

# High concentration of childhood deaths in the low-lying areas of Chakaria HDSS, Bangladesh: findings from a spatial analysis

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**Background:** Despite significant reduction of childhood mortality in Bangladesh, large spatial variations persist. Identification of lower level spatial units with higher concentrations of deaths can be useful for strengthening services in these areas. This paper reports findings from a spatial analysis of deaths in Chakaria, a rural subdistrict, where a Health and Demographic Surveillance System has been in place since 1999. Chakaria is an INDEPTH member site.

**Methods:** An analysis was done of 339 deaths among nearly 24,500 children under the age of five during 2005–2008. One ward, the lowest level of administrative units, was the unit of spatial analysis. Data from 24 wards were analyzed. The Discrete Poisson Probability Model was used to identify the clustering of deaths.

**Results:** Deaths were concentrated within 12 wards located in the low-lying deltaic flood plains of the Chakaria HDSS area. The risk of death in the low-lying areas was statistically significantly higher, 1.5 times, than the non-low-lying areas ( $p < 0.02$ ).

**Conclusion:** Spatial analysis can be a useful tool for identifying high-risk mortality areas. An understanding of the risk factors prevalent in the low-lying areas can help design effective interventions to reduce mortality in these areas.

Keywords: *Chakaria; childhood mortality; clustering; demographic surveillance; low-lying area; INDEPTH*

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Although medical progress in the past decades has led to reductions in the major causes of death, spatial variations in childhood mortality remain substantial in developing countries. The heterogeneity of childhood mortality is expressed at different geographic levels, from macro-regional differences to intra-state and intra-city variations (1–5). A child born in Bangladesh is less likely to reach the age of 82 than is a child born in Japan. Also, within Bangladesh, there is a considerable spatial variation in childhood mortality. Under-five mortality was 58 per 1,000 in the Khulna Division and 107 per 1,000 in the Sylhet Division, the first area being in the south-west and the second area in the north-east of Bangladesh (3). The declining rate of mortality also varied with reductions being low where mortality is high (3, 4).

Detecting spatial clusters with high concentrations of childhood deaths is essential for development of effective

health policies and programs. The traditional statistical methods in use for measuring the efficacy of interventions or setting priorities for resource allocation are purely temporal in nature (3). These statistical techniques are applied to monitor data from large areas without considering their geographical locations. These methods fail to detect clusters with higher death rates that are merged into large areas. Currently, with the development of a geographic information system, spatial information can facilitate the detection and localization of clusters where deaths are concentrated.

A Health and Demographic Surveillance System (HDSS) is a longitudinal, population-based health and vital registration system in a geographically defined population. It produces reliable data in time and space that can facilitate identification of the mortality of clustering. The goal of this paper is to see the spatial

distribution of childhood deaths in an HDSS area located in the southern coastal area of Bangladesh.

### Study population

Chakaria is one of the 481 Upazilas (subdistricts) in Bangladesh. It is located between latitudes 21°34' north and 21°55' north and longitudes 91°54' and 92°13' east in the south-eastern coast of the Bay of Bengal. Administratively, it is under Cox's Bazar district with a population of around 416,110 in 2008. The population density is 782 individuals per square kilometer, considerably lower compared to the national average of 939 per square kilometer (6). The climate of Chakaria is characterized by tropical monsoons and heavy rainfall from May to September and is mostly dry during the remainder of the year. The highway from Chittagong to Cox's Bazar passes through Chakaria. The east side of Chakaria is hilly, while on the west side, toward the Bay of Bengal, is lowland. A map showing the location of Chakaria is presented in Fig. 1.

The International Centre for Diarrhoeal Disease Research, Bangladesh (ICDDR,B) started its activities in Chakaria in 1994. The focus of the activities has been to facilitate local initiatives for the improvement of the health of the villagers in general and of children, women, and the poor in particular. Thus, the activities of the project have been participatory with emphasis on em-

powering people by raising awareness about health, inducing positive preventive behavior through health education, and providing technical assistance to any health initiatives taken by the village-based indigenous self-help organizations. The collection of data from households on a quarterly basis, referred hitherto as Chakaria Health and Demographic Surveillance System (Chakaria HDSS), has been initiated in the intervention and comparison areas since 1999. The primary purpose of this surveillance system is to monitor the impact of interventions with an equity focus and generate relevant health, demographic, and socioeconomic information for policies and programs and further research.

