ORIGINAL ARTICLE

Climatic variations and the incidence of dengue fever in Bandung, Indonesia

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ABSTRACT

Indonesia is a country endemic to dengue fever—and Bandung is one of the cities in Indonesia that is endemic to dengue fever. There have been efforts to control mosquitoes, one of which is by eradicating their nests, but this step has not optimally reduced the incidence of cases. The increase in cases is thought to have been caused by climatic variations. This study aimed to analyze the relationship between climatic variations (temperature, humidity, and rainfall) and the incidence of dengue hemorrhagic fever (DHF). This study used a correlation design and was carried out in Bandung. This study used secondary data. The samples were taken from data on the number of DHD patients from 2016 to 2021 recorded at the Health Office of Bandung, as well as temperature, humidity, and rainfall data from the Central Bureau of Statistics of Bandung from 2016 to 2021. The correlation between variables was assessed using the person correlation test. Climatic variations that are significantly correlated with the incidence of dengue hemorrhagic fever (DHF) are minimum temperature ($p=0.020$, and $r=-0.658$), maximum temperature ($p=0.006$, and $r=-0.739$), minimum humidity ($p=0.000$, and $r=0.825$), and rainfall ($p=0.037$, and $r=0.605$). The increase in the incidence of dengue hemorrhagic fever (DHF) is caused by climatic variations (temperature, humidity, and rainfall). Therefore, it is recommended that mosquito control and DHF surveillance program should be strengthened during the season following the rainy (wet) season.

Key words:
dengue fever; climatic variations; vector-borne diseases; Indonesia

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INTRODUCTION

Dengue infection has now become a burden affecting more than 40% of the world's population, especially in tropical and subtropical countries.[1] Global estimates vary, with around 50 million to 200 million dengue infections in the world, 500,000 cases are considered severe dengue (dengue hemorrhagic fever), and more than 20,000 deaths are attributed to dengue every year.[2] Dengue viruses are transmitted through the bites of infected mosquitoes. The mosquito species responsible for causing dengue fever are *aedes aegypti* and *aedes albopictus*. *Aedes aegypti* is the main vector associated with most of the endemic occurrences of dengue hemorrhagic fever. Whereas *aedes albopictus* is the secondary vector that is less efficient in transmitting and replicating the virus.[3]

The *aedes* mosquito vector breeds and transmits viral infections without a specific pattern of outbreaks, especially in subtropical countries. Studies have shown that climatic variations such as temperature, humidity, and rainfall encourage the transmission of dengue fever because climate plays an important role in the mosquito population, density, and survival rate.[4,5] Dengue fever has become a public health problem emerging in the last few decades, so it becomes a social burden with economic disruption in dengue-endemic areas. Available vaccines offer complete protection, while dengue prevention and control which are important for the future is mosquito vector control.[6]

Rapid geographical expansion and increased incidence have made dengue fever the highest vector-borne disease in Indonesia with a total of 65,602 reported cases. This incidence of cases increased to 248,127 cases in 2019. An increase has also occurred in the fatality ratio from 0.65 to 0. 94.[7] The infection continues to occur in cycles of 3-5 years, with Aedes aegypti and Aedes albopictus being the main causes of transmission.[8] The main effort currently carried out is to eradicate mosquito nests, but this approach is not optimal and is not yet able to reduce the number of cases.[9] The biology of the Aedes mosquito population is affected by temperature and humidity, especially in the eastern part of Indonesia, where studies have shown a positive relationship between temperature, humidity, and incidence of dengue.[10] Rainfall in the right amount creates abundant breeding sites for the mosquito vector, but excessive rain disrupts the mosquito larva cycle by sweeping them out of the breeding sites. In Thailand, higher rainfall is negatively correlated with the incidence of DHF.[11]

Bandung is a DHF endemic area.[12] It is located in a tropical zone, and climatic variations support the development of mosquito nests. The tropical climate strongly supports the breeding of the *Aedes aegypti* mosquito, as this vector naturally can live in areas with warm and humid climates.[13] Bandung is located in the western part of Indonesia with a relatively high incidence of dengue fever. The epidemiological studies of dengue in Bandung state that the high incidence of cases of dengue infection is strongly affected by the presence of Aedes aegypti mosquito larvae.[7] This is because hot and humid weather is ideal for the transmission of dengue fever which tends to have a seasonal pattern, namely increasing during the rainy season. Mosquito diet, reproduction, and population distribution are affected by weather variables and the *Aedes* vectors have adapted to living in human habitats, making it difficult to monitor and disrupt the transmission cycle. The dynamics of disease transmission are affected by climatic change. Thus, for most climate-sensitive infectious diseases, modeling the interaction between vector and host dynamics can be challenging as it

includes multiple complex factors such as vector reproduction, survival, and distribution of etiological agents to the host.[14,15]

