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SYSTEMATIC REVIEW

The Relationship of Environmental Factors to the Incidence of Malaria in Different Countries: Systematic Review

Muhammad Aandi Ihram[1], Hamzah Hasyim[2], Hilda Zulkifli[3], Didit Haryanto[4]

[1]Master Program, Faculty of Public Health, Universitas Sriwijaya Palembang, Indonesia.
[2]Faculty of Public Health, Universitas Sriwijaya, Palembang, Indonesia.
[3]Faculty of Mathematics and Natural Sciences, Universitas Muhammadiyah, Palembang, Indonesia.
[4]The Provincial Health Office of South Sumatera, Indonesia.

Corresponding Email: [1]10012682125022@student.unsri.ac.id,
[2]hamzah@fkm.unsri.ac.id,
[3]hilda.zulkifli@gmail.com

Abstract: Malaria is a global public health problem and is one of the causes of death caused by mosquito vectors. The risk of malaria is determined by many factors, one of which is environmental factors. The purpose of this study was to decide the environmental of determinants of the effect of malaria in various countries. This research is a descriptive observational study using the systematic review method. These articles are preferred in this study based on several inclusion and exclusion criteria set by the researcher. From the seventy-three selected literature, twenty-two articles apply in this study, including four articles discussing the incidence of malaria in general, five articles discuss the relationship between breeding places and the incidence of malaria, three articles discuss the relationship between land use change and the incidence of malaria, five articles discuss the relationship of building construction to the incidence of malaria, five articles discuss the relationship of meteorological factors to the incidence of malaria. Environmental factors have a significant relationship with the risk of malaria in various countries. Therefore, appropriate prevention and control strategies for an early warning and preparedness system for malaria prevention.

Keywords: Environmental Factors, Malaria, Systematic review

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INTRODUCTION

Malaria is a global public health problem. Based on the World Malaria Report 2021 report, around 241 million malaria cases occurred in 2020, with an estimated death toll of 602,000 people in 85 malaria endemic countries around the world.

The African region still bears the brunt of malaria morbidity (95%), followed by the Eastern Mediterranean region (5%), and the Southeast Asian region (2%).[1] global commitment through the Sustainable Development Goals (SDGs) contained in goal 3, namely ensuring a healthy life and seeking welfare for everyone, with specific goals, one of which is to end malaria until 2030. [2]

The risk of malaria is determined by many factors, including the type of Anopheles mosquito species, behavioral factors, environmental factors, and the presence of malaria parasites. Changes in each of these factors will affect the risk of malaria. (3-5) Currently, the world's attention to the risk of malaria is leading to the potential impact of environmental changes globally. Changes in the geographical environment of malaria have changed in response to climate change, land use patterns, biodiversity (biodiversity), and sociodemographic structures (including urbanization).[6] In addition, the malaria problem that continues to develop today is related to the weak efforts to reduce the incidence of malaria, such as the existence of breeding places (breeding grounds) of mosquitoes that spread in locations that are difficult to reach and home environmental conditions that do not meet health requirements (ventilation, ceiling roofs, inadequate house walls).[7]

Several studies in various countries, such as Indonesia, Haiti, France, Malaysia, Egypt, Kenya, Uganda, Pakistan, Ethiopia, Burkina Faso, Tanzania, America, Eritrea, South Africa, Malawi, and Sinegal show that environmental factors have a relationship to the incidence of malaria. Based on the description above, researchers are interested in conducting a systematic review study on "The Relationship of Environmental Factors to Malaria Incidence in various countries". The purpose of this study is to determine the relationship between environmental factors and malaria incidence that occurs in various countries.

METHOD

This research is an observational, descriptive study using the systematic review method. Reviews, summaries, and thoughts from several library sources are discussed according to systematically determined topics. The articles selected in this study are based on several criteria set by researchers, namely national and international journals that examine environmental factors that affect the incidence of malaria, are available in the form of full text (not only abstract), research article type with various research designs, and an indeterminate time span.

The identification results were obtained from several sources, such as Google Scholar, Pubmed, Science Direct,

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and DOAJ. The keywords used in the source search are "Malaria, Risk Factors of Malaria, Environmental Risk Factors of Malaria". The articles selected in this study are based on several inclusion and exclusion criteria set by the researcher.

