**The 2023 Fatal Dengue Outbreak in Bangladesh Highlights a Paradigm Shift of Geographical Distribution of Cases**

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**Abstract**

In 2023, Bangladesh experienced its largest and deadliest outbreak of Dengue virus (DENV), reporting the highest-ever recorded annual cases and deaths. Historically, most of the cases were recorded in the capital city Dhaka. We aimed to characterize the geographical transmission of the DENV in Bangladesh. From 1 January – 31 December 2023, we extracted and analysed daily data on dengue cases and deaths from the Management Information System (MIS). We performed a generalized linear mixed model to identify the associations between division-wise daily dengue counts and various geographical and meteorological covariates. The number of dengue cases reported in 2023 was 1.3 times higher than the total number recorded in the past 23 years (321,179 vs. 244,246), with twice as many deaths than the total fatalities recorded in the past 23 years (1705 vs. 849). Of the 1705 deaths in 2023, 67.4% (n=1015) died within one day after hospital admission. The divisions southern to Dhaka had a higher dengue incidence/1000 population (2.30 vs. 0.50, p<0,0.01) than the northern divisions. Festival-related travel along with meteorological factors and urbanization likely contributed to the shift of dengue from Dhaka to different districts in Bangladesh.

**Keywords: Dengue outbreak, geographical shift, meteorological factors, Bangladesh**

**Introduction**

In 2023, Bangladesh witnessed its most extensive and deadliest dengue outbreak on record, marked by the highest annual tally of cases and fatalities due to dengue virus (DENV) infection [1]. While dengue is endemic in Bangladesh, with reported cases annually since 2000 [2] the scale of the outbreak in 2023 is staggering and alarming. Recent years have seen a concerning uptick in dengue cases in Bangladesh, with over 82% of the total cases (n=202,425) and 69% of deaths (n=550) reported in the past five years (2018-2022) [2].

Historically, most of the dengue cases in Bangladesh have been reported in urban areas, with a particular concentration in the capital city of Dhaka [3] except in some years (e.g., 2019) when almost half of the cases were reported from outside Dhaka [4]. Sporadic dengue cases were documented in Dhaka in the 1960s, preceding the significant outbreak in 2000 in major cities, including Dhaka, Chattogram, and Khulna. [3,5]. Serological studies conducted across the country demonstrated substantial spatial heterogeneity in seropositivity with seroprevalence ranging from as high as 88% in urban Chattogram to as low as 3% in rural Maulvibazar in Sylhet division [6]. In the capital city Dhaka, the seropositivity of DENV ranged from 36 to 85% [6].

*Aedes aegypti,* the primary vector of dengue virus is known for its preference for urban and suburban environments [7]. Several factors contribute to this affinity for urban areas including the presence of artificial containers, human habitation and blood hosts, microclimate in urban areas, and adaptability [7]. On the other hand, *Aedes albopictus*, the second important vector of the dengue virus exhibits a broader habitat range including rural and urban areas [8]. Other factors that affect the spread of the dengue virus are urbanization, population density, rainfall, waste management and water distribution systems, and temperature [9]. As Bangladesh has recently experienced a country-wide distribution of dengue cases, it is important to understand the factors that affect the geographical distribution of dengue cases in Bangladesh. In this study, we aim to characterize the geographical transmission of dengue virus infection and identify the factors affecting the dispersion of dengue cases in Bangladesh.

**Methods**

**Data Source**

We collected publicly available data on all dengue cases and death records from 1 January to 31 December 2023 from the daily press release of the Management Information System (MIS) of the Ministry of Health and Family Welfare, Bangladesh [10]. The MIS defined dengue cases based on clinical symptoms (including fever and rash) and laboratory tests for IgM or IgG antibodies to DENV and/or nonstructural 1 protein (NS-1) of DENV [11]. The MIS collected data from 77 hospitals based in Dhaka city (20 public and 57 private hospitals) and the district hospitals of 63 other districts of the country including the hospitalized patients in tertiary care medical college hospitals [2]. We further collected anonymised individual patient data including age, sex, village/ward level address, and hospital stays from MIS. We collected 3-hourly meteorological data on temperature, relative humidity and daily cumulative rainfall from the Bangladesh Meteorological Department (BMD) over the period 2000–2023 from the meteorological stations located in divisional headquarters including Agargaon, Dhaka (Lat 23.46, Lon 90.23), Chattogram (Lat 22.16, Lon 91.49), Rajshahi (Lat 24.22, Lon 88.42), Rangpur (Lat 25.44, Lon 89.14), Sylhet (Lat 24.54, Lon 91.53), Barisal (Lat 22.45, Lon 90.20), Khulna (Lat 22.47, Lon 89.32), and Mymensingh (Lat 24.43, Lon 90.26). We drew an imaginary east-west line in the middle of Dhaka city to compare the incidence and weather pattern of the southern (Chattogram, Khulna and Barisal) and northern divisions (Rajshahi, Rangpur, Mymensingh, and Sylhet). As the Dhaka division is located centrally in Bangladesh, it was excluded from the southern or northern part.

