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Assessment of Bacteria and Physicochemical Characteristics of Service Water in Tertiary Hospitals in Rivers State

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ABSTRACT

Several water-related disease outbreaks have been attributed to deficiencies in water distribution systems. Hospital water sources can be effective sources of infection. This study assessed the bacterial and physicochemical characteristics of water supply in Rivers State university teaching hospital, Rivers State university medical centre, and University of Port Harcourt teaching hospital using standard procedures. Results showed that, counts of total heterotrophic bacteria (THB), total coliform (TCC), feacal coliform (FC), *Pseudomonas* (PC), and Salmonella/Shigella (SSC) ranged from 1.1±0.06 to 2.8±0.11 × 10^3 CFU/ml, 1.1±0.05 to 8.7±0.15 × 10^2 CFU/ml, 2±0.45 to 7±0.19 × 10^2 CFU/ml, 1±0.90 to 6±0.12 × 10^2 CFU/ml and 1±0.10 to 7±0.96 × 10^2 CFU/ml, respectively. Emergency unit recorded highest counts of THB and PC while Theater recorded highest counts of TCC, FC, and SSC. Three Gram positive bacteria isolated and identified with their occurrence (%) were; *Staphylococcus* (14%), *Bacillus* (10%), and *Enterococcus* species (7%), while nine Gram negative bacteria isolated were; *Escherichia coli* (21%), *Klebsiella* (14%), *Providencia* (7%), *Enterobacter* (7%), and, *Serratia* (6%) and *Shigella* (6%), *Salmonella* (4%), *Proteus* (3%), and *Pseudomonas* (1%). Mean values of physicochemical characteristics showed that temperature ranged from 27.5 to 28.6ºC, pH value 4.9 to 5.2, Electrical Conductivity ranged from 14.150 to 76.500 µs/cm, Total Dissolved Solids ranged from 25.150 mg/l to 128.55 mg/l, Dissolved Oxygen ranged from 4.8500mg/l to 5.0500 mg/l, Biological Oxygen Demand 1.6500 to 2.1500mg/l, Total suspended solids ranged from 0.0650 mg/l to 1.2500 mg/l. The pH values were below the recommended range by WHO, which could be a concern. Additionally, the EC and TDS values seem to be within reasonable limits. These findings highlight the need for improved water quality management in tertiary hospitals in Rivers State to ensure the safety of patients and staff.

Keywords: Service water, hospitals, bacteria, total coliform, fecal coliform, physicochemical characteristics.

Introduction

Several water-related disease outbreaks have been attributed to deficiencies in water distribution systems. Hospital water sources can be effective sources of infection. According to the World Health Organization (WHO, 2023) and Nwadike *et al*., 2024), drinking water should be free from anything that could endanger human health. Water is usually treated before distribution to users and their level of treatment before leaving the treatment facility should be within the limits set by World Health Organization.

Unfortunately, during use, the quality of water may vary from the treatment time (Williams *et al*., 2021). In addition, disinfection greatly reduces microbial load but does not eliminate them completely (Raimi *et al*., 2021). This allows the surviving bacteria to grow in desirable conditions. A decrease in water quality can lead to subsequent growth of highly pathogenic bacteria, due to systemic faults such as cross-linking, broken water pipes and contamination during pipe installation (Williams *et al*., 2021; Dey *et al*., 2024). Bacteria present in water pose serious health risks, particularly for vulnerable patient populations.

Citation: Lawson *et al*. (2024). Assessment of bacteria and physicochemical characteristics of service water in tertiary hospitals in Rivers State. *International Journal of Microbiology and Applied Sciences*. *3(1)*: 137 - 146.

Physicochemical parameters such as pH, turbidity, and chlorine levels also influence the quality of water and its suitability for various hospital activities. Despite the importance of water quality in healthcare settings, there is limited research on the bacterial estimation and physicochemical characteristics of service water supply in tertiary hospitals in Rivers State. The quality-of-service water supply in hospitals is often overlooked, leading to potential health risks for patients, staff, and visitors. There is a lack of comprehensive data on the assessment of bacteria and physicochemical characteristics of service water in tertiary hospitals in Rivers State, which hinders efforts to improve water management practices and ensure patient safety.

Materials and Methods

Description of Study Area

The study was conducted using service water from three hospitals within Port Harcourt metropolis in Rivers State, Nigeria. The hospitals were, Rivers State University Teaching Hospital (RSUTH) located in Port Harcourt Local Government, University of Port Harcourt Teaching Hospital (UPTH) situated in Obio-Akpor L.G.A, and Rivers State University Medical Centre (RSUMC) also located in Port Harcourt Local Government. Ethical approval was sought and received from the Ethics committee of Rivers State University Teaching Hospital, University of Port Harcourt Teaching Hospital (UPTH) and Rivers State University Medical centre.

