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Review Article

Behavioral, infrastructural and climate change Factors for Rising Diarrhea Episodes in Bangladesh

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More than 4.5 million people nationwide have experienced diarrhea in the country's most recent outbreak, which began on March, 2022. About 70% to 80% of patients (of whom 23% had severe diarrhea or cholera) were hospitalized. Several factors were associated with the risk for diarrhea include; unhygienic and unsafe environment, age, low educational status of mothers, employment status, family size, income, poor handling of drinking water at household level, place of residence, unhygienic disposal method of feces and wastes, lack of personal hygiene and lack of access to sanitation facilities. In addition, etiology, influence of climate and geographical location, diagnosis capability, hygiene education, and infrastructure are strongly linked to the high frequency of diarrhea and play a crucial role in efficiently managing diarrhea. We observed that a significant proportion of people with diarrheal illnesses continue to seek care from unqualified healthcare practitioners since inaccessibility from professional healthcare providers. Dissemination of information on health education, increasing the supply of skilled healthcare providers, and low-cost and quality healthcare services may encourage more people to seek care from professional healthcare providers, thus may help reducing mortality in the country. In conclusion, the policy mechanisms to increase systems' resilience, some engineering approaches include source, treatment, distribution, and point-of-use control measures could be implemented to manage microorganism proliferation in drinking water.

Keywords: Behavioral and infrastructure factors, Climate change, diagnosis capability, Diarrhea episodes and Bangladesh.

Introduction:

Diarrhea is an alteration in regular bowel movement characterized by increased water content, volume, or frequency of stools[1]. Diarrheal diseases are a global public health problem and a leading cause of morbidity and mortality worldwide. According to the latest Global Burden of Disease Study, about 2.39 billion diarrheal cases occurred globally, and approximately 0.53 million under-five children died yearly[2, 3] . Specifically, incidence and case-fatality ratios are much higher in lower and middle-income (LMI) countries[4]. In developing countries, diarrhea-related morbidity and mortality are directly linked to limited access to potable water and proper sanitation[5]. Several studies observed that epidemics of diarrheal disease are associated with episodes of flooding[6], socio-economic status[7], urban status[8], high population density, low education level, and the proximity of household clusters to contaminated surface water[9, 10, 11]. The diseases are also susceptible to the climate, showing seasonal variations in numerous sites[12]. Relative humidity and temperature influence the rate of replication of different pathogens, such as bacteria and protozoa, and the survival of enteroviruses in the environment, which is another cause of diarrheal diseases[13]. If the disease lasts "more than 7 days" and "at least 14 days" the term "prolonged" and "persistent" diarrhea is used respectively[14, 15].

Though diarrhea is preventable and managed with low-cost interventions, it is still the top cause of morbidity for patients seeking care from the Bangladesh public hospital system[16], and significant resources are expended in treating these patients. Diarrheal diseases affect people of all ages irrespective of their socio-economic status and are particularly prevalent among poor people. A significant cause for concern in Bangladesh is that approximately 26% of the people are below the poverty line. Sometimes, the episode can be managed at home and does not require hospital treatment. However, considering the direct and indirect costs of households, it represents a substantial economic burden for the affected households[17].

Most diarrhea episodes are caused by infection of the human intestine with enteric pathogens such as bacteria, viruses, and parasites[18, 19, 20]. Transmission is mainly via the fecal–oral route, and water and food are the primary vehicles for transmission, which is facilitated by inadequate knowledge, poor hygiene practices, and sanitary conditions[21, 18]. Individuals with altered immune status, such as neonates and infants, the severely malnourished, and the elderly, are often at higher risk of diarrhea[22, 23]. In developing countries, infections due to *Vibrio cholerae*, enterotoxigenic *Escherichia coli* (ETEC), rotavirus, and *Shigella* are common[22, 24]. Cholera outbreaks are commonly recorded in Bangladesh; however,

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cases are frequently found in decaying facilities[25]. Shigellosis has a worldwide distribution but predominates mainly in developing countries[26]. A study in Bangladesh reported bacterial pathogens such as *V. Cholerae,* ETEC, and *Shigella* as the most important causes of adult diarrheal illnesses[22].

There is a lack of information on the distribution of most common enteric pathogens, clinical features, and disease severity in adult populations. There is also limited information on the distribution of diarrheal pathogens in adults, which may differ between urban and rural adult populations[22, 18]. On the other hand, rotavirus is the most important aetiological agent of diarrhea in infants and young children worldwide[18, 27], although this pathogen may also cause dehydrating diarrhea in adults[27].