**Descriptive analysis**

We plotted the age and gender-wise distribution of cases. We also summarized the hospital stays of the death cases. The full details on the hospital stays for the cases who survived were not available.

**Relative increase of dengue cases by division**

We have estimated monthly relative changes in dengue cases in each division. The relative changes (an increase or decrease) of a division of dengue cases for a month were estimated with the formula as shown below

where *RCt*is the relative changes of dengue cases in *t* month, is the number of dengue cases reported in X city, *Nt*is the total number of cases in Bangladesh in *t* month. To avoid any complication of 0 cases in any city in any month we added 1 dengue case in both numerator and denominator.

**Incidence by district**

We calculated the annual cumulative district-wise incidence of dengue cases by taking the cumulative annual number of dengue cases of each district divided by the population of the district shown as -(The total number of dengue cases in a district in 2023) / Total number of populations of that district) \*1000. We then generated a map for Bangladesh showing district-wise incidence of dengue cases in 2023. We compared the incidence by divisions (southern vs. northern).

**Statistical Analysis**

We compared the dengue cases and deaths of the year 2023 with the previous 23 years (2000-2022) combined, prepared graphs, plots, and maps, and compared these data with meteorological parameters. We reshaped our dataset by incorporating division-wise outcome variables. We followed the list of districts for each division as shown in the daily dengue situation report shared by MIS [10]. We further collected division-wise population and geographical data from the Statistical Yearbook Bangladesh 2022 published by the Bangladesh Bureau of Statistics [12] including population size, the ratio of rural and urban population (which is a proxy variable for urbanization), and the distance of the district from the capital city, Dhaka. Additionally, we calculated population density by dividing the population size by the area of each district.

We used a generalized linear mixed model (GLMM) with negative binomial distribution to model the division-wise daily dengue counts enhancing modelling flexibility through the inclusion of random effects [13]. We introduced the random effect into the GLMM model to account for the time series effects in the data [12]. The choice of negative binomial distribution allowed us to model response data appropriately with extra variations in the data (overdispersion) [14]. Parameter estimation in GLMMs is challenging due to the integration of random effects in the likelihood function [15]. However, our model results are presented as adjusted incidence rate ratios (IRRs), considering dengue deaths, the urban-rural ratio (as an urbanization proxy), population density, and distance from Dhaka, along with corresponding 95% confidence intervals.

**Results**

**A record number of dengue Cases and Deaths in 2023**

During 2023 (1 January to 31 December), a total of 321,179 dengue cases were reported with 1,705 deaths (case fatality ratio: 0.53%). Between 2000 and 2022, Bangladesh reported a total of 244,246 dengue cases including 849 deaths with a case-fatality ratio of 0.49%. The number of cases reported in 2023 was 1.3 times higher than the total number of reported cases in the past 23 years: 2000-2022, (321,179 vs 244,246) and two times more deaths than the total number of fatalities recorded in the past 23 years (1,705 vs. 849) in the country **(Figure 1)**. Among the individuals with dengue cases, 60% were male and 56% were below 30 years of age. A total of 110,008 cases were reported from the capital city of Dhaka including 980 deaths (case-fatality ratio: 0.89%) while 211,171 cases were reported from outside Dhaka including 725 deaths (case-fatality ratio of 0.34%). A higher proportion of cases were detected among young adults of <30 years (55 vs. 45%) but a greater proportion of deaths were detected among older adults of >30 years (68 vs 32%) (Fig. S1 in the Supplementary material). Although males constituted a higher percentage of cases (60 vs 40%), females constituted a greater proportion of deaths(57 vs. 43%) (Fig. S2 in the Supplementary material).

Of the 1,705 people who died in 2023, 67.4% (n=1,015) died within one day after hospital admission, with a mean hospital stay of 2.5 days (range: 0-61 days). The death toll increased to 74.6% (n=1273) in the first 2 days or 81.9 % (n=1397) in the first 3 days **(Figure 2)**.

