Journal of Mechanical and Construction Engineering, 2024,
Vol. 04, Iss. 02, S. No. 065, pp. 1-7
ISSN (Online): 2583-0619

Drinking Water and Gastrointestinal Diseases: A Systematic Review

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How to cite this paper: Y. Ninama, "Drinking Water and Gastrointestinal Diseases: A Systematic Review," *Journal of Mechanical and Construction Engineering (JMCE), Vol. 04, Iss. 02, S. No. 065,* pp. 1–7, 2024.

https://doi.org/10.54060/a2zjournals.jmce.65

Received: 01/06/2024
Accepted: 11/10/2024
Online First: 26/10/2024
Published: 25/11/2024

Abstract

Access to clean water is vital for maintaining human health and supporting essential biological processes. Ensuring proper sanitation and clean water availability plays a crucial role in preventing the spread of diseases. In both rural and urban areas, poor hygiene practices and limited access to clean water are significant challenges that contribute to the prevalence of waterborne illnesses. Factors such as contaminated water, insufficient sewage management, and unhygienic living conditions create environments conducive to the breeding of mosquitoes and other disease vectors in residential areas. This article delves into the classification of waterborne diseases and explores various techniques used in bacteriological water analysis.

Keywords

Biological activity, Water-based diseases, Sewage management

1. Introduction

"Water scarcity remains a critical issue in many parts of the world. While access to clean drinking water is essential for survival, contaminated water is a significant contributor to various infections and health-related problems. Studies have shown that waterborne bacteria, particularly those causing diarrhea, are commonly transmitted through drinking water. A reliable and adequate water supply is fundamental for maintaining public health and well-being [1-5]. The World Health Organization

(WHO) estimates that over 1.1 billion people worldwide consume unsafe water, with poor sanitation, hygiene, and water quality being responsible for 88% of all diarrheal diseases globally [6-12]."

This review paper highlights the global challenges surrounding access to safe drinking water and the presence of water-borne pathogens. It underscores the critical role of clean water in human health, examining its link to illnesses such as diarrhea, gastroenteritis, E. coli infections, and dysentery, which significantly contribute to the global disease burden. The discussion includes the four major groups of pathogens—bacteria, viruses, protozoa, and helminths—while addressing issues related to water contamination, purification, and sanitation. The paper also summarizes key findings from both domestic and international studies, concluding with emerging concerns and global efforts to address water quality and accessibility [13-25].

2. Waterborne illness and pathogenic contaminants

2.1. Diarrhoea, Cholera and typhoid

Diarrhea remains a life-threatening condition for children under the age of five, often leading to malnutrition and weakened immunity. It is a major health concern in low-income countries, particularly in South Asia, including Bangladesh, where it is among the leading causes of illness and death in young children. The primary triggers of diarrhea include bacterial, viral, and protozoal infections. The condition results in significant water and electrolyte loss, causing dehydration and, in severe cases, death. Contaminated excreta are a major contributor to the spread of diarrheal diseases, which are further exacerbated by poor sanitation and unsafe water. Promoting simple practices, such as washing hands with soap and water, can effectively reduce the prevalence of diarrhea in both rural and urban settings [26-29].

Cholera is a severe intestinal infection caused by Vibrio cholerae serogroups O1 and O139, which are commonly found in freshwater zooplankton in warm regions. In developing countries, cholera outbreaks often occur seasonally and are closely associated with poverty and inadequate sanitation infrastructure. The disease is characterized by profuse watery diarrhea, which can lead to rapid dehydration and, if left untreated, a high mortality rate of 50–70% [28-30].

Typhoid fever, caused by Salmonella typhi, primarily affects young children, who are particularly vulnerable. Key symptoms include persistent fever, chills, and abdominal pain.

3. Major bacterial pathogens

Bacterial pathogens commonly associated with diarrhea include Shigella sp., Vibrio cholerae (O1 or O139), Campylobacter jejuni, enterotoxigenic Escherichia coli, and other enteric pathogens like E. coli. To a lesser extent, Aeromonas sp., Bacteroides fragilis, and Clostridium difficile also contribute to diarrheal illnesses, following rotavirus and Cryptosporidium parvum.

