**Two decades of Dengue outbreaks in Bangladesh (2000-2022): increasing trend of annual cases**

**Abstract: (200 words)**

**Background:** After 1964, the dengue virus reappeared in Bangladesh in 2000 and then the virus is detected every year. The objective of this study was to summarize the annual dengue cases for the period 2000-2022 and perform a time series model to identify whether annual total cases are increasing or not.

**Methods:** We collected monthly reported dengue cases and deaths data from the Ministry’s Health website for the period of 2000-2022 and perform summary statistics. We further performed times series models ARIMA, SARIMA, SES, and Prophet to understand the trend of annual total cases in the country. We also perform Sen’s slop test to detect the peak dengue season in Bangladesh.

**Results:** The overall mean (SD) of dengue cases was 725.11 (3642.55), with a lower mean for the first decade (2000-2010) of this century (184.72 vs 1231.01) compared to the rest period (2011-2022). The mean cases reach a peak in the August months with 3407.26, and in September (mean cases = 2034.26) are two other months with a high caseload. In the time series mode, we detect and increasing trend of dengue cases in Bangladesh with a much stiffer rise after 2019. We detected Jul-Oct (1182.48-1013.27) as Bangladesh’s peak season of dengue cases.

**Conclusion:** Over two decades, Bangladesh has experimented a significant burden of dengue cases with regular outbreaks and an increasing trend. Global warming, unusual rainfall, and urbanization population growth are some reasons for dengue cases.

**Introduction:**

**[First paragraph: Dengue virus burden in the world, South Asia, and Bangladesh]**

Dengue is a mosquito-borne common viral infectious disease worldwide and it is considered an endemic disease in many countries (Hossain et al., 2021). This disease is occurred by 4 serotypes of dengue viruses (DENV) which transmits by main vectors Aedes aegypti and Aedes albopictus through bites (Sharmin et al., 2015). Positive sense single-strand RNA containing Dengue virus belongs to the Flaviviridae family under the Flavivirus genus with ~11 kb genome size that contains 3 and 7 non-structural proteins (Murugesan et al., 2020). Dengue patients showed a large spectrum of signs and symptoms from mild febrile illness to severe dengue, while DHF or developing dengue hemorrhagic fever, DSS, or dengue shock syndrome are counted as the most serious condition (Wilder-Smith et al., 2019). A few very common clinical features of Dengue patients are fever (100%), headache (87%), body ache (86%), backache (58%), retro-orbital pain (41%), bleeding and rash (21%) (Whitehead et al., 2007) (Anderson et al., 2007) (Carod-Artal et al., 2013). Weakness, vomiting, abdominal pain, breathlessness, vertigo, sweating, and syncope were also observed as nonspecific symptoms. In addition diarrhea, sore throat, and neurological symptoms are also observed (Gubler et al., 1998).

