Microbial contamination of Drinking water and Community water in Bangladesh : A review

By

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A thesis submitted to the Department of Mathematics and Natural Sciences in partial fulfillment of the requirements for the degree of Bachelor of Science in Biotechnology

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It is hereby declared that,

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Abstract

Bangladesh, one of the most densely populated nations of the world, is blessed with abundant water sources, which are being polluted with many bacteria and pathogens. The country's groundwater and surface water are polluted with coliforms and organic and inorganic contaminants. Most of the country's population depends on this water, especially groundwater sources, which contain elevated amounts of coliforms and pathogens. These are causes of many diseases such as diarrhea, dysentery, skin infection, typhoid, and lots more. This study aims to determine the causes and effects of microbial water contamination in Bangladesh. It is a qualitative research paper, and information was collected from primary and secondary sources. Descriptive analysis is done on data collected from different research on microbial contamination of drinking water in Bangladesh, exploring the root cause of microbial water pathogens and coliforms. Based on the analysis, solution to the problems, and strategies are recommended for microbial contamination of drinking water.

Keywords- Bangladesh, Microbial Contamination, E. coli, Coliforms, bacteria, diarrhea, hepatitis, cholera, typhoid, surface water, Groundwater, sewage system.

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Chapter 1

Introduction

Water is considered the driving force for the human body. The fresh water on the earth accounts for 3% of the total water (Hinrichsen and Tacio, 2002). A small proportion (less than 0.01%) of freshwater is available for human consumption (Hinrichsen and Tacio, 2002. But water is indispensable for all life in, on, and above the earth. Not only humans but all sorts of animals, trees, and crops are also dependent on it. But if this drinking water gets contaminated, all living creatures will be extinct worldwide. Clean and safe water is crucial for everyday activities such as drinking, cooking, and maintaining personal hygiene. Water is deemed safe when there are no notable health hazards associated with consuming it throughout one's lifetime, according to the World Health Organization's (WHO) 2011 guidelines. However, water can become polluted in many ways, with microbial contamination being one of the causes.

In rural areas, microbial contamination in drinking water is the main contributor to waterborne diseases. In some respects, it is also known as bacterial contamination. It is mainly the contamination of pathogens that worsens the drinking water quality and causes diseases like diarrhea, hepatitis, cholera, typhoid, and cryptosporidiosis (Fawell & Nieuwenhuijsen, 2003). The problem is generated due to water contamination with wastes, particularly by humans, which contain pathogenic organisms. In many developing countries, bacterial contamination of water caused many diseases, for example- outbreaks of cholera and typhoid in Europe and North America in the 19th century and the prevalence of hepatitis in Sri Lanka in 2009 (Fawell & Nieuwenhuijsen, 2003). It is high time to eliminate the oral-fecal phase by impeding the contaminated water sources by demolishing pathogens. Nevertheless, these approaches must be implemented along with personal hygiene measures, such as hand washing, to reduce the risk of infection transmission.

Bangladesh, which is one of the most densely populated countries in the world and categorized as a third world country, is facing a significant challenge of water pollution and scarcity. It is situated in the delta region formed by the complicated Ganges–Brahmaputra–Meghna River systems, with over 24,000 kilometers of rivers and their tributaries and distributaries, freshwater marshes, mountain streams, brackish water impoundments, and winding seasonal creeks and canals. Being a tropical monsoon country, it experiences warm and humid summers, cold and dry winters, and heavy monsoonal rainfall, with approximately 80% of the total rainfall occurring during the five monsoon months (Bangladesh Planning Commission; General Economics Division, 2018). The country's topography is mostly flat floodplain, which undergoes frequent flooding, resulting in two primary water problems: high flow during monsoons and a long dry period in winter, lasting around six months.

Agricultural use accounts for approximately 80% of the water consumption in Bangladesh. Although most of the total population has access to water, the quality of the water is a significant concern. Waterborne diseases are prevalent in Bangladesh due to contamination of drinking water, which is often contaminated. Tap water in cities cannot be relied on for consumption without treatment such as boiling or filtering. Surface water in the country is highly contaminated due to various sources, such as untreated industrial effluents, domestic waste, and agricultural runoff. Water and sanitation issues are responsible for around 8.5% of the total deaths in Bangladesh (UN-Water, 2013).

To ensure the safety and hygiene of all water sources, it is essential to have a thorough understanding of their contamination state. The complete picture of the overall water pollution situation of Bangladesh is of great importance from every perspective. In this paper we have compiled the recent data in this regard from numerous journal articles, conference proceedings, reports published by renowned organizations, books and other reliable national and international materials. We have extracted meaningful information and systematically presented the current water pollution status of Bangladesh and how it impacts our public health. Various individual studies have indicated that drinking water in different regions of Bangladesh contains microbial contamination exceeding permissible limits. However, there has not been a systematic gathering and comparison of quantitative data on this matter in the past. The objective of this paper is to provide a comprehensive overview of microbial water

pollution in various regions of Bangladesh, focusing on its causes, sources, and associated health risks. This paper will assist researchers and administrative organizations in starting pertinent investigations and creating new regulations to stop future deterioration of water quality and ensure that the general public in the country has access to clean drinking water.

As it is qualitative research, the researcher collected data from primary and secondary sources. The researcher collected preliminary information from articles, related news, and literary criticisms. To assemble secondary sources, the researcher used scholarly journal articles. Since it is an information-based research paper, the researcher must adhere to the ethics rules.

