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Risk Factors of Malaria Transmission Dynamics Among Sand Mining Workers in the Kombos West Coast Region, The Gambia

Babucarr Jassey[1,3,5], Ririh Yudhastuti[2,*], Khuliyah Candraning Diyanah[1], Hourunisa[3], Muhammad Rasyid Ridha[1,4], Reny Indrayani[1], Musfirah[1], Eka Nur Sejati[1] and Buba Manjang[5]

[1]Doctorate Degree Program, Faculty of Public Health, Airlangga University, Surabaya, Indonesia
[2]Faculty of Public Health, Airlangga University, Surabaya, Indonesia
[3]Public Health Department, Syarif Hidayatullah State Islamic University, Ciputat, Indonesia
[4]Environmental Health Department, Badan Riset dan Inovasi Nasional (BRIN), Indonesia
[5]Department of Public Health Services, Ministry of Health, The Gambia

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***Correspondence:**
Ririh Yudhastuti
Address: Faculty of Public Health, Airlangga University, Surabaya 60115, Indonesia.
Email: ririhyudhastuti@fkm.unair.ac.id

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ABSTRACT

Background: Malaria eradication by 2030 is the UN's third Sustainable Development Goal (SDG). However, malaria still poses a severe threat to public health, especially in Sub-Saharan Africa, which includes The Gambia. The present study explores the factors that impact malaria transmission among artisanal small-scale miners (ASSM) in three districts in the West Coast Region of The Gambia: Kombo East, Kombo Central, and Kombo South. **Methods:** The researchers carried out a cross-sectional study using one hundred participants from the study area. Using a logistic regression model, the researchers looked at risk variables linked to malaria incidence in the Kombos. **Results:** Age (Adjusted Prevalence Ratio (APR) = 7.989 with 95% Confidence Interval (CI 1.724–37.002) and the existence of mosquito breeding places (APR = 7.685 with 95% Confidence Interval (CI 1.502–39.309) were shown to be risk variables for malaria in the multivariable analysis. On the other hand, protective factors included higher education level (APR = 0.104 with 95% CI 0.027-0.403), using insect repellents (APR = 0.138 with 95% CI 0.035-0.549), and the state of inside home walls (APR = 0.145 with 95% CI 0.0414-0.511). **Conclusions:** According to this study's findings, the Gambia's malaria risk variables include age and the presence of mosquito breeding grounds. In addition, having greater knowledge, using insect repellents, and having well-maintained interior walls are all protective factors against malaria. In order to eradicate malaria in Gambia's mining regions, it is strongly advised to decrease risk factors and increase prevention measures through effective communication, information, and education.

Keywords: Malaria transmission; mining workers; vector-borne diseases; occupational health; The Gambia

1. INTRODUCTION

The third target of the Sustainable Development Goals (SDGs) is to eradicate malaria by 2030. Nonetheless, malaria poses a serious threat to public health in The Gambia.[1,2] An Annual Parasite Incidence (API) of less than 1 per 1000 people, a Positivity Rate (PR) of less than 5% (positive malaria/blood preparations examined), and three years of consecutively zero native case incidences (malaria spread by local *Anopheles* mosquitoes carrying plasmodium) are the primary prerequisites for WHO certification.[3,4] To obtain certification for the eradication of malaria, all human malaria parasites must be stopped from spreading locally.[3,5] The API decreased in the Rural Gambia between 2012 and 2022. The API numbers for 2012, 2013, 2014, 2015, 2016, 2017, 2018, 2019, and 2019 were 0.90, 0.84, 0.71, 0.55, 0.49, 2016, 0.38, 2017, 0.21, and 0.14, respectively. Consequently, in 2020, 2021, and 2022, respectively, the statistics for the three most recent years were 0.01, 0.004, and 0.009.[2]

It is difficult to eradicate malaria in The Gambia's rural areas since many mosquito species, especially those of the primary malaria vectors, live in aquatic environments made possible by human activity, such as temporary waste sites and old tires.[6–8] *Anopheles gambiae* complex, which includes *An. gambiae* sensu stricto, *An. coluzzii*, and *An. arabiensis*, and *Anopheles funestus* group, which includes *Anopheles* sensu stricto, have been proven as vectors in rural Gambia, including the Kombos.[9] Furthermore, artisanal sand mining has a big impact on the miners' movement, especially for those who come from areas where malaria is endemic.[10,11] There is a chance that the plasmodium parasite from their home areas (imported cases) or drug side effects would cause these miners to relapse with malaria, which might spread to nearby residents and the mining site.[12,13]

Because artisanal or small-scale mining (ASSM) groups include a high-risk population, it is imperative to investigate malaria transmission within these communities.[12] Areas used for small-scale mining are especially vulnerable to the spread of malaria. For instance, there is a chance that sand miners in Tanjeh and Brufut, The Gambia, would get malaria.[14,15] Additional research has demonstrated that mining regions are more susceptible to malaria, with persistent evidence of malaria vectors flourishing there, as observed in the West Kenyan highlands.[4,16] Changes in land use can have an influence on the spread of malaria, and socioeconomic and behavioural variables are among the risk factors for malaria in mining regions.[2,17]

From a different angle, it is accepted that malaria is extremely rare among miners in The Gambia and the surrounding areas, even if the ASSM population has successfully eliminated the disease 10, 13, 18, and 19. Thus, research into malaria transmission among miners is really fascinating. The West Coast Region's Health Centers had a sharp decline in the Annual Parasite Incidence (API) during a five-year period in 2019 to 0.5, which was followed by 0.21 in 2020 and 0.04 in 2021.[2,18,19] In the West Coast Region, where the majority of ASSM areas are still unexplored, malaria is still prevalent. The National Malaria Control Program (NMCP) 2's malaria surveillance information system provided the API. To fill these information gaps, this study aims to investigate the variables that raise the risk of malaria in the West Coast region.