Although the Chakaria HDSS started in 1999 covering all of the households, a total of 27,000, in eight unions, the second lowest administrative unit of Bangladesh, data collection was interrupted during 2001–2003. Since 2004, quarterly data collection has resumed, and data are being collected from 3,727 and 3,315 systematically randomly chosen households in the intervention and comparison areas, respectively. Migration, birth, death, marriage, pregnancy, and motherhood practices are the main demographic and health variables that are collected quarterly (7).

Twenty-four trained workers collect data for the Chakaria HDSS. The data collectors are provided with written instructions for specific questions that

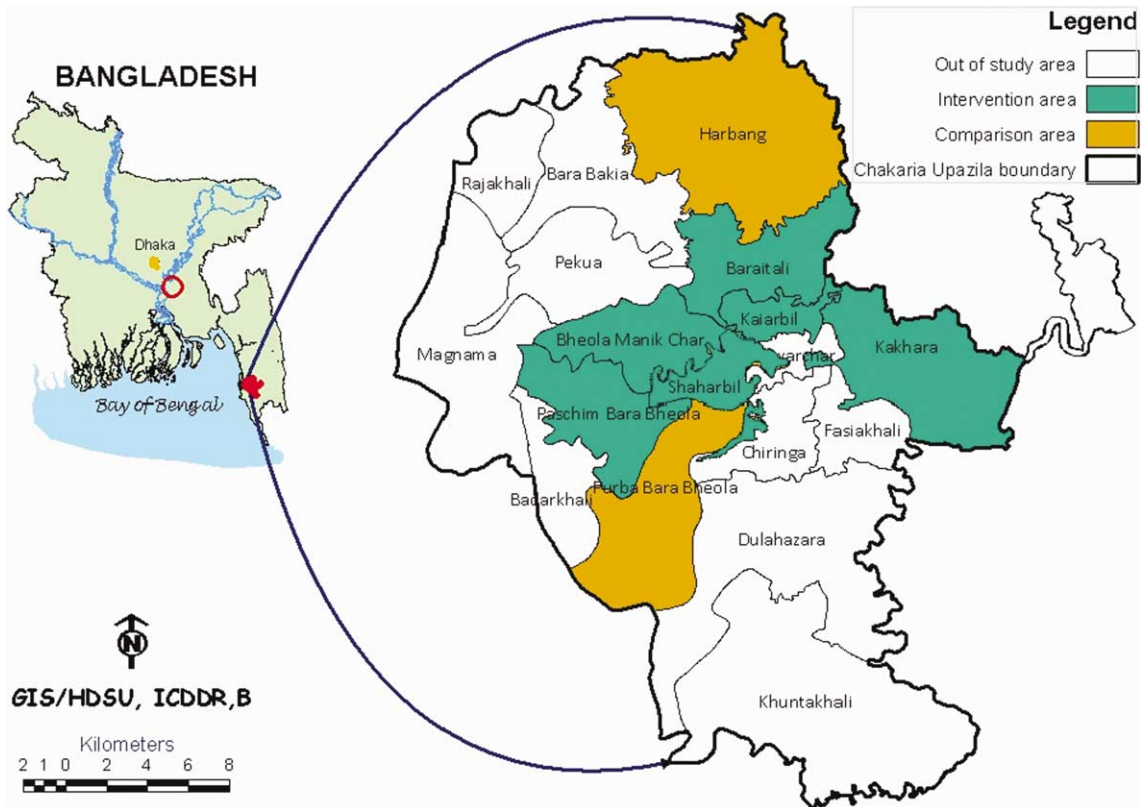


Fig. 1. Map of Chakaria showing intervention and comparison areas.

require added explanations. Four supervisors supervise the data collection process. To detect any anomalies, the supervisors revisit 5% of the households, chosen randomly, within 2 days of data collection by the field workers. Later on, the supervisors and the relevant field workers together sort out any inconsistencies in the collected data. All the filled-in questionnaires are manually checked for completeness and for any inconsistencies. Subsequently, computer-based, data-editing procedures are applied to maintain the quality of data (7).