Collection of Water Samples

About one hundred milliliter (100ml) of water samples were aseptically collected directly from the tap from different sampling points in the hospitals. The sampling points were the Theater, Gynae ward, Emergency, Laboratory, and the storage tank that receives water from borehole (source). Samples were labeled properly, placed in ice chest and immediately transported to the Department of Microbiology Laboratory, Rivers State University, Port Harcourt.

A total of 135 water samples were collected from the five (5) sampling points, on three different occasions, for a period of three (3) months (June 2023 to August 2023) from the three (3) hospitals.

Microbiological Analysis of Water Samples

Samples were prepared in accordance with the guidelines of the Clinical Laboratory Standard Institute (2011). The media for bacterial culture used were Nutrient Agar, Cetrimide Agar, *Salmonella* and *Shigella* Agar (SSA), Eosin Methylene Blue (EMB), and MacConkey Agar. All culture media were prepared according to Manufacturer's instructions.

Methods described by Prescott *et al.* (2011) was adopted, the samples were analyzed by measuring 1ml of the samples into 9ml of Normal Saline (diluent). The measured samples with the diluent were swirled gently homogeneity. Tenfold serial dilution was carried out aseptically using sterile pipette. After dilution, an aliquot (0.1ml) of the diluted samples were cultured on different media (Nutrient Agar, Cetrimide Agar, *Salmonella* and *Shigella* Agar (SSA), Eosin Methylene Blue (EMB), and MacConkey Agar) using sterile bent rod. The cultured plates were incubated aerobically at 37.2^{o}C for 24 hours except for Eosin Methylene Blue (EMB) Agar plates that was incubated at 44.5^{o}C according to the method adopted by Kpormon *et al.* (2023).

Isolation and Enumeration of the Bacterial Isolates

After culture incubation, the Total Heterotrophic count of the bacteria (THBC), Total coliform Count (TCC), *Pseudomonas* counts and *Salmonella* and *Shigella* counts were determined by counting the colonial growth on the cultured plates and the CFU/ml (colony forming unit) were calculated. The colony forming unit per millilitre was calculated using the formula below;

$$\text{CFU/ml} = \frac{\text{number of colonies}}{\text{Dilution x volume plated}} \quad \text{Equation 1}$$

Identification of Bacterial Isolates

Pure bacterial isolates were identified by the method described by Cheesbrough (2006). Pure bacterial isolates were subjected to Biochemical tests which include oxidase test, Catalase test, Indole test, oxidase, coagulase, methyl red test, Voges Proskauer test, Starch hydrolysis test, Citrate test, Sugar fermentation test and Triple sugar iron agar test. The identities of the bacterial isolates were confirmed by referring to Bergey's Manual of Determinative Bacteriology (Bergey and Holt, 2000).

Physicochemical Characteristics of Water Samples from the Storage tank (Source)

Physicochemical parameters such as pH, temperature, Electrical conductivity, biochemical oxygen demand, total suspended solids, total dissolved solid, were analyzed from the source using methods described by APHA (2005).

Statistical analysis

In this study, raw data was entered into Excel spreadsheets and analyzed using SPSS version 25.0 software. Statistical analysis involved determining the p-value through t-tests (< 0.1 considered significant), and one-way ANOVA was conducted using Graph Pad Prism software.

Results

Table 1shows the bacteriological counts of Service water from Rivers State University Teaching Hospital, Total heterotrophic bacteria counts ranged from 1.2±0.47 x10^3 CFU/ml (source) to 1.7±0.14 ' x10^3 CFU/ml (Theater), Total coliform counts ranged from 1.1±0.50 x10^2 CFU/ml (source) to 1.6±0.27 x10^2 CFU/ml (Theater), feacal coliform counts ranged from 3±0.92 x10 CFU/ml (source) to 7±0.19 x×10^2 CFU/ml (Theater), *Pseudomonas* species counts ranged from 1±0.90 x×10^2 CFU/ml (Theater), to 4±0.12 x×10^2 CFU/ml (Gynae Ward), *Salmonella* and *Shigella* counts ranged from 1±0.10×10^2 CFU/ml (Gynae Ward), to 7±0.96×10^2 CFU/ml (Theater).