Despite the prevailing rarity of malaria among miners in The Gambia and its surrounding areas, particularly attributed to the remarkable success of the Artisanal and Small-Scale Mining (ASSM) population in eradicating the disease, the West Coast Region of The Gambia presents a contrasting scenario. Despite a notable decline in the Annual Parasite Incidence (API) reported by the Health Centers in the region over five years from 2019 to 2021, with rates plummeting to 0.04, malaria remains prevalent, especially in areas where artisanal sand mining (ASSM) activities are predominant and largely unexplored. The data provided by the National Malaria Control Program (NMCP) underscores the need for a deeper understanding of the factors contributing to malaria transmission dynamics in this region. To address these critical information gaps, this study aims to investigate the specific variables that elevate the risk of malaria transmission among sand mining workers in the Kombos West Coast Region, with the ultimate goal of informing targeted interventions and strategies for malaria prevention and control.

2. METHODS

From June to October 2023, a structured questionnaire was used to conduct a cross-sectional analysis. Every technique used complied with the relevant regulations, including sampling devoid of biological specimens and satisfying ethical standards.[20] With the respondents' informed agreement, the interviews were carried out. The respondents gave the researcher their consent to collect data, free from coercion, and the researcher anonymized the respondents' identities to protect their privacy.

In the field, participation in this study was optional. To maintain the highest level of secrecy, participant-identifying codes were used for all analyses. The researchers selected the entire nation using a purposive sample technique; however, they concentrated mostly on Kombo Central, Kombo South, and Kombo North on the west coast. The research areas were chosen based on information regarding the locations in The Gambia with the largest concentration of sand and gravel mining activity. In Figure 1, the study regions are displayed.

2.1 Sample Size

In this investigation, a two-sided test with a 95% significance level, 5% type I error (α), and 80% test power is used to evaluate the hypothesis for two population proportions.[20] Based on the literature review, the projected population proportion 1 (P1) for malaria patients who do not use mosquito nets is 0.79, whereas the estimated population quantity 2 (P2) for respondents with malaria who use mosquito nets is 0.50. So, the minimum sample size needed for each group in this study is forty-two people. By multiplying the results by two, a two-proportion sample calculation is used, which leads to an anticipated minimum sample size of 84 people overall. The sample size was rounded to 92 respondents after being expanded by 10% to 91.4 to account for possible dropouts and other variables. 92 persons were found by the sample calculation as a whole. Using a cross-sectional research design, this recent study found that 14 (15.22%) of the respondents had malaria, whereas 78 (84.78%) did not.

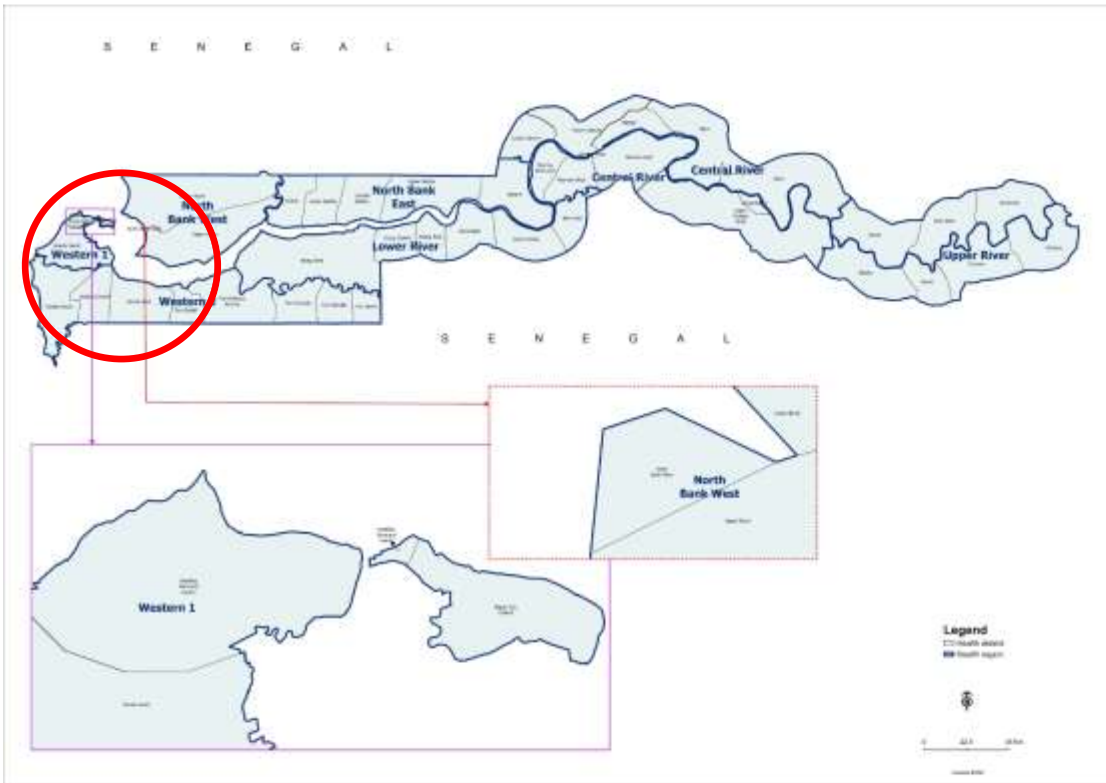

Figure 1. Approximate Location for mining point location in The Gambia

2.2 Sampling Technique

Purposive sampling was used in this study to choose villages or clusters. The village with the greatest concentration of small-scale miners was selected as the selection criterion. The sampling process was done at random in each village using the pre-existing sample frame in each town that was chosen. The number of samples obtained in each village was determined proportionally, and the minimum sample size attained represented the population of artisanal small-scale miners (ASSM) in these three districts. Since the community had people who tested positive for malaria, the responders were in danger of spreading the illness because of social and environmental factors that affect malaria in areas with small-scale mining.

The researchers classified each village's population by creating a cluster fraction sample using data from the Gambia Central Bureau of Statistics. Ultimately, the study region employed a two-stage cluster sampling technique to choose the respondents.[18,21,22] The present investigation has enhanced its internal and external validity. The people who reside in the villages have a variety of occupations;

in addition to working as workers and government employees, they also engage in farming, fishing, livestock management, and ASSM.[23] These three specially chosen communities have higher mining activity than the other places.

2.3 Data Collection

The at-risk population serves as the basis for the inclusion and exclusion criteria after random sampling. Accordingly, the respondent had to meet the following requirements in order to be eligible for this study—living in the West Coast region for more than six months, being a miner, be it legal or illegal, having appropriate communication skills, and being willing to engage in the study. The questionnaire must be completed, and the sampled respondent must be able to talk freely in order to be excluded.

