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## **Environmental Risk Factors that Influence Malaria Incidence: Literature Review**

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### **ABSTRACT**

**Background:** Malaria is an infectious disease that continues to pose a global health threat. Malaria cases will reach 247 million in 2021, with malaria accounting for an estimated 619,000 fatalities worldwide. Indonesia is the second largest provider of malaria cases in the WHO South-East Asia Region, trailing only India. In 2020, Indonesia contributed 254,050 positive cases of malaria. In 2021, the number of cases has risen to 304,607.

**Objective:** The goal of this research is to determine the factors of the physical condition of the house (including the use of wire mesh for ventilation, the presence of ceilings, and the density of walls) and the environment around the house (including the presence of bushes, puddles of water, and livestock pens) that influence the incidence of malaria.

**Method:** This research is a literature review that use the Preferred Reporting Items for Systematic Reviews and Meta-analyses (PRISMA) technique. The literature search was carried out on the internet using Google Scholar. Out of the search results, 11 articles were chosen for review.

**Results:** The results of this study indicate that the use of wire mesh for ventilation, the presence of ceilings, the density of walls, the presence of bushes, the presence of standing water, and the presence of livestock pens in the environment surrounding the house are risk factors that influence the incidence of malaria.

**Conclusion:** The physical condition of the house and the quality of the surrounding environment are both important factors to consider in malaria prevention measures.

**Keywords:** Malaria Incidence; Risk Factors; Environment

## INTRODUCTION

Malaria is an infectious disease that continues to pose a global health threat. *Plasmodium*, which are single-celled organisms (*protozoa*), are responsible for this sickness. The parasite enters the human body by a bite from a female *Anopheles* mosquito. Malaria sufferers commonly complain of fever, chills, sweating, headaches, nausea, vomiting, diarrhoea, and muscle discomfort or pains. Furthermore, malaria can directly cause anaemia, splenomegaly, and hepatomegaly. Malaria can be fatal, particularly in high-risk groups such as newborns, toddlers, and pregnant women (1). According to the World Health Organization's (WHO) World Malaria Report 2022, malaria cases are expected to exceed 247 million in 2021, with an anticipated 619,000 fatalities worldwide owing to malaria. These cases have increased from the previous year, but at a slower rate compared to the period 2019 to 2020. In the first year of the pandemic, the global tally of malaria cases reached 245 million with a death toll of 625,000, whereas before the pandemic hit there were 232 million confirmed cases of malaria with 568,000 number of deaths in 2019 (2).

Indonesia is the second largest contributor to malaria cases in the WHO South-East Asia Region, trailing only India (2). In 2020, Indonesia reported 254,050 positive malaria cases (3). This figure has risen to 304,607 instances in 2021. From 2015 to 2020, Indonesia successfully reduced the Annual Parasite Incidence (API) to fewer than one. However, in 2021, the API climbed from 0.94 to 1.12 per 1,000 people. The highest malaria API is still concentrated in eastern Indonesia, specifically in the regions of Papua, West Papua, and East Nusa Tenggara. To reduce the incidence of malaria, currently malaria control efforts have been designated as part of the Sustainable Development Goals (SDGs), namely as a global goal that must be achieved by 2030. At the national level, the malaria elimination program is listed in the Decree of the Minister of Health of the Republic of Indonesia Number 293/Menkes/SK/IV/2009 dated 28<sup>th</sup> April 2009 concerning "Elimination of Malaria in Indonesia" (4).

The emergence of malaria is produced by the interaction of several elements, including the host, agent, and environment. Environmental influences are classified as physical, biological, chemical, and socio-cultural. Temperature, humidity, rainfall, height, wind speed, and the state of the house are all part of the physical environment. Meanwhile, the biological environment consists of cattle management and cage structure, diverse vegetation (mangroves, moss, algae), and natural mosquito predators. The chemical environment, such as water pH and salinity. Socio-cultural environmental factors include the practice of undertaking activities outside the home at night, the usage of mosquito nets, the use of mosquito repellent, and visits to endemic areas (5). However, from all of these risk factors, the aim of this research is to determine the physical condition of the house (including the use of wire mesh for house ventilation, the presence of the house ceiling, and the density of the house walls) and the environment around the house (including the presence of bushes, the presence of standing water, and the presence of livestock pens) which influence the incidence of malaria.

