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Article

Spatial Analysis of Environmental Determinants of Dengue Hemorrhagic Fever (DHF) Endemic Areas in the Working Area of Puskesmas Purwokerto Selatan, Banyumas Regency, 2022-2023

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Abtract

Dengue Hemorrhagic Fever (DHF) remains a significant public health issue in Indonesia, particularly in endemic areas such as South Purwokerto. Despite a reported 61% decline in cases from 2022 to 2023, transmission persists, indicating the need for a deeper understanding of environmental determinants. This study aims to conduct a spatial analysis of environmental factors associated with dengue case distribution in the working area of the South Purwokerto Health Center during 2022–2023. This research employed an observational design with a qualitative exploratory approach. Data were collected from both primary and secondary sources, including direct measurements of indoor temperature and humidity, health center reports on larval-free index (LFI), larval density, rainfall, and case distribution. Geographic Information Systems (GIS) using ArcGIS software were utilized to analyze spatial patterns of dengue transmission. The findings showed that the average indoor temperature in patients' homes was 31°C and relative humidity was 70%, conditions that support mosquito breeding. In 2022, the pattern of dengue cases inversely correlated with rainfall, while in 2023 the pattern was inconsistent. The dominant transmission pattern was "separated" (>100 m radius) with 55% of cases in 2022 and 60% in 2023 falling into this category. Only one sub-district, Teluk, failed to meet the Larval-Free Index threshold in 2022, while all areas improved in 2023. In conclusion, although environmental indicators improved in 2023, the persistence of cases indicates hidden transmission risks. Targeted vector control interventions and increased community participation are essential for sustainable dengue prevention.

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Introduction

Dengue fever is one of the fastest spreading tropical diseases in the world and poses a serious threat to global public health. According to WHO[1] Between 100 and 400 million dengue infections occur each year, with about half the world's population now at risk of infection. This surge in cases is not only limited to tropical and subtropical regions, but has also begun to reach non-endemic areas, including several countries in Europe and North America, as a result of climate change and increased human mobility.

Increasing global temperatures have been shown to expand the distribution area of the Aedes aegypti mosquito, the main vector of dengue virus. Studies by Xu et al. [2] showed that higher annual minimum temperatures significantly increase dengue incidence, with a projected substantial increase in cases until 2100, especially in the African region, the Arabian Peninsula, and island countries in the Pacific and Indian Oceans. In addition, changes in rainfall and humidity patterns caused by climate change create environmental conditions that are more conducive to mosquito breeding, increasing the risk of dengue transmission.

In Indonesia, DHF remains a significant public health problem. Environmental factors such as temperature, humidity, rainfall, and land use have been identified as important determinants in the spread of this disease [3]. Research in Gunung Kidul District, Yogyakarta, found that most DHF cases occurred in areas with mixed land cover between buildings and vegetation, and at altitudes below 200 metres above sea level.[4]. These findings suggest that physical environmental characteristics play an important role in the dynamics of dengue transmission.

Geographic Information Systems (GIS) has become an effective tool in analysing and visualising spatial patterns of infectious diseases such as dengue.[5]. By integrating spatial and attribute data, GIS enables identification of high-risk areas, analysis of the relationship between environmental factors and disease incidence, and planning of more targeted interventions. The use of GIS in dengue mapping has been applied in various countries, including Bangladesh and Thailand, to identify transmission hotspots and contributing environmental factors.

However, despite the widespread use of GIS technology, there are still gaps in the understanding of how specific environmental factors, such as temperature and micro-humidity, affect the spread of DHF at the local level. Previous research in Nganjuk, East Java, showed that the presence of bushes around the house, stagnant water, and clothes hanging inside the house significantly increased the risk of DHF, while mosquito nest control activities and the participation of larva monitoring cadres could reduce the risk.[6]. These findings emphasise the importance of considering microenvironmental factors in dengue control strategies.

In addition, land use change and rapid urbanisation also contribute to the increase in dengue cases.[7]. A study in Dhaka, Bangladesh, found that areas with high population density and intensive land use had a higher incidence of dengue, largely due to increased interactions between humans and mosquitoes and the presence of man-made containers that serve as breeding grounds for mosquitoes.[8]. Therefore, spatial analyses that consider environmental and socio-economic factors are important in understanding and controlling the spread of DHF.

