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ANALYSIS OF MALARIA TRANSMISSION DYNAMICS AT BOROBUDUR HEALTH CENTER, MAGELANG REGENCY (CASE STUDY 2021-2022)

Naila Afnaniya[1], Aris Santjaka[2]*, Bahri Bahri[2]

[1]Bachelor of Applied Environmental Sanitation Study Program, Department of Environmental Health, Semarang Ministry of Health Polytechnic Semarang 50239, Indonesia
[2]Department of Environmental Health, Semarang Ministry of Health Polytechnic Semarang 50239, Indonesia

Corresponding Author:
*) arissantjaka@gmail.com

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Abstract

Introduction: *Magelang District received a malaria elimination certificate in 2014. No cases found at Borobudur Health Center since 2009 but in October 2021, there was a spike in the number of patients, with 38 instances spread across Giripurno Village, Giritengah Village, and Majaksingi Village. Therefore, it is necessary to study the dynamics of malaria transmission so that the methods of malaria transmission are known to prevent extraordinary malaria cases.* ***Methods:*** *This is qualitative research with a phenomenological approach. This study was conducted in 2023 by reviewing cases from 2021–2022. The respondents in this study included 38 people with malaria. This research uses descriptive analysis assisted by GIS applications to determine the distribution of malaria cases.* ***Results and Discussion:*** *Data processing results for 38 respondents in three villages revealed 23 index cases. Of the 23 cases, nine were within a radius of no more than 400 m and occurred within three days, thus including cluster classification. Theoretically, the same vector transmits it and has a high vectorial capacity. The other 15 patients were suspected to have secondary cases, with two transferred from the first case. The results of the breeding place survey or the potential breeding place after rearing revealed the species Anopheles balabacensis. Other predictors of malaria transmission are optimal temperature and humidity, environment, livestock places to rest mosquitoes, and patient behavior that causes a high frequency of mosquitoes biting humans.* ***Conclusion:*** *In this case, the transmission model was a cluster, and 100% of the cases were indigenous.*

INTRODUCTION

Regulation of the Minister of Health of the Republic of Indonesia Number 2 of 2023 concerning Environmental Health states that vectors are arthropods that transmit, move, and become a source of disease transmission in residential environments, four works, recreation areas, and public facilities (1). Malaria is a vector-borne disease that has spread worldwide in tropical and subtropical climates (2). Malaria is caused by *Plasmodium* and transmitted by *Anopheles spp.* mosquitoes (3). The World Malaria Report 2022 states that there will be an estimated 247 million malaria cases in 84 malaria-endemic countries in 2021 (4). Data from the Ministry of Health of the Republic of Indonesia in 2021 indicated that there were 304,607 malaria cases in Indonesia (5). The number of cases increased by 22.6% in 2020. Malaria cases in Central Java Province were described using Annual Parasite Incidence (API) values per 1,000 population. The API value of malaria in Central Java is 0.023 per 1,000 population (6).

31 of 35 regencies/cities in Central Java Province received malaria elimination certificates. Magelang Regency is one of the districts that received malaria elimination certificates in 2014. However, another outbreak in 2015 had 161 indigenous cases and five imported cases (7), with an API value of 0.92/1,000 population at risk. Malaria cases in the Magelang Regency continued to appear unevenly. From 2015 to 2017, malaria cases were found in the Magelang Regency, both imported and indigenous (8). In 2018, the number of malaria

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cases dropped to only one patient with an API value of 0.0007/1,000 population (9). In 2019, it increased again to five cases with an API value of 0.003/1,000 population (10), and in 2020, there were no cases of malaria (11).

Since 2009, no malaria cases have been reported in the working area of the Borobudur Health Center. However, in 2021, there was a spike in malaria cases in the Borobudur Health Center work area, with as many as 38 instances spread across Giripurno, Giritengah, and Majaksingi villages. Theoretically, surveillance negligence that does not routinely monitor patients has caused a spike in malaria cases in 2021 in the working area of the Borobudur Health Center. This study aimed to discover malaria transmission dynamics through case index, information, transmission model, and determinants in the Borobudur Health Center Work Area.

