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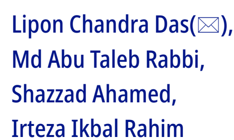
PAPER

Vulnerabilities and Impacts: Climate Change and Public Health in Bangladesh



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ABSTRACT

The escalating impacts of climate change are increasingly affecting human health, particularly in vulnerable groups. Rising temperatures have intensified heat stress, resulting in more cases of heat-related illnesses, especially among the elderly and individuals with chronic conditions. Simultaneously, climate change is extending the geographic spread of vector-borne diseases (VBDs) such as malaria and dengue while increasing the prevalence of waterborne illnesses due to contaminated supplies-placing additional pressure on healthcare infrastructure. Mental health issues are also growing due to climate-related anxiety, displacement, and trauma from extreme weather events. Additionally, worsening air quality, driven by industrial emissions and wildfires, contributes to respiratory and cardiovascular problems, disproportionately impacting urban populations. Forced migration due to climate-induced disasters further deepens health vulnerabilities. Together, these interconnected effects are amplifying the strain on public health systems, underscoring the urgent need for integrated adaptation strategies to address the health risks posed by a changing climate. Addressing these challenges requires coordinated policy action, cross-sector collaboration, and increased investment in climate-resilient healthcare systems.

KEYWORDS

climate change, human health, heat-related illnesses, vector-borne diseases (VBDs), food insecurity, mental health, healthcare infrastructure

1 INTRODUCTION

Climate change is increasingly recognized as a major global health threat, influencing a wide range of climate-sensitive infectious diseases. It affects the survival, reproduction, and distribution of disease-causing pathogens and vectors, as well as the environmental conditions necessary for their transmission. Countries with high population density, low adaptive capacity, and exposure to climate extremes—such as Bangladesh—are particularly vulnerable.

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Bangladesh's geographic location in a low-lying deltaic region, coupled with its socio-economic constraints, makes it highly susceptible to the health impacts of climate variability. Bangladesh is extremely vulnerable to climate change due to its exposure to various climate-driven disasters, such as sea level rise (SLR), cyclones, droughts, floods, and extreme heat (Das et al., 2024) [1]. Rising temperatures, increased humidity, and more frequent extreme weather events are already intensifying the incidence and geographic spread of vector-borne diseases (VBDs) such as malaria and dengue (Karmakar et al., 2014; WHO, 2023) [2] [3]. Moreover, prolonged heat waves are exacerbating cases of heat stress, disproportionately affecting vulnerable groups including outdoor workers, the elderly, and low-income communities (Ali et al., 2020) [4]. The public authority of Bangladesh has started different methodologies to battle the spread of dengue, for example, public mindfulness missions and mosquito control measures, including hazing and larvicidal medicines. Tending to these difficulties is urgent for diminishing the infection's effect on both public health and the economy (Ali, 2021) [5]. This has put an extra weight on the medical services framework, which is much of the time unprepared to deal with the flood of cases during outrageous intensity occasions (Molla et al., 2019) [6]. This incorporates upgrading the versatility of weak networks, further developing information assortment on environment-related wellbeing effects, and putting resources into long-haul arrangements like metropolitan cooling drives and further developed medical care access (Ahsan et al., 2011) [7]. Worldwide joint effort and backing are additionally fundamental to reinforce Bangladesh's capacity to adapt to the developing general wellbeing challenges presented by environmental change (Chakraborty et al., 2019) [8].

The motivation behind this study is to address the pressing public health risks posed by climate change in Bangladesh, particularly in the context of rising heat-related illnesses and the resurgence of VBDs. This paper examines the growing burden of heat stress and VBDs in Bangladesh and highlights the urgent need for climate-resilient health strategies.

