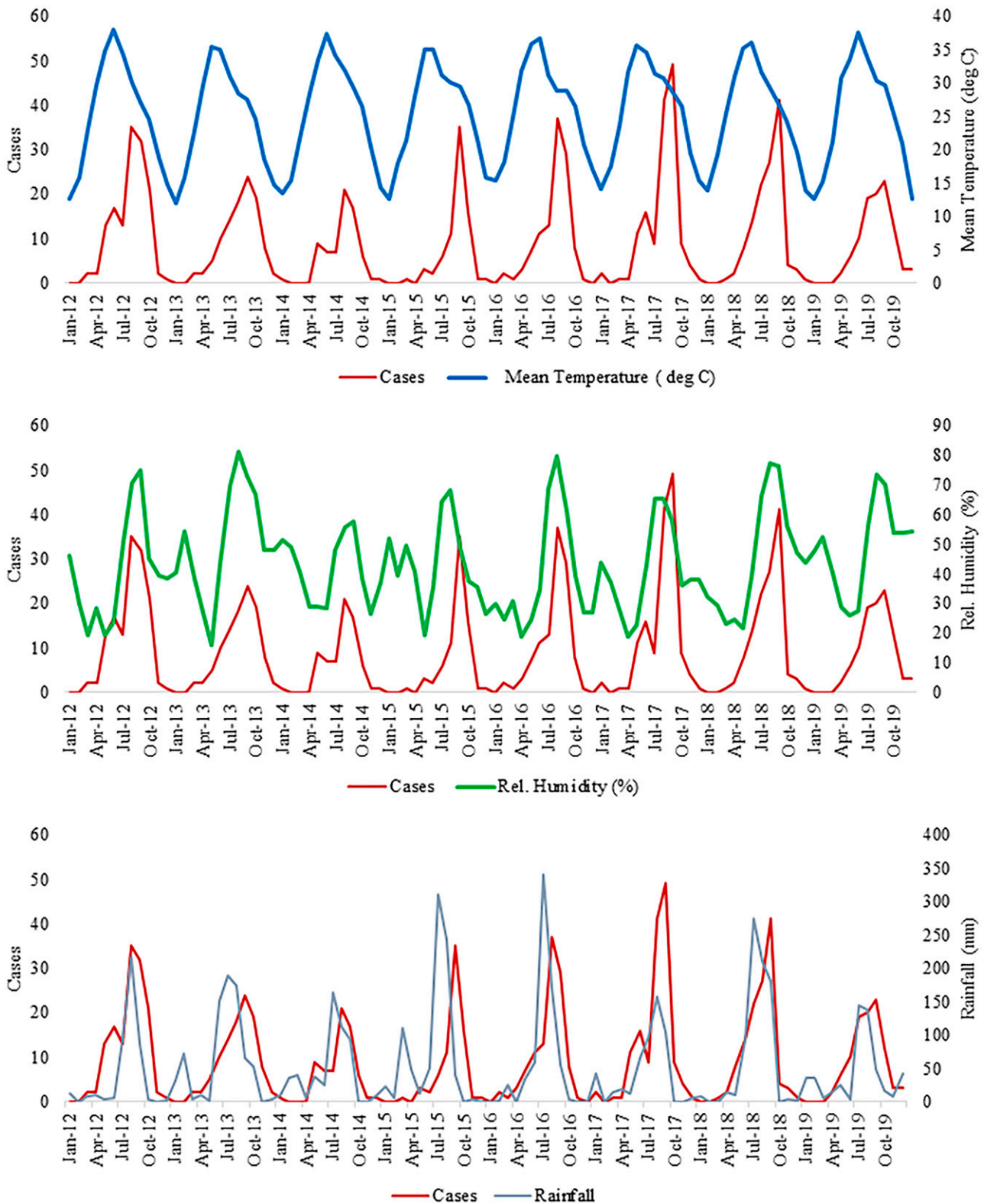


FIGURE 4. Annual trend in mean temperature, relative humidity, and rainfall with number of malaria patients. Rel. = relative. This figure appears in color at www.ajtmh.org.

