1. Introduction

Global warming produces various consequences that influence weather systems (1). It also, directly and indirectly, impacts the health of humans (1,2) and other species (3). As the air warms, polar and mountain ice caps and glaciers melt more rapidly (4), negatively impacting fresh water supplies and irrigation water supply resulting in drought and reduced food production (5). As increasing amounts of meltwater enter the oceans, sea level rise is exacerbated (6), threatening millions who live in coastal and low-lying areas. Rising sea levels directly threaten homes and agricultural land through flooding (7), water logging, and indirectly by raising salinity in groundwater aquifers (8). Over time, as glaciers melt and retreat, the reduction in major river flows will result in more common droughts.

The Arctic is warming three times faster than the global average (9). As the Arctic summer sea ice decreases in area, the (north) polar vortex becomes increasingly unstable (10), spilling cold air into the higher latitude jet streams, and disrupting normal weather patterns even to the temperate zones of Europe and North America (11).

As atmospheric temperatures rise, heat stress takes a greater toll on residents of exposed areas, especially crowded urban areas (through the heat island effect) (12), but it also results in changes in cropping patterns (18) and habitats and ranges of insects (13), larger animals, and plants (14).

As oceans warm, suitable habitats for a variety of sea life, especially fish (15), are altered and result in range changes – cold water fish species moving from tropical to more temperate or polar regions (16).

Corals, which while small in area, provide vitally important habitats for many breeding fish species. As temperatures rise, corals expel their symbiotic algae (17). They bleach and die, depriving many fish of that protective environment (18). Global fish stocks are already being negatively affected.

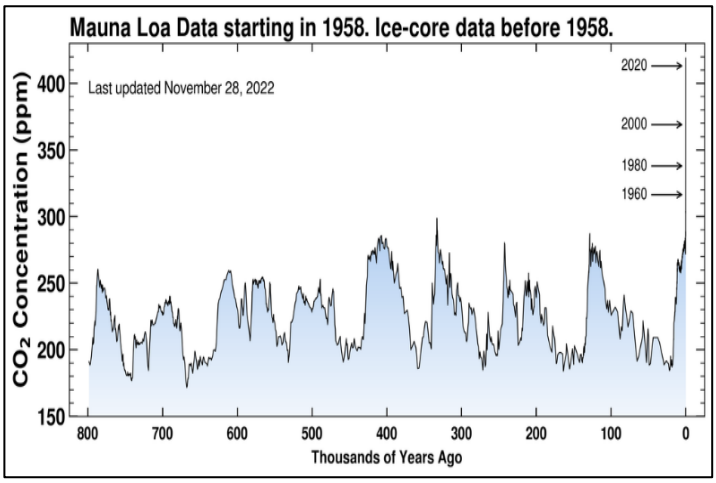
Historically, the oceans have absorbed a large proportion of atmospheric carbon dioxide, but as they warm, that capacity of being a CO_2 sink is declining (19). Due to higher levels of absorbed carbon dioxide (forming carbonic acid), as acidity levels rise, the capacity of shellfish to form protective shells declines, increasing their vulnerability (20).

The link between global warming and the great ocean currents is less clear. The El Nino Southern Oscillation (ENSO) and its sister La Nina (21); Pacific Decadal Oscillation (PDO) (22); North Atlantic Oscillation (NDO), all have effects on weather, though how their operation are affected by global warming is not clear. And the interaction between them is also not properly understood, for example, how does the Indian Ocean Dipole interact with ENSO in the Pacific Ocean (23)?

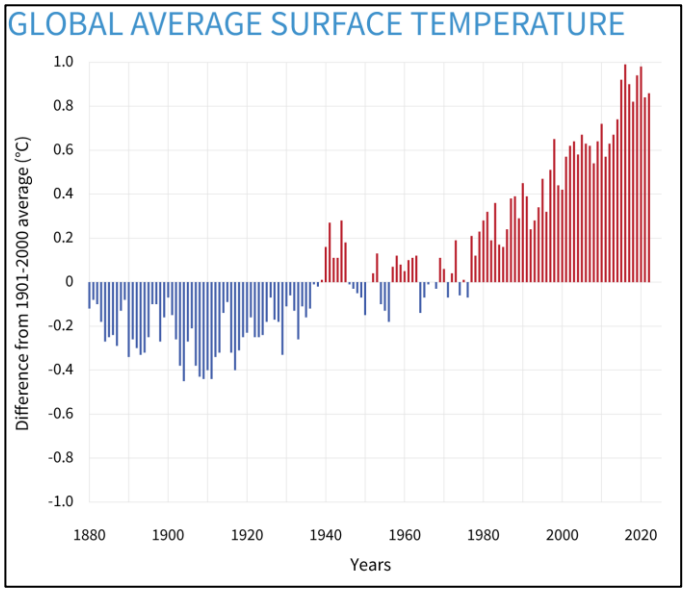
There is growing evidence that the Atlantic Meridional Overturning Current (AMOC) may be negatively affected or switched off as increasing amounts of fresh meltwater enter the salty northern oceans (24). This would be disastrous for northern areas that rely on the Gulf Stream's warming effects.