While these pathogens are less common in industrialized countries, where atypical strains of E. coli (entero-pathogenic EPEC) are more frequently associated with diarrhea, they remain a significant cause of infantile diarrhea in developing nations. Humans are the exclusive reservoir for typical EPEC (and related Shigella species), highlighting that poor sanitation and inadequate water management are primary contributors to the spread of these diseases [29-31].

3.1. Enteric viruses

"Rotaviruses are responsible for approximately 140 million cases of diarrhea each year, accounting for 80% of all viral-related diarrheal diseases. While these infections affect young children worldwide with similar frequency, they result in a significantly higher mortality rate in developing countries, leading to an estimated 870,000 deaths annually. In contrast, inadequate sanitation in low-income regions also contributes to early exposure to Hepatitis A, which, while causing short-term illness, confers long-term immunity. This early exposure provides protection against the severe effects typically observed in individuals over the age of 50 in industrialized nations."

3.2. Parasitic Protozoa

In developing countries, waterborne and foodborne parasitic protozoa such as Cryptosporidium parvum, Giardia lamblia, and Toxoplasma gondii are of significant concern, especially among immunocompromised individuals. Other notable parasites include Entamoeba histolytica, Cyclospora cayetanensis, and Sarcocystis sp. These parasites are major contributors to persistent diarrhea, defined as an episode that begins acutely and lasts for at least 14 days. Additionally, Cyclospora cayetanensis and Sarcocystis spp. have become recognized causes of traveler's diarrhea in developed regions, often contracted overseas [14].

4. Microbiological Contamination and Indicators

While less common than E. coli, fecal streptococci are frequently present in fecal matter. Due to their high resistance to drying, streptococci can be useful in routine water quality testing, particularly after the installation of new water mains or repairs to distribution systems. They are also valuable for detecting contamination in ground or surface waters, particularly from runoff [18].

A study of sewage effluent found Cryptosporidium oocysts in both surface waters and sewage effluent. The likely sources of contamination included agricultural runoff, recreational water activities, and leaks from septic tanks. Pathogenic bacteria are commonly identified through tests for total coliform and fecal coliform nonpathogenic bacteria [23].

"According to USEPA guidelines, the geometric meaning of fecal coliform content in at least five water samples should be below 100/100 ml for 50% of the samples, and below 1000/100 ml for 90% of the samples. Additionally, the density of E. coli in freshwater must be less than 126/100 ml, based on the logarithmic average of at least five samples collected over a 30-day period."

4.1. Total Coliforms

The presence of potentially harmful bacteria can be assessed by measuring total coliforms, which include Escherichia coli and fecal coliforms. While coliforms and feces are naturally present in the environment, fecal coliforms and E. coli are primarily associated with human and animal waste (EPA, 2008). To detect pathogenic bacteria, testing for both total and fecal coliforms is commonly used. The data presented in Figure 1 show that coliform levels were highest during the wet season and lowest during the winter [30,31].

Fecal coliforms (FC) and total coliforms (TC) have traditionally been considered reliable indicators of microbial contamination in water sources. The multiple tube fermentation (MTF) method remains the most commonly employed technique for detecting both total and fecal coliforms in water.

4.2. Coliform Bacteria

Escherichia coli is part of the broader coliform group of bacteria and is typically found in the intestines of animals. The highest concentrations of E. coli are observed during the rainy season (Fig. 1). While most strains of E. coli are harmless, E. coli O157:H7 can pose significant health risks. In recent years, waterborne zoonotic pathogens such as Cryptosporidium parvum, Campylobacter jejuni, and Escherichia coli O157:H7 have become more prevalent.

4.3. Faecal Streptococci

Fecal streptococci, a group of bacteria found in both human and animal gastrointestinal tracts, are commonly present in the feces of all warm-blooded animals and in the environments surrounding animal waste due to water pollution (Sandhu et al., 1979; Geldreich, 1967).