In this context, this study aims to map and analyse the environmental factors that influence the spread of DHF in endemic areas, using a GIS approach. By integrating spatial data and environmental attributes, this research is expected to identify high-risk areas and determinant factors that can be the basis for planning more effective and efficient interventions in DHF control.

Materials and Method

Research Design and Location

This research is an observational study with a qualitative design using an exploratory approach. The purpose of this approach is to explore in depth the environmental factors that become determinants in dengue fever endemic areas using geographic information system (GIS) based mapping. The research was conducted in the working area of Puskesmas Purwokerto Selatan, Banyumas Regency, Central Java Province. This location was chosen because it is a DHF endemic area. The study covered a period of two years, from 2022 to 2023, to illustrate trends and spatial changes in case distribution and environmental factors.

Approach and Data Type

This study used a qualitative exploratory approach that utilised spatial and non-spatial data. Spatial data was obtained through the geographical coordinates of the distribution of DHF cases, while non-spatial or attribute data included environmental variables such as temperature, humidity, rainfall, larva-free count (LFI), and mosquito density.

Data Collection Sources and Techniques

Data collection in this study utilised a combination of primary and secondary data. Primary data was obtained through direct measurement of air temperature and humidity in the houses of DHF patients using a thermohygrometer in 2023. Measurements were taken to determine the microclimate conditions of the patients' residences as one of the factors influencing the development of Aedes aegypti mosquitoes as DHF vectors. In addition, secondary data were used to enrich the analysis, including data on DHF cases, larva-free counts (LFI), and mosquito larvae density from the South Purwokerto Community Health Centre report, as well as rainfall data obtained from the local Water Resources Management Agency (BPSDA).

All DHF patients recorded during the study period were used as observation subjects through total sampling technique. Spatial data in the form of coordinates of the location of the patients' houses were collected and mapped using a geographic information system (GIS) with the help of ArcGIS software. The mapping process involved identifying patterns of case distribution, modelling spatial distribution based on the radius of spread (such as the separated model), and analysing the relationship between case distribution and local environmental conditions. In this mapping, spatial data (coordinates and boundaries) and attribute data (number of cases, temperature, humidity, rainfall, LFI, and larval density) were used.

Data analysis

Data were analysed descriptively to describe the characteristics of the area, the distribution of DHF cases, as well as the values of temperature, humidity, rainfall, LFI, and density figures from each kelurahan. Spatial analysis was used to identify the concentration and transmission patterns of DHF cases between areas from year to year, as well as to assess the effectiveness of mosquito nest eradication programmes in the field. The results of these analyses were then used to determine priority areas for dengue control interventions and formulate evidence-based recommendations to improve the effectiveness of future disease prevention efforts.

Results

Geography

Purwokerto Selatan Health Centre is located in Purwokerto Selatan Sub-district. The working area of Purwokerto Selatan Health Centre consists of 7 villages which include Berkoh Village, Karangklesem Village, Karang Pucung Village, Purwokerto Kidul Village, Purwokerto Kulon Village, Tanjung Village, and Teluk Village with an area of 13.75^{km2}.

Demographic Situation

Population growth data obtained from Purwokerto Selatan Sub-district, the total population in Purwokerto Selatan area in 2023 was 74,305 people consisting of 36,979 men and 37,326 women who were incorporated in 25,040 households/HH.