Many studies have been carried out on the climate and incidence of dengue fever in several regions across Indonesia. But still very little research is being carried out in Bandung, even though Bandung is one of the regions with a fairly high transmission rate. This study aimed to analyze the relationship between climatic variations (temperature, humidity, and rainfall) and the incidence of dengue fever (dengue hemorrhagic fever) in Bandung. The results are expected to provide scientific evidence that can guide future research in developing dengue early warning systems. Besides, the results of this study are also expected to help formulate measures to prevent and control dengue fever.

METHOD

Research location and design

This study was carried out in Bandung. Basic consideration for sample selection was because Bandung is a DHF endemic area. The method used was descriptive analysis with a correlation design.

Research population and sample

The population of this study was the total population of Bandung from 2016 to 2021 recorded at the Central Bureau of Statistics of Bandung. Data on temperature, humidity, and rainfall were collected from the Central Bureau of Statistics of Bandung data from 2016 to 2021 (https://bandungkota.bps.go.id/). The samples were taken from data on the number of DHF patients from 2016 to 2021 recorded at the Health Office of Bandung. The criteria for the selected samples were inclusion in the dengue patient data from 2016 to 2021 recorded at the Bandung Health Office. Sample data were taken from http://data.bandung.go.id/.

Data collection

This study used secondary data from the Health Office of Bandung and the Central Bureau of Statistics of Bandung. The data collected were in the form of temperature, humidity, rainfall, and the incidence of DHF cases. This research has been approved by the Health Research Ethics Committee of the Immanuel School of Health Sciences Bandung (No. 054/KEPK/STIKI/VI/2021).

Statistical Analysis

Data processing used a descriptive analysis followed by a correlation analysis between the variables of temperature, humidity, and rainfall with the incidence of DHF. These four variables were examined over the course of 1 year, namely from January to December 2021. The temperature was distributed in ^{0}C, humidity in percentage, rainfall in millimeters (mm), and the incidence of DHF cases in terms of the number of cases. To assess the correlation between these variables, the person correlation test was used.