2 METHODOLOGY

This study employed a mixed-methods approach to investigate the relationship between climate variables and public health outcomes in Bangladesh. Quantitative climate data from 1990 to 2023-including temperature, humidity, rainfall, and CO_2 levels-were sourced from NOAH, NASA, and the Climate Data Operators (CDO). Health data focusing on VBDs, heat-related illnesses, and waterborne infections were obtained from the Bangladesh Ministry of Health, the World Health Organization (WHO), and hospital records. Primary qualitative data were collected through 20 key informant interviews (KIIs) with health officials, focus group discussions (FGDs) in three climate-vulnerable districts, and field observations in flood- and dengue-prone areas. Purposive sampling targeted populations highly exposed to climate-related health risks. Data preprocessing involved cleaning, normalization, and integration, followed by feature extraction to identify key climatic indicators. Qualitative data were analyzed thematically to contextualize quantitative findings, ensuring a comprehensive understanding of the climate-health nexus.

3 RESULTS AND DISCUSSIONS

3.1 Increased heat stress

Climate change has huge ramifications for general well-being, especially in nations like Bangladesh, which is profoundly powerless because of its geographic area, populace thickness, and restricted framework. One of the most basic wellbeing gambles related to environmental change in Bangladesh is the expanded rate of intensity stress. Increasing temperatures, joined with high moistness levels, compound the recurrence and force of heat waves, presenting serious wellbeing dangers to weak population (Karmakar et al., 2014) [2]. High temperatures can likewise deteriorate previous circumstances like cardiovascular infections, respiratory issues, and kidney sicknesses. A time-series analysis conducted on data from 1990 to 2023 revealed that average monthly temperatures above 30°C are significantly correlated with increased hospital admissions for heat-related illnesses ($p < 0.01$). Even after adjusting for population growth and urbanization in the regression model, temperature remained the strongest predictor, explaining 62% of the variance in admissions. Besides, people with lower financial status, open air laborers, and the old are at elevated risk because of their more noteworthy openness to outrageous intensity and restricted admittance to medical care assets (Ali et al., 2021) [4]. Research demonstrates that heat-related mortality has previously been on the ascent, especially during the more sizzling long time of spring to June. For instance, a review distributed by the Bangladesh Meteorological Division found that Bangladesh's mean temperature has been expanding by around 0.1°C each 10 years, prompting more regular and delayed heat waves (Rashid et al., 2015) [9].

3.2 Vector-borne disease

Vector-borne diseases are a significant general wellbeing concern, and climate change is impacting their transmission elements, frequently compounding the spread and power of these infections. The VBDs are affected by the following major diseases, such as:

Malaria: Malaria stays a critical public health issue in Bangladesh, with high transmission rates in rustic and line regions, especially in the Chittagong hill tracts and a portion of the country's remote locale. Studies, for example, one distributed in the global diary of ecological exploration and general wellbeing in 2018, highlight the elevated weakness of Bangladesh to these movements. The review featured that the country's environment changeability portrayed by outrageous climate occasions like floods and dry spells would probably increment malaria flare-ups, especially in regions that were not generally endemic to the sickness (Ahmed and Rahman, 2018) [10]. Expanded precipitation and flooding, exacerbated by environmental change, are supposed to work with the reproduction of mosquitoes in both country and metropolitan regions, further confounding jungle fever control endeavors. A study in Bangladesh's Chittagong Hill Tracts found that each 1°C rise in average monthly temperature correlates with a 14% increase in malaria cases, independent of migration or deforestation factors. Increased rainfall also contributes to higher incidence, highlighting climate change's role in expanding malaria risk to new regions and complicating prevention efforts. Also, the World Malaria report (2021) [11] on climate and wellbeing gambles accentuates that climate change's effect on general wellbeing in South Asia, especially Bangladesh, will probably prompt higher

frequencies of jungle fever and other vector-borne illnesses, with serious ramifications for wellbeing frameworks that are now under tension.