Chapter 2

Research Methodology

2.1 Search Strategy

PubMed, Google Scholar, and ScienceDirect are used as core databases to discover scientific literature related to the topic. The search was conducted using a combination of keywords such as "water contamination", "microbial pollution", "drinking water", "water quality", "Bangladesh" and related terms. The search was limited to articles published between 2010 and 2023 and written in English.” Original reviews and research articles were derived from productive citations, which later helped to recuperate constructive information related to the subject.

2.2 Inclusion Criteria

The study was conducted in Bangladesh and examined microbial water pollution in any region of the country. It investigated the sources and causes of microbial water contamination in Bangladesh. Evaluation was made on health risks associated with microbial water pollution in Bangladesh. In addition, a summary was also provided of a literature that comprehends the symptoms and perplexities of polluted water.

2.3 Exclusion Criteria

Research that was not conducted in Bangladesh and did not examine microbial water pollution were excluded from the study. Along with that, the old data on microbial water contamination in Bangladesh were also excluded.

The Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines were followed to ensure the transparency and completeness of the search and selection process.

Chapter 3

Pathogens of concern

Waterborne pathogens are microorganisms that can cause diseases in humans and animals when consumed through contaminated water. Some of the pathogens of concern in water include bacteria such as Escherichia coli (E. coli), Salmonella spp., Vibrio cholerae, and Legionella pneumophila, as well as viruses such as hepatitis A virus, norovirus, and rotavirus.

Protozoan parasites such as Cryptosporidium spp. and Giardia lamblia are also common waterborne pathogens that can cause gastrointestinal illness. In addition, certain algae species like cyanobacteria can produce toxins that can cause illness in humans and animals if consumed or if skin contact is made with the contaminated water.

These waterborne pathogens can enter the water supply through various means, including agricultural runoff, sewage discharge, and inadequate treatment of municipal water. It is essential to monitor and control the presence of waterborne pathogens to prevent outbreaks of waterborne diseases and protect public health. Water treatment processes such as filtration, disinfection, and chlorination are effective measures to remove or kill waterborne pathogens and ensure the safety of drinking water.

3.2 Waterbrone bacteria

Table: 1.1 The waterbrone bacteria

Name of micro-organisms	Major disease	Mode of transmission	Major reservoirs and primary sources.
Bacteria			
Vibrio cholera, Serovarities O1 and O139	Cholera, gastroenteritis	Fecal-oral route	Human faces and freshwater zooplankton and phytoplankton
Salmonella typhi	Typhoid fever	Sewage contamination of food or water and through person-to-person contact.	Human faeces
Salmonella paratyphi	Paratyphoid fever	Fecal-oral route	Human faeces
Other *Salmonella*	Salmonellosis, gastroenteritis	Fecal-oral route	Human and animal faces
Shingella sp.	shingellosis	Fecal-oral route	Human faeces
Escherichia coli, serotype o157:H7	Diarrhea, hemorrhagic colitis, hemolytic uremic syndrome	Fecal-oral route	Raw or undercooked ground meat products and raw milk.
Enteropathogenic *E.coli*	Gastroenteritis	Fecal-oral route	Human faeces
Yersinia enterocolitica	Gastroenteritis	Consuming or handling contaminated food	Human and animal faeces
Compylobacter jejuni	Gastroenteritis	Consumption of raw or undercooked poultry or having something that touched it	Human and animal faeces
Legionella pneumophila and related bacteria	Acute respiratory illness (legionellosis)	Inhalation of contaminated aerosols	Thermally enriched water
Compylobacter sp.	Gastroenteritis, diarrhea	Consumption of contaminated food	Eating raw or undercooked poultry or eating something that touched it
Leptospira spp.	leptospirosis	Through water contaminated by urine from infected animals	Animal and human urine
Francisella tularensis	Tularemia	Arthropod bites, direct contact with infected animals and inhalation or ingestion of	Animals (especially rodents, rabbits and hares)

		contaminated water	
Mycobacterium avium complex (MAC)	Pulmonary disease, skin infection	Inhalation of contaminated aerosols	Water and soil
Helicobacter pylori	Gastritis, peptic and duodenal ulcer disease and gastric carcinoma	Oral-oral or fecal-oral transmission	Food and water
Aeromonas hydrophilla	Gastroenteritis, septicemia, meningitis and wound infections, intestinal disorders in children	Ingestion of contaminated water or food.	Ground water, fresh produce meat and dairy products
Tsukamurella sp.	Pulmonary and cutaneous infections, meningitis	Through clinical instruments such as catheters or lesions	Soil, arthropods, water, sludge foam and sponges.
Bacillus sp.	Diarrhea	Through drinking water	Spices, cereals and dried foods
Cynobacteria and *cyanotoxins*	Gastrointestinal symptoms, skin rashes, kidney disease	Through drinking water, bathing in contaminated water	Natural found in all types of water

3.2 Waterbrone viruses

Table: 1.2 The waterbrone viruses

Name of micro-organism	Major disease	Mode of transmission	Major reservoirs and primary sources.
Viruses			
Adenovirus	Gastroenteritis, respiratory, ocular and urinary tract infections	Inhalation of contaminated aerosols, fecal-oral route	Human faeces
Astrovirus	Gastroenteritis , respiratory infection	Fecal-oral route	Human faeces
Norovirus	Gastroenteritis, diarrhea	Fecal-oral route	Fomites and water
Sapoviruses	Acute viral gastroenteritis	Fecal-oral route	Human faeces
Hepatitis A viruses	Hepatitis	Fecal-oral route	Human feces
Hepatitis E viruses	Infectious hepatitis, miscarriage and death	Fecal-oral route	Human faeces
Rotavirus	Diarrhea, gastroenteritis	Fecal-oral route	Human faeces
Enteroviruses			
Polio viruses	Polimylities	Contact with the feces of an infected person	Human faeces
Echo viruses	Aseptic meningitis	Contact with fecal matter	Human faeces
Coxsackie A and B viruses	Aseptic meningitis	Person to person on unwashed hands and contaminated surfaces	Human faeces

