Weather dependency in Dengue cases in Dhaka City, Bangladesh

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***Abstract*—In Bangladesh, particularly in Dhaka city, dengue fever is a major factor in serious sickness and hospitalization. The weather influences the temporal and geographical spread of the vector-borne disease dengue in Dhaka. As a result, rainfall and ambient temperature are considered macro factors influencing dengue since they have a direct impact on Aedes aegypti population density, which changes seasonally dependent on this critical dengue disease.**

***Index Terms*—Dengue incidence, humidity, temperature, rainfall, wind speed, Dhaka Bangladesh**

I. Introduction

Dhaka City, Bangladesh, grapples with the formidable challenge of dengue fever, a mosquito-borne viral infection whose prevalence is intricately tied to the region's weather patterns. The tropical climate of Dhaka, characterized by warm temperatures and high humidity, creates an ideal habitat for the Aedes mosquitoes, the primary vectors of the dengue virus. The city's densely populated urban landscape further compounds the risk, as Aedes mosquitoes thrive in artificial water containers commonly found in and around households.

The seasonal dynamics of dengue in Dhaka are notably influence by the monsoon season, lasting from June to October. During this period, heavy rainfall leads to the accumulation of stagnant water in various receptacles, providing abundant breeding grounds for mosquitoes. The increased mosquito activity, coupled with conducive environmental conditions, amplifies the transmission of the dengue virus. Moreover, temperature and humidity play crucial roles in shaping the life-cycle and viability of Aedes mosquitoes, further highlighting the interdependence between weather conditions and dengue incidence.

II. Literature Review

A. The association between dengue incidences and provincial-level weather variables in Thailand from 2001 to 2014

Dengue is a mosquito-borne disease, in which Aedes aegypti is the main vector. This type of mosquito is commonly found in tropical countries. Dengue fever (DF) and dengue hemorrhagic fever (DHF), a severe form of the disease, are caused by four dengue serotypes represented by DEN 1, 2, 3, and 4. Reinfections of different serotypes can cause severe illnesses or deaths. Once infected, it can take 3–14 days for the virus to incubate. Dengue fever is the initial stage of dengue cases. Symptoms of dengue fever include a high fever, body and muscular aches, nausea, vomiting, skin rash, and fatigue. Dengue fever can last 5 to 7 days. Some patients may recover. However, the disease may develop into the next lethal stage called dengue hemorrhagic fever. Clinical manifestations of DHF include reduced blood pressure due to plasma leakage from capillaries and bleeding due to low platelet counts and impairment of platelet functions. If their blood pressure is extremely low, patients may enter the stage of dengue shock syndrome, lose consciousness, and pass into the last stage of shock. [1,2]

B. Climatic factors influencing dengue cases in Dhaka city: A model for dengue prediction

The dengue virus, one of the arboviruses causes classical dengue fever (DF) and dengue hemorrhagic fever (DHF) primarily in the tropical and subtropical regions. Bangladesh with the tropical climate has become an ideal land for dengue virus transmission. Though the first documented outbreak of DF from Bangladesh was in 1964 in Dhaka city followed by a few scattered cases of DF during 1977-1978 and 1996-1997, the first epidemic of DHF occurred in mid-2000, which was reported from all the major cities. Presence of both the vectors, Aedes. aegypti and Ae. albopictus, was also identified during different outbreaks. [3,4]

C. Climate Variability, Dengue Vector Abundance and Dengue Fever Cases in Dhaka, Bangladesh: A Time-Series Study

The potential impacts of climate change on the human environment and infectious diseases are significant and alarming. Dengue/Severe Dengue Fever (DF/SDF) is one of the most rapidly growing arboviral diseases in the tropics, for which there is currently no universally accepted cure or vaccine.