malaria elimination.¹⁶ Involvement of private health-care providers and use of real-time digital platforms, fever tracking apps, and digital dashboards may assist in the early recognition of an increase in patients.¹⁶⁻¹⁸

In our study, males were found to be affected by malaria more commonly than females, corroborating findings from previous studies. The reason could be relatively more involvement of males in outdoor activities, thus making them

exposed to frequent mosquito bites and thus infection.^{19–25} However, the real pattern in the community could be different from the pattern observed in the clinic, because the clinic population is not necessarily representative of the Delhi population. In terms of age distribution, patients who were 15 to 44 years old were found to be commonly affected by malaria. Similar findings were reported in earlier studies as well.^{20,22–24,26,27}

Overall, primaquine was given to 593 patients with malaria (68.6%) after G6PD testing. The reasons for low primaquine use were pregnancy, G6PD deficiency, patients unwilling to undergo G6PD testing, and patients not returning for follow-up visits for primaquine. The low use of primaquine by patients with *P. vivax* malaria increases the chances of relapse resulting from the persistence of hypnozoites.²⁸ Thus, tafenoquine administered as a single dose could be considered an option in similar settings for clearing the parasite reservoir.²⁹ In *P. falciparum* malaria, primaquine act as gametocytocidal and thus blocks the transmission of the parasite to mosquitoes. Thus, from a malaria elimination standpoint, it is vital to administer primaquine for its effects on hypnozoites in *P. vivax*, and gametocytes in *P. falciparum*. For this, minimizing the number of visits to the health-care facility for G6PD testing and initiating primaquine may increase its use.

There was a significant seasonal trend in the occurrence of malaria across the years. The peak in malaria cases was observed primarily in July through October, which corresponds to and follows the peak in rainfall in the study area. This is in agreement with the seasonal pattern observed in studies for *P. vivax* in Indian settings, resulting from the favorable environment for mosquito breeding, as reported in earlier studies.^{10,30} Notably, there were reports of malaria cases (~30% of total malaria cases) in the post-monsoon and pre-monsoon seasons. However, the numbers were low when compared with cases occurring during the monsoon season, pointing to factors other than rainfall. This might be attributed to the commonly occurring phenomenon of relapses for *P. vivax* malaria.

Climatic factors, including temperature and humidity, played a significant role in explaining the occurrence of malaria cases, and similar findings have been reported.¹⁰ The climate affects mosquito longevity, biting rate, and host-locating ability, and thus is important in disease transmission.³¹ Humidity of ~55% to 80% is most favorable for malaria transmission, and in the our study it was 60% to 80% during peak transmission.^{30,32} A temperature of 25 to 30°C is most favorable for the mosquito life cycle, and it corresponds to the peak in the number of malaria cases.^{33–35} The 1-month lag in rainfall peak and peak in malaria cases was corroborated by other studies,^{30,33,36} and the peak is a result of an increase in the breeding sites for mosquitoes and an increase in mosquito survival because of the humidity in the environment after rainfall.^{37,38}

Our study had certain limitations. Because it was based on malaria clinic data, the magnitude of the problem in the community can only be presumed and may not reflect the real pattern in the community. Another limitation is the unavailability of information regarding employment of the patients attending the clinic. Thus, we could not comment on disease transmission based on job profiles or working patterns of the patients.

In conclusion, malaria remains a public health problem in India, especially so in urban areas, and *P. vivax* is the dominant parasite reported in the study area. Males were affected by malaria more commonly than females. The use of primaquine was low among patients with malaria. The peak in malaria cases corresponded to a humidity of 60% to 80%, and followed the peak in rainfall, with a lag of almost 1 month. Thus, a targeted and collaborative approach is critical in achieving the national goal of malaria elimination by 2030.

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