Overview of DHF Cases

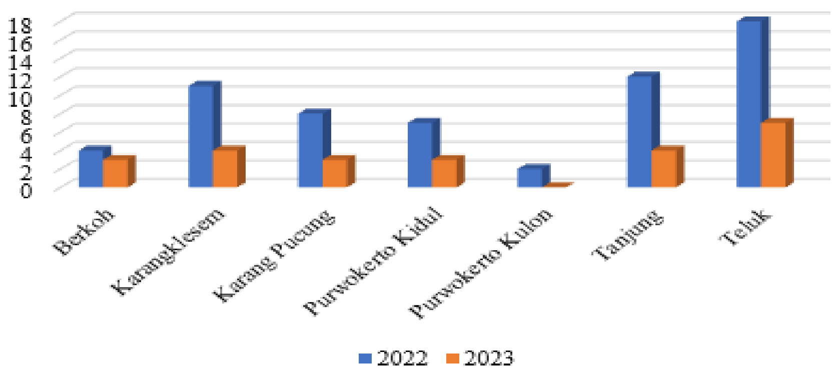

Figure 1: DHF cases by urban village

The highest cases of DHF for both 2022 and 2023 were in Teluk Village with 18 cases in 2022 (29%) and 7 cases in 2023 (29.2%) while the village with the lowest cases of DHF in 2022 and 2023 was Purwokerto Kulon Village with 2 cases in 2022 (3.2%) and no cases in 2023 (0%). This can be influenced by the area of the kelurahan, Teluk is the largest kelurahan area while Purwokerto Kulon is included in a small area in South Purwokerto Kemacatan.

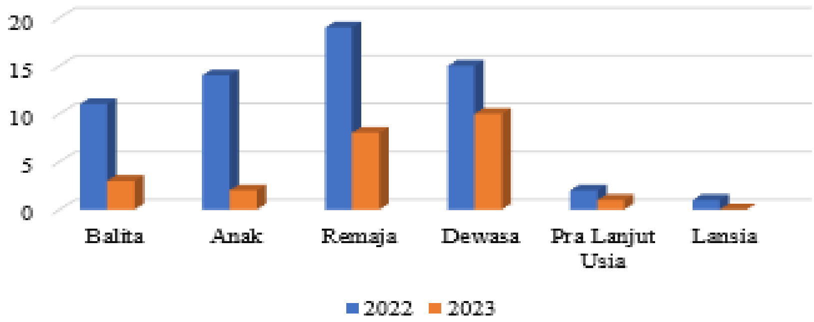

Figure 2. Cases by Age

DHF patients in 2022 - 2023 in the Purwokerto Selatan Health Centre working area were found to be mostly male with an age range of adults to adolescents. This can be assumed to be due to the greater mobility of men than women which can be attributed to work where generally more men do outside work with activities carried out in the morning - evening at the same time as the *Aedes ae* mosquito is active.

Distribution of DHF Cases

The distribution pattern of DHF cases for 2022 or 2023 was mostly found in the separated model (radius >100 metres). There were 16 separated models in 2022 (55%) and 6 models in 2023 (60%) while cluster transmission in 2022 was 13 models (45%) and 4 models (40%) in 2023. DHF cases in 2022 when compared to 2023 have a more diffuse pattern in all urban village areas, this can be influenced by larval density factors such as DF and LFI values in that period which still do not meet the requirements.

Transmission dynamics based on data obtained from community health centres for 2022, all cases were index cases. Case one on 4/1/2022 was an index case because the case point was >100 metres from case two and the time when the patient was exposed to DHF also exceeded the 7-day incubation period. Case two on 5/1/2022 and case three on 6/1/2022 were also index cases because the distance between the case points was within a 100 metre radius with a time span of 1 day In 2023 it was still the same as in 2022 where all cases were index cases. Case one on 14/1/2023, case two on 4/2/2023, and case three on 4/2/2022 were all index cases because they were not within the incubation period of the DHF virus and the distance was > 100 metres.

Rainfall on DHF Cases

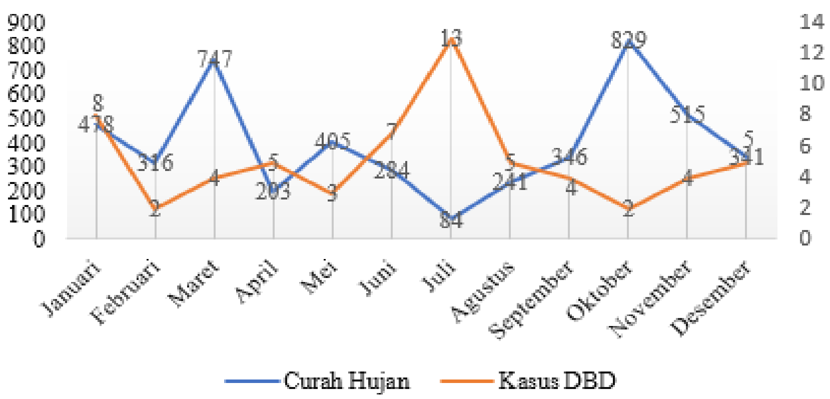

Figure 3. Rainfall on dengue cases in 2022

Rainfall and DHF cases in 2022 tended to be inversely proportional, when there was a significant increase in rainfall from September to October with rainfall of 346 mm to 839 mm DHF cases actually decreased from 4 cases to 2 cases, this result is in line with the research of (9) in the West Purwokerto Health Centre working area. Heavy rainfall can not only increase the number of breeding places but also eliminate breeding sites. Excessive rainfall can lead to a reduction in mosquito larvae as breeding sites are washed away by the flow of rainwater.

