

# Impacts of Climate Change in Bangladesh and its Consequences on Public Health

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**Abstract:** Climate change can affect many aspects of our lives, for example, health and environment, access to natural resources, safety and security, agriculture and food production. Health issues are the most crucial and burning difficulties for human beings in all of these aspects. The scope of this review considered commonly used methodologies for climate change-induced diseases research and assessment of climate-induced health problems throughout Bangladesh. Surveys, key informant interviews (KII), focus group discussion (FGD), registered hospital visit patient data as well as and other similar methodologies are found popular in this research area. Negligible studies are found that used experimental method including laboratory analysis and registered hospital visit of patient information. Very few experimental studies observed water sample tests and human health-related samples like urine and blood pressure. People living in the coastal part has climate-induced crisis like salinity intrusion, cyclone, storm surge that lead to health problems like diarrhea, cholera, skin diseases, typhoid, chicken pox. While people living in both drought-prone and flood prone areas have health problems like diarrhea, cholera, fever, and skin diseases. People living in the urban and the hilly regions have climate induced crisis of increased temperature and they suffer from vector-borne diseases. Waterborne communicable diseases are the most common climate-induced diseases found in this review. Waterborne non-communicable diseases like hypertension, pre-eclampsia, eclampsia and gynecological problems during pregnancy are common and women suffers a lot. Blood pressure and related cardiovascular diseases, jaundice, and respiratory issues are also getting worse day by day which has strong connection with climate change effects like temperature, rainfall and salinity.

**Keywords:** *Climate-induced, Communicable, Health, Salinity, Vector-borne, Waterborne*

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## 1. Introduction

Each of the last four decades has been consistently warmer than the decade before it since 1850 (IPCC, 2021). The global mean surface temperature was 1.09°C higher in 2011–2020 compared to 1850–1900 and global mean sea level between 1901 and 2018 was increased by 0.20 m with ranges 0.15 to 0.25 m. Rising temperatures, heat waves, and an increase in the frequency and intensity of complex extreme weather and climatic events such as salinity, sea-level rise, drought, floods, cyclones etc. all seem to be direct consequences of climate change (Hathaway & Maibach, 2018).

Public health consequences resulting from climate change may be the most significant global health

challenge of the twenty-first century (Fagliano & Diez Roux, 2018). It has already shown and will continue to reveal its devastating effects on the environment, livelihood, economy and public health (Tong & Ebi, 2019; Tariah, Abali, & Aminigbo, 2022). 23 percent of all deaths was estimated to result from modification to the environmental factors and from driving force of climate change (Prüss-Ustün et al., 2016). Deterioration of food and water quality, alteration of pathogens, changing pattern of disease distribution could be significant outcomes of climate change (Ebi et al., 2018; McMichael, 2013; Tong et al., 2016; Tong & Ebi, 2019). The occurrence of various cardiovascular and water and vector-borne diseases is directly linked to climate-induced events and disasters (Haines et al., 2006; Yasmin, 2016).

The effect of climate change is diversely associated with various geographical locations over a range of timescales (Morris et al., 2017). Being a geographically tropical and vulnerable region, the country is susceptible to climate change (Elahi, 2016). In recent years there has also been an increase in climate-related extreme events in Bangladesh (Shahid et al., 2016). Moreover, due to its dense coastal population and poor economic conditions, it has become more sensitive to climate change impacts on human health (M. Haque et al., 2019). Increasing frequency of flooding was also reported to cause disease outbreaks like diarrhea, skin diseases and cold cough in riverine areas of Bangladesh (Hossain et al., 2021). Vulnerable communities with low-income status are at high risk of climate-induced diseases like diarrhea, dysentery, malaria, dengue etc. (Kabir et al., 2016). For example, 1°C temperature rise resulted in significant non-cholera diarrheal diseases among the communities with poor education, housing and sanitation status (Masahiro et al., 2007).

Similarly, the risk ratio for cholera was found to be increased from 1.58 to 19.32 with a 5°C temperature rise whereas a 5°C increase in water temperature caused three-fold increase in cholera risk (A. Huq et al., 2005). The prevalence of malaria was observed higher with the increasing temperature, humidity and rainfall in hilly regions of Bangladesh (Amin et al., 2011). It is estimated that an increase of 10-mm of rainfall from the threshold value of 45-mm caused a 14% increase in cholera diseases (Masahiro et al., 2008). Again, Non-cholera diarrheal diseases are found to be increased about 5.1% and 3.9% for a 10 mm increase and 10 mm decrease in rainfall, respectively (Masahiro et al., 2007). Vulnerable communities are at high risk of exposure to climate-induced diseases like diarrhea, dysentery, malaria, dengue etc. In addition, climate-induced salinity intrusion in drinking water has caused pre-eclampsia, hypertension, and infant mortality in the coastal areas of Bangladesh among pregnant women (Shammi et al., 2019).

Public health concerns for Bangladesh will become more alarming in the coming decades. Health has been seen as a critical means for achieving sustainable development goal six (SDG6) and the ultimate goal of development is to improve public health well-being for all ages (Oleribe et al., 2015). But, in most cases health expenditure for the disease burden occurred as a result of extreme events that could not be afforded by the poor affected peoples (Kabir et al., 2016). The health and well-being of the people essentially cover the country's sustainable development goals. With its vast population and limited resources, improving public health standard is a crucial challenge and it is obvious to minimize the impacts of climate change on health to reach the committed goal of development. Identifying diverse and critical relationships among climate change and health and modifying factors is crucial for policymakers to get better insights and to include the right actions in the planning process.

A few studies have identified the relationships between climate change and associated health issues over different

periods. The available studies are concentrated mostly in the coastal or urban areas, reflecting a single or a couple of disease incidences. Northern and eastern parts of the country shall also have great impacts on public health due to climate-induced causes. There is scarce of a review that include climate change-induced health problems covering whole Bangladesh scenarios. In addition, very few studies are found to use hospital visit data to confirm the actual increase in disease frequency in terms of climate change. Most studies are based on key informant interviews (KII), focus group discussion (FGD), questionnaire surveys or sample data for a specific disease from a particular location. But, to generalize the concept, incorporating the results of the studies is needed. In particular, articles using hospital visit data need to be summarized to confirm the relationships and dimensions between disease incidents and climate change-induced events. In that case, understanding the disease occurrence frequency and spatial dimension by incorporating various studies results is essential. Considering this fact, this review paper aimed to identify the key relations between climate change and health systems and how climate change influences health and disease incidents. The prime objective is to assess climate change-induced health problems considering evidences from the whole of Bangladesh and to get an overview of the available study methodologies.