Dengue: The impact of climate change on the spread of dengue fever, especially in Bangladesh, is a complex and multifaceted issue that intertwines environmental, social, and health systems dynamics. Understanding this relationship is crucial because it provides insight into how climate change is directly affecting public health in tropical regions. Dengue fever is a critical public health worry in Bangladesh, where the illness' rate has flooded as of late. This ascent has put extensive strain on the country's medical services framework and raised worries about the drawn-out suggestions for general wellbeing (WHO, 2023) [3]. The rising number of dengue cases has overpowered medical services offices. Clinics, particularly in metropolitan places, frequently face deficiencies of medical clinic beds and fundamental clinical supplies during top flare-ups, which further strain the medical services foundation. Besides, serious instances of dengue require escalated care, adding extra strain to the wellbeing framework. The treatment costs and the weight on medical services laborers are significant, causing what is going on for the country's general wellbeing framework (Hossain, 2020) [12]. Roundabout costs come from the deficiency of efficiency because of sickness. For example, the 2019 flare-up prompted billions of Bangladeshi Taka in costs, featuring the critical financial effect of the illness (Rahman and Choudhury, 2020) [13]. This represents a drawn-out challenge to general well-being and requires versatile measures to adapt to the evolving environment (Zaman et al., 2019) [14]. A time-series analysis conducted in Dhaka city revealed a significant positive correlation between climatic factors and dengue incidence. The study found that for each 1°C increase in minimum temperature, there was a 6.1% increase in dengue cases (95% CI: 4.2%–8.0%). Additionally, a 1% increase in relative humidity was associated with a 2.5% increase in dengue cases (95% CI: 1.0%–4.0%). These associations persisted after controlling for other variables, indicating a strong link between climate variables and dengue transmission (Hossain et al., 2023) [15]. Dengue incidence rates exhibited marked variations between districts across the districts from 2019 to 2023. Dhaka emerged as the clear epicenter in 2019 with 3,772 cases per million people, followed by Barisal and Jessore with 1,482 and 1,378 cases per million, respectively. In contrast, Sunamganj, Panchagarh, and Netrakona have seen minimal dengue incidence which was below 50 cases per million. In 2021, the spatial distribution of dengue incidence, remained similar, with Dhaka reporting the highest incidence at 1,626 cases per million. Dengue incidence surged further in 2022, with Dhaka maintaining the highest burden of 2,675 cases per million populations. The situation escalated dramatically in 2023 when Manikganj district became the new epicenter, grappling with a staggering 8,200 cases per million populations. Dhaka and Pirojpur also reported significant dengue burdens, exceeding 7,500 and 6,000 cases per million populations, respectively. Sunamganj again recorded the lowest rate of 37 cases per million populations. Dengue outbreak in 2023 has already affected and caused deaths in both areas of previous outbreaks. This year, a total of 321,179 dengue patients have been admitted to hospitals, of whom 1,705 have died. For the first time in the country, the number of patients coming from outside Dhaka (211,171) exceeds those coming from Dhaka Metropolitan (110,008). Bangladesh has a dengue mortality rate of 0.53, which is higher compared to other countries in South and Southeast Asia and much higher than the previous year (see Figure 1). The analysis confirms that temperature and rainfall have strong positive correlations with disease prevalence, supporting climate change as a key driver (see Figure 2).

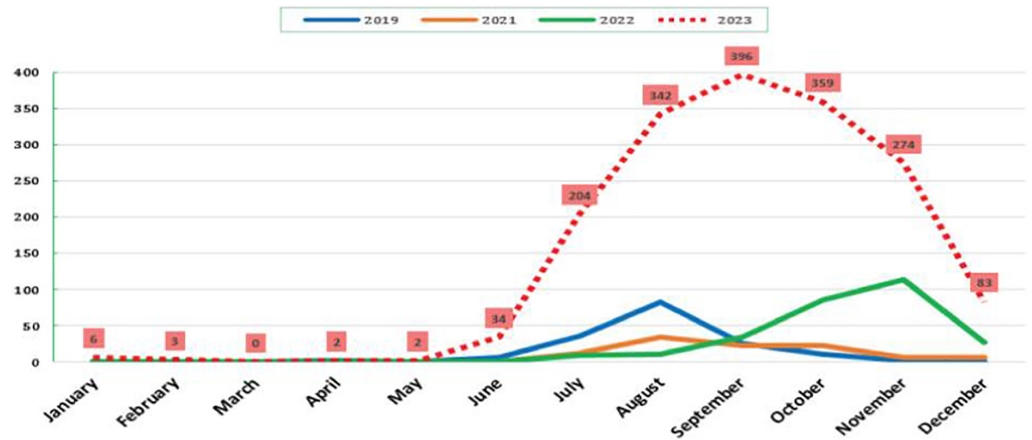

Fig. 1. Deaths caused due to dengue (month-wise from 2019–2023 (excluding 2020))