3.3 Waterborne protozoa

Table 1:3 The waterborne protozoa

Name of micro-organisms	Major disease	Mode of transmission	Major reservoirs and primary sources.
Protozoa			
Acanthamocba casterllani	Amoebic meningoencephalitis	Coming with contaminated water	Human faeces
Blantidium coli	Balantidosis (dysentery)	Fecal-oral route	Human and animal faeces
Naegleria fowleri	Primary amoebic meningoencephalitis	When water containting the amoeba enters the body through the nose	Warm water
Microsporidia	Microsporidiosis	Fecal-oral transmission	Water or soil
Cyclospora cayetanensis	Diarrheal illness, gastroenteritis	Fecal-oral transmission	Food or water
Cryptosporidium sp.	Cryptosporidosis	Fecal-oral route	Humans, cattle and other domestic and feral animals
Giardia intestinalis	Giardiasis (gastroenteritis)	Fecal-oral route	humans and animals, as well as contaminated waters
Entamoeba histolytica	Amebiasis	Fecal-oral transmission	Human faeces

3.4 Waterborne helminths

Table 1:4 The waterborne helminths

Name of micro-organisms	Major disease	Mode of transmission	Major reservoirs and primary sources
Helminths			
Dracunculus medinensus	Dracunlliasis	Consumption of contaminated water	Drinking water containing guinea worm larvae.
Fasciola hepatica, Fasciola gigantica	fascioliasis	Consumption of aquatic plants with metacercariae	Having raw watercress or other plants contaminated along immature parasite larvae
Ascaris lumbricoides	Ascariosis	Consumed with produce contaminated with soil containing infective eggs	Animal and human faeces
Schistosoma sp.	Schistosomoasis , liver and kidney damage	Penetrate the skin during contact with infested water	Cattle, dogs, cats, rodents, pigs, horses and goats

Chapter 4

Bacterial contamination of drinking water

Bacterial contamination is a significant problem in many parts of the world. According to the World Health Organization (WHO), around 2.2 billion people globally lack access to safe drinking water, and approximately 1.8 million deaths each year are caused by waterborne diseases (Pathak, 2015). In developing countries, bacterial contamination is often caused by poor sanitation practices and inadequate infrastructure for water treatment and distribution. In developed countries, bacterial contamination is less prevalent but can still occur due to failures in water treatment or distribution systems.

Microbial contamination of drinking and community water in Asian countries is a significant public health concern. Bacterial contamination of drinking water can occur in several ways. One common source of bacterial contamination is fecal matter from animals or humans that has entered the water supply. This can happen through faulty sewage systems, runoff from farms or landfills, or contaminated groundwater. Some perilous pathogens which are the main root of life-taking diseases are- *pylori, E.coli, Vibrio cholera*, Rotaviruses, and *Salmonella typhi* (Butt et al., 2012). There are also some protozoans like giardia and cryptosporidium. All these bacteria are the main causes of diarrhea, dysentery, hepatitis A, B, C, Cholera, and cancer. The problem of microbial contamination of drinking water in Asia is complex and multi-faceted. Another source of bacterial contamination is biofilm formation on the inside of pipes, which can harbor harmful bacteria such as *Legionella*, the causative agent of Legionnaires' disease. Many factors influence it, including population growth, urbanization, industrialization, and climate change. In many parts of Asia, the infrastructure for safe drinking water is inadequate, and water quality in both urban and rural areas could be better.

Drinking water and community water are essential for human survival and health, but their microbial contamination can cause serious health problems and even death. Bacteria such as *E. coli* and *Salmonella* can cause diarrhea, vomiting, and other gastrointestinal illnesses in humans (Fawell & Nieuwenhuijsen, 2003). In addition to the

gastrointestinal illnesses caused by bacterial contamination, some bacteria can cause more serious illnesses such as typhoid fever and cholera. Children, pregnant women, and the elderly are particularly vulnerable to the effects of contaminated water.

According to statistics, poor water quality, sanitation and hygine on public health globally are responsible for causing around 1.7 million deaths every year worldwide, mostly thorugh infectious diarrhea. Nearly all of these deaths occur in developing countries, and nine out of ten victims are children. The major pathogens responsible for these deaths include *Rotavirus, Campylobacter jejuni, enterotoxigenic Escherichia coli, Shigella spp.,* and *Vibrio cholerae O1*, among others (Nicholas John Ashbolt, 2004).

Preventing bacterial contamination of drinking water requires a multi-faceted approach. One important step is to ensure that sewage systems and waste disposal facilities are functioning properly and are not contaminating water sources. Proper management of industrial waste and agricultural chemicals is also essential. Regular testing of water supplies for bacterial and chemical contamination can help to identify and address problems before they become widespread. In addition, disinfection processes such as chlorination and ultraviolet radiation can help to kill harmful bacteria in water supplies (Centers for Disease Control and Prevention, 2021).