## METHOD

That research is a literature review that employs the Preferred Reporting Items for Systematic Reviews and Meta-analyses (PRISMA) technique. The literature search was carried out on the internet using Google Scholar. The keywords "malaria incidence" AND "risk factors" AND "environment" are used in the literature search approach. The inclusion criteria were as follows: the type of literature study was an article or research journal, the article was published between 2019 and 2023, the article contained research on environmental risk factors that influence malaria incidence, the research article had a case control design, the article was written in Indonesian, and the article was freely accessible.

Based on the search results for the keywords above, 985 articles were found in the Google Scholar database. Following that, a selection was made to filter out similar items, leaving 856. The 856 articles were reselected based on the inclusion criteria. A total of 844 articles were excluded, including published articles other than 2019-2023 (490 articles), articles that were not relevant to the topic (308 articles), literature reviews (12 articles), theses (16 articles), cross-sectional design articles (12 articles), English articles (3 articles), and inaccessible articles (3 articles). The number of articles remaining after selection based on the inclusion criterion, which is 12 articles. Then, from this number, it was re-selected and 1 article was excluded because it was an article that discussed factors that influence the incidence of malaria in pregnant women. A total of 11 articles were reviewed.

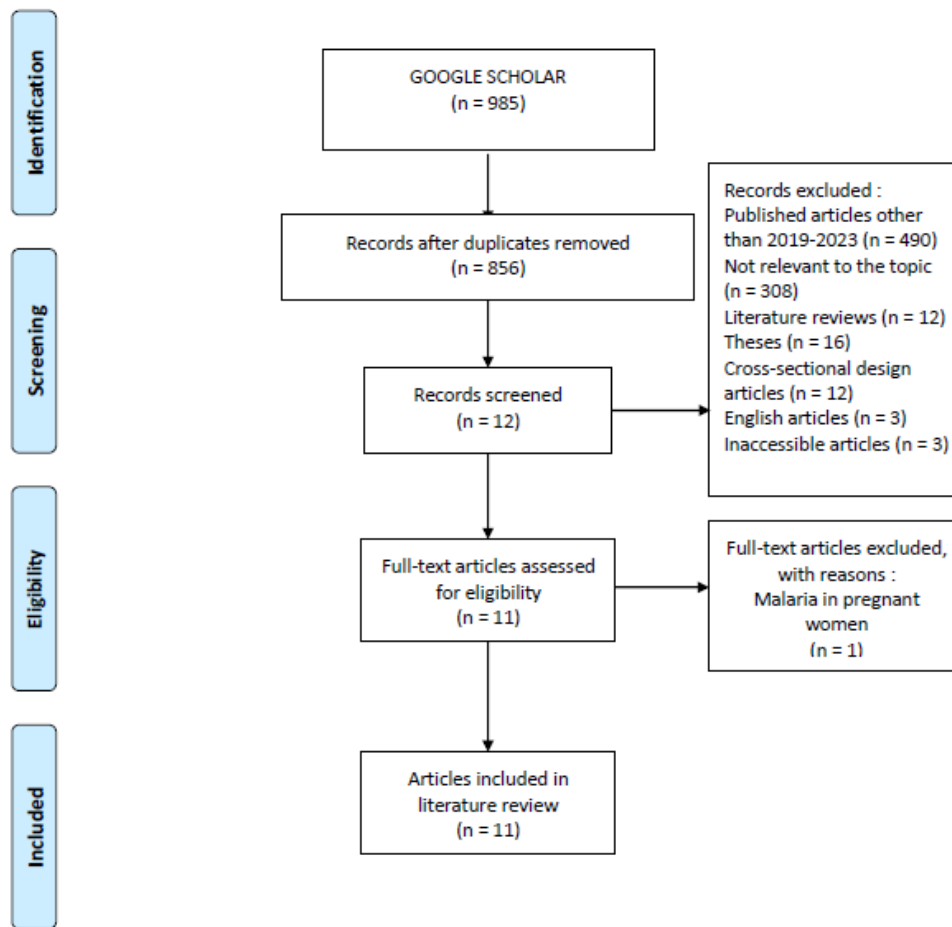


Figure 1. Collection of articles with PRISMA flow diagrams

RESULTS

Table 1. Related article

No	Researcher	Title	Variable	Design	Research result
1.	Fitni Hidayati, Mursid Raharjo, Martini, Nur Endah Wahyuningsih, Onny Setiani (2023)	The Relationship between Environmental Quality and Malaria Incidence (Malaria Endemic Area, Scope of Work of Kaligesing Community Health Center, Purworejo Regency, 2022)	Wire mesh, condition of walls, ceilings, livestock pens, bushes, and breeding place	Case control	The study's findings indicate that wire mesh, ceilings, livestock pens, bushes, and breeding place are significant environmental factors in the incidence of malaria
2.	Iwan Desimal, Moch. Taufik Hidayatullah, Muhammad Fauzi, Endang Setiawaty (2023)	Relationship between Ecological Factors and Malaria Incidence in Malaria Prone Areas, Sekotong District, West Lombok Regency	Ecological or environmental aspects (tailings ponds, excavation remains from unlicensed gold mining, ditches, cages, gardens/bushes, and hills) and geography (height of the location)	Case control	The research results reveal that there is a relationship between the existence of ditches, cages, gardens/bushes, and the height of the region, with the incidence of malaria