## **2. Materials and methods**

The literature was searched using combinations of 16 keywords (Table 1) between 24 and 30 November 2021 using different search engines such as PubMed, web of science, and Google scholar for gray literature. Only peer-reviewed journal articles and English language were considered. One hundred thirteen articles were primarily selected for review. Four researchers were involved in the literature search. All of the researchers briefly studied the titles and abstracts of primarily chosen articles. The researchers voted these 113 articles for the final selection of articles for further studies. Those articles got at least two votes to include in the process were selected, and finally, 35 articles were kept for review. Relevance of climate change-induced health problems reflecting study area in Bangladesh are considered to include the articles. Articles that didn't consider climate change-induced health problems and didn't discuss Bangladesh contexts were removed from the review process. Book chapters and review articles were also removed from the process.

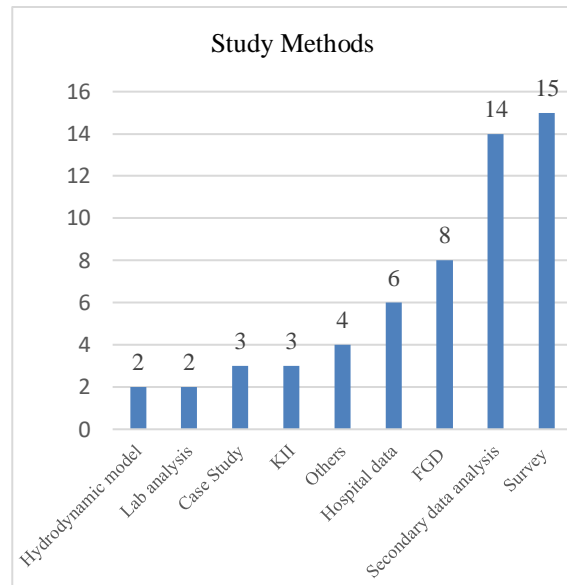
**Table 1:** Keywords used in the literature review

| S.N. | Key words  |
|------|--|
| 1    | Climate Change and Children Health in Bangladesh (1999-2021)             |
| 2    | Increase in temperature and child health in Bangladesh                   |
| 3    | Initial assessment of health hazards due to climate change in Bangladesh |
| 4    | Health hazards caused by climate change in Bangladesh                    |
| 5    | Women's health and climate change in Bangladesh                          |
| 6    | Climate change-induced health crisis in Bangladesh                       |
| 7    | Climate change effects on public health in Bangladesh                    |
| 8    | Climate change impacts on health in Bangladesh                           |
| 9    | Initial assessment of climate change and health impacts in Bangladesh    |
| 10   | Climate change impacts in Bangladesh                                     |
| 11   | Climate change vulnerability in Bangladesh                               |
| 12   | Climate change hazards and health in Bangladesh                          |
| 13   | Climate change and vulnerability of health in Bangladesh                 |
| 14   | Climate change impacts on health in Bangladesh                           |
| 15   | Health impacts of global warming in Bangladesh                           |
| 16   | Climate change impacts the coastal area of Bangladesh                    |

### 3. Results and discussion

#### 3.1. Climate-change induced health research methodologies in Bangladesh

Wide range of methodologies have been found in the selected articles (Figure 1). Key informant interview (KII), Focus group discussion (FGD), and Questionnaire survey were the most used methodologies in the selected articles. Secondary data analysis with climatic and environmental data collected from Bangladesh Meteorological Department (BMD) and similar organizations was another popular methodology in this review. Besides these, blood pressure data, urine specimen test data, and water quality test data were generated in experimental ways in some studies. Few articles collected hospital-registered data to check outbreaks of specified diseases in response to environmental factors. Standard methods used in the selected literature are briefly described in the following sections.



**Figure 1:** Common methodologies used in Bangladesh for climate change-induced health research

#### Collection of drinking water salinity data

In the earlier years up to the 1990s, sea level rise data were retrieved from proxy records. In later years sea level rise data are recorded using tide-gauge measurements. The newest development of sea-level rise data collection uses altimeter satellite technologies (Talukder et al. 2015). Salinity intrusion has been recognized as one of the significant impacts of sea-level rise. Salinity intrusion is closely connected to climate change events like cyclones, storm surges, and damage to coastal mangrove forests and wetlands. Lateral ground water movements during pre-monsoon and brackish or saline water for shrimp culture are also responsible for salinity intrusion in the coastal region (Shammi et al., 2019). Residents of the coastal region have to drink saline water due to the scarcity of safe water, which results from many diseases. A few articles tested water samples from drinking and other domestic use sources using laboratory protocol (Huq et al. 2005). Urine samples were also tested for 24 hours intervals to check the consumption and excretion of sodium through drinking water (Khan et al. 2011). Besides testing the salinity of collected water samples, salinity data were also collected for analysis from the Centre for Environment and Geographic Information System (CEGIS) in Bangladesh. Water salinity data produced for different research purposes by the International Center for Diarrheal Disease Research Bangladesh (ICDDR, B) were also used (Chakraborty et al. 2019).

#### Blood pressure and hypertension data

Drinking saline water causes more sodium entry into the human body which has a crucial impact on health. Specifically, hypertension or high blood pressure, skin diseases, and maternal health problems like pre-eclampsia are common in the coastal area (Shammi et al., 2019). The most common health problems discussed from drinking

saline water in the papers are hypertension and blood pressure. Relevant blood pressure and hypertension data of pre-selected voluntarily agreed people were collected by trained health assistants (Chakraborty et al. 2019). Consuming saline water directly impacts human health, which is linked to blood pressure, pre-eclampsia, eclampsia, and hypertension. Records of pregnant women's hypertension data were retrieved from hospitals to check the interrelation between drinking salinity and hypertension (Khan et al. 2011).