Based on 73 articles that have been determined by researchers on environmental risk factors and malaria incidence, 22 articles were selected that were used in this study.

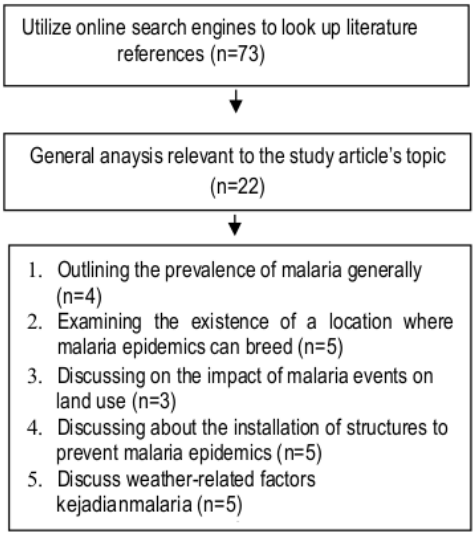

Figure 1. Prism Diagram

RESULT

Based on the 22 articles used in this study, 4 articles discussed the prevalence of malaria in general, 5 articles covered mosquito shelters for malaria events, 3 articles covered changes to mosquito shelters for malaria events, 5 articles covered building construction for malaria-resistant construction, and 5 articles covered meteorological factors for malaria-resistant construction. These publications' research is of the study type case control, cross-sectional, cohort, systematic review, meta-analysis, studi parasitologi dan entomologi systemic, distributed lag non linear modeling, spatial analysis, surveillance demographic, literature review, retrospective data analysis, r software was used to statistically analize the data.

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Tabel 1. Karakteristik Artikel yang di Identifikasi

Sumber	Negara	Metode	Hasil
Ashton et al., (2020) "Risk Factors for Malaria Infection and Seropositivity in the Elimination Area of Grand'Anse, Haiti: A Case–Control Study among Febrile Individuals Seeking Treatment at Public Health Facilities"	Grand' Anse, Haiti	*Case Control Study*	There were 192 cases (positive RDT) and 915 controls (negative RDT) in total. For all three infection and exposure metrics, consistent spatial clusters were identified, demonstrating the temporal stability of malaria transmission at these sites. Malaria risk factors in Grand'Anse are largely determined by the individual's location, including distance from health facilities, housing with porous walls that allow mosquitoes to enter easily, and proximity to forest areas. They are all linked to an increased likelihood of a positive RDT.
Awosolu et al., (2021) "A cross-sectional study of the prevalence, density, and risk factors associated with malaria transmission in urban communities of Ibadan, Southwestern Nigeria"	Ibadan, South-western Nigeria	*Cross Sectional Study*	165 (55.0%) of the 300 participants tested positive for Plasmodium falciparum, with an average (SD) parasite density of 1814.70 (1829.117) parasites/L blood. The prevalence and density of malaria infection parasites vary widely by age group (P 0.05). Children aged 5 years are more likely than adults to have malaria infection and a high parasite density (p 0.05). Similarly, in terms of sex, males had a higher prevalence (60.2%) and an average parasitic density (SD) of malaria infection [2157.73 (1659.570) of parasites/L blood] than females. Furthermore, those without a formal education had the highest prevalence (73.0%) and the highest average parasite density (SD) of infection [2626.96 (2442.195) parasitic/L blood. The presence of rivers or streams within a distance of -1 km was found to be the most significant risk factor for malaria events in a multivariate logistic regression analysis.
Sulistyawati et al., (2020) "Malaria Risk Factors in Banjarnegara, Indonesia: A Matched Case-Control Study"	Banjar-negara, Indonesia	*Case Control Study*	The study included 50 participants in total, with 25 cases and 25 controls. Chi-Square, Fisher Exact, and logistic regression were used to analyze the data. Malaria and not sleeping under mosquito nets (OR=2,087 [95% CI: 1,148_3,795]), not using wire in home ventilation (OR = 3.907 [95% CI: 0.647_24.452]), and inadequate preventive practices during outdoor activities (OR = 2,020 [95% CI: 1,033_3,953] were found to have a positive relationship.
Stefani et al., (2011) "Environmental, entomological, socioeconomic and behavioural risk factors for malaria attacks in Amerindian children of Camopi,	Camopi, French Guiana	*Cohort Study*	There were 238 per 1,000 children infected with Plasmodium falciparum, 514 per 1,000 people infected with Plasmodium Vivax, and 21 per 1,000 people infected with the mixture over a 9-year period (2001-2009). According to the findings, the incidence of malaria was higher in respondents who lived near the Camopi River and the banks of the Oyapock River, while the risk was lower in houses cleared of vegetation and more than 50 meters away from the forest. Meteorological and hydrological characteristics