**Extended monsoon season in 2023**

Bangladesh experienced a higher amount of rainfall in 2023 compared to the average annual rainfall of the period 2000-2022. The average rainfall for the period 2000 to 2022 was 1915.75 mm whereas in 2023 total annual rainfall increased to 2160.70 mm (Fig. S3 in the Supplementary material). In 2023, rainfall started earlier in the year with 75.8 mm of precipitation in March compared to an average of 45 mm amount of rainfall for the month of the period 2000-2022. There was a similar range of temperature between 2023 and the period 2000-2022 (26.46 °C for the period 2000-2022 vs. 27.06 °C in 2023.

**Dengue cases and meteorological data in southern vs. northern Divisions**

The divisions southern to Dhaka had a higher dengue incidence compared to the northern division (2.30 vs. 0.50, p<0,0.01) whereas the central Dhaka division had an incidence of 2.90 per thousand population. In 2023, the southern divisions recorded slightly higher annual temperatures (27.46 vs. 26.54 °C) and relative humidity (80.79 vs. 79.08%) than the northern division (Table S4 in the Supplementary material).

**Relative changes in dengue cases in each division**

Of 321,179 dengue cases, 207,716 (65%) were reported from outside Dhaka, whereas more than 57.5% (980 of 1705) deaths were recorded in Dhaka. Dhaka city was the primary outbreak site in 2023 and contributed to more than 50% of the total cases up until July and then cases started to increase outside Dhaka, where Dhaka division (excluding Dhaka city) and Chattogram division have been among the prominent sites of the outbreak **(Figure 3)**. The relative changes in dengue cases in different divisions became more evident after July when most divisions started to report an increased percentage of cases and Dhaka city started to report a lower percentage of cases **(Figure 3).** In November, the Dhaka division (except Dhaka city) reported almost 23% of dengue cases which was the highest number of dengue cases for any division in the country, the first record of surpassing the number of cases reported in Dhaka city by any division of the country (**Figure 3)**. The Sylhet division contributed to less than 1% of cases throughout the year. The amount of annual total rainfall recorded in the northern divisions was 2638.13 mm as compared to 2026.50 mm rainfall in the southern divisions (p<0.01). The mean annual temperature recorded in the southern divisions was 26.60 °C as compared to the 25.77 °C temperature of the northern divisions.

There was a parallel trajectory in both Dhaka city and outside until mid-April. After that, dengue cases started to increase exponentially in the capital city Dhaka which continued up until the end of July 2023, and then the number of cases outside Dhaka surpassed the capital city. Notably, dengue-related deaths were initially higher outside Dhaka City until February, after which an escalation within Dhaka City commenced and persisted till the end of the year (Fig S5 in the Supplementary material).

District-wise, Dhaka district reported the highest number of dengue cases at 113,233, followed by Chattogram (14,200 cases), Barisal (13,603), Manikganj (12,952), and Patuakhali (7,579). On the contrary, the lowest Dengue cases were recorded in Sunamganj (102), Maulvibazar (129), Panchagarh (187), Joypurhat (264), and Lalmonirhat (305). Dhaka district reported the highest death toll at 981, trailed by Barisal (167), Faridpur (138), Chattogram (106), and Khulna (41) districts **(Figure 4)**.

**Correlation coefficient of dengue cases and deaths**

For monthly dengue cases, a positive correlation was observed between the population size of the district and the number of dengue cases (*r*=0.44, p=<0.001) and deaths (r=0.43, p=<0.001). A similar association is evident between population density and dengue cases (r=0.47, p=<0.001) and deaths (r=0.43, p=<0.001). A negative correlation was identified between the distance of each district from Dhaka city and the occurrence of Dengue cases (r=-0.32, p=0.011) (Fig. S6 in the Supplementary material). Correlations were observed between monthly dengue cases and various meteorological parameters in the divisions of Bangladesh, including average temperature (r=0.13, p=0.032), total monthly rainfall (r=0.13, p=0.025), and average humidity (r=0.11, p=0.052).

In the GLMM, a statistically significant positive association was identified between the dengue cases and daily average temperature (IRR: 1.13, 95% CI: 1.11-1.14), daily average relative humidity of the division (IRR: 1.09, 95% CI: 1.08 – 1.09), urban and rural population ratio (IRR:1.04, 95% CI: 1.03-1.04). Daily total rainfall of the division (IRR: 0.99, 95% CI: 0.98-0.99), showed a significantly negative association between dengue cases. Population density and distance from Dhaka also exhibited weak negative associations **(Table 1)**.