Table 1: Mean Bacteriological counts of Service water from Rivers State University Teaching Hospital

Source of Water Sample	Microbial Counts (colony forming units per milliliter – CFU/ml)				
	Total heterotrophic bacteria (×10^3)	**Total Coliform (×10^2)**	**Faecal Coliform (×10)**	***Pseudomonas* (×10)**	***Salmonella/Shigella* (×10)**
Gynae Ward	1.5±0.13^{bc}	1.3±0.14^{ab}	6±0.30^{ab}	4±0.12^{a}	1.0±0.11^{a}
Emergency	1.6±0.14^{c}	1.4±0.16^{bc}	4±0.26^{b}	0.0±0.00^{a}	5±0.50^{a}
Laboratory	1.4±0.52^{b}	1.5±0.22^{bc}	4±0.29^{a}	0.0±0.00^{a}	0.0±0.00^{a}
Source	1.2±0.47^{a}	1.1±0.50^{a}	3±0.92^{ab}	0.0±0.00^{a}	0.0±0.00^{a}
Theater	1.7±0.14^{c}	1.6±0.27^{c}	7±0.19^{a}	1±0.90^{a}	7±0.96^{a}
P-value	0.000	0.006	0.082	0.000	0.239

*Means that those that do not share similar subscript down the group showed significance difference

Bacteriological counts of Service water from Rivers State University Medical centre is presented in Table 2, Total heterotrophic bacteria counts ranged from 1.1±0.06 x10^3 CFU/ml (source) to 2.6±0.50 x10^3 CFU/ml (Theater), Total coliform counts ranged from 1.8±0.17 x10^2 CFU/ml (source) to 8.7±0.15 x10^2 CFU/ml (Theater), feacal coliform counts ranged from 2±0.22 ×10^2 CFU/ml (source) to 5±0.25 ×10^2 CFU/ml (Ward), *Pseudomonas* species counts ranged from 4±0.16×10^2CFU/ml (Theater), to 6±0.12 ×10^2 CFU/ml (Emergency), *Salmonella* and *Shigella* counts ranged from 3±0.22 ×10^2 CFU/ml (Emergency), to 5±0.30×10^2 CFU/ml (Lab).

Bacteriological counts of Service water from University of Port Harcourt Teaching Hospital is presented in Table 3, Total heterotrophic bacteria counts ranged from 1.7±0.27 x10^3 CFU/ml (source) to 2.8±0.11 x10^3 CFU/ml (Emergency), Total coliform counts ranged from 1.1±0.05 x10^2 CFU/ml (source) to 1.5±0.12 x10^2 CFU/ml (Emergency), feacal coliform counts ranged from 2±0.45 ×10^2 CFU/ml (source) to 5±0.58 ×10^2 CFU/ml (Emergency), *Pseudomonas* species counts ranged from 1±0.90x10 CFU/ml (Ward), to 6±0.00×10^2CFU/ml (Emergency), *Salmonella* and *Shigella* counts ranged from 1±0.80 ×10^2CFU/ml (Theater), to 3±0.20 ×10^2 CFU/ml (Ward).

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Table 2: Bacteriological counts of Service water from Rivers State University Medical Centre

Source of Water Sample	Microbial Counts (colony forming units per milliliter – CFU/ml)				
	Total heterotrophic bacteria ($\times10^3$)	**Total Coliform ($\times10^2$)**	**Faecal Coliform ($\times10$)**	***Pseudomonas* ($\times10$)**	***Salmonella/Shigella* ($\times10$)**
Source	1.1±0.06 [a]	1.8±0.17 [d]	2±0.22[a]	0.0±0.00 [a]	0.0±0.0 [a]
Lab	1.1±0.03 [a]	7.7±0.18 [a]	3±0.17 [a]	0.0±0.00 [a]	5±0.30[a]
Emergency	1.2±0.06[a]	7.2±0.12[a]	3±0.16 [c]	6±0.12 [c]	3±0.22 [a]
Theater	2.6±0.50[a]	8.7±0.15[c]	4±0.16[b]	4±0.16[b]	0.0±0.00 [a]
Ward	1.2±0.05 [a]	2.8±0.17[b]	5±0.25 [a]	0.0±0.00 [a]	0.0±0.00 [a]
P-value	0.438	0.000	0.000	0.000	0.010

*Means that those that do not share similar subscript down the group showed significance difference

Table 3: Bacteriological counts of Service water from University of Port Harcourt Teaching Hospital

Source of Water Sample	Microbial Counts (colony forming units per milliliter – CFU/ml)				
	Total heterotrophic bacteria ($\times10^3$)	**Total Coliform ($\times10^2$)**	**Faecal Coliform ($\times10$)**	***Pseudomonas* ($\times10$)**	***Salmonella/Shigella* ($\times10$)**
Source	1.7±0.27[a]	1.1±0.05[a]	2±0.45[a]	0.0±0.0[a]	0.0±0.0[a]
LAB	1.9±0.74[b]	1.1±0.05[ab]	4±0.58[a]	4±0.17[ab]	1±0.12[b]
Emergence	2.8±0.11[e]	1.5±0.12[c]	5±0.58[c]	6±0.00[c]	2±0.00[c]
Theater	2.5±0.52[d]	1.3±0.03[b]	4±0.73[ab]	4±0.12[b]	1±0.80[ab]
Ward	2.2±0.13[c]	1.2±0.41[ab]	3±0.99[ab]	1±0.90[ab]	3±0.20[a]
P-value	0.000	0.000	0.000	0.000	0.000

*Means that those not do not share similar subscript down the group showed significance different

The identified bacteria isolates were three Gram's positive bacterial species, including *Staphylococcus*, *Bacillus*, and *Enterococcus* species, and nine Gram's negative bacteria, including species from the genera *Escherichia*, *Proteus*, *Salmonella*, *Enterobacter*, *Pseudomonas*, *Providencia*, *Serratia*, *Shigella*, and *Klebsiella* were isolated and identified from the various service water in the three hospitals.