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French Guiana"			such as temperature, water level, and climate also play a role in malaria incidence.
Sumber	**Negara**	**Metode**	**Hasil**
Steven et al., (2020) "Host and Environmental Factors that Influence Plasmodium Knowlesi Malaria Infection in Humans: A Systematic Review"	Sabah, Malaysia	*Systematic Review*	Plasmodium Knowlesi infection is associated to host factors such as (gender and age, as well as occupation) and environmental factors such as (land clearing that causes ecological changes, distance of residence, rainfall, and geographical height).
Bannister-Tyrrell et al., (2017) "Defning micro-epidemiology for malaria elimination: systematic review and meta-analysis"	21 negara	Systematic review dan Meta-analy- sis	51 studies were selected from 743 records collected, representing a population of more than 160,000 people in 21 countries with high and low endemism. Sixty-five risk factors were identified, with meta-analyses performed on 11 of them. Most studies focused on environmental factors, especially increased distance from mosquito breeding sites (OR 0.89.95% CI 0.86-0.92,10 studies). Individual mosquito nets provide protection (OR 0.63.95% CI 0.52-0.77, 12 studies). Malaria infection was associated with increases in home size (OR 1.08, 95% CI 1.01-1.15, 4 studies) and household density (OR 1.79, 95% CI 1.48-2.16, 4 studies).
Nuraisyah et al., (2021) "The Spatial Analysis for Malaria Surveillance in Yogyakarta Special Region, Indonesia: A Cross Sectional Study"	Yogyakar-ta, Indonesia	*Cross Sectional Study*	Malaria cases are increasing in watersheds (DAS) at a distance of 250 meters in Kokap District. The majority of malaria cases are found in rice fields within 250 meters of each other in Samigaluh District. The 250-meter plantation area in Nanggulang and the 250-meter forest area in Kalibawang District are where all malaria cases have been found. The buffering of malaria locations, that rivers, rice fields, and gardens are places prone to malaria transmission, can be seen in the spread of malaria cases.
Dahesh et al., (2009) "Socio economic And Environmental Factors Affecting Malaria Infection In Fayoum Governorate, Egypt"	Mesir	Studi parasitologi dan entomologi sistemik	Malaria infections are increasing with declining socioeconomic levels of families, the level of education of individuals examined, and among the unemployed or students, according to research. Infections are becoming widespread among those who live in muddy or poorly constructed houses near breeding grounds. Infection rates are significantly lower among those who have animal cages and a massive amount of animals. Malaria infection is unaffected by the use of malathion 5% indoors.
Lewinsca et al., (2021) "Risk Factors Affecting the Incidence of Malaria in Indonesia: A Literature Review 2016-2020"	Indonesia	*Literature Review*	According to the results of this study, environmental, behavioral, knowledge, attitude, preventive measures, socioeconomic, and demographic factors all contribute to the malaria epidemic. The use of mosquito nets, the presence of breeding places, the habit of going out at night, and the use of mosquito repellent are the dominant risk factors as the cause of malaria events in Indonesia, thus according 22 articles studied based on literature studies.
Eyanoer, (2018) "Dominant risk	Indonesia	*Case Control*	As many as 146 samples were taken based on the samples taken. All cases are registered patients at the