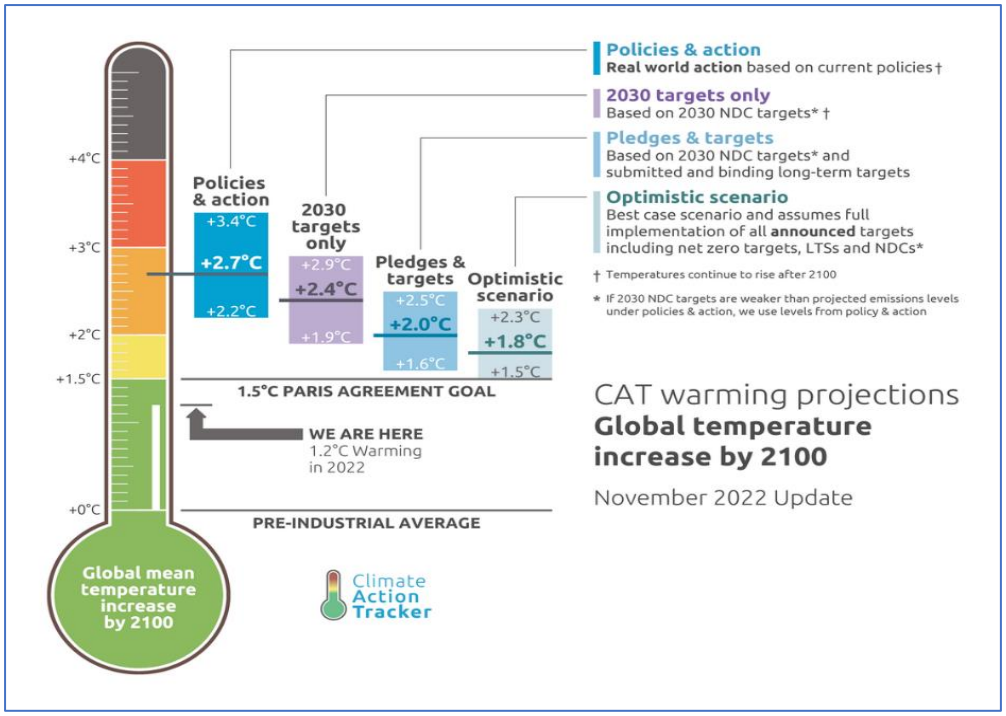
1.1 What is driving global warming?

Climate paleontology has shown that over the past 800,000 years' interglacial periods atmospheric CO_2 levels fluctuated between about 180 and 280 parts per million (ppm) (25). However, since the Industrial Revolution, atmospheric CO_2 has steadily risen to about 420 ppm (419.82 January 27, 2023) (26). This is mainly due to pumping into the atmosphere various greenhouse gasses, carbon dioxide in particular. Much of this has come from burning fossil fuels.



As a result of the warming effect of rising CO_2 levels, global temperatures have risen steadily since the 1970s to the extent that the atmosphere is around 1.0°C hotter than 20th-century levels (27). Some estimates are higher, but NASA's GISS says "at least 1.1°C (28). The COP 21 in Paris 2015 established an agreement that countries would attempt to limit their global emissions to gradually decrease to zero net emissions by mid-century – the Paris Agreement (29). The intention is to limit global temperature rise to 1.5°C and thereafter decline. Current temperature rises projections during the 21st century indicate a probable rise of 2.4°C if 2030 targets are achieved, to 2.7°C if only current policies and actions are carried out, well above the so-called safe limit. However, if all the pledges and targets are fulfilled the temperature will rise to 2°C, well above the Paris Agreement target.





