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Assessment of Coliform Bacteria in Sokoto Metropolis' Public Portable Water Supply: Implications for Health and the Environment

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ABSRTACT

Public water systems must provide reliable, safe drinking water 24/7 to prevent contamination and illness. Regular testing for coliform bacteria is crucial to ensure clean, dependable water for the public. This study aimed to find coliforms in the public water supply in the Sokoto Metropolis. Eight (8) sterile bottles were used to collect eight (8) water samples, two samples from each of the four water treatment plants in Gagi, Arkilla, Wamakko, and Tashar Illela. As directed by the manufacturer, nutrient agar media, MacCkonkey, and Eosine methylene blue were produced. Standard procedures were followed for the isolates' verification and isolation. The result of this study has shown that the sample obtained from Gagi water production had the highest total mean count (25.9×10^6 CFU/ml). The sample obtained from Arkilla had the lowest total mean count of 4.7×10^5 CFU/ml, and the total coliform (MPN) recorded indicated that the samples obtained from Wamakko had the highest Most probable number (14/100ml). In contrast, the samples obtained from Arkilla had the lowest coliform count (6/100ml). The bacteria identified include *Shigella spp* (12.5%), *Pseudomonas aeruginous* (37.5%), *Staphylococcus aureus* (12.5%), *Enterobacter spp* (12.5%) and *Salmonella spp (25%).* Improvements to the environmental conditions in the research location and regular testing by the treatment facilities for coliforms are advised to create better water.

Keywords: Public water, *Shigella spp., Salmonella spp., Staphylococcus aureus,* Environmental

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Introduction

The most prevalent material, accounting for at least 70% of the human body's mass, is water, an odourless, tasteless liquid. It functions as a solvent for numerous body solutes and is an essential part of the metabolic process.[1] The proper operation of the earth's ecology depends heavily on water. Humans use water for many different things, such as drinking, modes of transport, industrial and residential use, irrigation in agriculture, waste disposal, fishing, and recreation.[2] The inadequate treatment plant, untreated sewage discharged directly into rivers and streams, and ineffective pipe water distribution system management all contribute to the degradation of drinking water quality.[3] Due to users' joint consumption of water, the significance of water in the spread of infectious diseases is seen. Human performance suffers greatly when water is contaminated with faecal coliform.

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According to Hardalo and Edberg, four of the primary human pathogens that cause water contamination are *Salmonella, Campylobacter* spp., *Staphylococcus aureus, Pseudomonas aeruginosa, Clostridium botulinum, Vibrio cholerae,* and *Escherichia coli.* Almost all microorganisms are occasionally discovered in water, but bacteria are the main source of contaminants. Bacteria are present in the air, wastewater, organic waste, dead plants, and animals. As saprophytes, most bacteria in the natural world feed on dead, decomposing organic matter.[5] Toxins in food and water are also broken down by bacteria. Diseases that affect humans and other animals may arise from the presence of other species. Well, boreholes, streams, and river water are never chemically pure; even rainfall carries dissolved airborne particles and suspended dust mingled with microbes.[5]
Waterborne infections have been predicted to result in more than two million fatalities and 4 billion cases of diarrhoea sickness yearly.[6] Children under five years old are the most seriously impacted, with infectious diarrhoea accounting for the majority of mortality as well as morbidity.[6] Approximately 26% of deaths globally in 2001 were attributed to infectious diseases.[7] Gastrointestinal water-borne infections are among the most common infectious diseases that are emerging and reemerging globally. These infections primarily affect the gastrointestinal tract and the stomach. According to [eight,] they have varied aetiology and are primarily endemic, with a global distribution. It is projected that every child in Africa experiences five episodes of diarrhoea annually and that dehydration and diarrhoea cause 800,000 deaths in children each year. Kapwata, [9] asserts that environmental contamination, overcrowding, and poverty are the main causes of infectious diarrhoea. He mentioned that there have been widespread outbreaks of *Vibrio cholerae* and *Shigella dysenteriae* type 1 on the

southern African subcontinent. Numerous localities in Nigeria have also reported having contaminated drinking water due to diseases.[10;11;12] Enteric disease outbreaks through waterways have happened when surface waters polluted with enteric pathogens were exploited for recreational purposes or when public water supply sources were not sufficiently treated following contamination.[13] It is evident that point-of-use water quality is an important public health metric.[14] The process of boiling water for consumption is a measure taken in the "domestic domain" of contagious transmission of diseases.