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The rapid spread of both the dengue virus (DENV) and its mosquito vector (mostly Aedes aegypti and Aedes albopictus) in the past four decades poses an enormous risk to public health in tropical regions. The Halstead and Gubler studies suggested that the projected emergence will place around 2.5–3.0 billion people at risk of acute illness every year as tropical diseases spread to new areas, such as Europe and North America. As well, Aedes albopictus plays a noticeable role in dengue transmission in the USA and Europe, whereas, in Asia, Aedes aegypti is more dominant in spreading dengue. Presently, populations of 129 countries worldwide are vulnerable with the risk of dengue infection—caused by both kinds of Aedes mosquitoes—of which, 70 percent of the actual disease burden exist in Asia. About 5.2 million dengue cases were recorded by the WHO in 2019 with an annual death count of 4032 people. Apart from dengue, these mosquitoes are also vectors of chikungunya, yellow fever and Zika viruses. [5-8]

D. Association of climate factors with dengue incidence in Bangladesh, Dhaka City: A count regression approach

The study" Association of climate factors with dengue incidence in Bangladesh, Dhaka City: A count regression approach" aimed to investigate the relationship between climatic variables and the incidence of dengue in Dhaka City, Bangladesh. The study analyzed a total of 2253 dengue and climate data, including maximum and minimum temperature, humidity, wind speed, rainfall, and sunshine hours. The findings showed that factors such as maximum temperature, minimum temperature, humidity, and wind speed were crucial in the transmission cycles of dengue disease. However, dengue cases decreased with higher levels of rainfall and sunshine hours. The study found that the mean number of dengue cases increased with higher levels of maximum temperature (1.13), humidity (1.03), wind speed (1.25), and minimum temperature (1.07) . On the other hand, the mean number of dengue cases decreased with higher levels of sunshine hours (0.97) and rainfall (0.98) . These results suggest that climate factors play a significant role in the transmission of dengue in Bangladesh, particularly in Dhaka City. The study's findings can be helpful for policymakers to develop climate-based warning systems and take preventive measures against dengue outbreaks. As climate change continues to impact global health, it is essential to understand the relationship between climate factors and the spread of vector-borne diseases like dengue. (10)

E. Association between Climate Factors and Dengue Fever in Asuncion, Paraguay: A Generalized Additive Model

The association between climate factors and dengue fever has been studied in various locations, including Asuncion, Paraguay, and Bangladesh, Dhaka City. In the case of Asuncion, Paraguay, a study using a Generalized Additive Model found that rainfall, wind, atmospheric pressure, and humidity were significant climatic factors associated with dengue fever. Another study reported that wind and relative humidity were negatively associated with dengue cases, while minimum temperature was positively associated with dengue cases in the same region. These findings highlight the complex relationship between climate factors and dengue incidence in Asuncion, Paraguay. In the context of Bangladesh, particularly in Dhaka City, a study using a count regression approach revealed that factors such as maximum temperature, minimum temperature, humidity, and wind speed were crucial in the transmission cycles of dengue disease. Additionally, the study found that dengue cases decreased with higher levels of rainfall and sunshine hours. This research is valuable for understanding the impact of climate factors on dengue incidence and for informing the development of climate-based warning systems and preventive measures. The studies underscore the importance of considering various climate variables, such as temperature, humidity, rainfall, and wind, in assessing the risk of dengue fever. Understanding these associations is essential for public health planning and preparedness, particularly in the context of climate change and its potential impact on the transmission of vector-borne diseases like dengue. (11)

F. Assessing the impact of climatic factors on dengue fever transmission in Bangladesh

Several studies have assessed the impact of climatic factors on dengue fever transmission in Bangladesh, particularly in Dhaka City. These studies have highlighted the significant influence of various climate variables on the incidence of dengue fever. For example, a study using a count regression approach found that low humidity, low rainfall, and low wind speed promote Aedes survivability, contributing to dengue transmission. Another study examined the association between dengue disease and climate factors, revealing that the monthly mean temperature, total rainfall, and mean humidity were significantly associated with dengue incidence in Dhaka. Additionally, research has shown that factors such as maximum temperature, minimum temperature, humidity, and wind speed are crucial in the transmission cycles of dengue disease, while dengue cases decreased with higher levels of rainfall and sunshine hours. These findings collectively demonstrate the importance of considering various climatic factors, such as temperature, humidity, rainfall, and wind speed, in understanding the transmission dynamics of dengue fever in Bangladesh. The studies provide valuable insights for public health planning, the development of climate-based warning systems, and the implementation of preventive measures to mitigate the impact of dengue outbreaks. (12)