To prevent microbial contamination in drinking water, water treatment processes such as disinfection, filtration, and chlorination are commonly used. Chlorination of water can control most of these pathogens, except for *Cryptosporidium parvum*. Regular testing and monitoring of the water supply is also important to identify and address potential sources of contamination. However, the recontamination of treated water remains a significant challenge. Emerging environmental pathogens, such as *Helicobacter pylori* and *Burkholderia pseudomallei*, may also pose a significant threat in certain regions. There is a limited understanding of the long-term consequences of enteric infections in adults, including myocarditis, diabetes, reactive arthritis, and cancers that may manifest months or years after the initial infection. In addition to the traditional pathogens such as *helminths, Entamoeba histolytica, Giardia lamblia, hepatitis A and E, various enteroviruses, Campylobacter jejuni,* and *Helicobacter pylori* are emerging issues in adults (Nicholas John Ashbolt, 2004).

The detection of pathogens in drinking water is crucial for ensuring the safety and quality of the water supply. One of the most common methods for detecting pathogens in drinking water is through the use of microbiological testing. This involves collecting water samples and testing them for the presence of bacteria, viruses, and other microorganisms. Various techniques such as culture-based methods, molecular methods, and immunological methods can be used for detecting these pathogens. For example, the polymerase chain reaction (PCR) is a molecular method that can detect specific DNA sequences from pathogens in water samples (Paul et al., 2015).

Another important method for detecting pathogens in drinking water is through the use of indicator organisms. These are microorganisms that are commonly found in the environment and can indicate the presence of fecal contamination in water. The most commonly used indicator organism is *Escherichia coli (E. coli)*, which is a bacteria commonly found in the intestines of humans and animals (Nipa et.al, 2022). The presence of E. coli in drinking water can indicate fecal contamination and the potential presence of other harmful pathogens.

The detection of pathogens in drinking water is important for protecting public health. If a water sample tests positive for a particular pathogen, authorities may issue a boil water advisory or take other measures to disinfect the water supply. By identifying the presence of these pathogens, measures can be taken to protect public health and prevent the spread of waterborne illnesses.

Water can contain a variety of microorganisms, including bacteria, viruses, and protozoa. Typically, when examining water for microbes, scientists focus on identifying fecal coliforms. These coliforms are commonly found in the feces of warm-blooded animals, including humans and domestic animals, and are used as an indicator of water pollution. While coliform bacteria themselves may not be pathogenic, their presence indicates a possibility, but not a certainty, of hazardous disease-causing microbes being present. Coliform tests are widely accepted worldwide as a standard method for monitoring the quality of drinking water due to their ease of use, cost-effectiveness, and

ability to predict bacterial safety (Paul et al., 2015). The World Health Organization (WHO) standard for fecal and total coliforms in drinking water is 0 coliform per 100mL of water sample (WHO,2004).

Techniques like the microplate method, multiple tube fermentation (MTF), membrane filtration, MMO-MUG, DNA microarray, and fluorescent in situ hybridization (FISH) are used to detect and identify coliform bacteria in water. Though exceptions exist to the generalization of the coliform test, it remains the most commonly used and acceptable standard test for assessing the microbial quality of water (USEPA 2005).

Chapter 5

Microbial Contamination of drinking water in Bangladesh

Bangladesh is considered one of the most densely populated countries in the world, with enough water resources but mainly contaminated. Organic and inorganic pollutants contaminate both the ground and surface water. In 2013, the amount of drinkable water was only 34.6%, and only 2 out of 5 families could get safe drinking water (Chowdhury & Chowdhury, 2021). The surface water of Bangladesh is filled with fecal coliform, pesticides, toxic metals, antibiotic residue, and microplastics (Sarkar et al., 2022). The sediment between surface water and groundwater is shallow. That's why all these surface water contaminants easily get mixed with groundwater and pollute the drinking water of Bangladesh.

Bangladesh is at a perilous point of water contamination. According to WHO, Bangladesh's water contamination is considered the world's worst toxic contamination. The most contaminated area in Bangladesh is Savar, where *Shigella, E. coli, Enterobacter, Salmonella, Pseudomonas, Vibrio,* and *Yersinia enterocolitica* are found, which are very harmful to the human body (Moniruzzaman et al., 2011).

In Bangladesh, Rajshahi is considered to be the most water-polluted city. In Satkhira district's TalaUpazila, 72% of drinking water sources were inappropriate (Saha et al., 2019). Despite that, 40% of the district's population consumes that water, as they have no choice (Saha et al., 2019). As a result, they have to suffer from diarrhea, fever, and high blood pressure.

Table 2: Bacterial contamination of drinking water in several parts of Bangladesh

Location		Total Number of Samples	Water Type	Total Coliform (cfu/100 ml)	% total coliform	Fecal Coliform (cfu/100 ml)	% fecal coliform	References
City	Region/Area							
Dhaka	Sinduria	21	Drinking Water	8440	100%	516	95%	(Rahman, 2013)
Dhaka	Jatrabari	6	Surface Water	-	-	557,000	100%	(Shiekh, 2006)
Dhaka	Dhanmondi	6	Surface Water	-	-	25,500	100%	(Shiekh, 2006)
Dhaka	Gulshan	6	Surface Water	-	-	23.9	100%	(Shiekh, 2006)
Dhaka	Nobab-bari Pond	6	Surface Water	-	-	577,000	100%	(Shiekh, 2006)
Savar, Dhaka	Gakulnagar	20	Drinking Water	3	60%	-	-	(Rahman, 2009)
Chittagong	Hathazari road	1	Drinking Water	60	100%	-	-	(Zuthi et al., 2009)
Chittagong	Nasirabad road	1	Drinking Water	8	100%	3	100%	(Zuthi et al., 2009)
Chittagong	WASA-Patenga	3	Drinking Water	4	50%	0	50%	(Zuthi et al., 2009)
Chittagong	Chandpur	5	Drinking Water	17	100%	10	60%	(Islam et al., 2001)
Chittagong	Mohra- Batali Hill	9	Drinking Water	2800	55%	200	22%	(Zuthi et al., 2009)

