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REVIEW ARTICLE

MICROBIAL CONTAMINATION OF SURFACE WATER SOURCES IN NIGERIA: A REVIEW

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ABSTRACT

The microbiological quality of surface water has become a determining factor in water safety, usability and ecological sustainability. Surface water in most developing countries is frequently contaminated by faecal waste because of the typically poor sanitation practices both in rural and urban areas. This has resulted in water-related illnesses, including cholera, typhoid, polio, diarrhoea, dysentery, gastroenteritis, and wound infections, which are caused by water-borne microorganisms. This study investigated perspectives on microbial pollution of surface water sources in Nigeria. The objectives examined pollution pathways, public health implications, and management strategies. This study utilized the PRISMA 2020 systematic literature review methodology, which helped to provide a comprehensive overview of the current state of research in microbial contamination of surface water sources. A wide-ranging literature search identified 82 records from different electronic databases including Scopus, Research Gate, Google Scholars and Web of Science, the screening of subject title and abstract including the elimination of duplicates and irrelevant records. The outcome clearly revealed that Nigerian surface water resources are grossly contaminated with microorganisms exceeding water quality standards for surface water in most cases. The potential pollution sources and pathways identified included areas with high commercial activities around river catchments and direct exposure to open defecation. There was a high prevalence of microorganisms including Escherichia coli, Shigella spp., Salmonella spp., Klebsiella spp, Proteus spp., Bacillus sp., Staphylococcus spp. and several coliform bacteria including Faecal and total coliforms across the investigated water bodies. Microbial pollution pathways identified in this investigation were linked to indiscriminate waste disposal, runoff from agricultural lands, untreated domestic wastewater, and commercial activities occurring near water bodies. Therefore, developing and implementing efficient strategies to prevent and control microbiological pollution through routine water monitoring plans, improved water safety plans, sanitation, and waste management including real-time monitoring technologies is essential for the reduction of microbial contamination as well as protecting public health in Nigeria.

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1.0 Introduction

Water has become a substantial environmental resource useful for the preservation of public health, ensures food security, protect environmental sustainability, and fostering industrial and economic growth (Paruch & Paruch, 2022; Peters & Meyers, 2015). Despite its importance, a substantial proportion of surface water resources are unsuitable for domestic use due to pollution associated with human activity, such as untreated industrial waste, runoff from agricultural and waste from surrounding urban environment into water bodies (Egesi *et al.*, 2023; Xiao *et al.*, 2021). Surface water quality over time exhibited considerable spatial and temporal fluctuation as a result of seasonal variations, climatic conditions, and human activities. Therefore, continuous assessment is necessary to ensure water resource sustainability, management and prevention of pollution. (Paruch & Paruch, 2022).

In Nigeria, pollution of surface water bodies such as rivers, dams, stream systems had increased in recent years. This situation had been attributed to urbanization, unplanned industrial expansion, agricultural practices, uncontrolled development along riverbanks, and rapid population growth (Ogbe *et al.,* 2025). In addition, surface water was frequently contaminated by faecal waste because of the typically poor sanitation practices both in rural and urban area. This faecal contamination of water had become a significant threat to public health and to the ecosystem at large (Amatobi & Umezuruike, 2023). Faecal pollutant was a major route for transmission of diseases especially for large scale epidemic that propagated waterborne infections aside from food consumption (Ichor *et al.,* 2014). Some of the key water quality indicators including pH, BOD, DO, chloride levels, and microbiological contaminants had generated concerns because they frequently failed to meet regulatory standards in Nigeria (Amatobi & Umezuruike, 2023; Ichor *et al.,* 2014).

The microbiological surface water quality was another critical factor in assessing its overall quality, safety, usability and ecological sustenance (Amachree *et al.,* 2025; Odagiri *et al*., 2016; Ichor *et al.,* 2014). It was widely recognized that contaminated water served as a major transmission pathway to microbial pathogen posing, public health risk through the spread of water related diseases that can result to illness and mortality (Tenebe *et al.,* 2024; Babatimehin *et al.,* 2017). Human health concerns from microorganisms may occur directly or indirectly. Indirect health risks arise from direct contact with contaminated water during recreational activities or harmful algal bloom events as well as the consumption of polluted farm crops and aquatic food (Lawal *et al.,* 2024; Jurbe *et al.,* 2023). Waterborne diseases including cholera, typhoid viral hepatitis, polio, paratyphoid fever, dysentery, salmonellosis were transmitted through consumption of water contaminated with microorganisms. other water-based diseases such as schistosomiasis infection which occurred when there was contact with freshwater containing infected Schistosoma larvae (Ichor *et al.,* 2014).

These diseases had resulted in serious health difficulties and thousands of mortalities (Lawal *et al.,* 2024). For instance, a cholera outbreak in Nigeria in 2024 infected 5,951 individuals and 176 fatalities (NCDC, 2025), the most affected age group was children under five years followed by adults between 25–34 age range (NCDC, 2025; Tenebe *et al.,* 2024; Sow *et al.,* 2022). The persisting nature of this public health issue was further demonstrated by cholera outbreak in 2021 which was linked to 3,604 recorded deaths (Ayeni & Okonkwo, 2023). The causative organisms were usually found in human and animal faeces of infected persons which entered waterbodies used for household domestic activities (Ichor *et al.,* 2014).