Impact of Etiology

Consistency, frequency, and amount of waste excretions are three characteristics that define diarrhea as a symptom of many different medical conditions. The frequency and volume of excretions can vary throughout a wide range, from highly mild diarrhea to severe enough to jeopardize the patient's life. A healthy adult excretes about 300 ml of waste. The pathogenic mechanism of diarrhea is what causes intestinal transit to speed up. The World Health Organization (WHO) defines diarrhea as "the passage of three or more loose or liquid stools per day, or more frequently than is typical for the individual. From the epidemiological point of view, the cases can be sporadic or epidemic, and identifying the infection source and transmission mechanism is vital for prevention and control. The causative agent somehow enters the vulnerable person's mouth from some source in their environment, and the hands play a fundamental role in many situations. Diarrhea is the outcome of the body's defensive mechanisms conflicting with aggressive external factors (such as the toxicity or virulence of the causal agent or the dose of the inoculant). Among the defense mechanisms combating infectious agents, the following can be highlighted: gastric acid, gastrointestinal mucus, intestinal motility, bile salts, common intestinal bacteria, macrophage cells, lymphocyte cells, and type IgA immunoglobulin in the mucus.

Additionally, genetic factors can influence a person's resistance to a given infection. For instance, people with blood type O are more likely to contract cholera, whereas people with so-called nonsecretory traits with specific FUT 2 gene mutations are only partially susceptible to norovirus infection. Other external circumstances, such as the ingestion of alcohol or (nonvolatile) red wine, could act as protective factors against infection by *Salmonella* when the ingestion of the microorganism and that kind of drink are almost simultaneous. Occasionally, diarrhea presents itself as an accompanying symptom of chronic conditions, such as the collateral effect of some medicines or a sign of malnutrition.

Impact of geography

The distribution of cases of diarrhea vary geographically and according to age. Regardless of whether the countries are industrialized or not, slightly different trends have been seen in terms of the origin and severity of the instances. Examples of such diseases that the WHO continues to pursue internationally include cholera and certain parasites, both of which are still prevalent in some impoverished areas where they can thrive. In many underdeveloped nations, poor sanitation, nutrition, and personal hygiene conditions contribute to the prevalence of diarrhea. Regarding some viruses, the indicators of their lethality are noticeably different even when the incidence of infection does not show such pronounced geographic differences. For instance, the rotavirus is very common in all countries, but its severity (mortality rate) is more significant in developing countries. The most frequent causes of diarrhea in developed countries are *Campylobacter, rotavirus, norovirus, Salmonella, Giardia, and Cryptosporidium*. Since methods for virologically diagnosing gastroenteritis are now available, it has become clear that viruses are one of the most common causes of diarrhea in Western nations. In most cases, they do not result in severe illnesses for the individual although place a heavy social burden.

The age of the patients, illness severity and the capacity of the laboratories all affect the etiological diagnosis. Age bias, and technical proficiency should all be considered when analyzing epidemiological statistics. The likelihood of fecal analyses and the cause of diarrhea is related to age. When given a similar clinical profile, a kid is likelier than an adult to be diagnosed with an etiological diagnosis. Major and minor illnesses differ in similar ways. Mild diarrhea frequently has no identified etiology.

Impact of diagnosis

Ailments brought on by substances that the laboratory participating in the analysis cannot identify are treated similarly. Wet mount, coculture, antigen detection, toxin detection, or other fecal studies are typically used to determine the etiological diagnosis of acute infectious (or toxic) diarrhea. Specialized labs have access to more sophisticated procedures, which are generally more precise and sensitive but are also more expensive and challenging to employ. But many of the cocultures' based laboratory tests and requests come back with negative results. The following conditions can lead to a negative result: 1) the patient may have taken antibiotics; 2) diarrhea may not be infectious; 3) diarrhea may be brought on by an agent for which the laboratory has no information; 4) the test's sensitivity has failed, or 5) there may have been issues with fecal transport.

Further inquiry is unnecessary because the etiologies of cases with negative results vary. No risk variables were discovered in the EDICS study (Study of Infectious Diarrhea in Castellón) of risk factors in infantile diarrhea cases with a negative fecal analytical result. Vomit showing up as the first symptom, the absence of fecal blood (macro-or microscopic), and low PCR (reactive C protein) are indicators of viral etiology, particularly in youngsters. On the other hand, risk variables were discovered in instances of rotavirus, salmonellosis, and campylobacteriosis. This shows that the opposing group is made up primarily of

individuals who share few risk factors but have various etiological conditions.