Dhaka city	Municipal tap water	10	Potable water	1100	100%	-	-	(Islam et al., 2010)
	Bottle filtered water	8		1100	100%			
	Mineral water	8		47	100%			
Dhaka (Thana dependent on WASA water supply)	Dhaka university , Bangshal, DMCH, Basabo, Badda, Shobujbag, Shagun Bagichaa, Jatrabari, Mohammadpur, panthapath, elephant road , Shampur, Kamrangirchor, Kawranbazar, Lalbag, Hagaribugh, Sutrapur, Uttara, Mirpur, BIRDEM Hospital	25	Drinking water	24	64%	36	48%	(Sabrina et al., 2013)
Near Dhaka City	Buriganga River	6	Drinking Water	-	-	525,000	100%	(Shiekh, 2006)
Near Narayanganj	Balu River	6	Drinking Water	-	-	40,000	100%	(Shiekh, 2006)
Near Dhaka City	Turag River	6	Drinking Water	-	-	60,800	100%	(Shiekh, 2006)
Mymensing	Different market of different upazilla	10	Tap water	70	100%	0	10%	(Hassan et al., 2018)

Gazipur	Different market of different upazilla	5	Tap water	23	100%	0	20%	(Hassan et al., 2018)
sherpur	Different market of different upazilla	5	Tap water	13	100%	0	0%	(Hassan et al., 2018)
Khulna	Sonadanga, rupsh & hadis park, Khalishpur, Mujgunni, Nirala and khulna university campus	7 pump water and 11 residence water.	pump water and residence water	23	33% pump water and 93% residenc e water	93	36.36% pump water and 42.86% househol d water	(Tahera et al., 2009)

Table 2 points out a number of investigations which have revealed widespread bacteriological contamination of drinking water in Bangladesh. Here we can see Dhaka city and its nearby areas are most contaminated. Jatrabari, a metropolitan thana of Dhaka megacity with around 2.5 lac population, was found to have surface water contaminated with 557,000 fecal coliforms from 6 samples (Shiekh, 2006). In another thana, Sinduria, 8440 bacterial coliforms were found in 21 drinking water samples (Rahman, 2009). Even in diplomatic places such as Dhanmondi, Gulshan, and Nobab Bari's surface water was not free from fecal coliform. On the other hand, Chittagong is not far behind in bacterial contamination. Chittagong Mohra-Batali hill's water is mostly contaminated and TC is 2800cfu/100 ml which is really risky for the Mohra-Batal hill's community. In mymensing lowest concentration is 7cfu/100ml and 70 cfu/100ml is highest concentration . All the samples were contaminated of Mymensing, Gazipur, Sherpur but the presence of fecal coliform is 10%, 20% and 0. Patenga, considered the beach area of Chittagong, has approximately 50% total coliforms and 50% fecal coliforms present in its drinking water from 14 samples. All these geneses are used as drinking water production sources in those areas. If inhabitants of these areas drink water from those sources for a long time, they will likely be affected by different waterborne diseases. If we look carefully at the table, we can see that among all the samples collected from the mentioned areas, 95% of fecal coliform contamination was found.

Table 3: List of Bacteria in Drinking water in Bangladesh

Bacteria	Location of detection in Bangladesh	Reference
Escherichia coli	Dhaka, Sylhet, Chittagong, Barishal	(Todar, 2007)
Vibrio cholerae	Dhaka, chittagong, Mymensing	(HERRINGTON,1998; Alam, 2006)
Salmonella species	Tangail, Mymensing, Rajshahi, Gazipur, Sylhet, COxsbazar and Patuakhali	(farooqui, 2009)
Aeromonas hydrophila	Coastal areas like Gopalganj, narail, Jessore, Khulna, Bagerhat, Shatkhira, Bhola, Patuakhali and Noakhali	(Ahmed, 2013)
Staphylococcus species	Cox's Bazar, Rangamati, sajek, Magura, Bogus, Jamalpur, Swapnadeep	(Zerin et al., 2020)
Listeria species	Cities based on animal husbandry	(Acharjee,2011)
Enterobacter aerogenes	Noakhali Districtc	(Islam et al., 2021)
Pseudomonas aeruginosa	N/A	(Ahmed, 2013)
Shigella species	Hill track area like Chittagong, Rangamati and Bandarban	(Das et al., 2013)
Klebsiella species	Rajshahi, Dinajpur and river-based cities of the country like- Buriganga River, Shitalakhya River, Balu River, Korotoa River and Paria River	(Ahmed, 2013)

Chapter 6

Health risks Due to Microbial Water Contamination in Bangladesh

Water pollution arises when toxic particles enter the water and contaminate rivers, oceans, lakes, streams, and aquifers. It degrades the water quality by affecting water sources and making it poisonous to human health and the environment. More than 2 billion people live in water-polluted countries, and Bangladesh is not an exception (PIMENTEL et al., 2004). The country is considered one of the most affected countries as most of the population is dependent on groundwater as their main source of drinking water (Hossain et al., 2015). Microbial contamination of drinking water or insufficient fecal water treatment causes different bacterial diseases like – salmonelosis, cholera, shigellosis, diarrhea, dysentery, gastroenteritis, encephalitis, hepatitis, and lots more (Hasan et al., 2019). In Bangladesh, approximately 40% (1.2 million) are drinking bacterially contaminated water; as a result, hospital expenditures are around USD 3–13 per month/HH higher than the national expenses (Saha et al., 2019). Obtaining safe drinking water from different companies (bottled water) will cost 1 dollar for middle-class people per day (Saha et al., 2019).