Dengue fever was first identified in a Chinese medical encyclopedia known as ''water poison'' from the Jin Dynasty (265–420 AD) and linked with flying insects (McBride & Bielefeldt-Ohmann, 2000). In 1779 the disease is identified as dengue fever and Dengue epidemics were observed same time in the 1780s in Asia, Africa, and North America (Ferreira, 2012). Nowadays this disease is recorded minimum of 100 countries in Asia, the Pacific, the Americas, Africa, and the Caribbean. Bangladesh is a developing agricultural country that will become a middle-income country in 2026. Dealing with coronavirus was one of the most challenging issues for Bangladesh (Ahmed et al., 2021; Islam et al.;2021, n.d.; Islam et al., 2022; Jakariya et al., 2021). The corona vaccine is ensuring the people of the country as well as the overall development of the country even though its cost was a little higher in South Asia. This country also faced sporadically Dengue disease from 1964 until a large epidemic in 2000 established the virus (Noor, 2020). In 2000 Dengue epidemic was recorded for a virus strain from Thailand. Compared with previous four years from 2018 to 2021, this year case number is increasing drastically including death cases (Hsan et al., 2019). The prevalence of DENV depends on various factors and this disease are interconnected with deforestation, human behaviors, demography, movement, climate change, and globalization (Rahman et al., 2019). According to WHO, the highest confirmed DENV cases were confirmed in Bangladesh (101,000), Malaysia (131,000) Philippines (420,000), Vietnam (320,000) in Asia (WHO, 2022) (http://apps.who.int/iris/bitstream/handle/10665/352792/Dengue-20220113.pdf?sequence=1&isAllowed=y). Several countries such as Bangladesh, Brazil, Cook Islands, Ecuador, India, Indonesia, Maldives, Mauritania, Mayotte (Fr), Nepal, Singapore, Sri Lanka, Sudan, Thailand, Timor-Leste, and Yemen affected be dengue in 2020. Again, this was attacked in 2021 by Brazil, India, Vietnam, the Philippines, Cook Islands, Colombia, Fiji, Kenya, Paraguay, Peru and Reunion islands. In 2022 *confirmed cases and deaths found* [Cambodia](https://www.who.int/westernpacific/emergencies/surveillance/dengue" \t "_blank) (3 322/9), [China](https://www.who.int/westernpacific/emergencies/surveillance/dengue" \t "_blank) (5/0), [India](https://nvbdcp.gov.in/index4.php?lang=1&level=0&linkid=431&lid=3715" \t "_blank) (10 172/3), and [Indonesia](https://rdk.fidkom.uinjkt.ac.id/index.php/2022/08/12/kasus-dbd-meningkat-pemerintah-dorong-pengoptimalan-faskes-di-daerah-terdampak/" \t "_blank) (68 903/ 640) deaths have been reported. [Malaysia](https://www.moh.gov.my/index.php/database_stores/store_view/17" \t "_blank) (33 911 /22), [Maldives](http://health.gov.mv/" \t "_blank) (344/0), [Nepal](http://www.edcd.gov.np/resources/newsletter" \t "_blank) (695/0), [Oman](https://www.omanobserver.om/article/1117420/oman/health/over-70-dengue-cases-reported-in-oman" \t "_blank) (76/0) , [Pakistan](https://urdu.geo.tv/latest/296443-" \t "_blank) (875/0), [Philippines](https://www.who.int/westernpacific/emergencies/surveillance/dengue" \t "_blank) (82 597 / 319) [Singapore](https://www.nea.gov.sg/dengue-zika/dengue/dengue-cases" \t "_blank) (24 939/0), [SriLanka](http://www.epid.gov.lk/web/index.php?option=com_casesanddeaths&Itemid=448&lang=en" \t "_blank) (40 791/0) , [Vietnam](https://www.who.int/westernpacific/emergencies/surveillance/dengue" \t "_blank) (145 536 /53), [Afghanistan](http://www.emro.who.int/afg/information-resources/infectious-disease-outbreak-situation-reports.html" \t "_blank) (77/0) (<https://www.ecdc.europa.eu/en/dengue-monthly>) (<http://apps.who.int/iris/bitstream/handle/10665/352792/Dengue-20220113.pdf?sequence=1&isAllowed=y>).

**[]**

[Bangladesh](https://www.facebook.com/photo/?fbid=408013848096284&set=a.4056145467819786" \t "_blank) is going to face another worse situation for the dengue virus as 15,878 confirmed cases and 63 deaths have been reported on 24 October 2022. The first official dengue fevers this year was reported in January, and it was the lowest up to March since then the number of confirmed dengue patients increased highest in the last month (September). The first death due to dengue was confirmed in June and it was highest in September. In this particular year, more cases were reported in the post-monsoon period. This year, hardly any case was found to occur from January to June, and no deaths during this period. But, a significant number of cases were reported in July and reached a peak in September, and gradually increased at the end of the year. There has been a recent upsurge in dengue transmission in Rohingya refugee camps in Cox's Bazar district that significantly exceeds expected seasonal trends. According to [WHO](https://www.who.int/emergencies/disease-outbreak-news/item/2022-DON401" \t "_blank), as of 24 July 2022, a total of 7687 cases and six deaths have been reported, with 93% (7178) of the cumulative number of cases being reported since the start of the surge at the end of May 2022 (According to WHO).