It is noteworthy that Nigeria possesses abundance of natural water resources, such as surface and groundwater which are underutilized (Isukuru *et al.,* 2024). Conversely, several studies had shown the current condition of surface water bodies in Nigeria having significant pollution level which poses serious public health risk and danger to aquatic environment. For instance, Ichor *et al.,* (2014) investigated microbial pollution of water sources in rural areas of Benue State and identified microbial contamination levels higher than that of WHO's acceptable limit for drinking water. Also, Tenebe *et al.,* (2024) examined physicochemical and bacteriological contaminant such as total coliform count (TCC), heterotrophic plate count (HPC) and faecal coliform count (FCC) in a stored drinking river water in Benin City. The findings revealed that although physicochemical indicators met drinking water standard, the microbial contaminant counts exceeded WHO limits with higher count of total coliform. Similarly, Ozochi *et al.,* (2024) investigated microbial risk of pathogenic *Vibrio cholerae* in a River used for drinking and other domestic purposes in Enugu metropolis. It was observed that *V. cholerae* was present with highest risk range of ~ 0.9 associated, with exposure through drinking water. Amatobi & Umezuruike, (2023) conducted a microbial risk assessment of household drinking water sources in Eboyin State South-east Nigeria, the outcome revealed high risk of diarrhea across all drinking water sources examined, with value ranging from 0.032 to 0.090.

Despite the extensive evidence of microbial contamination in surface water and its association with public health problems, significant gaps remained in the integrated synthesis, the distribution, magnitude, temporal inconsistency, microbial indicators, pollution sources, and associated health risks reported across Nigeria. Existing studies focused primarily on location-specific, and vary in sampling techniques, analytical designs, microbiological indicators and reporting standards making it difficult to compare results and draw conclusion at national level. Although some studies had applied microbial risk assessment, a detailed analysis linking contamination levels with possible human exposure and associated health consequences remained limited in the literature. Therefore, a comprehensive assessment of the existing evidence is necessary to understand microbiological contamination dynamics, identify major microbial contaminants, pollution sources and assess associated health concerns. This study addressed this knowledge gap and promoted evidence-based water resource management. Specifically, this review investigated perspectives on microbial contamination of surface water sources in Nigeria. The objectives investigated pollution pathways, public health implications, and management strategies.

2. Method

This study used a systematic literature review method such as the Preferred Reporting Items for Systematic Review and Meta-Analysis (PRISMA 2020) (Haddaway *et al.,* 2022), which helped to provide a comprehensive overview of the current state of research in microbial contamination of surface water sources. A literature search gathered 410 records from different bibliographic databases, academic search engines and other supplementary data base platform including Google Scholar, Research Gates, Scopus and Web of Science. The reviewed literature comprised conference proceedings, journal articles, book chapters, dissertations, case report and data papers, all related to perspectives on microbial pollution on surface water sources, pollution pathways and public health implications. A total of 271 records were screened based on their tittles and abstracts after removing duplicates and irrelevant records. After screening, 196 reports were sought for retrieval while 75 records were excluded and 69 records could not be retrieved. Similarly, 127 full-text publications were evaluated for suitability after, 82 studies were included in the final systematic review after exclusion of 45 record of non-English Language reports. Figure 1 shows the PRISMA flow diagram.