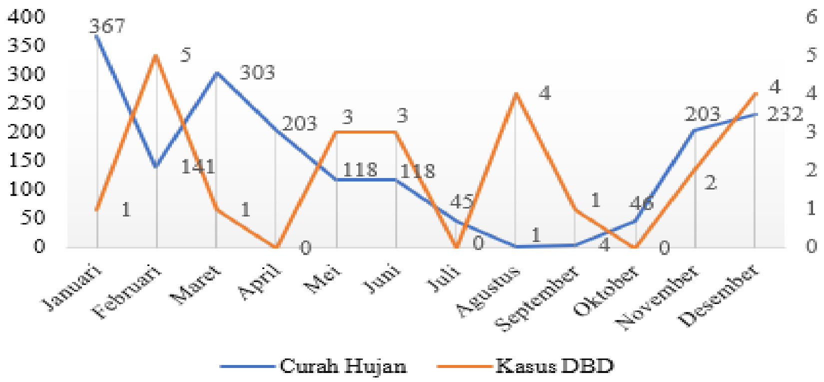

Figure 4. Curah Hujan Terhadap Kasus DBD Tahun 2023

Rainfall in 2023 obtained fluctuating results, in January - September the same as in 2022 tends to be inversely proportional but in October - December is directly proportional.

Temperature and Humidity of Houses with DHF Patients

The results of temperature and humidity measurements of houses with DHF patients in 2023 can be seen in Table 1.

Table 1. Temperature Measurement Results of Houses with DHF Patients

No.	Temperature Classification	Frequency	%
1.	Qualified (18 - 30oC)	9	37,5
2.	Does not meet (> 30oC)	15	62,5
Total		**24**	**100**

The optimum temperature for mosquito development is 25 – 27 °C, while at temperatures <10°C or >40 °C mosquitoes will die. The average temperature of the houses of DHF patients was 31°C. Based on the results obtained, the temperature in the patient's house is still within the scope of a good temperature for the development of mosquito life.

Table 2: Humidity Measurement Results of Houses with DHF Patients

No.	Temperature Classification	Frequency	%
1.	Qualified (40 - 60% Rh)	4	16,7
2.	Does not fulfil (>60% Rh)	20	83,3
Total		**24**	**100**

The optimal humidity for mosquito development ranges from 75 - 93% Rh, while humidity below 60% Rh can shorten the lifespan of mosquitoes. The average humidity of the houses of DHF patients was 70% Rh. If it is at the optimum humidity, the number of vectors will increase which has the potential to increase the frequency of dengue transmission.

Density Figure (DF) Terhadap Kasus DBD

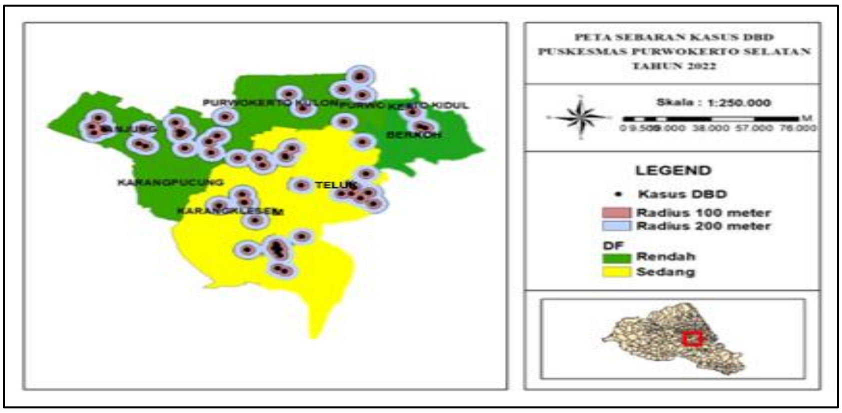

Figure 5. Density of DHF Cases in 2022

In 2022, there were two villages in the medium category, Karangklesem and Teluk, while the other villages were in the low category. When viewed from the number of DHF cases, the results of the DF analysis are in line with DHF cases because Karangklesem and Teluk are the top three areas with the highest DHF cases in 2022.