Using a standardized questionnaire, epidemiological, sociodemographic, behavioral risk factors, and observational environmental data were gathered. Thirty respondents from the sand mining hamlet of Sanyang were used to assess the validity and reliability of this questionnaire. The features of the research sample and the responders are identical. The respondents used the accurate and reliable questionnaire they had received to gather data on the risk variables of malaria episodes in the ASSM research region. The broad objectives were communicated to the eligible individuals. Prior to the interview, verbal consent was acquired, and data was documented in writing. Ninety-two small-scale miners who fulfilled the study's eligibility conditions were interviewed by researchers. The interviewer performed in-person interviews after using standardized questions.

2.3.1 Scope of Variables

Stata software was used to handle the data. Respondents who did not get the disease were allocated code 1 for the dependent variable (malaria incidence), whereas those who did so were assigned code 2. Rapid diagnostic tests (RDTs) have shown positive results for malaria patients with symptoms, whereas responders with negative RDT results were deemed healthy.

2.3.2 Behavioural Risk Factors

The respondents' use of mosquito nets is classified according to the questionnaire results: a code of 1 is given to the respondent who does not use a mosquito net for nighttime sleeping. If the responder uses a mosquito net, the response is scored as 2. The behaviours of the respondents are then divided into two categories: code 1 was assigned to those who did not routinely use mosquito repellent, and code 2 was assigned to those who did. Use code 1 if you take self-medication while out late at night. If you use self-medication and never go out at night, you utilise code 2 sometimes. Following that, the respondents' knowledge is divided into two groups: high knowledge and poor knowledge, with codes 1 and 2 assigned to the latter. Meanwhile, codes 1 and 2 denote, respectively, negative and positive attitudes and behaviours.

2.3.3 Environmental risk factors

There are two types of environmental factors: those found outside the house and those found inside. In the outside environment, there are areas for mosquito breeding and resting. The respondent's home location is rated 1 if the breeding and resting area is 100 metres or less away; if it is farther away, it is not in danger. Two significant environmental elements are the condition of the home's walls and the existence of a ceiling. More importantly, the state of the home's flooring Researchers assigned codes 2 and 1, respectively, to housing conditions that meet the guidelines and are considered suitable residences and housing conditions that do not.

Variables connected to the prevalence of malaria by the use of a standardised survey. Employees of mining companies made up the bulk of responders who submitted information. Among the dependent data gathered via a structured questionnaire were epidemiological statistics about the prevalence of malaria. The independent variable also includes the respondents' age, sex, years of service, length of employment, and educational attainment at the same time. Moreover, among the behavioural risk variables examined were self-medication, using an insect repellent, wearing a mosquito net, leaving the house at night, and KAP (knowledge, attitude, and practise). Environmental risk factors also included mosquito breeding grounds, resting areas, the condition of the walls, the presence of a ceiling, and the condition of the floor. Another research revealed that the absence of pesticide, having bamboo or wood house walls, and living less than 100 meters from the mosquito breeding location were risk factors for malaria68. Transmission is impacted by ambient housing characteristics, as demonstrated by the preceding studies. Locations where mosquitoes nest close to homes affect the spread of malaria69. Malaria therapies centered on households and neighborhoods might benefit high-burden countries. ITN use, age-related variations in malaria outcomes, and the reduction of malaria can all be achieved by targeted vector control techniques such indoor residual pesticide spraying.

Former mining quarries, lakes, marshes, ponds, ditches, and fields are all suitable places for *Anopheles* larvae to breed. The presence of breeding sites in each household was ascertained through the use of GPS readings and a questionnaire. Data on *Anopheles* were previously gathered by the health area of West Coast II.

2.4 Data analysis

Data was examined using logistic regression analysis, chi-square analysis, and descriptive statistics using STATA statistical software. Additional information that was retrieved included the relationship between these factors and the prevalence of malaria among small-scale miners, which is shown in Tables 1 and 2, respectively.

2.4.1 Descriptive Analysis

The age, sex, years of service, duration of employment, and educational attainment of the respondents are among their individual characteristics. Descriptive analysis is used to identify behavioral risk variables, which also include the usage of LLINs, the application of mosquito repellents, nighttime outdoor time, self-medication habits, and knowledge, attitude, and practices (KAP).

2.4.2 Bivariate Analysis

The Chi-Square test was utilised to assess the statistical significance of the correlation between each independent and dependent variable. This required comparing the probability value (p-value) with the alpha (α) = 0.05. When the independent and dependent variables have a statistically significant connection, the null hypothesis is rejected (p-value < 0.05). A p-value larger than 0.05, on the other hand, suggests that there is no statistically significant association between the independent and dependent variables and that the hypothesis is either accepted or fails to be rejected.

2.4.3 Multivariable Analysis

APR, or adjusted prevalence ratio, was used to assess the severity of the malaria risk. A greater than one prevalence ratio (PR) indicates a higher likelihood of malaria cases.

3. RESULTS AND DISCUSSION

3.1. Respondent characteristics and demographics

All research variables, including age, sex, length of service, years of service, education level, use of insecticide-treated bed nets, presence of mosquito breeding and resting areas, knowledge, attitude, behaviour, and factors related to household conditions, were observed using univariate analysis.[9,24] Additionally, the researchers compiled the essential elements that characterize the sociodemographic traits of the research subjects.[25] This addressed the relationship between these factors and malaria among miners, as shown in Table 1.

Of the participants in this research, 78 (84%) did not have malaria or tested negative for the disease, whereas 14 (16%) had. Of them, 62% were older than 30, and 38% were younger than 30. There were 35 women and 65 males in the research. Forty percent of respondents had fewer than five years of service, while sixty percent had more than five years. Out of the fifty-two responders, 42% worked eight hours or more, while 58% worked fewer than eight hours. In terms of education, 60 respondents had previously attended elementary and junior high school (60%) and senior high school (40%). Of those surveyed, 53% utilized LLINs and 47% did not.

