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RESIDENTIAL ENVIRONMENTAL RISK FACTORS ASSOCIATED WITH MALARIA INCIDENCE IN PAPUA, INDONESIA

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Abstract

Introduction: *Papua is the region with the highest malaria burden in Indonesia, accounting for about 84% of the total national malaria cases. The high incidence rate indicates the need for a multidimensional approach, including analysis of environmental determinants. Therefore, this study aimed to evaluate the influence of environmental risk factors on the incidence of malaria in Papua, Indonesia.* ***Methods:*** *A cross-sectional observational design was used based on secondary data from the 2023 Indonesian Health Survey. The analysis was conducted on 37,987 respondents using Chi-square test and binary logistic regression. The variables analyzed included housing conditions, physical quality of water, wastewater drainage systems, and waste management.* ***Results and Discussion:*** *The results showed that, based on bivariate analysis, four environmental factors were significantly related to malaria incidence (p<0.05). However, in the multivariate analysis, only three variables remained significant, wastewater drainage system (OR=1.203; p<0.001), poor waste management practices (OR=1.103; p<0.016), and housing conditions (OR=0.884; p<0.001). while water quality had no significant effect.* ***Conclusion:*** *These findings highlight the importance of incorporating environmental management into malaria control strategies, especially in endemic and resource limited regions like Papua, through multisectoral collaboration between health and environmental authorities.*

INTRODUCTION

Malaria is caused by *Plasmodium* parasites transmitted to humans through bites of infected female *Anopheles* mosquitoes (1). The burden of malaria is mainly concentrated in eastern Indonesian regions, with Papua Province being among the most affected (2). According to the malaria case trend data in Papua, a total of 216,868 cases were recorded in 2020, with an Annual Parasite Incidence (API) of 78.40 per 1000 population. In 2021, the number increased, with the API reaching 80.05 per 1000 population. Significantly, the Papua region accounted for around 81% of all reported malaria cases nationwide (3). In 2022, there was a further increase, with approximately 84% or 363,854 of the national malaria cases occurring in Papua, making it the region with the highest disease burden (4).

In 2023, malaria cases declined to 163,962; however, Papua remained the province with the greatest disease burden and the lowest elimination rate (0%). In early 2024, the API is estimated to increase significantly to 222.99 per 1000 population, the highest in Indonesia (5). This condition indicates the need for more comprehensive control, including an environment-based approach (6).

Transmission is influenced not only by biological factors, including *Anopheles mosquito vectors and* Plasmodium *parasites*, but also by the environmental conditions of residence (7). Relevant environmental factors include the quality of housing, access to clean water, wastewater disposal systems (8-9).

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Habitable houses are a key factor in preventing the entry of malaria-vector mosquitoes into the home (10). Remote areas in Papua are often found with inadequate housing, such as poor ventilation and poorly sealed walls, which facilitate the entry and breeding of mosquitoes. (11). A parallel study conducted in Nampula District, Mozambique, showed that adequate housing such as installing mosquito nets, sealing roof gaps, and improving door shapes led to a 94% reduction in Anopheles mosquito breeding than inadequate housing (12).

Poor physical water conditions with turbidity and stagnant water, which are known as ideal breeding areas for mosquito larvae (13). Papua is one of the places where sanitation development is still limited in many areas, then stagnant water caused by poor drainage and poor waste with no treatment makes conditions for Anopheles mosquitoes to breed (14). In addition, the lack of basic sanitation facilities, such as supportive latrines, leads to environmental shrinkage, which maintains mosquito populations (15). This is a concern in Papua, where the condition has a close relationship with the high rate of malaria transmission that continues to grow (16).

Poor waste management has a strong association with increased malaria cases in endemic areas (17). In an environment with accumulated garbage, puddles will form, creating a breeding ground for Anopheles mosquitoes, which are the main vectors of malaria incidence (18). Items that can collect rainwater such as used cans, plastic bottles, and packaging materials have the possibility of mosquito larvae to develop. This situation significantly contributes to the growth of mosquito populations in residential areas and makes malaria transmission flourish (19).

