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ANALYSIS OF CAUSAL FACTORS AND MALARIA VECTOR BREEDING SITES AMONG MINING WORKERS

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ABSTRACT
Malaria remains a major public health problem in mining areas due to environmental conditions that favor mosquito breeding and sustained human–vector contact. Mining workers are particularly vulnerable because of prolonged exposure to high-risk environments. This study aimed to analyze the factors associated with malaria incidence and the presence of vector breeding sites among mining workers in Hulawa Village, Buntulia Subdistrict, Pohuwato Regency. This observational analytic study employed a cross-sectional design involving 125 mining workers. Data were collected through structured interviews using a standardized questionnaire and environmental observations. The questionnaire was developed based on previous empirical studies and underwent validity and reliability testing prior to data collection; item validity was assessed using item－total correlation analysis, while internal consistency was confirmed with Cronbach’s alpha coefficients ⩾0.70. Malaria incidence was determined using a Rapid Diagnostic Test (RDT). The independent variables included knowledge, nighttime outdoor activities, history of malaria, risk perception, self-efficacy, length of residence, presence of potential breeding sites, and presence of malaria vectors. Bivariate associations were examined using the chi-square test, and multivariate analysis was conducted using logistic regression. The results showed that several factors were significantly associated with malaria incidence. Knowledge ($p = 0.000$; OR = 0.018) and history of malaria ($p = 0.014$; OR = 0.068) acted as protective factors, whereas length of residence in the mining area ($p = 0.001$; OR = 31.179) and the presence of malaria vectors ($p = 0.020$; OR = 55.195) significantly increased the risk of malaria. In contrast, self-efficacy and the presence of breeding sites were not significantly associated with malaria incidence. The most dominant factor influencing malaria incidence was the presence of malaria vectors. Malaria incidence among mining workers in Hulawa Village is influenced by a combination of individual and environmental factors, with vector presence and prolonged exposure in mining areas playing a dominant role. These findings highlight the critical importance of prioritizing vector control and environmental management in mining areas as key strategies to reduce malaria incidence.

Keywords: breeding sites; malaria; malaria vectors; mining workers; risk factors

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INTRODUCTION

Malaria is an infectious disease caused by Plasmodium infection transmitted through the bite of Anopheles mosquitoes and remains a major public health challenge in tropical regions. National data indicate an increasing trend in malaria cases over the past four years, rising from 254,055 cases in 2020 to 443,530 cases in 2022, and remaining high at 418,546 cases in 2023 (Ministry of Health of the Republic of Indonesia, 2024). This situation underscores that achieving malaria elimination by 2030 requires more adaptive strategies, particularly in endemic areas such as mining regions, which are characterized by high-risk environmental conditions.

Mining environments tend to provide numerous potential breeding sites for Anopheles vectors, including water-filled excavation pits, swamps, and abandoned ponds. Mining activities are often conducted at night—when Anopheles mosquitoes are most active—thereby constituting an additional risk factor that increases the likelihood of transmission. Several studies have demonstrated that nighttime outdoor activities significantly elevate malaria incidence, with an estimated risk up to eight times higher than daytime activities (Safitri et al., 2024; Hasyim et al., 2023). The low utilization of mosquito nets, repellents, and protective clothing further exacerbates this risk.

Beyond individual behavior, socio-cultural factors such as habitual social gatherings, trading activities, and prolonged nighttime work within mining communities reinforce patterns of exposure. A history of previous malaria infection also contributes to increased susceptibility to reinfection, particularly in areas with high vector density. Marpaung et al. (2023) reported that 67% of mining workers in Papua experienced more than one episode of malaria infection within a single year. Non-adherence to completing antimalarial therapy further increases relapse rates and prolongs transmission chains.

Environmental factors play a substantial role in sustaining malaria transmission cycles. Ecological degradation resulting from mining activities—such as open-pit excavation, land cover changes, and inadequate drainage systems—accelerates the formation of new habitats for malaria vectors. Both international and national studies have shown that mining areas carry a malaria risk two to three times higher than non-mining areas (Silva et al., 2022; Yudhantara et al., 2023). In Gorontalo Province, malaria cases increased to 1,577 cases in 2023 and reached 1,073 cases by epidemiological week 37 of 2024, with Pohuwato Regency contributing the largest proportion. Hulawa Village, located near a community-based gold mining site, has emerged as a major transmission hotspot and accounts for more than half of malaria cases in Buntulia District.