**Discussion**

In 2023, the global death toll from dengue virus infection reached a historic high of 7,000 annual deaths [16] , with Bangladesh accounting for over one-fourth of these fatalities (n=1,705). In addition to the high number of cases and deaths, the dengue outbreak in Bangladesh displayed several distinctive characteristics. There was a widespread distribution of cases across the country, extending beyond Dhaka. Notably, 67% of deaths occurred within the first 24 hours of hospital admission. The case-fatality ratio was exceptionally high in the capital city, Dhaka. Furthermore, the incidence of dengue cases was higher in the southern divisions compared to the northern divisions of Bangladesh. Dengue is a multi-factorial disease. The reasons why Bangladesh observed such a large outbreak in 2023 need detailed investigation.

A large majority of deaths (67%) occurred within the first day of hospital admission, suggesting severe disease and/or a considerable delay in seeking medical care. The precise cause of these deaths warrants thorough investigation. Below, we outline two possible explanations for this delay in seeking hospitalization. First, numerous patients likely arrived at the hospital with a delay. While primary dengue infection tends to be mild and self-limiting, subsequent infection may escalate to severe forms known as secondary dengue infection [17]. One key mechanism of secondary infection is antibody-dependent enhancement (ADE), where non-neutralizing antibodies increase disease severity [17]. Distinguishing between primary and subsequent dengue infection is often challenging. Hence, we advocate for raising awareness to promote documentation or self-preservation of dengue test results in regions where health data is not recorded systematically. Second, a significant portion of dengue patients (44%) [1] may have traveled to Dhaka from areas outside the capital city for treatment. This may explain the higher number of deaths in the capital city. These individuals either sought medical attention at a critical stage or were transferred after spending several days admitted to hospitals in districts or sub-districts, with those initial days not being counted as part of their final hospital admission. Many of these patients endangered their lives by undertaking long journeys to Dhaka without proper medication during the long journey. In Bangladesh, specialized medical care and management, including the facilities for ICU beds, are centralized in the country’s capital, Dhaka [1].

Dhaka is one of the most densely populated cities in the world with more than 22 million people living in approximately 300 square Kilometres, with a population density of 23,234 people/Km2 [18].Many people travel to their rural homes during the two large religious festivals: Eid-Al-Fitr and Eid-Al-Adha. In 2023, the Eid-Al-Adha was celebrated on 28th June. More than 15 million people left Dhaka and its surrounding cities to celebrate Eid-Al-Adha with their families in rural Bangladesh [19]. This large population movement probably played a role in spreading the DENV throughout the county. People infected with DENV can remain viraemic (infectious) for a maximum of 12 days [20]. Although *Aedes* *aegypti*, the key vector of DENV transmission is a city-adapted mosquito, *Aedes albopictus,* is adapted more to rural settings. Earlier studies in Bangladesh reported the presence of *Aedes albopictus* in different parts of Bangladesh [6,21]. In 2023, infected people traveling from Dhaka to rural areas may have spread the virus to the rural areas where the *Aedes albopictus* mosquito maintained the local transmission [1]. Contrary to the popular notion of dengue being an urban disease, the significant number of cases observed in the rural areas of Bangladesh during the 2023 outbreak suggests that dengue might pose a substantial threat to rural communities in Bangladesh. The rural cycle of DENV transmission is usually led by *Aedes albopictus* and there is some specific difference that makes *Aedes albopictus* a crucial vector for DENV. *Aedes albopictus* mosquito can bite non-human hosts tend to bite outdoors, and breed in tree holes and other natural settings, giving them better plasticity than *Aedes aegypti* [22].

Compared to the northern divisions, the southern divisions of Bangladesh had a higher incidence and case-fatality ratio (CFR) of dengue cases in 2023. Although Bangladesh is a small country there are some differences between the southern and northern parts of Bangladesh as districts in the southern parts observe higher rates of urbanization and population density. Also, the divisions in the south of Dhaka had 0.92 °C higher temperature (27.46 vs 26.54 °C, p<0.01) compared to the divisions in the north of Dhaka. Higher temperature has been associated with increased dengue cases because of its impact on the extrinsic incubation period of the virus and the increased biting rate of the mosquitoes [2,23,24]. However, it might be possible that a higher incidence of dengue cases in southern districts is an artifact of economic development in the regions which helped people visit healthcare facilities more frequently than their northern counterparts [25]. Our model also showed that the ratio of urban and rural population which we used as a proxy to indicate urbanization had an increased risk of having more dengue cases. We found a conflicting negative association between rainfall and dengue cases [24], which might be because of higher rainfall in the Sylhet division where the highest amount of precipitation is usually observed in Bangladesh. However, the relative humidity was positively associated with increased dengue cases in other countries including Thailand, the Philippines, and Sri Lanka [24].