Bacterial Distribution in Service water from Rivers State University Teaching Hospital is presented in Table 4. *Shigella*, *Salmonella*, *Pseudomonas*, *Proteus*, *Providencia, and Enterococcus*, *Klebsiella* were not isolated at source, *Shigella*, *Salmonella*, *Pseudomonas* were not isolated from the Lab. *Enterococcus* and *Proteus* species was absent in Emergency unit, *Enterococcus species was not isolated in theater while Serratia*, *Enterobacter* species were not isolated from Ward.

Table 5 shows the distribution of bacteria species in the different service water from different units of Rivers State Medical centre, *Shigella*, *Klebsiella*, *Salmonella*, *Pseudomonas*, *Proteus*, *Providencia and Enterobacter* were not isolated from the source, *Enterococcus* species was not isolated from the Emergency unit. *Shigella*, *Salmonella*, *Proteus*, and *Enterococcus* were absent in the theater unit while Serratia, *Shigella*, *Salmonella*, *Pseudomonas* and *Enterobacter* species were not isolated from the ward.

Bacterial distribution in the various units of the service water samples from University of Port Harcourt Teaching Hospital is presented in Table 6; the results revealed that *Salmonella*, *Pseudomonas*, *Providencia Klebsiella Enterobacter* and *Proteus* species were not isolated from the source. *Enterococcus* and *Proteus* were not isolated from theater while *Enterobacter* species was not isolated from Ward.

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Table 4: Distribution of Bacteria species Isolated from the Rivers State University Teaching Hospital

Isolates	Hospital water sample source				
	Source	**Lab**	**Emergency**	**Theater**	**Ward**
Serratia sp	+	+	+	+	-
Shigella sp	-	-	+	+	+
Enterobacter sp	-	+	+	+	-
Enterococcus sp	+	+	-	-	+
Staphylococcus sp	+	+	+	+	+
Providencia sp	-	+	+	+	+
Bacillus sp	-	+	+	+	+
Klebsiella sp	-	+	+	+	+
Escherichia coli	+	+	+	+	+
Pseudomonas sp	-	-	-	+	+
Salmonella sp	-	-	+	+	+
Proteus sp	-	+	+	+	+

Table 5: Bacterial Distribution in Service water from Rivers State University Medical Centre

Isolates	Hospital water sample source				
	Source	**Lab**	**Emergency**	**Theater**	**Ward**
Serratia sp	+	+	+	+	-
Shigella sp	-	+	+	-	-
Enterobacter sp	-	+	+	+	-
Enterococcus sp	+	+	-	-	+
Staphylococcus sp	+	+	+	+	+
Providencia sp	-	+	+	+	+
Bacillus sp	+	+	+	+	+
Klebsiella sp	-	+	+	+	+
Escherichia coli	+	+	+	+	+
Pseudomonas sp	-	-	+	+	-
Salmonella sp	-	+	+	-	-
Proteus sp	-	+	+	-	+

Table 6: Bacterial Distribution in Service water from University of Port Harcourt Teaching Hospital

Isolates	Hospital water sample source				
	Source	**Lab**	**Emergency**	**Theater**	**Ward**
Serratia sp	+	+	+	+	+
Shigella sp	+	+	+	+	+
Enterobacter sp	-	+	+	+	-
Enterococcus sp	+	+	+	-	+
Staphylococcus sp	+	+	+	+	+
Providencia sp	-	+	+	+	+
Bacillus sp	+	+	+	+	+
Klebsiella sp	-	+	+	+	+
Escherichia coli	+	+	+	+	+
Pseudomonas sp	-	+	+	+	+
Salmonella sp	-	+	+	+	+
Proteus sp	-	+	+	-	+

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Percentage occurrence of the bacteria isolated from the three hospitals is presented in Fig 1. The figure revealed the following percentages *Escherichia coli* 21%, *Klebsiella* 14%, *Staphylococcus* 14%, *Bacillus* 10%, *Providencia*, *Enterobacter* and *Enterococcus* 7%, *Serratia* and *Shigella* 6%, *Salmonella* 4%, *Proteus* 3%, and *Pseudomonas* 1%.