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factors for malaria at Puskesmas Labuhan Ruku, Talawi Batu Bara, Indonesia"		*Study*	Labuhan Ruku Health Center, and the control comes from the case's nearest neighbor. The results revealed that the use of repellent and being outside at night seemed to have the greatest influence on the incidence of malaria. Furthermore, there is a significant connection between the presence of puddles and the construction of buildings on malaria events.
Sumber	**Negara**	**Metode**	**Hasil**
Sewe et al., (2016) "Remotely Sensed Environmental Conditions and Malaria Mortality in Three Malaria Endemic Regions in Western Kenya"	Kenya	Pendekatan *Distributed Lag Non Linear Modeling*	The study identified lag patterns and associations between remote sensing environmental factors and malaria mortality in three malaria endemic areas of Western Kenya. Our results show that rainfall and temperature have the most consistent malaria transmission prediction patterns in malaria endemic research areas.
Musoke et al., (2018) "Malaria prevention practices and associated environmental risk factors in a rural community in Wakiso district, Uganda"	Wakiso district, Uganda	*Cross Sectional Study*	471 (64.8%) of the 727 households had at least one mosquito net. The higher the level of education and income, the more mosquito nets are used in households. Furthermore, participants who weren't working were less likely to use mosquito nets in their homes (aPR = 0.83 [95% CI: 0.70-0.98]). In the previous 12 months, 42 (5.8%) homes had undergone the IRS, while 220 (43.2%) households closed their windows before 6:00 p.m. The presence of vessels 414 (56.9%) and waterlogging in the complex 144 (19.8%) are environmental risk factors associated with the incidence of malaria in the household. Furthermore, the construction of buildings in houses that can trigger mosquito entry, such as the lack of filtering on the ventilator 645 (94.7%), and the outer door that does not fit the wall, allowing mosquito entry 305 (42.0%).
Umer et al., (2019) "Effects of Socio-Environmental Factors on MalariaInfection in Pakistan: A Bayesian Spatial Analysis"	Pakistan	Analisis Spasial	Over a three-year period, there were more than 750,000 confirmed cases of malaria in 136/146 districts in Pakistan (2013–2015). The maximum temperature (7.41104. 0.00140%, 1.05104%) was inversely proportional to malaria in Pakistan during the study period, while the minimum temperature (0.1398, 0.05275%, 0.2145%) was directly proportional. Spatial random effects maps show that relatively moderate risk clusters (RR, 0.75 to 1.24) and high RR (1.25 to 1.99) are spread equally across the country than low RR clusters (0.23 to 0.74). The annual incidence of malaria in Pakistan is influenced by socio-environmental factors.
Tsegaye et al., (2021) "Prevalence and associated factors of malaria in children under the age of five years in Wogera district, northwest	Wogera district, Ethiopia	*Cross Sectional Study*	Malaria was found in 51 (8.7%) of the 585 children who provided blood samples. Plasmodium falciparum was found in 33 (65%) of the cases and P. vivax in 18 (35%). Regular use of insecticidal mosquito nets (LLIN) was associated with a lower risk of malaria (AOR = 0.08.95% CI: 0.01-0.09). Children living in households with puddles in the complex have a higher risk of malaria (AOR = 6.7.95% CI: 3.6-12.6), as do children living outside at night (AOR = 5.5.95% CI: 2.7-11.1).