The aim of any water from the public water supply is to be able to reduce the number of contaminating microorganisms in the water by way of sedimentation, chlorination, filtration, and aeration of the water before it is pumped into our houses. In this vein, it is expected that after all these treatments, the sample of the water will be subjected to a critical bacteriological analysis to determine the number and type of pathogenic bacteria or otherwise that may be in the water. It is unfortunate to note that this bacteriological analysis is not usually carried out by our water treatment plants in this part of the country, thereby posing a threat of pumping water whose bacteriological status is not determined. Similarly, because of the dwindling economic situation in the country, water treatment plants sometimes complain of shortage or lack of supply of treatment chemicals needed to treat water. As a result, they either 'manage' the one they have, which may fall short of the normal concentration required to kill pathogenic bacteria in the water, or not even use it all, which is even more dangerous to the end users of the water.[1]

Every year, at least 1.6 million kids under the age of five worldwide die from unsanitary conditions and contaminated drinking water, with 84% of these deaths occurring in rural regions. Approximately 1.1 billion individuals lacked access to clean drinking water in 2006, and it was projected that waterborne diseases claimed 1.8cdc million lives annually. All warm-blooded species, including humans, and the environment contain coliform bacteria. It is unlikely that coliform bacteria will cause disease. Nonetheless, the fact that they are present in drinking water suggests that the water system may contain pathogens or organisms that cause disease. The majority of germs that might pollute water sources are found in animal or human excrement. The process of testing drinking water for every potential pathogen is costly, time-consuming, and complex. Coliform bacteria may be easily and affordably tested for. Water system operators search for the cause of pollution and restore safe drinking water if coliform bacteria are discovered in a sample of water.

Over time, it has been determined that contaminated water is a major factor in the spread of a variety of human illnesses.[15] Given that people rely on water for domestic and drinking purposes on a daily basis, it is important to ensure that human activity does not contaminate the accessible water supplies. Governmental and commercial organisations must also monitor drinking water sources to ensure they adhere to international requirements for drinkable water. Testing for water-borne pathogens, such as fecal coliform analysis, as indications of water contamination was one of the main bacteriological indexes for water pollution. The WHO set limits of 1–10/100 ml for total coliforms and 0/100 ml for fecal coliforms.[15] Researchers, Consumers, water providers, regulators, and healthcare authorities are concerned about the bacteriological condition of drinking water.[16] The potential for drinking water to spread microbial infections to large populations and cause illness is well-documented in numerous nations at all economic development levels. As a result, the current research will be very helpful in preventing the spread of any diseases transmitted by water and in warning the authorities about the potential consequences of inadequate treatment. This research aims to ascertain the overall coliform in the water sample, separate the coliform species, and identify the isolated coliform using microscopy and biochemistry in Sokoto City's public water supply.

Materials and methods

Study Area

The research was conducted in Sokoto Metropolis of Sokoto State. Sokoto State is situated in the northwest of Nigeria (Figure 1). Its total size is around 25973 km^2, with an average temperature of 28°C.

Sample Collection

Eight sterile bottles were used, and eight samples of water were gathered from each of the four water treatment facilities in Gagi, Arkilla, Wamakko, and Tashar Illela. Samples were collected between June and September 2023 and tagged with the location of collection when they were collected in the treatment plant. Collections were made to sample at least two from each of the four water treatment facilities in the Sokoto metropolis. This was made to ensure that all available portable water within the city was sampled. The microbiology laboratory at Sokoto State University received all the samples that had been gathered and were ready for examination.

