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Analyzing the Effect of Wind Flow at Openings, Wall Density and Distance of Livestock Cages on the Spread of Malaria Mosquitoes Using Ecotect Simulation

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Abstract

*The government has set a target for Indonesia to become malaria-free; However, this goal has not yet been fully achieved, particularly in eastern regions such as Sikka Regency in East Nusa Tenggara. One of the factors contributing to the spread of malaria-carrying mosquitoes is the proximity of openings, wall density, and the distance of livestock enclosures from residential buildings, especially when less than 1 meter apart. Based on this, field observations were conducted in malaria-affected locations. These observations were followed by experiments using *Ecotect Analysis* to analyze wind patterns and velocities by comparing the distance between openings, wall density, and the distance of livestock enclosures at 1 meter and more than 5 meters. The study revealed that while distance does not influence wind velocity, it significantly affects wind flow patterns. Greater distances between openings result in broader air circulation patterns, which, in turn, impact the spread of mosquitoes in the area.*

Introduction

According to the World Health Organization, malaria is still a global health problem and Indonesia is one of the areas affected by malaria (Ministry of Health, 2022); "Malaria: (still) a global health priority," 2021; (Sankineni et al., 2023) . Based on this situation, Indonesia has set a target of being malaria-free by 2030, and the eastern part of Indonesia is a priority, including Sikka Regency. Sikka Regency is a dry tropical climate region. (Hildegardis et al., 2019), which experienced an increase in cases of 55 cases in 2022. when compared to other districts in East Nusa Tenggara (Jehadu, 2022; Langga, 2022; Suratri et al., 2023; Lobo et al., 2024).

Based on research conducted by (Sutarto, 2017) shows that climate is one of the factors that contribute to the spread of various diseases in Indonesia, including malaria. As a country with a tropical climate, Indonesia is known to have a high rate of malaria development (Sugiarto et al., 2022; Fahmi et al., 2022). Based on the Köppen climate classification, the tropical climate in Indonesia is divided into three types, namely tropical rainforest climate (Af), tropical monsoon (Am), and tropical savanna or dry tropical (Aw). Of the three types, East Nusa Tenggara, especially Sikka Regency, is included in the area with a dry tropical climate with the highest recorded malaria cases (Munthe et al., 2022; Nau & Buku, 2020).

Malaria is an infectious disease caused by the Plasmodium parasite and transmitted through the bite of the Anopheles mosquito (Wardani & Arifah, 2016). Sikka Regency, as a tropical area with high humidity, has ideal conditions for the development of malaria vector

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mosquitoes (Rachman et al., 2017; Sulasmi et al., 2017). The physical quality of the building, especially the density of the walls of the house and the location of the livestock pen, plays an important role in determining the level of risk of malaria transmission, especially in several factors such as the condition of the density of the walls of the house and livestock pens (Lewinsca et al., 2021; Puspaningrum et al., 2016).

In addition, (Ngambut & Sila, 2013) also explained that the physical condition and environment around the house are important determinants of malaria in Kupang Regency. It was also explained that the condition of the openings and walls of the house affects the air flow and wind speed on the spread of mosquitoes (Babba, Suharyo, & Suwandi, 2007). Research (Pareira et al., 2023) in the Sikka Police housing complex found that the distance and dimensions of the openings influenced the incidence of malaria in an environment so that residential barriers were needed between the openings in one residence and another.

So based on the findings above, further research was conducted, from the example of a residence in Hoder Village, Sikka to analyze the effect of openings based on the distance and location of the openings using ecotect simulation. Where the direction of the openings between residences is given a distance of 1 meter, 5 meters to 10 meters as a comparison of the air flow that occurs.