METHODS

This type of research is qualitative, with a phenomenological approach that aims to explore how malaria is transmitted by mapping the distribution of cases using the Geographic Information System (GIS) application so that the dynamics of malaria transmission can be known, namely, the extent of distribution, distribution models, and determinants of malaria in Giripurno Village, Giritengah Village, and Majaksingi Village, the working area of the Borobudur Health Center, Magelang Regency.

The respondents in this study were 38 malaria sufferers in the Borobudur Health Center working area in 2021–2022, with a population of 9,343 people in three villages. The data collection method was primarily based on interviews with respondents and secondary data, namely reports from the Borobudur Community Health Center and the Yogyakarta Center for Environmental Health Engineering and Disease Control. Data processing and presentation were carried out by collecting all information and data, which were then analyzed using qualitative methods, namely, data reduction, data presentation, and conclusion. The processed data are then presented in narrative form. In this research, the analysis also used a GIS application with mapping techniques to determine the distribution of cases and the dynamics of malaria transmission. The variables in this research were the distribution of malaria cases based on person, place, time, temperature, humidity, potential breeding place, and type of *Anopheles spp*. Mosquito, type of *plasmodium*, presence of livestock pens, presence of bushes, use of mosquito nets, use of anti-mosquito medication, and habit of leaving the house at night.

RESULTS

Malaria cases in the working area of the Borobudur Health Center, Magelang Regency, with the number of malaria sufferers in 2021–2022, namely 38 people were divided into Giripurno Village, Giritengah Village, and Majaksingi Village. The API value of malaria incidence in the Borobudur Health Center working area in 2021 is 0.52 per 1,000 people, while in 2022, it is 0.13 per 1,000 population. The location of malaria incidence in the working area of Borobudur Health Center is Menoreh Hill, which is a malaria-endemic area in Central Java Province.

Hilly areas have very dense trees that block sunlight from penetrating the ground, resulting in high humidity and ensuring the survival and longevity of mosquitoes, which are important in malaria transmission.

Malaria Cases by Person, Place and Time

The distribution of malaria based on patients is shown in Table 1, which shows that 38% of malaria sufferers with the most 38 cases are at the age 40–60 years.

Table 1. Characteristics of Malaria Sufferers

Characteristic	Sum	Percentage
Age		
<5 years	2	5.26%
6–15 years	2	5.26%
16–25 years	8	21.05%
26–40 years	9	23.66%
41–60 years	14	38.64%
>60 years	3	7.82%
Gender		
Man	17	55.26%
Woman	21	44.74%
Work		
Self-employed	2	5.26%
Farmer	9	23.68%
Laborer	16	42.11%
Housewife	7	18.42%
Not Working Yet	4	10.53%

Based on gender, men were more dominant than women, namely 21 people (55.26%), and most jobs were workers, with as many as 16 sufferers (42.11%).

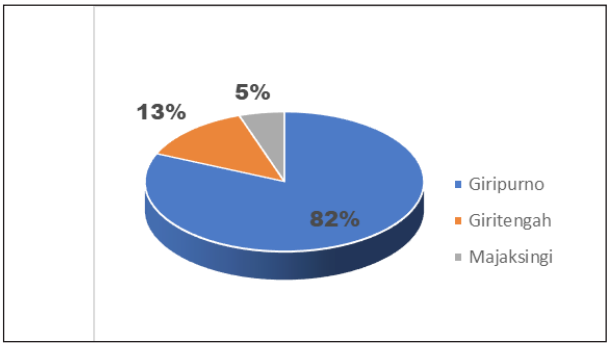

Figure 1. Distribution of Malaria Cases by Village in the Borobudur Health Center Working Area in 2021–2022

Malaria cases occurred in Giripurno Village, Giritengah Village, and Majaksingi Village. The highest number of cases in the three locations was in Giripurno Village with 31 cases (81.5%), followed by Giritengah Village with five cases (13.2%), and Majaksingi Village with two cases (5.25%).