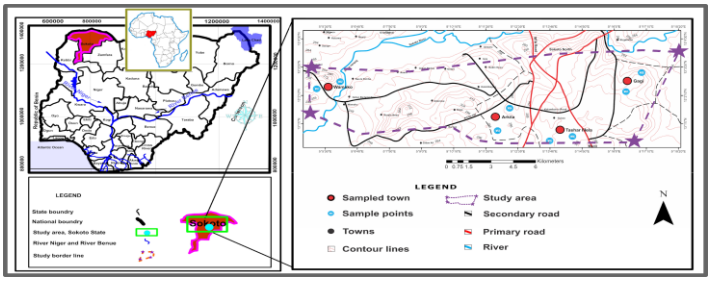

Figure 1: A map of the study area and the sample locations.

Media Preparation

Nutrient Agar: The nutrient agar medium was made in line with the processor's directives, which call for suspending 28g of nutrient agar in 1000ml of distilled water, mixing it well, and heating it on a hot plate until it dissolves completely. The preparation was put into sterile Petri dishes for bacterial isolation after being autoclaved for 15 minutes at 121ºC and left to unheated to 45ºC.[17]

MacConkey Agar: 300ml of distilled water was used to dissolve 7.8g of MacConkey agar powder to create the medium. After covering the mouth of the conical flask with aluminium foil and sterile cotton wool, the mixture was agitated and heated on the hot plate to achieve total dissolution. An autoclave operating at 121ºC for 15 minutes was used to sterilise the dissolved media.[17]

Simon's Citrate Agar: An amount (3.45g) of citrate powder was measured using a weighing balance and incorporated into 150 of distilled water in a conical flask, and the resultant mixture was enclosed with sterile cotton wool and aluminium foil, and the combination was hot plated and dispersed entirely, followed by finally autoclaved at 121ºC for 15 minutes.[17]

Eosine Methylene Blue (EMB) Agar: In order to prepare the medium, 9.72g of EMB agar was dissolved in 270 ml of distilled water in a conical flask, which was then covered and heated to ensure optimal suspension. For fifteen minutes, the material was autoclaved at 121ºC.[17]

Preparation of the Sample and Inoculation

Culturing: Following serial dilution, 0.1 ml of each sample was drawn from 10^{-5} to 10^{-6} dilutions using a sterile syringe and placed onto the centre of nutritional agar that had been prepared. It was spread all over the agar surface with sterilized L-bend glass employing the spread method methodology. The infected plates were adequately marked for simple identification before being incubated for 24 hours at 37°C.[18]

Sub-culturing

Using a sterile wire loop, a separate colony from a mixed culture was selected and put on a brand-new nutritional agar medium in order to acquire pure bacterial isolates. The petri dish was streaked and then incubated for 24 hours at 37°C. For additional analysis, every isolate from this pure culture was kept in an agar slant.[19]

Most Probable Number (MPN) for Coliform Counts

Presumptive test: The Most Probable Number (MPN) techniques, as previously published by [20, 21, and 22,] were used to determine the coliform counts of borehole water samples using sterile MacConkey broth. A

sterile 10 ml double-strength lactose soup was contained in the first set of three tubes, whereas the second and third sets contained 10 ml single-strength broth. Durham tubes were included in every tube prior to sterilisation. Water samples in volumes of 1 ml, 0.1 ml, and 0.01 ml were given to each of the three sets of tubes. The test was run in a couple, with one set of tubes used to estimate the overall amount of coliform bacteria and a second set used to estimate the amount of faecal coliform. After that, tubes were incubated for 24-48 hours at 37˚C to estimate total coliforms and for 24-48 hours at 44.5˚C to estimate faecal coliforms. After that, they were checked for the formation of gas and acid. The lactose broth's colour changed from reddish purple to yellow to indicate the presence of acid, and the Durham tubes were tested for gas entrapment to confirm the presence of gas. After noting any positive tubes, MPN was ascertained.