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Ethiopia: A cross sectional study"			
Fornace et al., (2019) "Environmental risk factors and exposure to the zoonotic malaria parasite Plasmodium knowlesi across northern Sabah, Malaysia: a population-based cross sectional survey"	Sabah, Malaysia	*Cross Sectional Study*	Between September 17, 2015 and December 12, 2015, a total of 10,100 people from 2,849 households in 180 villages were sampled, with an average age of 25 years (03 months - 105 years). Plasmodium vivax, falciparum, malaria, and knowlesi were found in nine samples. Age, gender, ape contact, forest use, and home construction are all associated with increased exposure, whereas higher geographic altitudes and insecticide use are protective. Agricultural and forest variables, such as land cover type proportion and fragmentation, predict exposure at different spatial scales in each household.
Sumber	**Negara**	**Metode**	**Hasil**
Rouamba et al., (2019) "Socioeconomic and environmental factors associated with malaria hotspots in the Nanoro demographic surveillance area, Burkina Faso"	Burkina Faso	*Surveillance Demogra-phic*	That social and environmental factors play an important role in malaria transmission. With time lags of 9 and 14 weeks, respectively, rainfall and temperature were positively and significantly associated with malaria incidence. During the study period, there was relatively stable spatial autocorrelation of significant malaria and host events, according to spatial analysis. Furthermore, low socioeconomic status households are strongly associated with malaria incidence (OR = 1.21, 95% confidence interval: 1.03-1.40).
Mosha et al., (2020) "Risk factors for malaria infection prevalence and household vector density between mass distribution campaigns of long-lasting insecticidal nets in North-western Tanzania"	Tanzania	*Cross Sectional Study*	27.7% of people used LLIN. Only 16.9% of households have enough mosquito nets to cover all of their beds. Malaria infection is associated with LLIN access (OR: 0.57; 95% CI 0.34-0.98). LLIN less than 2 years old is slightly more protective than older LLIN (53 vs 65% infection prevalence), while there is no evidence that LLIN in good condition (hole index 65) is more protective than perforated LLIN. Age, group, the height of the premises, and the quality of house construction are all risk factors for malaria infection. Altitude, wind, livestock, home quality, open roofs, and LLIN use are independent risk factors for vector density which are consistent with malaria outcomes. The indoor collection consists of 4.6% Anopheles funestus and 95.4% Anopheles gambiae of which 4.5% are Anopheles arabiensis and 93.5% are Anopheles gambiae sensu.
Fornace et al., (2021) "Achieving global malaria eradication in changing landscapes	Amerika Tenggara dan Selatan	*Literature Review*	Malaria transmission is very complex and specific; changes in the environment and demographics in specific settings can lead to an increase or decrease in malaria risk. Due to the interactions between the environment and intrinsic factors such as species composition and ecology, demographic changes affecting socioeconomic status, risky behaviors, and access to control measures, impacts can vary by space and time.
Mihreteab et al., (2020)	Eritrea	*Retrospective*	The limit of more than 97% by the end of 2017 indicated a decrease in malaria mortality. Malaria incidence

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"Retrospective data analyses of social and environmental determinants of malaria control for elimination prospects in Eritrea"		*data analysis*	decreased during the period (from 33 to 5 per 1000 inhabitants), indicating a decrease of at about 86% (R2 = 0.3), slightly smaller than the decrease in deaths. In general, the distribution of insecticidal mosquito nets decreased between 2001 and 2014 (R2 = 0.16) and increased from 2015 to 2017, while the number of people spraying indoor residue increased slightly (R2 = 0.27). Higher rainfall is strongly connected to an increase in the number of malaria cases. Rainfall and temperature covariates predict malaria incidence better than irs and LLIN. The IRS and LLIN, on the other hand, are a more significant pairing for predicting death cases.
Sumber	**Negara**	**Metode**	**Hasil**
Tiu et al., (2021) "Literature Review: Impact Of Temperature And Rainfall On Incident Malaria"		*Literature Review*	This review reveals that temperature and rainfall have an impact on the incidence and spread of malaria. High temperatures and rainfall contribute to an increase in malaria cases over time. The study's result support the need for an early warning system as part of malaria prevention plans. The combination of environmental factors, geographical conditions and spatial stratification of the region, socioeconomic factors, and public health interventions in relation to malaria incidence needs to be investigated further.
Adeola et al., (2016) "Environmental factors and population at risk of malaria in Nkomazi municipality, South Africa"	Nkomazi, Afrika Selatan	*R software was used to statistically analyse data*	Between January 1997 and August 2015, a total of 60,718 malaria cases were reported in 48 health facilities in the municipality of Nkomazi. Malaria is strongly associated with irrigated land (P = 0.001), bodies of water (P = 0.011), and heights of 400 m (P = 0.001). According to the multivariate model, a 10% increase in the area of irrigated areas increased the risk of malaria by nearly 39% throughout the study area and by nearly 44% in the 2 km buffer zone in selected villages. Malaria is more prevalent in the economically active population aged 15-64 years and in men. During the study period, both the incidence and mortality rate of cases decreased dramatically.
Siregar, Tarigan and Hasibuan, (2021) "Analysis of Risk Factors Malaria Incidence in Indonesia (Data Analysis of Basic Health Research 2018)"	Indonesia	*Cross Secrtional Study*	According to the results of this study, the majority of respondents aged >24 years suffered from malaria as many as 14,769 (55.4%), female respondents suffered from malaria as many as 13,827 (51.9%), respondents with low education suffered from malaria as many as 19,926 (74.7%), respondents who worked with malaria as many as 15,570 (58.4%), respondents living in rural areas suffered from malaria as many as 18,558 (69.6%), and respondents who slept without mosquito nets suffered from malaria. Malaria affected 18,104 respondents who did not use repellent (67.9%), 14,059 (52.7%) respondents who did not use mosquito coils in home ventilation, and 22,369 (83.9%) respondents in Indonesia suffered from malaria as many as 8.076 (30,3%).