RESULTS

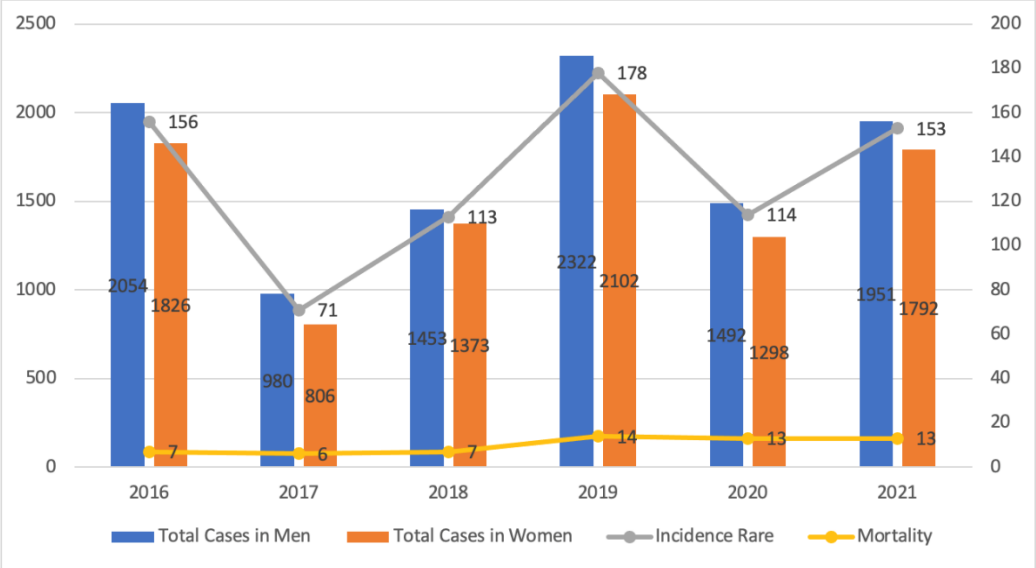

Figure 1. Incidence Rate of DHF Cases and Mortality Due to DHF in Bandung

Figure 1 shows that incidence rate of DHF in Bandung in 2016 was 156 / 100,000 people. In 2017, the incidence rate decreased to 71 / 100,000 people. However, in 2018, the incidence rate increased to 113 / 100,000 people and in 2019 the incidence rate increased again to 178 / 100,000 people. Then, in 2021, the incidence rate decreased to 114 / 100,000 people, but in 2021, the incidence rate rose again to 153 / 100,000 people. Mortality due to DHF in 2020 and 2021 was 13 cases, respectively.

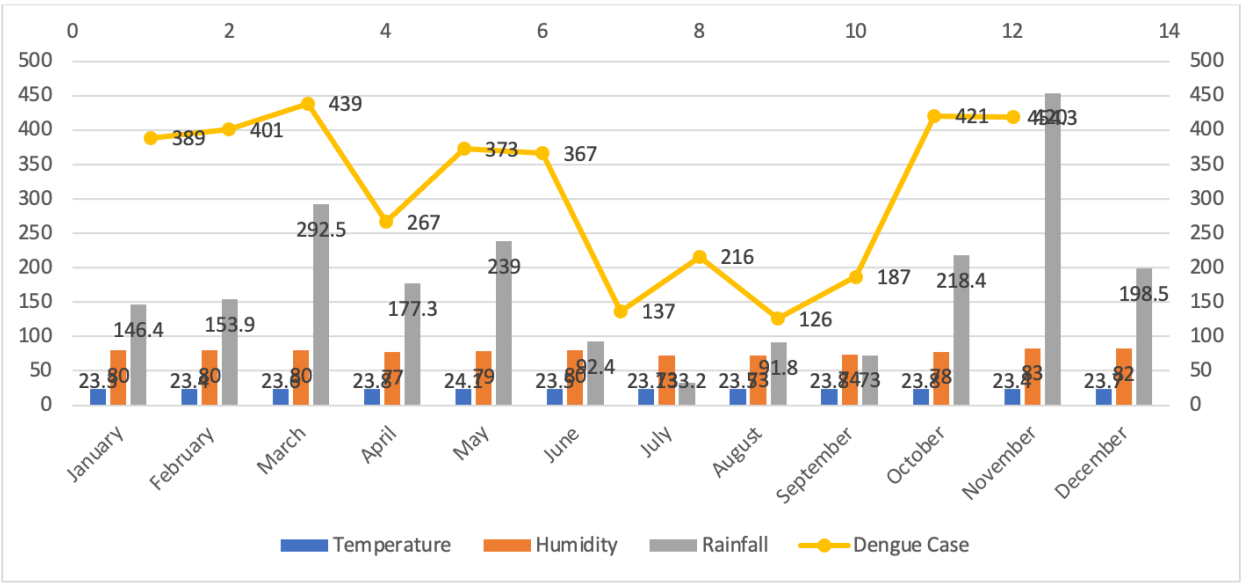

Figure 2. Temperature, Humidity, Rainfall and Incidence of DHF in 2021

Figure 2 shows that the highest temperature in Bandung in 2021 occurred in May at 24.1◦C, while the lowest occurred in June at 23.1◦C. The highest humidity

occurred in November at 83%, while the lowest occurred in July and August at 73%. The highest rainfall occurred in November at 454.3 mm, while the lowest occurred in July at 33.2 mm. The highest incidence of DHF occurred in March with 439 cases, while the lowest occurred in July with 137 cases.