G. Climatic variables associated with dengue incidence in a city of the Western Brazilian Amazon region

A study conducted in Rio Branco, the capital city of the state of Acre in the Western Brazilian Amazon region, aimed to examine the association between the monthly incidence of dengue fever and climate variables such as temperature, humidity, and the Acre River level. The study used generalized autoregressive moving average models with negative binomial distribution and tested multiple no-lag, 1-month lag, and 2-month lag models. The results of the study showed that the number of days with precipitation and maximum temperature were significantly associated with the subsequent incidence of dengue fever. Specifically, each additional day of precipitation per month was associated with a 3 percent increase in the incidence of the disease (IRR: 1.03, 95percent CI: 1.00-1.06). This indicates that climate factors, particularly precipitation and maximum temperature, play a significant role in the transmission of dengue fever in the region. These findings are consistent with other studies conducted in Brazil and other tropical regions, which have shown that dengue cases follow a seasonal pattern with higher incidence in months of higher rainfall and high temperatures [5]. The results of this study provide valuable insights for public health planning, the development of climate-based warning systems, and the implementation of preventive measures to mitigate the impact of dengue outbreaks in the Western Brazilian Amazon region. (13)

H. How air pollution altered the association of meteorological exposures and the incidence of dengue fever

A study published on December 9, 2022, investigated the association between meteorological exposures and the risk of dengue fever, as well as the modification effect of major air pollution. The study found that temperature and precipitation were significantly associated with dengue, and diverse patterns of the effect modification by air pollution on these relationships were revealed. This included the facilitation effects of some pollution conditions on the health impact of increased temperature and precipitation, as well as the prohibition effects of some other pollution conditions on the impact of increased temperature and precipitation. The study suggested that higher air pollution levels may affect both human behaviors and the activities of Aedes mosquitoes as a potential mechanism. The research provided insights into how air pollution may modify the association between dengue and meteorological exposures, highlighting the need to consider the interplay of multiple environmental factors in dengue transmission dynamics. This study contributes to the understanding of the complex interactions between meteorological exposures, air pollution, and dengue incidence, emphasizing the importance of integrated approaches to address the impact of environmental factors on dengue fever transmission. (14)

I. Analysis of the correlation between climatic variables and Dengue cases in the city of Alagoinhas/BA

A study conducted in the city of Alalongas, Bahia, Brazil, aimed to analyze the correlation between climatic variables and dengue cases. The study found a moderate correlation between relative humidity and the incidence of dengue cases in the municipality of Alalongas. Additionally, the study revealed an inverse correlation between air temperature and confirmed cases of dengue in the city. The research applied the detrended cross-correlation coefficient to measure the correlation between non-stationary series and found that the predominant factor in the incidence of dengue cases in the city of Alalongas is the relative humidity. These findings suggest that climatic variables, particularly relative humidity, play a significant role in the transmission of dengue fever in the city of Alalongas. The study provides valuable insights for public health planning, the development of climate-based warning systems, and the implementation of preventive measures to mitigate the impact of dengue outbreaks in the region. It is worth noting that the study was conducted in a specific location and may not be generalizable to other regions. However, the findings are consistent with other studies that have shown the influence of climatic factors, such as temperature and humidity, on the incidence of dengue fever in other tropical regions. (15)

J. Assessing the Effect of Climate Factors on Dengue Incidence via a Generalized Linear Model

A study titled" Assessing the Effect of Climate Factors on Dengue Incidence via a Generalized Linear Model" re- veiled the following significant findings: Rainfall, temperature, humidity, and wind speed were statistically significant with dengue incidence, with most of them showing a negative effect. Among these variables, wind speed had the most significant impact on dengue incidence. The study focused on dengue hot spots in Malaysia for the year 2014 and used a Generalized Linear Model (GLM) via Poisson and Negative Binomial to examine the effects of climate factors on dengue incidence by considering the collinearity between variables. The findings of the study are consistent with other research, indicating that changes in climate factors such as temperature, rainfall, humidity, and wind speed can significantly impact the incidence of infectious diseases like dengue. These results provide valuable insights into the relationship between climate factors and dengue incidence, which can inform public health planning, the development of climate-based warning systems, and the implementation of preventive measures to mitigate the impact of dengue outbreaks. (16)