Confirmative tests
Using the streaking method, a loop containing samples from positive tubes was inoculated onto Petri dishes with Eosine Methylene Blue (EMB) agar, and the plates were then incubated at 37°C for 24 to 28 hours. This selective and differential agar media inhibit Gram-positive bacteria, while Gram-negative coliforms are allowed to proliferate. Coliforms generated large pinkish colonies with dark centres and green metallic shine. This affirmative test was achieved to verify if the coliforms are of faecal ancestry or not. The presence of typical colonies at 37˚C verified the existence of coliforms, as well as those at 44.5˚C indicated the presence of E. coli. [20;21;22]

Completed test
In order to complete the test, colonies from the verified test were subcultured onto nutrient agar slants, and lactose broth tubes were then incubated at 37°C for a full day. Following the incubation time, colonies growing on nutritional agar slants were stained with Gramme stain, and the lactose decoction was examined for the formation of gas. After Gramme blotching, if the bacteria are Gram-negative, non-spore-forming rods and created gas in the lactose broth tube, then it was regarded affirmative for the existence of coliforms in this sample of water.[17;21]

Grams Staining
On a glass slide, a thin smear of bacterial isolates was created, allowed to air dry, and then adjusted by running it over a hob flame three times or more. The smear was first coated for one minute with a crystal violet stain, followed by a minute of washing, a minute of covering with Lugol's iodine, a minute of decolourisation with acetone, and a brief period of washing. After a minute, the smear was cleaned and coated with safranin. Cotton wool was used to wipe the back of each slide, and it was then left to air dry. Using an oil immersion microscope, the dried smear was inspected under a microscope with an x100 objective lens.[17]

Biochemical Characterization of the Isolates
The physical (colonial) features of each bacterial isolate, such as shape, colour, odour, and pigmentation, as well as biochemical tests including Gram's staining, Coagulase, Catalase, Indole, Urease, Citrate, Mannitol Salt Agar, Voges Proskauer test, Methyl red test, and Oxidase test, were used to identify them all.

Coagulase Test
A colony of the test organism was emulsified in sterile glass slide sand that had two drops of physiological saline added to it. Human plasma in the form of a loop was added to the mixture and thoroughly mixed. For a minute, the slide was held and titled back and forth. The mixture clumped together, indicating a successful test.[17]

Indole Test
To make peptone water, combine 10g of tryptone with 100ml of distilled water. After adding precisely 0.5 grammes of sodium to the mixture, the pH was finally brought to 7.2. Following that, 5 ml was transferred into sterile test tubes, which were then loosely capped and autoclaved at 121°C. After that, it was allowed to cool to 30°C, infected, and incubated for 48 hours at 35°C. Then, 0.5 millilitres of Kovac's reagent was added, and the mixture was gently shaken. Ten minutes were allotted for it to stand. Red was a good colour, and the response was noted.[17]

Urease Test
A little part of the organism was removed and injected into urease media that had been created using a sterile wire loop. This was then incubated for a full day at 37°C. A shift in the medium's hue from yellow to pink signified the presence of urease.[17]
Methyl Red (M-R) and Voges Proskauer (V-P) Test: Each isolate was inoculated in small amounts into the glucose-phosphate peptone water medium, which was then incubated for 48 hours at 37 °C. Methyl Red was applied sparingly to the culture in the test tube. Red colour development at the medium's surface signalled an MR positive. The MR test is typically administered in conjunction with the VP exam. A positive VP test result is shown by the medium's initial colour remaining after the MR test. Consequently, an organism was positive for either VP or MR, but not both.[17]
Oxidase Test: Hydrochloride tetramethyl-p-phenylene diamine in aqueous solution at one per cent (1%). When distinguishing Pseudomonas from specific other enteric or gram-negative bacteria, this test (the regent employed) is quite helpful. On a nutrient agar plate containing a 24-hour culture streaked from a nutrient agar slant, a few drops of reagents were applied along the streak line of each culture. Whereas oxidase-negative colonies did not create this purple colouration, oxidase-positive colonies acquired a pink tint that gradually turned purple over 30 seconds [23]

