Original Article

ASSOCIATION BETWEEN WEATHER FACTORS AND DENGUE IN DHAKA: A TIME-SERIES ANALYSIS

Shafia Shaheen[1]

ABSTRACT

Background: There was an epidemic of dengue fever that happened in Bangladesh in the year of 2019. Temperature of this country has been raising which leads to changing in rainfall pattern. This study was aimed to investigate the relationship of weather factors and dengue incidence in Dhaka. Dhaka.

Methods: A time series analysis was carried out by using 10 years weather data as average, maximum and minimum monthly temperature, average monthly humidity and average and cumulative monthly rainfall. Reported number of dengue cases was extracted from January 2009 to July 2019. Firstly, dengue incidence rate was calculated. Correlation analysis and negative binomial regression model was developed.

Results: Dengue incidence rate had sharp upward trend. Dengue incidence and mean, maximum and minimum average temperature showed statistically significant negative correlation at 3 months' lag. Highest incidence Rate Ratio (IRR) of dengue was found at minimum average temperature at 0 and 1-month lag. Average humidity showed positive and significant correlation with dengue incidence at 0-month lag. Average and cumulative rainfall also showed negative and significant correlation only at 3-months lag period.

Conclusion: Weather variability influences dengue incidence and the association between the weather factors are non-linear and not consistent. So the study findings should be evaluated area basis with other local factors to develop early warning for dengue epidemic prediction.

1. *Assistant Professor (Epidemiology), Department of Epidemiology, National Institute of Preventive and Social Medicine (NIPSOM), Mohakhali, Dhaka-1212*

Correspondence:
Shafia Shaheen,
e-mail: sshaheen69@yahoo.com

INTRODUCTION

Most countries of the tropical Asia had experienced varied clinical profile of dengue fever during 2019.[1] Dengue is a mosquito-borne viral disease occurred mostly in rainy season from June to October. Its clinical feature was ranged from flu-like symptoms to sever dengue shock syndrome (DSS) and dengue hemorrhagic fever (DHF) which may lead to fatal incidence.[2]

Bangladesh is one of the tropical country of Southeast Asia and its capital Dhaka is a densely populated mega city. Area of Dhaka city is 1463.6 sq. meter with 23,234/ m^2 population density.[3] There were 10,528 reported cases of dengue from various hospitals of Dhaka city from January to July 2019 (Directorate General of Health Services). Dengue case is always confirmed by laboratory investigation. So, the reported cases were laboratory confirmed and it could be assumed that actual dengue infected cases were several fold more.

Dengue viruses are nurtured and transmitted mostly by female mosquito *Aedes aegypti* and lesser extent by *Aedes albopictus*. This mosquito has to go through four stages in its life cycle as egg, larvae, pupae and adult and its life span ranged from one and half week to three weeks. The laid egg transforms into larvae even within two days if their ideal temperature is there but may wait up-to one year for having optimum temperature and touch of water.[4] The ideal temperature for breeding is 24^0-28^0 Celsius and damp and moist surface is required.[5] The infected mosquito lays virus infected egg.[6] For surviving and reproduction Aedes mosquito has to depend on environment and that is why weather factors may act as important predictor of dengue fever incidence.

World's temperature has risen 1.9^0 F since 1880 and the temperature of Bangladesh has been rising 0.0186^0/year.[7,8] This global warming leads to change in rainfall pattern worldwide.[7] The rainfall pattern in Bangladesh showed increased trend in monsoon and post-monsoon season.[8] This changing weather brings us to face various adverse health effects. In 2019, Dhaka the capital of Bangladesh observed epidemic and atypical dengue fever incidence. The objective of the study was to identify the weather predictors of the occurrences of dengue so that early warning could be made and preventive measures could be taken accordingly.

METHODS

Study Area

This study was conducted in the city Dhaka which is situated at the center of Bangladesh. Its area about 1463.6 m^2 and 20,283,552 people lived here. It was the most densely populated city in Bangladesh and its density was about 23,234 per square meter. Rural to

urban migration was the main cause of its growth and population growth rate was 3.62%.[3]

Data source

Data was collected from three government sources. Number of dengue reported cases was extracted from Directorate General of Health Services (DGHS) and Institute of Epidemiology disease Control & Research (IEDCR). Weather related data was taken from Bangladesh Meteorological Department (BMD) of Dhaka. In both cases last 10 years' data from January 2009 to July 2019 were taken.