K. Spatial Analysis on the Spread of Dengue Hemorrhagic Fever in Baubau, Southeast Sulawesi, Indonesia

A study conducted in Baubau, Southeast Sulawesi, Indonesia, examined the spatial patterns of Dengue Hemorrhagic Fever (DHF) transmission using Moran's Index, a spatial analysis tool. The study found different patterns of DHF risk, such as cold spots, hot spots, and low risk areas, with relative humidity being the most significant factor in the incidence of DHF cases. Another study conducted in Sulawesi Tenggara Province, Indonesia, aimed to forecast the prevalence of dengue hemorrhagic fever using the ARIMA model. The study found that there would be an increase in dengue hemorrhagic fever prevalence over the next two years, with a mean absolute percentage error value of 4.41percent. Additionally, a study conducted in Bandung, West Java, Indonesia, analyzed the spatial and temporal patterns of hospitalized dengue patients and found that children under 10 years old were at the highest risk of dengue infection. These studies provide valuable insights into the transmission dynamics of dengue fever in Indonesia and can inform public health planning, the development of climate-based warning systems, and the implementation of preventive measures to mitigate the impact of dengue outbreaks in the region. (17)

L. Association between climate variables and dengue incidence in Nakhon Si Thammarat Province, Thailand

A study conducted in Nakhon Si Thammarat Province, Thailand, examined the association between climate variables and dengue incidence. The study found that temperature, sea-level pressure, and wind speed had the most significant effect on reported dengue cases, while rainfall and pan evaporation had the least effect. Another study revealed a significant association between environmental variables and dengue incidence when comparing the seasons, with temperature, sea-level pressure, and rainfall being significant predictors of dengue incidence in the province. The findings of these studies suggest that climate variables play a significant role in the transmission of dengue fever in Nakhon Si Thammarat Province, Thailand. The results provide valuable insights for public health planning, the development of climate-based warning systems, and the implementation of preventive measures to mitigate the impact of dengue outbreaks in the region.(18)

III. Methods

A. Data All data on Dengue (2019 and 2022) in Dhaka city was gathered from the Kurmitola General Hospital (KGM) in Bangladesh. Maximum and minimum temperature, humidity, rainfall, sunshine hour, and wind speed data (2019 and 2022) in Dhaka city were collected from Bangladesh Meteorological Department (BMD) (9). Daily basis data were collected for each year and month (January to December).

B. Outcome variable Daily basis dengue data (total dengue cases that occurred in a day) in Dhaka was considered as an outcome variable for this analysis.

C. Independent variable Maximum and minimum temperature (∘C), humidity (grams of water vapor per kilogram of air g.kg- 1), rainfall (mm), sunshine hour (in (average) hours per day), and wind speed (knots (kt)) in Dhaka were considered as the independent variables for this study.

D. Multiple imputation procedure A total of 5048 dengue and climate data were used for this study. We found around 8 Percent missing values in our data sets and we used multiple imputation techniques using the classification and regression trees method to impute the missing values [32]. The multiple imputation method imputes the missing values multiple times by using an appropriate model [33]. The aim of multiple imputation is to consider the uncertainty that the imputed values are the sample draws for the missing values instead of the actual values. A number of m copies of the data set are found by substituting each missing values by a set of m ¿ 2 imputed values that are simulated from an apropos imputation model. Each imputed data set is then considered as a complete data set and analyzed using the standard method. The results from the m imputed data sets are then combined using Rubin's formula [34]. In our study, we used R packages mice with 5 number of multiple imputations (m = 5), 50 number of iterations (maxi = 50), and also used set. seed = 500 for getting the fixed finalized data sets [35].

E. Classification and regression trees CART, unlike logistic and linear regression, does not create a prediction equation. Instead, data is partitioned along the predictor axes into subsets with homogenous dependent variable values—a process represented by a decision tree that may be used to create predictions based on new observations [36].

