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An Assessment of Water Quality and Its Public Health Implications in Bombali District, Sierra Leone

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Abstract

This study investigates the physicochemical and microbiological quality of drinking water sources in Makeni City, Bombali District, Sierra Leone, and examines their implications for public health. Water is a fundamental human necessity, yet in many low-income regions, its contamination continues to threaten both health and development. In Sierra Leone, where more than 80% of the population relies on groundwater, access to safe drinking water remains a critical concern. Fifty water samples were collected from wells, taps, and bottled sources and analysed for *Escherichia coli* contamination, turbidity, and key chemical parameters. Findings revealed that 94% of the samples were contaminated with *E. coli*, predominantly from uncovered wells and surface water sources, indicating substantial microbial risk. Although most chemical indicators met World Health Organisation (WHO) standards, several samples exhibited high pH levels, which are suggestive of corrosion or plumbing issues. Additionally, excessive turbidity and discolouration raised both aesthetic and safety concerns. These results highlight the urgent need for improved water infrastructure, systematic monitoring, and community sensitisation regarding safe water handling and storage. The study further identifies significant gaps in national water quality surveillance and calls for stronger policy action by local authorities and agencies such as the Sierra Leone Water Company (SALWACO). Ensuring access to clean and safe water is essential not only for disease prevention but also for the advancement of sustainable public health and socioeconomic development in Bombali District and other similar communities across Sierra Leone.

Keywords: Physicochemical, Biological Quality, Drinking Water, Implications on Public Health and Makeni City, BombaliDistrict, Sierra Leone.

Introduction

Background of the Study

Water, often referred to as the universal solvent, is one of the most vital natural resources for sustaining life. It exists naturally in three physical states—solid, liquid, and gas—under normal environmental conditions (APHA, 1991). Approximately three-quarters of the Earth's surface is covered by water in the form of oceans, seas, rivers, lakes, and swamps. At the same time, substantial quantities also exist underground as groundwater and in the atmosphere as vapour. Fog and clouds serve as visible manifestations of this atmospheric water vapour (APHA, 1991). Beyond its physical ubiquity, water is indispensable for human survival, facilitating the optimal functioning of cells and organs, and playing a crucial role in disease prevention and treatment. Studies indicate that adequate hydration, such as consuming eight glasses of water daily, can significantly lower the risk of colon cancer by 45%, bladder cancer by 50%, and potentially breast cancer (Britton, 1991).

Despite its health benefits, water can act as a medium for disease transmission, particularly in regions lacking adequate sanitation. The World Health Organization (WHO) has estimated that nearly 80% of health problems in developing countries stem from poor water quality and inadequate sanitation facilities (Cheesbrough, 2000). Contaminated water is a known vector for diseases such as typhoid fever, diarrhoea, dysentery, and schistosomiasis, all of which undermine public health and economic productivity (Okoufu et al., 1990). According to WHO (2008), over one billion people worldwide lacked access to safe drinking water, resulting in more than two million annual deaths from waterborne diseases, particularly in developing nations. In 2015, Sub-Saharan Africa recorded some of the highest global deficits in clean water and sanitation, affecting approximately 319 million and 695 million people, respectively (WHO/UNICEF, 2015).

In developing contexts, rapid population growth continues to intensify pressure on limited freshwater resources. Environmental degradation—resulting from improper waste disposal, industrial effluents, mining discharges, and agricultural runoff—further exacerbates the problem, posing serious risks to both surface and groundwater quality (Srinivas et al., 2015). In Sierra Leone, over 80% of the population depends on groundwater for domestic consumption. However, widespread contamination and insufficient access to treated water present serious public health concerns (Pedley& Howard, 1997; Prüss-Üstün et al., 2008). Since attaining independence in 1961, Sierra Leone has made concerted efforts to improve water supply and sanitation, notably during the International Drinking Water and Sanitation Decade (1981-1990). During this period, the Water Supply Division of the Ministry of Energy and Power prioritised water improvement projects in rural districts, while the Guma Valley Water Company managed supply in Freetown and its environs (Donkor et al., 2007). Nevertheless, significant gaps persist, as many rural and peri-urban communities continue to rely on rainwater and groundwater due to limited piped water infrastructure (Jimmy et al., 2012).

This study, therefore, assesses the physicochemical and microbiological quality of drinking water from multiple sources in Bombali District and evaluates the corresponding public health implications. The findings aim to inform policymakers and guide the efforts of national agencies, such as the Sierra Leone Water Company (SALWACO) and the Environmental Protection Agency of Sierra Leone (EPA-SL), in developing evidence-based interventions to improve water quality and safeguard public health.

Problem Statement

In Sierra Leone, inadequate access to safe drinking water and the frequent contamination of available water sources pose significant public health threats. Polluted water serves as a primary medium for the transmission of infectious diseases such as typhoid fever, diarrhoea, and dysentery, which in turn constrain productivity and economic growth (Okoufu et al., 1990). The World Health Organization (WHO, 2008) reported that more than one billion people globally lacked access to safe drinking water, resulting in over two million annual deaths from waterborne diseases, predominantly in less developed nations. Once a water source becomes contaminated, restoring its original quality is both costly and technically challenging. Therefore, continuous monitoring and management of the physical, chemical, and biological parameters of water are essential for ensuring safety and sustainability. In Sierra Leone, where reliance on groundwater is widespread, these measures are particularly crucial in preventing disease outbreaks. Effective monitoring systems are vital to reducing the national burden of water-related illnesses and promoting overall public health.

The significance of this study lies in its potential to inform evidence-based policymaking and improve water resource management. By providing empirical data on the quality of drinking water from multiple sources, the study offers a valuable foundation for public health interventions and environmental governance. Its findings are expected to guide national agencies, such as the Sierra Leone Water Company (SLWACO), the Environmental Protection Agency of Sierra Leone (EPA-SL), and the Ministry of Water Resources, in addressing risks of contamination. Additionally, the study will support both international and local nongovernmental organisations that work to prevent waterborne diseases and enhance community health. It also addresses a significant research gap in Sierra Leone by systematically comparing water quality across urban and rural settings. The insights derived can help policymakers and planners formulate effective strategies for improving water supply systems. Ultimately, this research underscores the vital link between access to clean water and the nation’s broader objectives for sustainable development and public well-being.

Study Aim

The primary aim of this study is to investigate and compare the physical, chemical, and biological characteristics of drinking water sourced from various locations within Bombali District, Sierra Leone. This research aims to assess the extent to which these water quality parameters comply with both national and international standards for safe drinking water. By analysing indicators such as pH, turbidity, total dissolved solids, and microbial contamination, the study provides a scientific basis for evaluating potential health risks. The findings will help identify variations in water quality across wells, taps, and bottled water sources, revealing underlying factors that contribute to contamination. Furthermore, the study aims to establish correlations between poor water quality and the prevalence of waterborne diseases in the local population. The outcomes are expected to inform public health policies and community-based water management strategies. Ultimately, the goal is to promote safer drinking water practices and support the development of sustainable interventions that protect human health and enhance environmental safety in Sierra Leone.