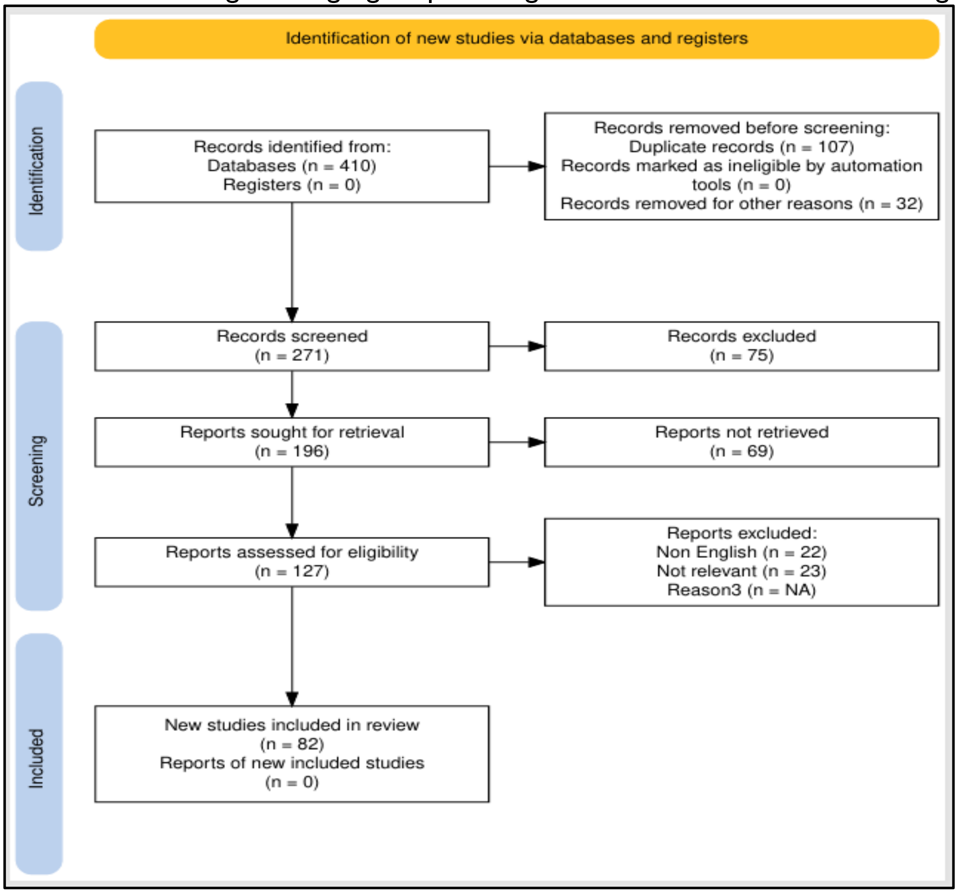

Figure 1: PRISMA flow chart

3. Overview of Surface Water Resources in Nigeria

Nigeria is endowed with an abundance of water resources for several uses (Nouban *et al.,* 2020). This included surface and groundwater resources, encompassing both major and minor rivers and dams, the exact scope of which was impossible to estimate because of differences caused by seasonal variations and geographical disparity (Ibrahim *et al.*, 2022). However, access to clean water has become a major challenge in the country with increasing water scarcity for different demands (Omokaro *et al.,* 2024; Ibrahim *et al.,* 2022). Interestingly, Nigeria has many Rivers used for many purposes. However, Lohdip & Gongden, (2013), reported the major rivers as Niger and Benue Rivers which span approximately 10,812,400 hectares, or 11.5% of the country's estimated 94,185,000 hectares of surface area. The country also featured a reasonably close network of rivers and streams which enables an efficient drainage flow as in Figure 2a. The five primary drainage systems in Nigeria include the Niger-Benue River, Lake Chad Basin, Cross River, Anambra, and Ogun-Oshun River Basins. (Figure 2b) (Oguntade *et al.,* 2014). The water bodies are separated into freshwater, saltwater deltas and estuaries. Freshwater covers roughly 3,221,500 hectares, in contrast, the total surface area of the deltas and estuaries, with their saline wetlands, is 858,000 hectares. Approximately 1% of Nigeria's total geographical area is made up of thirteen lakes and reservoirs with surface areas ranging from 4000 to 550,000 (Ibrahim *et al.,* 2022). There are numerous smaller streams and canals, lakes, and ponds, which also contributed to the country's drainage basin network (Doro *et al.,* 2020). The runoff volumes from drainage basins vary greatly and are equally influenced by a number of variables, including rainfall intensity and volume, vegetation and climate, topography and geology of the region. In addition to river drainage systems, FOA (2016) estimated that the country has 264 dams with a combined capacity of 37.46 billion cubic meters (BCM). This capacity represents roughly 10% of Nigeria's total potential water resources (Omokaro, *et al.,* 2024).

The groundwater in Nigeria also exhibited spatial variability that was influenced by geology and climate (Abugu *et al.,* 2024; Ejepu, 2020). The region's hydrogeology regulates groundwater resources, which are usually based on the occurrence patterns of aquifers, aquitards, or aquicludes (Aladejana *et al.,* 2021). Due to the hydrological cycle, groundwater and surface water are practically one resource. Most of the water on and above the earth's surface is continuously circulated through various processes known as hydrological circle (Tijani, 2017). The groundwater is equally known to be largely free of sediments and biological contaminants (Tijani, 2017); therefore, it is typically suitable and adequate for domestic, agricultural (irrigation and livestock watering), and industrial uses (Ibrahim *et al.,* 2022; Idu, 2015). It has been asserted that over 110 million people worldwide access water for domestic use from lakes, ponds, or streams while nearly 300 million lack an improved water supply, and about 282 million have limited access to potable water (Dhiman *et al.,* 2026; Isukuru *et al.,* 2024; Khilchevskyi & Karamushka, 2022). Access to drinkable water is still a big problem in Nigeria, with significant proportion of the population lacking reliable access to safe water. Interestingly, approximately 42% of residents in urban and semi-urban areas have access to clean water, compared to 71% of those in rural areas (Isukuru *et al.,* 2024; Ezeudu, 2020; Yahaya *et al.,* 2020). Available water resources are estimated to 14.3% of its land area which contrasts sharply with the rate at which freshwater was being consumed (Ehinomen *et al.,* 2018). This was increasing annually due to a number of factors, such as population growth, urbanization, and an increase in industrial activities (Pona *et al.,* 2021; Yahaya *et al.,* 2020).

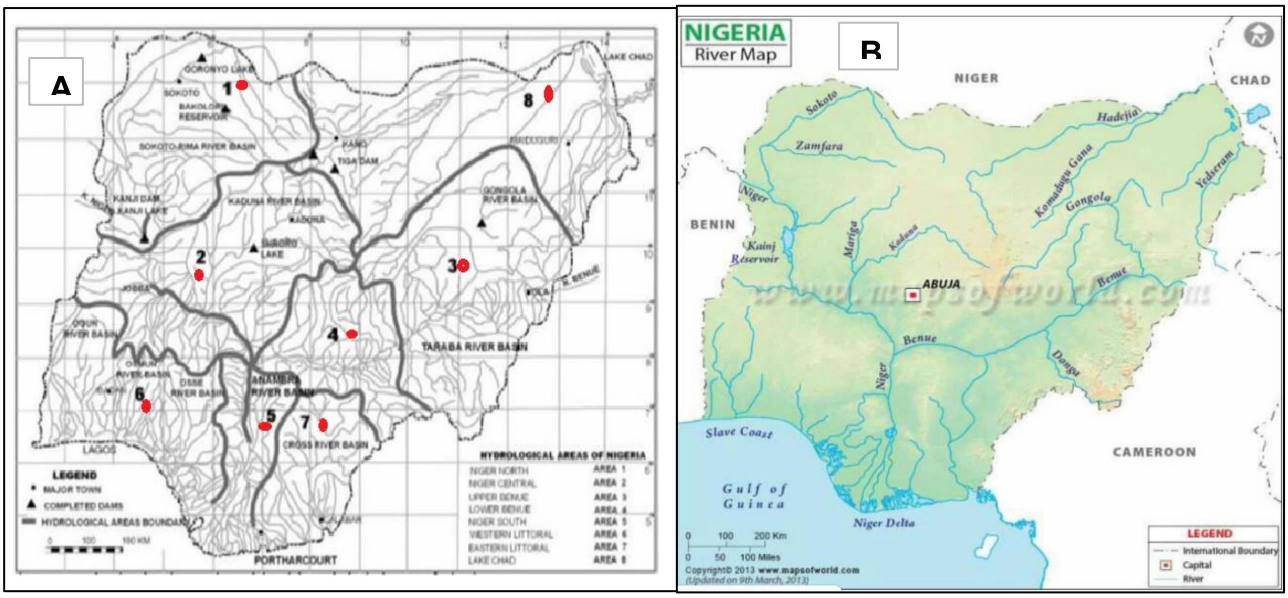

Figure 2: a) Hydrological pattern of Nigeria and b) River basin map (Oguntade *et al.,* 2014; Lohdip & Gongden, 2013)