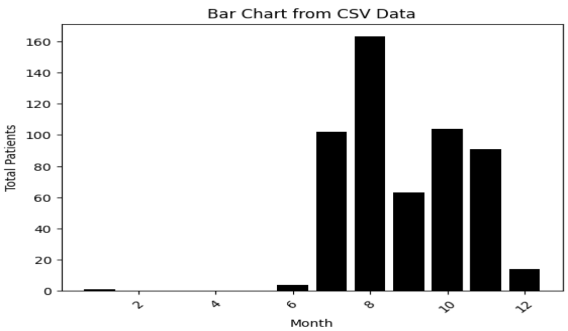
F. Statistical analysis Firstly, descriptive statistics were performed to see the basic characteristics of each variable (mean, sd, min, max) for each year. Secondly, Pearson correlation analysis was performed among outcomes and all predictor variables to see whether there is any correlation between them. Since our main goal is to test whether there is an association between climate factors and dengue cases regardless of time frame, we used a stationary test using R packages tseries for Augmented Dickey-Fuller Test. We found the time series process is stationary and considered this problem as a cross-sectional instead of a time series analysis. Since our outcome is count data, we used the Poisson regression model at first. After that, we checked for zero inflation and overdispersion using the R function check zero inflation (supplementary material Climate Dengue .R code file) and R packages AER, respectively. We fitted the Poisson regression model (Model-1), the Negative binomial regression model in case of overdispersion (Model 2), and the zero-inflated Poisson regression model in case of zero inflation (Model-3) using R packages MASS and pascal. Moreover, the goodness of fit of these models was checked using Akaike information criterion (AIC) values. Finally, a final model was selected based on the minimum AIC values, and the multicollinearity of this model also was investigated using R car packages and the function.

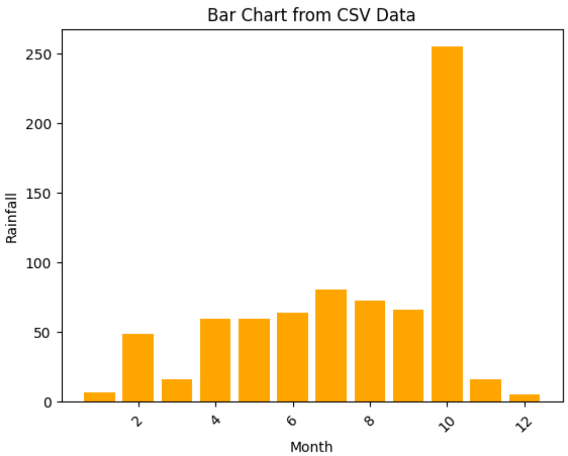
IV. Result

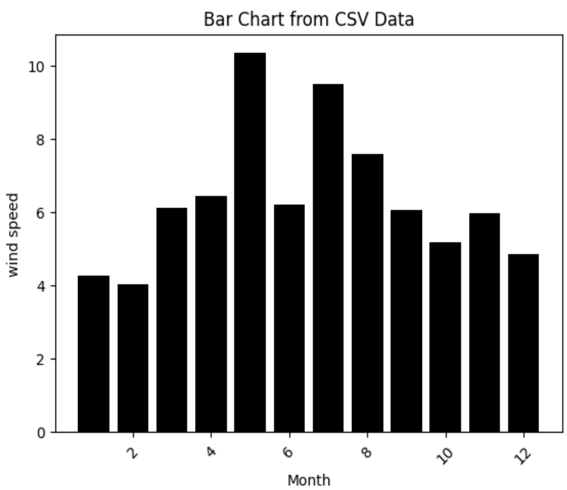
Descriptive statistics A total of 5048 dengue and climate data was used for this study from 2019 and 2022. We observed around 403 missing values and imputed them by using multiple imputation techniques. After imputation, the total number of observations is 2853. The descriptive statistics such as the total number of observations, mean, standard deviation, and minimum and maximum of both dengue cases and climate factors showed in supplementary materials for each year separately in descriptivism file. The mean maximum temperature was highest in 2019 and it shows ups and down trends over the periods. The minimum temperature means was decreasing after 2022 and it also showed an increasing trend after 2019. The mean of rainfall reported ups and down patterns over the periods. The maximum mean of humidity was observed in 2019 and this showed some fluctuations over the time interval. The mean of the sunshine hour showed the reverse of humidity, and it showed the highest point in 2019. Wind speed also reported some fluctuations with the maximum point in 2019. The mean number of dengue cases showed slightly increasing trends from 2019 to 2022, after that, it reported a rapid increase trend in 2019.