Previous studies have examined the causal factors of malaria, with one region, Papua, staunchly reporting one of the highest malaria incidence rates in Indonesia. However, most of these studies have been geographically limited and focused on specific regions. To address these issues, this study takes a broader, island-level approach using data from the 2023 Indonesian Health Survey (IHS), a nationally representative data set from the Ministry of Health. This study allows for a more comprehensive analysis of the relationship between environmental conditions and malaria incidence in the Papua region as a whole (20). This study aims to determine how factors such as housing conditions, physical water, sewage systems, and waste management are associated with malaria transmission in Papua, Indonesia (2).

This study hypothesizes a significant association between environmental risk factors and malaria incidence in Papua, Indonesia. The findings of this study can serve as a foundation by providing a basis for more comprehensively targeted malaria control countermeasures, by presenting evidence-based insights into how environmental conditions contribute to disease transmission (9).

METHODS

This study uses an observational method with a cross-sectional approach to analyze how environmental risk factors contribute to the incidence of malaria in Papua, Indonesia (21). Data were obtained from the 2023 Indonesian Health Survey (IHS) obtained from the Ministry of Health, which has obtained permission to be used in this study. The study population consisted of all IHS 2023 data in Papua Province, totaling 37,987. Samples were taken purposively based on inclusion criteria, namely having complete data on malaria incidence and environmental factors analyzed.

Malaria incidence within the past 12 months served as the dependent variable based on the diagnosis of health workers, categorized as binary (yes/no). The independent variables include four environmental indicators: housing conditions, physical condition of water, wastewater drainage system, and waste management. All variables were categorized as binary (feasible/unfeasible or good/bad) according to national standards.

The data processing process started with cleaning, outlier checking, and recoding in Microsoft Excel (22), followed by analysis with IBM SPSS Statistics version 26. Descriptive statistics in the form of univariate analysis were conducted to outline the frequency distribution of the variables. Bivariate relationships were examined using Chi-square tests. For multivariate analysis, binary logistic regression was employed while controlling for potential confounders. Variables showing a p-value less than 0.25 in the bivariate analysis were selected for inclusion in the regression model to minimize potential bias.

RESULTS

The majority of respondents were females (52.6%) and young (68.2%). Most have a low level of education (70.2%), with 53.9% working. In terms of economic status, the majority came from low-economic groups (68.8%), and the incidence rate of malaria was recorded at 12.6%. From the aspect of environmental health, 56.0% of respondents lived in uninhabitable houses, 87.3% did not have an adequate wastewater drainage system,and 74.6% had poor waste management.

Table 1. Distribution of Respondent Characteristics, Malaria Incidence Rate, and Environmental Health Indicators in Papua based on IHS data in 2023

Variables	Frequency	%
Gender		
Male	17,931	47.2
Female	20,056	52.8
Age		
Young	25,910	68.2
Old	12,077	31.8
Education		
Higher education	11,321	29.8
Primary education	26,666	70.2
Employment Status		
Work	20,485	53.9
Not Working	17,502	46.1
Status Economy		
Tall	2,231	5.9
Intermediate	9,624	25.3
Low	26,132	68.8
Housing Conditions		
Proper	16,717	44.0
Not eligible	21,270	56.0
Physical Conditional of Water		
Good	6,400	16.8
Bad	31,587	83.2
Wastewater Management Channel		
Proper	4,823	12.7
Not eligible	33,164	87.3
Waste Management		
Good	9,632	25.4
Bad	28,355	74.6
Incidence of Malaria		
Yes	4,773	12.6
No	33,214	87.4

The results of the Chi-Square test, which is appropriate for categorical data and doesn't require a normality test, showed that all the variables studied, such as the feasibility of housing, physical condition of water, wastewater management channels, waste management, had a significant relationship with the incidence of malaria. Respondents living in uninhabitable homes had a higher risk of developing malaria (p-value = 0.000; PR = 1.16), as well as those who used water with poor physical condition (p-value = 0.012; PR = 1.11), does not have a wastewater drainage systems (p-value = 0.000; PR = 1.33), inadequate waste management (p-value = 0.000; PR = 1.22). Therefore, all these factors were linked to a higher risk of malaria compared to those in better environmental conditions.