Citrate Utilization Test
Using a sterile wire loop, a tiny amount of the test organisms were injected into the prepared citrate medium, and the mixture was then incubated for 72 hours at 37 °C. Turbidity creation and a shift in the medium's hue from light green to blue indicated a positive test.[23]
Triple Sugar Iron (TSI): Each isolate was divided into small pieces using a sterile inoculating needle, which were then inserted into triple sugar agar media and cultured for 24 hours at 37°C. Fermentation of any sugar (Glucose, lactose, or sucrose) was detected by changing the colour of the medium from red to yellow. The slope turned yellow to indicate lactose and sucrose fermentation, and the butt turned yellow to indicate TSI glucose fermenters. However, a red butt and a yellow slope showed the fermentation of lactose and sucrose but not glucose.[23]

Results and Discussion

The total mean count of the water sample collected from Gagi water production was the greatest at 25.9×10^6 CFU/ml, while the sample from Arkilla had the lowest total mean count at 4.7×10^5 CFU/ml (Table 1). The study's findings showed that the sample from Tashar Illela had the highest total mean count (1.7×10^6 CFU/ml), followed by the sample from Wamakko with 7.8×10^5 CFU/ml, and the sample from Arkilla with the lowest total mean count (4.7×10^5 CFU/ml). The sample from Gagi water production had the highest total mean count. The location where the samples were taken may have had a subpar sanitary system, which could account for the high bacterial coliform count from Gagi.
The total coliform count was presented in Table 2, where the samples obtained from Wamakko had the highest Most probable number (14/100ml). In contrast, the samples obtained from Arkilla had the lowest coliform count (6/100ml). Additionally, samples taken from Arkilla had the lowest levels of bacterial coliform, which may have been caused by variations in local residents' hygiene habits. As a result, the WHO (2018) noted that the total bacterial counts in the current investigation were higher than the standard levels (1.0 ×102 cells/ml). According to Bashir et al.,[24,] who attempted to investigate the bacteriological quality of borehole water in Wamakko local government, Sokoto state, Nigeria, the results of the current study agree. They stated that, in comparison to other sampling locations, the bacterial, total, and faecal coliform burdens were highest in the borehole

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water samples from the federal low-cost Arkilla facility. This finding aligned with a prior investigation by Bello et al.,[25,] which revealed an elevated bacterial load in select borehole water samples gathered from Ijebu-Ode, situated in South Western Nigeria. Comparably, Okoro et al. [26] found that borehole water sources in the Nigerian state of Enugu had higher total heterotrophic bacterial counts.

Table 1: Bacterial Count of the Water Sample

Sample	Dilution	Count	Total viable count (CFU/ml)	Total mean count (CFU/ml)
TL	10^{-2}	160	1.8×10^5	
TL2	10^{-4}	200	1.6×10^7	1.7×10^6
Gg	10^{-2}	372	32.5×10^5	
Gg2	10^{-4}	112	19.4×10^7	25.9×10^6
AR	10^{-2}	16	1.8×10^4	
AR2	10^{-4}	66	7.6×10^6	4.7×10^5
WMK	10^{-2}	61	8.1×10^4	
WMK2	10^{-4}	41	7.5×10^6	7.8×10^5

Key: Gg = Gagi, AR = Arkilla, WMK =Wamakko and TL = Tashar Illela

Table 2: Total coliform count detected in water samples

Sample	TC (MPN/100ml)
TL	7
TL2	9
Gg	10
Gg2	13
AR	7
AR2	7
WMK	15
WMK2	15

Key: Gg = Gagi, AR = Arkilla, WMK =Wamakko and TL = Tashar Illela

The total fecal coliform count presented in Table 3 indicated that only one sample (Gg2) was found to have a faecal count of 1/100ml), and yet no faecal coliform count is detected in the rest of the samples. The biochemical identification of the isolated bacterial species is presented in Table 4.