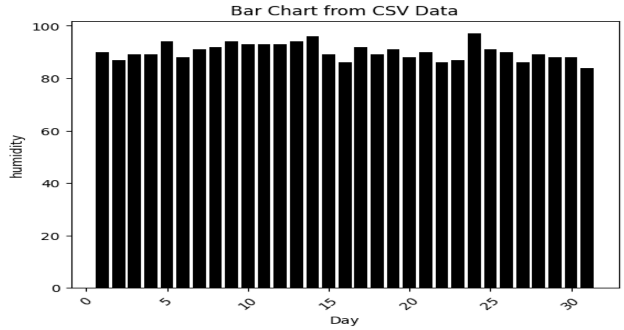
V. CORRELATION ANALYSIS

temperature, humidity, and wind speed were positively correlated with dengue cases. However, rainfall was negatively associated with dengue cases. Since all climate factors showed a correlation with dengue cases, we considered all climate variables as predictor variables for the outcome of dengue cases.

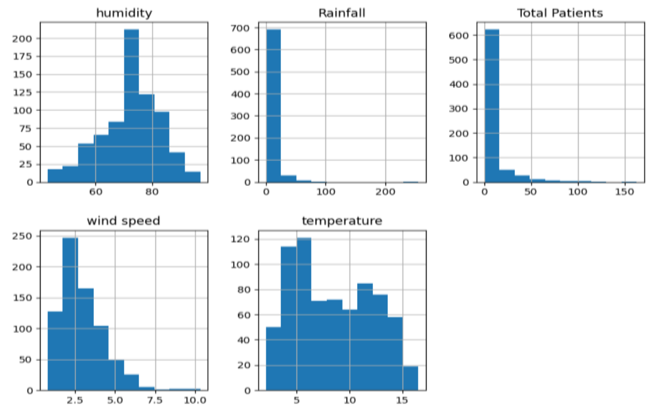








Histrogram of dataset



VI. Acknowledgment

We would like to show our gratitude to IEDCR and BMD for creating an open-access data source for information on Dengue and Weather.

VII. Discussion

In Dhaka City, Bangladesh, the incidence of Dengue fever exhibits a pronounced dependency on weather conditions. The tropical climate, characterized by high temperatures and heavy rainfall during the monsoon season, creates an optimal environment for the Aedes mosquito, the primary vector for the dengue virus. Elevated temperatures accelerate the mosquito's life cycle and the replication of the virus, while abundant rainfall leads to the formation of stagnant water, ideal breeding grounds for mosquitoes.

The monsoon season, from June to October, coincides with a surge in Dengue cases as mosquito populations proliferate. The city's humidity further supports mosquito survival and the efficient transmission of the virus. As a result, Dhaka experiences periodic outbreaks of Dengue fever, with the risk peaking during the post-monsoon period.

Understanding the weather dependency of Dengue in Dhaka is vital for effective prevention and control strategies. Public health measures, such as mosquito control programs and community awareness campaigns, can be intensified during periods of heightened risk. Additionally, early warning systems based on weather forecasts can aid in proactive responses, helping to mitigate the impact of Dengue outbreaks in this weather-sensitive context.

VIII. Data availability

The authors did not personally collect data for this study. Dengue and Meteorological data were extracted from the IEDCR (Institute of Epidemiology, Disease Control, and Research), Kurmitola General Hospital(KGH) and Bangladesh Meteorological Data (BMD)

IX. Limitation

Though this study has many implications, it has some limitations too. This study aims to find the impact of climate parameters on dengue incidences in Bangladesh. But there were many missing or incomplete data in the dataset, which indicates that the data is poor record-keeping and reporting system. It may happen because of a flawed monitoring system or a lack of awareness among the reporting authorities. This lack of data or the poor record system of population data is a crucial gap. The actual estimate might be affected by under or over-reporting bias because the dengue data includes confirmed and suspected cases.

X. Conclusion

This study aims to find the relationship between climate factors and dengue incidence in Dhaka, Bangladesh. Maximum temperature, minimum temperature, humidity, and wind speed positively impact dengue incidence, while rainfall and sunshine hours have a significantly negative effect. This research observed a potential alert system by modeling dengue outbreaks using climate variables, which is required to improve Bangladesh's public health and disease control systems. The findings of this study will be helpful for policymakers to develop a climate-based warning system in Bangladesh. Therefore, future attempts to build a model to predict the total number of dengue cases, including immunological, and entomological data, demographical factors, and climatic factors, and also for community-based observation to develop more practical dengue prevention strategy in Bangladesh at the time of dengue pandemic.

XI. References

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