Table 1. Mean, Standard Deviation, Minimum-Maximum Values of Temperature, Humidity, Rainfall, and Incidence of DHF in Bandung in 2021

Variable	Mean	SD	Min	Max
Temperature	23.5833	0.27247	23.10	24.10
Humidity	78.2500	3.36087	73.00	83.00
Rainfall	180.8917	114.19867	33.20	454.30
Incidence of DHF	311.9167	117.68869	126.00	439.00

Based on the results described in Table 1, the mean value of temperature in Bandung in 2021 was 23.5◦C with an SD of 0.27◦C, the lowest temperature was 23.10◦C, while the highest was 24.10◦C. The mean value of humidity in Bandung in 2021 was 78.2% with an SD of 3.3%, the lowest humidity was 73.0%, while the highest was 83.0%. The mean value of rainfall in Bandung in 2021 was 180.89 mm with an SD of 114.196 mm, the lowest rainfall was 22.20, while the highest was 454.30. The mean incidence of DHF in Bandung in 2021 was 311.91 cases with an SD of 117.68, the lowest incidence of DHF was 126 cases, while the highest incidence of DHF was 439 cases.

Table 2. Results of Correlation Analysis of Temperature, Humidity, Rainfall on Incidence of DHF in Bandung in 2021

Climate	Dengue incident		Significance
	p-value (p)	Correlation coefficient (r)	
Minimum Temperature	0.020	-0.658	The correlation is significant, the negative is strong
Maximum Temperature	0.006	0.739	The correlation is significant, the positive is very strong
Minimum Humidity	0.000	0.825	The correlation is significant, the positive is very strong
Maximum Humidity	0.704	0.123	The correlation is not significant
Rainfall	0.037	0.605	The correlation is significant, the positive is strong

Based on the results described in Table 2, the results of the person correlation test for minimum temperature and the incidence of DHF obtained (p) of 0.020 <0.05. The correlation coefficient (r) was -0.658, meaning that there is a significant relationship between minimum temperature and the incidence of DHF. With a significant correlation between the p-value and the correlation coefficient, it can be concluded that the close relationship between minimum temperature and the incidence of DHF has a strong negative correlation. Then, the results of the person

correlation test for maximum temperature and the incidence of DHF obtained (p) of 0.006 <0.05. The correlation coefficient (r) was 0.739, indicating that there is a significant relationship between maximum temperature and the incidence of DHF. With a significant correlation between the p-value and the correlation coefficient, it can be concluded that the close relationship between maximum temperature and the incidence of DHF has a strong positive correlation.

Next, the results of the person correlation test for minimum humidity and the incidence of DHF obtained (p) of 0.000 <0.05. The correlation coefficient (r) was 0.825, implying that there is a significant relationship between minimum humidity and the incidence of DHF. With a significant correlation between the p-value and the correlation coefficient, it can be concluded that the close relationship between minimum humidity and the incidence of DHF has a very strong positive correlation. Whereas the results of the person correlation test for maximum humidity and the incidence of DHF obtained (p) 0.704 >0.05, meaning that there is no significant relationship between maximum humidity and the incidence of DHF.

Finally, the results of the person correlation test for rainfall and the incidence of DHF yielded (p) 0.037 >0.05. The correlation coefficient (r) was 0.605, meaning that there is a significant relationship between rainfall and the incidence of DHF. With a significant correlation between the p-value and the correlation coefficient, it can be concluded that the close relationship between rainfall and the incidence of DHF has a strong positive correlation.

DISCUSSION

The incidence of dengue fever (DHF) in Bandung in 2021 reached 3,743 cases. This figure was higher than the previous year, but lower than in 2016 and 2019. The incidence of dengue fever is affected by many factors, one of which is climate. It is thought that an increase in world temperature is associated with an increase in vector-borne diseases.[16] Rainfall has been described as one of the reasons for the increase in DHF cases.[17] Meanwhile, an increase in humidity can help adult mosquitoes survive longer and spread dengue fever.[18] This study only conducted an investigation of climatic variations in 2021 and found that minimum and maximum temperatures are strong predictors for an increase in the incidence rate of dengue fever cases. The optimum temperature for mosquito breeding is 20∘C to 35∘C. The *aedes aegypti* mosquito will breed and transmit the dengue virus only when exposed to temperatures within 20^0C to 35^0C.[19] In this study, the minimum (lowest) temperature was 23.10^0C, while the maximum (highest) was 24.10^0C. A Vietnam study suggests that the short-term exposure-response relationship between temperature and incidence of DHF is not only non-linear but also differed between outbreak size categories. As a comparison, temperature has the greatest impact on large dengue outbreaks, with an estimated 21.9% of total cases or 19.8 cases per 100,000 people due to the effects of temperature.[20] The lower temperature limit for Aedes aegypti is around 10°C, below this temperature, the mosquito becomes sluggish and unable to move.[21] Rowley and Graham reveal that female Aedes aegypti can fly sustainably between 15°C and 32°C. Whereas at temperature extremes, namely 10°C and 35°C, they can still fly but only for short periods of time. Optimal flight temperature, in terms of flight duration and distance, is set at 21°C, but overall, the flight performance of tethered female