3.1 Microbial Contamination Pathways

Water bodies such as rivers, lakes, oceans, groundwater, and aquifers become unsuitable for aquatic life, human consumption, and other ecological processes when they are contaminated. This occurred when contaminants such as chemicals, garbage, microorganisms, and toxins were introduced into water sources in quantities greater than what the ecosystem can naturally self-clean (Innocent & Olusegun, 2019). The identified pollution pathways are presented in Figure 3. It demonstrated the conceptual framework through which human populations were exposed to microbiological contaminants originating from human and animal excreta

(Chigor *et al.,* 2019). The framework recognized human and animal waste as the primary sources of harmful microorganisms including bacteria, viruses, protozoa, and helminths. These sources represented the initial points of contamination in the environmental system where pollution occurred (Wang *et al.,* 2022). Environmental exposure pathways and sanitation-related pathways were the two main transmission domains depicted in the process (Chigor *et al.,* 2019). The spread of pathogens from excreta into surface water and underground aquifers increased the likelihood of widespread pollution (Mattioli *et al.,* 2015). The pollution pathways included leakage from pit latrines, sewage networks, and inappropriate wastewater disposal (Lin *et al.,* 2022; WHO, 2017). This result was a continuous cycle of transmission, particularly in Nigeria, where poor waste management and limited sanitation infrastructure existed.

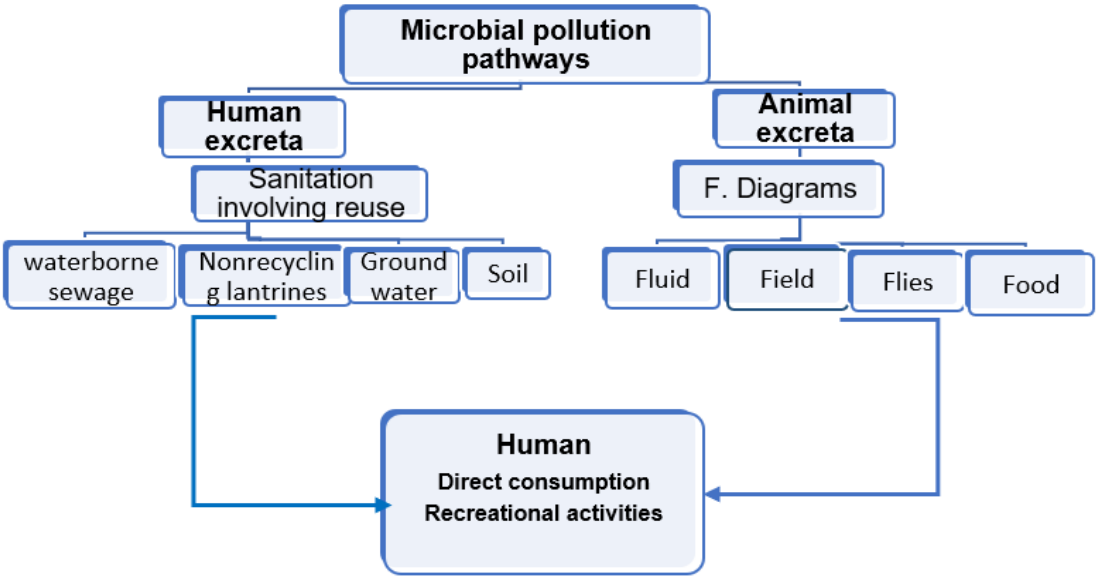

Figure 3: Framework of microbial pollution pathways. (Source: Chigor *et al.,* 2019).

4. Microorganisms Contaminants Identified in Surface Waters

Microorganisms are present in most natural streams and are widely distributed in nature. Their diversity and abundance serve as indicators of water quality for aquatic animals, especially fish species (Okaa *et al.,* 2024). The presence and prevalence of microorganisms reflect the quality of available water. Furthermore, certain microorganisms in water can be regarded as native, while others might be considered as pollutants, depending on their reactions and activities. The concentration of these microorganisms in water varies depending on the shedding rate, population size and the level of wastewater discharged into the water body (Okaa *et al.,* 2024). Table1 provides comprehensive information on selected microorganisms affecting different water sources including microorganisms that have been identified in Nigerian surface water body (Ozochi *et al.,* 2024; Amatobi & Umezuruike, 2023).

Table 2 presents microbial indicators of water sources and habitat grouping. Studies in the literature had identified some of these indicators in surface water bodies in Nigeria (Tenebe *et al.*, 2024; Okaa *et al.,* 2024; Ozochi *et al.,* 2024; Amatobi & Umezuruike, 2023). These indicators facilitate the identification of specific changes in microbial communities, including individual organisms, populations, ecological groups and their responses to environmental stimuli (Weller *et al.,* 2020). Microbial indicators play an essential role in detecting changes in water bodies and accessing environmental situations (Zaghloul *et al.,* 2020). Bio-indicators are microorganisms that are considered useful indicators of environmental pollution (Logares *et al.,* 2020). These bioindicators are classified into two categories, accumulation indicators and response indicators. The accumulation indicators store pollutants within their tissues or surrounding environments whereas, response bioindicators react to pollutants through circular changes in cell or visible signs of damage when exposed to harmful substances (Majumdar *et al.,* 2020).

4.1 Pollution Sources

The pollution sources presented in Figure 4 included agricultural runoff, municipal sewage, urban runoff / flooding, industrial effluents, and natural factors. These sources significantly contributed to the microbial pollution of surface water bodies on a global scale including those in Nigeria. These sources of pollution further created significant entry points for viruses into surface water systems thereby increasing the risk of waterborne illnesses and environmental deterioration.