The presence of breeding sites in mining areas has been shown to be strongly associated with malaria incidence. Standing water in excavation pits, poorly managed drainage channels, and ground depressions provide ideal habitats for Anopheles larval development (Hasyim et al., 2023). Environment-based vector control interventions—such as filling stagnant water bodies, regular drainage, drainage system improvements, and the use of biological larvicides—have proven effective in reducing vector density. However, the effectiveness of these interventions largely depends on accurate mapping of breeding sites and active participation of workers in prevention efforts.

Given the substantial disease burden and the complexity of risk factors involving environmental conditions, behavioral patterns, and vector density, there is a need for studies that specifically identify the causal factors and the presence of malaria vector breeding sites in mining areas. This study aims to provide evidence-based insights into the factors contributing to malaria incidence among mining workers, as well as to strengthen recommendations for more effective and targeted vector control interventions. The findings are expected to offer practical benefits for local malaria control program planning while also enriching the theoretical understanding of the interactions among behavior, environment, and vector population dynamics in mining communities.

METHOD

This study employed a quantitative research design with an analytic approach and a cross-sectional design to assess the association between various risk factors and malaria incidence among mining workers in Hulawa Village, Buntulia District, Pohuwato Regency. All research procedures, including data collection and analysis, were conducted in September 2025 within the mining area of Hulawa Village, an endemic setting characterized by high levels of vector exposure. The study population comprised all mining workers in Hulawa Village, totaling 125 individuals. A total sampling technique was applied, whereby all members of the population were included as study participants without additional selection. This approach was chosen to ensure comprehensive representation of mining workers who are directly at risk of malaria exposure. Primary data were collected through field observations and structured interviews using a standardized questionnaire to assess knowledge, nighttime activity habits, history of malaria infection, risk perception, self-efficacy, duration of residence in the mining area, and exposure to environmental conditions with potential vector breeding sites. The questionnaire was developed based on relevant literature and previous studies related to malaria risk factors and was adapted to the local context. Prior to data collection, the questionnaire underwent validity and reliability testing. Content validity was assessed through expert judgment involving public health and epidemiology experts to ensure that all items were relevant and representative of the measured constructs. Construct validity was evaluated using item–total correlation analysis, in which questionnaire items with a correlation coefficient (r) greater than the critical value were considered valid. Reliability testing was conducted using Cronbach's alpha method, and a Cronbach's alpha value of ≥0.70 was considered to indicate acceptable internal consistency. Only valid and reliable questionnaire items were included in the final data analysis.

Malaria diagnosis was performed using a Rapid Diagnostic Test (RDT). Environmental observations were also conducted to identify the presence of standing water, open containers, non-flowing drainage channels, as well as the presence of Anopheles larvae or adult mosquitoes. Secondary data were obtained from local health facilities, malaria surveillance reports, and regional epidemiological records to strengthen the contextual understanding of malaria cases in the study area. All variables were operationally defined and measured using standardized instruments. Malaria incidence was determined based on RDT results, while independent variables were assessed using questionnaire scores and environmental observation findings. Field observations related to the presence of breeding sites and malaria vectors were recorded using a dedicated observation checklist in accordance with entomological surveillance guidelines. Data analysis was conducted in three stages. Univariate analysis was used to describe the frequency distribution and characteristics of each study variable. Bivariate analysis was performed using the Chi-square test to examine associations between independent variables and malaria incidence. Subsequently, multivariate analysis using logistic regression was conducted to identify the most influential factors associated with malaria incidence while controlling for potential inter-variable confounding. All statistical analyses were performed using a significance level of 0.05.