3.	Renold Markus Mofu (2022)	Biological Environment, Behavior and Nutritional Status with Malaria Incidence in the Hamadi Community Health Center Working Area	The presence of puddles of water, bushes, larvae, behaviour of using mosquito repellent, behaviour of using mosquito nets, behaviour of leaving the house, behaviour of wearing long clothes, behaviour of opening doors, behaviour of opening windows, and nutritional status	Case control	The study found a link between the presence of standing water, bushes, mosquito larvae, the use of mosquito repellent, the behaviour of being outside the house at night, the behaviour of opening the door of the house at night, nutritional status, the behaviour of wearing long clothes, and the incidence of malaria
4.	Sitti Madayanti, Mursid Raharjo, Hary Purwanto, (2022)	Risk Factors that Influence Malaria Incidence in the South Jayapura District Area of Jayapura City	The density of the walls of the house, the existence of the ceiling/ceiling of the house, the presence of screens in the ventilation, the existence of a breeding place, the existence of a resting place, the degree of knowledge, attitudes and actions	Case control	The results of the study show that risk factors that are related to the incidence of malaria are the density of the walls of the house, the presence of the ceiling/ceiling of the house, the presence of screens in the ventilation of the house, the existence of a breeding place, the existence of a resting place, and actions
5.	Suriyani, Elen R.V. Purba, Frengky Apay (2022)	Analysis of Risk Factors for Malaria Incidents in the Arso City Health Center Area, Keerom Regency, Papua Province in 2022	Environmental risk factors in the house (cleanliness of the house, house walls, ventilation, and temperature), environmental risks outside the house (puddles of water, rice fields, and bushes), and community behavior (habits of using mosquito nets, habits of using mosquito repellent, and habits being outside the house at night)	Case control	The study's findings indicate that house cleanliness, the use of mosquito nets, temperature, living near rice fields, the presence of standing water, the presence of bushes, and the habit of staying outside the house are the most closely associated and relevant factors in malaria incidence
6.	Frans Manangsang, Abdul Ganing, Elen R. V. Purba, Ester Rumaseb, Raden Jaka Sarwadhamana (2021)	Analysis of Environmental Risk Factors for Malaria Incidence in Kerom Regency, Papua Province	Pets, puddles and bushes	Case control	The study's findings revealed that the presence of bushes and standing water near the house was one of the environmental factors associated with malaria incidence
7.	Putra Apriadi Siregar, Izzah Dienillah Saragih (2021)	Malaria Risk Factors for Coastal Communities in Pantai Cermin District, Serdang Bedagai Regency	Ventilation mesh, type of house walls, the presence of animal pens, individual activities outside the house at night, and the usage of insecticide-treated	Case control	According to the study's findings, the type of house walls, individual activities that require leaving the house at night, and the usage of insecticide-treated mosquito nets while sleeping