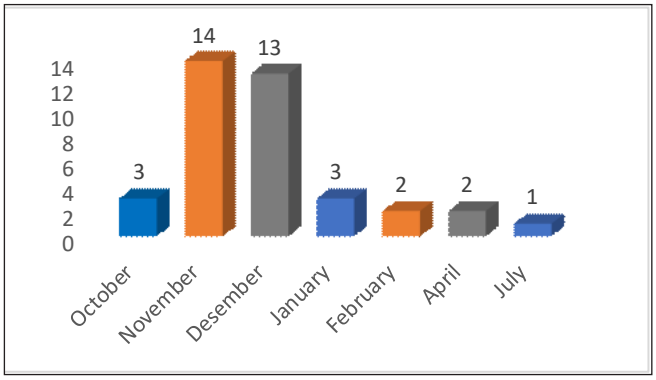

Figure 2. Distribution of Malaria Cases By Month in the Working Area of Borobudur Health Center in 2021–2022

The highest number of malaria cases occurred in November 2021, with 14 cases (36.8%) and December 13 cases (34.2%). The peak of malaria cases was in November 2021, with 14 cases (36.8%), and malaria cases will continue to fall until one issue remains in July 2022.

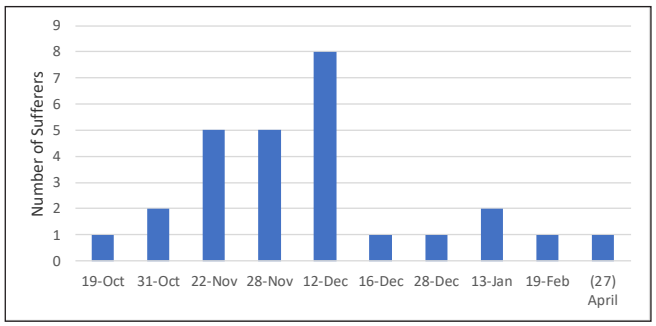

Figure 3. Distribution of Malaria Cases by Day in the Working Area of Borobudur Health Center in 2021–2022

Malaria cases by day were highest on December 12, with eight cases (21%), followed by November 20 and 22, with five cases (13.5%).

Potential Breeding Place and Mosquito Catching

The Center for Environmental Health Engineering and Disease Control conducted observations of breeding locations and mosquito catching in 2022.

Table 2. Number of Potential Breeding Places in Giripurno Village, Giritengah Village, and Majaksingi Village

Village	Hamlets	Number of Breeding	Positive Flick
Giripurno	Gayam	3	0
	Pokoh	2	0
	Miriombo Kulon	2	0
Giritengah	Secang	5	5
Majaksingi	Keruk Batur	1	0

The survey results obtained 13 breeding locations with the number in each village, namely in Giripurno Village, there were seven locations: Giritengah Village, five locations, and Majaksingi Village, one location. However, only five breeding places tested positive for larvae was only 5 locations, and all were in Giritengah Village.

Table 3. Results of Rearing Larvae

Habitat	Kind	Sum	Density
Spring	*An. balabacensis*	1	0.2
Puddle 1	*An. Kochi*	1	1
Puddle 2	*An. Kochi*	7	1
Puddle 3	*An. Vagus*	6	0.7
Brick water	*An. vagus*	1	0.8

Source: The Center for Environmental Health Engineering and Disease Control Yogyakarta (18)

The mosquitoes produced by rearing larvae were *Anopheles kochi*, *Anopheles vagus*, and *Anopheles balabacensis*. In the spring, one *Anopheles balabacensis* was found; in puddle one, there was one *Anopheles kochi* larva; in puddle two, there were seven *Anopheles kochi* larvae; in puddle three, there were six *Anopheles vagus* larvae, and in the location of water used to soak bricks, one was found *Anopheles vagus* larvae. Habitat type found in *Anopheles spp*. Mosquito larvae. Giritengah Village has a habitat of springs, puddles of water for watering plants, puddles of water channels, and rice fields.

Table 4. Mosquito Catching Results

Kind	Sum
An. Barbirostis	1 tail
An. vagus	4 tails
An. kochi	3 tails

Source: The Center for Environmental Health Engineering and Disease Control Yogyakarta (18)

The results of mosquito catching carried out by The Center for Environmental Health Engineering and Disease Control Yogyakarta are as follows: There are three types of *Anopheles spp.* Mosquitoes. Those caught with a capture time of 12 hours, namely from 18.00–06.00, were 1 *Anopheles barbirostis*, 4 *Anopheles vagus*, and 3 *Anopheles kochi*.