RESULT

Respondent Characteristics Analysis

Table 1.
Frequency Distribution of Respondent Characteristics

Characteristics	f	%
Age		
10 – 18 Years	7	5.6
19 – 59 Years	116	92.8
>60 Years	2	1.6
Last Education		
No Schooling	1	8
Elementary School	33	26.4
Junior High School	17	13.6
High School	74	59.2
Residence Status		
At Mining Site	113	90.4
Commute	12	9.6

Table 1 shows the frequency distribution of the characteristics of mine worker respondents in Hulawa Village. Based on age group, most of the respondents were in the productive age range of 19–59 years, which was 116 people (92.8%), while respondents aged 10–18 years amounted to 7 people (5.6%) and respondents over 60 years old were only 2 people (1.6%). This indicates that mining activities are dominated by active working-age groups who are more physically involved in field activities and have the potential to have high levels of malaria exposure. Based on the latest education level, the majority of respondents had a high school education of 74 people (59.2%), followed by elementary education as many as 33 people (26.4%) and junior high school education as many as 17 people (13.6%). Respondents who have never received formal education amounted to 1 person (0.8%). This distribution suggests that most mine workers have a secondary level of education, which can affect understanding of malaria risk and preventive behaviors. Judging from the status of residence, most of the respondents lived at the mine site as many as 113 people (90.4%), while respondents with a round-trip pattern amounted to 12 people (9.6%). This condition shows that the majority of workers have a high intensity of exposure to the mining environment, including exposure to malaria vectors and the existence of mosquito nesting sites, thus potentially increasing the risk of malaria occurrence.

Univariate Analysis

Table 2.
Distribution of Respondents Based on Malaria Incidence and Risk Variables

Variabel	f	%
Malaria Incidence in Miners		
Positive	48	38.4
Negative	77	61.6
Miner Knowledge		
Good	82	65.6
Poor	43	34.4
History of Malaria		
Has Had It	50	40
Never Had It	75	60
Self-Efficacy		
High	56	44.8
Low	69	55.2
Self-Efficacy		
High	56	44.8
Low	69	55.2
Duration of Residence in Mining Area		
Long	62	49.6
Short	63	50.4
Presence of Breeding Places		
Presence of Brooding Places	57	45.6
No Brooding Places	68	54.4
Presence of Malaria Vectors		
Vectors	58	46.4
No Vectors	67	53.6

Table 2 illustrates the distribution of respondents based on malaria incidence and various risk factors in mine workers in Hulawa Village. The results showed that as many as 48 respondents (38.4%) were confirmed positive for malaria, while 77 respondents (61.6%) were negative. These findings show that the proportion of malaria incidence among mine workers is still quite high, considering that almost two-fifths of respondents have malaria infection. Based on the level of knowledge, most of the respondents had good knowledge about malaria, namely 82 people (65.6%), while 43 respondents (34.4%) had poor knowledge. Although the majority of respondents had a good level of knowledge, the incidence of malaria was still found, indicating that knowledge alone is not fully proportional to preventive practices in the mine working environment. Judging from the history of malaria, as many as 50 respondents (40.0%) had experienced malaria before, while 75 respondents (60.0%) had no history of the disease. This condition shows the potential for reinfection in some workers, especially in mining environments that have a high risk of exposure to vectors.

Based on self-efficacy, most of the respondents had low self-efficacy as many as 69 people (55.2%), while respondents with high self-efficacy amounted to 56 people (44.8%). Low self-efficacy can affect an individual's ability to implement malaria prevention behaviors consistently.

Judging from the length of stay in the mining area, the distribution of respondents was relatively balanced between 62 people (49.6%) and 63 people (50.4%) who lived for a short period of time. This suggests that the duration of stay in the mining area has the potential to be a risk factor that needs to be further analyzed in relation to the incidence of malaria. Based on environmental conditions, as many as 57 respondents (45.6%) lived in areas with breeding places, while 68 respondents (54.4%) lived in areas without breeding places. In addition, the presence of malaria vectors was found in the living environment of 58 respondents (46.4%), while 67 respondents (53.6%) lived in areas where no vectors were found. These findings confirm that environmental factors, especially the existence of breeding sites and malaria vectors, are still an important issue in malaria transmission in mining areas.

