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Interlinkages Between Nutritional Deficiencies & Malaria Susceptibility In Pregnant Women , Under - 5 Children & Others In Hooghly District Of West Bengal, India.

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Abstract: Malaria and nutritional deficiencies continue to be a major overlapping public health concerns in rural India, particularly among pregnant women and children under 5 years of age. These two conditions share a bidirectional and synergistic relationship that exacerbates morbidity and mortality in vulnerable populations. Nutritional deficiencies- especially of iron, folate, vitamin A and zinc-compromise both innate and adaptive immune functions, thereby heightening susceptibility to *Plasmodium* infection and reducing the efficacy of anti-malarial immunity. Conversely, repeated malaria infections contribute to malnutrition through hemolytic anemia, reduced nutrient absorption, appetite loss and increased metabolic demands. The present study explores the complex interlinkages between nutritional status and malaria susceptibility in rural endemic district of Hooghly, where poverty, food insecurity and limited healthcare access amplify disease risk. Employing a community based mixed-method approach, the research integrates clinical surveillance, anthropometric measurements, biochemical assays and dietary intake analysis among pregnant women and children below five years. Preliminary findings reveal a significant correlation between iron-deficiency anemia and higher malaria parasitemia rates with undernourished children demonstrating prolonged parasite clearance and frequent relapses. Pregnant women with low micronutrient reserves exhibited increased risk of placental malaria, adverse birth outcomes, and low birth weight infants. Repeated episodes of malaria and intestinal infections disrupt gut microbiota, further worsening malnutrition by impairing digestion and nutrient absorption. These findings underscore the necessity for holistic public health interventions that address both malaria control and nutritional improvement simultaneously. Integrating nutritional supplementations, anemia control, vector management and community-based health education could substantially reduce malaria-related morbidity and enhance maternal and child survival in rural India. This review highlights the key issues and possible interventions aimed at malaria control and eradication in India's rural areas.

Index Terms- Malaria, Nutritional Deficiency, Iron-deficiency Anemia, Placental Malaria, Pregnant women, Under-five children.

I. Introduction

In 2019,World Health Organization (WHO) reported that 87 malaria-endemic countries together accounted for about 229 million malaria cases globally. WHO data indicates that around 94% of malaria cases worldwide were reported from Africa, with the South-East Asia region recording approximately 4% in 2025. In this region, India reduced malaria cases from approximately 20 million in 2000 to 4.8 million in 2025. Globally 5 countries accounting more than half of global malaria cases; Nigeria;27%, Democratic Republic of Congo;13%, Uganda;7%, Mozambique;5% and Niger;2%. India made significant strides, reducing malaria cases by 69% (from 6.4 million in 2017 to 2 million in 2023) and deaths by 68% according to WHO. This progress led to India exiting the High Burden to High Impact (HBHI) group in 2024.Malaria remains a public health issue in many rural parts of India. India has substantial burden of both nutrient deficiencies and malaria, especially among vulnerable populations like pregnant women, infants and young children in rural and tribal areas. These two problems interacts in complex ways: nutritional states can influence risk of malaria infections and severity and malaria can worsen nutritional status (through anemia , appetite loss , increased metabolic demands). Micronutrients (iron, vitamin A, zinc) are essential for immune competence; deficiencies can impair innate and adaptive responses and may increase susceptibility to infectious diseases including malaria. Conversely, iron supplementation in malaria-endemic areas must be carefully managed. Iron deficiency reduces malaria risk.

II. OBJECTIVES: To determine associations between micronutrient status (iron, vitamin A, zinc) and laboratory – confirmed malaria infection in pregnant women and 6-59 months children and others in rural India. To describe prevalence of micronutrient deficiencies and malaria parasitemia levels. Identification of regions with high malaria prevalence in Hooghly district.