Objectives

I. To analyse the physical properties of drinking water from different sources and their impact on public health in Bombali District
II. To evaluate the chemical quality of drinking water from various sources and its implications for public health
III. To examine the microbial content of drinking water from different sources and its effect on public health

Research Questions

I. How do the physical properties of drinking water affect public health in Bombali District?
II. What are the public health effects of the chemical quality of drinking water from different sources?
III. How does the microbial content of drinking water impact public health?

Definition of Key Terms

Turbidityrefers to the degree of cloudiness in the water. This can vary from a river of mud and silt, where it would be impossible to see the water.

Conductivity is the degree to which a specified material conducts electricity, calculated as the ratio of the current density in the material to the electric field which causes the flow of current.

Total Suspended Solids are particles that are larger than 2 microns found in the water column.

Total Dissolved Solids:is the term used to describe the inorganic salts and small amounts of organic matter present in water.

Colour: the water colour varies with the ambient conditions in which that water is present. At the same time, relatively small quantities of water appear to be colourless.

Lead is a poisonous metal that can cause long-term health and behavioural problems.

Iron: can be a troublesome chemical in water supplies. Making up at least 5% of the earth's most plentiful resources.

Copper is a transition metal that is suitable in its metallic state and forms monovalent (cuprous) and divalent (cupric) cations.

Escherichia coli is a type of coliform bacteria commonly found in the intestines of animals and humans. The presence of E. coli in water is a strong indication of recent contamination from sewage, as well as animal and human waste. Sewage may contain many types of disease-causing organisms.

Faecal Coliforms are bacteria that are associated with human or animal waste.

Salmonella typhi is a bacteria that infect the intestinal tract and the blood. The disease is referred to as typhoid.

Scope and Delimitation

The study focuses on tap water, well water, and bottled/plastic water in Makeni, Bombali District. The findings may not apply to other regions due to geographic and demographic differences. The study will analyse only selected water sources due to sample size limitations.

Significance of the Study

More than 80% of residents in developing countries rely on groundwater for their drinking needs (Pedley& Howard, 1997). Inadequate access to clean water and sanitation remains one of the leading global causes of mortality, with millions of people in low-income regions dying annually from diarrhoea and other waterborne illnesses (Prüss-Üstün et al., 2008). According to the World Health Organization (2008), over one billion people globally lack access to safe drinking water, resulting in more than two million deaths each year, predominantly in less developed countries. In Sierra Leone, the majority of communities continue to rely on clean water for both drinking and domestic purposes, thereby heightening their vulnerability to contamination. This study seeks to enhance public understanding of groundwater safety in relation to its physical, chemical, and microbial properties, as well as the spatial relationship between contamination sources and community water points. The findings will be instrumental in helping policymakers develop effective regulations and interventions targeting water pollution. Furthermore, the research will assist health workers, government agencies, non-governmental organisations, and community leaders in assessing the extent of well-water contamination in urban and peri-urban areas of Makeni, Bombali District, and in formulating evidence-based public health responses.

Literature Review

Introduction

Access to safe drinking water remains a critical public health issue, particularly in sub-Saharan Africa, where millions of people lack reliable water and sanitation services. Drinking water quality is influenced by its physical, chemical, and biological properties, which determine its suitability for human consumption and the risk of disease transmission. Recent statistics indicate that in 2015, approximately 319 million people in sub-Saharan Africa lacked access to safe drinking water, while 695 million were without adequate sanitation (WHO/UNICEF, 2015). Rapid population growth, urbanisation, and environmental pressures such as industrial effluents, agricultural runoff, and improper waste disposal exacerbate these water challenges (Srinivas et al., 2015). Contaminated water has been linked to widespread waterborne diseases, including diarrhoea, cholera, typhoid fever, and other infections, which have profound implications for public health and economic development (WHO, 2008). In Sierra Leone, groundwater serves as the primary drinking water source for over 80% of the population, highlighting the need for rigorous monitoring and management of water quality (Pedley& Howard, 1997). This study examines the physical, chemical, and microbial quality of drinking water in Bombali District to understand its potential impact on community health.

Conceptual Framework

The conceptual framework of this study illustrates the relationships between drinking water quality and public health outcomes. Drinking water quality is classified into three categories: physical, chemical, and biological parameters, each of which directly or indirectly influences human health. Physical parameters, including turbidity, colour, taste, odour, and conductivity, affect the sensory acceptability and immediate safety of water. Chemical parameters, such as pH, nitrate, heavy metals, and hardness, influence long-term health risks and water usability. Biological parameters encompass microbial contamination, including Escherichia coli, Salmonella spp., and faecal coliforms, which are primary indicators of waterborne disease risk. The framework highlights that interventions targeting water treatment, hygiene practices, and socio-economic factors can mitigate the adverse effects of poor water quality. Consequently, improving water quality alone is insufficient without integrated public health strategies addressing both behavioural and environmental determinants.