Table 1: Microorganism in water sources

S/N	Pathogen	Types of Species	Health Implication	Duration in water
A		**Bacteria Organisms**		
1	*Burholderia*	*B. pseudomallei*	High	multiplying in host
2	*Campylobacteria*	*C. Coli & C. jejuni*	High	multiplying in host
3	*Escherichia coli-*	*Diarrhoea*	High	minimal duration
4	*E. coli*	*E. coli* OIS7	High	minimal duration
5	*Francisella*	*F,tularensis*	High	longer duration
6	*Shigella*	*S. dysenteriae*	High	short duration
7	*Vibrio*	cholerae 01&0139	High	short/high duration
B		**Virus Organisms**		
1	Adenoviridae	Adenoviruses	Moderate	long duration
2	Astroviridae	Astoroviruses	High	long duration
3	Hepeviridae	Hepatitis E. virus	High	long duration
4	Reoviridae	Rotaviruses	High	Long duration
C		**Protozoa**		
1	*Acanthamoeba*	*A. culbertsoni*	High	multiplying host
2	*Cryptosporidium*	*C. hominis/parvum*	High	Longer duration
3	*Cyclospora*	*C. cayetanensis*	High	Longer duration
4	*Entamoeba*	*E. histolytica*	High	minimal duration
5	*Helminths Dracunculus*	*D. medinensis*	High	minimal duration

Source: (WHO, 2023)

Table 2: Microorganisms Indicators in Water Body

S/N	**Indicator Organisms**	**Organism Group**
1	Faecal coliforms	Faecal indicator
2	Total coliforms	Total coliforms
3	*Escherichia col* (*E. coli*)	Faecal indicate
4	Faecal streptococci	Faecal indicate
5	Enterococci	Faecal indicate
6	*Bacteroides*	Faecal indicate
7	*Clostridium perfringens*	Faecal indicator
8	*Bifidobacteria*	Faecal indicator
9	Bacteriophages (phages)	Model Organism

(Source: WHO, 2023)

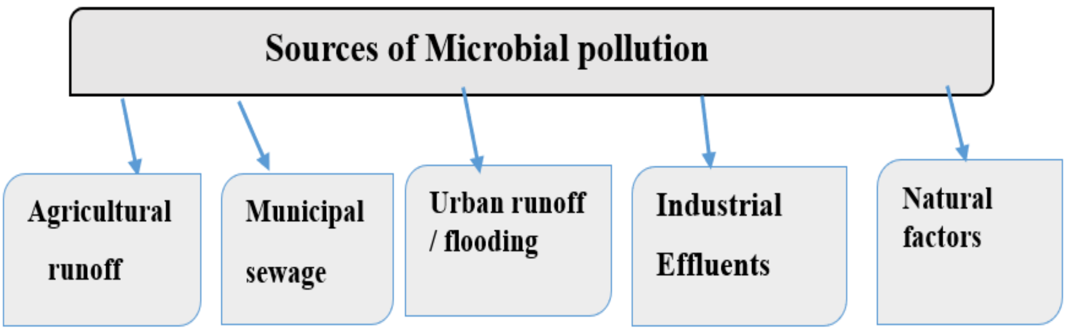

Figure 4: Common pollution sources

i. **Agricultural processes / Storm runoff:** The application of chemicals such as pesticides, insecticides, fertilizers and other agrochemicals in crop production remained a major environmental concern as well as pathway to water pollution. (Ifeanyi-Amalin, 2024; Sravani & Saritha, 2023) In Nigeria for instance, agricultural runoff has been connected to surface water contamination in several rivers including River Niger and River Benue, Kaduna catchment Rivers and Ogun River (Idris, 2021; Oguche *et al.,* 2022; Abdulkadir & Abubakar, 2019). A study by, Idris, (2021) examined how agrochemicals affected the soil and water quality in the catchments of the River Niger and Kadunam River. The study established that mineral elements such as phosphate, nitrate, and nitrite, were spatially dispersed throughout the sampled water. The area studied revealed that the soil and water were contaminated by a number of organochlorine pesticide compounds. Abdulkadir & Abubakar, (2019) investigated the impact of agricultural activities on water quality in Suleja Dam in Niger state. The findings showed that bacteria (Coliform and *E. coli*) were present in every sampled location especially during the rainy season indicating the impact of agricultural runoff on microbial pollution. Other agricultural activities that contributed to the introduction and transport of microorganisms into water bodies included overgrazing and frequent ploughing, poor animal feeding operations, improper application of fertilizers and excessive irrigation (Kodiya *et al*., 2025; Khanna & Gupta, 2018; Divya & Belagali, 2012).

ii. **Municipal sewage waste**: Insufficient and improper sewage treatment facilities caused household and human waste to be discharged directly into rivers and coastal seas. The increased rate of illegal dumping of municipal solid waste was becoming alarming (Isukuru *et al.,* 2024). In Nigeria, approximately 50% of the total human wastes generated were discharged into the surface water without proper treatment (Jamwal, 2018). Furthermore, studies from literature had also confirmed that illegal disposal and dumping of unprocessed solid wastes remained a contributing source of pollution of surface waters. (Fayomi *et al.,* 2025; Ogbonna & Ajubo, 2017; Ochuko & Thaddeus, 2013). Significant microbial counts, including total coliforms, heterotrophic bacterial counts, and faecal contaminants, were found to be responsible for microbial accumulation in water bodies.

iii. **Urban Storm runoff / flooding:** Urban stormwater runoff flows along with municipal waste, industrial effluents, and commercial pollutants into surface waterbodies. These pollutants contributed to microbial contamination, environmental degradation and deterioration of surface water bodies in Nigeria (Eze *et al.,* 2026; Fayomi *et al.,* 2025). The increased acceleration of urban runoff flow which transport wastewater and debris from untidy environment into the surface water bodies was continuously increasing the microbial activities in surface water bodies (Eze *et al.,* 2026). Flooding had also contributed to the degradation of water quality (Amatobi & Adenaike, 2021), where, increased bacteriological parameters in a surface water after a rainfall event was observed in Anambra State.