### Hospital registered data

One of the exciting studies was conducted by retrieving recorded data of admitted typhoid patients from 11 major hospitals around Dhaka (Dewan et al. 2013). The study aimed to find the relevance of environmental factors like temperature to the outbreak of germs for typhoid. Research works led by scientists of ICDDR, B used registered patient data for analysis who were visiting ICDDR, B for treatment of cholera or rotavirus (Hashizume et al. 2007, 2008). The correlation between climate change factors and the outbreak of malaria was researched using secondary data of Blood Slide Examined, and Malaria Cases Detected retrieved from Management Information System (MIS), Directorate General of Health Services (DGSH) (Amin et al. 2011)

### Focus group discussion (FGD) and key informant interviews (KII)

FGDs were conducted using different groups of people. For example, group people consisting of working people who serve at Upazila and Union levels. Another group was formed, including social workers, local leaders like Union Porishod members, farmers, businessmen, fishermen, NGO workers etc. (Kabir et al. 2014). KIIs were conducted including representatives from local residents and different professionals like school teachers, community leaders like a member of Union Parishad and government and NGO officials (Hossain et al. 2020)

### Questionnaire survey and case studies

A questionnaire survey was a popular method used to get a general overview of the climate change effects on a certain area (Hossain et al. 2020, Rahman 2013). An online survey using social media like Facebook platform (Rahman et al. 2020) was interesting way of data collection besides physical survey method (Chakraborty et al. 2019). Case studies were conducted to look up in-depth insights into climate change effects and health crises (Rahman 2013).

### Meteorological and water level data

Environmental data were the essential elements of the review's studies. Those data temperature, rainfall, humidity etc., were collected from the Bangladesh meteorological department from relevant stations in the study area (Titumir and Dey 2013). Water level data is another important element in knowing salinity intrusion in the coastal area and the availability of drinking water in other parts of the country. Water level data were collected

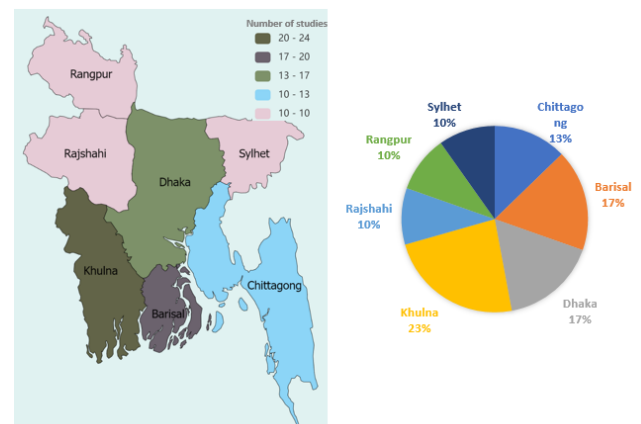
from Bangladesh Water Development Board (Hashizume et al. 2007). Safe drinking water availability information were also collected from local government officials and NGO workers (Abedin et al. 2018).

### Software based modeling and statistical analysis

Modeling and simulation are very common to visualize upcoming scenarios of climate change effects. Use of IPCC modelling is very common in climate change-relevant research (Talukder et al. 2015). Effective software-based modeling was used to know future scenarios of possible flood, storm surge, salinity intrusion etc (Karim and Mimura 2019). Statistical analysis plays a vital role in interpreting what data refers to the research. Collected data were arranged according to do analysis, for example linear Poisson regression models (Hashizume et al. 2007a) and logistic regression (Khan et al. 2011). Table 1 shows the results found in the selected articles with references.

### 3.2. Zone-based climatic disease intensity

The study revealed some interesting findings about climate change effects on human health in Bangladesh. All administrative divisions of Bangladesh were covered in this study. Out of 35 studies majority percentages were conducted in Khulna, Barisal and Dhaka (including Mymensingh) division. Very few studies were found in Rajshahi, Rangpur and Chittagong divisions (Figure 2). Coastal districts of Khulna, Barisal and Chittagong divisions had the most studies. Results from studies are shown in table for overall Bangladesh (Table 2), coastal region (Table 3), urban region (Table 4), flood-prone region (Table 5), and hilly regions (Table 6).



**Figure 2:** Bangladesh map and pie chart showing different divisions of Bangladesh with number and percentage of studies used in the review

### Overall Bangladesh

As a low carbon emitter country, Bangladesh suffers the most adverse effects of strong climate change and heavy monsoon rainfall (Rahman et al., 2021). Agricultural production is greatly affected as consequences climate change impacts like salinity intrusion, flood or drought. These effects cause food crisis

leading to nutrient deficiencies and malnutrition. Loss of agricultural production and potable water crisis is one of the major causes of economic disturbances. The economic stresses produce mental health risks in the short and long term (Hayward & Ayeb-Karlsson, 2021). Relatively poorer and economically disadvantaged communities are more vulnerable to climate change effects. Women are most susceptible in terms of health condition. Their death rates also higher compare with men (Alam and Rahman 2015). Wider range of health issues are found all over Bangladesh associated with climate change (Shahid 2009 and Vineis et al. 2011). From IPCC report it also clear that direct health impacts such as hypothermia, diarrheal diseases, dehydration and aggravation of cardiovascular and respiratory diseases increased during extreme temperatures and heat waves throughout the whole country of Bangladesh (IPCC 2014).

### **Coastal region**

A maximum number of the article of this review paper focused on coastal zone which clarify that the relevant climate change research in Bangladesh is mostly concentrated in the coastal zone. Sea level rise and salinity intrusion are the most unpleasant output of climate change in Bangladesh that makes coastal people livelihood more difficult (Minar et al., 2013; Vineis et al., 2011). People living in the coastal belt have very limited options to get freshwater, so they are forced to use saline water for drinking and domestic purposes days after days, leading to numerous health hazards (Vineis et al., 2011). The IPCC report provided clear indication that salinity intrusion along with temperature variability and rainfall, has significant impact on human health (IPCC a, 2014). The studies reported waterborne, vector-borne, communicable and non-communicable diseases have increased in coastal area of Bangladesh. The potential impacts of climate change in the western coastal zone of Bangladesh is big where the largest mangrove forest, the Sundarbans, is located (Agrawala et al., 2003). Millions of coastal residents earn their livelihood from Sundarbans and the adjacent coast. This livelihood pattern changed significantly over last couple of decades due to climate change effects (Minar et al., 2013).