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DISCUSSION

1. **The Existence of a Breeding Location**

   The existence of a breeding place (breeding ground) for mosquitoes is a risk factor for malaria transmission. Breeding places can be rivers, rice fields, sewers or ditches, puddles, wells, ex-dug basins, pot containers, and other places of standing water. Based on the results of previous studies, it was stated that a person whose place of residence is adjacent to the breeding place is at a 5,077-times greater risk of malaria transmission than someone whose place of residence is far from the breeding place.[7] This is in line with research conducted in the French country using cohort studies over a period of 9 years stating that there was a higher incidence of malaria in respondents who lived near the lower and upper reaches of the Camopi and Oyapock rivers and were adjacent to forests compared to respondents who were far away from rivers and forests with lower case findings.[8]

The study of spatial analysis and buffering analysis of malaria locations illustrates that the radius of locations such as rivers, rice fields, parks and gardens is a risk factor for malaria transmission. In this study, the distance with a radius of <250 meters were used as an estimate of the size limit or radius of the nearest or farthest location from the case with the potential breeding ground for Anopheles mosquitoes. The results showed that mosquito breeding areas such as rivers, rice fields, standing water, parks, and plantations are potential habitats that are at high risk of malaria transmission. In the buffer zone of 500 meters, positive malaria cases were found at a distance of <250 meters from the area where mosquitoes breed. This is because the risk factor is a necessary medium for the oviposition and breeding stage of mosquito larvae and as a resting place for Anopheles mosquitoes during the day.[9]

Research conducted in Ethiopia found that risk factors for malaria incidence in children under the age of 5 years are prevalent in those who live around their homes where there is standing water. This is because water storage is one of the favorable conditions for mosquito breeding, which in turn increases the transmission of malaria.[10] In line with research conducted by rural communities in Uganda's Wakiso district on strategies for preventing and managing the environment against malaria, this practice found that environmental management by eliminating mosquito breeding sites on 56.9% of houses that had vessels that had the potential to hold standing water for mosquito breeding, and 76.3% had plants within 5 meters. The results of this preventive practice have shown hope in the control of malaria vectors in the premises.[11]

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2. **Changes in Land Use**
   Land use changes, such as deforestation and agricultural expansion, have been linked to changes in the dynamics and geographical distribution of malaria and other vector-borne diseases globally. A growing body of evidence suggests that changes in the anthropogenic environment can also alter the human risk of malaria parasites. Transmission tends to be driven by ecological changes that affect the proximity between humans and mosquito vectors. As reported in parts of Malaysia, the leading cause of malaria in humans, the highest proportion is due to the loss of forest global hotspots due to rapid land conversion for agricultural activities that have been shown to affect the presence of disease reservoirs and vectors in disturbed forest areas.[12]

Land cover refers to the physical and biological cover of terrestrial surfaces such as water, soil, vegetation, and infrastructure, while land use refers to the management and human activities that modify land surface processes. The impact on vector biology directly affects the Anopheles mosquito population, changing the abundance, species composition, and life cycle of the malaria vector. Ecological changes in the soil, sun cover, vegetation type, and water temperature affect the breeding conditions of malaria vectors with varying effects on each anopheles species. For example, deforestation reduces shady water bodies, preferred breeding habitats of some Anopheles species. Anopheles species develop in water bodies with increased direct sunlight that can improve larval survival, adult mosquito productivity, intrinsic growth rates, and shorten gonotrophic cycles significantly so as to increase vector capacity.[13] Based on research conducted in South Africa, the incidence of malaria is strongly associated with irrigated land, water bodies, and altitude. The results of the analysis showed that with a 10% increase in the area of irrigated areas, the risk of malaria increased by almost 39% throughout the study area and by almost 44% in the 2 km buffer zone in selected villages.[14]

