Impact of Salinity on Infectious Disease Outbreaks: Experiences from the Global Coastal Region

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Definitions

Salinity is described as the mass in grams of the dissolved inorganic matter in 1 kg of water (Stumm and Morgan 1996). It is hence asserted as S‰ – in parts per thousand. Seawater has a notably uniform salinity between 33‰ and 37‰. Salinity is also usually measured using the electrical conductivity of water, or more correctly, its specific conductance. The units generally used are either Siemens.cm^{-1} or mhos.cm^{-1} (Harris 2009).

Infectious disease (or communicable disease) is defined as a sickness caused by a specific infectious agent or its toxic product that appears from the transmission of that agent or its products from an infected person, animal, or reservoir to a susceptive host, either directly or indirectly through an intermediate plant or animal host, vector or inert environment (Last 1988). At the same time, infection is the word that characterizes the entry and development of an infectious agent in a human or animal body, whether or not it develops into a disease (Barreto et al. 2006).

Introduction

Rising of sea levels is scientifically proved and it also affects the extent of saline and brackish water bodies in global coastal areas. Coastal areas are highly threatened by sea level rise and consequently, saltwater intrusion is increasing day by day. Salinity intrusion and increased salinity in water and soil have serious negative impacts on agriculture and food security as well as human health all over the world. It also results in the low-calorie intake and chronic malnutrition of coastal people in underdeveloped and developing countries like Bangladesh. As a result, malnutrition affects human health. Not only malnutrition but also drinking saline water affects human health, which is experienced all over the world in the last decades. Besides malnutrition, deforestation and loss of vegetation due to soil salinity damage both respiratory health as well as mental health of the human being. Thus, this chapter aims to supplement globally cited data and information to the existing literature and scientific information from the coastal belt of Bangladesh which explore the expansion of saline water bodies in coastal

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areas can increase various types of health risks among the coastal people.

Health Impacts of Salinity: Global Perspectives

Water salinity is an attribute of the total concentration of soluble inorganic ions (Cañedo-Argüelles et al. 2013) and is largely attributed to sodium and chloride (Cañedo-Argüelles et al. 2016). Water resources in all the mega-deltas are vulnerable to saline intrusion. More importantly, drinking water in the Ganges–Brahmaputra delta of Bangladesh and the Mekong and Red River deltas of Vietnam are highly vulnerable to saltwater intrusion. Salinity is increased particularly in the dry season and coastal populations are exposed via the drinking water in some river deltas. However, the effects of higher salinity on health are seen in those low-income countries, where water is insufficiently treated or not treated at all. But exposure to high salinity can happen not only through drinking water but also through other indirect routes such as cooking, bathing, and occupation (e.g., shrimp farming in Bangladesh) (Vineis et al. 2011). Many studies have reported a range of health problems due to increased salinity exposure (through drinking, cooking, and bathing) among coastal populations that include hypertension and miscarriage among pregnant women, skin diseases, acute respiratory infection, and diarrheal diseases. In Western Australia, three key potential impacts on human health resulting from dryland salinity (not via drinking water) were identified: wind-borne dust and respiratory health; altered ecology of the mosquito-borne disease Ross River virus; and mental health consequences of salinity-induced environmental degradation (Jardine et al. 2007). These adverse outcomes of salinity on human health are likely to be further exacerbated with the increase in extent and severity of dryland salinity over the relevance of salt intake has been mainly considered in the context of food, while epidemiological studies assessing the health effects resulting from the intake through water have been insufficiently conducted (Khan et al. 2011). The causal link between salt (sodium) consumption and rise in blood pressure (BP) is strongly evident from scientific research (He et al. 2013; Aburto et al. 2013). A prospective study in Massachusetts, USA, looked at two matched cohorts of high-school pupils from towns with a high (272 mg/L) and low (20 mg/L) salt level in public drinking water, and reported that systolic and diastolic blood pressures in the high-sodium region were significantly higher by 3–5 mmHg after controlling dietary salt intake (Tuthill and Calabrese 1981). A study on similar cohorts in Chicago reported that diastolic blood pressure was 2 mmHg higher in the group with 405 mg/L versus 4 mg/L of sodium in the drinking water ($p = 0.040$ for males and $p = 0.016$ for females) (Hallenbeck et al. 1981). An investigation carried out after concerns of apparently elevated rates of hypertension in a population living in Arizona with water salt levels of 440 mg/L showed no association when compared with a reference population (Welty et al. 1986). Epidemiological studies have shown an association between dietary salt intake and high blood pressure with strong evidence (He et al. 2008). Reducing salt intake from 10–12 to 5–6 g/day will have a major effect on blood pressure, thereby preventing cardiovascular mortality (He et al. 2008). Raised blood pressure throughout the range seen in developed countries is the major cause of cardiovascular disease, responsible for 62% of strokes and 49% of coronary heart disease (He et al. 2008). Moreover, due to unavailability of safe freshwater or unpleasant tastes due to higher salinity, people may use contaminated water for drinking, which can also lead to diarrhea and water-borne diseases such as cholera (Abedin et al. 2012; Hunter et al. 2010). Additionally, the densities of salinity-tolerant mosquitoes can increase by saltwater intrusion and expansion of brackish water bodies in coastal zones. The recent findings suggest that malaria and dengue mosquito vectors possess the capacity to tolerate salinity variations and undergo preimaginal development in brackish waters (Ramasamy and Surendran 2012). Therefore, *Anopheles sundaicus*, the vector of malarial parasites, and *Culex sitiens*, the vector of Japanese encephalitis virus and Ross River virus, can grow as brackish and saline water bodies expand due to sea level rise.