1.2 Carbon Budget

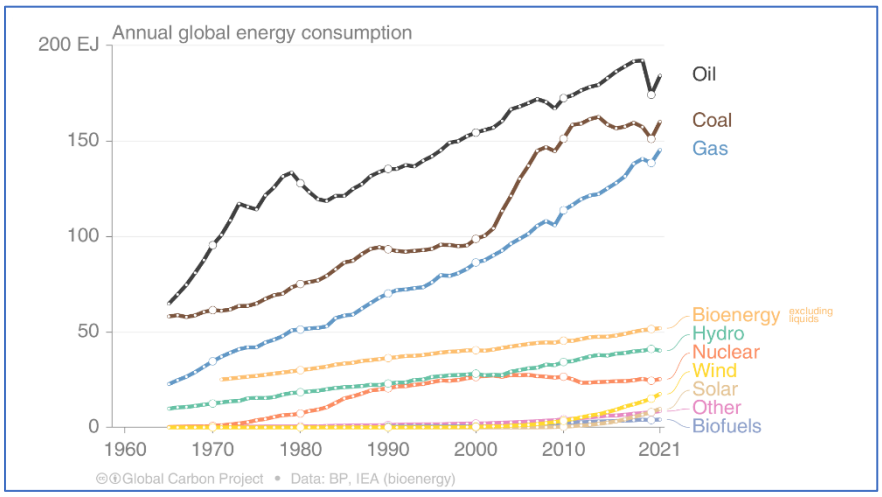
Since the industrial revolution, some 1.5 trillion tons (1,500 Gigatons) have been pumped into the atmosphere. The annual level keeps rising apart from a blip during the Covid pandemic when travel decreased (30). The latest figures by Carbon Brief show about 39.4 Gt emitted in 2021 which, by their new measure of land-use change, is the same as the 2011 level (31). The Global Carbon Project projects a slightly lower level (than Carbon Brief) of 37.5 Gt in 2022 (32). There is a Carbon Budget that would allow a certain amount of GHGs to be emitted over coming years but keep temperature rise to 1.5°C. This budget estimates that emissions could be 380 Gt more – which at current rates is only 9 years of emissions. The permitted amounts of emissions to stabilize at 1.7°C would be 730 Gt, and 2°C would be 1,230 Gt. For comparison, some 2,6120 Gt have been emitted since 1750. There is considerable disagreement over the size of the permitted carbon budget (33).

1.3 Energy Sources

The primary approach to reducing CO_2 emissions is to switching energy supplies from fossil fuels to renewables (34). This is proving challenging and is likely to take more time that the world has to keep temperature rise to 1.5°C, or even 2°C above 20th-century levels.

Progress has been impressive with renewables, but they still account for a small share of total global energy production. Prices of solar panels have declined massively this past decade, and installations have expanded widely in both developed and developing countries. Wind power continues to expand but faces opposition in land-based systems

more than ocean-based systems (35). The primary challenge for acceptance of both solar and wind power generation is the storage of energy for when the sun is not shining (e.g., at night) or the wind is not blowing (36). Nuclear is being promoted as non GHG emitting energy source (37). Still, the old concerns about radiation leaks (e.g., Chernobyl, Three Mile Island, etc.) persist, even with the development of newer mini-reactor designs (defined as less than 300 MWe) (38). The time needed to construct reactors and bring them online is challenging.



While coal use has dropped in many countries, halving in the USA in the past decade, it has almost quadrupled in China, driving global use up by 60% since 2000. The fossil fuel industry is remaining true to character and resisting any limits on oil and gas production from which it profits massively. A recent expose of Exxon Mobil's research from the 1970s into the global warming impacts of continued use of fossil fuels shows how the industry has resisted responsibility for its key product (39). The 'greenwashing' by fossil fuel producers is gaining ground, with the next Climate Change COP28 - taking place in the UAE in late 2023, a major oil producer, and the Chair will be the Chair of the Abu Dhabi National Oil Company (40). How did that get agreed to by UNFCCC (41)? If the 640 lobbyists for the fossil fuel industry at COP 27 in Egypt were not enough, there would likely be even more next time.

2. Impact of global warming and climate change on health

Climate change affects almost all aspects of human life, including health. The impact of climate change on human health and well-being can be manifested through different direct and indirect pathways and mediated through complex biophysical and social dynamics.This section will summarize health impacts of climate change on global to regional scale, and then focus on Bangladesh.