Control of frequent DENV outbreaks in Bangladesh and other tropical areas is difficult as temperatures help mosquito reproduction. To manage the ongoing dengue condition, it is essential to find out the related factors linked with the rapid spreading of DENV. It has been observed from previous studies that various diseases such as cystic fibrosis, acute bronchitis, emphysema, chronic bronchitis, chronic obstructive pulmonary disease (COPD), shortness of breath, and lung cancer are related to climatic factors (8, 9). Some other studies have also shown that weather factors have a significant effect on the growth and activity of viral diseases (Bi et al., 2007; Park et al., 2020; Tan et al., 2005; van Doremalen et al., 2013). For instance, one experimental finding claimed, animal tests using the influenza virus showed that the spreading of the virus was more proficient at five degrees celsius than at twenty degrees Celsius (Lowen et al., 2007). When the virus is exposed to increased relative humidity and temperatures, as well as simulated solar light, the virus becomes even less stable (half-life, 3 min) (*DHS S&T Launches Indoor Predictive Modeling Tool for Coronavirus Stability*, 2020).

**[Final paragraph Objective:**

**Identifying the trend and seasonality will help Bangladesh authority to invest its resources for controlling dengue cases in Bangladesh. The objective of our study was to i) summarize the annual and monthly cases for past 22 years ii) identify the seasonality of dengue cases and iii) identify whether dengue cases are increasing in the country or not.]**

In this study, we investigated the correlation of weather factors with Dengue cases in Bangladesh analyzing last year's data. The novel findings of this study will add value to supplement the evidence on Dengue climatic consequences. Finally, it would give a window into the perspectives from the point of view of a densely populated city of a developing nation, which can enable public health officials to design their public health response to an outbreak like these in the future.

**Methods:**

**Data sources:**

The secondary data on the number of reported dengue‐infected people have been extracted from the Directorate General of Health Services (DGHS)'s website (https://old.dghs.gov.bd/index.php/bd/home/5200-daily-dengue-status-report) over the period from January 2000 to October 2022.

**Statistical analysis**

We divided the data into two period: first between 2000-2012 as the first decades of 21st Century and second between 2012 and 2022 as the latest decade of 21st Century. We compared the mean number of cases between these two periods.

Generalized linear models (GLM) aware used to accommodate the non-normality, heteroscedasticity, and non-linearity typical of count data. Models for count time series should take into account that the observations are nonnegative integers and they should capture suitably the dependence among observations. A convenient and flexible approach is to employ the generalized linear model (GLM) methodology (Nelder and Wedderburn 1972) for modeling the observations conditionally on the past information. This methodology is implemented by choosing a suitable distribution for count data and an appropriate link function. Such an approach is pursued by Fahrmeir and Tutz (2001, Chapter 6) and Kedem and Fokianos (2002, Chapters 1–4), among others. Another important class of models for time series of counts is based on the thinning operator, like the integer autoregressive moving average (INARMA) models, which, in a way, imitate the structure of the common autoregressive moving average (ARMA) models (see the review article by Weiß 2008). A different type of count time series models are the so-called state space models. We refer to the reviews of Fokianos (2011), Jung and Tremayne (2011), Fokianos (2012), Tjøstheim (2012) and Fokianos (2015) for an in-depth overview of models for count time series. Advantages of GLM-based models compared to the models which are based on the thinning operator are the following: (a) They can describe covariate effects and negative correlations in a straightforward way. (b) There is a rich toolkit available for this class of models. State space models allow to describe even more flexible data generating processes than GLM models but at the cost of a more complicated model specification. On the other hand, GLM-based models yield predictions in a convenient matter due to their explicit formulation.

**Time series model to predict the trend**

Four forecasting models (i.e., auto-regressive integrated moving average (ARIMA), seasonal auto-regressive integrated moving average (SARIMA), automatic time-series forecasting model which is also known as ‘Prophet model’, and simple exponential smoothing (SES), to identify the trend of reported dengue cases. We selected the ARIMA, SARIMA, SES and Prophet Models because the key outcome variable is dependent on previous records (time-series events) and all these four models can take this into account. Using the time series models with the reported dengue cases data, we forecasted trends for the prospective one year (12 months) and visualized in the figure. SES is suggested as a good benchmark model to compare the performance of the ARIMA, SARIMA and Prophet models. We also used M-K trend analysis to identify the daily or weekly cumulative trend (increasing or decreasing) of reported dengue cases 25. The details of the SES, ARIMA, and Prophet models are discussed in an earlier article 6. All analyses were carried out using the statistical software R version 3.5.2.2 24.