III. High Malaria prevalence in different areas of West Bengal: West Bengal continues to face significant malaria transmission, particularly in its forested, tribal, and rural regions. Districts such as **Jalpaiguri, Alipurduar, Bankura, Purulia, Paschim Medinipur, and Birbhum** have historically reported higher malaria prevalence compared to the southern and urban districts. The climatic conditions of these regions—characterized by high humidity, dense vegetation, and seasonal rainfall—create favourable breeding environments for *Anopheles* mosquitoes, the primary malaria vectors. In addition, socio-economic factors such as poor housing, inadequate sanitation, and limited access to healthcare contribute to sustained transmission. The **northern and western parts of the state**, lying within the sub-Himalayan and plateau zones, show higher *Plasmodium falciparum* infection rates, whereas *P. vivax* is more common in the plains and peri-urban regions. Despite intensive control measures under the National Framework for Malaria Elimination (NFME), sporadic outbreaks still occur due to vector adaptation and migration of infected individuals. Continuous surveillance, early diagnosis, and targeted intervention in high-risk blocks remain crucial for achieving malaria elimination in West Bengal. For instance, a state-wide epidemiological overview reveals that the incidence of *Plasmodium vivax* in West Bengal surged to approximately **338 cases per million population in 2022**, after remaining below 250 per million in 2018-21. PMC+1 At the district / urban-area level, the Kolkata region alone recorded **about 10,177 malaria cases in 2024**, placing it among the 7 highest-burden districts in India that year. MillenniumPost A household-level study conducted during 2020–22 in both urban (Chetla, Kolkata) and rural (Singur, West Bengal) settings found malaria-infection prevalence's of 6.1% (urban) and 18.8% (rural) respectively, with key risk-factors including no mosquito-protection, presence of mosquito breeding places, and poor housing conditions. Lippincott Journals+1 Furthermore, large portions of the western and northern districts – such as Purulia – historically identified as high-risk areas, saw block-wise reductions in risk category from 2020 to 2024 after mass distribution of long-lasting insecticidal nets (LLINs). Directory of Open Access Journals+1 Nonetheless, despite these interventions, the sustained burden in both urban and rural zones underscores persistent vulnerabilities. Contributing factors include climatic suitability for vector breeding, migration and occupation-related exposures, and structural challenges in housing and sanitation that remain more acute in tribal and remote blocks. In light of the data, intensified surveillance, targeted block-level interventions, and continued improvement of housing and vector-control infrastructure remain essential to achieve elimination goals in West Bengal.

IV. Epidemiological linkages between malaria and nutrient deficiency : Malaria disease is caused by *Plasmodium falciparum, Plasmodium vivax, Plasmodium malariae , Plasmodium ovale*. India is a major contributor of malaria , *P.falciparum* and *P. Vivax* are contributor more than 95% cases. The relation between malaria and malnutrition represents a complex and bidirectional interaction that poses a major public health challenge in low and middle income families, particularly in rural and resource – poor settings. Malaria increases metabolic demands and destruction red blood cells leading to anemia. It affects pregnant women and young children, who are highly vulnerable to both conditions. In these groups, coexisting malaria and malnutrition contribute to adverse pregnancy outcomes, low birth weight, stunted growth and increased morbidity and mortality. Environmental and socio-economic factors such as poverty, food insecurity, inadequate healthcare infrastructure and poor health-seeking behavior. A comprehensive approach combining nutrient supplementation, vector control, prompt malaria treatment and community based health education is crucial to break this cycle and improve the overall health outcomes of affected populations.

2.1 Socio-Economic and environmental climatic factors influencing rural malaria:

Malaria continues to be a significant public health challenge in rural India , where socio-economic deprivation, environmental conditions, and limited healthcare access contribute to persistent transmission. The rural population, particularly those residing in forested, tribal and agrarian regions, bears a disproportionate share of India's malaria burden. In these areas, inadequate housing, poor drainage systems, stagnant water bodies and a lack of awareness about preventive measures create ideal breeding conditions for Anopheles mosquitoes. Moreover, poor health infrastructure, delayed diagnosis, and limited availability of anti-malarial drugs further intensify disease morbidity and mortality. Vulnerable groups such as pregnant women, agricultural laborers and children under five face the greatest risks due to higher exposure and weaker immunity. Despite national efforts like the National Framework for Malaria Elimination (NFME 2016-2030) and National Vector Borne Disease Control Programme (NVBDCP), rural areas still account for a majority of reported malaria cases in the country. The persistent burden in these settings highlights the need for integrated community based interventions focusing on vector control, health education, nutritional improvement and early diagnosis. Strengthening rural healthcare infrastructure and promoting behavioral change are essential to reduce malaria transmission and achieve India's goal for malaria elimination.