			mosquito nets while sleeping		are all risk factors for increasing malaria transmission
8.	Hermanto Putra, Muhammad Badiran, Arifah Devi Fitriani (2020)	Factors Influencing Malaria Incidence in the Leuser Community Health Center Working Area, Southeast Aceh Regency, Aceh Province	Air temperature, puddles of water, distance between the house and the breeding place, animal cages, lights, house walls, mosquito repellent, habit of leaving the house at night, counselling, house spraying, and treatment	Case control	The study's findings indicate that standing water, distance between the house and the breeding place, the presence of animal cages, house walls, the use of mosquito repellent, counselling, and treatment all have an impact on malaria transmission
9.	Nur Hamdani N, Kartini, Misrykordiati Mira (2020)	Factors Associated with Malaria Incidents in the Work Area of Wandai Health Center, Wandai District, Intan Jaya Regency, Papua	The existence of animal pens, the existence of mosquito breeding sites, the practice of using mosquito nets, the habit of leaving the house at night	Case control	The study's findings revealed that the existence of brooding sites near the dwelling, the use of mosquito nets, and the practice of leaving the house at night were all linked to the occurrence of malaria
10.	Deviani Utami, Tusy Triwahyuni, Yelin Julita (2019)	The Relationship between Home Environment and Malaria Incidence in Sidodadi Village, Pesawaran Regency in 2018	Bushes, animal pens, and ponds/ditches	Case control	The research results show that there is a relationship between the occurrence of malaria and bushes, animal pens, and puddles of water or ditches
11.	Laila Isnaeni, Lintang Dian Saraswati, M. Arie Wuryanto, Ari Udiyono (2019)	Behavioral Factors and Environmental Factors Associated with Malaria Incidence in the Gebang Community Health Center Working Area, Purworejo Regency	Habit of leaving the house at night, travelling to endemic areas, usage of mosquito nets, use of anti-mosquito medication, existence of breeding locations, distance between breeding places, existence of resting spots, and existence of cattle pens	Case control	The study's findings revealed a significant correlation between the habit of leaving the house at night, the use of mosquito repellent, the presence of breeding places, the distance between breeding places, the presence of resting places, and the presence of livestock pens and the incidence of malaria

## DISCUSSION

### Use of wire mesh in house ventilation

Four of the eleven studies analysed discussed the effect of utilising wire mesh in house ventilation on the occurrence of malaria. Two of the four publications reported a link between the usage of wire mesh in home ventilation and the occurrence of malaria. Hidayati's (2023) study on 80 respondents in Purworejo Regency found that the presence of wire mesh in house ventilation was one of the environmental quality parameters that had the greatest influence on the incidence of malaria, where the value of  $p = 0.001$  and  $OR = 12.117$  was obtained. This indicates that occupants of houses with ventilation without wire mesh are 12.117 times more likely to get malaria than residents of houses with wire mesh installed (7). This study has similarities with Madayanti's (2022) investigation on 120 respondents in Jayapura City, which found that the presence of wire mesh in house ventilation was associated to the incidence of malaria, where the value of  $p = 0.000$  and  $OR = 5.182$  was obtained. This indicates that dwellers of houses without wire mesh ventilation have a 5.182 times higher chance of developing malaria than those with wire mesh ventilation (6). Using wire mesh in ventilation is a protective strategy to keep mosquitos out of your home. This will decrease contact between household inhabitants and female *Anopheles* mosquitoes, lowering

the risk of malaria transmission (7). The presence of wire mesh will, of course, work best in limiting the space for mosquitos to enter the house if it is installed in good condition and has the number of holes deemed optimal, which is 14-15 per inch (6). This result is different from research conducted by Siregar (2021) on 72 respondents in Serdang Bedagai Regency which obtained a value of  $p = 0.083$  ( $p\text{-value} > 0.05$ ) stating that the presence of wire mesh in house ventilation is not related to the incidence of malaria.