Aedes aegypti is better when the temperature is below 27°C.[22] This study found that minimum humidity and rainfall are correlated with increased incidence of DHF. In this study, the minimum (lowest) humidity was 78.25%. Meanwhile, the mean value of rainfall in Bandung was 180.89 mm. Dengue fever cases are more common during the rainy season when the relative humidity is higher. Higher humidity during the rainy season supports the development and breeding of mosquitoes, causing an increase in the number of infected mosquitoes.[23,24] The cumulative effect of temperature and humidity greatly affects the number of mosquito blood bites, the vector survival rate, and the probability of mosquitoes being infected with dengue fever.[25] According to studies carried out around the world, relative humidity and temperature are the most important climate predictors of changes in dengue transmission.[26–28] Therefore, through its effect on the Aedes vector, temperature, rainfall, and relative humidity are important factors that determine the geographic areas where dengue transmission can occur.[25]

In this study, the highest number of DHF cases was reported in March (429). Temperature, rainfall, and humidity have been reported to be the most important climate predictors of changes in dengue transmission, the most ideal combination of high relative humidity and high temperature was present in March 2021 compared to other months in the study period, resulting in the most dengue cases. Several studies have reported that the climatic variations indices from the El Niño Southern Oscillation and the Indian Ocean Dipole play an important role in the transmission of dengue fever.[29] Variations in ocean sea surface temperature are also found to be responsible for the increase in dengue cases.[30] Furthermore, the increased caseload is also caused by the lack of public concern for environmental hygiene. Unstructured mosquito control measures and lack of supervision, excessive focus on fogging-based vector control, and the government taking action only after an increase in cases have emerged are all problems that need attention.

Based on the results of this study, temperature, humidity, and rainfall are significantly correlated with the incidence of DHF, thus mosquito control and DHF surveillance program should be strengthened during the season following the rainy (wet) season. This can be done because there is sufficient time to mobilize health workers to implement intervention steps to minimize the impact of the epidemic.[31] A study carried out in Sleman shows similar findings, namely that the three climatic variations (temperature, humidity, and rainfall) contribute to dengue cases by 13.5%-27.4% simultaneously. Humidity is the most important climatic factor affecting dengue cases.[32]

Public health is critical to knowing the magnitude and pattern of climate impacts and their significance for prioritizing and allocating resources to protect populations. Unfortunately, the health research community is largely working in isolation from other sectors. This also happens in the health sector when dealing with health problems, especially infectious disease problems. Whereas, to ensure sustainable development, all aspects of urban public health must be considered, particularly to prepare cross-sector climate change policies and climate services. The multi-sector collaboration has increased over the past few years through the Project of Impact Model Comparison in Cross-Sector. Such multi-sector collaboration is urgently needed today. There are a large number of mitigation strategies that will enable cities (municipalities) to face the health challenges posed by climate change. The multi-sector collaboration will optimize the limited resources a city has to manage many problems that are expected to arise.[33]

CONCLUSION AND RECOMMENDATIONS

The results of this study support the conclusion that there is a significant relationship between temperature, humidity, rainfall, and incidence of DHF. Therefore, the researchers of this study recommend that the government of Bandung carry out cross-sector collaboration to overcome DHF problems and carry out public awareness campaigns emphasizing the importance of doing 3R (Reduce, Reuse, and Recycle) to reduce mosquito resting and breeding places. Furthermore, subsequent studies need to be carried out by covering more complete data on the incidence of DHF and climatic variations so as to obtain more optimal results.