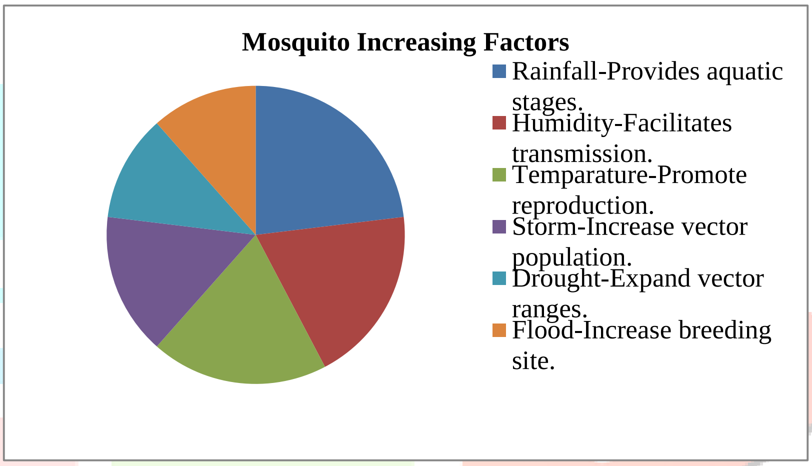

Fig-1. Various environmental climatic factors which influence malaria disease.

2.2 Building resilient health systems through local engagement and coordination:

Building a resilient health system requires not only strong infrastructure and funding but also active engagement of local communities and effective coordination among multiple governance levels. Local engagement strengthens the responsiveness of health systems by ensuring that interventions are context-specific, culturally appropriate, and socially inclusive. In rural areas, where health resources are often limited, community participation helps bridge the gap between formal healthcare services and local needs. Community health workers, Accredited Social Health Activists (ASHAS), Anganwadi workers, and local volunteers play a crucial role in early disease detection, nutrition surveillance and dissemination of preventive health messages.

Coordination among local governance bodies, such as Panchayati Raj Institutions, primary health centers and district health authorities, ensures that health initiatives are well integrated with development programs in water, sanitation, education and nutrition. This cross-sectoral collaboration enhances system efficiency and decentralized decision making and participatory planning allow for rapid responses during disease outbreaks, natural disasters or other emergencies – key indicators of a resilient system. When local communities are empowered to participate in monitoring and feedback mechanisms, they not only strengthen accountability but also foster trust in public health institutions. Over time, such synergy between community engagement and coordinated governance leads to adaptive, equitable and sustainable health systems capable of addressing both routine healthcare needs and emerging public health threats such as malaria, malnutrition and other infectious diseases.

2.3 Impact of Malaria on Maternal Health and Pregnancy outcomes :

Malaria in pregnancy remains one of the most pressing public health concerns in endemic regions, particularly across sub-Saharan Africa and South and South-east Asia, including rural India. Pregnancy induces a partial suppression of the immune system, reducing the body's capacity to mount an effective response against *Plasmodium* parasites.

This immunological alteration makes them more susceptible to *Plasmodium falciparum* and *P. vivax* infections, even in areas of stable malaria transmission. The consequences are often severe: maternal anemia, hypoglycemia, acute pulmonary edema, and cerebral malaria are among the most dangerous complications that can lead to maternal morbidity and mortality. From a reproductive health prospective, malaria infection is closely associated with placental sequestration of parasites, which impairs nutrient and oxygen transfer to the fetus . This can result in intrauterine growth restriction, low birth weight, pre term labor and stillbirth all of which are major contributors to neonatal mortality . Additionally repeated or chronic infections during pregnancy can disrupt hemoglobin synthesis. Socio-economic factors such as poverty, limited access to antenatal care and inadequate health infrastructure in rural settings further exacerbate these risks. To mitigate this burden the World Health Organization (WHO) recommends a combination of intermittent preventive treatment in pregnancy (IPTp) using sulfadoxine-pyrimethamine, use of insectiside–treated bed nets(ITNS) and strengthened antenatal surveillance for early detection and treatment.

Gender	Analysis of malaria cases in Hooghly district in different years					Total(5 years)
	2020	2021	2022	2023	2024	
Male	1852	1345	645	325	160	4327
Female	1345	920	210	156	100	2731
Pregnant Women	462	345	152	55	65	1079
Children(Under5)	860	576	233	125	85	1879
Total	4519	3186	1240	661	410	10,016

Table 1- Analysis of malaria cases in Hooghly district based on demographic factors from 2020 to 2024.

3. Study Design & Setting:

3.1 Study sites: 4 Sub-divisions and 18 blocks are present in our Hooghly district. 6 rural clusters in the district of Hooghly with known seasonal malaria transmission. Pandua, Tarakeswar, Singur, Mogra, Bolagarh and Dhaniakhali are more malaria prone areas.

3.2 Study population: (a) Pregnant women (any trimester) residing in village and consenting; (b) children aged 6-59 months with parental consent.

3.3 Data collection: This epidemiological study examined malaria cases in all 18 blocks of Hooghly district between January 1, 2020 to December 31,2024.Data were collected from primary health centers, local pathologies, Arambagh P.C.Sen Medical College and Hospital, Sub division hospitals, different sub centers etc.