**Results:**

During Jan 2000- Sep 2022, 725.11 (SD=3642.55) mean number of dengue cases is detected in Bangladesh. The mean annual number of cases detected in the first decade [2000-2010] of 21st century was 184.72 (SD=436.04) and the recent period [2011-2022] as 725.11 (SD=3642.55) (Table 1). The mean dengue cases of first decade and latest decade significantly differ (P<0.001). Month wise, highest number of cases were detected in the months of August month with a mean value of 3407.22 cases (10871.65) (Table 3).

Table 1. Summary of annual dengue cases reported in Bangladesh, 2000-2022

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | Cases | | |  |
|  | Minimum | Mean (SD) | Maximum | Total |
| 2000 | 0 | 462.58 (684.63) | 2290 | 5551 |
| 2001 | 0 | 202.5 (255.76) | 655 | 2430 |
| 2002 | 0 | 519.33 (1004.11) | 3281 | 6232 |
| 2003 | 0 | 40.5 (108.19) | 372 | 486 |
| 2004 | 0 | 327.83 (460.57) | 1261 | 3934 |
| 2005 | 0 | 87.33 (132.56) | 337 | 1048 |
| 2006 | 0 | 183.33 (314.48) | 972 | 2200 |
| 2007 | 0 | 38.83 (66.92) | 179 | 466 |
| 2008 | 0 | 96.08 (161.2) | 475 | 1153 |
| 2009 | 0 | 39.5 (71.66) | 188 | 474 |
| 2010 | 0 | 34.08 (66.38) | 183 | 409 |
| 2011 | 0 | 113.25 (200.89) | 691 | 1359 |
| 2012 | 0 | 55.92 (81.71) | 262 | 671 |
| 2013 | 0 | 145.75 (177.14) | 495 | 1749 |
| 2014 | 0 | 31.25 (33.27) | 82 | 375 |
| 2015 | 0 | 263.5 (375.09) | 965 | 3162 |
| 2016 | 3 | 505 (588.63) | 1544 | 6060 |
| 2017 | 36 | 230.75 (165.27) | 512 | 2769 |
| 2018 | 7 | 845.67 (1064.1) | 3087 | 10148 |
| 2019 | 17 | 8446.17 (15226.54) | 52636 | 101354 |
| 2020 | 10 | 117.08 (155.13) | 546 | 1405 |
| 2021 | 3 | 2369.08 (3054.99) | 7841 | 28429 |
| 2022 | 20 | 5198.5 (7801.19) | 21932 | 62522 |
| Overall | 0 | 884.95 (4007.44) | 52636 | 244246 |

Table 2: Paired t-test of the reported dengue cases between two decades

|  |  |
| --- | --- |
|  | **Mean cases** |
| First Decades | 184.72 (436.04) |
| Second Decades | 1526.83 (5462.80) |
| P-value | 0.025 |

Table 3: Aggregated mean number of cases in each month (Jan- Dec) for the period 2000-2022

|  |  |  |  |
| --- | --- | --- | --- |
|  | **Dengue Cases** | | |
| Months | Minimum | Mean (SD) | **Maximum** |
| Jan | 0 | 23.57 (49.87) | 199 |
| Feb | 0 | 7.26 (15.21) | 58 |
| Mar | 0 | 6.70 (10.68) | 36 |
| Apr | 0 | 11.17 (20.57) | 73 |
| May | 0 | 30.22 (56.62) | 193 |
| Jun | 0 | 187.65 (406.95) | 1884 |
| Jul | 3 | 1182.48 (3337.07) | 16253 |
| Aug | 4 | 3407.22 (10871.66) | 52636 |
| Sep | 3 | 2034.26 (4083.52) | 16856 |
| Oct | 0 | 1922.78 (4776.24) | 21932 |
| Nov | 0 | 1416.91 (4044.43) | 19334 |
| Dec | 0 | 389.17 (1066.58) | 5024 |

**Growth Factors:**

The mean monthly growth factor was 0.02 (SD=1.15) with highest monthly GF recorded at the month of July (2.09) and lowest in the month of January (-1.88). The 95% CI of GF was above 1 for the months of June and July.



Table 2. ARIMA model selection using AIC, AICc, Bayesian Information Criteria (BIC).