### **Urban region**

Climate change-induced diseases increased in the urban area since last one-decade (Yasmin 2016). City dwellers are more suffering with water and vector borne diseases including cholera, typhoid fever, malaria, skin diseases, diarrhea (Amin et al., 2011; Dewan et al., 2013; A. Huq et al., 2005). Slum residents as well as other urban people are more vulnerable to cholera and diarrheal diseases during extreme climate change events like heat waves and excessive rainfall (Yasmin 2016).

### **Flood-prone region**

The study found few studies discussing health and economic issues of flood-prone area. Water-borne diseases are suffering people in the flood prone area. Besides, economic crisis is utmost crisis caused by flood.

People loss their work, house and properties which make them economically more vulnerable.

### **Hilly region**

Vector-borne diseases are the most crucial challenges in the hilly region. Climatic factors are responsible for changing vectors' adaptive capabilities that lead to newer disease variants (Amin et al. 2011). The unavailability of safe drinking water in the hilly region is also causing health crisis. People of those areas very often collect water from nearby streams, rivers or canals that are unsafe to drink or cook and responsible for water-borne diseases.

## **3.3. Climate change and health impacts**

### **Climate-induced waterborne communicable diseases and health effects**

Water-borne diseases like cholera, diarrhea, dysentery, skin diseases, typhoid etc. are gigantic health crises in Bangladesh. Cholera is the most common health crisis highly connected to climatic conditions. Excessive heat, polluted or saline water, both high and low rainfalls significantly increase cholera cases (Dewan et al., 2013; Masahiro et al., 2008). Water temperature defines favorable conditions for coped, cyanobacteria, fecal coliforms, and gene coding for cholera toxins to be present in water that make *Vibrio cholera* effective to cause disease (Huq et al., 2005). Typhoid is a major cause of death in Bangladesh and worldwide. Scientific evidence showed that both diseases are highly connected with heavy monsoon rainfall, high summer temperature, and rising river water levels (Dewan et al., 2013). Heat stress or hypothermia, diarrheal diseases, dehydration, and aggravation of cardiovascular diseases have a close connection with safe drinking water (Shahid, 2010). The outbreak of rotavirus infection is also linked to increasing temperature, relative humidity, and rising river levels (Hashizume et al., 2008).

### **Climate-induced waterborne non-communicable diseases and health effects**

Women suffer the most critical consequences of the effects of climate change effects in Bangladesh as well as the whole world (Neelormi et al., 2009; Rahman, 2013). Health crisis during pregnancy, including hypertension, pre-eclampsia, and eclampsia, are major sufferings of women which are allied to lack of food, safe drinking water, and proper sanitation, increased frequency of extreme weather events (Khan et al., 2011). Gynecological problems are increasing due to the use of unhygienic water for cooking, drinking and other domestic purposes (Neelormi et al., 2009). Another bold suffering of women and children is migration which is linked to work loss, changing patterns of livelihood as a result of climate change effects like cyclone, long term water logging due to flood or storm surge, river bank erosion, drought, heat exposure (Rylander et al., 2013). Most of the climate victims migrate to slum areas in bigger cities from origin of their residence (Yasmin, 2016). Climate change impacts are strongly shown up among urban slum

dwellers and their livelihood. Sufferings of the migrated slum dwellers remain miserable for water, sanitation, and hygiene.

**Climate-induced vector-borne diseases and health effects**

The climate of Bangladesh is becoming unpredictable, and it is changing gradually to more harsh characteristics (Kabir et al., 2016; Yasmin, 2016). Temperature, rainfall and relative humidity are the core components of climate change, changing their regular pattern in Bangladesh resulting in climate change effects. Sufferings of human health are determined in direct effects due to extreme weather frequency changes, for example, droughts and

floods that lead unavailability of safe drinking water. In another way, climate change indirectly affects human health by changing natural systems such as carriers or vectors of diseases, water, and air pollution (Ashrafuzzaman & Furini, 2019; Oo & Thin, 2022). Climate-induced vector-borne diseases and health effects are critical in urban and hilly areas. Malaria and dengue fever are two crucial diseases that frequently outbreak in Bangladesh. These diseases are extremely dependent on the living and growth of their vector mosquito. Climatic factors rainfall and temperature significantly affect the lifecycle of mosquitoes.

**Table 2:** Climate change-induced diseases reported considering study areas overall Bangladesh with significant results

| S.N. | Disease name   | Study location     | Study method                                  | References                   | Results  |
|------|--|--------------------|---|------------------------------|--|
| 1    | Dengue   | Whole Bangladesh   | Survey  | Rahman <i>et al.</i> (2020)  | Respondent believed that climate change can affect Dengue Fever. |
| 2    | Overall  | Whole Bangladesh   | Disability-adjusted life year (DALY)          | Nelsen (2002)                | A major storm event both deaths and injuries.                    |
| 3    | Hypertension, miscarriage, skin diseases, acute respiratory infection and diarrhea | Whole Bangladesh   | Secondary data from MoEFCC Hydrodynamic model | Vineis <i>et al.</i> (2011)  | Increased salinity intrusion has link to increase diseases.      |
| 4    | Social and economic contexts   | Whole Bangladesh   | Secondary data analysis from BMD              | Basak <i>et al.</i> (2013)   | Increasing trend of temperature and rainfall found.              |
| 5    | Social and economic contexts   | Whole Bangladesh   | Secondary data analysis from MoEFCC and BMD   | Al-Amin <i>et al.</i> (2013) | Discussed strategies and policies of climate change issues.      |
| 6    | Environment and economic contexts  | Whole Bangladesh   | Hydrodynamic model                            | Karim and Mimura (2008)      | Temperature rise has link to sea level rise and flood.           |
| 7    | Heat stress, dehydration, diarrhea, cardiovascular and respiratory diseases        | Overall Bangladesh | IPCC report                                   | Shahid, 2009                 | Temperature rise reflect on renal disease and mental disorders.  |
| 8    | Malnutrition and skin disease  | Overall Bangladesh | Survey FGD                                    | Alam and Rahman (2015)       | Women suffer more than men during and after climate disasters.   |