3.4 Quality control: Use standardized assay kits, run controls and duplicates (5-10%). Calibrate instruments and maintain chain-of-custody and logbooks. Records hemolysis and sample quality.

4. Data analysis plan: Prevalence of deficiencies (adjusted), malaria positivity (microscopy, RDT), anemia prevalence. Compare prevalence of malaria by deficiency status . Test interactions between iron status and age group (pregnant vs child) or between micronutrients. For pregnant women include gestational age in models. Consider mixed model with random effect for village. Season-wise change patterns of the malaria cases over different months of the 5 years study period were reported. According to the collecting reports from rural of Hooghly district areas, it can be observed that post-monsoon seasons show the most prevalence of malaria in 2020 to 2024.10 cases have been found in both monsoon and post-monsoon seasons which indicates the increasing trend of malaria in these localities.

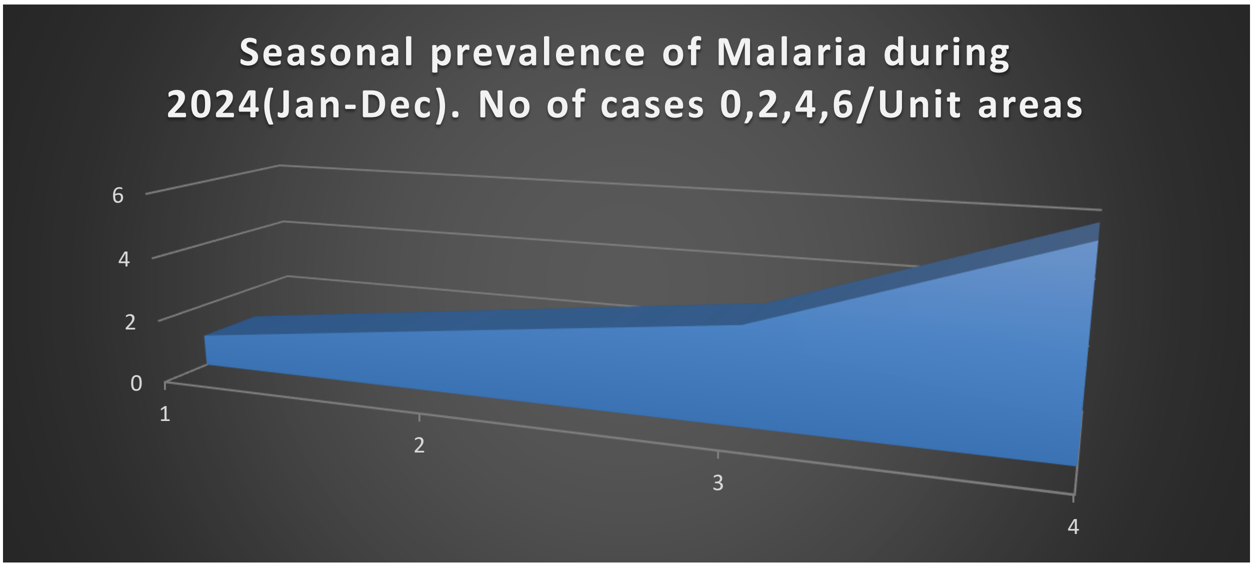

Fig: 2 Seasons: winter-summer-monsoon-Post Monsoon /Quarterly divided the months as per / Indian Meteorological Department Series. (In a year).

4.1 Expected results & interpretation:

Prevalence estimates of iron deficiency, vitamin A deficiency, zinc deficiency, anemia and malaria. Iron deficiency may be associated with lower malaria parasitemia in some studies (hypothesized due to limited iron available to parasite) or conversely deficiency may increase susceptibility via impaired immunity. Vitamin A and zinc deficiency are more likely to be associated with increased infection risk due to immune compromise.

Name of Blocks	Block wise Malaria cases under Hooghly District in different years				
	2020	2021	2022	2023	2024
Arambagh	99	50	29	9	6
Balagarh	23	17	4	0	0
Chanditala-1	18	25	7	2	1
Chanditala-2	34	24	30	22	19
Chinsurah-Mogra	456	312	210	120	54
Dhaniakhali	95	35	16	12	4
Goghat-1	105	40	12	0	2
Goghat-2	234	144	32	22	23
Haripal	41	18	10	5	1
Jangipara	45	17	2	1	0
Khanakul-1	62	15	0	8	3
Khanakul-2	220	112	81	60	30
Pandua	1576	986	432	234	120
Polba-Dadpur	9	2	1	0	1
Pursurah	55	26	8	2	0
Serampore-	371	195	62	45	25

Uttarpara					
Singur	540	234	154	34	56
Tarakeswar	534	345	150	85	65
Total Death	2	0	0	1	0

Figure3: Block-wise malaria cases analysis in Hooghly district over the year of 2020-2024.Color spectrum from red to green indicates progressively decrease in number of malaria cases.