Impact of Epidemiological Characteristics

Two questions come to mind when faced with an epidemiological instance of diarrhea: first, if the etiology is already known; and second, if other cases are connected to the original. Table 1 depicts these two components, each cell denoting a different epidemic concern.

Following an outline inspired by the epidemic cases of Table 1, three situations can be distinguished according to the characteristics of the affected population. First, a defined, open population with a specific exposure refers to people who only momentarily share an exposure factor, for example, attending a shared dinner or banquet. Second, a defined, closed population with lasting exposure factors, for example, permanent residents within a closed institution, who continually share meals, places, and activities, and third, an indefinite population, with or without specific exposure, occurs when there is no apparent relationship between people and they are implicated in an outbreak solely by sharing an exposure factor distributed throughout the population.

In the case of laboratory analysis, an epidemic is identified where some rare microorganism in vast numbers of people is detected in a reasonably prolonged time frame. The epidemiology of the agent implicated is often recognized when the etiology is well understood. For example, an outbreak of acute diarrheal disease was seen at a rural Bangladesh hospital in 1975, and *V. cholerae* 01 was isolated from 28% of 1,964 patients. The epidemic was related to the consumption of contaminated water. Depending on how widespread or relevant an outbreak is, there are observable differences in how diarrhea cases are approached when conducting an epidemiological investigation. Figure 1 shows a detailed theoretical diagram for the ARMIGO system's investigation of cases of transmissible diseases (agent, reservoir, mechanism of transmission, individual, group, and other people).

Table 1

The epidemiologic first approach to a case of diarrhea[28]

			Etiology	
			Known	Unknown
Aggregation	Sporadic	Usual	A	B[a]
		Unusual in the area	C	D[a]
	Epidemic	Small cluster	E	F
		Outbreak cohort defined[b]	G	H
		Epidemic cohort undefined	I	J

[a]Defined by clinical symptoms, i.e., clinical diarrhea and fecal specimens of usual or unusual characteristics.
[b]Open cohort in an 'open' setting (i.e., banquet) or in a 'closed' setting (i.e., nursing home).

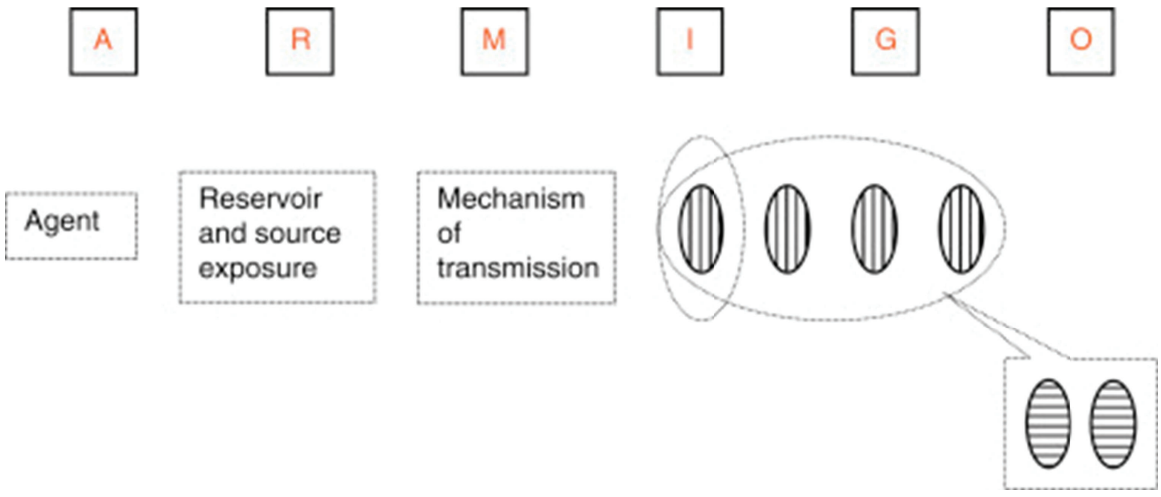

Fig. 1. *A schematic theoretical diagram of a communicable transmissible disease, for example, diarrhea, obtained by using ARMIGO system. Agent: bacterial, viral, other (biotoxin, chemical); reservoir and exposure source: animal, soil, surfaces, water, food, ill person, carriers; mechanism of transmission: food, water, hands, aerosol, or dust swallowed via mouth; individual at risk: age, earlier health status, genetic susceptibility; group at risk: the same opportunity to exposure; other related people: contact with the primary ill or asymptomatic person*[28].