Results of mean physicochemical characteristics of the service water of the hospitals are presented in Table 7. Results of mean concentration of physicochemical parameters obtained revealed that temperature range from 27.5 to 28.6ºC. The pH value for service water from River State University Medical centre was the lowest (4.9) followed by service water sample from Rivers State University Teaching Hospital (5.1) and University of Port Harcourt service water (5.2) respectively. Electrical Conductivity ranged from (14.150 to 76.500 µs/cm), Service water sample from Rivers State University Medical centre (RSUMC) recorded had the lowest and Rivers State University Teaching Hospital recorded the highest Electrical Conductivity value. Total Dissolved Solid ranged from 25.150 mg/l to 128.55 mg/l while Dissolved Oxygen ranged from 4.8500mg/l to 5.0500 mg/l), Biological Oxygen Demand (1.6500 to 2.1500mg/l), Total suspended solid ranged from 0.0650 mg/l (RSUHC) to 1.2500 mg/l (RSUTH).

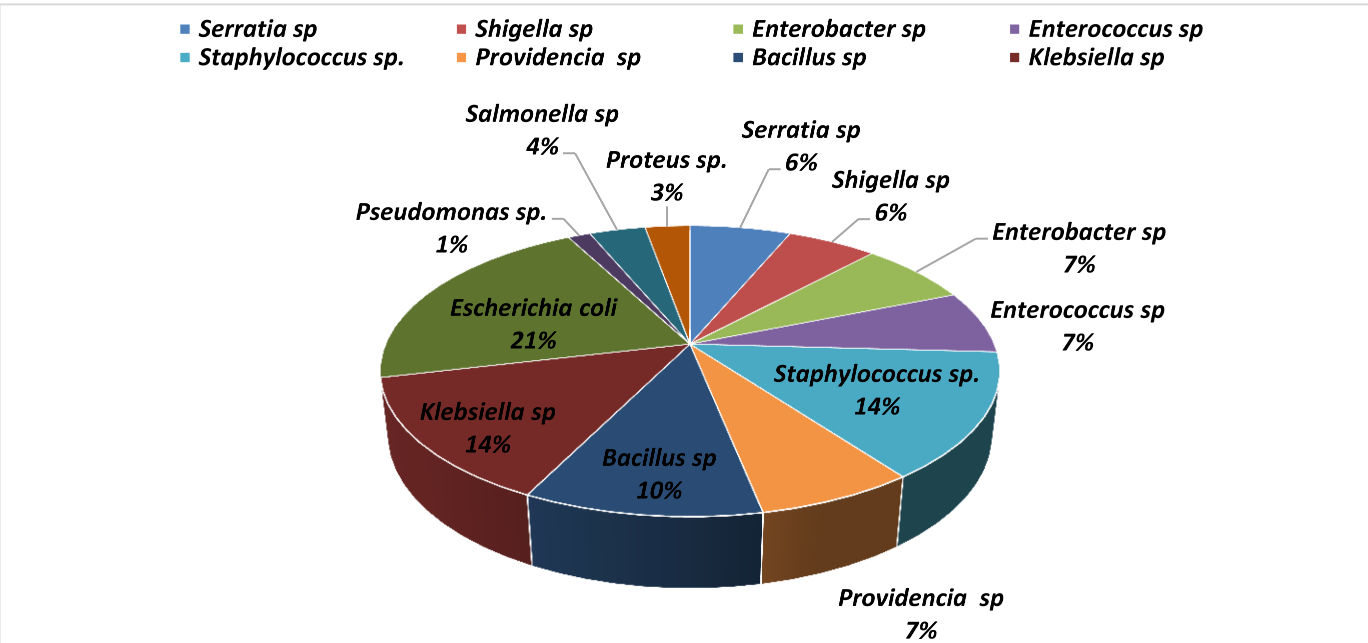

Fig. 1: Occurrence (5) of the Bacterial Isolates from the Service water from the three Hospitals

Table 7: Mean Concentration Physicochemical Characteristics of Service Water from the Three Hospitals

Parameter	Hospital		
	RSUTH	**RSUMC**	**UPTH**
Temperature (^oC)	27.50±0.65	28.65±0.06	27.50±0.52
pH	5.150±0.07	4.950±0.07	5.200±0.13
TDS (mg/l)	128.55±0.19	25.15±0.07	96.50±0.65
EC (µs/cm)	76.50±0.65	14.15±0.07	49.40±0.26
TSS (mg/l)	1.250±0.07	0.065±0.01	1.150±0.07
DO (mg/l)	4.850±0.06	5.0500±0.07	4.950±0.06
BOD (mg/l)	2.150±0.07	1.850±0.06	1.650±0.07

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Discussion

The result showed significant variations in the bacteriological counts across the different hospitals, indicating potential differences in the quality-of-service water provided in these healthcare facilities. The mean bacteriological counts of service water from Rivers State University Teaching Hospital showed variations in total heterotrophic bacteria, total coliform, feacal coliform, *Pseudomonas* species, and *Salmonella* and *Shigella* counts. The highest counts were observed in the Theater, indicating a potential risk of contamination in this area. However, there was no significant difference in feacal coliform and *Salmonella* and *Shigella* counts, suggesting that these parameters may be relatively consistent across different areas within the hospital. Similarly, the bacteriological counts of service water from Rivers State University Medical centre and University of Port Harcourt Teaching Hospital also showed significant difference in total coliform, feacal coliform, Pseudomonas species, and Salmonella and Shigella counts. For the total heterotrophic bacteria counts, there was no significant difference in Rivers State University Medical centre, while University of Port Harcourt showed significant different.