Additionally, whereas 47% did not utilize mosquito coils, 53% did. While 62% of people left their homes, 38% did not. Of the 68 participants, 73.91% used self-medication, whereas 26.09% did not. Of the responders, fifty-three (57.61%) were knowledgeable and 42.39% wanted further information. Moreover, 55.43% lacked a positive mindset, compared to 44.57% who did. Out of the 92 responders, 42.39% had good practices and 57.61% had bad practices. The majority of miners (60.87%) were at danger, according to the breeding locations. Near at-risk resting places, 65.22% of respondents resided. 38.04% of respondents had qualified home walls, compared to 61.96% with ineligible ones. Furthermore, of the respondents, 55.40% satisfied the requirements for their home condition, whilst 44.60% did not. Lastly, 34.78% of respondents had eligible home walls, compared to 65.22% who had non-eligible ones.

A number of factors have statistically significant relationships with the prevalence of malaria, according to the bivariate analysis table. The number of years of service and working hours during malaria episodes

Table 1. Bivariate analysis of the participants' initial sociodemographic data (n = 92). the percentage's 95% confidence interval in bivariate analysis. The 95% confidence bounds for the cell percentage are, respectively, lb Lower Bound and ub Upper Bound

Variable	Malaria				PR; 95%CI (lb-ub)	p-value
	Positive		negative			
	n	%	n	%		
Age						
<35 years old	3	8.57	32	91.43	1.33 (0.95–1.85)	0.163
≥35 years old	11	19.30	46	80.70		
Gender						
Female	4	13.33	26	86.67	1.07 (0.74–1.54)	
Male	10	16.13	52	83.87		0.724
Years of service						
<Five years	1	2.70	36	97.30	1.72 (1.34–2.21)	0.006
> Five years						
Working hours						
<Eight hours	2	5.00	38	95.00	1.67 (1.23–2.26)	0.017
≥Eight hours	12	23.08	40	76.92		
Level of Education						
High (senior high school)	8	25.00	24	75.00	0.61 (0.33–1.15)	0.054
Low (primary school and junior high school)	6	10.00	54	90.00		
The Use of LLIN						
Use	11	22.45	38	77.55	0.41 (0.14–1.16)	0.033
Don't Use	3	6.98	40	93.02		
The Use of Mosquito Repellents						
Use	11	25.58	32	74.42	0.36 (0.13–1.00)	0.005
Don't Use	3	6.12	46	93.88		
Out of the house						
Indoors	3	8.57	32	91.43	1.33 (0.95–1.85)	0.163
Outdoors	11	19.30	46	80.70		
Self-medication						
Do self-medicate	12	17.65	56	82.35	0.50 (0.13–1.91)	0.278
Don't self-medicate	2	8.33	22	91.67		
Knowledge on Malaria						
High	12	22.64	41	77.36	0.30 (0.08–1.10)	0.028
Low	2	5.13	37	94.87		
Attitude						
Good	10	24.39	31	75.61	0.47 (0.20–1.10)	0.021
Bad	4	7.84	47	92.16		
Prevention Practice						
Good	7	17.95	32	82.05	0.84 (0.48–1.47)	0.535
Bad	7	13.21	46	86.79		
Mosquito breeding Sites						
Not Available	2	5.56	34	94.44	1.51 (1.13–2.02)	0.036
Available	12	21.43	44	78.57		
Insect Resting place						
Not available	1	3.13	31	96.88	1.54 (1.22–1.94)	0.014
Available	13	21.67	47	78.33		
House wall condition						
Standard	9	25.71	26	74.29	0.53 (0.26–1.10)	0.021
Sub-standard	5	8.77	52	91.23		

Table 1. (*continued*)

Variable	Malaria				PR; 95%CI (lb-ub)	p-value
	Positive		negative			
	n	%	n	%		
The ceiling of the house						
Standard	8	16.00	42	84	0.92 (0.48–1.77)	0.816
Substandard	6	14.29	36	85.71		
Household Floor condition						
Standard	8	25.00	24	75.00	0.61 (0.33–1.15)	0.054
Substandard	6	10.00	54	90.00		

were significantly correlated (p = 0.017; p = 0.006). Additionally, the chi-square test revealed a statistically significant link between the use of mosquito nets (p = 0.033) and insect repellent (p = 0.005) in malaria cases. Furthermore, the chi-square test revealed a statistically significant association between attitude (p = 0.021) and knowledge (p = 0.028) about malaria. Additionally, a significant association was found between malaria and the locations of mosquito breeding (p = 0.036) and resting (p = 0.014) sites. Last but not least, a statistically significant relationship (p = 0.021) was seen between malaria occurrences and subpar in-house wall conditions.

For multivariable regression models, we used the backward stepwise approach, which begins with a saturated model and progressively eliminates variables to identify the best model that fits the data. When a variable's p-value became negligible throughout the stepwise backward approach, it was eliminated. A p-value < 0.25 was utilized in the bivariate selection process, and the variables with the highest p-value were eliminated from consideration until a model with a p-value < 0.05 was discovered during the modeling stage. The variable that has the greatest relevance is regarded as the dominant variable on the result since these factors may have an impact on one another. As a result, the prevalence ratio also known as adjusted is multivariable. Moreover, as indicated in Table 2, a multivariable analysis was carried out to determine the predominant risk variables for malaria.

Table 2. The low endemic region (n = 92) underwent a multivariate study of the parameters linked to the prevalence of malaria. Ref: A row of one in the contrast matrix is the reference category. a primitive prevalence ratio (PR). The APR stands for adjusted prevalence ratio

Variable	PR Crude (95% CI)[a]	p-value	PR adjusted (95% CI)[b]	P-value
Age				
<35 years old				
≥35 years old	1.33 (0.95–1.85)	0.163	7.98 (1.72–37.00)	0.008
Level of Education				
High (senior high school)				
Low (primary school and junior high school)	0.61 (0.33–1.15)	0.054	0.10 (0.02–0.40)	0.001
The Use of Mosquito Repellents				
Use				
Don’t Use	0.36 (0.13–1.00)	0.005	0.13 (0.03–0.54)	0.005
Mosquito breeding Sites				
Not Available				
Available	1.51 (1.13–2.02)	0.036	7.68 (1.50–39.30)	0.014
House wall condition				
Standard				
Sub-standard	0.53 (0.26–1.10)	0.021	0.14 (0.04–0.51)	0.003

The most important influencing factors were identified by a multivariable analysis. Ultimately, multivariable analysis revealed that, with a p-value of 0.008, age was the primary risk-determining factor.