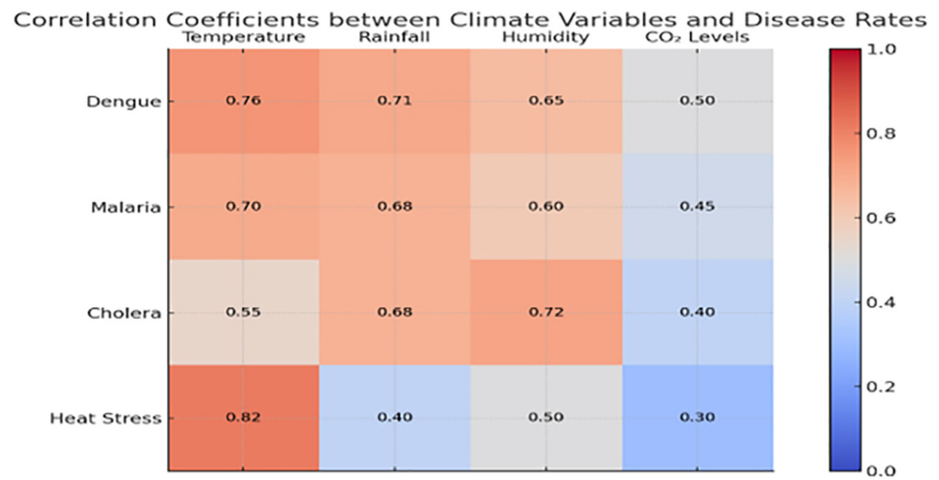

Fig. 2. Correlation coefficients between key climate variables (temperature, rainfall, humidity, CO_2 levels) and disease incidence rates (dengue, malaria, cholera, heat stress) from 1990–2023

3.3 Water-borne disease

Floods occur annually in the Brahmaputra and the Ganges basin in Bangladesh due to South Asian monsoon rainfall between June and September. Both rivers originate from the high altitude of the Himalayan mountain range in the Tibet region in China (Frenken, 2012) [16]. The drainage area of the Brahmaputra is estimated as 580,000 km2, of which China, India, Bangladesh, and Bhutan share 50.5%, 33.6%, 8.1%, and 7.8%, respectively (Bora, 2004) [17]. The basin area of the Ganges is about 1,089,370 km2, which extends over an area Bora of Tibet (China) (3.67%), Nepal (12.85%), India (79.2%) and Bangladesh (4.28%) (Rajmohan and Prathapar, 2013) [18]. Both basins consist of diverse landscapes, from high altitude Himalayan mountain to floodplain deltas (see Figure 2) and despite being close and connected (the Brahmaputra flows downstream into the Ganges), they present different characteristics, with different river topologies and diversified climatic patterns (Mirza et al., 1998) [19]. In both basins, around 60% to 70% of annual precipitation falls during the monsoon (Bhattachaiyya and Bora, 1997; Immerzeel, 2008) [20] [21], and especially the regional and temporal distribution of monsoon rainfall (Das et al., 2024) [22], with higher precipitation in the Brahmaputra basin, especially in upstream areas, with respect to the Ganges (Mirza et al., 1998) [18] . The average river discharge at Bahadurabad on the

Brahmaputra and Hardinge Bridge on the Ganges river during the monsoon season (June–September) is 41,000 and 23,314 m^3s^{-1}, respectively (BWDB, 2017) [23]. The flood characteristics of the two basins vary remarkably in terms of magnitude, timing, and duration (see Figure 3), with large inter-annual variability for both basins. Flood records show the Ganges River experiences floods in August and September, whereas the Brahmaputra can experience multiple flood pulses from June to September.