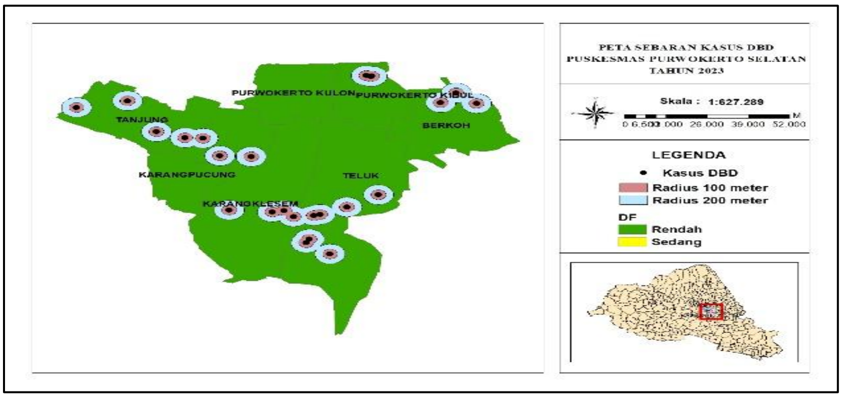

Figure 6. Density of DHF Cases in 2023

In 2023, there was a better improvement than the previous year, with all regions already in the low category. This is in line with the number of DHF cases which decreased significantly from 62 cases to 24 cases. The increase in the DF value was due to the fact that during this period Larval Source Management (LSM) was routinely carried out so that mosquito larvae were reduced and the chain of dengue transmission decreased.

Flies Free Rate to DHF Cases

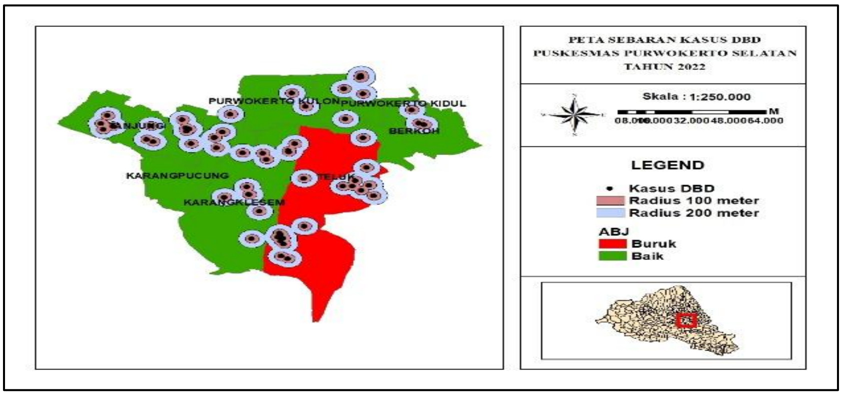

Figure 7. Larval-Free Index against dengue cases in 2022

Tahun 2022 nilai LFI terdapat satu kelurahan yang masuk dalam kategori buruk dengan nilai LFI < 95% yaitu Kelurahan Teluk sedangkan untuk kelurahan lainyya sudah masuk dalam kategori baik dengan nilai LFI ≥ 95%.