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | ARIMA (0,1,0) | ARIMA (1,0,0) | ARIMA (0,0,1) | **ARIMA (1,1,1)** | ARIMA (1,0,1) |
| AIC | 5272.94 | 5237.08 | 5252.93 | 5221.04 | 5232.26 |
| AICc | 5272.96 | 5237.17 | 5253.02 | 5221.13 | 5232.41 |
| BIC | 5276.56 | 5247.94 | 5263.79 | 5231.89 | 5246.74 |
|  | SARIMA (0,0,2)(2,1,0)[12] | SARIMA (0,1,1)(1,1,0)[12] | SARIMA (1,1,1)(0,1,0)[12] | SARIMA (1,0,1)(1,1,0)[12] | **SARIMA (0,0,1)(1,1,1)[12]** |
| AIC | 5070.89 | 5130.36 | 5161.27 | 5091.98 | 5048.46 |
| AICc | 5071.13 | 5130.45 | 5161.36 | 5092.14 | 5048.62 |
| BIC | 5088.77 | 5141.08 | 5171.98 | 5106.29 | 5062.76 |

Fig. 2. Cross-correlation between Dengue confirmed cases and weather variables. Here, Tmin is Minimum Temperature, Tmax is Maximum Temperature.



Fig. 2 shows that the cross-correlation between the weather variables and Dengue cases at lags 0 to 12 days. Here only positive lags would be considered because the positive value indicated that climatic factors could affect Dengue cases a certain period later. For Rainfall, lag 1 and 2, for maximum temperature, lag 1 to 4 and lag 7 to 8, for minimum temperature, lag 1 to 3 and 7 to 9, and for average temperature, lag 1 to 4 and 7 to 9 are statistically significant, and all other lag failed to prove the statistically significant correlation with Dengue cases (Fig. 3).







Fig 2: Top – Mean monthly growth factor for the period of 2000-2022. Bottom: The Monthly growth factor for individual year 2000-2022.





Fig. 4. Top: Observed and predicted dengue cases using a simple exponential smoothing (SES) model. Middle: Observed and predicted dengue cases using an auto-regressive integrated moving average (ARIMA) model. Bottom: Observed and predicted dengue cases using an automatic forecasting time-series model (Prophet). Black dots = observed data; the blue line = predictive CFR; the shaded area = 95%confidence interval of predicted dengue cases.

**The Trend of reported dengue cases:**

In the ARIMA, SARIMA and Prophet Model, we found a strong declining trend for five to six months then an increasing trend of next months reported dengue cases between observed and predictive with an R2, RMSE, and MAE value of 37.60% 34.75%, and 9.12, 3377.91, 3454.41 and 4076.64, and 718.58, 729.36 and 2080.13, respectively (Figure 4 and Table 4). In terms of accuracy, the ARIMA model performed better over SARIMA, Prophet, and SES model (with better R2, RMSE, and MAE value). The coefficient of determination of the ARIMA model was larger and errors are lower than SARIMA, Prophet, and SES model. According to the forecast in SES models, the reported dengue cases is expected to constant trend considerably in the coming 1 year (Fig 4). In M-K trend analysis, we found a positive trend of reported dengue cases (p <0.001 and tau = 0.34). In Sen’s slop test, the slope was 0.36 (95% CI: 0.19 to 0.70).

**Table 4.** The summary of Simple Exponential Smoothing (SES), Auto-Regressive Integrated Moving Average (ARIMA), Seasonal Auto-Regressive Integrated Moving Average (SARIMA), Automatic forecasting time-series model (Prophet), Mann-Kendall (M-K) trend and Sen’s slope analysis. The SES, ARIMA and Prophet models used dengue cases data. The Kendall’s Tau value permits a comparison of the strength of correlation between two data series 28.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Method & Period** | **R2** | **RMSE** | **MAE** | |
| ***Simple Exponential Smoothing*** | | | | |
| Overall | 24.18% | 3483.06 | 756.36 | |
|  |  |  |  | |
| ***Auto-Regressive Integrated Moving Average*** | | | | |
| Overall ARIMA (1,1,1) | 37.69% | 3157.54 | 674.40 | |
| ***Seasonal Auto-Regressive Integrated Moving Average*** |  |  |  | |
| Overall SARIMA (0,0,1) (1,1,1) [12] | 35.15% | 3221.24 | 670.63 | |
|  |  |  |  | |
| ***Automatic Forecasting time-series model*** | | | | |
| Overall | 7.24% | 3852.74 | 1935.07 | |
| ***Mann-Kendell trend analysis*** | **Non seasonal** | | **Seasonal** | |
|  | **tau** | **P** | **Tau** | **P** |
|  | 0.27 | <0.001 | 0.41 | <0.001 |
| *Sen’s slop test* |  |  |  |  |
|  | Sen’s Slope | 95% CI | Sen’s Slope | 95% CI |
|  | 0.18 | 0.19 to 0.70 | 1.8 | 1.2 to 2.5 |