**Table 3:** Climate change-induced diseases reported considering coastal areas of Bangladesh with significant results

| S.N. | Disease name                                 | Study location | Study method | References                   | Results   |
|------|--|----------------|--------------|------------------------------|---|
| 1    | Diarrhea, skin disease, typhoid, chicken pox | KhulnaBarisal  | FGD          | Kabir <i>et al.</i> (2014)   | Infectious diseases increased after the occurrence of Sidr. |
| 2    | Diarrhea, typhoid, skin diseases, jaundice   | Barisal        | FGD          | Kabir <i>et al.</i> (2014 a) | Diseases increased just after Sidr.                         |

|    |  |                                 |  |                                |   |
|----|--|---------------------------------|--|--------------------------------|---|
| 3  | Arthritis, tonsil, fever, cough, feeling weak, skin burns, eyesight problems, back pain, chest pain. | Khulna                          | Survey<br>FGD  | Chowdhury <i>et al.</i> (2020) | Increased temperature, rainfall, and disaster over last ten years has direct impacts on health.   |
| 4  | Skin diseases and malnutrition   | Khulna                          | FGD<br>Risk and Resource Mapping (RRM)<br>Vulnerability Assessment | Huq <i>et al.</i> (2015)       | Climate change significantly had long-term impacts such as skin diseases and malnutrition.  |
| 5  | Overall  | KhulnaDhaka                     | Survey<br>Secondary data analysis from BMD                         | Afrin <i>et al.</i> (2018)     | Increased temperature, erratic precipitation, increased groundwater uses, increased flood and drought frequency resulted increased health hazard. |
| 6  | Diarrhea, fever as well as cold, accidental disability   | Khulna                          | Survey   | Garai (2014)                   | Increased diseases due to increased frequency of natural disasters.   |
| 7  | Overall  | Khulna<br>Barisal<br>Chittagong | Secondary data analysis  | Minar <i>et al.</i> (2013)     | Negative impacts of climate change found on ecosystems and socio-economic systems in the coastal zone.  |
| 8  | Cholera, malaria, typhoid, jaundice  | Barisal                         | Survey<br>Secondary data analysis                                  | Rahman (2013)                  | Women are quite conspicuous compared with their male counterpart.   |
| 9  | Cold related diseases  | RajshahiKhulna                  | Survey<br>FGD<br>KII   | Haque <i>et al.</i> (2012)     | Frequency of water, heat and cold related diseases had increased.   |
| 10 | Cholera  | Barisal<br>Sylhet<br>Chittagong | Lab analysis   | Huq <i>et al.</i> (2005)       | Significant correlations between cholera toxin producing bacteria and water temperature & depth, rainfall, conductivity, copepod count was found. |
| 11 | Social and economic contexts   | Khulna                          | KII<br>FGD<br>Case study   | Pouliotte <i>et al.</i> (2011) | Economic vulnerability of poor villager increased due to climate change.  |
| 12 | Diarrhea, dysentery, skin diseases   | Khulna                          | Survey   | Abedin <i>et al.</i> (2019)    | Waterborne diseases increased due to scarcity of safe drinking water.   |
| 13 | Gynecological problems   | Khulna                          | Case study   | Neelormi <i>et al.</i> (2009)  | Gynecological problems increased due to unhygienic water use.   |

|    |                                      |                |   |                                  |   |
|----|--------------------------------------|----------------|---|----------------------------------|---|
| 14 | Hypertension                         | Khulna         | Secondary data analysis from CEGIS Hospital data from Upazila Health Complex and ICDDR, B | Khan <i>et al.</i> (2011)        | Hypertension during pregnancy was higher in the dry season than in the rainy season.                            |
| 15 | Hypertension                         | Khulna Barisal | Survey  | Nahian <i>et al.</i> (2017)      | Hypertension increased with elevated salinity level in drinking water.  |
| 16 | Social and economic contexts         | Khulna         | Survey  | Carrico <i>et al.</i> (2020)     | Extreme weather leads families to accept less desirable marriage proposals.                                     |
| 17 | CVD, diarrhea, and abdominal pain.   | Khulna Barisal | Survey Laboratory analysis Hospital data from ICDDR, B                                    | Chakraborty <i>et al.</i> (2019) | People living in high salinity areas visited hospital more frequently than people living in low salinity areas. |
| 18 | Diarrhea, skin disease, malnutrition | Khulna         | Survey Secondary data analysis from BMD, BBS  | Monibul and Shovon (2019)        | Women are greatly affected by several water borne diseases during disaster.                                     |

**Table 4:** Climate change-induced diseases reported considering urban areas of Bangladesh with significant results

| S.N. | Disease name   | Study location | Study method  | References                       | Results  |
|------|--|----------------|---|----------------------------------|--|
| 1    | Diarrhea   | Dhaka          | Secondary data analysis from BMD and BWDB                               | Hashizume <i>et al.</i> (2007)   | Non-cholera diarrhea cases increased with increase of rainfall.  |
| 2    | Skin diseases, cholera, fever, malaria, dengue, headache, vomiting, tiredness, respiratory infections. | Dhaka          | Survey KII Case Study   | Yasmin (2016)                    | Disease increased in last one decade due to climate change.  |
| 3    | Diarrhea   | Dhaka          | Hospital data ICDDR, B Secondary data analysis from BMD and BWDB        | Hashizume <i>et al.</i> (2007 a) | High temperature, low humidity and high river-level increase the incidence of rotavirus diarrhea in Dhaka. |
| 4    | Cholera  | Dhaka          | Registered Hospital data from ICDDR, B Secondary data analysis from BMD | Hashizume <i>et al.</i> (2008)   | Cholera cases increased with rainfall.   |
| 5    | Typhoid  | Dhaka          | Registered hospital data Secondary data analysis from BMD.              | Dewan <i>et al.</i> (2013)       | Typhoid cases increased with temperature, rainfall and river level.  |