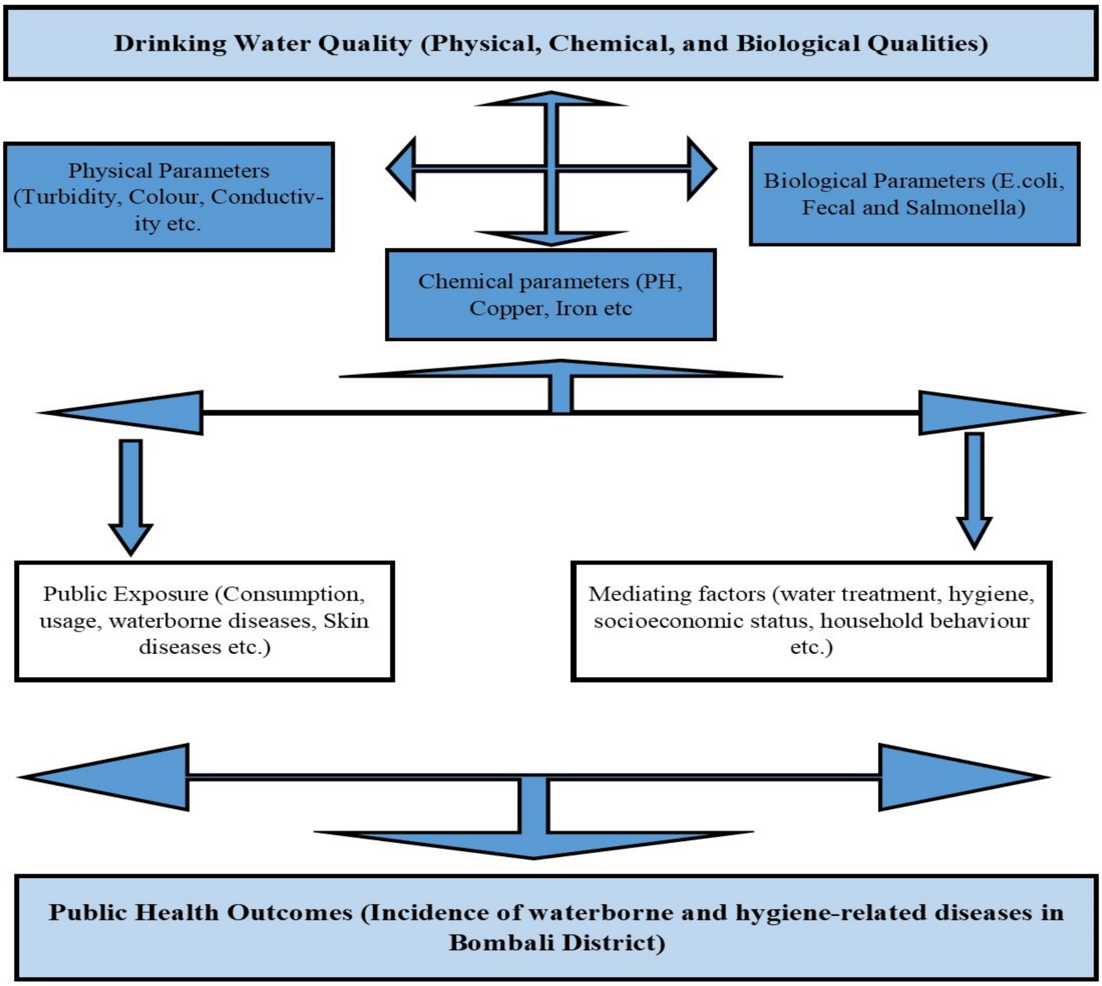

Figure 1: Conceptual Framework

Water Quality Situation in Sub-Saharan Africa

Rapid urbanisation in sub-Saharan Africa has increased reliance on self-supplied water sources, often derived from unprotected wells, surface water, or informal distribution systems (UN-Habitat, 2003). Surface runoff and poor sanitation infrastructure frequently contaminate shallow wells and other groundwater sources, posing severe health risks. Subsurface contamination pathways, such as vertical soil percolation from pit latrines and burial sites, further exacerbate microbial and chemical contamination. The Millennium Development Goals and subsequent global initiatives have emphasised improving access to safe water, yet millions remain underserved, with only 2.5% of the Earth's water suitable for human consumption (United Nations, 2013; Ahuja, 2013). Climate change, population growth, and industrial expansion intensify water scarcity while simultaneously diminishing water quality (Zeng et al., 2013). Contaminated water contributes to an estimated 1.2 billion people consuming unsafe water, resulting in over 5 million annual deaths from water-related diseases worldwide (Ahuja, 2013). Therefore, monitoring and managing both quantity and quality of water is essential for public health protection and sustainable development in the region.

Physical Properties of Drinking Water and Public Health Implications

Physical parameters, including turbidity, colour, taste, and odour, are critical determinants of water safety and acceptability. High turbidity, often resulting from suspended solids and microbial loads, reduces disinfection efficacy and promotes the survival of pathogens (WHO/FWC/WSH, 2017). Colouration, caused by organic matter, metals, or industrial pollutants, indicates possible contamination and may affect consumer perception of water quality (Kargbi, 2018). Water taste and odour deviations, while not always toxic, may signal chemical or microbial contamination, impacting consumption behaviour (WHO, 2016). Total dissolved solids (TDS) reflect the concentration of inorganic and organic substances, influencing scaling, hardness, and aesthetic qualities. Elevated levels pose indirect health risks (EPA, 2009b). Studies have shown that groundwater in urban and peri-urban areas can exhibit varying turbidity and TDS levels, increasing vulnerability to microbial colonisation (Mohsin et al., 2013; Al-Khatib et al., 2023). Therefore, routine monitoring of physical water parameters is crucial for detecting contamination and ensuring public health standards are maintained.

Chemical Quality of Drinking Water and Health Impacts

Chemical constituents of drinking water, including nitrates, heavy metals, and hardness, have significant long-term health implications. Nitrate contamination, often linked to agricultural runoff or faecal pollution, can cause methemoglobinemia in infants if concentrations exceed 50 mg/L (Adnan et al., 2019). Hardness, caused by calcium and magnesium ions, may provide cardiovascular protection but can cause scaling in infrastructure (WHO, 1984). Heavy metals, including iron, lead, cadmium, and zinc, may originate from industrial effluents, corroded pipes, or geogenic sources, leading to acute or chronic health effects (Lapworth et al., 2017). Iron, for instance, can promote the growth of iron bacteria, causing biofouling, staining, and potential microbial proliferation (Sogaard, 2014). While many chemical parameters fall within WHO guidelines, local variations and episodic contamination can pose intermittent risks to consumers.

Understanding chemical composition and implementing treatment measures are, therefore, crucial to prevent adverse health outcomes. Integrated management, which combines chemical analysis, community education, and regulatory oversight, ensures that vulnerable populations have access to safer drinking water.

Microbial Contamination and Public Health Risks

Microbial contamination represents the most immediate health risk associated with drinking water. Pathogens such as Escherichia coli, Salmonella spp., and other faecal coliforms are indicators of unsafe water and a high likelihood of disease transmission (Cabral, 2010; WHO, 2008). Contamination often arises from poor sanitation, unprotected wells, and inadequate waste management, particularly in densely populated urban areas (Haruna et al., 2005). Studies in Nigeria and Uganda have demonstrated that untreated industrial and domestic effluents exacerbate microbial hazards, contributing to high incidence rates of diarrheal diseases and typhoid fever (Lapworth et al., 2017; Murphy et al., 2017). Antibiotic-resistant strains of E. coli and Salmonella have been increasingly reported, further complicating treatment and public health management (Sobur et al., 2019). Targeted interventions, including biological disinfection, safe sewerage systems, and monitoring, are necessary to mitigate these risks. Therefore, understanding and controlling microbial contamination is essential for preventing waterborne diseases and safeguarding community health.

Methods and Materials

Research Design and Rationale

This study focused on evaluating the quality of drinking water in Makeni City, Bombali District, by examining key variables, including physical properties, chemical composition, microbial contamination, sanitation, and external pollution sources. Three main factors—physical, chemical, and biological characteristics—were examined to assess their impact on water quality and associated public health risks. An experimental research design was employed to facilitate the systematic collection and analysis of water samples from various sources, thereby providing reliable and balanced data. This approach enabled the direct measurement of water quality parameters under controlled laboratory conditions, ensuring accurate responses to the research questions. Demographic and environmental characteristics of water sources, including location, proximity to potential contamination sources, and surrounding sanitation conditions, were also documented. The experimental design was selected due to its suitability for assessing multiple water quality indicators across diverse sources while accounting for potential confounding factors. Consequently, this design ensures that the findings are scientifically robust and applicable for guiding policy and public health interventions.

Study Area

The study was conducted in the urban areas of Bombali District, with Makeni City selected as a representative case study. Makeni is the provincial headquarters of Bombali District and the economic hub of Sierra Leone's Northern Province, with an estimated population of 125,970, one-third of whom are under the age of 18 (Statistics Sierra Leone, 2016). The city is approximately 172.5 km east of Freetown and is among the most densely populated provincial cities in Sierra Leone. Makeni's urban population relies heavily on a combination of groundwater wells, piped water supplied by SALWACO, and bottled or sachet water provided by local vendors. Within the urban boundaries, there are over 100 groundwater wells, while approximately 40 commercial suppliers provide bottled or sachet water. The study focused on drinking water sources that served the majority of residents, ensuring that the findings accurately reflect the water quality available to the community. Mapping of the city was conducted to organise water sources according to cardinal directions, enhancing systematic sampling coverage.