Literatur Review

Wall density and malaria incidence

Several previous studies have shown a close relationship between the physical condition of the house and the spread of malaria (Puspaningrum et al., 2016). According to the World Health Organization (WHO), houses with tight walls can reduce the risk of mosquito bites because mosquitoes have difficulty entering the interior of the house. Research conducted by (Lindsay et al., 2002) and Kirby et al. (2008) showed that houses with tight walls, especially those made of solid materials such as concrete, are more effective in preventing the entry of Anopheles mosquitoes. Houses with loose or perforated walls increase the likelihood of mosquito bites at night, thereby increasing the risk of malaria. In addition, studies conducted in Indonesia such as in Jayapura by (Madayanti et al., 2022) and (Pamangin & Irjayanti, 2024), and in Banjarnegara by (Puspaningrum et al., 2016) and Utami et al. (2022) showed that physical environmental variables related to malaria incidence include the density of house walls, the use of gauze on ventilation, the presence of ceilings, mosquito breeding sites, and mosquito resting areas are factors in buildings that influence malaria incidence.

In addition, research in Indonesia by Reku (2013) in Sumba and (Rahayu et al., 2019) confirmed that traditional houses made of bamboo or wood or stilt houses are more susceptible to mosquitoes when compared to houses with concrete walls (Nawa et al., 2024; Salca & Fekete-Kaszoni, 2022).

Location of livestock pens and malaria incidence

Based on research conducted by (Yuana et al., 2014) in South Kalimantan, (Habibi et al., 2019) and Wibowo regarding the influence of the location of the pen and the incidence of malaria, it is known that the presence of livestock pens around the house can help reduce interactions between healthy humans and mosquitoes that cause malaria. This is in accordance with research by Harijanto (2000), which states that cows and buffaloes can reduce the frequency of mosquito bites in humans. However, the condition is that the livestock pen must be placed outside the house at a distance far enough to function as an effective "barrier" between humans and mosquitoes, where the suggestion in the study is that it is necessary to add a distance or radius variable between the house and the livestock pen, in order to complete further research. Meanwhile, based on this statement, it is known that the distance between buildings affects the pattern of mosquito spread (Hildegardis et al., 2021).

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Methods

The steps taken in the research related to the Evaluation of the Effect of Openings on the Spread of Malaria, namely:

Literature search

Previous studies that focused on environmental observations related to malaria cases have been explored in depth to formulate effective and applicable design standards. These studies are mainly rooted in the field of public health science which has a dominant role in studying the relationship between environmental factors and malaria incidence. Through these studies, a number of conclusions have been identified that show how certain environmental conditions and management can affect the spread of malaria. By understanding these factors, it is hoped that environmental and building approaches can be designed that not only support malaria control but also improve the quality of life of people in areas prone to the disease.

Field approach

At this stage, primary data collection is carried out in the form of direct measurements in the field to determine the physical environmental conditions in selected areas in Sikka Regency. The review and determination of the location carried out are based on data obtained from the Sikka Regency Health Office in 2024. From the available data, the focus of field observations is a comparison of houses in the opening model, wall density and distance of livestock pens. Field measurements are carried out using an Anemometer to determine the wind speed at the location.

Data analysis

After the conclusion of the literature study is determined and field measurements are carried out, the analysis process is continued by processing the data obtained. The data includes information from the literature study, field observation results, and observations related to climate conditions and physical characteristics of the building. All collected data is then modeled using the SketchUp program and further analyzed with the help of Ecotect Analysis 2011 software to obtain more detailed and in-depth results.

Results and Discussion

Initial survey results

The results of an initial survey conducted in Sikka Regency on malaria-affected houses (based on data from the Sikka Regency Health Service) showed that houses with loose walls, which are mostly made of wood or bamboo, are more susceptible to malaria transmission than houses with concrete walls.