Direct health impacts due to climate change: The direct impacts on health are casuality and injury due floods, cyclones and other extreme weather events. Direct impacts propagate through change in weather and climate, resulted into increased burden of vector borne diseases such as malaria (42), dengue fever (43), kala azar (44), cholera (45), and certain other diseases like chikungunya (46), Nipah (47) and Zika (48) viruses. Also, potential

increases in hypertension due to consumption of saline drinking water in coastal areas is another consequences of global warming and climate change (49).

Heat waves is particularly important and there may be multiple impacts. For example, heat stress may impact pregnant women (50), and outdoor workers in tropical climates (51) will be at particular risk. With climate change and heat waves in urban cities, air pollution could become increasingly dangerous to both the mother and the growing fetus (52).

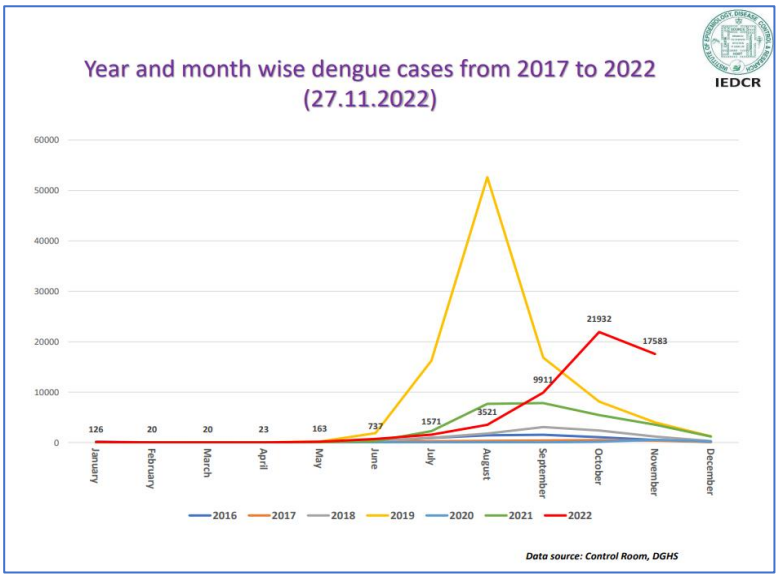
Indirect health impacts due to climate change: Indirect impacts include reduced food security (53) through loss of agricultural land due to floods, water logging, salinity intrusion into soil and groundwater. Also, changing seasonal weather patterns, such as monsoon rains, are affecting cropping patterns (54). Changing habitats and ranges of insects, fungi, and other diseases threaten agriculture. Increased drought can also threaten agriculture, as seen in the Horn of Africa just now (2022) where long years of drought have been compounded by 3 years of La Nina and a negative Indian Ocean Dipole (55). In recent years, drought related wildfires have destroyed huge swathes of agricultural land in many parts of the world (56).

There are likely to be second-level indirect impacts of climate change. For example, there is evidence that in rural areas, especially along the coast, the loss of agricultural land due to floods, waterlogging and salinization, has resulted into families abandoning their properties and migrating to the city in search of employment (57). Land previously used for crop production, has now been converted into shrimp production and this brough little benefit to local communities in terms of food insecurity, livelihood loss and damage to critical ecosystem resoruces.

2.1 How does climate change/ global warming impact human health in Bangladesh?

2.1.1 Malaria is limited geographically to the hilly Chittagong Hill Tracts in the southeast. It is already at maximum elevation in these CHT areas, so it seems unlikely that it can expand habitat as temperatures increase, as both the vector (Anopheles) and the parasite (Plasmodium) prefer a temperature range of 24-28°C. Regarding monitoring impacts of warming on malaria, the National Malaria Program has successfully reduced case and deaths numbers, so there is no natural non-intervened trend to permit such an analysis. No epidemiological data is on the IEDCR website(s).