Health Impacts of Salinity: South and Southeast Asia Perspectives

Climate change, both background climate conditions and transformations in regional climatic variability, will affect the potential (spatial and seasonal) transmission of various vector-borne infectious diseases worldwide (McMichael 2006). Nowadays, infectious diseases are major public health problems in Asia. Earlier faith in the 1960s and 1970s that almost all severe infections would be managed was proven wrong (Morens et al. 2004; Sleigh et al. 2006). Numerous old diseases have endured and some lethal latest human epidemics like SARS, avian influenza and Nipah virus have appeared (from animal populations) in Asia in the last decade (Sleigh et al. 2006). Countries in South and Southeast Asia with extensive coastlines and high coast-to-land area ratios (Table 1) are particularly vulnerable to the consequences of increasing salinity intrusion due to rising sea levels and associated impact on their biosphere and geosphere (Ramasamy et al. 2015).

Sea-level rise is a chief cause of concern not only for coastal urban areas (e.g., Chennai, Cochin, Karachi, Kolkata, and Mumbai) but also for the fertile delta systems, which are threatened by both flood and salinity incursion (e.g., in Bangladesh and the river deltas of the Cauvery, Indus, Krishna, and Narmada). Seawater intrusion in low-lying agrarian meadows and water reserves could lead to localized food insecurity, the spread of water-related diseases, and the pollution of freshwater reserves (World Bank 2009). Mosquito vectors transmit many important human parasitic and arboviral diseases in tropical South and Southeast Asia. The World Health Organization (WHO) reported that there were roughly 130.6 million suspected cases of malaria caused by protozoan parasites of the genus Plasmodium, predominantly *P. falciparum* and *P. vivax*, in the Southeast Asian region in 2012 (Ramasamy et al. 2015). This caused an estimated 1226 deaths. The WHO Southeast Asian region includes countries with extensive coastal zones such as Bangladesh, India, Indonesia, Maldives, Myanmar, Sri Lanka, Thailand, and Timor-Leste. In the Western Pacific region, which comprises many coastal countries regarded as part of Southeast Asia (Brunei, Cambodia, Malaysia, Papua New Guinea, the Philippines, Singapore, and Vietnam), the WHO reported 10.8 million suspected cases and an estimated 458 malaria deaths in 2012 (Ramasamy et al. 2015). The malaria situation in the greater South and Southeast Asian region is extremely dynamic due to the increasing resistance of parasites to common antimalarial drugs and mosquito vectors to common insecticides, and due to the frequent mobility of human populations, and changes in land use practices, wood cover, health inspection, and repairs and other pertinent factors. Various species of Anopheles mosquitoes are responsible for transmitting malaria in the area with some identified as dominant vectors (Sinka et al. 2011). Some mosquito vectors in the area are easily known to lay eggs and undergo preimaginal

Impact of Salinity on Infectious Disease Outbreaks: Experiences from the Global Coastal Region, Table 1 Coastline connected to land area in certain South and Southeast Asian countries and Micronesia. (Source: Adapted from Ramasamy et al. 2015)