## Methods

### Statistical methods

This paper is based on the data collected from the Chakaria HDSS area that covers 24 wards (the lowest administrative unit). A ward was considered as a cluster and was the unit of spatial analysis. A ward has 6,000 inhabitants on average. Spatial and temporal analysis was employed for identifying the most likely cluster for under-five deaths.

Subsequently, the survival status of children was compared between the area where mortality was concentrated with the area outside of it. Characteristics of study areas, socioeconomic status (SES) of households, and causes of death data were analyzed to explain the clustering or concentration of mortality in certain areas.

### Investigating the clustering of deaths

Spatial and temporal analysis scanning for high-childhood mortality rates were performed using the Discrete Poisson Probability Model with the SaTScan™ software. The three database files used were (1) population with person-years and year, (2) a case file with observed death and year, and (3) a coordinated file with the midpoint of each cluster. In this procedure, a circular window is imposed on a map by the spatial scan statistic and it allows the center of the circle to move across the study region. For any given position of the center, the radius of the circle changes continuously so that it can take any value between zero and a random upper limit. The circle is therefore able to include different sets of neighboring wards. A cluster is captured if it lies within the circle (8).

The method creates a set containing many distinct circles. Each of these circles could contain a different set of neighboring clusters and each of the circles is a potential cluster of childhood mortality in the study area. For each circle, the spatial scan statistic calculates the likelihood of monitoring the observed number of cases inside and outside the circle. The circle with the maximum likelihood is defined as the most likely cluster, implying that it is least likely to have occurred by chance. For each circle, the method tests the null hypothesis against the alternative hypothesis, which states that there is at least one circle for which the underlying risk of

mortality is higher inside the circle as compared to outside it. Generally, the method tests the null hypothesis that the risk of children dying is the same in all clusters in the study area. This method is discussed in Kulldorff (8).

### Survival of children

We graphed the Kaplan-Meier estimator of survivorship function for under-five children living in the identified clusters with a high-mortality risk and outside the cluster. A Log-rank test was applied to compare the survivor curves of the two groups.

### Risk factors of mortality clustering

Causes of death of the children who died by the age of five years between 2005 and 2008, were classified with medical synonyms. Death case numbers were compared between clusters with high-risk mortality and those lying outside the clusters. Household asset scores were derived and the percentages of households in the lowest quintiles were compared between the identified cluster and those outside of it. Characteristics of study areas and households were tabulated.

## Results

### High risk cluster

A statistically significant circular cluster ( $p < 0.02$ ) comprised of 12 wards, located on the west side of the Chakaria HDSS area, a low-lying delta area of the Matamuhuri River, was identified. The cluster had a relative risk of 1.5; that is, a child residing in this cluster is 1.5 times more likely to die than a child who resides outside this cluster (Table 2, Fig. 2).

A temporal analysis scanning for high rates using the Discrete Poisson Probability Model for the period 2005–2008 was also employed. A temporal cluster for the period from 2005 to 2006 was identified that was not different from the temporal cluster formed for the period of 2007–2008 ( $p > 0.16$ ).

### Childhood mortality

Crude death rates with a 95% confidence interval for area and year have been presented in Table 1. The overall death rate was 13.9 per 1,000 person-years of under-five children for the period between 2005 and 2008. Childhood mortality decreased steadily between those years. The death rate is statistically significantly higher ( $p < 0.0005$ ) in the low-lying area than in non-low-lying area (16.6 versus 11.3 per 1000 person-years).

### Survival of children

Both groups, children from low-lying and non-low-lying areas, have shown a similar pattern of survival: a rapidly descending survivorship function at an early age – within 1 month of birth. The survival probability of under-five

Table 1. Childhood mortality rates with 95% confidence interval and person-years by year and area