Dengue incidence

Dengue incidence rate was calculated by using annual dengue cases and population which was estimated by using the annual growth rate from UN World Urbanization Prospects.[3] Month wise reported number of dengue cases is shown in Figure 1.
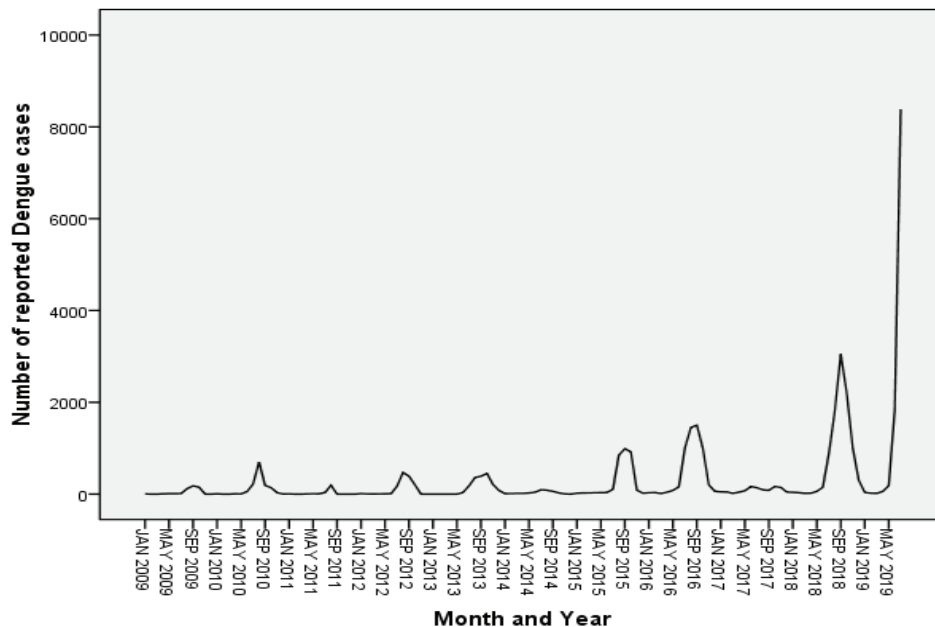

Figure 1: Reported Number of dengue cases from January 2009 to July 2019

Weather factors

There was daily average temperature, daily average humidity and daily average rainfall data. The daily data was converted into monthly basis and temperature data was sub-grouped into monthly average,

maximum monthly and minimum monthly temperature. Two variables were created by rainfall data: one is average monthly rainfall and monthly cumulative rainfall (Figure 2).
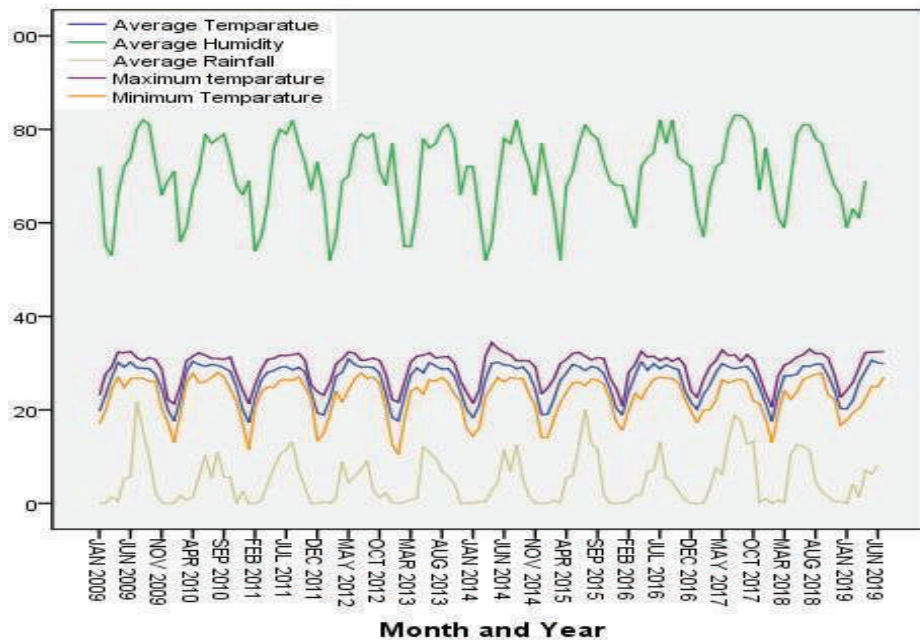
Figure 2: Weather data from January 2009 to June 2019

Statistical analysis

Firstly, bivariate correlation analysis was carried out to find out the relationship status of each of weather factors and dengue incidence. Temperature, humidity and rainfall may have lag time effect on mosquito breeding as well as dengue incidence. To investigate the time lag relationship with dengue incidence correlation was extended into 1 month and 3-month lag.

Dengue incidence was the outcome variable and it was found by counting. So to find out the association between weather factors and dengue incidence generalized linear models were developed with or without time lag. To correct over-dispersion, the negative binomial regression model was used. In this model monthly average temperature, monthly average maximum temperature, monthly average minimum temperature, monthly average humidity and monthly average rainfall were incorporated as covariates and predictors. Monthly reported dengue cases in 0 month, I month and 3-month lag period were response variables. MS-Excel and SPSS was used for data analysis and presentation.