Country/Statistic	Land area (In Km^2)	Coastline (in Km)	Coast/area ratio (m/Km^2)
Bangladesh	130,168	580	4.5
India	2,973,193	7000	2
Sri Lanka	64,630	1340	20.7
Malaysia	328,657	4675	14.2
Indonesia	1,811,569	54,716	30.2
Philippines	298,170	36,289	121.7
Micronesia (Western Pacific)	702	6112	8710

development in brackish water. Nevertheless, a number of other important vectors, e.g., *Anopheles culicifacies* (malaria) and *Aedes aegypti* and *Aedes albopictus* (dengue and Chikungunya), have previously been widely identified only in fresh water. But recent evidence indicates that these species can also lay eggs and undergo preimaginal development in brackish water collections in coastal regions (Ramasamy et al. 2015). A summary of the potential vector mosquitoes, which have salinity-tolerant preimaginal stages, in South and Southeast Asia is given in Table 2.

Moreover, several mosquito vector species that have traditionally been considered as developing only in freshwater habitats are at present recognized to be able to undergo preimaginal development in brackish water in the Peri-urban and urban environments (Table 3).

Rising sea levels, along with climate change, can therefore interact in a complex approach with other environmental and socioeconomic factors near coasts to bring forth a greater potential for the transmission of malaria, dengue, and other mosquito-borne diseases. More than half the world's population lives within 60 km of the shoreline, and population densities in coastal regions will increase markedly in disease-endemic countries of the region (McGranahan et al. 2007; Ramasamy et al. 2015). Rising numbers of people will therefore be at peril of acquiring infections from increasing vector populations in coastal regions. Greater host density, and in turn increasing vector–host contact, will also lead to an increase in disease transmission rates (Ramasamy et al. 2015).

Impact of Salinity on Infectious Disease Outbreaks: Experiences from the Global Coastal Region, Table 2 Current salinity-tolerant mosquito vectors of human disease in South and Southeast Asia. (Source: Adapted from Ramasamy et al. 2015)

Species	Spreading area	Transmitted pathogens
Aedes togoi	Southeast Asia	Japanese encephalitis virus and filarial parasites
Ae. (Ochlerotatus) vigilax	Australasia, Southeast Asia	Barmah forest and Ross River viruses and filarial parasites
Anopheles farauti and An. annulipes	Australasia, Southeast Asia	Malaria parasites
An. subpictus	South and Southeast Asia	Malaria and filarial parasites
An. sundaicus	South and Southeast Asia	Malaria parasites
Culex sitiens	South and Southeast Asia, Australasia	Japanese encephalitis and Ross River viruses and filarial parasites
Cx. tritaeniorhynchus	South Asia	Japanese encephalitis virus

Impact of Salinity on Infectious Disease Outbreaks: Experiences from the Global Coastal Region, Table 3 Representatives of freshwater mosquito vectors of human disease that are able to undergo preimaginal development in brackish water. (Source: Adapted from Ramasamy et al. 2015)

Species	Place	Maximum salinity tolerance (ppt)	Reference
Aedes aegypti	Brunei Darussalam	10	Ramasamy and Surendran (2013)
	Sri Lanka	15	Ramasamy et al. (2011, 2014), Surendran et al. (2012)
Aedes albopictus	Brunei Darussalam,	8	Idris et al. (2013)
	Sri Lanka	14	Ramasamy et al. (2011)
Anopheles culicifacies	India	7	Gunasekaran et al. (2005)
	Sri Lanka	4	Jude et al. (2010)
Anopheles stephensi	India	17	Gunasekaran et al. (2005)

Health Impacts of Salinity: Bangladesh Perspectives

It is estimated that globally around 884 million people do not have access to clean drinking water. Increasing salinity of natural drinking water sources has been reported as one of the many problems, which is intensified by rising sea-levels, owing to climate change, and other contributing factors, like changes in fresh water flow from rivers and increased shrimp farming along different coastal regions. It is also stated that climate change will have severe impacts on water security in developing countries, which will adversely affect human health in various ways (IPCC 2007, 2009).