Table 3: Faecal coliform count detected in water samples

Sample	TC (MPN/100ml)
TL	0
TL2	0
Gg	0
Gg2	1
AR	0
AR2	0
WMK	0
WMK2	0
WHO limit	0

Key: Gg = Gagi, AR = Arkilla, WMK =Wamakko and TL = Tashar Illela, FC= Faecal coliforms

The identified bacteria were *Shigella* spp, *Pseudomonas aeruginosa*, *Staphylococcus aureus*, *Enterobacter* spp, and *Salmonella* spp. Table 5 presents the Percentage frequency of the isolates. The result shows that *Pseudomonas aeruginosa* had the highest percentage occurrence (37.5%) followed by *Salmonella* spp (25%), while *Shigella spp*, *Enterobacter* spp, and *Staphylococcus aureus* obtained the lowest percentage occurrence of 12.5%. The result of this study also shows evidence growth of coliform. The isolates among the coliform detected included *Shigella* spp (12.%), *Pseudomonas aeruginosa* (37.5%), *Enterobacter* spp (12.7%), and *Salmonella* spp (25%). Thus, *Staphylococcus aureus* was also detected with a percentage frequency of 12.5%. As a result, samples containing coliforms are not safe by all standards. The primary method of determining the microbiological safety of water for consumption has been testing for bacterial "indicators" of faecal pollution.[6] The presence of coliforms in drinking water, however, may be a sign of insufficient disinfection because they are relatively susceptible to it.

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Table 4: Morphology and Biochemical Identification of the Isolates

Sample	G.rxn	Shape	Cat	Coa	More	MR	VP	Cit	Glu	Gas	Lac	Suc	H_2S	Ure	Ind	Bacteria identified
TL	-	Rod	+	+	-	+	-	-	-	-	-	-	-	-	-	*Shigella* spp
TL2	-	Rod	+	-	+	-	-	+	-	+	-	-	-	-	-	*Pseudomonas aeroginosa*
Gg	+	Cocci	+	+	-	+	-	+	+	-	+	+	-	+	-	*Staphylococcus aureus*
Gg2	-	Bacillus	+	-	+	+	-	+	+	+	+	+	-	+	-	*Enterobacter* spp
AR	-	Rod	+	-	+	+	-	-	+	-	-	-	+	-	-	*Salmonella* spp
AR2	-	Rod	+	-	+	-	-	+	-	+	-	-	-	-	-	*Pseudomonas aeroginosa*
WMK	+	Cocci	+	+	-	+	-	+	+	-	+	+	-	+	-	*Staphylococcus aureus*
WMK2	-	Rod	+	-	+	-	-	+	-	+	-	-	-	-	-	*Pseudomonas aeroginosa*

Key: : + = Positive, - = Negative, G. rxn = Gram reaction, Coa = Coagulase, Cat = Catalase, Glu = Glucose, Suc = Sucrose, Lac = Lactose, H_2S= Hydrogen sulphide, MR = Methylred, VP = Voge's Proskaeur, Ure = Urease, Cit = Citrate, Mor = Motility and Ind = Indole, Gg = Gagi, AR = Arkilla, WMK =Wamakko and TL = Tashar Ille

Table 5: Percentage Frequency of the Isolates

Isolates	No of occurrence	Percentage frequency (%)
Shigella spp	1	12.5
Pseudomonas aeroginosa	3	37.5
Staphylococcus aureus	1	12.5
Enterobacter spp	1	12.5
Salmonella spp	2	25
Total	N = 8	100%

Although 37.5% of the samples had *Pseudomonas aeruginosa* found in them, only *P. aerugunosa* is medically significant in drinking water quality analysis among the several species that make up the genus *Pseudomonas*. According to Hardalo and Edberg,[27] healthy people are typically resistant to *P. aerugunosa* infection through drinking water, with the exception of those who have certain predisposing circumstances (burn and surgical wounds, physically damaged eyes, profound neutropenia, and cystic fibrosis). It is linked to a water-born epidemic in recreational water (Aysel et al., 2012). Thus, drinking water with *P.aeruginosa* is not a significant source of infection, according to WHO (2006), but it is linked to complaints about the taste, odour, and turbidity of packaged water. Hardalo and Edberg,[27], stated that removing *P. aerugunosa* from our drinking water is not only impractical but also likely to result in disinfection byproducts that are far more dangerous than the original species. It cannot, therefore, be a sign of insufficient disinfection when it is found in drinking water.