The comparative analysis of total heterotrophic bacterial counts across the three hospitals revealed significant differences, indicating that the quality-of-service water may vary significantly between different healthcare facilities in Port Harcourt. The contamination of the water could be directly from the source where the water is stored before distribution (Okafor *et al*., 2023), or may be attributed to the state of piping materials as some pipes were found to have been broken. This finding is in line with the findings of studies by Agbabiaka *et al.,* (2014) and Williams *et al.* (2021), which in a study that was comparable to this one and assessed drinking water, found increased faecal coliform levels. The contamination of service water by bacteria is of paramount significance due to its potential implications for public health. Bacterial contamination in service water sources, such as those in hospitals, poses a significant risk as it can lead to the spread of infectious diseases, particularly through contact or consumption. In healthcare settings like hospitals, where vulnerable individuals are present, such contamination can result in a heightened risk of surgical site infections and other nosocomial infections (CDC, 1992). Additionally, bacterial contamination of service water can lead to increased morbidity and mortality rates among patients, further burdening healthcare systems. This contamination can also contribute to antibiotic resistance, complicating treatment options for affected individuals.

These findings suggest potential contamination of hospital service water with pathogenic bacteria, posing a threat to patients, staff, and visitors. According to Oludairo and Aiyedun (2016), pathogenic bacteria are frequently found in borehole water systems, particularly in underdeveloped countries. Many researchers (Amadi, 2022; Atobatele & Owoseni, 2023; Elijah, 2023; Eze *et al*., 2023; Nvene, *et al*., 2024; Amadi *et al.*, 2022; Onuorah *et al.*, 2018; Akinola *et al.*, 2018), have isolated coliforms and other Gram-negative bacteria from boreholes in various parts of Nigeria. Agbabiaka *et al*. (2014) state that the presence of potentially harmful organisms, such as *Enterobacter* sp. and *Klebsiella* sp., in certain service water samples is undesirable from the perspective of public health. As a result, care must be taken in using these water sources. Eniola *et al.* (2007) discovered some coliform members in samples of borehole water, which reveals the isolation of coliform bacteria species. These species are proven to induce gastroenteritis in humans and renders portable water unsuitable for ingestion (WHO, 2017). Investigation involved the isolation of two coliform bacteria species: *Escherichia* and *Klebsiella*. Due to their proven ability to induce gastroenteritis in humans and the fact that they render potable water unsuitable for ingestion, (WHO, 2017). Furthermore, the existence of coliforms in water samples that have been examined suggests that the WHO guidelines have not been met (Eniola *et al.*, 2015).

The temperature of water affects many aspects of life, including growth and biological activity, chemistry, quantity measurements, and the types of species that inhabit water bodies. The temperature of water has an impact on how quickly microbes proliferate (Adesakin *et al.*, 2020).

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In this study the temperature ranged from 27.5–28.6^{0}C and is considered appropriate for the growth of heterotrophic bacterial species. One of the most significant factors affecting water quality is pH. The acidity or alkalinity of the water is determined by measuring pH. If the pH of water is less than 7.0, it is deemed acidic. If the pH is greater than 7.0, it is considered alkaline. Acidic water can cause the plumping system and metal pipes to corrode. In the meantime, alkaline water exhibits water disinfection. The World Health Organization (WHO, 2017) and the National Drinking Water Quality Standard (NIS, 2015) specify that the normal pH range for drinking water is between 6.5 and 9. The pH values in this investigation ranged from 4.9 to 5.2 for water samples taken from the different hospital service water sources.

The analysis revealed that the different water samples tested were acidic. This is consistent with research by Williams *et al.* (2021), which similarly found an acidic pH in their study ranging from 5.15 to 5.73. One of the many natural phenomena that can cause this is rain that is somewhat acidic. Rainfall lands become slightly acidic because of carbon dioxide from the atmosphere and soil bacteria that generate acids and release carbon dioxide (Macaulay *et al.*, 2020). Electrical conductivity shows how well a substance conducts electricity. Water samples' electrical conductivity can be used to determine their level of salinity, ion content, or impurity, the lower the conductivity, the purer the water. With RSUTH having the maximum electrical conductivity, the range of electrical conductivity was 14.15 to 76.500µs/cm.