iv. **Industrial Effluents**: Industrial effluents had affected several waterbodies in Nigerian (Abdulsalam *et al.,* 2023; Salisu & Bichi, 2020). Industries frequently discharged untreated waste into nearby water bodies especially in major industrial cities across Nigeria. These pollutants may contain chemical pollutants, organic matter, heavy metals and nutrients that may have a negative impact on water quality and aquatic habitats. Osibanjo *et al.,* (2011), reported that nutrients elements such as nitrate and total phosphorus accumulated in River Ona and River Alaro within the Oluyole Industrial Estate in Oyo State. The industrial expansion and uncontrolled urbanization have increased population growth and economic activities in urban and peri-urban areas thereby intensifying pressure on available water resources (Adegoke *et al.,* 2023). The constant discharge of untreated industrial effluents may affect the physicochemical properties of receiving water bodies and promote the growth of microorganisms

v. **Natural Factors:** Various natural processes such as biological, geological and physical factors including rising sea level, melting glaciers, volcanic activities, underground rocks discharge, atmospheric haze, rainwater and stormwater can act as natural pathways that represent potential pathways for microbiological contamination (Kelman *et al.,* 2020). In Nigeria, Edegbene *et al.,* (2025), detected microorganisms such as *Klebsiella sp., Proteus sp., Shigella sp., Bacillus sp., Escherichia coli and Staphylococcus spp*. in selected surface water sources in Benue South, Nigeria. Most of these contaminations were associated with widespread adsorption, diffusion, heating, cooling, evaporation and exchange of gas in the atmosphere (Kelman *et al.,* 2020). These processes can become very crucial during periods of heavy rainfall when stormwater runoff may transport and introduce microbial contaminant into surface waterbodies.

5. Public Health Implications Caused by Microbial Pollutants

Drinking water contaminated by microorganisms and water-borne pathogens can lead to severe public health illnesses such as cholera, dysentery, diarrhoea, hepatitis, and typhoid fever (Chigor *et al.,* 2019; Ubani *et al*., 2014; Mazvimavi *et al.,* 2022). The consumption of contaminated water contributed to an estimated 485,000 diarrheal fatalities annually, with substantial proportion occurring in sub-Saharan Africa including Nigeria. (Amatobi & Umezuruike, 2023). Nigeria had experienced one of the highest rates of cholera in its history with records of 111,062 cases and 3,604 fatalities. For instance, in 2020, 144,724 deaths in Nigeria were attributed to diarrheal related diseases accounting for 9.77% of all casualties (Water Aid, 2023, Ayeni & Okonkwo, 2023). In 2024, cholera outbreak in Nigeria affected 5951 individuals and resulted to 176 fatalities. Children under five years of age were the most affected, followed by those between the ages of 25 and 34 (Tenebe *et al.,* 2024; Amatobi & Adenaike, 2021). Diarrhea is typically a sign of an intestinal tract infection caused by a number of bacterial, viral, protozoan, or parasitic organisms. This water related diseases can be categorized into water-washed, water-based diseases and water related vectors as presented in Table 3. The associated illnesses include diarrheal diseases, skin infections, typhoid, Scabies, dysentery among others (Ozoh *et al*., 2021; WHO 2017; WaterAid, 2023). Bacterial intestinal infections account for more than 50% of diarrhoea diseases cases. Furthermore, diarrhoea remained a major cause of death for children under five years of age contributing substantially to world's disease burden (WHO, 2017). Waterborne infections can also be transmitted through inhalation of aerosols and through contact with the skin and mucous membranes during bathing (Mazvimavi *et al.,* 2022).

Table 3: Diseases associated with the presence of pathogens in water

Water Borne Disease Categories	Pathogen / Water nature	Related Illnesses
Water-washed a) Skin and eyes infection b) Diarrhoeal diseases	Poor access to clean water and sanitation	Typhoid, legionellosis, Poliomyelitis, Scabies, trachoma, bacillary dysentery
Water-based diseases a) Skin transmissible infection b) Ingested	Contagion by causative agent that live their life cycle in water	Schistosomiasis
Water-related vectors a) Vectors that bite near water b) Breeding host in water	Transmissible through vectors that breed in host and bite near water	Malaria, West Nile Fever

(Source: WHO, 2023)

5.1 Review of Microbial Assessment Studies in Nigeria

Table 4 summarizes the selected microbial assessment studies in Nigeria. It presents the study purpose and the contribution to understanding microbial pollutants in surface water bodies. The findings revealed both strengths and opportunities as well as weaknesses and threats, associated with microbial water quality management in Nigeria. Collectively, the studies provided substantial evidence of widespread occurrence of microbial contamination across different water sources and geographical regions in Nigeria. The contamination occurred across diverse water sources, such as rivers, streams, boreholes, wells, packaged bottled water, sediments, and water supplies in school environments. Continuous pressures from human activities including stormwater runoff which may further transport faecal contaminants to surface and groundwater represented a major threat to microbial water quality. Despite this substantial evidence, the bulk of the studies were geographically restricted to specific rivers, localities, local government area, or particular water-use areas, which limited the applicability of their findings to Nigeria as a whole. Additionally, most of the studies relied on conventional culture-based microbiological assessment methods and thus, provided limited information regarding real-time monitoring technologies. The available evidence offered an opportunity to strengthen comprehensive microbiological water quality monitoring in Nigeria.

6. Discussions

The study revealed that most Nigerian River water system used directly for domestic purposes were grossly contaminated with microorganisms exceeding water quality standards in most cases. Microbial pollution was predominantly driven by human activities including poor sanitation and deficiency of sanitation infrastructure, runoff from agricultural land, indiscriminate waste disposal and management. Other key sources and pathways included untreated domestic wastewater, and commercial activities in proximity to waterbodies, as well as direct pollution connected with open defecation. These activities had frequently been linked to elevated faecal coliforms, and other pathogens in waterbodies, thereby degrading water quality and increasing potential public-health risks. Seasonal variability had equally been identified as a major factor influencing microbial pollution in waterbodies. The increased pollution of microorganisms during the rainy season, may happen due to stormwater runoff transporting suggest that pathogens, organic wastes, faecal matter and pathogenic microorganisms into the waterbodies from surrounding urban areas into surface waterbodies.