| Year  | Low-lying area |        |       |           | Non-low-lying area |        |       |           | Both areas   |        |       |           |
|-------|----------------|--------|-------|-----------|--------------------|--------|-------|-----------|--------------|--------|-------|-----------|
|       | Person-years   | Deaths | Rates | 95% CI    | Person-years       | Deaths | Rates | 95% CI    | Person-years | Deaths | Rates | 95% CI    |
| 2005  | 2,943          | 60     | 20.4  | 15.7–26.5 | 3,306              | 38     | 11.5  | 8.1–15.8  | 6,249        | 98     | 15.7  | 12.8–19.2 |
| 2006  | 2,930          | 46     | 15.7  | 11.5–20.9 | 3,242              | 45     | 13.9  | 10.1–18.6 | 6,172        | 91     | 14.7  | 11.9–18.2 |
| 2007  | 2,906          | 49     | 16.9  | 12.5–22.3 | 3,156              | 33     | 10.5  | 7.2–14.7  | 6,062        | 82     | 13.5  | 10.8–16.9 |
| 2008  | 2,948          | 40     | 13.6  | 9.7–18.5  | 3,046              | 28     | 9.2   | 6.1–13.3  | 5,994        | 68     | 11.3  | 8.8–14.5  |
| Total | 11,727         | 195    | 16.6  | 14.4–19.1 | 12,750             | 144    | 11.3  | 9.5–13.4  | 24,477       | 339    | 13.8  | 12.4–15.3 |

children was 0.9547. The survival probability was lower in the low-lying area than in the non-low-lying area (0.9422 versus 0.9659). The figure also shows a separation of the functions for the two groups. The estimated survivorship function for the non-low-lying area is completely above that for the low-lying area. The group defined by the upper curve lived longer than the group defined by the lower curve at any given point in time. The children of the low-lying area have significantly poorer survival experience compared to the children of the non-low lying area ( $p < 0.001$ ) (Fig. 3).

The low-lying area is characterized by the lack of development activities, poor health behavior, economic deprivation, lack of access to modern facilities, and low utilization of health services apparent in Table 3.

Distribution of death cases and their causes presented in Table 4 shows that hepatitis, nutritional disorders, drowning, premature and low birth weight (LBW), and respiratory illnesses are the major causes of death in cases that are higher in the low-lying area compared to the non-low-lying area. Also, unknown causes of deaths for the babies who died within 2 days after birth showed a higher proportion of death cases in the low-lying area compared to the non-low-lying area.

## Discussion

Childhood mortality is higher in the study area compared to the HDSS site Matlab area (13.5 versus 10.2 per 1,000 person-years), another rural area of Bangladesh with a long presence of ICDDR,B but without any special health services from them. Several earlier studies have shown that Chakaria is also lagging behind in terms of health indicators like family planning, immunization, tobacco use, prenatal and postnatal care, and fertility (7, 9–15). The cluster with a high concentration of childhood mortality identified by the Discrete Poisson Probability Model showed consistent results estimated by the Kaplan–Meier survivorship functions and Log-rank test. This indicates that SaTScan™ is an effective tool for understanding the spatial distribution of deaths.

The study revealed that mortality was clustered in the low-lying delta area and plains of the Matamuhuri River in the southeastern region of Bangladesh. The river bifurcates at Betua Bazar (Fig. 2, cluster number 9) and immediately downstream of the bifurcation point, a large loop is formed in its right branch. The loop length is about 5.3 km. Due to the presence of this loop, water jamming occurs in the area and severe bank erosion takes place at the outer bank. Local irrigation is very much dependent on the flow of this river. The low flow in the left channel creates a tremendous environmental hazard. Mortality concentrates in the clusters that are surrounded by this loop of water (Fig. 2).

The quality of water used in the households is recognized as an important factor for the incidence of



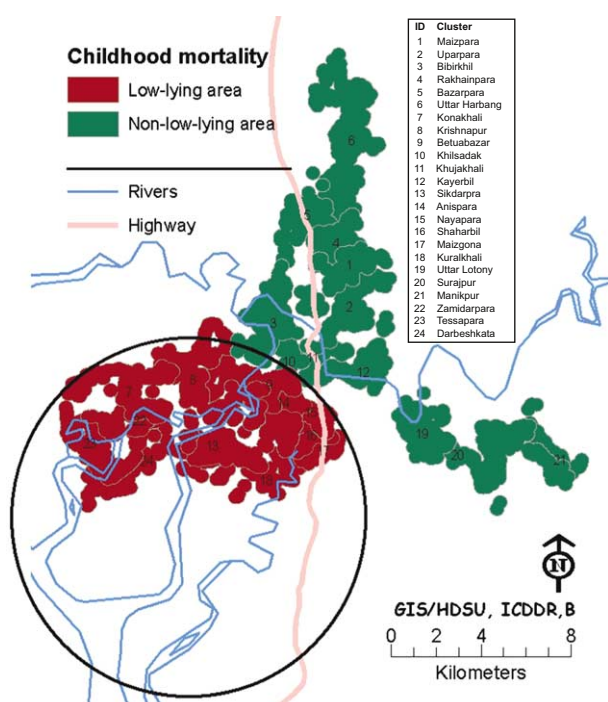
**Table 2.** High risk clusters and relative risks