A discharge or other source of disturbance may have lowered the relative health or condition of the water body and its accompanying biota, as seen by the significant changes (increases) in conductivity. When human activity increases the number of dissolved solids that enter waters, conductivity rises as a result (Boyd & Boyd, 2020).

According to the World Health Organization (WHO, 2017), electrical conductivity values should not exceed 400 microsiemens per centimeter (µS/cm). The National Drinking Water Quality Standards (NDWQS) has established a maximum recommended limit of 25 mg/L for total suspended solids (TSS).

There were relatively little total suspended particles in the water samples. This is because the water sources were equipped with filtering devices that eliminated suspended particles including silt, clay, and other inorganic particles. The amount of total dissolved solids in the water samples under investigation did not exceed the 600 mg/l maximum standard permissible level (WHO, 2023). The TDS values ranged from 25.15 to 128.55. This reading agrees with the findings of Akpan *et al*. (2020).

The total suspended solid (TSS) content of water samples was measured. TSS is a water quality metric that can be used to evaluate a sample of any kind of water or body of water. The study's TSS varied between 0.065 and 1.250. The obtained results are within the 2-micron standard (WHO, 2023).

The amount of oxygen that bacteria and other microbes consume during the aerobic decomposition of organic matter is known as biochemical oxygen demand, or BOD. As such, the BOD is a trustworthy indicator of an organism's organic contamination in a body of water (Maitera *et al*., 2010).

In this investigation, the BOD ranged from 1.65 to 2.15. Concentration-based permits typically range from 250 to 300 mg per liter for wastewater discharge to sewer systems, but wastewater discharged directly into the environment normally requires permits much lower, typically 10 mg per liter (WHO, 2023). It is evident from this that the value is within the acceptable range.

In conclusion, the bacteriological investigation of the service water samples in this study revealed that both total heterotrophic bacteria and coliform bacteria counts exceeded the satisfactory drinking water criterion set by the World Health Organization.

Various bacteria, including species from genera such as *Staphylococcus*, *Bacillus*, and *Enterococcus*, as well as *Escherichia*, *Proteus*, *Salmonella*, *Enterobacter*, *Pseudomonas*, *Serratia*, *Shigella*, and *Klebsiella*, were identified in the service water from different hospitals, indicating a high level of bacterial contamination. The physicochemical investigation of water samples from the three hospitals revealed inadequate quality.

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Reference

Adesakin, T. A., Oyewale, A. T., Bayero, U., Mohammed, A. N., Aduwo, I. A., Ahmed, P. Z. & Barje, I. B. (2020). Assessment of bacteriological quality and physico-chemical parameters of domestic water sources in Samaru community, Zaria, Northwest Nigeria. *Heliyon, 6(8),* 1-13.

Agbabiaka, T. O., Sule, I. O. & Oyeyiola, G. P. (2014). Spatial assessment of public water supplies in densely populated areas of Ilorin Metropolis, Kwara State, Nigeria. Fountain *Journal of Natural and Applied Sciences, 3(1),* 20-28.

Akinola, O.T., Ogunbode, T.O. & Akintunde, E.O. (2018). Borehole water quality characteristics and its potability in Iwo, Osun state Nigeria. *Journal of Scientific Research and Reports. 18(1),* 1-8.

Amadi, L. O., Emeka, F. T. & Lekia, G. I. (2022). Biofilm Production in Borehole Water Sources and their Susceptibility to Antibiotics and Antibiofilm Effect of Noni Foliar Extracts. *South Asian Journal of Research in Microbiology, 14(3),* 24-33,

APHA (American Public Health Association) (2005). *Standard Methods for the Examination of Water and Wastewater (21st ed.). Washington, DC:* American Public Health Association.

Atobatele, B. O., & Owoseni, A. (2023). Distribution of multiple antibiotic-resistant Gram-negative bacteria in potable water from hand-dug wells in Iwo, Nigeria. *H2Open Journal, 6(1),* 40-51.

Bergey, D. H. I. & Holt, J. G. (2000). *Bergey's Manual of Determinative Bacteriology, 9th Edition. Lippincott Williams and Wilkins,* Philadelphia. *Pp.* 12-18.

Centers for Disease Control and Prevention. (2004). National Nosocomial Infections Surveillance (NNIS) System report, data summary from January 1992 through June 2004, issued October 2004. *American Journal of Infection and Control, 32,* 470-85.

Cheesbrough, M. (2006). *District laboratory practice in tropical countries, part32*. Cambridge university press.

CLSI. (2011). *Methods for Antimicrobial Dilution and Disk Susceptibility Testing of Infrequently Isolated or Fastidious Bacteria; Approved Guideline—Second Edition*. CLSI document M45-A2. Wayne, PA: Clinical and Laboratory Standards Institute.