Our study has several limitations. The data we presented in this study has been recorded through hospital-based passive surveillance in Bangladesh [10]. The surveillance covers a mere fraction (5%) of the country’s total health healthcare facilities [1]. We do not have the circulating serotype data for the 2023 outbreak. However, several studies including WHO’s report on the Bangladesh dengue situation revealed that DENV- 2 which reappeared in the country in 2023, became a predominant serotype (62%) along with DENV-3 (29%), and co-infection of DENV-2 and DENV-3 (10%) [26,27]. Earlier, all four serotypes of the dengue virus have been recorded in Bangladesh at different times since 2000 [28,29]. DENV-3 caused a larger outbreak in 2019 and remained a dominant serotype until 2022. DENV-4 reappeared in the year 2022 with co-circulation of DENV-1 and DENV-3 [28].Thus, exposure to heterogenous serotypes in 2023 likely increased the risk of severe dengue infection which has a much higher CFR than the primary infection [20]. While we observed significant differences in dengue incidence and CFR between the southern and northern divisions, potential biases linked to the passive surveillance method cannot be ruled out. While improbable, there’s a chance that district health officials in the southern division may have reported more diligently than those in the northern divisions, despite the reporting system being the same throughout the country.

**Conclusions**

Bangladesh observed a large outbreak in 2023 with the number of deaths being more than double the cumulative number of deaths of the previous 23 years. A major geographical shift of dengue cases from the capital city Dhaka to different districts of Bangladesh with a higher incidence of dengue in the southern compared to the northern division was observed in Bangladesh 2023 outbreak. A constellation of factors including mass human movement linked to a religious festival, circulating strains of the pathogens, meteorological factors, urbanization, and widespread availability of a potent vector (*Aedes albopictus*) may have contributed to the widespread transmission of dengue across Bangladesh. A large proportion (67%) of deaths were recorded within one day of hospitalization, indicating a late admission of patients with severe disease. A higher proportion of deaths were recorded in the capital city Dhaka, which might be associated with increased secondary or subsequent infection in the city or care seeking of severe dengue cases from all around the country to the capital city hospitals. The transmission of dengue cases was facilitated by urbanization, as indicated in the proportion of urban vs rural population, and a higher temperature, humidity, and lower rainfall in the southern districts. Bangladesh needs active case and death surveillance that incorporates vector and meteorological data. Research exploring the causes of increased deaths could lead to improved dengue care. Improved estimation of mild or subclinical cases, their associated risk factors, and temporal trends are essential for implementing effective public health interventions. In contrast to the idea of an urban disease, dengue poses a significant threat to rural communities in Bangladesh.

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**Conflicts of interest**

The authors declare no conflict of interest.

**Ethics statement**

We used data that are publicly available in the daily press release of the Ministry of Health and Family Welfare (<https://old.dghs.gov.bd/index.php/bd/home/5200-daily-dengue-status-report> ). There are no identifiable individual-level data, and ethical approval is not required.

**Author´s Contributions**

Conceptualization: NH, MA, and MNH. Data curation: MNH, SAAA, MA, MR.

Formal Analysis: MNH, NH, MA. Writing original draft: NH, MNH. Supervision: AZ

Writing, review, and editing: MR, MU, SAAA, KMR, KKP, MFRS, FH, AS, DP, PP, MA, AZ.

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**Figures legends**

**Figure 1.** The total number of dengue cases and deaths reported in each month in 2023 vs the number of cases and deaths for the period of 2000-2022 in Bangladesh. Log 10 base is used to display the cases and deaths for the convenience of visualization and comparison.

**Figure 2.** The number of days of hospital stays of 1705 dengue cases in Bangladesh: 1 January to 31 December 2023. More than 67% (n=1015) of people died within one day of hospital admission.

**Figure 3.** A (Top) The daily number of dengue cases in different divisions of Bangladesh (1 January – 31 December 2023). B (Bottom).The monthly relative changes of Dengue cases in each division in Bangladesh, 2023 from previous months. Although Dhaka city remains the centre of the outbreak, the percentage of cases has increased outside Dhaka city after July 2023.

**Figure 4. A (Left).** The distribution of dengue cases in different districts of Bangladesh, 1 January 2023 – 31 December 2023. **B (Right)** The incidence of dengue cases in each district in Bangladesh (1January- 31 December 2023). The horizontal line in the middle of the country divides the southern and northern divisions. The southern divisions (Khulna, Barisal, and Chattogram) have a higher mean incidence (2.30 vs. 0.50) and case-fatality ratio (0.24 vs. 0.13) of dengue cases than the northern divisions. The southern division also had a higher annual mean temperature (27.46 vs 26.54 °C) compared to the northern divisions in 2023.