5. Physico-chemical indicators

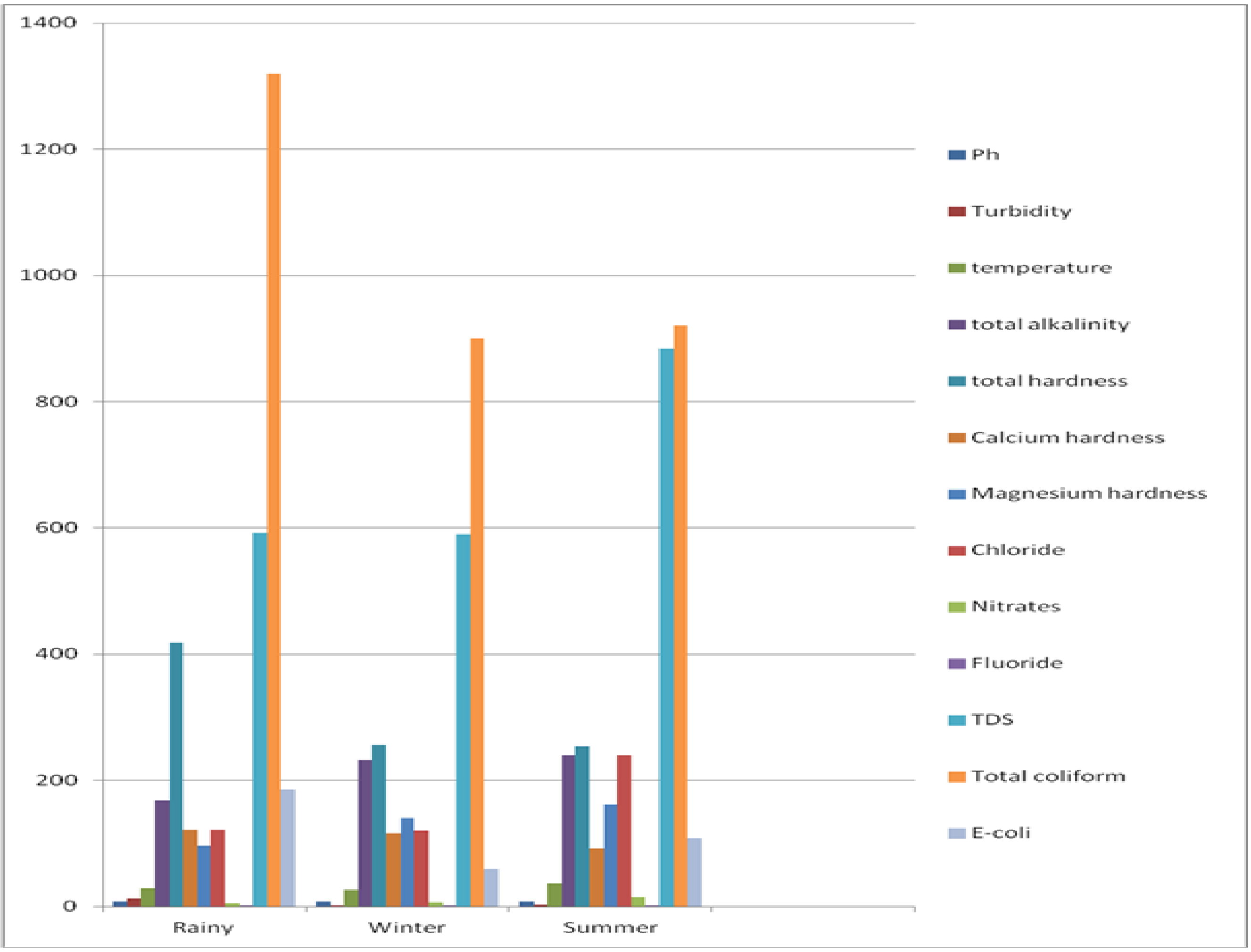

Figure 1. Graphical representation of seasonal variation in different parameters

5.1. pH and Alkalinity

Drinking water should have a pH range of 6.5 to 8.5. Rainwater, when uncontaminated, is naturally acidic due to the dissolution of CO2. Hard water exhibits a slight alkalinity. A positive correlation between total alkalinity and electrical conductivity with pH has been observed.

Alkalinity refers to the water's ability to neutralize a strong acid, which is determined by the presence of hydroxyl ions that can combine with hydrogen ions. Changes in pollutant levels often lead to fluctuations in alkalinity.