### **The presence of the house ceiling**

Of the 11 articles analysed, two discussed the effect of the existence of house ceilings on malaria incidence. According to both articles, the presence of house ceilings is associated with an increase in malaria incidence. Hidayati's (2023) study of 80 respondents in Purworejo Regency found a value of  $p = 0.000$ , indicating a strong association between the existence of ceilings and malaria incidence. In this study,  $OR = 35.286$  was likewise obtained, implying that occupants of houses without ceilings had a 35.286 times higher risk of developing malaria than residents of houses with ceilings (7). Apart from Hidayati's (2023) research, similar results were also obtained in Madayanti's (2022) research which stated that the presence of house ceilings was related to the incidence of malaria in Jayapura City with a value of  $p = 0.010$  and  $OR = 3.250$  (6). The existence of a ceiling in the house serves as a barrier against mosquitos entering the residence. The ceiling serves as a barrier between the top walls and the roof and can be formed of wood, interior, or woven bamboo. A house without a ceiling will have holes or gaps between the walls and the roof, allowing mosquitoes to enter more easily. The likelihood of contact between home residents and *Anopheles* mosquitoes is higher than in houses with ceilings. This ceiling will, of course, function best if it is in good condition and accessible throughout the room (7).

### **House wall density**

Five of the 11 articles reviewed discussed variables related to home wall density. Three of the five articles, written by Madayanti (2022), Siregar (2021), and Putra (2020), found a link between the density of house walls and malaria incidence. Madayanti's (2020) study of 120 respondents in Jayapura City yielded a value of  $p = 0.018$  and  $OR = 3.872$ , indicating that residents of houses with loose walls are 3.872 times more likely to get malaria than residents of houses with tight walls (6). Siregar's (2021) research conducted on 72 respondents stated that the density of house walls was related to the incidence of malaria in Serdang Bedagai Regency with a value of  $p = 0.035$  and  $OR = 1.157$  (8). Putra's (2020) research conducted on 128 respondents stated that the density of house walls was related to the incidence of malaria in Southeast Aceh Regency with a value of  $p = 0.008$  and  $OR = 3.051$  (9). The density of the walls of the house is determined based on the materials used. Brick walls are tighter than walls constructed of other materials including boards, plywood, and woven bamboo. Walls composed of planks, plywood, or woven bamboo are more likely to have gaps or holes that mosquitoes can use to enter the house, increasing the chance of interaction between mosquitoes and house occupants (6). The condition of the home walls is also affected by house spraying activities (internal residual spraying). The insecticide that is sprayed will seep into the house's walls, causing mosquitoes to die when they land on them (9).

These results are different from 2 other research articles conducted by Hidayati (2023) and Suriyani (2022). Research by Hidayati (2023) shows that there is no significant relationship between the condition of house walls and the incidence of malaria in Purworejo Regency because the  $p\text{-value} = 0.203$  ( $p\text{-value} > 0.05$ ) was obtained (7). These results are similar to research by Suriyani (2022) on 145 respondents in Keerom Regency, Papua Province which obtained a  $p\text{ value} = 0.172$  ( $p\text{-value} > 0.05$ ) so it was stated that the condition of house walls was not related to the incidence of malaria (10).

### **The presence of bushes**

Of 11 articles reviewed, 8 discussed the varying presence of bushes (resting places), and all of these articles concluded that there was a link between the presence of bushes and the occurrence of malaria. Hidayati's (2023) research in Purworejo Regency in 2022 found that the presence of bushes is one of the environmental quality elements that has a significant effect on malaria incidence, with a value of  $p = 0.000$  (7). Decimal's (2023) research on 76 respondents in West Lombok Regency yielded the similar results as Hidayati's (2023) research, namely an association between bushes and malaria incidence with a  $p\text{ value of } 0.026$  (11). Research by Mofu (2022) on 102 respondents in the Hamadi Community Health Center working area stated that the presence of bushes and the incidence of malaria were related with a value of  $p = 0.042$  and  $OR = 2.541$ . These results show that residents of houses that have bushes in the surrounding environment are at 2,541 times greater risk of contracting malaria than residents of houses that do not have bushes in the surrounding environment (12). Apart from this research, in the same year there was also similar research conducted by Madayanti (2022) in Jayapura City and Suriyani (2022) in Keerom Regency, Papua Province. Madayanti's research (2022) obtained a  $p\text{ value} = 0.001$  and  $OR = 3.512$  (6). Meanwhile, Suriyani's research (2022) obtained a value of  $p = 0.050$  and  $OR = 3.780$  (10). The results of these two studies show that there is a