In Bangladesh, diarrhea, bacillary dysentery, and typhoid are common waterborne diseases due to microbial water pollution (Lin et al., 2022). These diseases have taken around 30,000 lives due to drinking polluted water (Saha et al., 2019). The Buriganga is infected with germs and bacteria, which causes immediate reactions. Therefore, cancer and skin infection are common diseases in this country. On the other hand, due to poor water purification and distribution, deadly viruses like *Hepatitis A, Hepatitis E,* and *Cholera* attack people each year (Saha et al., 2019). Some deadly pathogens like Salmonella and E Coli are found in Dhaka's WASA water supply (Saha et al., 2019).

Bangladesh, a third-world country, is known for its dense population. According to WHO, even though 97% of people in the country have access to water, its quality is questionable (Hasan et al., 2019). The country has over 230 large and small rivers, where human intervention has caused contamination. As a result, bacteria in groundwater are very high, and 35 to 77 million people are affected by this (Hasan et al., 2019). Microbial water contamination causes around 8.5% of deaths yearly. Due to this contamination, diarrhea,

dysentery, cholera, skin irritation, lung cancer, and renal infection are common in this country.

Many diseases occur due to fecal contamination in urban communities in Bangladesh. Around 23% of total deaths and 24% of total diseases are caused by consuming microbial contaminated water (Amin et al. 2019). Fecal contamination has become a common problem all over the country due to unplanned urbanization, poor sewerage system, sluggish sanitation, frequent flooding, and domestic household chores. All these causes are connected to converse health outcomes such as environmental enteric dysfunction, diarrhea, and stunting (low height). The contamination of *E. coli* is found in low and middle-income neighborhoods in their municipal water, open drains, street food shops, and shared latrine swabs. In the low-income area, the counting of *E. coli* is around $p < 0.05$ (Amin et al. 2019). As a result, urine infection, cholangitis, diarrhea, and dysentery are common diseases in their daily life.

In the previous chapter, (Table 2: List of Bacteria in Bangladesh's Drinking Water). We can see that pathogen like, *Escherichia coli, Vibrio cholera, Salmonella species, Enterococcus species, Aeromonas hydrophila, Staphylococcus* species*, Listeria* species*, Enterobacter aerogenes, Pseudomonas aeruginosa, Shigella* species*,* and *Klebsiella* species are very common in Bangladesh. The most contaminated cities are Dhaka, Chittagong, Sylhet, Mymensingh, Barishal, Khulna, Coxsbazar, and other hill track areas. On the other hand, prominent rivers like Buriganga, Shitalakhya, Balu, Korotoa, and Paira are also severely contaminated. As a result, people near these cities and rivers always suffer from Cholera, Typhoid, lung infection, Hepatitis A & B, Diarrhea, Urinary infection, abdominal pain, Endocarditis, gastroenteritis, food poisoning, superficial skin lesions, and tenesmus.

In Bangladesh, tube wells connected to groundwater are used as the primary source of drinking water, especially in rural areas. But due to insufficient supervision of fecal wastewater, unsanitary pollutants, and poor water purification system, water-borne diseases like Jaundice, Diarrhea, Dysentery and typhoid erupted all over the country (Dey et al., 2017). In 2016, in the southwest region of Bangladesh, approximately 2.25% of the population suffered from diarrhea and Dysentery (Dey et al., 2017). On the other hand, Bangladesh being a river-based country, flooding is common in its different regions. As a result, the drinking water of flood-affected areas is highly contaminated by life-taking

pathogens like *Salmonella, hepatitis A virus, Vibrio,* and *Shigella* species causing diarrheal diseases (Azmuda et al., 2019). In 2015, 6% of 0.119 million deaths were caused by diarrheal diseases (Chowdhury et al., 2015). On the other hand, water pollution is connected to 5000 deaths in the country yearly, where 50% is microbial pathogenically affected diseases (Sarker et al., 2019). Multidrug-resistant and ESBL-producing *E. coli* are infectious diseases that pose a significant threat to Bangladesh, and if antibiotic resistance is present, it can spread with drinking water (Sarker et al., 2019).

Chapter 7

Causes and Sources of Microbial Contamination of Water in Bangladesh

Ominous human exercises are the main reasons behind microbial water pollution. One of the most significant causes behind this issue is the unacceptable transfer of household, civil, and mechanical garbage into water channels, lakes, rivers, and waterways (Azizullah et al., 2011). Two primary sources of water pollution can be divided into Point and Non-Point sources (Arefin & Mallik, 2018).

Point source water pollution is substances entering the water from a single line, for example, a production line pipe coming from an individual line (Jovanovich et al., 1974). Some point sources of water pollution include- industrial and municipal water full of garbage, leachate and runoff from disposal areas, runoffs from animal fecal, runoffs from industrial sites, oil fields, and mines, overflow of mixed sanitary wastes and floods, and drainage of construction sites (Arefin & Mallik, 2018). All these points can calibrate the big ocean's water bodies and make them hazardous for fish and other sea creatures (Arefin & Mallik, 2018).