Table 2. Bivariate Analysis

Variables	Incident of Malaria				PR 95% CI	*P-Value**
	No Malaria		Malaria			
	n	%	n	%		
Housing Conditions						
Proper	1,445	86.4	2,272	13,6	1.156 (1.096-1.219)	0.000
Not eligible	18,769	88.2	2,501	11.8		
Physical Conditional of Water						
Good	5,567	88.4	743	11.6	1.113 (1.024-1.210)	0.012
Bad	27,557	87.2	4,030	12.8		
Wastewater Management Channel						
Proper	4,321	90.0	482	10.0	1.334 (1.212-1.478)	0.000
Not eligible	28,873	12.9	4,291	12.9		
Waste Management						
Good	8,573	89.0	1,059	11.0	1.220 (1.135-1.321)	0.000
Bad	24,641	86.9	3,714	13.1		

Ket: **P-Value* : 0.05, Signifikan

The multivariate logistic regression analysis showed that the variable of livable housing had a significant impact on malaria incidence (p = 0.000; OR = 0.884), An odds ratio (OR) value < 1 indicates that the physical condition of the house is a protective factor, meaning that better housing conditions reduce the risk of malaria

Table 3. Multivariate Analysis

Variable	B	SE	Wald	OR (CI 95%)	*P-value**
Housing conditions*	-0.124	0.033	13.927	0.884 (0.828 – 0.943)	0,000
Physical Condition of Water	0.002	0.045	0.003	1.002 (0.918 – 1.095)	0,958
Wastewater Management Channel*	0.257	0.051	25.125	1.203 (1.170 – 1.430)	0,000
Waste Management*	0.098	0.041	5.834	1.103 (1.019 – 1.194)	0.016

Ket: **P-Value* : 0.05, Signifikan

The physical condition of water showed no significant effect on malaria incidence (p = 0.958), whereas wastewater management systems had a significant effect (p = 0.000; OR = 1.28). Respondents with inadequate wastewater drainage systems had a 1.28-fold higher risk of contracting malaria compared to those with adequate drainage systems. Waste management practices also had a significant effect (p = 0.016; OR = 1.13), indicating that respondents with poor waste management had a 1.13 fold higher risk of malaria infection compared to those with proper waste management.

The analysis results showed that the dominant variables influencing malaria incidence were wastewater drainage systems, which increased the risk by 21.2%, and waste management, which increased the risk by

10.3%. In contrast, housing conditions reduced the risk by 11.1%, while the physical condition of water had no significant effect.

DISCUSSION

Malaria is predominantly influenced by environmental factors, as poor conditions create breeding grounds for Anopheles mosquitoes, the primary vector of the disease (23). In Indonesia, the highest malaria incidence is recorded on the island of Papua, with greater prevalence in remote areas such as Mamberamo Raya, Tambrauw, and the Arfak Mountains (24). The 2021 findings from the *Malaria Journal* indicated a significantly higher prevalence approximately fivefold of asymptomatic malaria parasites in children from rural Kinshasa compared to those in urban areas ($p < 0.001$) (25). The analysis of four environmental indicators covering various issues showed that, after simultaneous analysis of the variables, there were associations with livable housing, water physical condition, wastewater drainage systems, and waste management (26).

Relationship Between Housing Conditions and Malaria Incidence

Multivariate logistic regression analysis showed a significant relationship between housing conditions and malaria incidence ($p = 0.015$; OR = 0.91). Contrary to expectations, living in substandard housing was associated with 8.8% lower odds of malaria infection than residing in adequate housing. This finding contradicts general theory and is likely influenced by unmeasured confounding factors, such as local malaria control interventions, differences in population mobility, or variations in micro-environmental conditions that affect mosquito exposure. Poor physical housing features such as wall density, floor and roof type, and inadequate lighting can increase the risk of malaria. A study conducted in Tanzania (2020) using multivariate analysis design found that individuals living in low-quality houses had nearly four times the risk of malaria compared to those living in high quality housing (27).