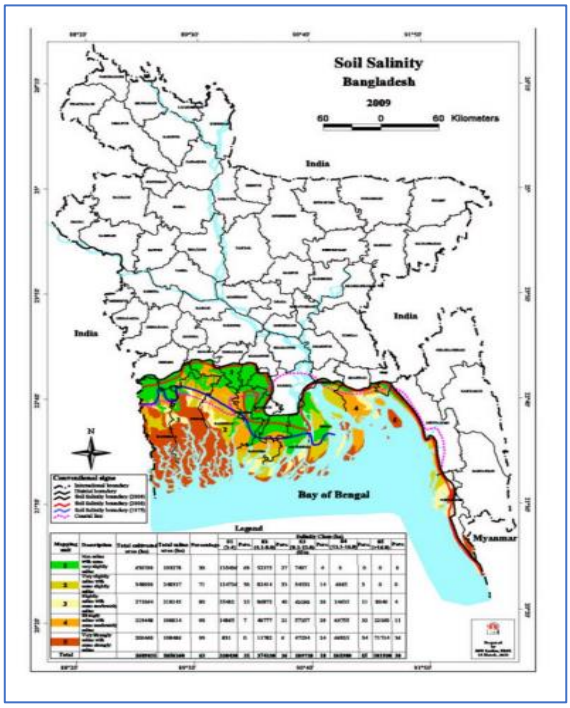
2.1.2 Dengue Fever (DF) is different with a different mosquito vector (Aedes Aegypti) which thrives in urban areas as long as still, clean water is available for breeding. Post monsoon outbreaks have been increasing, in Dhaka in 2019 at least. Cases may also be increasing in rural areas as detection receives more attention. It is not clear what impact changes in monsoon rainfall patterns may have on DF (58).



2.1.3 Kala Azar (KA) has been gradually spreading south over recent decades. It is not clear if this is related to changing climate or to the continuing construction of river embankments which provide an ideal habitat for the KA vector, the sandfly to breed.

2.1.4 Cholera is thankfully rare in Bangladesh, and deaths very rare due to decades of education, provision of tube well water sources, and ready availability of ORS. However, peaks in cases still occur pre- and post-monsoon (59). The relationship between the cholera vibrio and the environment is complex and not entirely understood, but it appears that changing sea surface temperatures linked to phytoplankton blooms and explosions of the copepod vector may be important.

2.1.5 Other VBDs are less well understood, as chikungunya can easily be confused with DF, Nipah virus is very localized in the central north, where date palm juice harvesting is prevalent, and some degree of control is now exercised by ensuring the vector, virus-carrying bats, are prevented from accessing the juice (60).



2.2 Heat stress is not widely recognized as a threat in Bangladesh. This may be because the country's climate is moderated by the Bay of Bengal and the many rivers. It is rare for temperatures to reach 40°C, whereas central and NW India, Pakistan, Afghanistan, and the Middle East regularly experience summer temperatures above 45°C, even 50°C in 2022. However, it can be expected that in the future outdoor works in the agricultural and construction sectors and indoor workers in certain manufacturing sectors such as poorly ventilated mills, will experience the impact of high temperatures. All future population growth in Bangladesh will be in urban areas, half of that due to natural increase and half due to in-migration from rural areas. Many of these migrants will live in slums, initially at least. The housing in these slums tends to be made of tin (galvanized iron sheets) achieves considerably higher temperatures than better-insulated buildings made of brick or cement. There can be no doubt that many cases of heat stress will arise in these living conditions in coming years. The question is, will these heat stress/heat stroke symptoms be recognized and managed appropriately at health facilities?

2.3 Salinity is one of major concerns as sea levels inexorably rise, areas along the 700 kms coast of Bangladesh are experiencing saline intrusion of the groundwater aquifers and soils (61). This is affecting the safety of drinking for the 30+ million inhabitants as well as suitability of irrigation water for crops.

Negative impacts at the individual level are already being suspected on levels of hypertension among consumers of such water. At the household level, agricultural land subject to such saline conditions is unable to produce traditional staple crops like rice and wheat. Although salt-tolerant rice varieties have been developed (BRRI dhan 47, etc.) there is a limit to how much salt they can tolerate (up to 6-8 dS/m), and salt levels exceed that in many places.

3. What are the gaps in information to monitor the impacts of climate change on health in Bangladesh?

3.1 Weather data: The Bangladesh Meteorological Department operates 35 weather stations across Bangladesh. These data are collected daily from 1970, although unsurprisingly, there are many missing values around the time of the Independence War. The variables collected include daily minimum, average and maximum temperatures, humidity, rainfall, wind speed and direction, and cloud cover. There was a lag in obtaining the cleaned data in earlier days, but the situation is improved with online requests possible now (62). Many more weather stations are needed, and there is a plan to expand the number to 200.