Types of *Plasmodium*

Results of malaria *Plasmodium* examination conducted by Borobudur Health Center showed one patient with *Plasmodium vivax* (2.7%) and 37 patients with *Plasmodium falciparum* (97.3%).

Table 5. Malaria Plasmodium Test Results

Types of Plasmodium	Sum	Percent
P. falciparum	37	97.3
P. vivax	1	2.7

Source: Borobudur Health Center Data

Temperature and Humidity

Air temperature measurements carried out in the Giripurno Village area for 3 days were 25°C, 27°C, and 26°C, with an average of 26.4°C; the measurement result in Giritengah Village was 27.2°C; and in Majaksingi Village, it was 26°C. Air temperature measurements were carried out in the Giripurno Village area, Giritengah Village, and Majaksingi Village, with averages of 80.3%, 74%, and, 88%.

The Environment around the Patient's Home

The results of a survey on the environment around the patient's house showed that 17 respondents had animal cages. The number of cage ownership by village is 14 cages in Giripurno Village, one cell in Giritengah Village, and two cages in Majaksingi Village. The results of the survey of bushes around the homes of malaria sufferers were 100%.

Table 6. Quality of the Environment around the Patient's Home

Environmental Quality	Sum	Percentage
Cage Ownership		
Exist	17	44.7%
None	21	55.3%
The Presence of Shrubs		
Exist	38	100%
None	0	0%

Patient Behavior

The results of the behavioral interviews with patients with malaria are shown in table 4. The government has given malaria patients in all three villages insecticide-treated mosquito nets, so all patients have used mosquito nets with a percentage of 100%. Malaria respondents who had a habit of moving at night comprised 31.5%.

Table 7. The Behavior of Malaria Sufferers

Behavior	Sum	Percentage
Use of Insecticide-treated Mosquito Nets		
Already	31	100%
Do not	0	0%
Do Activities Outdoors at Night		
Already	12	31.5%
Do not	26	68.5%
Use of Mosquito Repellent		
Already	30	79%
Do not	8	21%

Of the 12 respondents who had the behavior of doing activities at night, as many as 11 people (91.7%) had used long clothes, and only one person (8.3%) did not wear long dressed. The use of mosquito repellents is not a culture of the people in Giripurno Village, Giritengah Village, and Majaksingi Village; overall, as many as 30 people (79%) do not use mosquito repellents at night, and eight respondents (21%) use mosquito repellents.

Spatial Analysis of Malaria Transmission Dynamics

The transmission dynamics map in Figure 4 shows the results of buffers with a radius of 100 m in the first circle (white), the second circle at 200 m (orange), and the third circle at 400 m (brown)—the flight range of *Anopheles spp.* Mosquitoes can reach ± 400 m, which is the basis for determining their radius. The following is a buffer map of the malaria transmission dynamics.

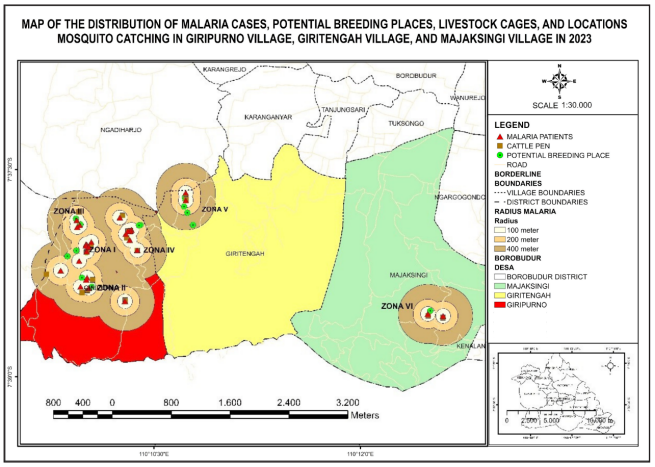

Figure 4. Map Of Dynamics of Malaria Transmission in Giripurno Village, Giritengah Village, and Majaksingi Village in 2021–2022

The buffer results of the distribution of malaria cases in zone I (Gayam Hamlet, Giripurno) were 14 patients with an index number of five points and a second case of nine. Zone II (Miriombo Kulon Hamlet, Giripurno) had five patients with case index three and secondary case two. Zone III (Pokoh and Parakan Hamlets, Giripurno) had three patients with index case one and secondary case two. In zone IV (Miriombo Wetan, Giripurno), nine patients with an index number of cases eight and secondary case one. Zone V (Secang Hamlet, GiriTengah) had five patients with case index four and one secondary case. Zone VI (Keruk Batur Hamlet, Majaksingi) included two patients with two case indices.