| Type of cluster | Location        |                  | Number of cases | Expected cases | Relative risk | p-Value |
|-----------------|-----------------|------------------|-----------------|----------------|---------------|---------|
| Most likely     | Konakhali (7)   | Krishnapur (8)   | 195             | 162            | 1.5           | 0.019   |
|                 | Betuabazar (9)  | Sikdarpra (13)   |                 |                |               |         |
|                 | Anispara (14)   | Nayapara (15)    |                 |                |               |         |
|                 | Shaharbil (16)  | Maizgona (17)    |                 |                |               |         |
|                 | Koralkhali (18) | Zamidarpara (22) |                 |                |               |         |
|                 | Tessapara (23)  | Darbeshkata (24) |                 |                |               |         |

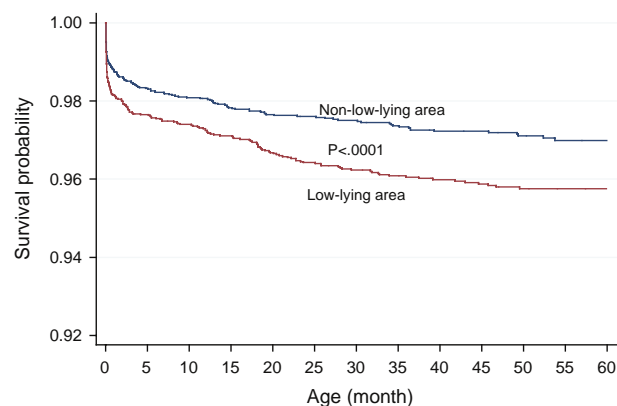
morbidity and mortality in children. In Bangladesh, water-borne diseases account for a substantial number of deaths. The low-lying delta lands of the Matamuhuri River in the tidal zone of southern Bengal are flooded with saline water as well as by direct rainfall. A recent study proved that this type of river delta has a high river vibrio growth and causes increasing risks for infectious diseases (16). Several studies reveal that environmental or geographical factors such as climate and diseases in the environment play an important role in determining childhood survival (17). Also, drowning may be one of the major factors associated with high childhood deaths in the low-lying area. Children, ages 1–4 years old, become independent and move around freely. Water is present most of the time near the homes in the low-lying areas and those children sometimes fall into the surface water and die accidentally (18).

The proximal causes of death for under-five mortality (in which cases are high in the low-lying area versus the non-low-lying area) include hepatitis, nutritional disorder, drowning, premature and LBW, and respiratory disorders. The underlying cause of all these deaths is that one area’s environment is poorer to live in than the other.

Increasingly, research suggests that properties of environmental residence influence health outcomes. Developed residential areas are defined by education, organizational, economic, environmental, and advocacy efforts that foster healthful behaviors and settings. Increasing the practice of healthy behavior, e.g. where a woman living in the developed area receives prenatal care more often and earlier in her pregnancy, and seeks medical care at an earlier stage of the disease can lead to better health outcomes ranging from decreased morbidity to decreased mortality. Contrarily, a family living in a poverty-deprived area is often in the poorest health, has multiple risk factors for serious illnesses, receives the poorest health care, and is less likely to receive preventive care. The people residing in the low-lying area have poorer characteristics in terms of occupation, ownership of modern communication devices, access to educational institutions, markets, exposure to flash floods, and presence of development organizations like non-governmental organizations (NGOs). The NGOs have been working in Bangladesh for economic development with microcredit



**Fig. 2.** Map of study area showing location of identified clusters of higher childhood mortality rates in 2005, 2006, 2007, and 2008.