relationship between the presence of bushes and the incidence of malaria. Several previous studies also showed the same results, including research by Manangsang (2021), Utami (2019), and Isnaeni (2019). Sequentially, the three studies obtained results, namely  $p$  value = 0.000 and OR = 17.073,  $p$  value = 0.000 and OR = 7.028,  $p$  value = 0.003 and OR = 4.313 (13–15).

The condition of lush shrubs can block sunlight from accessing the soil's surface, leading it to become shaded and moist. *Anopheles* mosquitoes prefer vegetation with high humidity as a place to rest during the day, and insects may miss a location if there is stagnant water under the bushes (10). Furthermore, the presence of bushes might be employed as a location for *Anopheles* mosquitoes to suck flower nectar for additional food (7). Therefore, the presence of bushes around the house with a distance of  $\leq 100$  m will increase the number of mosquito populations around the house and cause residents who live in houses with bushes around them to have a greater risk of contracting malaria compared to the residents of the house which there are no bushes around (13).

### The presence of standing water

Of the 11 articles analysed, 10 discussed the variable of standing water (breeding place), and all of these articles stated that there was a link between the presence of standing water and malaria occurrence. Hidayati (2023) found a strong link between the presence of standing water and the incidence of malaria in his study of Purworejo Regency with 80 respondents ( $p = 0.001$ ) (7). This is in line with research by Decimal (2023) in West Lombok Regency regarding the relationship between the presence of sewers and the incidence of malaria which obtained a value of  $p = 0.026$  (11). Mofu's (2022) research on 102 respondents in the Hamadi Community Health Center working area stated that the presence of standing water around the house was a risk factor for malaria with a value of  $p = 0.034$  and OR = 2.759. The standing water found in the working area of the Hamadi Community Health Center is mostly in the form of swamps, ditches, water spinach ponds, and pools of muddy water that do not flow (12). Madayanti's (2022) research on 120 respondents in Jayapura City obtained a value of  $p = 0.037$  and OR = 2.753, which means that the existence of breeding places in the form of ditches, swamps and ponds in the environment around the house is related to the incidence of malaria (6). Suriyani's (2022) research on 145 respondents in Keerom Regency, Papua Province obtained a value of  $p = 0.008$  and OR = 5.823 (10). Apart from this research, several previous studies which also stated that there was a relationship between the presence of standing water and the incidence of malaria were carried out by Manangsang (2021), Putra (2020), Hamdani N (2020), Utami (2019), and Isnaeni (2019). Manangsang's (2021) research on 200 respondents in Kerom Regency, Papua Province obtained a value of  $p = 0.019$  and OR = 4.097 (13). Putra's research (2020) on 128 respondents in Southeast Aceh Regency obtained a value of  $p = 0.001$  and OR = 3.667 (9). Hamdani N's (2020) research on 96 respondents in Intan Jaya Regency, Papua obtained a value of  $p = 0.005$  (16). Utami's (2019) research on 62 respondents in Pesawaran Regency obtained a value of  $p = 0.000$  and OR = 14.175 (14). Meanwhile, Isnaeni's (2019) research on 106 respondents in Purworejo Regency obtained a value of  $p = 0.000$  and OR = 5.077. From the results of observations made during the research, seven types of breeding places were found in Purworejo Regency, namely puddles of water in bushes, ditches, containers near wells, basins in pots, trash containers, clay containers, and rivers (15).