Nonpoint source of water pollution means the contaminants which manipulate the water body from disseminated sources (Peavy et al., 1985). Some examples of nonpoint water sources are- runoffs from irrigated agricultural lands, streams flowing from pastures, urban population mixture of drained and undrained sources, leakage from septic lines, and observation of atmospheric precipitation over a water surface (Arefin & Mallik, 2018). Water that has been contaminated by rainfall from several locations can also be regarded as a nonpoint pollution source.

Water can get contaminated by pesticides, toxic metals, erosion, sedimentation, decomposable organics, and nitrate. Together all these are known as microbial water contamination, which occurs from agricultural tools, industrials, domestic chores, marine dumpings, oil leaks, and unplanned pipelines.

Based on Chaudhry & Malik's research (2017), the main reasons are pathogens, industrial garbage, saltwater intrusion, environmental elements, chemical hazards, and agricultural pollutants. However, industrial garbage are the most perilous among all these sources of pollutants as they contain pesticides, herbicides, and chemicals (Chaudhry & Malik, 2017). Pathogens in polluted water are the main reason behind the world's 65% of diseases. Due to these diseases, approximately 14000 people die daily (Chaudhry & Malik, 2017).

Domestic chores and farming consume 70% of the earth's total supply of water but are also considered the main water pollutant (Kumar & Kumar, 2021). In Bangladesh, agricultural activities or farming are the most significant reasons behind microbial water pollution. Most local farmers use carbamate and organophosphorus pesticides due to the need for proper instructions and knowledge, which pollutes the groundwater and water surface (Hasanuzzaman et al., 2016). During rain or flood, pesticides, animal wastes, and fertilizers used in the farmland get mixed with nearby lakes, ponds, or rivers. On the other hand, pathogens and nutrients which contain viruses and bacteria also contaminate the water. According to the World Bank, in Bangladesh, 6% of farming pesticides get mixed with water due to flood or rain, eventually affecting the waterbody (Meisner, 2004).

The main industrial cities of Bangladesh are Dhaka, Khulna, Chittagong, Savar, and Bogura (Arefin & Mallik, 2018). The core industries which cause water pollution are pharmaceuticals, paper, metals, pesticides, tannery, and garments (Arefin & Mallik, 2018). According to BIWTA (Bangladesh Inland Water Transport Authority), approximately 350,000 kilograms of garbage and toxic items are thrown by 7000 industries into the river (Md. Kamruzzaman & Sakib, 2022). Most of the country's rivers are filled with substantial untreated mechanical wastes. For example, approximately 700 tanneries in Dhaka city throw around 1600 garbage into the river (Arefin & Mallik, 2018).

Marine dumping means dumping garbage from households and industries into the ocean is known as marine dumping. Due to this type of unloading garbage, the water gets microbially attacked from its main root. Bangladesh is one of those countries that are known for its marine dumping.

Harmful pathogens, bacteria, and chemicals are common in Bangladesh's sewage lines, and freshwater lines are interconnected. On the other hand, this wastewater is released into the nearby river, ponds, or lakes. Bangladesh's sewage line contains human and animal feces of pathogens like E.coli, Salmonella, Rotavirus, Hepatitis A, and Vibrio Cholera (Harris et al., 2017). These pathogens can cause diarrhea, dysentery, cholera, and Hepatitis A (Harris et al., 2017). For instance, the hospitals of the country produce more than 500 tons of harmful discharges without proper treatment, and later on, most of this garbage is thrown into sewage lines (Islam et al., 2017).

Chapter 8

Discussion

In the 21st century, maintaining safe water quality is a significant issue threatening human health. Humans need to use water sensibly and effectively to preserve these precious resources. In some advanced countries, wasted water is discharged into surface water aquifers. Their natural process comprised dilution, sedimentation, and volatilization. Sometimes the reaction to sunlight reduces the contamination before water is stored in the drinking water facilities.

Tube wells are the main water source for most of Bangladesh's rural areas, and fecal coliforms are mostly found in high and low-concentrate tube wells (Ercumen et al., 2015). As a result, they are usually affected by different pathogens, which possess different diseases like dysentery and diarrhea. Around 65% of tube wells in Bangladesh contain fecal indicators and coliforms like *Escherichia coli* (*E. coli*), *Vibrio cholera, Rotavirus, Shigella, Enterotoxigenic* and *Shigella* (Ercumen et al., 2015). All these microbial elements result in approximately 16,600 to 27,700 deaths due to diarrheal disease each year.

The following table is found from a research showing Bangladesh’s tube well, household, pond, river, and mineral water contamination level with microbial pathogens like fungus, Heterotrophic plate, fecal coliforms, salmonella, and *E.coli.* Comparatively, tubewell and bottled water had less pathogenic contamination than rivers, ponds, and household water. There was considerable contamination of Coliforms, *E. coli*, and *Salmonella* in rivers, ponds, and house water. In contrast, tube wells and bottled water were free of Faecal Coliforms, *E. coli,* and *Salmonella.*