A study in Costa Rica found that incremental improvements in housing quality significantly contributed to the decline in malaria cases, moving the country closer to a pre-elimination stage (28). Conversely, a study in Uganda demonstrated that modern homes could reduce mosquito bites by 53% and gastrointestinal diseases by 24%, though with no effect on malaria or respiratory infections (29). Better housing conditions may help reduce mosquito bites and gastrointestinal diseases among children and adults (30).

Relationship Between Water Physical Conditions and Malaria Incidence

The analysis showed that the majority of respondents (83.2%) reported poor water physical conditions, such as abnormal color, odor, taste, and turbidity. While the combined analysis may not have demonstrated a significant effect, individual characteristics of water quality were found to be associated with malaria incidence. This is consistent with research that tested the effectiveness of *Anopheles stephensi* larvae, showing that polluted water quality influences the development of malaria vector mosquitoes (31).

A meta-analysis conducted in Indonesia (2016–2023) found that poor water physical conditions were associated with a 4.10 times higher likelihood of contracting malaria (OR = 4.10; $p < 0.001$) (32). More specifically, a study in Cameroon mentioned that water quality, particularly conductivity and total dissolved solids (TDS), impacted the larval distribution of *Anopheles gambiae*, the primary malaria vector (33).

Relationship Between Wastewater Drainage Systems and Malaria Incidence

The most influential variable in this study was wastewater management channels, which increased the malaria risk by 20.3%. A significant percentage of respondents (90%) reported inadequate wastewater drainage systems conditions, indicating a significant association with malaria incidence ($p = 0.000$). Open sewerage systems contribute to the growth of malaria, as stagnant water in drains provides an ideal growth habitat for Anopheles mosquitoes. A study in Mimika, Papua, supports this research by showing a statistically significant association between open drainage systems and malaria incidence ($p = 0.006 < 0.05$) (34), which drives the crucial role of wastewater management in malaria prevention efforts.

In line with research from Nigeria, sewerage significantly influences malaria risk, with homes close to the sewerage system having a higher likelihood of infection than those farther away (35). In addition, research in Southwest Sumba shows the presence of open wastewater sources near residential areas significantly increases the likelihood of causing malaria transmission (36).

Relationship Between Waste Management and Malaria Incidence

The results showed a significant relationship between waste management and malaria incidence, with an increased chance of 10.3%. Poor waste management by 74.6% of respondents such as poor waste management, including open dumping, indiscriminate dumping, as well as dumping waste le river or drainage stream. This study is in line with Kinshasa, Congo (2024), which showed a malaria incidence rate with a percentage of 97.2% in areas with inadequate waste management. Logistic regression results showed a strong association, with OR = 6.81 (p = 0.009) (37). In line with the research in Tanzania, it shows that most of the population with waste accumulation as the main factor causing malaria transmission, with a relative importance index of 0.81 (38).

This study is in line with that conducted in Muara Enim, South Sumatra, Poor waste disposal has an association with the development of Anopheles mosquitoes, which emphasizes the importance of waste management aimed at vector control (39). In addition, concurrent research from Paynesville shows that poor sanitation characterized by unmanaged garbage and open drains create conditions for mosquito breeding and increase the risk of malaria growth (40).

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CONCLUSION

These results highlight the essential importance of environmental determinants such as housing conditions, physical quality of water, wastewater drainage systems, and waste management in influencing malaria transmission in Papua, Indonesia. Inadequate wastewater management (OR = 1.203; p < 0.001) and poor waste management practices (OR = 1.103; p < 0.016) were identified as significant risk factors, underscoring the urgent need for integrated environmental sanitation interventions. Interestingly, housing conditions were negatively associated with malaria incidence (OR = 0.884; p = 0.000), which may reflect the influence of unmeasured confounding factors, such as targeted vector control programs or variations in micro-environmental conditions. The physical quality of water, however, showed no statistically significant association. These findings highlight the importance of incorporating environmental management into malaria control strategies, especially in endemic and resource limited regions like Papua, through multisectoral collaboration between health and environmental authorities.

AUTHORS' CONTRIBUTION

YKA: Conceptualization, Methodology, Reviewing, and Editing. PS: Methodology, Writing-Reviewing and Editing. AML: Methodology, Data curation and Writing-Original draft preparation.

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