**Table 5:** Climate change-induced diseases reported considering flood prone areas of Bangladesh with significant results

| S.N. | Disease name                                       | Study location | Study method  | References                   | Results  |
|------|--|----------------|---------------|------------------------------|--|
| 1    | Diarrhea, cold and cough with fever, skin diseases | Rangpur        | Survey<br>FGD | Hossain <i>et al.</i> (2021) | Char dwellers experienced the highest disease outbreaks as indicators of climate change. |
| 2    | Social and economic contexts                       | Rangpur        | Survey        | Hossain <i>et al.</i> (2020) | Floods make respondent economically more vulnerable.                                     |

**Table 6:** Climate change-induced diseases reported considering hilly areas of Bangladesh with significant results

| S.N. | Disease name                   | Study location                                       | Study method  | References                 | Results  |
|------|--------------------------------|--|---|----------------------------|--|
| 1    | Malaria                        | Chittagong<br>Sylhet<br>Dhaka                        | Registered hospital data from MIS<br>Secondary data analysis from BMD | Amin <i>et al.</i> (2011)  | Malaria have positive correlation with yearly average maximum temperature, yearly total rainfall and yearly average humidity in Rangamati. |
| 2    | Dengue, malaria, and pneumonia | Khulna<br>Barisal<br>Chittagong<br>Dhaka<br>Rajshahi | Survey  | Kabir <i>et al.</i> (2016) | Incidence of dengue was 1.29 and malaria 13.86 per 1,000 adult populations for 12 months preceding the data collection.                    |

#### 4. Conclusion

The rising temperatures, heat waves, increasing frequencies and intensities of complex extreme events have directly affected the public health. However, very limited research and publications address climate change-induced health issues. Scientific evidence for establishing connections between disease outbreaks and climate change factors are very limited. Most of the published literature is based on surveys, KII and FGD. Very few studies are found considering hospital registered data and primary experimental data. The available studies are concentrated on the specific region like Union or Upazila (a smaller unit of the country's administration). Therefore, there is huge scope to do more comprehensive research considering experimental setup and hospital registered data.

#### References

- Abedin, M.A., Collins, A.E., Habiba, U., & Shaw, R. (2019). Climate Change, Water Scarcity, and Health Adaptation in Southwestern Coastal Bangladesh. *International Journal of Disaster Risk Science*, 10(1), 28–42. <https://doi.org/10.1007/s13753-018-0211-8>
- Afrin, N., Habiba, U., Das, R.R., Auyon, S. T., & Islam, M. A. (2018). Impact and vulnerability assessment on climate change of Jessore and Mymensingh districts in Bangladesh. *Progressive Agriculture*, 29(4), 320–335.
- Agrawala, S., Ota, T., Ahmed, A. U., Smith, J., & Aalst, M. van. (2003). *Development and climate change in Bangladesh: Focus on coastal flooding and the sundarbans*. Organisation for Economic Co-operation and Development. <https://www.oecd.org/env/cc/21055658.pdf>
- Al-Amin, A. Q., Kari, F., & Alam, G. M. (2013). Global warming and climate change: Prospects and challenges toward long-term policies in Bangladesh.