Dey, S., Veerendra, G. T. N., Manoj, A. V. P., & Padavala, S. S. A. B. (2024). Removal of chlorides and hardness from contaminated water by using various biosorbents: A comprehensive review. *Water-Energy Nexus*, *7*, 39-76.

Elijah, E. U. (2023). Bacteriological assessment of pipe-borne, borehole, and well water sources available to students in Nasarawa State University Keffi, Nasarawa State, Nigeria. *Sustinere: Journal of Environment and Sustainability*, *7(2),* 112-121.

Eniola, K.I.T., Obafemi, D.Y., Awe, S.F., Yusuf, I.I. & Falaiye, O.A. (2007). Effects of Containers and Storage conditions on Bacteriological Quality of Borehole Water. *Nigerian Journal of Microbiology*, *21*, 1578 – 1585.

Eze, V. C., Ifeanyi, V. O., & Effiong, E. (2023). Antibiotics Susceptibility Pattern of Bacterial Isolates Obtained from Potable Water Sources in Okerenkoko Community, Delta State, Nigeria. *Journal of Life and Bio Sciences Research, 4(02),* 51-57.

Kpormon, L. B. & Ogbonna, D. & Wemedo, S. & Williams, J & Douglas, S. (2023). Prevalence and Antibiotic Resistance Patterns of Biofilm-producing *Escherichia coli* Strains from Water Sources Around Major Slum in Port Harcourt City, Nigeria. *International Journal of Pathogen Research. 12,* 37-45.

Macaulay, B. M., Owoeye, J. A., Abiya, S. F., Raji, J. I., & Hung, Y. T. (2020). Acid Rain: A Growing Global Concern. In *HANDBOOK OF ENVIRONMENT AND WASTE MANAGEMENT: Acid Rain and Greenhouse Gas Pollution Control. 1,* 59-93.

Maitera, O. N., Ogugbuaja, V. O., & Barminas, J. T. (2010). An assessment of the organic pollution indicator levels of River Benue in Adamawa State, Nigeria. *Journal of Environmental Chemistry and Ecotoxicology, 2(7),* 110-116.

Nigerian Industrial Standard (2015). *Nigerian Standard for Drinking Water Quality. NIS Publication,* Abuja, Nigeria. *pp.*20-21.

Nvene, V. O., Ikevude, C. T., Okafor, U. C., & Owhonda, G. C. (2024). Evaluation of the bacteriological quality of underground well water in Oyi local government area of Anambra State, Nigeria. *International Journal of Community Medicine and Public Health, 11(1),* 34-.44.

Nwadike, B. I., Falodun, O. I., & Ogunjobi, A. A. (2024). Bacterial and viral contaminants in drinking water: Why do they really matter to us. *In: Environmental Pollution and Public Health,* 3-28.

Okafor, A.C., Aleruchi, O., Robinson, V.K. and Chinagorom, C.C. (2023). Antibiotic susceptibility pattern of bacteria isolated from stored water in some residential homes. *International Journal of Pathogen Research. 12(3),* 27-34.

Oludairo, O. & Aiyedun, J. (2016). Contamination of commercially packaged sachet water and the public health implications: An overview. *Bangladesh Journal of Veterinary Medicine. 13(2),* 73-81.

Onuorah S, Nwoke J, & Odibo F. (2018). Bacteriological assessment of the public hand-pump borehole water in Onueke, Ezza south local government area, Ebonyi state, Nigeria. *International Journal of Photochemistry and Photobiology, 2(2),* 39-48.

Prescott, L. M., Harley, J. P. and Klein, D. A. (2011). *Microbiology. 8th ed. McGraw Hill,* London.

Raimi, O. M., Sawyerr, O. H., Ezekwe, C. I., & Salako, G. (2021). Many oil wells, one evil: Potentially toxic metals concentration, seasonal variation and human health risk assessment in drinking water quality in Ebocha-Obrikom Oil and Gas Area of Rivers State, Nigeria. *MedRxiv*, 2021-2011.

Williams, J.O., Douglas, S. I. & Onyedibia, G.C. (2021). Antibiogram and Bacteriological Analysis of Biofilm Producing Isolates in Bore Hole Water from Hospitals facilities in Port Harcourt Rivers State. *International Journal of Current Microbiology and Applied Sciences, 10(12),* 2319-7706.

WHO - World Health Organization. (2023). *Cholera: https://www.who.int/news-room/fact-sheets/detail/cholera.* Retrieved 8th Febuary 2024.

WHO - World Health Organization (2023). *Drinking-water. https://www.who.int/news-room/fact-sheets/detail/drinking-water.* Retrieve Febuary 18th 2024.

WHO - World Health Organization. (2017). *Guideline for Drinking Water Quality (Fourth Edition) Incorporating The First Addendum Geneva, Switzerland: WHO Library Cataloguing in Publication*. ISBN 978-92-4- 154995-1549960.

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