*RMSE: Root Mean Square Error; MAE: Mean Absolute Error*

Table: Relative risks of average temperature and rainfall to Dengue cases in Bangladesh using time-series GLM methods

|  |  |  |
| --- | --- | --- |
|  | IRR (95% CI) | P-value |
| Average temperature | 1.23 (1.01 – 1.49) | 0.042 |
| Rainfall | 1.31 (1.30 – 1.32) | <0.001 |

Time-series GLM models suggest that for every degree increase in average temperature, the relative risk of Dengue cases increased by 1.2% and for every mm of rainfall, the relative risk of Dengue cases in Bangladesh by 1.3%.

**References**

Ahmed, F., Islam, M. A., Kumar, M., Hossain, M., Bhattacharya, P., Islam, M. T., Hossen, F., Hossain, M. S., Islam, M. S., Uddin, M. M., Islam, M. N., Bahadur, N. M., Didar-ul-Alam, M., Reza, H. M., & Jakariya, M. (2021). First detection of SARS-CoV-2 genetic material in the vicinity of COVID-19 isolation Centre in Bangladesh: Variation along the sewer network. *Science of The Total Environment*, *776*, 145724. https://doi.org/10.1016/j.scitotenv.2021.145724

Anderson, K. B., Chunsuttiwat, S., Nisalak, A., Mammen, M. P., Libraty, D. H., Rothman, A. L., Green, S., Vaughn, D. W., Ennis, F. A., & Endy, T. P. (2007). Burden of symptomatic dengue infection in children at primary school in Thailand: a prospective study. *The Lancet*, *369*(9571), 1452–1459. https://doi.org/10.1016/S0140-6736(07)60671-0

Bi, P., Wang, J., & Hiller, J. E. (2007). Weather: driving force behind the transmission of severe acute respiratory syndrome in China? *Internal Medicine Journal*, *37*(8), 550–554. https://doi.org/10.1111/j.1445-5994.2007.01358.x

Carod-Artal, F. J., Wichmann, O., Farrar, J., & Gascón, J. (2013). Neurological complications of dengue virus infection. *The Lancet Neurology*, *12*(9), 906–919. https://doi.org/10.1016/S1474-4422(13)70150-9

*DHS S&T Launches Indoor Predictive Modeling Tool for Coronavirus Stability*. (2020).

Ferreira, G. L. C. (2012). Global dengue epidemiology trends. *Revista Do Instituto de Medicina Tropical de São Paulo*, *54*(suppl 18), 5–6. https://doi.org/10.1590/S0036-46652012000700003

Gubler, D. J. (1998). Dengue and Dengue Hemorrhagic Fever. *Clinical Microbiology Reviews*, *11*(3), 480–496. https://doi.org/10.1128/CMR.11.3.480

Hossain, M., Saiha Huq, T., Rahman, A., Aminul Islam, M., Naushin Tabassum, S., Nadim Hasan, K., Khaleque, A., Sadique, A., Salim Hossain, M., Mohammed Bahadur, N., Ahmed, F., & Mahmud Reza, H. (2021). *Novel mutations identified from whole-genome sequencing of SARS-CoV-2 isolated from Noakhali, Bangladesh*.

Hsan, K., Hossain, M. M., Sarwar, M. S., Wilder-Smith, A., & Gozal, D. (2019). Unprecedented rise in dengue outbreaks in Bangladesh. *The Lancet Infectious Diseases*, *19*(12), 1287. https://doi.org/10.1016/S1473-3099(19)30616-4

Islam et al.;2021. (n.d.). *Sex-specific epidemiological and clinical characteristics of COVID-19 patients in the southeast region of Bangladesh 2021.MedRxivhttps://doi.org/10.1101/2021.07.05.21259933.* https://doi.org/doi.org/10.1101/2021.07.05.21259933.