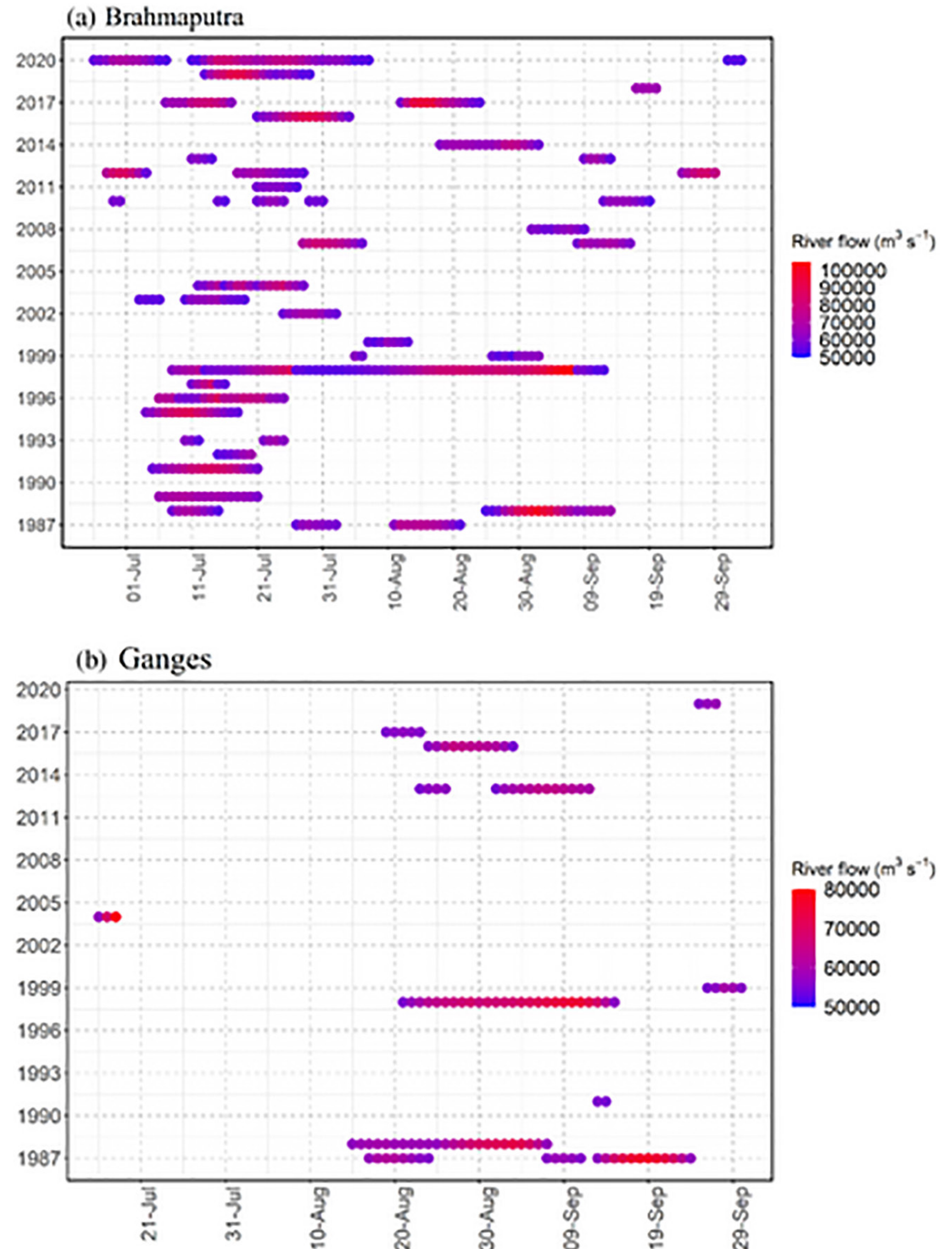

Fig. 3. Comparative analysis of flood magnitude, timing, and duration between two river basins

Note: Floods at the Bahadurabad station on (a) the Brahmaputra River and (b) at Hardinge Bridge on the Ganges River. Dates indicated by a colored dot show when river discharge exceeded the flood threshold (90th percentile). The color indicates the river flow (from low, blue, to high, red). The figure is inspired by a similar one for the Brahmaputra River (Hossain et al., 2019) [24].