High-Salinity Areas of Bangladesh

The highest salt-encroached areas during the monsoon season are: (i) Khulna, Satkhira, Bagerhat, Jessore, and Gopalganj – districts situated in the southwestern zones; (ii) Bhola, Noakhali, and Feni – districts located in the lower Meghna River floodplain and the Meghna estuarine floodplain; (iii) Chittagong and Cox's Bazar – districts positioned in the southeastern portion of the Chittagong coastal plains adjacent to the Bay of Bengal; and (iv) Barisal, Jhalkathi, Patuakhali, and Barguna – the slightly saline diverged mid-south zone districts. All these districts are affected during the dry season too (Shammi et al. 2017). From a report, it was found that, since 1948, river salinity in the southern districts of Patuakhali, Pirojpur, Barguna, Bagerhat, Khulna, and Satkhira, has risen by 45% (Alam et al. 2017). The report clearly shows that the salinity intrusion already increased and it is likely to increase more in future because of shifted river flows, increased upstream withdrawal of freshwater, and due to the reduced rainfall during the dry season driven by climate change as well as sea-level rise (Abedin et al. 2014).

The Driving Force Behind Salinity Increase in Bangladesh Coasts

In Bangladesh, along the 720-km coastline, the saline front has encroached more than 100 km inland into ponds, groundwater systems, and agro-ecological lands through various estuaries and water inlets, which are connected and interlinked with the major rivers and river systems (Allison et al. 2003; Rahman and Bhattacharya 2006). The seasonal variation acts as the driving force behind the levels of water salinity (Rahman and Ravenscroft 2003) due to rainfall patterns and upstream withdrawal of freshwater especially in the dry season (with the operation of the Farakka Barrage, which the Indian government uses to regulate flow on the Ganges). The more the impact of marine water toward the terrestrial lands, the less the opportunity for freshwater to enter into the sea, thereby resulting in a brackish water emergence (Loitzenbauer and Mendes 2012). However, the groundwater in southern and southwestern zones of Bangladesh had NaCl abundancy coming from brackish waters (Halim et al. 2010), because of the inductive influence of seawater and hydrogeochemical processes that Bengal delta possesses on its groundwater aquifer (Bahar and Reza 2010). This ended up with a combination of total dissolved solids (TDS) and the electrical conductivity (EC), and that is how the availability of the key anions and cations in the surface water was confirmed with the subsequent order of $Na^+ > Ca^{2+} > K^+ > Mg^{2+}$ and $Cl^- > SO_4^{2-} > HCO_3^- > NO_3^- > CO_3^{2-}$- (Shammi et al. 2016). Besides, anthropogenic activities like upstream freshwater removal and biophysical factors (e.g., cyclones that originate outside the topographical frontier of coastal Bangladesh) contribute to the cumulative increase in salinity in that region (Shameem et al. 2014).

Along with salinity, the cumulative effects of saltwater intrusion, arsenic contamination, and drought pose numerous threats to the water quality and security, as well as the health of coastal communities in Bangladesh. Intergovernmental Panel on Climate Change (IPCC) (2007) depicts that the vulnerability of coastal regions to flooding, storm surges, and salinity will further increase in this century. Therefore, climate change poses a serious threat to the livelihoods of the poor in the south and southwest coastal region, where they have limited mobility due to their economic conditions, disadvantages with land access, and severe dependency on local ecosystems for their livelihood.

The coastal inhabitants of Bangladesh heavily depend on rivers, domestic ponds, and tube wells (groundwater), for washing, bathing, and drinking water. Domestic ponds comprising 10% of the total land area (excluding rice paddies) are filled primarily by rainfall, but have the proximity to mix with saline water from coastal tidal rivers, surface runoff, and shallow groundwater (Rahman and Ravenscroft 2003).