5.2. Total Dissolved Solids and Electrical Conductivity

Total dissolved solids (TDS) in water consist of inorganic salts and small amounts of organic materials. The primary ions contributing to TDS include carbonate, bicarbonate, chloride, sulfate, nitrate, sodium, potassium, calcium, and magnesium. According to Park (1997), water with a TDS concentration of less than 600 mg/liter is generally considered to have good palatability.

5.3. Sodium, Potassium and Chloride

Sodium is found in many minerals, with rock salt (sodium chloride) being the most common source. Seawater contains approximately 10 grams of sodium per liter. Sodium concentrations are typically highest in lowland rivers and groundwater. While most drinking water sources worldwide contain less than 20 mg/l of sodium, some regions may have levels as high as 250 mg/l.

Potassium, on the other hand, is a less abundant cation in water and is typically present at lower concentrations. Any increase in potassium levels is usually accompanied by higher concentrations of chloride and other anions. Excessive potassium levels may indicate greater contamination, leading to a decline in drinking water quality [23-28].

Sodium (NaCl), potassium (KCl), and calcium salts are the most prevalent forms of chloride found in nature, making up about 0.05% of the Earth's lithosphere. Chlorides are found in all water sources, including rainfall. In uncontaminated water, chloride concentrations are typically below 10 mg/l, and sometimes even below 1 mg/l. A recommended standard for chloride concentration is 200 mg/l, with 600 mg/l being the maximum tolerable level.

5.4. Hardness, Calcium and Magnesium

Water hardness is an essential quality parameter for both residential and commercial consumption. According to guidelines from the WHO and India, the maximum allowable hardness in drinking water is 150 ppm and 200 ppm, respectively, as $CaCO_3$. Groundwater in Hyderabad exhibits hardness levels ranging from 204 to 1288 mg/l. Excessive hardness and total solids content are primarily attributed to contamination from unprotected wells and surface water (Srinivas et al., 2000). Hardness levels are typically higher in the summer compared to other seasons. In a study by Desai (1995), water hardness, measured as $CaCO_3$, varied between 13.3–264 mg/l and 12.5–208 mg/l during two separate research periods. Hard water is primarily caused by the presence of calcium and magnesium cations. Certain anions, including phosphates, sulfates, and nitrates, also contribute to water hardness. Several studies have investigated the concentrations of calcium and magnesium in surface water, groundwater, and polluted water sources. The increase in Ca^{++}, Mg^{++}, and Mn^{++} ions during the winter months may be a contributing factor to the rise in water hardness [25-30].

5.5. Dissolved Oxygen and Biochemical Oxygen Demand

When the oxygen content in drinking water decreases, microorganisms can convert nitrates to nitrites and sulfates to sulfides, often leading to odor issues. Additionally, the concentration of ferrous iron in solutions may increase as a result. According to the results of the CPCB's water quality monitoring program, which focuses on indicators of pathogenic bacteria (total coliform and fecal coliform) and oxygen-demanding substances (biochemical oxygen demand or BOD), there has been a noticeable decline in water quality over time.

Biochemical Oxygen Demand (BOD) is widely recognized as one of the most important indicators of pollution levels in river water. Low oxygen concentrations can significantly harm aquatic ecosystems, as insufficient oxygen impairs the survival and growth of aquatic organisms.

5.6. Nitrate, Sulphate and Phosphate

The concentrations of phosphate, sulfate, and nitrate in water bodies are influenced by factors such as organic load, mineralization rates, and geochemical conditions. Nitrate levels, in particular, are believed to increase with rainfall. Phosphate and nitrate are considered two of the most essential nutrients for the growth of algal populations. Additionally, sulfate levels may rise during the summer due to increased evaporation and higher temperatures.

6. Conclusion

Deaths from diarrhea and gastroentritis may be reduced by public awareness by educating them and providing medical treatment. Water-related diseases affect people loss of their money for treatment, earnings on workdays, mental health and put an economic burden on family. People have to adopt water treatment facilities. Govt. should supply clean water by water filtration plant. Health awareness programmes should be organized in schools, colleges and public places collaborated with NGOs for sanitation and hygiene education will make concern to insufficient water management and less infrastructure all over the world.

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