Study Setting and Sampling

The study population included all accessible wells, piped water sources, and bottled/plastic water providers within Makeni. Water sources were purposively selected based on their location within East, West, North, South, and Central areas of the city, resulting in fifty (50) water sources sampled. This included twenty (20) wells, fifteen (15) piped water sources, and fifteen (15) bottled/plastic water sources. Permission was obtained from water source owners and community leaders prior to sample collection to ensure ethical compliance. Data collection took place in January 2025, and all selected water sources were documented, including their geographic coordinates and relevant environmental characteristics. A random sampling technique was employed to select individual samples at each site, thereby minimising bias. Each sample was collected in a 500 ml sterilised high-density polyethene or glass container, pre-rinsed with the source water, labelled with location, code, and date, and stored in coolers with ice packs before transportation to the laboratory.

Determination of Physicochemical Properties

Physical parameters assessed included pH, turbidity, electrical conductivity (EC), total dissolved solids (TDS), total suspended solids (TSS), and colour. Chemical analyses focused on essential and potentially harmful elements, including total iron (Fe), copper (Cu^{2+}), and lead (Pb). In situ measurements were performed using a combined Accumet AC 85 Fischer Scientific pH and conductivity meter, which was calibrated according to standard protocols before and during fieldwork. Chemical analyses were conducted in the laboratory using PHENANTHROLINE SPECTROPHOTOMETRY, following strict Standard Operating Procedures (SOPs) to ensure precision and reliability. Total dissolved solids, hardness, and metal concentrations were measured to assess potential long-term health effects and infrastructure-related risks. Turbidity and colour were analysed as indicators of microbial load and contamination by organic or inorganic matter. This comprehensive approach provided a robust assessment of both aesthetic and safety-related water quality parameters.

Determination of Microbiological Content

Microbial contamination was assessed by analysing Escherichia coli, faecal coliforms, and Salmonella typhi using the membrane filtration technique. Each water sample was examined in relation to its proximity to potential contamination sources, including latrines, dumping sites, and burial grounds, measured using a tape meter. Colonies were enumerated using a magnifying lens or colony counter, with Lauryl Membrane Broth used for E. coli and faecal coliforms, and XLD agar for Salmonella typhi. This methodology enabled the accurate determination of microbial density and the identification of waterborne pathogens. The results were used to evaluate the risk of waterborne diseases for populations consuming water from different sources. Regular calibration of laboratory equipment and adherence to SOPs ensured data reliability. The microbiological analysis complemented the physicochemical assessment to provide a holistic understanding of water quality and associated health risks.

Sample Frame and Data Collection Procedures

The sample frame encompassed all groundwater wells, piped water sources, and bottled/sachet water suppliers within Makeni. Water sources were purposively selected to ensure representation across all urban areas, with sampling proportional to population served. Owners were briefed on the study objectives, and informed consent was obtained prior to sample collection. Supplementary data on environmental factors and sanitation practices were gathered using a structured questionnaire. Water samples were labelled, stored, and transported according to SOPs, with refrigeration maintained until laboratory analysis. Data were recorded systematically on evaluation checklists and organised for ease of analysis. The procedures ensured the collection of accurate, reproducible, and ethically collected data across all water sources.

Data Analysis and Ethical Considerations

The collected data were processed using Microsoft Excel and Epi_Info version 7.5.2 and presented in tables, charts, histograms, and graphical formats. Statistical summaries and visual representations were used to facilitate the interpretation of physicochemical and microbial water quality parameters. Ethical clearance was obtained from the university and the Department of Public Health, and permission was sought from the water source owners before sampling. All procedures adhered to ethical guidelines, ensuring the safety and confidentiality of participants and the community. The combination of experimental design, rigorous laboratory analysis, and adherence to ethical standards provided reliable evidence for evaluating water quality. These methods establish a robust foundation for subsequent chapters, which present and discuss the findings. The study's methodology ensures that results are both scientifically credible and practically relevant for policy and public health interventions.

Findings

Data Collection

The time frame for data collection was three months (1st October to 31st May 2025). The recruited water sources selected for this study included Urban and peri-urban indigenous water sources in Makeni, Bombali District. There is no discrepancy in data collection from the plan in Chapter Three because all variables were screened for missing data by reviewing frequency tables for each variable. Although there were almost no missing data in the records, several records contained unidentified values that were excluded from the sample size.

WHOGuidelines for Portable Water

Table 1: Shows the WHO Guidelines for Portable Water

No	Parameters	Units	WHO Guidelines
1	pH		6.5-8.1
2	Turbidity	NTU	<5.0
4	Color	TCU	<15
3	Conductivity	ʂµ/cm	<450
4	TDS	mg/l	<284
5	TSS	mg/l	<65
6	Iron	mg/l	<0.3
7	Lead	mg/l	<0.01
8	Copper	mg/l	<2.0
9	E-Coli	CFU/100ml	Zero
10	Fecal Coliforms	CFU/100ml	Zero
11	Salmonella typhi	CFU/100ml	Zero

Study Results and Interpretations

The majority of water sources sampled were uncovered wells (58%), followed by covered wells (16%) and packaged water (16%). River/stream sources made up 8% of the samples, while treated water accounted for only 2%. The high dependence on uncovered wells is concerning, as these are more vulnerable to contamination from environmental pollutants. The high reliance on uncovered wells increases exposure to contamination due to environmental factors and inadequate treatment.

Table 2: Shows the Type of Water Sources

Type of Water Source	Frequency	Proportion
Covered Well	8	16
River/Stream	4	8
Treated Water	1	2
Uncovered Well	29	58
Water Packaging	8	16
TOTAL	50	100

The physical properties of drinking water from different sources and their impact on public health

The analysis of physical parameters, including turbidity, conductivity, colour, total dissolved solids (TDS), and total suspended solids (TSS), revealed variations in water quality across different sources. Turbidity (2.48 NTU on average) mainly was within the WHO's standard limit of 5.0 NTU, except for some cases where it reached 24 NTU, indicating possible contamination. Conductivity (mean: 59.33 µS/cm) varied significantly, with a maximum value of 248 µS/cm, which could indicate dissolved minerals or contaminants. Watercolour (mean: 35.86 TCU) exceeded the WHO limit of 15 TCU in several samples, suggesting contamination from organic matter, iron, or industrial waste. Total Dissolved Solids (TDS) and Total Suspended Solids (TSS) remained within acceptable limits, although the highest TSS value of 56 mg/L indicates occasional pollution. The physical analysis highlights that uncovered wells and river/stream sources are at higher risk of contamination due to turbidity and colour variations, which may indicate the presence of harmful dissolved substances, making them unsafe for direct consumption without treatment.

Physical parameters

Table 3: Show the Physical Parameters

Physical parameters	Mean	Std Dev	Min	Median	Max	Mode
Turbidity (NTU)	2.48	4.6257	0	2	24	0
Conductivity (şμ/cm)	59.33	36.5443	10	52.5	248	34
colour (TCU)	35.86	79.4139	0	0	351	0
TDs(mg/l)	37.6792	23.0404	6.4	33.6	158.7	22
TSS(mg/l	2.78	8.6809	0	0	56	0

Water Source Turbidity Compared with the WHO Standard

About 90% of samples met the WHO standard for turbidity, with only uncovered wells exceeding the safe limit.The turbidity levels were mostly below the WHO standard of 5.0 NTU, except for uncovered wells, where 5 out of 29 (17.2%) samples exceeded the threshold. This indicates that uncovered wells may pose a higher risk of contamination due to exposure to environmental pollutantscompared to other sources.