Islam, M. A., Haque, M. A., Rahman, M. A., Hossen, F., Reza, M., Barua, A., Marzan, A. Al, Das, T., Kumar Baral, S., He, C., Ahmed, F., Bhattacharya, P., & Jakariya, M. (2022). A Review on Measures to Rejuvenate Immune System: Natural Mode of Protection Against Coronavirus Infection. *Frontiers in Immunology*, *13*. https://doi.org/10.3389/fimmu.2022.837290

Jakariya, M., Ahmed, F., Islam, M. A., Ahmed, T., Marzan, A. Al, Hossain, M., Reza, H. M., Bhattacharya, P., Hossain, A., Nahla, T., Bahadur, N. M., Hasan, M. N., Islam, M. T., Hossen, M. F., Alam, M. D. ul, Mou, N., & Jahan, H. (2021). Wastewater based surveillance system to detect SARS-CoV-2 genetic material for countries with on-site sanitation facilities: an experience from Bangladesh. *MedRxiv*, *8852000*, 2021.07.30.21261347.

Ling, S. (2009). Particulate matter air pollution exposure: role in the development and exacerbation of chronic obstructive pulmonary disease. *International Journal of Chronic Obstructive Pulmonary Disease*, 233. https://doi.org/10.2147/COPD.S5098

Lowen, A. C., Mubareka, S., Steel, J., & Palese, P. (2007). Influenza Virus Transmission Is Dependent on Relative Humidity and Temperature. *PLOS Pathogens*, *3*(10), e151. https://doi.org/10.1371/JOURNAL.PPAT.0030151

McBride, W. J. ., & Bielefeldt-Ohmann, H. (2000). Dengue viral infections; pathogenesisand epidemiology. *Microbes and Infection*, *2*(9), 1041–1050. https://doi.org/10.1016/S1286-4579(00)01258-2

Murugesan, A., & Manoharan, M. (2020). Dengue Virus. In *Emerging and Reemerging Viral Pathogens* (pp. 281–359). Elsevier. https://doi.org/10.1016/B978-0-12-819400-3.00016-8

Noor, R. (2020). Reemergence of dengue virus in Bangladesh: Current fatality and the required knowledge. *Tzu Chi Medical Journal*, *32*(3), 227. https://doi.org/10.4103/tcmj.tcmj\_193\_19

Park, J., Son, W., Ryu, Y., Choi, S. B., Kwon, O., & Ahn, I. (2020). Effects of temperature, humidity, and diurnal temperature range on influenza incidence in a temperate region. *Influenza and Other Respiratory Viruses*, *14*(1), 11–18. https://doi.org/10.1111/irv.12682

Rahman, S., Hossain, S., & Jahan, M. (2019). Thunderstorms and Lightning in Bangladesh. *Bangladesh Medical Research Council Bulletin*, *45*(1), 1–2. https://doi.org/10.3329/bmrcb.v45i1.41801

Sharmin, S., Viennet, E., Glass, K., & Harley, D. (2015). The emergence of dengue in Bangladesh: epidemiology, challenges and future disease risk. *Transactions of The Royal Society of Tropical Medicine and Hygiene*, *109*(10), 619–627. https://doi.org/10.1093/trstmh/trv067

Tan, J., Mu, L., Huang, J., Yu, S., Chen, B., & Yin, J. (2005). An initial investigation of the association between the SARS outbreak and weather: with the view of the environmental temperature and its variation. *Journal of Epidemiology and Community Health*, *59*(3), 186–192. https://doi.org/10.1136/jech.2004.020180

van Doremalen, N., Bushmaker, T., & Munster, V. J. (2013). Stability of middle east respiratory syndrome coronavirus (MERS-CoV) under different environmental conditions. *Eurosurveillance*, *18*(38), 20590. https://doi.org/10.2807/1560-7917.ES2013.18.38.20590/CITE/PLAINTEXT

Whitehead, S. S., Blaney, J. E., Durbin, A. P., & Murphy, B. R. (2007). Prospects for a dengue virus vaccine. *Nature Reviews Microbiology*, *5*(7), 518–528. https://doi.org/10.1038/nrmicro1690

Wilder-Smith, A., Ooi, E.-E., Horstick, O., & Wills, B. (2019). Dengue. *The Lancet*, *393*(10169), 350–363. https://doi.org/10.1016/S0140-6736(18)32560-1

Supplementary files



Fig. S1. Number of dengue cases reported through national dengue fever surveillance in Bangladesh, 2000–2022.