DISCUSSION

Distribution of Malaria Cases

The determinants of malaria transmission can be determined based on epidemiological variables such as person, place, and time. The first is a person variable. It has several variables, including age, sex, and occupation. It can be seen in table 1 that the ratio of the adult group, namely 16–60 years, has a higher prevalence rate than toddlers and old age. Malaria cases affect men more than women, which can be related to the habits of male adults who have the habit of going out at night.

Second, the place and time variables. The number of malaria cases in three villages in the Borobudur Health Center work area because the height of the location affects malaria transmission (12) and damp virgins that affect the lifespan of mosquitoes live longer (13). Malaria cases based on time are shown in figure 2; in November, there were 14 cases, and in December, there were 13 cases. Based on the data in the figure, the three most cases in a day were on December 12, which included eight cases. An explosion in malaria cases occurs during the rainy season because high rainfall causes high humidity, so mosquitoes live longer, which can increase the potential for transmitting malaria cases (14). The time interval of malaria diagnosis is close and clustered in November and December; therefore, it is possible that those who bite between patients are the same mosquito because it is calculated through sporogony cycles in mosquitoes 8–12 days (15) and the incubation period of *P. falciparum* in the human body 9–14 days (16).

Potential Breeding Place and Capture of *Anopheles spp.*

The larvae and mosquitoes of *Anopheles spp*. are indicators of the potential for malaria transmission. *Anopheles* mosquitoes breed in water, so surveying mosquito larvae breeding sites or breeding sites is necessary (17). A survey of *Anopheles sp*. larvae the Center for Environmental Health Engineering and Disease Control Yogyakarta was carried out in three villages: Giripurno, Giritengah, and Majaksingi. However, *Anopheles* larvae were found only in breeding places in Giritengah Village. The breeding sites found were puddles, springs, and water pools used to soak bricks (18).

The larvae were then taken to the laboratory for rearing in order to determine their type. The results of rearing larvae showed three types of larvae, namely one *Anopheles balabacensis*, eight *Anopheles kochi*, and seven *Anopheles vagus*, in two breeding places. *A. balabacensis* is the primary vector for malaria transmission (19). Both males and females lived for approximately 42 days under laboratory conditions, although males had a greater range of longevity (4–62 days) (20). The information on cases that occurred in just one night indicates that mosquitoes with a high vectorial capacity are the main factor in pathogen transmission (21).

Adult mosquitoes from the Center for Environmental Health Engineering and Desase Control, Yogyakarta, found three types of *Anopheles spp*. mosquitoes: *Anopheles barbirostis*, *Anopheles vagus* and *Anopheles kochi*. The number of mosquitoes caught by *Anopheles barbirostis* is one tail, Anopheles vagus is four tails and *Anopheles kochi* is three tails. This mosquito capture is a continuation of the larval survey activities in Giritengah Village. Adult mosquitoes are captured in livestock pens, as evidenced by the results of catching, namely *Anopheles vagus* and *Anopheles kochi*, which forage by biting animals or are zoophilic (22).

Types of *Plasmodium*

Data from *plasmodium* examination by Borobudur Health Center showed that 97.3% (37 cases) identified *Plasmodium falciparum*, and 2.7% (1 point) identified *Plasmodium vivax*. The results of this *plasmodium* examination are related to a spike in circumstances that occurs at one time. *Plasmodium falciparum* itself has an incubation period of 9–14 (16) days and a sporogony cycle of 8–12 days (15), so the time it takes for mosquitoes to bite patients who have *plasmodium* and then bite others until the person has symptoms is 20–24 days. *P. vivax* has a sporogon cycle time of 8–9 days with an incubation period of 16–18 days (23).