Water Source Turbidity Compared with the WHO standard (5.0 NTU)

Table 4: Water Source Turbidity Compared with the WHO standard (5.0 NTU)

Turbidity	Covered Well	River/Stream	Treated Water	Uncovered Well	Water Packaging	TOTAL
<5.0 NTU	**8**	**4**	**1**	**24**	**8**	**45**
	17.8	8.9	2.2	53.3	17.8	100.0
	100.0	100.0	100.0	82.8	100.0	90.0
≥ 5.0 NTU	**0**	**0**	**0**	**5**	**0**	**5**
	0.0	0.0	0.0	100.0	0.0	100.0
	0.0	0.0	0.0	17.2	0.0	10.0
TOTAL	8	4	1	29	8	50

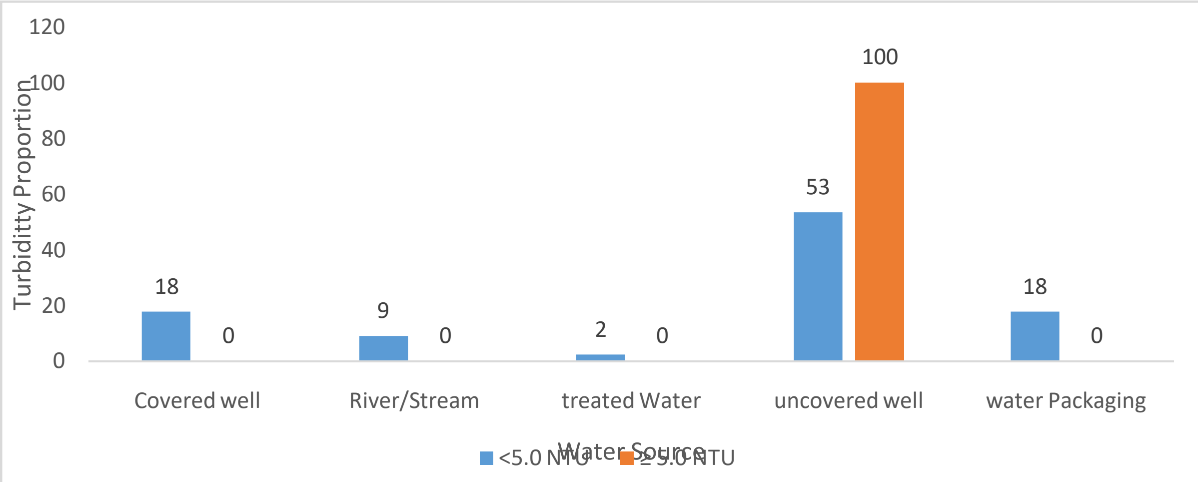

Figure 1: Water Source Colour Compared with the WHO Standard

From the total water sources samples analysed, 17/50 (34%) exceed the >15TCU WHO water quality standard, majority of those sources were from uncovered wells which are 8/17 (47.1%) and rivers/streams 4/17(23.5%) which indicates potential pollution at those sources. This suggests that untreated surface water and uncovered wells require filtration or treatment before consumption.

Table 5: Water Source Colour Comparison with the WHO standard (15 TCU)

Colour	Covered Well	River/ Stream	Treated Water	Uncovered Well	Water Packaging	TOTAL
<15TCU	**5**	**0**	**1**	**21**	**6**	**33**
	15.2	0.0	3.0	63.6	18.2	100.0
	62.5	0.0	100.0	72.4	75.0	66.0
≥ 15TCU	**3**	**4**	**0**	**8**	**2**	**17**
	17.6	23.5	0.0	47.1	11.8	100.0
	37.5	100.0	0.0	27.6	25.0	34.0
TOTAL	8	4	1	29	8	50

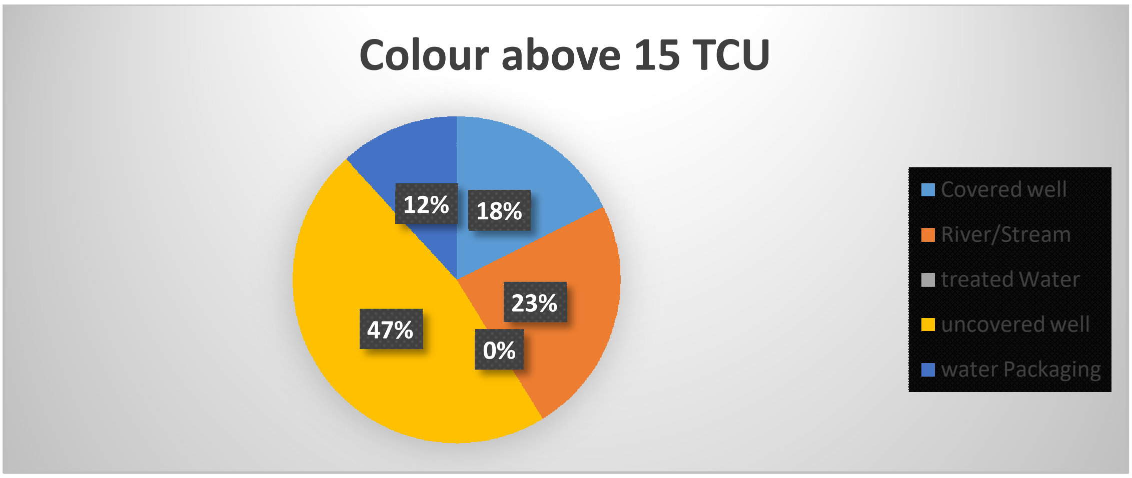

Figure 2: The chemical quality of drinking water from different sources and its impact on public health

The chemical analysis examined pH, copper, iron, and lead concentrations in different water sources. pH values ranged from 7.0 to 8.4, with a mean of 7.47. While most samples fell within WHO's recommended range (6.5 - 8.1), some exceeded 8.1, which may cause water scaling issues. Copper levels (mean: 0.0778 mg/L) were below WHO's guideline (2.0 mg/L), indicating no significant health risk. Wherein, Iron concentrations (mean: 0.025 mg/L) were within acceptable limits, meaning no major concerns regarding iron-related contamination. And no lead was detected, which is a positive outcome, as lead contamination can have severe health implications. Copper and iron levels were generally low and within safe limits, except for some minor variations. Importantly, no lead was detected in any of the samples, indicating that lead contamination is not a concern in the studied water sources. These results suggest that, chemically, the drinking water in Bombali District is mostly safe; however, monitoring is necessary, particularly for pH fluctuations that might influence other water quality parameters.

Table 6: ShowChemical Parameters

Chemical Parameters	Mean	Std Dev	Min	Median	Max	Mode
pH	7.47	0.4215	7	7.3	8.4	7.2
Copper (mg/l)	0.0778	0.1472	0	0.04	1.05	0.04
Iron (mg/l)	0.025	0.0305	0	0.02	0.19	0.01
Lead (mg/l)	0	0	0	0	0	0

From the laboratory results, it was clearly stated that 39/50 (78%) of samples fell within WHO's acceptable range (6.5 - 8.1), but 22% (mainly from uncovered wells) exceeded 8.1. And uncovered wells had the highest proportion of samples exceeding 8.1 which 8/11 (72.4%). The higher Ph level at some water sources may lead to unpleasant taste and corrosion of pipes, which can affect water taste and household plumbing.