3.2 Morbidity / Mortality data for relevant conditions: This is a major gap in the possibility of monitoring the impacts of climate change on health. The epidemiology of the major VBDs are the responsibility of the Institute for Epidemiology and Disease Control Research (IEDCR). They collect and publish data on cases and deaths for malaria, dengue fever, and kala azar and conduct some diarrheal disease surveillance. There is a challenge to obtain up to date data. As their name suggests, they are not responsible for data on non-infectious disease cases and deaths. These are collected by the MoHFW, and published in annual Health Bulletins, but only on a fraction of estimated annual deaths, so biases in reporting of facility deaths cannot easily be corrected.

The Bangladesh Bureau of Statistics (BBS) runs an annual Sample Vital Registration Survey on several hundred thousand households which reports on distribution of deaths by cause, sex and age. The quality of the verbal autopsy data is questionable, especially for NCDs which may be the key causes for detecting the impacts of heat stress.

3.3 Migration: As mentioned, it is believed that many households vulnerable to impacts of climate change have adopted survival strategies, such as sending one or more family members away as labour migrants, either domestically or internationally. International cross-border migration is more easily tracked e.g., the World Bank's Groundswell report suggesting up to 40 million people in South Asia will be forced to migrate by 2050 due to climate impacts (63). Finding data on such numbers by age, sex, place of origin and destination, and reasons for migration is challenging but essential to quantify social impacts. The BBS Sample Vital Statistics Survey (the latest is 2020) is one source, although the hardcopy reports do not provide this level of detail (64).

An additional aspect of these social impacts is the potential security implications for women in the household. Not only is there anecdotal evidence that young female family members may have burdensome tasks of collecting potable water from distant alternative sources, but they may drop out of school to accommodate these additional responsibilities.

There are also reports of young girls being 'encouraged' to marry earlier than usual to reduce the financial burden on the household. Few data are available on these issues.

3.4 Food Security: The Ministry of Agriculture, Department of Agricultural Extension (MOA DAE) is responsible for collating data on crop production at district level. These data tend to appear very positive, even in areas where negative impacts, such as salinity, are believed to be a problem. The BBS publishes crop production data, presumably provided by the MoA DAE.

4. Conclusion

The Paris Agreement was a major achievement of countries concerned about restricting global warming to 1.5°C above pre-industrial levels. Many countries made commitments (NDCs), but a substantial number of these have not and likely will not be met. Even if they were all met, the global average temperature rise will exceed 1.5°C and probably exceed 2°C.

The shift from fossil fuels to renewables as global sources of energy does not appear to be occurring quickly enough to reduce CO_2 emissions to net zero by 2050.

Thus, the health sector must prepare for substantial increases in temperatures in many parts of the world, with more frequent and intense heat waves. The habitats of insects and other vectors of disease will likely expand towards the polar regions. Food security will likely be threatened in many areas by increased flooding caused by more intense cyclones and other extreme weather systems, drought due to the loss of freshwater sources from melting mountain glaciers, as well as sea level rise from both thermal expansion and increasing rapid melting of polar ice sheets and glaciers.

Bangladesh has considerable experience living with annual monsoonal floods but will need to expand this knowledge to new areas. Systems of disease surveillance will need to be strengthened to monitor impacts and assist in developing interventions to prevent or minimize the negative impacts of climate-related diseases. Many sectors will need to be involved in developed heat action plans to protect inhabitants of cities, and some rural areas and occupations, from inevitable rising temperatures. Climate change should be integrated with every developmental action, and health adaptations must be mainstreamed within the national health systems.

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SCAN ME

About the https://cch.icddrb.org website

Monitoring the growing impacts of climate change (CC) on health in Bangladesh requires various data on climate change, health, and population outcome. To bring together relevant data sources and essential links, to provide a more up-to-date climate change and health scenario in the Global and Bangladesh context in a single web-based platform, a resource website “https://cch.icddrb.org” has been developed under the USAID's Research for Decision Makers (RDM) Activity. The website provides essential resources and relevant data sources for health professionals to enhance their understanding of climate change and utilize the knowledge in health research and intervention design, which may minimize the negative impacts of climate change.

The website shows real-time data and interactive graphs on climatic parameters such as hourly, daily, and monthly temperature, humidity, and air pollution (Air Quality Index, PM2.5) through an integrated iQAir device. The website also generates dynamic graphs on the meteorological parameters collected from Bangladesh Meteorological Department (BMD). The website showcases icddr,b works on climate change and health. We believe the resources website should enable researchers, program managers, and policymakers with essential data and discussion to measure and monitor climate change's impact on health and design interventions that may minimize such negative impacts.

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