Temperature and Humidity

Environmental factors such as temperature, humidity, attractiveness of the host, and standing water as a breeding place influence the lifespan and movement of *Anopheles spp*. mosquitoes—adults–causing high transmission of malaria cases (24). Temperature and humidity also affect the breeding of mosquitoes. An environment where mosquitoes breed, with an optimum temperature for mosquito larvae (23–25°C) (25), will increase the potential for transmission of malaria cases. A relative humidity of more than 60% also increases the possibility of mosquitoes transmitting malaria cases (26). The distribution of malaria cases in the Borobudur Health Center work area was also related to temperature and humidity. Giripurno Village has an optimum temperature and humidity of 26°C with a humidity of 80.2%, so many cases occur because moist air enters the mosquito's abdomen through its spiracles and regulates the mosquito's body moisture, causing a longer mosquito life (23).

Physical Environment around the Patient's Home

The physical environment around the patient's house is a livestock shed, and the presence of bushes. Livestock is located adjacent to the patient's house, which can affect the presence of mosquitoes because mosquitoes are attracted to hosts that emit CO_2 (27). Thus, the more significant the CO_2 level, the higher the interest in mosquitoes. Animals such as cows, goats,

and buffaloes have high metabolism, emit a lot of CO_2 and cause denser mosquito densities in livestock sheds (27). This explains why the *Anopheles* mosquito, which is more dominant, is zoophilic or sucks the blood of livestock (28).

The malarial species found by the Center for Environmental Health Engineering and Disease Control Yogyakarta in livestock sheds are *Anopheles vagus*, *Anopheles kochi*, and *Anopheles barbirostis*. The mosquito is zoophilic but does not rule out the possibility of being able to bite humans, such as *Anopheles barbirostis* which is zooantrophilic or can suck the blood of humans and animals (29). One of the efforts to prevent malaria mosquito bites is to keep livestock cages away from homes because, in general, livestock cages are the most strategic places for malaria vectors to rest and breed (30). *Anopheles balabacensis* mosquitoes found in rearing results are vectors that have a habit of resting around cattle sheds (31).

The presence of bushes can also affect the presence of malaria. It is a good place for *Anopheles spp.* mosquitoes to rest during the day after sucking blood because it has high humidity owing to leaves that block direct sunlight from hitting the mosquito's body (32). In this study, shrubs, bamboo, and other trees around the homes of malaria sufferers were examined. The vegetation is so dense that it can block sunlight so that it has high humidity, and mosquitoes will rest in places with high humidity (31). This is in line with study conducted in Purworejo on 2022 which stated that the presence of bushes contributes to the incidence of malaria. Bushes are an environmental risk factor that affects the incidence of malaria because bushes are breeding sites for mosquitoes (32). Homes near mosquito breeding sites have a greater risk of malaria (33).

The Behavior of Malaria Sufferers

The behavior of patients who can affect the incidence of malaria is the use of insecticide-treated mosquito nets, the habit of patients leaving the house at night, and the use of mosquito repellents. Insecticide-treated mosquito nets can be used to prevent malaria (34). This insecticide-treated mosquito net is distributed to all residents in malaria-prone areas in Indonesia, and Giripurno Village, Giritengah Village, and Majaksingi Village have 100% mosquito net usage. To reduce mosquito density, researchers can use a mosquito net for five years (35). The research conducted in Sumatera on 2018 stated that people who do not use mosquito nets have a 2.28 times greater risk of malaria. Hence, mosquito nets play an essential role in malaria incidence because they can reduce the frequency of bites by *Anopheles spp.* mosquitoes (36).

Anopheles spp. mosquitoes are active at night, so the habit of going out at night affects malaria cases. The research conducted in Lampung on 2019 research states that there is a relationship between activity at night and the incidence of malaria (37). This was because the mosquito *Anopheles spp.* is exophagic (38) or prefers to bite outside the house, so the habit of going out at night causes a high risk of human contact with mosquitoes.

Mosquito repellency is a preventive effort to reduce contact between humans and mosquitoes. Residents who do not use mosquito repellents while sleeping at night are vulnerable to malaria (39). The results of this study showed that 79% of patients did not use mosquito repellents. One of the reasons people do not use mosquito repellents is to feel crowded because they use the type of mosquito repellent commonly sold near mosquito repellents. Another reason is economic problems and is considered ineffective in killing mosquitoes. The research conducted in Sumatera on 2018 stated that exposure to smoke from mosquito coils poses acute and chronic health risks and is less optimal for preventing mosquito bites (36).