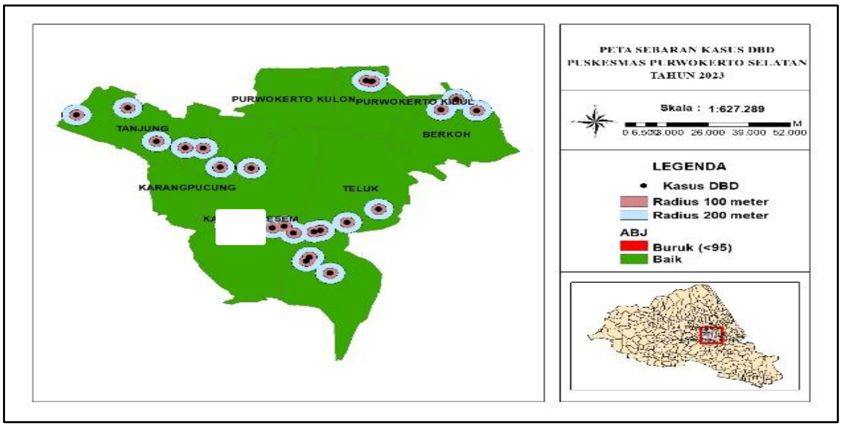

Figure 8. Larval-Free Index for DHF Cases in 2023

The LFI values for 2023 where all kelurahan are categorised as good with LFI values ≥ 95%. The LFI and DHF incidence values for both 2022 and 2023 were not significant. This is because the LFI values are already good for each kelurahan but in reality there are still many DHF cases found in the area, especially for 2022 where there were 62 cases. Based on the results of interviews with the puskesmas, the discrepancy is because when mosquito larvae inspection or LSM is carried out, residents are informed in advance so that before the implementation begins, residents have cleaned the surrounding environment and then when LSM is carried out, the results are obtained with environmental conditions that are clean from larvae. Therefore, the LFI value can reach ≥ 95% even though there are still many DHF cases found.

Discussion

This study aims to analyse the spatial and environmental determinants that play a role in the endemic incidence of Dengue Fever (DHF) in the working area of Purwokerto Selatan Health Centre during the period 2022-2023. The 61% decrease in the number of cases from 2022 to 2023 indicates significant progress in vector control and public awareness. However, the fact that six out of seven villages remain endemic indicates that dengue virus transmission is still active and requires a more comprehensive evaluation of environmental, spatial, and behavioural aspects.

Spatial analysis shows that the pattern of dengue transmission in this area is dominated by the *separated* model with a radius of >100 metres, 55% in 2022 and 60% in 2023, respectively. This pattern indicates that the transmission of DHF is not limited to household clusters, but spreads widely within the community. This is in line with the findings of [9] who stated that dengue transmission can occur randomly in densely populated communities that have high mobility and poor sanitation.

Research [10] in Semarang showed that densely populated areas with poor sanitation and inadequate waste management tend to have a diffuse spatial distribution of dengue cases. The use of Geographic Information Systems (GIS) has proven effective in mapping and visualising patterns of case distribution, as well as identifying priority areas for intervention. In this study, Kelurahan Teluk consistently showed the highest number of cases for two consecutive years, indicating the need for special attention to environmental characteristics and population density in the area.

The temperature and humidity measurements of the houses of DHF patients showed that 62.5% of the houses had temperatures above 30°C with an average temperature of 31°C, and 83.3% had humidity above 60%, with an average humidity of 70% Rh. These temperatures and humidity are optimal conditions for the development of *Aedes aegypti* mosquitoes. Liu-Helmersson et al. [11]

confirmed that temperatures between 26-30°C are the optimal range for mosquito reproduction and dengue virus replication. High temperatures can accelerate the incubation of the virus in the mosquito body and shorten its life cycle. However, extreme temperatures (>34°C) can reduce mosquito survival rates. In this context, 31°C is still within the optimal range.

Relative humidity also plays an important role. Lahdji & Putra [12] reported that high humidity can increase the lifespan of mosquitoes and increase the likelihood of transmission. The humidity measurement in this study, at 70%, showed very favourable conditions for adult mosquito survival. Rahman et al. [13] also showed that humidity above 60% was significantly positively correlated with mosquito population abundance in urban tropical areas.

An interesting finding from this study is that the relationship between rainfall and the number of dengue cases is not always linear. In 2022, an increase in rainfall was actually followed by a decrease in dengue cases. For example, in October, although rainfall reached its peak, the number of DHF cases decreased. This phenomenon supports the findings of [14] which states that extreme rainfall can cause mosquito larvae to be washed away with the flow of water, thus reducing the adult mosquito population.