- International Journal of Global Warming*, 5(1), 67–83. <https://doi.org/10.1504/IJGW.2013.051483>
- Alam, M. B., & Rahman, K. M. A. (2017). Women and climate change in Bangladesh. *Cross-Cultural Communication*, 13(8), 7–9. <https://doi.org/10.3968/9858>
- Amin, M.R., Tareq, S.M., & Rahman, S.H. (2011). Impacts of Climate Change on Public Health: Bangladesh Perspective. *Global Journal of Environmental Research*, 5(3), 97–105.
- Ashrafuzzaman, M., & Furini, G.L. (2019). Climate change and human health linkages in the context of globalization: An overview from global to southwestern coastal region of Bangladesh. *Environment International*, 127, 402–411. <https://doi.org/10.1016/j.envint.2019.03.020>
- Basak, J.K., Titumir, R.A.M., & Dey, N.C. (2013). Climate Change in Bangladesh: A Historical Analysis of Temperature and Rainfall Data. *Journal of Environment*, 2(2), 41–46.
- Carrico, A.R., Donato, K.M., Best, K.B., & Gilligan, J. (2020). Extreme weather and marriage among girls and women in Bangladesh. *Global Environmental Change*, 65. <https://doi.org/10.1016/j.gloenvcha.2020.102160>
- Chakraborty, R., Khan, K.M., Dibaba, D.T., Khan, M.A., Ahmed, A., & Islam, M. Z. (2019). Health implications of drinking water salinity in coastal areas of Bangladesh. *International Journal of Environmental Research and Public Health*, 16(19), 1–10. <https://doi.org/10.3390/ijerph16193746>
- Chowdhury, M. A., Hasan, M. K., Hasan, M. R., & Younos, T. B. (2020). Climate change impacts and adaptations on health of Internally Displaced People (IDP): An exploratory study on coastal areas of Bangladesh. *Heliyon*, 6(9), e05018. <https://doi.org/10.1016/j.heliyon.2020.e05018>
- Dewan, A.M., Corner, R., Hashizume, M., & Ongee, E. T. (2013). Typhoid Fever and Its Association with Environmental Factors in the Dhaka Metropolitan Area of Bangladesh: A Spatial and Time-Series Approach. *PLoS Neglected Tropical Diseases*, 7(1), 12–15. <https://doi.org/10.1371/journal.pntd.0001998>
- Ebi, K.L., Boyer, C., Bowen, K. J., Frumkin, H., & Hess, J. (2018). Monitoring and evaluation indicators for climate change-related health impacts, risks, adaptation, and resilience. *International Journal of Environmental Research and Public Health*, 15(9), 1–11. <https://doi.org/10.3390/ijerph15091943>
- Elahi, K.M. (2016). Climate change and health impacts in Bangladesh. *Advances in Asian Human-Environmental Research*, 207–219. [https://doi.org/10.1007/978-3-319-23684-1\\_12](https://doi.org/10.1007/978-3-319-23684-1_12)
- Fagliano, J.A., & Diez Roux, A.V. (2018). Climate change, urban health, and the promotion of health equity. *PLoS Medicine*, 15(7), 8–11. <https://doi.org/10.1371/journal.pmed.1002621>
- Garai, J. (2014). The impacts of climate change on the livelihoods of coastal people in bangladesh: A sociological study. *Climate Change Management*, 151–163. [https://doi.org/10.1007/978-3-319-04489-7\\_11](https://doi.org/10.1007/978-3-319-04489-7_11)
- Haines, A., Kovats, R.S., Campbell-Lendrum, D., & Corvalan, C. (2006). Climate change and human health: Impacts, vulnerability and public health. *Public Health*, 120(7), 585–596. <https://doi.org/10.1016/j.puhe.2006.01.002>
- Haque, M.A., Yamamoto, S.S., Malik, A.A., & Sauerborn, R. (2012). Households' perception of climate change and human health risks: A community perspective. *Environmental Health: A Global Access Science Source*, 11(1), 1–12. <https://doi.org/10.1186/1476-069X-11-1>
- Haque, M., Pervin, M., Sultana, S., & Huq, S. (2019). Towards establishing a national mechanism to address losses and damages: A case study from Bangladesh. *Climate Risk Management, Policy and Governance*, 451–473. <https://doi.org/10.1007/978-3-319-72026-5>
- Hasan, S.M., & Shovon, M.B.S. (2019). Women's vulnerability due to climate change in the coastal area of Bangladesh. *Proceedings on International Conference on Disaster Risk Management*, 349–354.
- Hashizume, M., Armstrong, B., Wagatsuma, Y., Faruque, A.S.G., Hayashi, T., & Sack, D.A. (2008). Rotavirus infections and climate variability in Dhaka, Bangladesh: A time-series analysis. *Epidemiology and Infection*, 136(9), 1281–1289. <https://doi.org/10.1017/S0950268807009776>
- Hashizume, M., Armstrong, B., Hajat, S., Wagatsuma, Y., Faruque, A. S. G., Hayashi, T., & Sack, D. A. (2007). Association between climate variability and hospital visits for non-cholera diarrhoea in Bangladesh: Effects and vulnerable groups. *International Journal of Epidemiology*, 36(5), 1030–1037. <https://doi.org/10.1093/ije/dym148>
- Hashizume, Masahiro, Armstrong, B., Hajat, S., Wagatsuma, Y., Faruque, A. S. G., Hayashi, T., & Sack, D. A. (2008). The effect of rainfall on the incidence of cholera in Bangladesh. *Epidemiology*, 19(1), 103–110. <https://doi.org/10.1097/EDE.0b013e31815c09ea>
- Hathaway, J., & Maibach, E. W. (2018). Health Implications of Climate Change: a Review of the Literature About the Perception of the Public and Health Professionals. *Current Environmental Health Reports*, 5(1), 197–204. <https://doi.org/10.1007/s40572-018-0190-3>
- Hayward, G., & Ayeb-Karlsson, S. (2021). 'Seeing with Empty Eyes': a systems approach to understand climate change and mental health in Bangladesh. *Climatic Change*, 165(1). <https://doi.org/10.1007/s10584-021-03053-9>
- Hossain, B., Shi, G., Ajiang, C., Sarker, M.N.I., Sohail, M.S., Sun, Z., & Hamza, A. (2021). Impact of climate change on human health: evidence from riverine island dwellers of Bangladesh. *International Journal of Environmental Health Research*. <https://doi.org/10.1080/09603123.2021.1964447>