Table 7: Water Source PH Compared with the WHO standard (6.5 - 8.1)

Water PH	**Covered Well**	**River/Stream**	**Treated Water**	**Uncovered Well**	**Water Packaging**	**TOTAL**
< 8.1	**6**	**3**	**1**	**21**	**8**	**39**
	15.4	7.7	2.6	53.8	20.5	100.0
	75.0	75.0	100.0	72.4	100.0	78.0
≥ 8.1	**2**	**1**	**0**	**8**	**0**	**11**
	18.2	9.1	0.0	72.7	0.0	100.0
	25.0	25.0	0.0	27.6	0.0	22.0
TOTAL	8	4	1	29	8	50

The microbial content of drinking water from different sources and its impact on public health

Microbiological analysis showed significant contamination across multiple sources, especially in uncovered wells and river/stream water. E. coli, faecal coliforms, and Salmonella were present in the majority of these sources, indicating faecal contamination and potential health risks. E. coli was detected in 87.64 CFU/100ml on average, with a maximum of 330 CFU/100ml, indicating severe contamination. And faecal coliforms (mean: 155.94 CFU/100ml) and Salmonella (mean: 95.54 CFU/100ml) exceeded WHO safety limits in multiple samples. Treated water and packaged water showed the least contamination, reinforcing the importance of water treatment for safe consumption. These findings emphasise the urgent need for improved water, sanitation, and hygiene measures, especially for households relying on uncovered wells and surface water sources. The high presence of these pathogens suggests contamination from human or animal waste, which poses a serious health risk, as bacterial contamination is linked to waterborne diseases such as cholera, typhoid, and diarrhoea.

Table 8: Show Microbial Parameter

Microbial Parameter	Mean	Std Dev	Min	Median	Max	Mode
E.coli (CFU)	87.64	71.0466	0	89	330	89
Fecal(CFU)	155.94	99.2764	0	157	410	130
Salmonella(CFU)	95.54	69.8328	0	90	298	90

Water Source E. coli Compared with the WHO Standard

With regards to E. coli concentration in water sources sampled, only 3 out of 50 samples had 0 CFU/100ml, meaning 94% of samples were contaminated. Uncovered wells (62%) and river/stream water (9%) had the highest contamination levels, indicating poor sanitation practices. Packaged and treated water showed minimal contamination. The above result might encourage water-related diseases. And waterborne illnesses like diarrhoea and cholera are a serious risk for individuals consuming untreated water.

Table 9: Water Source E. coliComparison with the WHO standard (CFU/100ml)

E. coli	Covered Well	River/ Stream	Treated Water	Uncovered Well	Water Packaging	Total
≥ 1 CFU/ 100ml	**8**	**4**	**0**	**29**	**6**	**47**
	17.0	8.5	0.0	61.7	12.8	100.0
	100.0	100.0	0.0	100.0	75.0	94.0
0 CFU/ 100ml	**0**	**0**	**1**	**0**	**2**	**3**
	0.0	0.0	33.3	0.0	66.7	100.0
	0.0	0.0	100.0	0.0	25.0	6.0
TOTAL	8	4	1	29	8	50

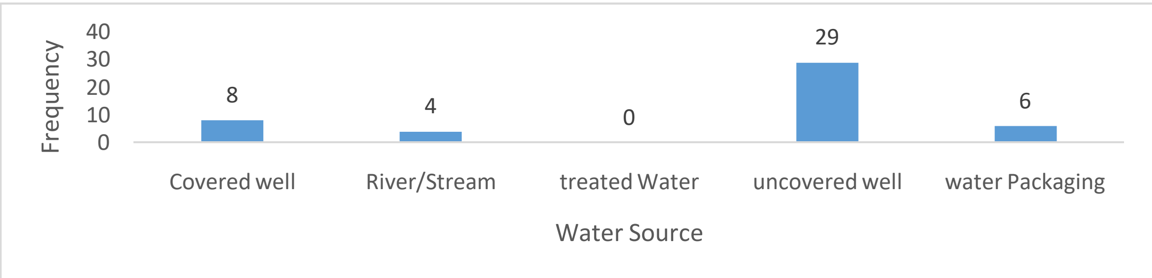

Figure 3: Water sources with their E. Coli concentration according to sample reading.

Faecal concentration

Again, the faecal concentration is very similar to the E. coli in readings, as 46/50 samples (92%) were contaminated beyond WHO limits. This suggests faecal pollution is widespread, making untreated water unsafe for consumption. Similar patterns were observed, with over 60% of uncovered well samples exceeding WHO safety standards. Treated water and packaged water showed the least contamination, reinforcing the importance of water treatment for safe consumption.

Table 10: Water Source FaecalConcentration Compared with the WHO standard (CFU/100ml)

Fecal concentration	Covered Well	River/Stream	Treated Water	Uncovered Well	Water Packaging	TOTAL
≥ 1 CFU/ 100ml	**8**	**4**	**0**	**29**	**5**	**46**
	17.39130435	8.695652174	0	63.04347826	10.86956522	100
	100	100	0	100	62.5	92
0 CFU/100ml	**0**	**0**	**1**	**0**	**3**	**4**
	0	0	25	0	75	100
	0	0	100	0	37.5	8
TOTAL	8	4	1	29	8	50

Water Source Salmonella Compared with WHO Standard; 92% of samples contained Salmonella, further confirming the presence of disease-causing bacteria. Packaged water and treated water showed lower contamination levels, reinforcing the need for proper water treatment before consumption. The existence of Salmonella increases the risk of typhoid fever and gastrointestinal infections, which impact the health of the communities where the samples were collected.

Table 11: Water Source Salmonella Compared with the WHO standard (CFU/100ml)

Salmonella	Covered Well	River/Stream	Treated Water	Uncovered Well	Water Packaging	TOTAL
≥ 1 CFU/ 100ml	**8**	**4**	**0**	**29**	**5**	**46**
	17.4	8.7	0.0	63.0	10.9	100.0
	100.0	100.0	0.0	100.0	62.5	92.0
0 CFU/ 100ml	**0**	**0**	**1**	**0**	**3**	**4**
	0.0	0.0	25.0	0.0	75.0	100.0
	0.0	0.0	100.0	0.0	37.5	8.0
TOTAL	8	4	1	29	8	50

Discussion

This study aimed to answer three key research questions regarding the physical, chemical, and microbial quality of drinking water and their associated public health impacts in Makeni City, Bombali District. The first research question examined how physical characteristics of water—turbidity, colour, total dissolved solids (TDS), and total suspended solids (TSS)—influence health outcomes. Findings revealed that uncovered wells and surface water sources such as rivers and streams exhibited turbidity and colour levels exceeding World Health Organisation (WHO) guidelines. Turbidity is a critical indicator as it can obscure pathogenic microorganisms, increasing the risk of gastrointestinal infections (Kumpel& Nelson, 2016; Levy et al., 2016). Colour, in turn, often signals contamination with metals or organic matter, which can make water unappealing and unsafe for consumption (EPA, 2020). Sources of colouration may include industrial effluents, corroded pipes, or naturally occurring organic materials, highlighting both anthropogenic and environmental influences on water quality (WHO, 2015, 2016; Kurbi, 2018). Elevated turbidity and colour not only reflect contamination but also indicate the potential presence of chemical and microbial hazards, reinforcing the need for continuous monitoring and treatment interventions (WHO/FWC/WSH, 2017).