4.2 Heat map analysis of malaria cases(2020-2024)- A heat map illustrating blook- wise malaria cases in Hooghly district from 2020-2024 is shown in the fig-3, using a color gradient from green to indicate areas with lower case counts, yellow (medium number of malaria cases) to red (high number of malaria cases). Death cases indicate black color. In 2020, more than 500 cases were reported for 3 blocks (highlighted red color). More than 200 cases were reported for 4 blocks (deep yellow color), >50 cases reported for 4 blocks (blue color) and < 50 reported for 6 bolcks (light green color).

4.3 Discussion- Malaria indicators serve as epidemiological tools designed to collect, assess, and apply data on malaria prevalence and distribution, helping to identify and prioritize risk factors for the appropriate selection of intervention strategies that enhance surveillance and control efforts. These tools assist in identifying priority areas and designing effective intervention strategies for efficient surveillance and control measures. In the Hooghly district, the 18 administrative blocks showed notable disparities in malaria transmission intensity and infection risk. The Annual Parasite Incidence (API) for 2020 was used to assess malaria prevalence and epidemiological impact across the district, enabling stratification of malaria hotspots based on risk levels. The findings of this study contribute to refining and evaluating public health policies and action plans targeted at malaria prevention and control. The results indicated that API peaked in 2020 and showed a consistent decline thereafter. Malaria affected individuals across all age groups in the study region. Notably, the highest proportion of cases occurred among individuals aged 5 years and above (n = 4327, representing 71.63% of total cases). The disease was also found to be more prevalent among males (62.09%) than females, likely due to behavioral patterns. Previous studies have suggested that individuals who remain outdoors or at worksites during the early evening are at a greater risk of infection. Block-wise analysis of malaria data from 2020 to 2024 in Hooghly revealed that the disease burden was significantly higher among tribal populations and slum areas besides railway station compared to other groups. The presence of numerous streams and tributaries surrounding tribal settlements in Hooghly supports mosquito breeding year-round, leading to a marked increase in malaria cases during the monsoon and post monsoon season. Addressing malaria in these tribal areas requires an integrated, multi- sectoral approach combined with efforts to improve the socio-economic conditions of these communities. The majority of malaria cases were concentrated in remote forested and . Based on the 2020 data, Long-Lasting Insecticidal Nets (LLINs) were distributed among populations at risk in 10 highly endemic blocks during 2021 and 2022, assuming population stability across these years. The experiments also revealed a noticeable decline in malaria incidence following the LLIN distribution campaign. Insights derived from these maps and datasets were provided to health administrators and local staff to enhance decision-making, optimize malaria control activities, and strengthen surveillance systems within the constraints of limited financial and human resources.

5. Indigenous knowledge and it's role in Malaria Prevention:

Indigenous knowledge plays a vital role in malaria prevention, especially in rural communities where formal healthcare access remains limited. Over generation, local populations have developed context-specific strategies to understand disease patterns, manage mosquito populations and promote community health. Traditional practices such as using herbal repellents derived from Neem *(Azadirachta indica)* ,Tulsi *(Ocimum sanctum)*, Lemongrass *(Cymbopogoncitrates)* , Lavender*(Lavandula angustifolia)*, Peppermint*(Mentha piperita)* Rosemary*(Rosmarinus officinalis)* are common for deterring mosquitoes. Communities also apply environmental management techniques- like draining stagnant water, burning dried leaves to produce smoke and using mosquito – repelling plants around houses – to control breeding sites.Moreover, indigenous healers often serve as the first point of care, using plant – based formulations to treat fever and malaria – related symptoms, providing an essential health safety net in remote areas. Scientific validation of traditional remedies and community – led awareness initiatives can help bridge the gap between traditional and biomedical systems.

6.1 Ethical Considarations: This study was permitted by the CMOH of Hooghly district (Chinsurah, pin-712101), Memo No-122: Dt-12.12.2024. The ethical approval was obtained from Diamond Harbour Women's University.The data were de-identified and compiled at the Zilla Swastha Bhawan, ensuring no individual patient details were included.

6.2 Acknowledgments: Greatefully acknowledges from my guide Dr. Somnath Paul, my partents , labmates for their kind support.

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