The climate in Bangladesh plays a huge part in the transmission and force of cholera outbreaks. The country is exceptionally helpless against climate change, encountering successive flooding, twisters, and rainstorm which disturb water and disinfection frameworks and make conditions that are helpful for the spread of *Vibrio cholerae*. These super climate occasions, alongside occasional movements, give an optimal climate for the microscopic organisms to flourish and spread. During the storm season, which normally endures from June to October, weighty downpours lead to flooding that influences water quality, builds the defilement of water supplies, and upgrades the gamble of cholera transmission (Islam et al., 2018) [25].

In general, climate change and Bangladesh's openness to outrageous climate occasions fundamentally impact the recurrence and seriousness of cholera episodes, making progressing general wellbeing challenges (Christaki et al., 2020) [26]. The transaction between environment factors, unfortunate disinfection, and the absence of admittance to safe water makes Bangladesh especially vulnerable to cholera, particularly during times of extraordinary precipitation and flooding.

3.4 Malnutrition and food insecurity

Malnutrition and food insecurity continue to have a profound impact on public health in Bangladesh, with significant social and economic consequences. Undernutrition in Bangladesh stays a public health need because of its drawn-out impacts on wellbeing results, especially for youngsters. Hindering isn't just a marker of lacking sustenance during youth but also additionally has deep-rooted outcomes on mental turn of events and future monetary efficiency. A concentrate features that unhealthiness is connected to diminished efficiency and expanded wellbeing costs, which obstruct monetary advancement in Bangladesh (Rahman et al., 2020) [27]. Food frailty, driven by neediness, environmental change, and agrarian difficulties, further worsens the ailing health issue. The World Bank (2022) reports that around 24% of the populace lives underneath the neediness line, which limits admittance to nutritious food. Country regions are especially powerless against food instability because of insufficient framework and lower agrarian yields, exacerbated by continuous catastrophic events like floods and tornadoes (Ahmed and Rahman, 2021) [28]. Environmental challenges, including irregular monsoon patterns and temperature anomalies, have increased food insecurity in Bangladesh. A national survey (2010–2022) found that variability in crop yields, particularly rice, is significantly linked to erratic monsoon timings ($r = -0.64$), affecting food availability. Temperature fluctuations negatively impact rice productivity, contributing to undernutrition in rural areas, where access to reliable, quality food is already limited (Chowdhury et al., 2021) [29]. Food uncertainty and ailing health in Bangladesh are likewise affected by orientation and financial differences. Ladies and youngsters, particularly in country regions, are lopsidedly impacted by unhealthiness. Studies have shown that maternal sustenance is a vital determinant of baby wellbeing results, including birth weight and youth improvement (Saha and Hossain, 2022) [30]. Moreover, food designation inside families frequently leans toward men, which compounds the nourishing status of ladies and youngsters (Chowdhury et al., 2020) [31]. This orientation imbalance in food access and sustenance further sustains the pattern of destitution and chronic weakness results.

3.5 Air pollution

Air pollution in Bangladesh is caused by vehicle emissions, especially from diesel engines and old vehicles, traffic congestion, and the use of traditional fuels like firewood and cow dung. Brick kilns, industries (textile, garments, tanneries, and power plants), and poor waste disposal—especially medical waste—also contribute significantly. Urban areas in Bangladesh suffer from severe air pollution due to industrial emissions and vehicular exhaust, while rural regions, though cleaner, are increasingly affected by agro-industrial activities and climate-induced wildfires that elevate PM2.5 levels by 35% above annual averages. Deforestation and hill-cutting worsen environmental degradation. Studies show most industrial emissions exceed safe limits, leading to serious health problems including respiratory and cardiovascular diseases. In 2019, air pollution caused about 173,500 deaths in Bangladesh, highlighting the urgent need for clean energy, better waste management, and greener transportation systems. Figure 4 illustrates the sector-wise industrial emission of Bangladesh. Several studies have been conducted on industrial emission of air pollutants such as particulate matter, nitrogen oxides, carbon monoxide, and sulfur dioxide (Table 1). Most of them exceeded the permissible limit, which has a hazardous effect on human health.