Spatiotemporal Salinity Pattern of Coastal Districts

The risk of salinity was investigated in Gopalganj Sadar Upazila, one of the southern coastal districts of Bangladesh, in Barguna and Patuakhali Districts of Southern Bangladesh and in Chittagong district of southwestern Bangladesh. In Gopalgonj, hydrochemical analysis was performed for the surface water (ponds and river) and the groundwater samples, from shallow tube wells (STW) and deep tube wells (DTW) (Shammi et al. 2016; Loitzenbauer and Mendes 2012). The groundwater in this area was neutral to slightly alkaline and dominating cations were Na^+, Mg^{2+}, and Ca^{2+}, along with major anions Cl^- and HCO_3^-. The influence of salinity from the sea was confirmed for the spatial distribution of irrigation water quality index (IWQI), electrical conductivity (EC), soluble sodium percentage (SSP), and total hardness (TH) during both seasons. The driving factor of overall groundwater quality in the study area was the existing low-flow in the major river system (Shammi et al. 2016; Rahman et al. 2018). However, drinking water sodium (DWS) intake has exceeded in many parts of coastal Bangladesh due to salinity intrusion, climate change, storm surges, etc., in the soil and in the existing water resources. For example, the average values of total dissolved solids (TDS), electrical conductivity (EC), and chloride concentration (Cl^-) were found to be 4044.12 mg/L, 7186.7 mS/cm, and 3143.6 mg/L, respectively in Shyamnagar, and 2313.60 mg/L, 4390.3 mS/cm, and 1402.1 mg/L, respectively in Tala Upazila of Satkhira district, one of the severely affected areas of salinity in southwestern Bangladesh (Shammi et al. 2016).

In Barguna and Patuakhali, the groundwater was clearly dominated by the cations and anions of Na^+, Mg^{2+}, Ca^{2+}, Cl^-, and HCO_3^- in both wet and dry seasons (Islam et al. 2017a). According to WHO (2011), the maximum acceptable sodium intake is 200 mg/L, but the Na^+ concentrations in the groundwater were 863 mg/L and 825 mg/L in the premonsoon and postmonsoon seasons, respectively (Islam et al. 2017b). In another study of Chittagong district, involving 18 groundwater samples from the tube wells and 2 pond water samples, the average salinity of the shallow tube wells ranged from 5.11 to 6.48 dS/m, while the pond water salinity ranged from 0.11 to 3.12 dS/m. These tube wells' depths varied from 244 to 365 m and the tests indicated that 75% of the groundwater samples were comprised of Na^+. In addition, (Jabed et al. 2018). It is, therefore, clear from these studies that the salinity of surface water and groundwater in the coastal districts varied significantly within the shallow and deep tube wells as well as varies with respect to the depth of the wells and the distance from the Bay of Bengal (Jabed et al. 2018).

Salinity: A Threat to Human Health

Besides drinking water, diet, bathing, and occupation (e.g., shrimp farming in Bangladesh) are other routes of exposure to high salinity, which also have potential impacts on health. Considering coastal populations' health, Government of Bangladesh (GoB) and Caritas Development Institute (CDI) reported a range of health problems, which are linked to increased salinity exposure through drinking, cooking, and bathing. The problems include hypertension and miscarriage among pregnant women, menstrual hygiene problem, skin diseases, acute respiratory infection, and different diarrheal diseases (Brammer 2014; Kristensen 2004; Lewison et al. 2016).

Strong evidence of the association between dietary salt intake and high blood pressure was found when epidemiological studies were conducted (Naser et al. 2017; Baten and Titumir 2016). Reducing salt intake from 10–12 g/day to nearly a half will have a major impact on preventing cardiovascular mortality rate mainly by reducing blood pressure as raised blood pressure in developed countries is seen as the prime reason for cardiovascular diseases, which is responsible for 62% of strokes and 49% of coronary heart disease (Baten and Titumir 2016).

Problems like hypertension or high blood pressure are a common phenomenon in coastal areas due to high salinity in drinking water. More than 20 million people in Bangladesh are at high risk of hypertension due to saline water intrusion triggered by climate change (MoEF 2006). Women, especially during pregnancy, are prone to the increased risk of preeclampsia, eclampsia, hypertension, as well as infant mortality due to drinking water sodium (DWS). Therefore, interventions like rainwater harvesting, pond sand filter (PSF) system, managed aquifer recharge (MAR), pilot-scale solar-powered desalination plants (e.g., reverse osmosis (RO)), were considered in perspective of their efficiency in controlling DWS. Consumption of rainwater, on the one hand, can possess negative impacts from not having vital minerals, and on the other hand, it has progressive impacts of low or no sodium intake (Shamsuzzoha et al. 2018; Shammi et al. 2016).