Infections with *Salmonella* are linked to consuming contaminated food, surface water, or groundwater. They can cause gastroenteritis, bacteremia or septicaemia, typhoid fever, and enteric fever.[28;29] *Salmonella* spp. were isolated from 25% of the samples, but 25% of the *Salmonella* spp. Found are linked to typhoid fever, including *S. typhi* (Table 2). An estimated 17 million people contract typhoid fever annually, which results in 600,000 fatalities.[29] Pathogens often enter the water system through faecal contamination from wastewater discharge.[6] Because of its relative sensitivity to disinfection, its presence in drinking water is a sign of insufficient disinfection. In 12.5% of the samples, *Shigella* spp. were isolated. Contaminated drinking water has the potential to trigger epidemics of *shigellosis*.[28] Additionally, intestinal diseases of all kinds, such as bacillary dysentery, which causes over two million infections annually and approximately 600,000 deaths (mostly in developing nations), can be caused by any species.[6] On the other hand, Kotloff and Winickoff, [30] estimates that there are 165 million instances of *Shigella* infection annually, with 1.1 million deaths—mostly in children under five—resulting from the infection. Enteric pathogens such as *Shigella* spp. can spread through polluted water through the faecal-oral pathway. However, they are not very stable in a water environment. As a result, their existence in drinking water suggests that human faeces have recently contaminated the area.[6] Of the samples, 12.5% included the isolate *Staphylococcus aureus*, a bacterium linked to human illness. According to WHO, associated illnesses include pneumonia, osteomyelitis, septicemia, and endocarditis. In addition to being infrequently seen in the gastrointestinal tract, they can enter waterways through human contact or sewage contamination. However, there is no indication of transmission through the intake of such water.[6] Consequently, it might not be cause for alarm if *Staphylococcus aureus* is found in drinking water. Better yet, the presence of such a non-spore-forming bacterium may be a sign of insufficient disinfection.

The complex relationship of Chemical, physical, and biological factors also impacts coliform bacteria levels in water.31 The different elements in different aquatic environmental ecosystems control these interactions and their relationships. In surface water, faecal coliform survival and concentration are significantly influenced by physical and meteorological factors, including water temperature, rainfall, runoff, sun radiation, dissolved nutrients, competition with other bacteria, and various physicochemical factors.[32] Further studies are at this moment encouraged on these factors so as to delineate the factors responsible for the bacterial coliform proliferation in the Sokoto metropolis.

Conclusion

The present study's data indicates that the total bacterial loads and coliform counts in the water production plants located in Tashar Illela, Gagi, Arkilla, and Wamakko exceeded the WHO standard. Additionally, it is shown that the water is contaminated with bacteria that cause illnesses in humans and animals, including *Shigella* spp., *Staphylococcus aureus*, *Enterobacter* spp., *Salmonella* spp., and *Pseudomonas aeruginosa*, which has the greatest proportion of occurrence (37.5%). This research highlights the necessity of monitoring, managing, and remediating potable water in the Sokoto metropolis to address the potential presence of disease-causing microbes. Water treatment plants are, as a result of this, advised to step up their water treatment facilities and ensure that the microbial levels in the water are always below minimum WHO standards. Government agencies and NGOs should also carry out mass campaigns to educate people on the risks involved with waterborne illnesses. Local authorities need to monitor, manage, and remediate portable water within the Sokoto metropolis for potential disease-causing microbes.

Conflict of Interest

The authors declare no conflict of interest.

Authors' Declaration

The authors hereby declare that the work presented in this article is original and that any liability for claims relating to the content of this article will be borne by them.

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