Table 1. Some industrial emission of air pollutants

Source of Pollutants	Name of the Pollutant	References
Garments Industries	Nitrogen Oxides and Sulphur Dioxide	Hasan et al., 2018 [32]
Brick kiln	PM10 and PM2.5	Begum et al., 2011 [33]
Textile industries	CO_2, NO_2, SO_2	Mia et al., 2019 [34]
Coal based power plant	SO_2, NOx, PM2.5, PM10, and CO	Hossain, 2019 [23]
Landfill site	NOx, SO_2, SPM, PM10, PM2.5, and CO	Hossain et al., 2019 [35]
Vehicle emission	CO, Nox, and Sox	Hasan et al., 2013 [36]

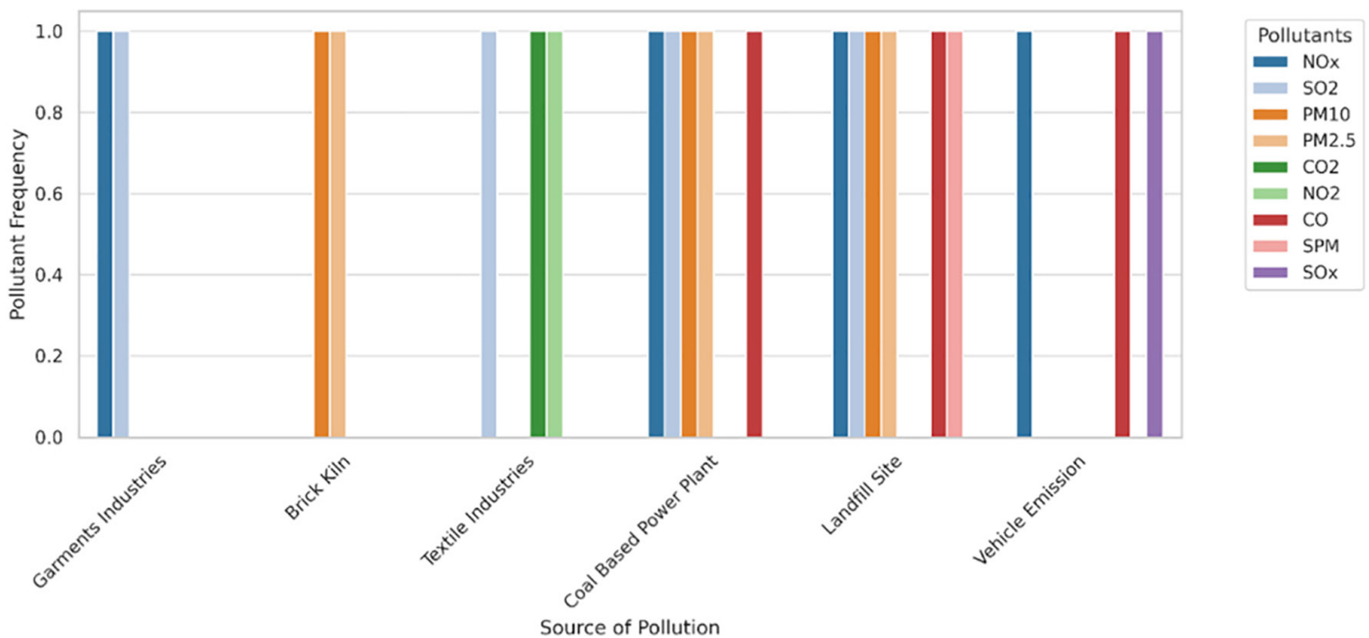

Fig. 4. Pollutants emitted by different sources

Here's a bar graph showing the presence of specific pollutants by different sources of pollution. Each colored bar represents a different pollutant, and the height indicates how many times that pollutant is reported for each source.