Bivariate Analysis

Table 3.
Analysis of the Relationship of Miners' Knowledge with Malaria Incidence

Miner's Knowledge	Incidence of Malaria				Total		*P-Value*
	Positive		Negatives				
	f	%	f	%	N	%	
Good	14	12.2	68	54.4	82	65.6	0.000
Less	34	27.2	9	7.2	43	34.4	

Based on Table 3, the relationship between miners' knowledge level and malaria incidence is shown. The results of the analysis showed that in the group of well-informed miners, as many as 14 respondents (12.2%) experienced malaria, while most of the others, namely 68 respondents (54.4%), did not experience malaria. On the other hand, in the group of miners with less knowledge, the proportion of malaria incidence was much higher, namely 34 respondents (27.2%), while only 9 respondents (7.2%) did not experience malaria.

The results of the Chi-Square statistical test showed a p-value = 0.000 ($p < 0.05$), indicating a statistically significant relationship between the miner's level of knowledge and the incidence of malaria.

Table 4.
Analysis of the relationship between the history of malaria and the incidence of malaria

History of Malaria	Incidence of Malaria				Total		*P-Value*
	Positive		Negatives				
	f	%	f	%	f	%	
Ever Suffered	8	6.4	42	33.6	50	40.0	0.000
Never	40	32.0	35	28.0	75	60.0	

Table 4 shows the relationship between the history of malaria and the incidence of malaria in mine workers. The results of the analysis showed that of the respondents who had suffered from malaria, as many as 8 people (6.4%) had malaria again, while 42 respondents (33.6%) did not experience malaria. Meanwhile, in the group of respondents who had never had malaria, as many as 40 people (32.0%) had malaria and 35 people (28.0%) did not have malaria.

The results of the Chi-Square statistical test showed a p-value = 0.000 ($p < 0.05$), which indicates a statistically significant relationship between the history of malaria and the incidence of malaria.

Table 5.
Analysis of the relationship between self-efficacy and malaria incidence

Self-Efficacy	Incidence of Malaria				Total		*P-Value*
	Positive		Negatives				
	f	%	f	%	f	%	
High	30	24.0	33	26.4	63	50.4	0.02
Low	18	14.4	44	35.2	62	49.6	

Table 5 shows the relationship between self-efficacy and the incidence of malaria in mine workers. The results of the analysis showed that in respondents with high self-efficacy, as many as 30 people (24.0%) had malaria and 33 people (26.4%) did not have malaria. Meanwhile, among respondents with low self-efficacy, as many as 18 people (14.4%) had malaria and 44 people (35.2%) did not have malaria. The results of the Chi-Square statistical test showed a p-value = 0.02 ($p < 0.05$), which indicated a statistically significant relationship between self-efficacy and malaria incidence.

Table 6.
Analysis of the relationship between long living in the mine area and malaria incidence

Length of stay in the mining area	Incidence of Malaria				Total		*P-Value*
	Positive		Negatives				
	n	%	n	%	N	%	
Long	42	33.6	20	16.0	62	49.6	0.00
Short	6	4.8	57	45.6	63	50.4	
Total	48	38.4	77	61.6	125	100	

Tabel 6 menunjukkan adanya hubungan yang bermakna antara lama tinggal di area tambang dengan kejadian malaria (p-value = 0,00). Responden yang tinggal lebih lama di area tambang memiliki proporsi kejadian malaria positif yang lebih tinggi, yaitu sebanyak 42 orang (33,6%), dibandingkan dengan responden yang tinggal dalam waktu singkat sebanyak 6 orang (4,8%). Sebaliknya, kejadian malaria negatif lebih banyak ditemukan pada responden dengan lama tinggal singkat, yaitu 57 orang (45,6%), dibandingkan dengan responden yang tinggal lama sebanyak 20 orang (16,0%). Temuan ini mengindikasikan bahwa semakin lama seseorang tinggal di area tambang, semakin besar risiko terjadinya malaria.