**Fig. 3.** Estimated Kaplan-Meier survivorship functions for children living in low-lying area and outside it.

**Table 3.** Characteristics of village, households, and utilization of services

| Characteristics                           | Low-lying area (%) | Non-low-lying area (%) | p-Value |
|---|--------------------|------------------------|---------|
| <b>Village level</b>                      |                    |                        |         |
| NGO working                               | 43.8               | 59.6                   | 0.0325  |
| Number of villages                        | 89                 | 94                     |         |
| <b>SES at household level</b>             |                    |                        |         |
| Selling menial labour                     | 57.9               | 55.0                   | 0.0298  |
| Owned phone                               | 35.3               | 39.5                   | 0.0002  |
| Electricity connection                    | 21.1               | 25.0                   | 0.0001  |
| Had TV                                    | 7.5                | 12.6                   | 0.0001  |
| Households in lowest quintile             | 22.0               | 17.8                   | 0.0001  |
| Number of households                      | 3,511              | 3,955                  |         |
| <b>Health behavior at household level</b> |                    |                        |         |
| Consumed raw salt in cooking              | 98.5               | 86.0                   | 0.0001  |
| Number of households                      | 3,511              | 3,955                  |         |
| <b>Utilization of health services</b>     |                    |                        |         |
| Receiving at least one antenatal check-up | 56.5               | 61.1                   | 0.0060  |
| Receiving at least one postnatal check-up | 26.8               | 30.9                   | 0.0080  |
| Number of live births                     | 1,709              | 1,752                  |         |

for the last 20 years and some studies show that this has a positive impact on the child survival status (19).

The study of the mortality difference between low- and non-low-lying areas indicates a spatial variation in childhood deaths existing within a subdistrict in Bangladesh. The mortality concentrates within the low-lying area and is characterized by a poor neighborhood,

**Table 4.** Causes of death for children that died before their fifth birthday

| Causes of Death   | Low-lying area | Non-low-lying-area |
|---|----------------|--------------------|
| Drowning  | 16             | 8                  |
| Diarrheal disease   | 6              | 6                  |
| Hepatitis   | 7              | 2                  |
| Nutritional disorder  | 9              | 4                  |
| Premature and LBW   | 10             | 6                  |
| Respiratory illness   | 53             | 40                 |
| Unknown causes of children that died within 2 days of birth | 27             | 16                 |
| Other causes  | 67             | 62                 |
| Total number of death cases                                 | 195            | 144                |

which is a predictor of health outcome. Thus, we can say that the spatial distribution of childhood mortality may be associated with environmental characteristics. Deprived communities, segregated from society, are of special concern and should be the subject of the best public health initiatives.

Bangladesh lies north of the Bay of Bengal, where the world's largest river delta meets the sea. It has one of the largest river networks in the world with a total of 700 rivers (20). The low-lying areas are the deltas of the rivers where people are exposed to several environmental risk factors like diarrhea, cholera, hepatitis, and so on. The low-lying areas are characterized by unemployment or underemployment, and lack of access to medical or health services. Bangladesh, for instance, is already experiencing growing storm surges and rising salinity in coastal areas. One-third of the country could be flooded if the sea rises by one meter, affecting 20 million of its 140 million people.

Monitoring the progress of childhood deaths is limited in Bangladesh. Findings from the Bangladesh Demographic Health Surveys (BDHS) are published periodically that report cumulative childhood death rates for the last 5 years and not for a particular year. Spatial variation of childhood mortality can only be seen up to the division level. For making health policies or planning for resource allocation, there is a need for monitoring at the lowest level; that is, where service providers provide services at the doorstep.

The BDHS data show that mortality is associated with the health services received by children. For example, in Bangladesh, postnatal care, immunization coverage, and under-five child mortality was 28.4%, 89%, and 58 per 1,000 live births for the Khulna division and these were 16%, 71%, and 107 per 1,000 live births for the Sylhet division. Here we see that where there is a greater prevalence of postnatal care and immunization there is lower mortality. In this study we found a similar relation between antenatal care, postnatal care, and childhood mortality. Therefore, to reduce mortality and morbidities, better health services are necessary. Better health services can be achieved when these services are monitored regularly. Currently, there exist a number of tools to monitor services that can be used rapidly and at a minimum cost (21–23).

## Conclusion

Identifying the risk factors to prevent early childhood deaths in the delta and the plains of the rivers in Bangladesh is vital. Studies such as this can be used to identify priority areas for appropriate interventions. In the future with the prospect of rising sea levels that could create many more low-lying areas in Bangladesh, more vulnerable areas of high mortality and morbidity risks are likely to increase. Precautions should be taken

now so that the health system in Bangladesh is prepared to face these potential health risks.

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