In contrast, at the end of 2023, there is an increase in the number of DHF cases along with the increase in rainfall, showing a positive correlation. This is most likely due to the occurrence of standing water after moderate intensity rainfall, which becomes a potential breeding ground for *Aedes* mosquitoes. Wang et al. [15] stated that moderate rainfall tends to create new breeding sites from open containers, clogged drains, and household waste.

Fauzi et al. [16] through time-series analysis in West Java found that rainfall of 100-300 mm/month was positively correlated with DHF incidence, with a lag of 2-4 weeks. However, rainfall above 500 mm/month decreased the number of cases. Therefore, it is important to incorporate periodic local climatological data in dengue control planning.

Assessment of the Density Figure (DF) and Flies Free Rate (FFR) showed an improvement in environmental conditions between 2022 and 2023. In 2022, two neighbourhoods were categorised as medium (Karangklesem and Teluk), while five were low. By 2023, all kelurahan had fallen into the low category. For LFI, 2022 showed that only Kelurahan Teluk did not meet the ≥95% threshold, while by 2023 all kelurahan had reached it.

However, although the LFI and DF values showed improvement, dengue cases were still found in these areas, indicating a discrepancy between entomological data and clinical cases. This may be due to bias during the implementation of LSM, where the community has cleaned the environment first before the inspection. The same thing was revealed by Masturoh et al. [17], who stated that LFI reporting can be biased because it is influenced by the readiness of residents ahead of inspections. Baharom et al. [18] emphasised that LFI and DF are not the only indicators to predict dengue outbreaks. Surveillance of adult mosquitoes and detection of virus in mosquito bodies are more sensitive indicators in assessing the actual risk of transmission.

The distribution of DHF patients is dominated by adolescent and adult males. High mobility and outdoor activities during mosquito active times (morning and evening) make this group more vulnerable to mosquito bites. Mamenun et al. [19] in his study in Kendari City also reported that men are more exposed to mosquito bites because they are more active outside the home.

Teluk urban village, which is the largest urban village, showed the highest number of cases for two consecutive years. This could be related to its size, population density, and low effectiveness of environmental control. Budianto and Budiarti[20] in a study in Yogyakarta stated that densely populated residential areas with poor sanitation and suboptimal drainage systems were prone to DHF transmission, even though environmental indicators such as DF and LFI looked good.

The results of this study indicate that effective dengue control cannot rely solely on technical interventions such as fogging or periodic larval examination. An integrated vector management (IVM) approach that combines spatial monitoring, community education, hygienic behaviour and real-time climate data is needed.

The use of technologies such as mobile GIS applications and satellite monitoring can support the prediction of high-risk areas and direct interventions more quickly and appropriately. [21] in Singapore showed that the integration of GIS with a community-based digital notification system was successful in reducing the number of cases through early identification of hotspots of transmission. In addition, community education should emphasise the importance of continuous environmental cleaning, not just ahead of inspections. A community-based behaviour change campaign with a local socio-cultural approach will improve the sustainability of the LSM programme.

This study has several limitations. Firstly, the data on rainfall and DHF cases are secondary, so they depend on the accuracy of the records of the relevant agencies. Secondly, temperature and humidity measurements were only taken in the homes of sufferers with no control of non-affected homes for comparison. Third, the absence of adult mosquito surveillance or virus detection limits comprehensive transmission risk analysis. Further research is recommended to include dengue virus detection in vectors, adult mosquito surveillance, as well as integration of high-resolution satellite image data for more accurate spatial analysis.

Conclusions

This study shows that the working area of Purwokerto Selatan Health Centre is classified as a DHF endemic area with six out of seven villages experiencing DHF cases during 2022-2023. Despite a significant decrease in the number of cases by 61% from 2022 to 2023, Kelurahan Teluk remains the location with the highest cases. The environmental factors reviewed, such as house temperature and humidity, were mostly within the range favourable for *Aedes aegypti* mosquito development, with an average temperature of 31°C and humidity of 70% Rh.

Spatial analysis showed that the pattern of dengue transmission was dominated by the separated model (radius >100 metres), indicating dispersed rather than cluster-based transmission. While the 2023 larva-free rate (LFI) and Density Figure (DF) showed improvement, with all wards categorised as good, this was not fully in line with the number of cases still found. This mismatch may be due to reporting bias during LSM activities, where residents have cleaned their neighbourhoods prior to inspections.

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