The second research question assessed the chemical properties of drinking water, specifically pH, copper, iron, and lead levels. The average pH was 7.47, within the WHO's acceptable range of 6.5 to 8.1; however, some samples from uncovered wells exceeded 8.1, posing a risk of scaling in pipes and water infrastructure (U.S. EPA, 2020). Copper and iron concentrations were generally low, suggesting minimal immediate health risks. Lead, a highly toxic metal with well-documented neurological effects, particularly in children, was not detected in any samples, indicating a positive finding regarding chemical safety (Flora et al., 2019). Hardness and other minor chemical parameters were essentially within safe limits, reinforcing the relative chemical suitability of water from these sources. However, occasional deviations in pH and localised chemical anomalies highlight the need for periodic testing and maintenance of water supply systems. These results suggest that, while chemical contamination is not currently a significant concern, continued vigilance is required to prevent future hazards.

The third research question investigated microbial contamination, focusing on Escherichia coli, faecal coliforms, and Salmonella typhi. WHO guidelines recommend zero colony-forming units (CFU) of these microorganisms per 100 ml of drinking water. Alarmingly, 94% of samples tested positive for E. coli, and 92% were positive for faecal coliforms and Salmonella. Uncovered wells and surface water sources exhibited the highest levels of contamination. These findings are consistent with prior research, which demonstrates that shallow wells and surface sources are highly susceptible to faecal contamination due to poor sanitation, open defecation, and proximity to waste disposal sites (Bain et al., 2014; WHO, 2016). The presence of faecal coliforms indicates potential co-occurrence of other harmful pathogens, increasing the risk of waterborne diseases such as cholera, typhoid, dysentery, and persistent diarrhoea (Cabral, 2010; Ashbolt, 2004). Comparative studies in Malawi and other sub-Saharan African contexts confirm the vulnerability of similar water sources, reinforcing the urgent need for improved water treatment and sanitation interventions (Pritchard et al., 2020; Mapoma&Xie, 2014).

Limitations of the Study

Despite its contributions, this study has several limitations. The research focused solely on Makeni City, excluding other parts of Bombali District, which may limit the generalisability of findings. The sample size of fifty water sources was relatively small and may not capture the full variability of water quality across the district. Sanitation practices, water treatment methods, and broader water security issues were not assessed, yet these factors can significantly influence water safety. Time and financial constraints restricted the scope of laboratory testing and data collection. The use of purposive sampling, while practical for targeting representative water sources, may have introduced selection bias. Finally, environmental and seasonal variations in water quality were not considered, which may affect the reproducibility of results across different periods.

Recommendations

The findings of this study align with prior research on water quality challenges in developing countries and support the following recommendations. First, nationwide studies should be conducted by the Ministry of Water and Sanitation to provide a comprehensive assessment of water quality across Sierra Leone. Second, community health education should promote point-of-use treatment methods, including chlorination, filtration, and boiling, to reduce microbial contamination. Third, local authorities must invest in public sanitation infrastructure, including covering wells, constructing latrines away from water sources, and developing effective drainage systems. Fourth, public awareness campaigns should emphasise safe water handling, treatment, and storage practices to foster community participation in safeguarding drinking water. Fifth, policymakers, government agencies, and NGOs should collaborate to enforce water safety regulations and invest in sustainable water supply systems. These actions are crucial for reducing exposure to contaminated water and protecting public health in urban and peri-urban settings.

Implications for Social Change

This research contributes to social change by improving public health awareness and informing policy development in Sierra Leone. The enhanced dissemination of study findings empowers communities to make informed decisions about water use and treatment, thereby reducing the risk of waterborne diseases. The results provide evidence for policymakers to develop targeted regulations and interventions that address water quality challenges, creating systemic improvements. Healthcare professionals and NGOs can utilise the findings to implement targeted public health initiatives, ultimately improving health outcomes. Encouraging local community participation in protecting water sources fosters a sense of collective responsibility, which is critical for achieving sustainable health improvements. Promoting evidence-based practices supports the development of healthier living environments and strengthens resilience against water-related diseases. Ultimately, these interventions contribute to broader societal benefits, including improved quality of life, reduced healthcare burdens, and progress toward sustainable development goals.

Conclusion

This study confirms that many drinking water sources in Makeni City, particularly uncovered wells and surface water sources, present significant public health risks due to microbial contamination. While chemical parameters were generally within safe limits, physical factors such as turbidity and colour highlight ongoing water quality challenges. Urgent measures, including regular water quality monitoring, improved sanitation infrastructure, and comprehensive community education on water safety, are essential. Long-term solutions require investments in clean water technologies, policy enforcement, and equitable access to safe drinking water. Ensuring safe water is not only a health priority but also a social responsibility and a critical component of sustainable development. Community-driven initiatives combined with governmental support can substantially reduce the prevalence of waterborne diseases. Ultimately, improving water quality will enhance the overall well-being and resilience of residents in Sierra Leone and similar contexts.

References

Adnan, M., Khan, S., & Ahmed, A. (2019). Groundwater Nitrate Contamination and Associated Health Risks in Urban Areas*Environmental Monitoring and Assessment, 191*(3), 187. https://doi.org/10.1007/s10661-019-7279-0

Ahuja, S. (2013). *Monitoring water quality: Assessing pollution, analysing water quality, and implementing remediation*. Elsevier.

Al-Khatib, A., Hamed, S., & Al-Meer, S. (2023). Analysis of drinking water quality for public health. *Journal of Environmental Studies, 45*(2), 123-138.

Ashbolt, N. J. (2004). Microbial Contamination of Drinking Water and Public Health Risks. *Water Research, 38*(12), 2874-2884. https://doi.org/10.1016/j.watres.2004.03.028

Bain, R. E. S., Wright, J. A., Christenson, E., & Bartram, J. K. (2014). Rural: Urban inequalities in post-2015 targets and indicators for drinking-water. *Science of the Total Environment, 490*, 509-513. https://doi.org/10.1016/j.scitotenv.2014.05.007

Cabral, J. P. S. (2010). Water microbiology. Bacterial pathogens and water. *International Journal of Environmental Research and Public Health, 7*(10), 3657-3703. https://doi.org/10.3390/ijerph7103657

Chakraborti, D., Rahman, M. M., Ahamed, S., Dutta, R. N., Pati, S., & Mukherjee, S. C. (2016). Arsenic contamination of groundwater and its induced health effects in Shahpur block, Bhojpur district, Bihar state, India: Risk evaluation. *Environmental Science and Pollution Research*. https://doi.org/10.1007/s11356-016-6149-8

Crittenden, J. C., Trussell, R. R., Hand, D. W., Howe, K. J., &Tchobanoglous, G. (2012). *Water treatment: Principles and design* (3rd ed.). John Wiley & Sons.