Bangladesh is a river-based country where flooding is a common phenomenon, and many people suffer from displacement and rising water every year. The rainy season or monsoon appears from June to October, which causes annual flooding, with a water level of 26 000 km to 52 000 km (WARPO, 2001). The floods of 1954, 1968, 1978, and 1984 ranged from 35 000 km2 to 52 000 km, where around 85% water was contaminated (Rahman et al., 2006). The 1998 flood was the most fearsome, where two-thirds of the country was covered by water and affected millions of people, and as a result, diarrheal diseases were everywhere as a post-flood effect (Sirajul et al., 2007). Several factors have contributed to flooding

contamination, including inadequate protection for water reservoirs, unprotected wells, and shallow groundwater around the country. In Bangladesh, waterborne diseases are considered the sources of significant health issues. In 2000, 4 billion cases of waterborne diseases contributed 54.7% to global mortality (WHO, 2002). After the flood, the surface water of the country gets filled with bacterial coliforms like *E. coli, vibrio cholera,* and fecal *Streptococci* contaminating the tube well water (Sirajul et al., 2007; Ahmed et al., 2021). In most cases, increased rates of waterborne diseases are reported in some districts of the country devastated by disasters, yet few studies have been undertaken and reported in this regard.

According to WHO, safe water management depends on 5 categories: Unimproved services, minimum basic services, safely managed services, limited services, and no services (WHO, 2017). In 2021, around 59% of people in Bangladesh (from both urban and rural areas) can access safe drinking water (World Health Organization, 2019). In the South Asian region, this access rate is higher than in Pakistan, Nepal, Tajikistan, Bhutan, and Afghanistan and lower than in Turkmenistan, Iran, and Kazakhstan (WHO, 2021). The following table shows that the rate of safe water management in Bangladesh is only 59%, whereas the rest of the world has more than 70%.

Table 4: Comparison between Bangladesh and the rest of the world in drinking water services in 2020 (Rahman et al., 2022).

Access to the Level of Services of Drinking Water	Bangladesh (%)	World (%)
Unimproved service	<1	5
At least basic service	98	90
Safely managed service	59	74
Limited service	<1	4
No Service	<1	2

WHO reports that approximately 83% of Bangladesh's population consumes non-piped water, and only 15% consumes piped water (WHO, 2021). In Dhaka, DWASA is the only supplier of piped water to all classes and all areas of people (Rahman, 2021). However, most pipes are contaminated by different bacteria due to faulty connections and leakages. In this issue, to avoid waterborne diseases, people have to boil water or use chlorine tablets (Thomas et al., 2020).

Unimproved service means drinking water from an unprotected dug well or unprotected spring. At least basic service means time is not more than 30minutes for collecting drinking water from a safe source. Limited service means exceeding 30 minutes for a rountrip to collect drinking water from an improved source including queuing.Safely managed service means drinking water from an developed water source which is located in ground and available when water is essential and free of faecal contamination. When drinking water is collected from a river, lake, pond, stream, canal it is known as no service (WHO, 2017).

Chapter 9

Conclusion

Water is particularly susceptible to pollution, sometimes known as a "universal solvent," as it dissolves more substances than other elements. According to WHO, approximately 1.2 million people die from contaminated water (Smith & Mehta, 2003). At the same time, our freshwater sources are finite; less than 1% of the total water is consumable for humans (Smith & Mehta, 2003). So, it is high time for the world to take necessary actions to diminish this problem; otherwise, human life will be extinct sooner.

To stop water contamination, the countries should adopt some necessary steps like - throwing away garbage in a specific dustbin, sweeping pesticides and fertilizers into the farming land so that it cannot pave into the river, composting the farming waste, water from the housing area and industrial wastes should be separated from the drinking water line. The primary purpose of the Millennium Development Goal (MDG) was to improve around 2.6 million people's drinking water sources (Dey et al., 2017). In 2015, approximately 91% of the world's population had the chance to drink purified drinking water, but still, in some regions, people depend on groundwater (Dey et al., 2017). They aimed to save around 829,000 people by the time 2030 by providing safe drinking water (Dey et al., 2017). The main purpose of MDG was to stop pollution, poor management, misuse, and over-extraction of groundwater.

In 2013, the Bangladesh government started a new framework called Bangladesh Water Act 2013 (BWA) (Arifuzzaman et al., 2019). The main purpose behind this act was to purify, manage, protect, distribute, extract, coordinate, and integrate the water resources in the country. The Bangladesh government recently relocated industries and housing from the Buriganga River to save and purify the river. There is another program called "Green Dhaka, Clean Dhaka', where one of their primary purposes is to clean the river and diverge the garbage.

The execution of prevention options can be assisted by establishing guidelines and monitoring their implementation periodically. The government should monitor the agricultural and industrial activities which can cause water contamination. Public awareness is considered equally important in maintaining water sources.

Chapter 10

Recommendations

Some recommendations which can minimize and control microbial water contamination in Bangladesh are given below:

- Bangladesh Water Development Board (BWDB) should ensure proper disinfection and filtration before the water gets supplied to the public. They should also ensure 100% monitorization of public water.

- The old and rusty drinking water pipelines should occasionally be exchanged with new ones.

- Disconnecting sewerage lines from water supply pipes should be placed so they have a safe distance.

- BWDB should order the industries to manage their garbage before discharging it into the sea or river. Here the industries of Bangladesh should abide by NEQS (National Environmental Quality Standards) rules and regulations.

- The Municipal corporation should ensure plant observation and sewerage collection procedures.

- The governmental NGOs should raise awareness programs about the importance of safe drinking water. Electronic media and educational institutions can significantly influence these awareness programs.

- The government should raise awareness and monitor the households, especially in the highest contaminated areas, to not throw their garbage into the river.

- BWDP should implement strict environmental laws with zero compromises.

- A separate budget should exist for the governmental fund's water pipe servicin

Chapter 11

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