The extensive detection of microorganisms including *Escherichia coli, Shigella spp., Salmonella spp*., and several coliform bacteria across different regions in Nigeria strongly suggested that faecal contaminant originating from human and animal waste contributed meaningfully to the contamination of water systems. Udoh *et al*., (2021) also identified inadequate water treatment as a significant contributor to microbial contamination especially in bottled water intended for direct consumption. Their findings highlighted deficiencies in water treatment systems as well as post-treatment handling and management practices. Similarly, Amachree *et al*., (2025) and Okaa *et al*., (2024) reported that interaction between sedimentation and surface water interaction can constitute a potential pathway for microbial contamination. The detection of microbial contaminants both in sediments and surface waters indicated that sediments could act as a reservoir for range of pathogenic microorganisms, which, if subjected to favourable environmental circumstances, might then be discharged into the overlying water.

Table 4: Review of Microbial Studies in Nigeria

Authors	Study purpose	Key findings
Edegbene *et al.*, (2025)	investigated physico-chemical and microbial characteristics of water quality in Benue South.	Microorganisms detected include *Klebsiella sp., Proteus sp., Shigella sp., Bacillus sp., Escherichia coli and Staphyloccus* sp. The sites had elevated total coliform counts exceeding WHO limit
Okaa *et al.*, 2024	evaluated the microbiological quality of sediment and water samples from a selection of surface waters in Southeast Nigeria	Microorganisms identified includes *Citrobacter sp., Planococcus sp., Flavobacterium sp., Mucor sp., Allescheria sp., Saccharomyces sp., Escherichia*
Ojekunle *et al.*, (2014)	investigated the effect of commercial activities on the surface water quality of Ogun River, Nigeria	Elevated faecal Coliform, nutrients, and trace metals was found above the acceptable limits.
Jurbe *et al.*, 2023	examined bacterial contamination of water sources for domestic use in Jos (North-central) Nigeria and environs.	Out of the seven distinct water sources examined, stream water had the highest pollution level (MPN 300/100 ml)
Udoh *et al.*, 2021	evaluated the level of microbiological contamination in bottled drinking water.	The outcome revealed prevalence for total coliforms was higher (95% CI: 39.05–66.98, I2 = 81%, $p < 0.01$, 42 studies), indicating that treatment failure is a significant factor in the poor microbiological quality observed in the included research.
Ichor *et al.*, 2014	examined the microbial contamination of surface water sources in South-south Nigeria's Guma Local Government Area	The result revealed high occurrence of *Escherichia coli* (84:4%), *Salmonella spp.* (71.4%) and *Shigella spp.* (64.6%), rainy season had more contamination than the dry one.
Amachree *et al.*, 2025	evaluated microbial quality in sediment and surface water in Amadi Creek in Rivers State, Nigeria.	Microbiological counts in surface water exceeded the European Union standard (EU) indicating severe microbial contamination.
Amatobi & Umezuruike, 2023	This study evaluated the drinking water sources for households in Southeast Nigeria using a quantitative microbiological risk assessment (QMRA) that considered the impact of boiling water.	The results showed a considerable risk of diarrhoea in drinking water source that was investigated. Diarrhea risk varied from 0.090 to 0.190 for water sources from boreholes, 0.004 to 0.032 for spring water sources, and 0.039 to 0.125 for sachet water sources.
Osikanmi *et al.*, 2020	developed a water safety plan for a subset of packaged water manufacturing businesses in Abeokuta, Southwest Nigeria.	The findings identified 26 potentially dangerous occurrences that could jeopardize the quality of water, including on-site septic tanks, effluents released at the source, inadequate system maintenance and hygiene procedures.
Olalemi *et al.*, 2024	The study's objective was to ascertain the likelihood of hepatitis A virus (HAV) infection linked to human consumption of water from Owena River, Nigeria.	The findings showed that the rainy period had higher levels of faecal coliforms and E. coli than the dry period ($p<0.05$). Similarly, dry season had a higher HAV concentration than the rainy period ($p<0.05$).
Ozochi *et al.*, 2024	assessed the prevalence of toxic V. cholerae in the Asata River in the Enugu Metropolis, Nigeria. The risks of contracting the disease from drinking, domestic, and recreational uses of the river's water was equally estimated.	For all exposure scenarios, in both seasons, the estimated risks of contracting cholera in those exposed to untreated Asata River water were greater than 0.5. Similarly, the annual risk of infection was calculated to have a chance of 1.0, with the largest risks (~ 0.9) occurring from drinking water exposure.
Lawal *et al.*, 2024	evaluated the levels of microbiological contamination of water at public secondary schools in Sokoto Metropolis, Northern Nigeria.	Microbial investigation revealed that the various water sources had differing degrees of contamination. E. coli counts in dug wells were the highest, averaging 11.33 CFU/100 ml.
Iweriolor *et al.*, 2023	investigated the Orogodo River's microbiological assessment and antibiotic susceptibility exposed to slaughterhouse effluent in Niger Delta region. Nigeria.	Bacteria counts was found to be higher in the abattoir wastewater sample with 7.7x105 including the point of entry sites 4.0x105.
Kelechi *et al.*, 2021	evaluated microbiological components of water and sediment in South eastern Nigeria. in comparison to WHO benchmark for drinking water	The findings showed that the surface river water had measurable levels of microbial activity in both seasons. Every measurement was higher than the WHO's drinking water permitted limit.

The reviewed literature demonstrated that Nigerian surface water sources were frequently contaminated by microbial pathogens through various human activities and environmental pathways. Therefore, the direct consumption of untreated water sources remained a critical public health concern. Despite the increasing awareness of microbial water pollution, efforts to control microbial pollution in Nigeria faces significant challenges. These challenges included inadequate sanitation infrastructure, illegal waste disposal, inadequate wastewater management, and poor water treatment infrastructures These infrastructure deficiencies increased the possibility of pollution from multiple sources, including untreated sewage, domestic waste and agricultural runoff (Izah & Ogwu, 2025). Effective efforts to minimize these pollutants were further impeded by inadequate water quality surveillance and monitoring systems therefore, restricting the timely detection of pollution and implementation of appropriate remedies. Consequently, developing methods for preventing and implementing microbiological pollution through routine water monitoring plans, improved water safety plans, sanitation and waste management and real-time monitoring technologies is vital for the reduction of microbial contamination as well as protecting public health in Nigeria.