3. **House Building Construction**
   The construction characteristics of a house building, including the overall quality of construction, such as walls, windows, roofs, and floor materials, are associated with the risk of malaria transmission.[15] Individuals living in households that do not have walls or wall structures made of elongated leaves or bamboo are found to have a chance of becoming infected with malaria. This type of house structure leaves a large gap in the wall that allows mosquitoes to enter the house easily. These results confirm that those living in households with walls made of unsealed natural

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materials or without walls have a higher risk of developing mosquito bites indoors.[16] According to the results of a study conducted in Egypt on the risk factors of house building construction and the incidence of malaria, among infected people (35.5%) lived in houses made of muddy walls and wooden ceilings, (46.7%) lived in houses made of red brick walls and wooden ceilings, and (17.8%) lived in modern houses made of red brick walls and cement ceilings. The study compared sub-samples of malaria-infected and uninfected people based on the type of house construction. The resultss show that well-built houses can reduce malaria infection rates when compared to poorly constructed houses.[17] According to research conducted in Northwest Tanzania on risk factors for malaria infection and vector density in households, approximately (76.8%) of household building constructions were built with earthen walls and floors, and (61.2 %) of houses had open roofs. According to the results, children living in livable homes had a lower risk of malaria infection than those living in uninhabitable homes (OR 0.27; 95% CI 0.13-0.54), and individuals living in open-roof homes had a stronger association with malaria infection than those living in houses with closed roof slits (OR 0.59; 95% CI 0.51-0.69).[18]

4. Meteorological Factors

Malaria transmission is closely related to climatic conditions such as temperature and rainfall, which can affect environmental conditions and thus Anopheles vector breeding. Changes in rainfall, such as an increase in rainfall at certain periods followed by a long dry season, as well as temperature increases, have an impact on the life cycle of mosquitos and parasites that cause malaria.[19] Meteorological factors such as rainfall, temperature, season, and humidity have been shown to have a temporal and spatial relationship with the incidence of malaria. These meteorological factors, when combined, increase the duration of larval development, shorten the incubation period of parasites, prolong mosquito survival, provide a favorable swamp habitat for vectors, and increase the number of mosquitoes and their bites, all of that are positively associated with malaria incidence.[20]

The modified nature and human environments interact to create favorable conditions for mosquito vector abundance. Precipitation causes puddles, which provides as an ideal breeding ground for vectors, whereas temperature determines the development of Anopheles mosquitoes. Using a non-linear lag distribution modeling approach, the researchers modeled the relationship of exposure

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response between three variables (temperature, rainfall, and vegetation index) and malaria mortality in three regions of Western Kenya. The results revealed a non-linear relationship and delayed effect between the three variables' data and consistent malaria mortality across the three study regions in Western Kenya, illustrating how meteorological patterns drove vegetation changes and were a precursor to malaria deaths in the study area. This supports biological interactions between malaria vectors, parasites, and humans as hosts, that the result in malaria incidence, morbidity, and mortality.[21]

According to longitudinal observational studies conducted in the country of Burkina Faso, rainfall and humidity were positively and significantly associated with malaria events with a time lag of 9 weeks. The 9-week time lag represents the period of time between the peak of rainfall and the peak of malaria incidence (increase in malaria cases). The second component revealed that, with a 14-week lag, temperature was positively and significantly related to malaria cases.[22] A similar research conducted in Eritrea discusses key strategic efforts and the implications of interventions used in investigating the role of climate parameters in the spread of malaria cases. Higher temperatures are associated with decrease malaria cases, whereas higher rainfall is associated with an increase in the number of malaria cases. Low temperatures during the rainy season support the spread of malaria. Temperature and rainfall changes are very crucial in predicting the number of malaria cases and deaths.[23]

CONCLUSION

Based on the results of the systematic review study above, it can be concluded that environmental factors have a significant relationship with the incidence of malaria in various countries. To overcome these problems, appropriate prevention and control strategies are needed, as is the need for an early warning system and malaria prevention preparedness. The combination of environmental factors, such as geographical conditions and spatial stratification of the region, socioeconomic factors, and public health interventions related to the incidence of malaria needs to be further studied.

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