- Hossain, B., Sohel, M.S., & Ryakitimbo, C.M. (2020). Climate change induced extreme flood disaster in Bangladesh: Implications on people's livelihoods in the Char Village and their coping mechanisms. *Progress in Disaster Science*, 6. <https://doi.org/10.1016/j.pdisas.2020.100079>
- Huq, A., Sack, R.B., Nizam, A., Longini, I.M., Nair, G.B., Ali, A., Morris, J.G., Khan, M.N.H., Siddique, A.K., Yunus, M., Albert, M.J., Sack, D.A., & Colwell, R. R. (2005). Critical Factors Influencing the Occurrence of *Vibrio cholerae* in the Environment of Bangladesh. *Applied and Environmental Microbiology*, 71(8), 4645–4654. <https://doi.org/10.1128/AEM.71.8.4645>
- Huq, N., Hugé, J., Boon, E., & Gain, A.K. (2015). Climate change impacts in agricultural communities in rural areas of coastal bangladesh: A tale of many stories. *Sustainability*, 7(7), 8438–8460. <https://doi.org/10.3390/su7078437>
- IPCC. (2021). *Climate change 2021: The physical science basis summary for policymakers working group I contribution to the sixth assessment report of the Intergovernmental Panel on Climate Change*.
- IPCC a. (2014). *Climate change 2014: Synthesis report summary*.
- Kabir, M.I., Rahman, M.B., Smith, W., Lusha, M. A.F., & Milton, A.H. (2016). Climate change and health in Bangladesh: A baseline cross-sectional survey. *Global Health Action*, 9(1). <https://doi.org/10.3402/gha.v9.29609>
- Kabir, R., Khan, H.T.A., Ball, E., & Caldwell, K. (2014). Climate change and public health situations in the coastal areas of Bangladesh. *International Journal of Social Science Studies*, 2(3), 109–116. <https://doi.org/10.11114/ijsss.v2i3.426>
- Kabir, R., Khan, H.T.A., Ball, E., & Caldwell, K. (2016). Climate Change Impact: The Experience of the Coastal Areas of Bangladesh Affected by Cyclones Sidr and Aila. *Journal of Environmental and Public Health*. <https://doi.org/10.1155/2016/9654753>
- Karim, M.F., & Mimura, N. (2008). Impacts of climate change and sea-level rise on cyclonic storm surge floods in Bangladesh. *Global Environmental Change*, 18(3), 490–500. <https://doi.org/10.1016/j.gloenvcha.2008.05.002>
- Khan, A.E., Ireson, A., Kovats, S., Mojumder, S.K., Khusru, A., Rahman, A., & Vineis, P. (2011). Drinking water salinity and maternal health in coastal Bangladesh: Implications of climate change. *Environmental Health Perspectives*, 119(9), 1328–1332. <https://doi.org/10.1289/ehp.1002804>
- McMichael, A.J. (2013). Globalization, climate change, and human health. *New England Journal of Medicine*, 368(14), 1335–1343. <https://doi.org/10.1056/nejmra1109341>
- Minar, M.H., Hossain, M.B., & Shamsuddin, M.D. (2013). Climate change and coastal zone of Bangladesh: Vulnerability, resilience and adaptability. *Middle East Journal of Scientific Research*, 13(1), 114–120. <https://doi.org/10.5829/idosi.mejsr.2013.13.1.64121>
- Morris, G.P., Reis, S., Beck, S. A., Fleming, L. E., Adger, W. N., Benton, T. G., & Depledge, M. H. (2017). Scoping the proximal and distal dimensions of climate change on health and wellbeing. *Environmental Health: A Global Access Science Source*, 16, 69–76. <https://doi.org/10.1186/s12940-017-0329-y>
- Nahian, M. A., Ahmed, A., Lázár, A. N., Hutton, C. W., Salehin, M., & Streatfield, P. K. (2018). Drinking water salinity associated health crisis in coastal Bangladesh. *Elementa*, 6(2), 1–14. <https://doi.org/10.1525/elementa.143>
- Neelormi, S., adri, N., & Ahmed, A. U. (2009). Gender dimensions of differential health effects of climate change induced water-logging: A case study from coastal Bangladesh. *IOP Conference Series: Earth and Environmental Science*, 6(14), 142026. <https://doi.org/10.1088/1755-1307/6/4/142026>
- Nelson, D. I. (2003). Health impact assessment of climate change in Bangladesh. *Environmental Impact Assessment Review*, 23(3), 323–341. [https://doi.org/10.1016/S0195-9255\(02\)00102-6](https://doi.org/10.1016/S0195-9255(02)00102-6)
- Oo, K.T., & Thin, M.M.Z. (2022). Climate change perspective: The advantage and disadvantage of COVID-19 pandemic. *Journal of Sustainability and Environmental Management*, 1(2), 275–291.
- Oleribe, O.O., Crossey, M.M.E., & Taylor-Robinson, S.D. (2015). Sustainable health development goals (SHDG): Breaking down the walls. *Pan African Medical Journal*, 22, 1–5. <https://doi.org/10.11604/PAMJ.2015.22.306.6468>
- Pouliotte, J., Smit, B., & Westerhoff, L. (2009). Adaptation and development: Livelihoods and climate change in Subarnabad, Bangladesh. *Climate and Development*, 1(1), 31–46. <https://doi.org/10.3763/cdev.2009.0001>
- Prüss-Ustün, A., Wolf, J., Corvalán, C.F., Bos, R., & Neira, M.P. (2016). *Preventing disease through healthy environments: a global assessment of the burden of disease from environmental risks*. World Health Organization. <https://doi.org/https://apps.who.int/iris/handle/10665/204585>
- Rahman, M.S. (2013). Climate change, disaster and gender vulnerability: A study on two divisions of Bangladesh. *American Journal of Human Ecology*, 2(2), 72–82. <https://doi.org/10.11634/216796221302315>
- Rylander, C., Odland, J. øyvind, & Sandanger, T.M. (2013). Climate change and the potential effects on maternal and pregnancy outcomes: An assessment of the most vulnerable - the mother, fetus, and newborn child. *Global Health Action*, 6(1). <https://doi.org/10.3402/gha.v6i0.19538>
- Shahid, S. (2010). Probable impacts of climate change on public health in Bangladesh. *Asia-Pacific Journal of Public Health*, 22(3), 310–319. <https://doi.org/10.1177/1010539509335499>
- Shahid, S., Wang, X.J., Harun, S. Bin, Shamsudin, S.B., Ismail, T., & Minhans, A. (2016). Climate variability

- and changes in the major cities of Bangladesh: observations, possible impacts and adaptation. *Regional Environmental Change*, 16(2), 459–471. <https://doi.org/10.1007/s10113-015-0757-6>
- Shammi, M., Rahman, M.M., Bondad, S.E., & Bodrud-Doza, M. (2019). Impacts of salinity intrusion in community health: A review of experiences on drinking water sodium from coastal areas of Bangladesh. *Healthcare*, 7(1). <https://doi.org/10.3390/healthcare7010050>
- Siddikur Rahman, M., Karamelic-Muratovic, A., Baghbanzadeh, M., Amrin, M., Zafar, S., Rahman, N.N., Shirina, S.U., & Haque, U. (2021). Climate change and dengue fever knowledge, attitudes and practices in Bangladesh: A social media-based cross-sectional survey. *Transactions of the Royal Society of Tropical Medicine and Hygiene*, 115(1), 85–93. <https://doi.org/10.1093/trstmh/traa093>
- Talukder, M.R.R., Rutherford, S., & Chu, C. (2015). Climate Change Impacts and Responses in Bangladesh. *The International Journal of Climate Change: Impacts and Responses*, 8(1), 21–32. <https://doi.org/10.18848/1835-7156/CGP/v08i01/37260>
- Tariah, I.M.I., Abali, T.P., & Aminigbo, L.M.O. (2022). Impact of climate and land use changes on the livelihood of residents in Calabar river basin, south-eastern Nigeria. *Journal of Sustainability and Environmental Management*, 1(2), 151–160.
- Tong, S., & Ebi, K. (2019). Preventing and mitigating health risks of climate change. *Environmental Research*, 174, 9–13. <https://doi.org/10.1016/j.envres.2019.04.012>
- Tong, S., Confalonier, U., Ebi, K., & Olsen, J. (2016). Managing and Mitigating the health risks of climate change: Calling for evidence-informed policy and action. *Environmental Health Perspectives*, 124(10), 176–180.
- Vineis, P., Chan, Q., & Khan, A. (2011). Climate change impacts on water salinity and health. *Journal of Epidemiology and Global Health*, 1(1), 5–10. <https://doi.org/10.1016/j.jegh.2011.09.001>
- Yasmin, S. (2016). Impact of climate change on urban slum dwellers in Bangladesh: A case study of four selected slums in Dhaka City. *Archives of Current Research International*, 4(3), 1–15. <https://doi.org/10.9734/acri/2016/26501>



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