Impact of Socio-demographic factors

Diarrhea is usually spread through drinking or eating contaminated water and food from one person to another due to poor hygiene[29]. In Bangladesh, diarrhea tops the list of water-borne infections due to poor sanitation. The incidences of diarrhea are more rampant within the first two years of life and decline as the child progresses in age[30]. Studies have documented that diarrhea is medically related and associated with economic, social, environmental, and behavioral factors[31]. Some of the socio-economic factors influencing diarrhea include, unhygienic and unsafe environment, age, low educational status of mothers, overcrowding, unhygienic disposal method of feces and wastes, poor handling of drinking water, lack of personal hygiene and lack of access to sanitation facilities[32]. In addition, employment status, family size, income, and place of residence are strongly linked to the high frequency of diarrhea and play a crucial role in efficiently managing diarrhea. However, most of the death can be prevented by proper management approaches, e.g., continued feeding and timely use of oral rehydration solution (ORS)[33]. Alternatively, use of clean water and proper sanitation, along with behavioral characteristics of the household, diarrheal disease is almost preventable[34]. The lack of awareness and insufficient knowledge of mothers about hygiene leads to frequent exposure of children to diarrhea[35].

A household water survey by NFSL in the year 2021 reported that 30% of glass water, 25% kitchen water, 75% of storage tank water, 45% of bath water were contaminated with *E. coli* and fecal coliform bacteria i.e. *Enterobacter faecalis*. Although no *Vibrio* species were detected in the glass water, *V. cholerae* was found in bath and storage tank water. Another study targeting 316,766 individuals in 79,438 households at risk for diarrhea, using five criteria: overcrowding, poor sanitation, unhealthy and unhygienic living condition, unsafe water use, and low-income dwelling, was done by Chowdhury et al.[25]. An increased risk for diarrhea was observed among young children, males, those staying in a rented house, lower family members in the house, those using a non-sanitary toilet, those living in a community (within 100m around the household) with a less educated adult or less use of their water source for drinking, and those living in a shorter distance to the hospital. Although the prevalence of diarrhea was higher among young children, the burden was higher among older individuals, as they account for the majority of the population. The observation that adult women are at a greater risk than adult men could be due to greater access to unsafe water for household activities. The higher prevalence among young males compared to young females could be that young males are more likely to wander off in unsanitary surroundings than young females. One study conducted at icddr,b hospital shows that males are admitted more than females to the ICU (64% vs. 36%) with diarrhea[36].

A study on shigellosis in Thailand found that people living in rented homes were at a much higher risk for shigellosis than those living in owned homes[37]. Home ownership status used as a proxy for socio-economic status and wealth has been positively correlated with health status[38, 39]. Therefore, it's probable that people who lived in rented homes were less well-off than those who owned their homes, making them more susceptible to diarrheal sickness. Those who stayed in the region for a long time had a lower risk of contracting the disease than those who just visited occasionally. Due to their prolonged residence in the area, they may have a regular healthcare facility and solid ties with the local physicians. Our study found that people with diarrhea were less likely to reside in a neighborhood with more educated residents or where more people drank safe water. This suggests that limiting illness transmission depends on the community's health behaviors and knowledge. We also found higher reporting of diarrheal illness among people living proximate to the hospitals in our study, and similar findings were reported by Ali et al.[40] ; Carrel et al.[41].

Most participants (80%) in a study by Das et al.[42], sought their care from an unlicensed healthcare provider first. They were less likely to choose a professional healthcare provider as their second or third option even after not recovering from the treatment provided by the first healthcare provider. The belief that the episodes were not severe enough may have prevented people from seeking professional medical attention. The other factor might be that poor individuals in Bangladesh have difficulty accessing high-quality medical treatment due to their social exclusion. Additionally, evidence demonstrates a pro-rich bias in the distribution of health gains, even for straightforward and inexpensive health measures[43, 44, 45].