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REFERENCES

1. Wu T, Wu Z, Li Y. Dengue fever and dengue virus in the People's Republic of China. Rev Med Virol. 2022;32(1):e2245. doi: 10.1002/rmv.2245.
2. Budianto R, Budiarti N. Dengue Hemorrhagic Fever: Past, Present, and Future. Berkala Kedokteran. 2019;15(1):45–58. doi: 10.20527/jbk.v15i1.6122.
3. Medlock JM, Leach SA. Effect of climate change on vector-borne disease risk in the UK. Lancet Infect Dis. 2015;15(6):721–30. doi: 10.1016/S1473-3099(15)70091-5.
4. Ewing DA, Cobbold CA, Purse B V, Nunn MA, White SM. Modelling the effect of temperature on the seasonal population dynamics of temperate mosquitoes. J Theor Biol. 2016; 400:65–79. doi: 10.1016/j.jtbi.2016.04.008.
5. Tran A, L'ambert G, Lacour G, Benoît R, Demarchi M, Cros M, et al. A rainfall-and temperature-driven abundance model for Aedes albopictus populations. Int J Environ Res Public Health. 2013;10(5): 1698–719. doi: 10.3390/ijerph 10051698.
6. Christofferson RC, Mores CN. A role for vector control in dengue vaccine programs. Vaccine. 2015; 33(50):7069–74. doi: 10.1016/j.vaccine.2015.09.114.
7. Sutriyawan A, Herdianti H, Cakranegara PA, Lolan YP, Sinaga Y. Predictive Index Using Receiver Operating Characteristic and Trend Analysis of Dengue Hemorrhagic Fever Incidence. Open Access Maced J Med Sci. 2022;10(E):681–7. doi: 10.3889/oamjms.2022.8975.
8. Samal RF. Analisis Spasial dan Faktor Risiko Kejadian Demam Berdarah Dengue di Kelurahan Tamamaung Kota Makassar. Window of Public Health Journal. 2022;2076–86. doi: 10.33096/woph.v3i4.169.
9. Sutriyawan A, Wirawati K, Suherdin S. The Presence of Aedes Aegypti Mosquito larvae in Bandung City in 2021. Disease Prevention and Public Health Journal. 2022;16(2):70–7. doi: 10.12928/dpphj.v16i2.5121.

10. Monintja TCN, Arsin AA, Amiruddin R, Syafar M. Analysis of temperature and humidity on dengue hemorrhagic fever in Manado Municipality. Gac Sanit. 2021; 35:S330–3. doi: 10.1016/j.gaceta. 2021.07.020.
11. Abdulsalam FI, Antunez P, Yimthiang S, Jawjit W. Influence of climate variables on dengue fever occurrence in the southern region of Thailand. PLOS Global Public Health. 2022;2(4):e0000188. doi: 10.1371/journal.pgph.0000188.
12. Prasetyowati H, Fuadzy H, Astuti EP. Pengetahuan, Sikap dan Riwayat Pengendalian Vektor di Daerah Endemis Demam Berdarah Dengue Kota Bandung. ASPIRATOR-Journal of Vector-Borne Disease Studies. 2018;10(1):49–56.
13. Widyatama EF. Faktor risiko yang berpengaruh terhadap kejadian demam berdarah dengue di wilayah kerja Puskesmas Pare. Jurnal Kesehatan Lingkungan. 2018; 10(4):417–23.
14. Sulekan A, Suhaila J, Wahid NAA. Assessing the effect of climate factors on dengue incidence via a generalized linear model. Open Journal of Applied Sciences. 2021;10(04):549. doi: 10.4236/ ojapps.2021.104039.
15. Harrington LC, Fleisher A, Ruiz-Moreno D, Vermeylen F, Wa C V, Poulson RL, et al. Heterogeneous feeding patterns of the dengue vector, Aedes aegypti, on individual human hosts in rural Thailand. PLOS Negl Trop Dis. 2014;8(8):e3048. doi: 10.1371/journal.pntd.0003048.
16. Islam MA, Hasan MN, Tiwari A, Raju MAW, Jannat F, Sangkham S, et al. Correlation of Dengue and Meteorological Factors in Bangladesh: A Public Health Concern. Int J Environ Res Public Health. 2023;20(6):5152. doi: 10.3390/ijerph20065152.
17. Singh PS, Chaturvedi HK. A retrospective study of environmental predictors of dengue in Delhi from 2015 to 2018 using the generalized linear model. Sci Rep. 2022;12(1):1–10. doi: 10.1038/s41598-022-12164-x.
18. Chumpu R, Khamsemanan N, Nattee C. The association between dengue incidences and provincial-level weather variables in Thailand from 2001 to 2014. PLOS ONE. 2019; 14(12):e0226945. doi: 10.1371/ journal.pone.0226945.
19. Carrington LB, Armijos MV, Lambrechts L, Scott TW. Fluctuations at a low mean temperature accelerate dengue virus transmission by Aedes aegypti. PLOS Negl Trop Dis. 2013; 7(4):e2190. doi: 10.1371/journal. pntd.0002190.
20. Cheng J, Bambrick H, Yakob L, Devine G, Frentiu FD, Toan DTT, et al. Heatwaves and dengue outbreaks in Hanoi, Vietnam: New evidence on early warning. PLOS Negl Trop Dis. 2020;14(1):e0007997. doi: 10.1371/ journal.pntd.0007997.
21. Bayona-Valderrama A, Acevedo-Guerrero T, Artur C. Cities with mosquitoes: A political ecology of Aedes aegypti's habitats. Water Alternatives [Internet]. 2021 [cited 2023 May 24];14(1):186–203. Available from: https://www.water-alternatives.org/index.php/alldoc/articles/vol14/v14issue1/609-a14-1-4/file
22. Reinhold JM, Lazzari CR, Lahondère C. Effects of the environmental temperature on Aedes aegypti and Aedes albopictus mosquitoes: a review. Insects. 2018;9(4):158. doi: 10.3390/insects 9040158.