Insect repellent, higher education, and the condition of the inside walls were protective variables, with PR < 1.

3.2 Key findings:

Given the significant risk of malaria transmission, it is imperative to investigate the spread of the disease in smallholder mining regions. Although several risk factors increase the likelihood of malaria transmission in traditional mining, the study revealed relatively little evidence of the disease in miners, a population targeted for malaria eradication. This study's key finding was that smallholder mining operations were high-risk areas for the spread of malaria. Out of the 14 affected people, 12 had P. falciparum, while the other 2 had a mix of P. falciparum and P. vivax. The Rapid Diagnostic Test (RDT) and microscopy results showed that P. falciparum was the most prevalent parasite in the study area.

The current study demonstrated that mosquito breeding areas and the age of small-scale mining respondents were risk factors for malaria. Higher education levels, insect repellent use, and interior walls condition in dwellings were further protective factors against malaria in the studied location. In the multivariate study, those over 35 had a 7.98-fold greater risk of acquiring malaria compared to those under 35 (adjusted PR: 7.98; 95% CI 1.72–37.00; p-value: 0.008) after adjusting for education, the use of insect repellent, mosquito reproduction, and the condition of the home walls. Additionally, there was a significant connection (adjusted PR: 0.13; 95% CI 0.03–0.54; p-value 0.005) between the use of insect repellent and a decreased risk of malaria.

The impact of artisanal and small-scale mining (ASSM) activities on malaria transmission dynamics presents a complex interplay between socio-economic development, environmental degradation, and public health concerns. While ASSM has been hailed as a potential solution for reducing poverty and improving local economies, studies have increasingly highlighted its unintended consequences on malaria prevalence and transmission.[26] Indeed, the expansion of ASSM activities has been associated with heightened land degradation, leading to conducive breeding environments for mosquito vectors and subsequent increases in malaria transmission rates.[27]

Recent research corroborates these findings, demonstrating a clear correlation between ASSM activity and malaria prevalence in affected regions. For instance, studies conducted in The Gambia have shown a notable rise in Plasmodium falciparum malaria cases coinciding with increased ASSM operations in the region.[28] This resurgence of malaria can be attributed to several factors, including the proliferation of mosquito species favored by environmental changes induced by mining activities and climate change.[29,30] Furthermore, the association between age and malaria transmission underscores the vulnerability of older individuals, who may face heightened risks of contracting the disease in ASSM-affected areas.[31]

The creation of man-made breeding sites by mining operations has emerged as a significant contributor to the proliferation of vector mosquitoes and subsequent malaria transmission. This phenomenon is particularly evident in regions such as the Amazon, where Brazilian gold miners have transformed vast areas of land through excavation activities, resulting in the formation of ditches, trenches, and abandoned pits.[32] These stagnant water bodies serve as ideal breeding grounds for mosquito vectors, facilitating their reproduction and the spread of malaria within affected communities.[32] Recent research on the impact of mining-related breeding sites on malaria transmission has highlighted the critical role of environmental modifications in exacerbating disease risk. Studies conducted in the Amazon basin have documented a direct association between the presence of man-made water bodies and increased mosquito abundance, with subsequent implications for malaria incidence.[10,11] Moreover, interventions aimed at reducing mosquito breeding places have shown promise in mitigating adult mosquito production and larval habitats, thereby curtailing malaria transmission in mining-affected areas.[26]

The survey revealed that respondents exhibited diverse living arrangements in relation to their employment, with some residing in close proximity to their workplaces while others opted for on-site accommodations for extended periods.[6,33] Interestingly, certain miners chose to live near mining regions, underscoring the close association between residential proximity and occupational activities. Analysis of mosquito samples collected from the study area identified *Anopheles gambiae* sensu stricto, *Anopheles quadriannulatus*, and *Anopheles melas* as vectors of malaria in the Rural Gambia Regency, affirming their role in disease transmission within the region.[9,19] Notably, both mosquito species exhibited distinct biting preferences and were observed to be most active during the period between twilight and sunrise.[27] Furthermore, the findings underscore the heightened risk of mosquito-borne illnesses, particularly among miners who lack personal protective equipment such as long sleeves or insect repellent lotion.[32] Given the occupational hazards associated with mining activities, including prolonged outdoor exposure and limited access to preventive measures, individuals working in these environments are particularly vulnerable to malaria transmission. Addressing these vulnerabilities requires targeted interventions aimed at promoting the use of personal protective equipment, implementing mosquito control measures in workplaces, and enhancing access to healthcare services for mining communities.[4,6,16]

The life cycle and behavior of *Anopheles* mosquitoes play a crucial role in the transmission dynamics of malaria, a vector-borne disease caused by the Plasmodium parasite. Female *Anopheles* mosquitoes require blood meals to nourish their eggs, thus driving them to actively forage for hosts during the nighttime hours. This behavior increases the risk of malaria transmission, as mosquitoes have the capacity to disperse the Plasmodium parasite to humans during their feeding activities.[34] Moreover, the abundance of mosquitoes typically rises during and following the wet season, as conducive environmental conditions promote breeding and larval development.[26] Recent research corroborates these findings, highlighting the correlation between mosquito abundance and malaria incidence in densely populated regions.[9] Studies conducted in various malaria-endemic settings have consistently demonstrated a higher prevalence of the disease in areas with dense human populations, where the likelihood of mosquito-human contact is increased.[6] Additionally, the occupational risks associated with mining activities have emerged as a significant factor contributing to malaria transmission dynamics. Illegal workers and migrants engaged in nighttime labor without adequate protection are particularly vulnerable to mosquito bites, resulting in a higher incidence of malaria infections among individuals working in these settings.[35,36]

In relation to the sociodemographic issues, a different study conducted in southeast Nigeria revealed that greater education improves awareness of and adherence to malaria prevention measures.[37] According to other study, spatial repellents (SR) can either completely stop or significantly limit the transmission of malaria.[15,38] Consistent with the findings of a previous study that looked at housing and malaria, the condition of the in-house wall was shown in this study to be a protective factor against malaria in the study region. Good house design in Uganda decreased the danger of malaria by preventing mosquito vectors from entering the country.[39,40]