Impact of Health Care systems

Bangladesh has a health system run by the public and private sectors. The public sector is used mainly for outpatient, in-patient, and preventive care, while the private sector primarily uses outpatient and in-patient curative care. The private sector is run by local entrepreneurs, NGOs, and international organizations. Over the last decade, Bangladesh has significantly improved the health sector, making it an example for other developing countries even though it is a resource-poor country[46]. In 2016, approximately 2.5 million diarrheal cases were reported in Bangladesh[47]. However, the actual diarrheal burden is even more significant since many cases are managed at home with oral rehydration solution (ORS) and are left unreported[48]. The Dhaka Hospital of the International Centre for Diarrhoeal Disease Research, Bangladesh (icddr,b), located at the heart of Dhaka, the capital of Bangladesh, is one of the largest dedicated diarrheal disease hospitals in the world. The hospital generally experiences biannual seasonal peaks of diarrheal cases–the summer peak is predominantly associated with *V. cholerae* and enterotoxigenic *E. coli* (ETEC), and the winter peak is mainly due to rotavirus. In April 2018, a diarrhea epidemic broke out in Dhaka city and adjoining areas, which continued through May. Dhaka Hospital had a considerable upsurge of in-patients during the epidemic,

with 40,950 diarrheal patients in April and May, which is 42% higher than the average number of patients during the same period in the past five years[49].

This diarrhea epidemic occurred due to *Vibrio cholera* contamination in water, and *Campylobacter*, enterotoxigenic *Escherichia coli*, and rotavirus had a secondary role. Despite the increased disease severity during the epidemic, the case fatality rate was less than 0.1%. The people of the Dhaka metropolitan area who were relatively poor and lacked safe water, sanitation, and hygiene (WASH) practices were more vulnerable to the epidemic. The Dhaka Hospital saved as many as 17,265 lives during the epidemic.

Impacts of Climate Change

A growing body of evidence suggests that climate change may alter the incidence of diarrheal diseases. Climate change is increasingly understood as an environmental issue of increased temperature and heavy rainfall, threatening human health and well-being. The health effects undermine the gains made in public health and development during the past half-century. Anthropogenic climate change has caused increases in the number of warm days and nights and the frequency and intensity of droughts and heavy rainfall events[50]. This has implications for water-borne diseases, as high temperatures can alter pathogen survival, replication, and virulence, and heavy rainfall events can mobilize pathogens and compromise water and sanitation infrastructure. Drought can concentrate pathogens in limited water supplies[51]. Diarrheal diseases, commonly transmitted via water-borne pathways, comprise a substantial proportion of the global burden of diseases[52, 53].

Globally, diarrhea morbidity and mortality are declining[52], but climate change may slow this downward trajectory, undermining multinational investments to reduce the diarrheal disease burden, with impacts concentrated in some of the world's most vulnerable populations. These health impacts are focused on young children in low-income settings, where pediatric diarrhea can lead to impaired growth and cognitive development and trigger a cascade of ill health that reinforces poverty[54, 55, 56]. Much of the recent work has found significant, positive associations between temperature and bacterial diarrhea, but not viral diarrhea[57, 58], and evidence for increased diarrhea following heavy rainfall events and flooding. It is now clear that the impacts of climate change on diarrheal diseases depend not simply on meteorological conditions but the underlying socio-economical and existing water and sanitation infrastructure to local pathogen distribution that influence a population's exposure, sensitivity, and adaptive capacity. The complex interplay of climate, social vulnerability, ecology, infrastructure, and health conditions has been recognized to cause rising diarrheal diseases in Bangladesh.

Conclusion

Integrating knowledge of different types of systems—biological, social, and engineering—can improve our ability to estimate the health impacts of future climate conditions and extreme weather events and act to reduce vulnerability. On the other hand, to build resilient climate change systems, a variety of strategies and mechanisms has been recommended, including the assessment of water resources, the use of climate-resilient water safety plans as a risk management tool, a focus on utility management organizations with central support for decentralized management structures, and the development of public-private partnerships to boost resilience systems, including through investments in disaster preparedness. In addition, the story of a water safety plan (WSP) outlined in the WHO Climate resilient water safety plans[59] provides a systematic framework to manage climate change risks with an emphasis on the identification of hazardous events and the development and implementation of control measures. Furthermore, the policy mechanisms to increase systems' resilience, some engineering approaches include source, treatment, distribution, and point-of-use control measures that may be implemented to manage microorganism proliferation in drinking water. Examples include, but are not limited to, drawing water from cooler depths, adding or increasing secondary booster disinfection, designing or altering the system to shorten pipe residence times, and/or painting exposed pipes and tank roofs white to reduce heat absorption and lower internal temperatures, which in turn inhibit bacterial growth[59].

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