3.6 Impact on healthcare infrastructure

Climate change significantly affects healthcare foundations in Bangladesh, as climbing temperatures, unpredictable atmospheric conditions, and the rising recurrence of cataclysmic events put huge weight on the nation's, as of now, stressed medical care framework. The harm to medical services foundations, such as clinics, facilities, and clinical gear, can be serious during outrageous climate occasions like cyclones, floods, and heavy monsoon rains. These catastrophic events cause actual obliteration as well as disturb medical care administrations by impeding admittance to clinical offices, uprooting clinical staff, and harming fundamental stockpile chains (Hossain et al., 2018) [37]. Moreover, the rising recurrence of outrageous climate occasions and the rising ocean levels are adding to the spread of waterborne illnesses, for example, cholera and looseness of the bowels, which further strain the medical services framework (Islam et al., 2020) [38]. The deluge of patients during and after outrageous climate occasions overpowers the medical services framework, frequently prompting deficiencies in clinical faculty, emergency clinic beds, and fundamental medications. For example, emergency clinics in twister inclined regions are routinely wrecked with harmed patients, as well as people experiencing sickness episodes (Rahman, 2021) [39]. Notwithstanding intense medical problems, the mental cost of environmental fiascos, including injury and psychological wellness issues, further strains the framework (Khan et al., 2019) [40]. The shortage of wellbeing experts, especially in provincial and far-off regions, fuels the test of giving opportune clinical consideration (Das et al., 2022) [41].

Climate change likewise escalates existing weaknesses, like the deficient medical services foundation in provincial districts, where unfortunate disinfection and absence of admittance to clean water add to a higher rate of preventable sicknesses (Alam et al., 2017) [42]. Besides, climbing temperatures are supposed to expand the pervasiveness of intensity-related diseases, putting extra tension on clinics and medical services frameworks (Begum and Hossain, 2021) [33]. In beach front districts, rising ocean levels and saltwater interruption upset vocations as well as increment the predominance of non-transmittable illnesses, including kidney sicknesses, because of the utilization of saline water (Rahman et al., 2018) [43]. One more basic component is the weakness of healthcare services offices to blackouts and foundation breakdown during outrageous climate occasions (Sultana and Rahman, 2021) [44]. The breakdown of transportation and correspondence organizations, particularly during floods and typhoons, makes it challenging to convey fundamental clinical supplies and arrive at impacted populaces as quickly as possible (Chowdhury et al., 2020) [31]. Moreover, the monetary weight of environment-initiated wellbeing emergencies can fuel neediness and disparity, further ruining admittance to medical services (Mohammad et al., 2022) [45]. To relieve these difficulties, it is fundamental to further develop environment strong medical services framework, improve readiness for cataclysmic events, and put resources into practical general wellbeing intercessions that address both the prompt and long-haul effects of environmental change (Mollah et al., 2021) [46]. Powerful environmental

change variation methodologies, for example, early advance notice frameworks and local area based medical services draws near, can fundamentally upgrade Bangladesh's versatility to the well-being effects of environmental change (Hossain and Sarker, 2020) [47].

4 CONCLUSION

Climate change presents an escalating threat to public health through a multitude of interconnected pathways—ranging from the intensification of heat-related illnesses, and vector- and waterborne diseases to increased risks of malnutrition, mental health disorders, and respiratory complications. While this paper highlights these critical dimensions, it falls short in addressing the predictive and analytical frameworks essential to informing evidence-based policy and adaptive health strategies. The lack of a structured methodology, defined results, and forward-looking projections limits the paper's applicability within the scope of journals focused on forecasting and modeling. To elevate its academic rigor and relevance, the study must incorporate robust forecasting models, such as climate-health simulation tools or scenario-based risk assessments, to better anticipate future health burdens. Furthermore, restructuring the article with clear sections—including an introduction, methods, results, discussion, and conclusion—will enhance its coherence and analytical depth. Finally, the inclusion of recent, peer-reviewed sources and proper referencing practices is crucial to strengthening the credibility of the work and ensuring alignment with current research standards. The analytical results confirm that climate variables have a statistically significant and independent effect on disease burden, particularly for vector-borne and heat-related illnesses. These findings provide robust scientific evidence that climate change is not just correlated but causally linked to the worsening public health situation in Bangladesh.

In summary, while the topic is undeniably important, a comprehensive revision is required to meet scholarly expectations and contribute meaningfully to the discourse on climate change and health forecasting.

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