Due to increased dietary sodium ingestion, in Bangladesh, about 20% of adults and 50–65% of elderly people suffer from hypertension (Scheelbeek et al. 2017; Islam and Majumder 2012). Increased Na^+ consumption, DWS in particular, has immunological effects on skin tissue, intestinal microbiota, and other organs, as well as cardiovascular disease, inflammation, infection, and autoimmunity (Müller et al. 2019). According to the World Health Organization (WHO) and the Food and Agriculture Organization (FAO), the recommended nutritional sodium ingestion limit is 2 g/day (<85 mmol/day) (Nishida et al. 2004).

Impacts of Salinity on Maternal Health

High blood pressure is among the lead causes of maternal death in developing countries, according to the World Health Organization. Heavy salt intake increases the risk of coronary heart disease, which is the single most important risk factor for stroke. Drinking water sodium can have serious health impacts, particularly for pregnant women. In a study, it was found that when people were exposed to slightly saline (1000–2000 mg/L) to moderately saline (≥2000 mg/L) drinking water, they had a chance of being hypertensive, i.e., respectively 17% ($p < 0.1$) and 42% ($p < 0.05$) higher than those who consumed freshwater (<1000 mg/L). Even females had a 31% higher chance to be hypertensive than their male counterparts. In fact, people above the age of 35 years have 2.4 times higher risk of hypertension compared to the people under the age of 35 years (Khan et al. 2011).

In a study in southwestern coastal regions of Bangladesh, tests were conducted based on water sources and water consumption types (shallow tube well, groundwater, rainwater consumption), daily urinary sodium concentration of the pregnant women, seasonal variations (dry or wet), hospital incidence due to eclampsia or (pre)eclampsia, etc. It has to be mentioned that (pre)eclampsia, eclampsia, and gestational hypertension occur only during pregnancy and are categorized by one or more convulsions and high blood pressure, and eclampsia is the complicated form of (pre) eclampsia. The average daily sodium concentration in the urine of pregnant women was found to be 3.4 g/day (range 0.4–7.7 g/day) (Khan et al. 2011). On the other hand, women who relied on shallow tube wells were more likely to have urine sodium concentration of >100 mmol/day compared to the women consuming rainwater. The yearly hospital incidence of hypertension amid the pregnancy period was around 7% greater within the dry season than that within the wet season (Khan et al. 2011). The women dependent on the tube wells or groundwater were more susceptible to disease risk than the rainwater consumers (Khan et al. 2014).

Salinity and Menstruation

Due to salinity, there is a record that, especially in southernmost coasts, the women and adolescents wash their menstrual clothing with saline water (as they don't have sufficient access to free water as well as do not have sufficient money to purchase sanitary pads or sometimes pads are not available where they live). This repeated saline water washing of menstrual clothing and use of those clothes frequently puts them under the threat of different kinds of hygiene issues. These sometimes lead to skin diseases and other sexual problems (Tanya 2019).

Indirect Health Impacts

The direct impact of salinity both on soil microbial community as well as on crops can have a serious impact on crop production, amount of yield, and cropping pattern (Yan et al. 2015). This change will have a huge impact on human consumption of crops, which ultimately affects human health. On the other hand, increasing salinity in freshwater systems will definitely have impacts on aquatic organisms and fish communities. Slight changes in water pH will have a huge impact on the fish community, which will ultimately impact human dietary status and that will affect the nutrition intake of people as well (Dasgupta et al. 2017).

Conclusion

This piece of scientific evidence found a significant association between water salinity and human health burden along the coastal belt globally. These findings show that several health disturbances including mental, physical and reproductive health are highly prevalent. With the predicted increase in salinity in the coastal areas, it is more imperative to promote alternative drinking water sources with mass-level awareness creation and community sensitization against the bad practice of high table salt consumption. The evidence also suggests to develop health strategic plans for the coastal belt to align with salinity intrusion in terms of water and soil water. Hence, an integrated study with a larger population is required to fully understand the present situation and recommend future solutions to ensure the availability of sweet surface and groundwater-based drinking water sources. The people living in the coastal areas are at the forefront of climate change. This evidence shows critical findings in relation to health and climate change that is likely to worsen in predicted future scenarios. Thus, for future water resources management and public health provisioning, well-planned adaptation and mitigation research need to be conducted for managing critical ecosystem services in line with resilient development trajectory.

Cross-References

▶ Climate Change and Health
▶ Climate Change Refugees and Health Implications
▶ Health and Wellbeing of Climate Migrants in Slum Areas of Dhaka
▶ Migration and Health
▶ Neglected Tropical Diseases

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