Dynamics of Malaria Transmission

The incidence of malaria was 31 in Giripurno Village, five in Giritengah Village, and two in Majaksingi Village. Giripurno Village is comprised of five hamlets: Gayam Hamlet, Pokoh Hamlet, Parakan Hamlet, Miriombo Kulon Hamlet, Miriombo Wetan Hamlet. Giritengah Village is only one hamlet, Secang Hamlet, and Majaksingi Village, and is also only one hamlet, Keruk Batur Hamlet.

Malaria transmission dynamics for the case index, transmission model, and determinant (23). Regarding the incidence of malaria in Giripurno Village, Giritengah Village, and Majaksingi Village, 38 malaria patients were included in the cluster transmission model. This is based on the distance between case indices (first case) that are less than 400 m (mosquito flight distance) (24). Patients have passed the mosquito sporogony cycle, and the incubation period of *Plasmodium* in humans is ± 20–24 days for *Plasmodium falciparum*. Thus, the cluster transmission model is malaria transmission, where the location of the first and other cases is ± 400 m from the first sufferer. Analysis of malaria transmission in the three villages found 23 index cases and 15 secondary cases. The case index is based on the date of events that do not exceed the mosquito sporogony cycle and the incubation period of *Plasmodium* in humans, or can

be said to occur soon. Theoretically, the same vector is the cause of the spike in malaria cases occurring at the same time.

The incidence of malaria in the working area of the Borobudur Health Center was declared as an indigenous case. However, there is something strange because the *plasmodium* found in the patient's body is *Plasmodium falciparum*, which does not cause relapses such as *Plasmodium vivax* and *Plasmodium ovale* (40). Conversely, a case is declared indigenous if it comes from the area, but the first to third cases have a distance of less than the incubation period, and all are declared as a case index. Therefore, there may be patients in the Borobudur Health Center who do not exhibit symptoms of malaria. However, the gametocyte cycle in the body is still running, and gametes are formed, sucked by the existing vector, and transmitted simultaneously until an explosion of cases occurs. This relapse probably occurred after the Magelang District received a malaria elimination certificate in 2014. Because the mosquito *Anopheles spp*. is still present, malaria cases can be transmitted, and there was an explosion of cases in Salaman District in 2015 (8).

This surge in malaria cases is influenced by the determinants of malaria, namely breeding place or potential breeding place, temperature, humidity, environment around the house, and patient behavior. Breeding or a potential breeding place that is positive for larvae found by the Center for Environmental Health Engineering and Desase Control Yogyakarta, which is a potential malaria transmission. The location of the discovery of potential breeding sites is also close to the patient's home; thus, when it becomes a mosquito, it can be a vector that transmits malaria. Temperature and humidity also affect malaria incidence, because the optimum temperature and humidity are 23–25°C, respectively, and more than 60% will extend the life of malaria vectors. The environment around the house, in the form of livestock cages and shrubs, also affects the incidence of malaria, because it is used as a resting place for mosquitoes. Patient behavior, such as night exit habits, mosquito nets, and mosquito repellents are preventive measures for malaria that affect the incidence of malaria.

CONCLUSION

The malaria transmission model is cluster shaped and includes indigenous species. There were 23 index and 15 secondary cases. The determinants are: 1) the existence of a breeding place with rearing results of mosquito larvae *Anopheles balabacensis*, *Anopheles vagus*, and *Anopheles kochi*. 2) The mosquitoes found were *Anopheles barbirostis*, *Anopheles vagus*, and *Anopheles kochi*. However, *Anopheles vagus* and *Anopheles kochi*. 3) Results of *Plasmodium* examination with *P. falciparum* and *P. vivax*. 4) The results of the physical environment survey found that 78.8% of patients had livestock, while for bushes, 100% of the environment around the patient's house was bushes. 5) The results of the interviews regarding the behavior of patients (100%) used mosquito nets, 21% used insect repellents, and 31.7% of patients moved at night.

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