EPA. (2009). *Drinking water quality and health standards*. U.S. Environmental Protection Agency.

EPA. (2021). *National primary drinking water regulations*. U.S. Environmental Protection Agency.

Flora, G., Gupta, D., & Tiwari, A. (2012). Toxicity of lead: A review with recent updates. *Interdisciplinary Toxicology, 5*(2), 47-58. https://doi.org/10.2478/v10102-012-0009-2

Haruna, R., Ejobi, F., & Kabagambe, E. K. (2005). The quality of water from protected springs in Katwe and Kisenyi parishes, Kampala city, Uganda. *African Health Sciences, 5*(1), 14-20.

Jang, J., Hur, H.-G., Sadowsky, M. J., Byappanahalli, M. N., Yan, T., & Ishii, S. (2017). Environmental persistence and replication of Escherichia coli in varying conditions: Implications for its use as an indicator organism in aquatic environments. *Microbial Ecology, 74*(3), 619-632. https://doi.org/10.1007/s00248-017-0970-5

Jimmy, D. H., Sundufu, A. J., Malanoski, A. P., Jacobsen, K. H., Ansumana, R., Leski, T. A., Bangura, U., Bockarie, A. S., Tejan, E., Lin, B., & Stenger, D. A. (2012). Water Quality-Associated Public Health Risks in Bo, Sierra Leone. *Environmental Monitoring and Assessment, 185*, 241-251. https://doi.org/10.1007/s10661-012-2548-6

Jimmy, I. O., & Ukpaka, C. P. (2012). Impact of turbidity on water quality and human health. *Journal of Environmental Science and Public Health, 6*(4), 1-10.

Karbi, G. (2018). Water Pollution Indicators in Urban Drinking Water. *Water Pollution Journal, 5*(1), 15-22.

Kargbi, I. (2018). Water Pollution and Its Public Health Implications. *African Journal of Public Health, 9*(3), 198-206.

Khan, M., et al. (2021). Waterborne diseases in different drinking water sources. *Water and Health, 16*(2), 104-113.

Khan, S., Ahmad, A., & Sadiq, M. (2021). Waterborne Diseases and the Role of Safe Water Supplies in Low-Income Settings. *Journal of Global Health Reports, 5*, e2021043. https://doi.org/10.29392/001c.25927

Kumpel, E., & Nelson, K. L. (2016). Intermittent water supply: Prevalence, practice, and microbial water quality. *Environmental Science & Technology, 50*(2), 542-553. https://doi.org/10.1021/acs.est.5b03973

Kurbi, M. I. (2018). Challenges in Water Quality Monitoring in Developing Countries. *Water Science, 32*(1), 15-24.

Lapworth, D. J., MacDonald, A. M., Krishan, G., Rao, M. S., & Gooddy, D. C. (2017). Groundwater quality in the Indo-Gangetic Basin. *Environmental Science & Technology, 51*(1), 556-563. https://doi.org/10.1021/acs.est.6b03838

Levy, K., Woster, A. P., Goldstein, R. S., & Carlton, E. J. (2016). Untangling the impacts of climate change on waterborne diseases: A systematic review. *Environmental Science & Technology, 50*(10), 4905-4922. https://doi.org/10.1021/acs.est.5b05950

Lin, J., et al. (2022). Water pollution and its impacts on public health: Global perspectives. *Public Health Reviews, 43*, 12001. https://doi.org/10.3389/phrs.2022.12001

Mohsin, M., Safdar, S., Asghar, F., & Jamal, F. (2013). Assessment of drinking water quality and its impact on residents' health in Bahawalpur City. *International Journal of Humanities and Social Science, 3*(15), 114-128.

Mohsin, M., Safdar, S., Asghar, F., & Jamal, F. (2013). Assessment of drinking water quality and its impact on residents' health in Bahawalpur City. *International Journal of Public Health Science, 4*(1), 52-65.

Murphy, J. L., et al. (2017). Typhoid fever and water contamination in Kampala: Public health implications. *Journal of Infectious Diseases, 216*(Suppl 1), S293-S298. https://doi.org/10.1093/infdis/jix293

Mwabi, J. K., Mamba, B. B., &Momba, M. N. B. (2011). Removal of Escherichia coli and faecal coliforms from surface water and groundwater by household water treatment devices/systems: A sustainable solution for improving water quality in rural communities of Africa. *Water SA, 37(*4), 479-486.

Prüss-Üstün, A., Bartram, J., Clasen, T., Colford Jr., J. M., Cumming, O., Curtis, V., & Freeman, M. C. (2014). Burden of disease from inadequate water, sanitation, and hygiene for selected adverse health outcomes. *Tropical Medicine & International Health, 24*(5), 551-568. https://doi.org/10.1111/tmi.13389

Prüss-Üstün, A., Bos, R., Gore, F., & Bartram, J. (2008). *Safe water, better health: Costs, benefits and sustainability of interventions to protect and promote health*. WHO Press.

Ramakrishnaiah, C. R., Sadashivaiah, C., &Ranganna, G. (2008). Assessment of the Water Quality Index for Groundwater in Tumkur Taluk, Karnataka State, India. *E-Journal of Chemistry, 6*(2), 523-530. https://doi.org/10.1155/2009/757901

Sako, T., Jabbari, F., & Raji, I. (2020). Physicochemical analysis of water sources in Sierra Leone. *Journal of Water Research, 65*(2), 112-121.

Sobur, A., et al. (2019). Public health significance of antibiotic-resistant E. coli and Salmonella spp. from dairy farms. One Health, 8, 100105. https://doi.org/10.1016/j.onehlt.2019.100105

Sogaard, E. G. (2014). *Chemistry of advanced environmental purification processes of water*. Elsevier.

Srinivas, K., Venkatesh, B., & Shankar, A. (2015). Environmental challenges in the developing world. *Journal of Environmental Science, 39*(1), 17-25.

U.S. Environmental Protection Agency (EPA). (2020). *National recommended water quality criteria—Human health criteria*. U.S. Environmental Protection Agency.

United Nations (UN). (2009). Water in a changing world. UN World Water Development Report

United Nations (UN). (2013). *The Millennium Development Goals Report.*

Water Science School. (n.d.). *Turbidity and water*. U.S. Geological Survey. Retrieved from https://www.usgs.gov/

World Health Organisation (WHO) & UNICEF. (2015*). Progress on Sanitation and Drinking Water: 2015 Update and MDG Assessment*. New York: UNICEF.

World Health Organisation (WHO). (1984). *Guidelines for drinking-water quality*. Geneva: World Health Organization.

World Health Organisation (WHO). (2008). *Guidelines for drinking-water quality* (3rd ed.). Geneva: World Health Organisation.

World Health Organisation (WHO). (2013). *Iron in drinking water*. Geneva: World Health Organisation.

World Health Organisation (WHO). (2016). Water safety planning for small communities. Geneva: World Health Organisation.

World Health Organisation (WHO). (2017). Water Quality and Health Strategy 2013-2020. Geneva: World Health Organisation.

World Health Organisation (WHO). (2022). *Guidelines for drinking-water quality*. Geneva: World Health Organisation.