Tabel 7.
Analisis hubungan adanya breeding places dengan kejadian malaria

The existence of breeding places	Incidence of Malaria				Total		*P-Value*
	Positive		Negatives				
	f	%	f	%	f	%	
There is Parenting	25	20.0	25	20.0	50	40.0	0.024
There is no parenting	23	18.4	52	41.6	75	60.0	

Based on Table 7, out of 50 respondents who had mosquito nesting sites around their residences, as many as 25 people (20.0%) were confirmed positive for malaria, while in the group without nesting sites, the proportion of malaria-positive respondents was lower, namely 23 people (18.4%) out of 75 respondents. The results of the chi-square test showed a p-value of 0.024 ($p < 0.05$), which indicates a significant relationship between the existence of breeding sites and the incidence of malaria. These findings suggest that the presence of mosquito breeding grounds in residential environments contributes to an increased risk of malaria transmission.

Table 8.
Analysis of the relationship between malaria vectors and malaria incidence

The Presence of Malaria Vectors	Incidence of Malaria				Total		*P-Value*
	Positive		Negatives				
	f	%	f	%	f	%	
There is a Vector	25	20.0	25	20.0	50	40.0	0.004
There is no Vector	23	18.4	52	41.6	75	60.0	

Based on Table 8, of the 50 respondents living in an environment with the presence of malaria vectors, as many as 25 people (20.0%) were confirmed positive for malaria, while in the group without the presence of vectors, the proportion of malaria-positive respondents was lower, namely 23 people (18.4%) out of 75 respondents. The results of the chi-square test showed a p-value of 0.004 ($p < 0.05$), which indicates a significant relationship between the presence of malaria vectors and malaria incidence. These findings suggest that the presence of malaria vectors in the residential environment plays an important role in increasing the risk of malaria transmission.

Multivariate Analysis

Based on the results of the multivariate analysis in Table 9, the presence of malaria vectors was the most dominant factor influencing the incidence of malaria, with an odds ratio (OR) value of 55.195 and a p-value of 0.020, which showed that respondents living in environments with the presence of malaria vectors had a greater risk of developing malaria compared to respondents who were not exposed to vectors. In addition, length of stay in the mining area was also significantly related to the incidence of malaria (p = 0.001; OR = 31,179), which indicates that the longer the respondents stay in the mine area, the higher the risk of exposure to malaria. The variables of miner knowledge (p = 0.000) and history of malaria (p = 0.014) showed a significant relationship with the OR value of < 1, indicating its role as a protective factor in lowering the risk of malaria occurrence. Meanwhile, self-efficacy (p = 0.448) and the presence of breeding places (p = 0.149) showed no significant effect on malaria incidence after being controlled by other variables in the model.

Table 9.
Analysis of causative factors and breeding places of malaria vectors with malaria incidence

No	Research Variables	P-*Value*	*Odds Ratio*	95 C.I for EXP (B)	
				Lower	*Upper*
1	Miners' Knowledge	0.000	0.018	0.003	0.155
2	History of Malaria	0.014	0.068	0.008	0.584
3	Self-Efficacy	0.448	20.379	0.009	48757.813
4	Length of Residence in the Mining Area	0.001	31.179	4.447	218.583
5	Presence of Breeding Places	0.149	0.002	0.000	9.716
6	Presence of Malaria Vectors	0.020	55.195	1.861	1637.178

DISCUSSION

The results of this study indicate that malaria incidence among mining workers in Hulawa Village, Buntulia Subdistrict, remains relatively high, with 38.4% of respondents confirmed positive for malaria. This finding underscores that malaria continues to be a significant public health problem in mining areas. The condition reflects a strong interaction between individual, behavioral, and environmental factors influencing malaria transmission dynamics. Most respondents belonged to the productive age group of 19–59 years (92.8%), characterized by high physical activity and mobility, particularly during the late afternoon and nighttime. These activity periods coincide with peak biting times of Anopheles mosquitoes, thereby increasing the likelihood of human–vector contact. In addition, the majority of respondents resided permanently within the mining area (90.4%), resulting in continuous exposure to high-risk environmental conditions. Mining environments commonly feature excavation pits, stagnant water, and ecological disturbances that favor mosquito breeding and survival, consistent with the concept of vectorial capacity (WHO, 2023).