According to the findings from this study, most of the infected respondents (61.96%) who engage in small-holder mining and have malaria were between the ages of 18 and 65, with an average age of 43. Thus, it is imperative that efforts to prevent malaria focus on this population.[41] Furthermore, the results of the current study demonstrated that most of mine workers were at risk due to mosquito breeding sites (60.87%), as well as the presence of mosquito resting spaces (65.22%) near breeding sites. Significant environmental changes were brought about by ASSM operations, one of which was the establishment of mosquito breeding grounds.[12,32] These changes are linked to the spread of malaria because they facilitate the growth of disease vectors. Another research conducted in Sumatra, Indonesia, found that mining trenches might enhance the growth of malaria vectors.[12]

In a similar vein, malaria is spread by mosquito breeding grounds close to dwellings in sub-Saharan Africa.[15] According to a different research, changes in land cover have a major impact on Africa's highland temperatures and the spread of malaria vectors.[6,14,15] Additionally, it raises the danger of malaria in the highlands as well as the pace at which sporogony develops and adult vectors survive.[27] The number of *Anopheles* mosquitoes can be significantly decreased by taking steps to remove standing water and mosquito breeding grounds. As a result, it was advised to get rid of mosquito breeding grounds in the mining region.[30] The information presented in this study pertains to the transmission of malaria in ASSM. This is consistent with several studies that demonstrate the importance of public health education in the fight against malaria. Prior research has demonstrated the importance of public health education in the fight against malaria.[33] According to this survey, respondents' general levels of practice, attitude, and understanding about malaria were all rather excellent.[42] Therefore, the deficiencies found by this study must be addressed in health education in order to increase community knowledge of the condition. Identifying behavioral and social risk factors as well as knowledge gaps in areas where malaria is widespread is essential to developing workable disease preventive strategies.[37,43] To close the information gap on malaria in local communities, health workers working in malaria-endemic regions should be trained to offer more effective counseling that addresses cultural behaviors including sleeping outside at night, using bed nets inappropriately, and using pesticides irregularly. Strategies for combating disease must take into account the knowledge and behavior of the populace.[24,34] However, since more than half of the population self-medicates, public health officials should continue educating the public about treating and preventing malaria since failing to do so might result in drug resistance and the disease's continuous spread. Employees in the forest run the risk of getting sick if they do not wear personal protective equipment, such as long sleeves or insect repellent lotion.[8,26] It is crucial to enhance respondents' knowledge, attitudes, and practises (KAP) in order to halt the spread of malaria. In order to do this, national malaria control programmes should help local communities in putting more effective malaria preventative and control measures into place as well as promoting educational opportunities.[29]

High rates of malaria are caused by hazardous behavior and poor levels of education in Yunnan Province, China.[44] The ASSM survey revealed that the respondents' educational attainment is poor and that more specialized information regarding stopping the spread of malaria is needed.[8] For the purpose of eliminating malaria, it is imperative to increase accurate public awareness and quick treatment-seeking behavior. Effective treatment for malaria is hampered by patients' ignorance, attitudes, and beliefs as well as by their inability to obtain and adhere to artemisinin-based combination therapy (ACT).[5,14]

Furthermore, a number of studies have demonstrated that using a repellent for malaria stops the disease from spreading.[23,41] Additional research emphasizes the necessity of enhancing personal mosquito repellent techniques for the prevention and control of plasmodium infections. In addition, mosquito coils are common in nations where malaria is endemic.[12,23,45] According to the current study, the majority of miners were not using mosquito coils (53.26%), had low levels of education (65.22%), and frequently left their homes late at night (61.96%). These behaviors are risk factors for malaria. It is consistent with another study that found that malaria is efficiently reduced by making changes to the home and that outside miners were vulnerable to mosquito bites.[37,45]

Mosquito density within a house can be decreased by home screening. Because of better living conditions, malaria is declining in regions where it has been endemic for generations, such as the south coast of England.[29] The malaria vector in The Gambia favors open rooftops. Compared to homes with metal roofs, thatched roofs are home to more malaria vectors.[19,40] Therefore, it is important for future studies to assess the protective impact of incorporating particular internal features.[14,42] The results of the current investigation indicated a relationship between malaria transmission and the state of the ceiling (55.40%) and inside walls (61.96%). Similar findings were found in another study, which indicated that contemporary, upgraded dwellings had a 47% lower risk of malaria infection than traditional ones.[15,39] In contrast, Ghana's high malaria frequency is caused by both human behavior and subpar building structure.[4,46]

3.3 Limitations of the research

Many risk factors have an impact on malaria transmission in the study region, albeit not all of them have been taken into account as research variables. This feature offers a chance to examine it in more detail. Still, the majority of the variables being studied now have to do with the social and environmental aspects of malaria in small-scale mining sites. It is significant to highlight that the study's sample size is limited, which might lead to bias in the findings, especially when determining the percentage of patients who test positive for malaria. The sample size was calculated using the sampling method for evaluating the two-proportion hypothesis, with certain factors and data from earlier research pertaining to P1 and P2. By using this method, the study's internal and external validity has been strengthened, and it is now more typical of artisanal mining in the three communities. These communities are home to a varied range of people, including small-scale farmers, ranchers, miners, and fishers. It's funny that the research neglected to include the respondents' working hours, which may have an impact on their risk of *Anopheles* mosquito bites. In spite of this, it was discovered that respondents had different work schedules; some worked eight hours or more, while others worked fewer than eight. Given that more hours worked equated to better compensation, the majority of respondents (56.5%) chose to work longer hours in order to enhance their daily income. Therefore, a large number of respondents increased their working hours due to financial concerns. Most people work from dawn to evening, however, other people stay late to finish. It is important to note that *An. vagus* likes to bite indoors, whereas *An. gambiens* typically bites outdoors. They are both awake from nightfall until dawn. These results can be extended to other small-scale mining regions and may have wider ramifications.