6.1 Microbial Pollutant Preventive Approaches

Preventing microbial pollutants in surface water bodies, their pathways and associated diseases remained essential for improving water quality and ensured sustainable access to safe water (Folorunso, 2025). Preventive approaches will require cohesive management strategies that combine continuous monitoring plans, infrastructure availability, risk assessment, and policy implementation (Mishra *et al.,* 2021), as presented in Figure 5. Monitoring strategies should embrace regular evaluation and sampling of microbial indicators including total coliforms, faecal coliforms, *Escherichia coli, Salmonella spp*. and *Shigella spp*. across surface water bodies in urban and rural areas. This will help regulatory bodies and institutions to identify pollution hotspots to prevent outbreak of infections. Monitoring should concentrate on communal water sources, rivers, streams, and shallow wells especially in the rural areas since they are frequently exposed to livestock activities, open defecation, agricultural runoff, and commercial activities around water bodies. Additionally, surveillance efficiency and response to pollution occurrences can be improved by collaborative water basins monitoring by grassroots government agencies, community participation, public health parastatals, and environmental officials.

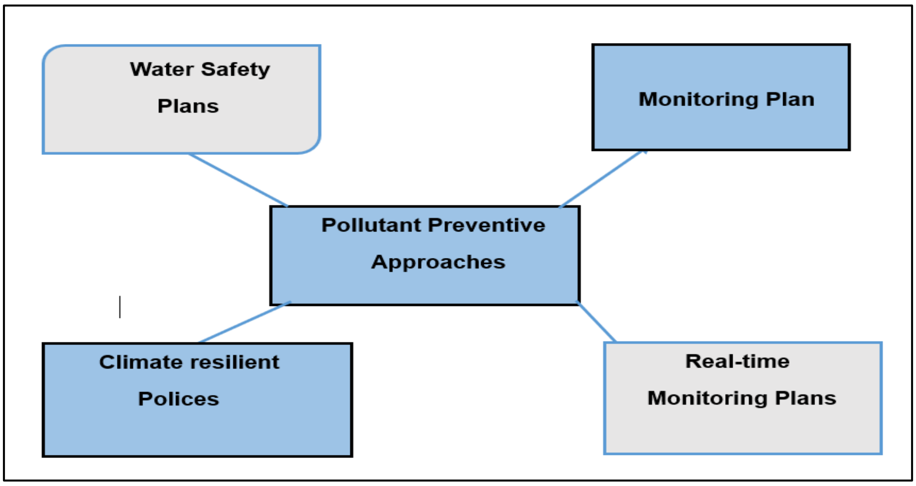

Figure 5: Microbial preventive approaches

Water Safety Plans (WSPs) provide preventive and precautionary risk-management strategies recommended by the World Health Organization (WHO) to ensure safe drinking water from various sources to the point of consumption. This approach involves systematic identification and assessment of potential hazards, the implementation of appropriate control measures and continuous monitoring of water quality (Amadio *et al.,* 2024). In the Nigeria context, the adoption of WSP principles will require strategies designed to combat microbial pollution in different stages of water supply chain. Priority should be given to protecting surface and ground water from indiscriminate waste disposal and sewage discharge, improving sanitation infrastructures, increase awareness of water treatment practices such as boiling and safe water storage including community hygiene. These efforts are particularly crucial in areas with inadequate access to reliable sanitation services and centralized water treatment. However, microbiological risk management in urban environments should extend beyond source protection to include efficient stormwater management, wastewater treatment, and proper management of sewage networks.

Other approaches to improve WSP implementation were also offered by recent technological advancements. Remote sensing technologies, Internet of Things (IoT) devices, and automated monitoring devices can complement conventional sampling by enabling near real-time information on changes in water quality (Ogwu, 2026; Liu *et al.,* 2019). Furthermore, climate-resilient measures such as improved drainage infrastructure, flood-resistant sanitation infrastructure, adequate protection of wetlands and water basins and sustainable wastewater management to reduce the influence of climate change on microbial water pollution (Goh *et al.,* 2024). This can be achieved through forecasting of other extreme weather events which can enable early management and identification of potential microbial contamination risks. A comprehensive approach to mitigate microbiological pollution should also involve strengthening environmental rules, enhancing rural water infrastructure, and raising public knowledge of environmental sanitation and hygiene.

7. Conclusion

This study investigated diverse perspectives on microbial contamination of surface water sources in Nigeria. The objectives examined pollution pathways, public health implications and management strategies. The study clearly revealed that Nigerian surface water resources were grossly contaminated with microbial pollutants exceeding water quality standards in most cases. There was an extensive prevalence of microorganisms such as *Escherichia coli, Shigella spp., Salmonella spp, Klebsiella sp., Proteus sp., Shigella sp., Bacillus sp.,* and *Staphyloccus sp.* The reported diseases were categorised into water borne and water-based diseases causing major illnesses such as diarrhea, cholera, typhoid viral hepatitis, polio, paratyphoid fever, dysentery, salmonellosis and Schistosoma larvae. Microbial pollution pathways were linked to poor waste management, runoff from agricultural lands, untreated domestic wastewater, and commercial activities occurring near water bodies were often associated with faecal coliform concentrations. Sediment and water interaction was also mentioned as one of the pathways that further contributed to microbial contamination of surface water. The study has demonstrated that Nigerian surface water sources were regularly contaminated with microbial organisms through different identified pathways therefore, the direct consumption of these water sources remained a public health concern especially in the rural area. Therefore, incorporating microbial pollution prevention approaches such as monitoring plans, water safety strategies, real-time monitoring systems, and climate-resilient policies both in urban and rural area will be needed to address the problem.

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