23. Karim MN, Munshi SU, Anwar N, Alam MS. Climatic factors influencing dengue cases in Dhaka city: a model for dengue prediction. Indian J Med Res. 2012;136(1):32.
24. Ahmed T, Hyder MZ, Liaqat I, Scholz M. Climatic conditions: conventional and nanotechnology-based methods for the control of mosquito vectors causing human health issues. Int J Environ Res Public Health. 2019;16(17):3165. doi: /10.3390/ijerph16173165.
25. Naish S, Dale P, Mackenzie JS, McBride J, Mengersen K, Tong S. Climate change and dengue: a critical and systematic review of quantitative modelling approaches. BMC Infect Dis. 2014;14(1):1–14. doi: 10.1186/1471-2334-14-167.
26. Ramachandran VG, Roy P, Das S, Mogha NS, Bansal AK. Empirical model for estimating dengue incidence using temperature, rainfall, and relative humidity: a 19-year retrospective analysis in East Delhi. Epidemiol Health. 2016;38. doi: 10.4178/epih.e2016052.
27. Earnest A, Tan SB, Wilder-Smith A. Meteorological factors and El Nino Southern Oscillation are independently associated with dengue infections. Epidemiol Infect. 2012;140(7):1244–51. doi: 10.1017/S095026881100183X.
28. Descloux E, Mangeas M, Menkes CE, Lengaigne M, Leroy A, Tehei T, et al. Climate-based models for understanding and forecasting dengue epidemics. PLOS Negl Trop Dis. 2012;6(2):e1470. doi: 10.1371/journal.pntd.0001470.
29. Banu S, Guo Y, Hu W, Dale P, Mackenzie JS, Mengersen K, et al. Impacts of El Niño southern oscillation and Indian Ocean dipole on dengue incidence in Bangladesh. Sci Rep. 2015;5(1):16105. doi: 10.1038/srep16105.
30. Adde A, Roucou P, Mangeas M, Ardillon V, Desenclos JC, Rousset D, et al. Predicting dengue fever outbreaks in French Guiana using climate indicators. PLOS Negl Trop Dis. 2016;10(4):e0004681. doi: 10.1371/journal.pntd.0004681.
31. Choi Y, Tang CS, McIver L, Hashizume M, Chan V, Abeyasinghe RR, et al. Effects of weather factors on dengue fever incidence and implications for interventions in Cambodia. BMC Public Health. 2016;16(1):1–7. doi: 10.1186/s12889-016-2923-2.
32. Kesetyaningsih TW, Andarini S, Sudarto S, Pramoedyo H. Determination of environmental factors affecting dengue incidence in Sleman District, Yogyakarta, Indonesia. Afr J Infect Dis. 2018; 12(1S):13–25. doi: 10.21010/ajid.v12i1S.3.
33. Ligsay A, Telle O, Paul R. Challenges to mitigating the urban health burden of mosquito-borne diseases in the face of climate change. Int J Environ Res Public Health. 2021;18(9):5035. doi: 10.3390/ijerph18095035.