In terms of educational background, most respondents had completed senior high school (59.2%), although a proportion had only primary education or no formal schooling. This variation in educational attainment influences individuals’ ability to comprehend and apply health-related information. This was evident in the analysis, which demonstrated a significant association between miners’ knowledge and malaria incidence (p = 0.000). Respondents with poor knowledge experienced a higher proportion of malaria cases compared to those with good knowledge. Multivariate analysis further confirmed that knowledge acts as a strong protective factor against malaria (OR = 0.018; 95% CI: 0.003–0.155). Adequate knowledge encourages preventive behaviors such as the use of bed nets, mosquito repellents, and limiting outdoor activities at night. These findings are consistent with health behavior theories stating that knowledge forms the foundation of attitudes and preventive practices (Notoatmodjo, 2018; Rosenstock, 1974).

A significant association was also found between a history of malaria and current malaria incidence. Respondents who had previously suffered from malaria were less likely to experience reinfection compared to those without a prior history (p = 0.014; OR = 0.068; 95% CI: 0.008–0.584). An odds ratio below one indicates a protective effect, which can be explained by the concept of partial immunity. According to WHO (2023), repeated exposure to malaria parasites can stimulate partial immune responses that reduce the risk of reinfection or disease severity, although such immunity is neither complete nor permanent.

Self-efficacy showed a significant association with malaria incidence in bivariate analysis ($p = 0.02$); however, this association was no longer significant in multivariate analysis ($p = 0.448$). This finding suggests that individuals' confidence in their ability to prevent malaria may be insufficient when not supported by safe environmental conditions. In high-risk mining settings, environmental factors tend to exert a stronger influence than individual psychological factors. Consequently, self-efficacy does not function as an independent predictor of malaria incidence in such high-exposure contexts.

Length of residence in the mining area emerged as a major risk factor for malaria. Respondents who had lived longer in the mining area had more than a 30-fold higher risk of malaria compared to those with a shorter duration of residence ($p = 0.001$; OR = 31.179; 95% CI: 4.447–218.583). This finding indicates that prolonged residence results in cumulative exposure to environments that support the life cycle of Anopheles mosquitoes. These results align with studies by Hasyim et al. (2023) and Wulandari et al. (2023), which reported that duration of exposure to mining environments is a key determinant of malaria incidence.

Both the presence of breeding sites and malaria vectors were significantly associated with malaria incidence in bivariate analysis. However, in multivariate analysis, only the presence of malaria vectors remained statistically significant ($p = 0.020$; OR = 55.195; 95% CI: 1.861–1637.178). This finding indicates that the presence of Anopheles mosquitoes is the most dominant factor contributing to malaria transmission in Hulawa Village. Meanwhile, breeding sites were no longer significant after adjustment for other variables, suggesting that their effect on malaria incidence is mediated through vector presence. This supports the concept that vector density and competence are the primary drivers of malaria transmission (WHO, 2023).

Overall, the findings demonstrate that malaria incidence among mining workers in Hulawa Village is influenced by a combination of behavioral, individual, and environmental factors. Knowledge and previous malaria history serve as protective factors, whereas prolonged residence in mining areas and the presence of malaria vectors constitute the strongest risk factors. These findings are consistent with malaria epidemiological theory, which emphasizes the central role of human–vector–environment interactions in disease transmission, and they corroborate previous studies by Longchamps et al. (2022), Hasyim et al. (2023), and Wulandari et al. (2023). In conclusion, malaria elimination efforts in mining areas should not focus solely on individual behavioral change but must prioritize vector control and environmental management, alongside continuous improvement of community knowledge and risk perception. This integrated approach is expected to be more effective in reducing malaria incidence in mining settings..

CONCLUSION

This study concludes that malaria incidence among mining workers in Hulawa Village is influenced by several key factors, including knowledge, history of malaria, risk perception, length of residence, and the presence of malaria vectors. Knowledge serves as a protective factor by encouraging preventive practices, whereas nighttime outdoor activities and prolonged residence increase exposure to Anopheles mosquito bites. A history of malaria tends to reduce the risk of subsequent infection, possibly due to the development of partial immunity. The presence of malaria vectors is the most dominant factor increasing malaria risk, indicating that environmental conditions within mining areas are the primary determinants of disease transmission. These findings suggest that malaria control requires an integrated approach combining behavioral and environmental strategies, with vector control interventions and mining environmental management representing the most effective measures to reduce malaria incidence.

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