4. CONCLUSION

In conclusion, this research has shed light on the intricate dynamics of malaria transmission among sand mining workers in the Kombos West Coast Region of The Gambia. We have gained valuable insights into the underlying drivers of malaria prevalence and transmission in this population through a comprehensive investigation of various risk factors, including occupational hazards, environmental conditions such as the availability of mosquito breeding sites, and socio-economic determinants such as age. The findings highlight the multifaceted nature of malaria risk among sand mining workers, emphasizing the importance of targeted interventions and strategies to mitigate transmission and reduce the burden of the disease. Moving forward, efforts to address these risk factors and implement effective malaria control measures must be prioritized to safeguard the health and well-being of sand mining workers and the broader community in the Kombos West Coast Region. By leveraging these insights, we can work towards creating a healthier and more resilient environment for all region residents.

After conducting a multivariable analysis, age, and mosquito breeding were found to be the main risk factors for malaria transmission dynamics among sand miners in The Gambia. Protective variables include using insect repellent, having a high level of knowledge, and having in-home walls. Raising awareness, using protective clothing or insect repellent, and improving living circumstances as a protective factor can all assist in eradicating breeding sites in mining locales or stop direct interaction between artisanal miners and the vectors around the breeding sites. At the very least in the scientific domain, it is essential to carry out preventive and promotional actions as a first step towards the global eradication of malaria.

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Conflict of Interest

The authors declare no conflict of interest.

REFERENCES

1. Lindblade KA, Li Xiao H, Tiffany A, Galappaththy G, Alonso P, Abeyasinghe R, et al. Supporting countries to achieve their malaria elimination goals: the WHO E-2020 initiative. Malar J. 2021;20(1):1–11.
2. NMCP. National Malaria Control Program, The Gambia, Annual Malaria Intervention Profile and Report in The Gambia: Global Fund, UNICEF, WHO, CRS Project 74. Gambian Profile Rep. 2022;2022–23(Malaria Situation):74–82.
3. World Health Organization. WHO Guidelines for malaria - June 2022. Who. 2022;1–396.
4. Ashley EA, Poespoprodjo JR. Treatment and prevention of malaria in children. Lancet Child Adolesc Heal. 2020;4(10):775–89. http://dx.doi.org/10.1016/S2352-4642(20)30127-9
5. Lalloo DG, Shingadia D, Bell DJ, Beeching NJ, Whitty CJM, Chiodini PL. UK malaria treatment guidelines 2016. J Infect. 2016;72(6):635–49. http://dx.doi.org/10.1016/j.jinf.2016.02.001
6. Battle KE, Lucas TCD, Nguyen M, Howes RE, Nandi AK, Twohig KA, et al. Mapping the global endemicity and clinical burden of Plasmodium vivax, 2000–17: a spatial and temporal modelling study. Lancet. 2019;394(10195):332–43. http://dx.doi.org/10.1016/S0140-6736(19)31096-7
7. Paaijmans KP, Huijben S. Taking the "I" out of LLINs: Using insecticides in vector control tools other than long-lasting nets to fight malaria. Malar J. 2020;19(1):1–6. https://doi.org/10.1186/s12936-020-3151-x
8. Li XH, Zhou HN, Xu JW, Lin ZR, Sun XD, Li JY, et al. Seven decades towards malaria elimination in Yunnan, China. Malar J. 2021;20(1):1–16. https://doi.org/10.1186/s12936-021-03672-8
9. Jassey B, Manjang B, Camara J, Jallow AH, Marong L, Jawneh SS, et al. Overview of malaria prevention and treatment management in The Gambia: a descriptive study. JHeS (Journal Heal Stud. 2023;7(1):37–45.
10. De Salazar PM, Cox H, Imhoff H, Alexandre JSF, Buckee CO. The association between gold mining and malaria in Guyana: a statistical inference and time-series analysis.