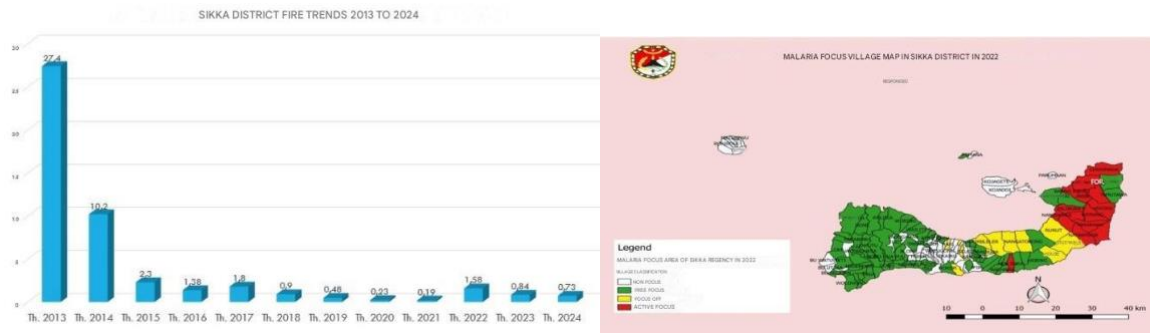

Figure 1. Health Service data for areas affected by malaria

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Of the 50 houses surveyed, 30 had loose walls, and of these houses, 65% of the residents had suffered from malaria in the last two years. Meanwhile, only 15% of the concrete-walled houses reported malaria cases.

In addition, it was found that the distance of livestock pens close to loose-walled houses increased the risk of malaria. Of the 30 loose-walled houses, 18 had livestock pens less than 10 meters away. Residents of these houses reported higher incidences of malaria compared to houses with livestock pens further away from the main building.

The results of the literature review and initial survey showed a significant relationship between the density of house walls and the location of livestock pens on the risk of malaria transmission. Houses with loose walls provide more gaps for Anopheles mosquitoes to enter and bite the occupants of the house, while houses with concrete walls are more protected from mosquito bites. In addition, livestock pens that are located too close to the house also increase the risk of malaria transmission, especially in houses with loose walls, where this is more related to the pattern of wind distribution that affects the pattern of mosquito distribution that flies.

This study confirms the results of previous studies that suggest the importance of home design and environmental planning in reducing the risk of malaria. By modifying home design and maintaining a safe distance between livestock pens and main buildings, the risk of malaria can be reduced.

Air flow at the opening with the dwelling is 1 meter away

Air flow between buildings with a distance between dwellings of 1 meter can have several implications for the spread of malaria mosquitoes, especially if the air flow allows the movement of mosquitoes between dwellings. Relatively close distances between dwellings, such as 1 meter, can allow malaria mosquitoes to move between dwellings more easily. This can increase the risk of disease spread if infected mosquitoes are in one dwelling and then move to another.

Figure 4. Distance between buildings 1 meter

The simulation was conducted based on the model that had been created using wind speeds ranging from 0.00 to 1 m/s, in accordance with the results of field measurements. Through simulations using the *Ecotect Analysis* software, it was found that the wind speed at the openings facing each other with a distance between openings of 1 meter was in the range of 0.02 m/s to 0.03 m/s. These results provide an overview of the air flow patterns that occur under these conditions, which can be the basis for further analysis regarding their impact on the surrounding environment.

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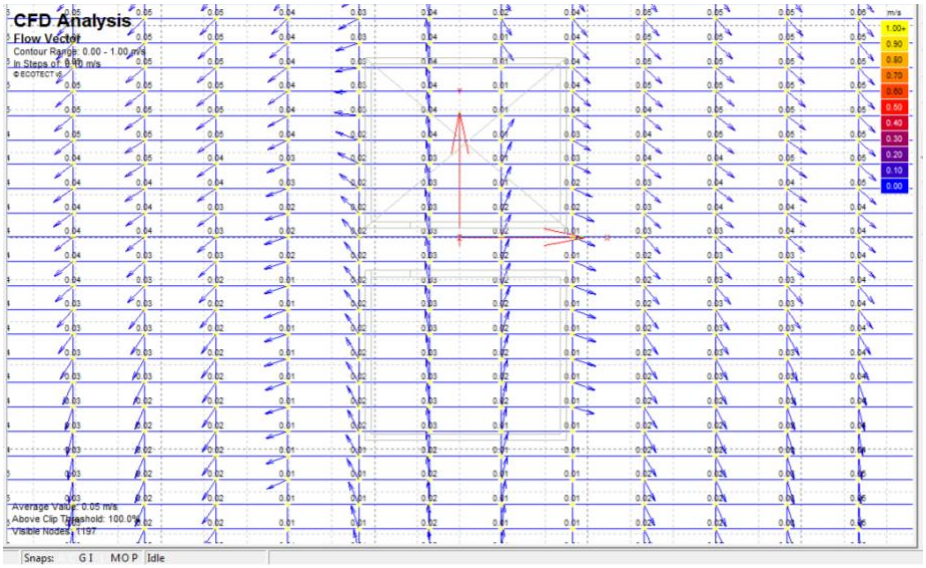