RESULTS

Descriptive statistics

Data was analyzed from January 2009 to July 2019 and total reported dengue cases were 35319. Dengue incidence rate varied from 1.7 per 1, 00,000 population per year to 48.9 per 1, 00,000 population per year up-to 2018. In 2019 in first 7th months total number of cases were 10528. (Fig: 3). Data of weather factors showed that mean of average temperature of total 127 months was 26.30^0 C, mean of maximum temperature was 29.14^0 C, mean of minimum temperature was 22.85^0 C, the mean humidity of total 124 months was 70.79% and the mean of average and cumulative rainfall of 125 months was 4.78 mm and 146.85 mm respectively. (Table:1).
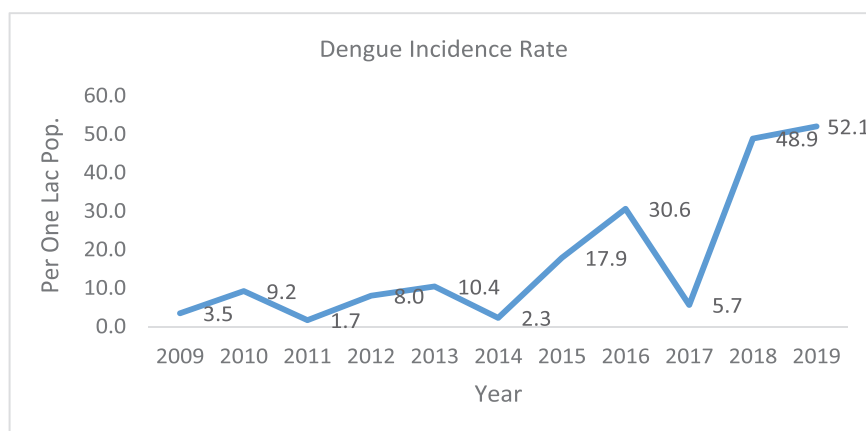
Fig 3: Dengue Incidence Rate

Table 1: Descriptive statistics of 10 years weather factors

Weather factors	Minimum	Maximum	Mean	Std. Deviation
Average Temp. (C)	17.28	30.90	26.30	± 3.84
Max. Temp. (C)	20.60	34.40	29.14	± 3.43
Min. Temp. (C)	10.40	28.00	22.85	± 4.29
Average Humidity (%)	52	83	70.79	± 8.24
Average Rainfall (mm)	0	21.81	4.78	± 5.18
Cumulative Rainfall (mm)	0	676.00	146.85	± 158.75

Correlation analyses

Correlation analysis (Table: 2) showed that there was negative correlation coefficient between reported dengue cases and average monthly temperature (r= -.41, p < .000) in 3 months' lag effect. Relationship between average maximum monthly temperature and average minimum monthly temperature with reported dengue cases was found negative and statistically significant only in 3 months' lag effect. There was positive relationship between average monthly humidity and reported number of dengue cases in 0-month lag time (r= .301, p = .001). Average monthly rainfall showed negative association only in 3 months' lag time (r= -.311, p <.000).

Table 2: Correlation coefficient between number of dengue cases and weather factors with time lag effects

Weather Factors	Correlation coefficient 'r'		
	Lag Time (Months)		
	0	1	3
Average Monthly Temperature	.211*	.097	-.410**
Average Maximum Monthly Temperature	.202*	.099	-.414**
Average Minimum Monthly Temperature	.236**	.164	-.321**
Average Monthly Humidity	.301**	.162	-.159
Average Monthly Rainfall	.073	-.121	-.311**
Accumulated Monthly Rainfall	.08	-.121	-.311**

**p-value <0.01, *p-value <0.05

Generalized Linear Model with Negative binomial regression

To predict the dengue occurrence weather factors acted as predictors. To estimate the Incidence Risk Ratio (IRR) negative binomial regression model was developed. Output of the models in 0 month, 1 month and 3 months' lag period showed all of were statistically significant and models were well fitted. Incidence Risk Ratio, 95% CI and level of significance

is shown in Table 3. Here IRR is the log of Odd's ratio and it meant that 1^0 C increase of maximum average temperature led to an increase of dengue cases 33% (CI: 3.1 – 71.4) at 3 months of lag. In case minimum average temperature, 1^0 C increase at 0 lag led to an increase of dengue cases 52% (CI: 29.4 – 79.3) and at 1 month lag it would lead to 78% increase (CI: 51.2 – 211.5). Average temperature and average rainfall would had inverse effect.