Lancet Planet Heal. 2021;5(10):e731–8. http://dx.doi.org/10.1016/S2542-5196(21)00203-5
11. de Aguiar Barros J, Granja F, Pequeno P, Marchesini P, Ferreira da Cruz M de F. Gold miners augment malaria transmission in indigenous territories of Roraima state, Brazil. Malar J. 2022;21(1):1–11. https://doi.org/10.1186/s12936-022-04381-6
12. Hasyim H, Dewi WC, Lestari RAF, Flora R, Novrikasari N, Liberty IA, et al. Risk factors of malaria transmission in mining workers in Muara Enim, South Sumatra, Indonesia. Sci Rep. 2023;13(1):1–11. https://doi.org/10.1038/s41598-023-40418-9
13. Olapeju B, Adams C, Hunter G, Wilson S, Simpson J, Mitchum L, et al. Malaria prevention and care seeking among gold miners in Guyana. PLoS One. 2020;15(12 December). http://dx.doi.org/10.1371/journal.pone.0244454
14. Mbye H, Mane K, Diop MF, Demba MA, Bojang F, Mohammed NI, et al. Plasmodium falciparum merozoite invasion ligands, linked antimalarial resistance loci and ex vivo responses to antimalarials in The Gambia. J Antimicrob Chemother. 2022;77(11):2946–55. https://doi.org/10.1093/jac/dkac244
15. Cirera L, Sacoor C, Meremikwu M, Ranaivo L, F. Manun'Ebo M, Arikpo D, et al. The economic costs of malaria in pregnancy: evidence from four sub-Saharan countries. Gates Open Res. 2023;7(May):1–18.
16. Shanks GD, Hay SI, Omumbo JA, Snow RW. Malaria in Kenya's Western Highlands. 2022;11(9):1425–32. Available from: www.cdc.gov/eid
17. MoH The Gambia. Maternal and Child Health Reports, The Gambia. Minist Heal Gambia [Internet]. 2021;Vol 3(Maternal and Child Health Program). Available from: www.moh.gm
18. MICS. Gambia Multiple Indicator Cluster Survey, Survey Findings Report. 2018;260–3. Available from: https://www.statistics.sl/images/StatisticsSL/Documents/sierra_leone_mics6_2017_report.pdf
19. E-theses D. Malaria vector ecology and housing in The Gambia. 2023;0.
20. Edwards KJ, Gaber MM. Research Methodology; Tools and Techniques. Vol. 6, Studies in Big Data. 2014. 43–48 p.
21. Change C, Resources N. Government of The Gambia Ministry of Environment , Climate Change and Natural Resources THE GAMBIA ` S LONG-TERM. 2022;1–84.
22. Axelsson J, Benmarraze S. The Gambia Climate Promise The NDC Update Report. 2021;(June).
23. Center for Global Health Division of Parasitic Diseases and Malaria. Insect Repellents Help Prevent Malaria and Other Diseases Spread by Mosquitoes. Centers Dis Control Prev [Internet]. 2015; Available from: www.cdc.gov/travel
24. Olapeju B, Adams C, Wilson S, Simpson J, Hunter GC, Davis TA, et al. Malaria care-seeking and treatment ideation among gold miners in Guyana. Malar J. 2022;21(1):1–10. https://doi.org/10.1186/s12936-022-04045-5
25. Library M. Gambia - Integrated Household Survey. 2020;1–11.
26. Sanchez JF, Carnero AM, Rivera E, Rosales LA, Christian Baldeviano G, Asencios JL, et al. Unstable Malaria transmission in the southern peruvian amazon and its association with gold mining, madre de dios, 2001-2012. Am J Trop Med Hyg. 2017;96(2):304–11.
27. Atiele H, Zouh G, Yaw A, Mwanzo I, Githeko A, Yan G. Insecticide-treated net (ITN) ownership, usage, and malaria transmission in the highlands of western Kenya. Parasites and Vectors. 2019;4(113):1–10.
28. Wangdi K, Canavati SE, Ngo TD, Tran LK, Nguyen TM, Tran DT, et al. Analysis of clinical malaria disease patterns and trends in Vietnam 2009-2015. Malar J. 2018;17(1):1–15. https://doi.org/10.1186/s12936-018-2478-z
29. Gonçalves BP, Huang C-Y, Morrison R, Holte S, Kabyemela E, Prevots DR, et al. Parasite Burden and Severity of Malaria in Tanzanian Children. N Engl J Med. 2019;370(19):1799–808.
30. Hutchings RSG, Sallum MAM, Ferreira RLM, Hutchings RW. Mosquitoes of the Jaú National Park and their potential importance in Brazilian Amazonia. Med Vet Entomol. 2018;19(4):428–41.
31. Kafulafula UK, Hutchinson MK, Gennaro S, Guttmacher S, Chirwa E. Practice environment related barriers to Antenatal Care Attendance among HIV-positive Pregnant Women in Blantyre, Malawi. Health (Irvine Calif). 2019;05(09):1412–21.
32. Arcos AN, da Silva Ferreira FA, Tadei WP, da Cunha HB, Roque RA. Limnological variables associated with the presence of Anopheles Meigen, 1818 (Diptera: Culicidae) larvae in breeding sites in Amazonas, Brazil. Rev Chil Entomol. 2023;49(4):871–85.
33. Murta FLG, Marques LLG, Santos APC, Batista TSB, Mendes MO, Silva ED, et al. Perceptions about malaria among Brazilian gold miners in an Amazonian border area: perspectives for malaria elimination strategies. Malar J. 2021;20(1):1–14. https://doi.org/10.1186/s12936-021-03820-0
34. Smith NR, Trauer JM, Gambhir M, Richards JS, Maude RJ, Keith JM, et al. Agent-based models of malaria transmission: A systematic review. Malar J. 20AD;17(1):1–16. https://doi.org/10.1186/s12936-018-2442-y
35. Boggs D, Hydara A, Faal Y, Okoh JA, Olaniyan SI, Sanneh H, et al. Estimating need for glasses and hearing aids in the gambia: Results from a national survey and comparison of clinical impairment and self-report assessment approaches. Int J Environ Res Public Health. 2021;18(12):1–19.
36. Babbitt CW, Babbitt GA, Oehman JM. Behavioral impacts on residential food provisioning, use, and waste during the COVID-19 pandemic. Sustain Prod Consum. 2021;28:315–25. https://doi.org/10.1016/j.spc.2021.04.012
37. Balami AD, Said SM, Zulkefli NAM, Bachok N, Audu B. Effects of a health educational intervention on malaria knowledge, motivation, and behavioural skills: A randomized controlled trial PACTR201610001823405 PACTR. Malar J. 2019;18(1):1–14.

https://doi.org/10.1186/s12936-019-2676-3

38. J. II, I. UC, H. MC, U. UA, I. OS, E. OP, et al. Effect of Health Education on Malaria Control Practices among Mothers of Under-Five Children in a Rural Nigerian Community. J Adv Med Med Res. 2020;32(15):57–67.
39. Rek JC, Alegana V, Arinaitwe E, Cameron E, Kamya MR, Katureebe A, et al. Rapid improvements to rural Ugandan housing and their association with malaria from intense to reduced transmission: a cohort study. Lancet Planet Heal. 2018;2(2):e83–94. http://dx.doi.org/10.1016/S2542-5196(18)30010-X
40. Kristan M, Abeku TA, Lines J. Effect of environmental variables and kdr resistance genotype on survival probability and infection rates in Anopheles gambiae (s.s.). Parasites and Vectors. 2018;11(1):1–10.
41. Gabaldón Figueira JC, Wagah MG, Adipo LB, Wanjiku C, Maia MF. Topical repellents for malaria prevention. Cochrane database Syst Rev. 2023;8:CD015422.
42. Jawo E, Kargbo A, Mendy PA, Mendy E, Sanyang B. Knowledge , Beliefs and Attitude towards Malaria Control and Prevention among Students in Tertiary Institutions in The Gambia Study location. 2022;35(1):18–30.
43. Sari MP, Muttaqi RN, Hamdie T, Pangaribuan HU. Malaria Risk Factor at the Tabalong Cross-Borders, South Kalimantan, Indonesia. J Commun Dis. 2022;54(4):46–53.
44. He YQ. Malaria in Yuanyang, Yunnan, People's Republic of China - New control strategy (1992 - 1996). Southeast Asian J Trop Med Public Health. 2000;31(3):431–3.
45. Maia MF, Kliner M, Richardson M, Lengeler C, Moore SJ. Mosquito repellents for malaria prevention. Cochrane Database Syst Rev. 2018;2018(2).
46. Akowuah JA, Agyei-Baffour P, Awunyo-Vitor D. Determinants of antenatal healthcare utilisation by pregnant women in third trimester in peri-urban Ghana. J Trop Med. 2018;2018(2000).