*Anopheles* mosquitoes require water as a breeding site throughout their life cycle. *Anopheles* mosquitoes deposit eggs on the water's surface and hatch into larvae, pupae, and adult mosquitoes (14). *Anopheles* mosquitoes can spawn in a variety of environments, including both fresh and brackish water, and must always be in direct contact with the soil (9). *Anopheles* mosquitoes prefer nesting areas such as non-flowing ditches, swamps, ponds, and excavated holes that collect rainwater (6). The existence of this breeding location is quite impossible to avoid, such as the gutter, which is always found in practically every property. The gutter is a drainage canal for water runoff from the kitchen and bathroom. However, the flow of water in numerous ditches is not smooth, resulting in pools in the canals where mosquitoes can breed (11). The presence of mosquito breeding places adjacent to the residence raises the danger of malaria spread. This is due to the fact that *Anopheles* mosquitoes, after reproducing on the water's surface, can fly a radius of 50 m in one trip to areas where mosquitoes can bite humans and livestock (7). The presence of mosquito breeding sites in the environment around the house will increase the population of *Anopheles* mosquitoes and cause residents living in the house to be more at risk of transmitting malaria compared to residents living in houses that do not have mosquito breeding areas nearby.

### The presence of livestock pens

Of the 11 articles analysed, 8 of them discussed the existence of cattle pens. Of the eight publications, five said that there was a link between the existence of livestock pens and the occurrence of malaria, whereas the other three stated that there was none. According to Hidayati (2023), the existence of livestock pens is the environmental quality factor that has the greatest influence on the prevalence of malaria in Purworejo Regency, with a value of  $p = 0.040$  and an OR of 3.797 (7). This finding is consistent with Decimal (2023)'s research in West Lombok Regency, which yielded a  $p$ -value of 0.026 (11). Research by Putra (2020) in Southeast Aceh Regency obtained a value of  $p =$

0.001 and OR = 3.695 (9). Meanwhile, previous research conducted by Utami (2019) in Pesawaran Regency obtained a value of  $p = 0.000$  and OR = 7.028, while research by Isnaeni (2019) in Purworejo Regency obtained a value of  $p = 0.000$  and OR = 10.014. These two studies showed the same results, namely that there was a relationship between the presence of livestock pens and the incidence of malaria (14,15). *Anopheles* mosquitoes love to hang out in dirty cattle cages. Furthermore, if there are puddles or puddles of water inside the cage that are caused by animal waste or water storage containers used to provide cattle water (11). The smell of cattle urine can attract mosquitoes to the cage. Aside from that, mosquitoes can suck the blood of cattle in cages due to their Anthrophilic (biting people) and Zoophilic (drinking animal blood) features (7). As a result, livestock pens close to homes can make it easier for female *Anopheles* mosquitoes to travel from the enclosure and into the home, where they can bite and spread malaria.

These results differ from previous studies by Manangsang (2021) and Hamdani N (2020). Manangsang's (2021) research in Kerom Regency yielded a value of  $p = 0.370$  ( $p\text{-value} > 0.05$ ), indicating that the presence of cattle pens had no relationship with malaria incidence (13). These findings are consistent with research conducted by Hamdani N (2020) in the Wandai Community Health Centre operating area, which yielded a value of  $p = 0.309$  ( $p\text{-value} > 0.05$ ), indicating that the presence of livestock pens was not associated with the incidence of malaria (16).

## CONCLUSION

Based on the 11 articles reviewed, it is possible to conclude that the variables of using wire mesh in house ventilation, the presence of house ceilings, the density of house walls, the presence of bushes, the presence of puddles of water, and the presence of livestock pens in the environment around the house are environmental risk factors for malaria transmission. Thus, the physical condition of the house as well as the quality of the surrounding environment must be considered in malaria control efforts.

## SUGGESTION

To achieve malaria control, the community health cent, health service, and local community must work together to regulate the environment both inside and outside the home. Environmental management in the home can be accomplished by keeping mosquitos out (tight walls, installing a ceiling, and inserting wire mesh in the ventilation). Outdoor environmental management can be accomplished by cleaning the home on a regular basis, cutting bushes to limit the presence of thick bushes, cleaning livestock pens, maintaining cleanliness and draining clogged gutters, and blocking holes or locations where mosquitoes can breed.

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