Figure 5. Simulation results of a building distance of 1 meter

Air flow at openings with a distance of more than 5 meters from the residence

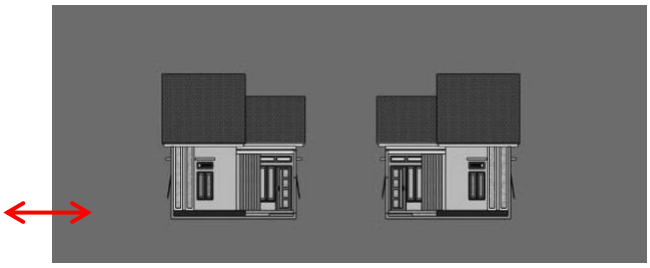

Figure 6. Distance between buildings 5 meters

The simulation results using the *Ecotect Analysis* software show that the wind speed that occurs between the openings is in the range of 0.00 to 0.02 m/s. This speed is lower than the wind speed detected at a distance between openings of 1 meter. This finding indicates that the smaller the distance between openings, the lower the resulting wind speed. This can provide important insights into the effect of the distance between openings on airflow patterns, which in turn can affect aspects of comfort, ventilation, and the potential for the spread of particles or disease vectors in the environment.

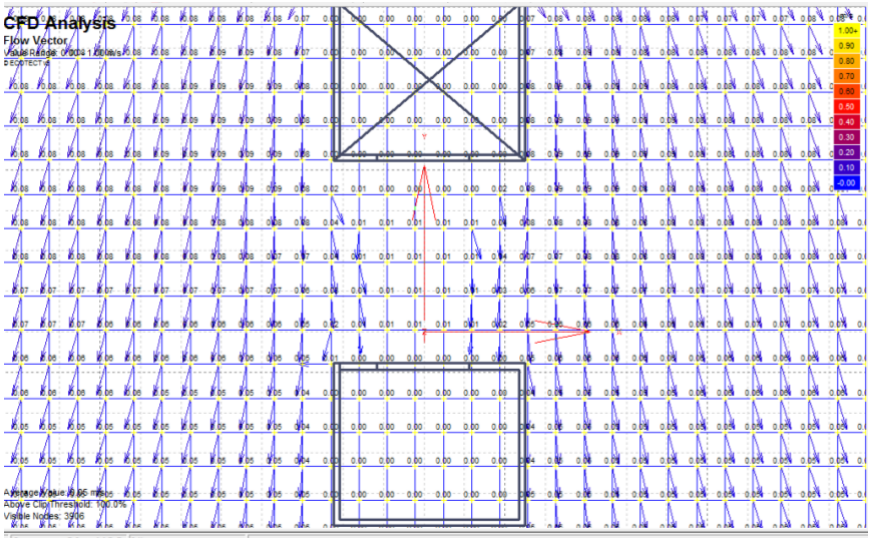

Figure 7. Ecotect CFD Analysis simulation on a building 5 m away

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Conclusion

Based on the analysis that has been done, it is known that the highest wind speed was recorded at an opening distance of 1 meter. Conversely, the wind speed measured at an opening with a distance of 5 meters was lower than 1 meter. In addition to differences in wind speed, the analysis also shows variations in the distribution pattern or air flow between openings, which have a significant impact on the spread of mosquitoes. To improve the results of this analysis, further evaluation is recommended involving the effects of temperature, humidity, and lighting using the same software, so that architectural design solutions can be formulated that support the creation of healthy and mosquito-free housing. Based on the results of the literature review and initial survey, it was also found that the density of house walls and the distance of livestock pens from the house have a significant effect on the risk of malaria in Sikka Regency. Houses with loose walls tend to be more susceptible to mosquito bites, while concrete walls provide better protection. In addition, the distance of livestock pens that are too close to the house can increase the risk of malaria transmission. This is closely related to the pattern of mosquito distribution which is influenced by air flow around the house, especially in houses with loose walls. These findings emphasize the importance of planning the layout and design of housing that takes into account environmental aspects to reduce the risk of disease.

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