Table 3: Incidence Rate Ratio (IRR) of Dengue in 3 lag times

Weather factors	0 Month		1 Month		3 Month	
	IRR	95% CI	IRR	95% CI	IRR	95% CI
Avg. Temp.	.680*	.482-.958	.429**	.304-.605	.474**	.351-.644
Max. Temp.	1.122	.875-1.439	1.337*	1.034-1.728	1.330*	1.031-1.714
Min. Temp.	1.523**	1.294-1.793	1.789**	1.513-2.115	1.199*	1.031-1.393
Avg. humidity	1.179**	1.137-1.223	1.189**	1.145-1.234	1.103**	1.056-1.153
Avg. rainfall	.850**	.807-.896	.798	.760-.839**	.865**	.824-.903
Accumulated rainfall	1.037	.986- 1.091	1.010	.960- 1.062	1.004	.956- 1.053

CI represents confidence interval **p-value <0.01 *p-value <0.05

DISCUSSION

Dengue incidence had been increasing since decades and had become endemic in more than 100 countries worldwide.[9] Dengue in Dhaka also showed upward trend especially in the years of 2018 and 2019 where it had showed sharp rise where data was up-to July 2019.

Dengue fever occurrence has a very complex interrelationship variable as it is a specific type of mosquito borne disease and caused by dengue virus. Dengue virus (DENV) is a Flavivirus with four serotypes and all of them can produce full blown disease.[10] The variables of weather play important role in mosquito population, virus replication and vector to host transmission. In recent years the clinical features vary from simple flu like symptom to death like fatal and it has become public health challenge. This study was attempted to find out the relationship between dengue incidence and various weather factors. Last 10 years' weather data as daily average temperature, daily humidity and daily rainfall and dengue reported cases were considered for the statistical analysis.

It was found that temperature had very highly significant relationship with dengue incidence at 0, 1 and 3 months' lag effect. Average monthly temperature and dengue incidence was moderately

negatively correlated at 3 months' lag period (r= -.410, p=.000). Average maximum temperature was statistically significant only at 3 months' lag and negatively associated (r= -.414, p=.000). Average minimum temperature showed positive correlation at 0-month lag, but it became negative correlation at 3-month lag period and also highly significant. Study findings at Argentina showed that only raised temperature was not cause of dengue incidence rather geography and demography had important role on it.[11] Using weather factors as mean temperature, maximum temperature, minimum temperature and rainfall with dengue incidence a study was conducted in three provinces of Cambodia in 2016. Similar statistical analysis was carried out like this study. In that study mean, maximum and minimum temperature had positive correlation in 0-3 months' lag period in the provinces except one province at minimum temperature. Weather factors especially temperature and rainfall was significantly associated with dengue incidence and it was also found that this association varied by locality.[12] Study in Mexico found that weather had significant influence in dengue incidence but the relationship was non-linear. The Mexico study showed that increased risk of dengue incidence in above 18^0 C of average minimum temperature and risk raised at peak at 20^0 C to 32^0 C of average maximum temperature.[13] Increasing risk of dengue incidence was

shown with increasing mean temperature above 24^0 C and highest transmission at 30^0 C with 0 to 3 weeks lag.[14]

Weather of Dhaka had 70.79% average humidity with ± 8.24% SD. Average monthly humidity was positively correlated and statistically significant (r = .301, p= .001) at 0 month lag but afterwards their association was not statistically significant. Consistent result found in a study in Taiwan where warmer temperature in 3 months' lag and higher humidity with high mosquito density had increased risk of dengue.[15]

Aedes aegyti is container- inhabiting mosquito.[16] Heavy rainfalls is not necessary for this mosquito breeding. Dengue mosquito population developed independently to rainfall.[17] Seasonal variations had been evident in recent years that there was early start of monsoon in Dhaka. Current study findings showed that average and accumulated monthly rainfall had statistically significant relationship only at 3 months' lag and it was negative and in case of both variables correlation coefficient and level of significance was same (r= -.311, p= .000). Weather of Cambodia showed that rainfall and dengue was positively correlated in 0, 1 and 2 months' lag time in three provinces but not consistently and was highly significant.[12] Weather of India variability in different lag period has shown significant association. Rainfall showed higher transmission risk of dengue between 8 to 15 weeks lag.[14]

In the year 2019, dengue outbreaks hit the all-time dengue history of Bangladesh and from the capital Dhaka dengue had spread to all over the country due to inter-district travelling of the people. The whole period of monsoon would be risk of dengue for all the people of Bangladesh.

CONCLUSION

Weather factors had significant role in Aedes mosquito breeding and dengue virus transmission to human host. Further studies can be done to ascertain any relationship with geography, population density and socioeconomic condition of particular locality. Weather factors and local factors may help to develop early warning model to predict dengue fever epidemic in a certain area.

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