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Physicochemical and Bacteriological Quality of Water from Storage Tanks in a Tertiary Institution in Rivers State, Nigeria

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Water quality analysis is essential in assessing the suitability of different water sources used for various purposes, including industrial and domestic uses. This study was therefore aimed at determining the physicochemical and bacteriological quality of water samples from different storage facilities in a tertiary institution in Port Harcourt, Rivers State, Nigeria. The study involved eighty (80) water samples obtained from water storage tanks situated at 16 locations within the premises of the institution, to ascertain the physicochemical property, presence and population of different bacterial groups influencing the quality of these water sources. *In-situ* and *ex-situ* physicochemical analyses as well as bacteriological investigations were carried out on all samples, using standard laboratory procedures. Results of physicochemical analysis showed that the pH ranged from 4.15±0.14 to 7.16±0.08; conductivity, from 50.55±0.49 (µs/cm) to 364.00±2.83; salinity, from 0.02±0 (ppt) to 0.18±0; temperature, from 27°C to 28°C; Chloride, from 1.03±0.06 (mg/l) to 10.80±0.79; total alkalinity, from 4.00±0 (mg/l) to 11.00±1.41; Dissolved oxygen from 3.04±.020 to 7.36±0.08 (Mg/l) and BOD ranged from 0.81±0 to 4.23±0.09 (Mg/l). Results for bacterial population showed total heterotrophic bacteria ranging from 1.03±1.19 x 10^3 CFU/ml in water from reservoir tanks at the Faculty of Engineering, to 5.89±2.59 x 10^3 CFU/ml at Road A

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Block B; total coliform count ranged from 0 CFU/ml in most samples, to 10.00±2.36 x 10^2 CFU/ml in Block B reservoir tanks. Water reservoirs in clinic area recorded the highest *Salmonella/Shigella* counts (1.00±0.23 x 10^1 CFU/ml) with other stations having zero counts. Hall F (Hostel Ext) on the other hand had the highest counts for *Vibrio* (2.20±3.01 x 10^1 CFU/ml). The phenotypic characterization identified *Citrobacter* spp. as the most occurring (27.27%) bacterial isolate in the study, followed by *Alcaligenes faecalis* and *Klebsiella* spp. (18.18% each). *Enterobacter* spp., *Edwardsiella* spp., *Erwinia psidii*, *Acinetobacter* spp., *Pseudomonas* spp., *Providentia* spp. and *Salmonella* spp. all appeared as the least occurring, having a percentage of 4.55%, each. *Tatumella* spp. on the other hand had a percentage occurrence of 9.09%. This study has buttressed the need for increased water hygiene of reservoir tanks as well as water sources in these locations.

Keywords: Bacteriological quality; enteric bacteria; physicochemical; storage tanks; tertiary institution.

1. INTRODUCTION

Water is one of the most essential and universally used single necessity of life [1]. Water quality has been a subject for global public health concern for a very long time, as water related diseases continue to be one of the major health problems globally [2]. Approximately, a proportion of sixty percent (60%) of persons in developing countries lack access to safe drinking water, and only about one in four has any kind of sanitary facilities [2]. Water can become contaminated via various means, at the sources, during its distribution or transportation or even through its handling in households or industrial settings as the case may be [3].

Efforts towards improving access to safe drinking water will no doubt bring about tangible health benefits for humans because the ingestion of water contaminated with microorganisms, particularly those from faecal origin pose a great risk to humans [2]. Enteric bacteria are facultative anaerobic gram-negative rods naturally occurring in the gastrointestinal tracts of humans and animals [4]. Enteric bacteria causing diseases are transmitted through the faecal-oral route mostly due to unsafe sources of water or food [5]. Enteric bacteria families include the Enterobacteriaceaes, Vibrionaceaes and Pasteurellaceaes [6]. However, the pathogens of interest are the Enterobacteriaceae and Vibrionaceae.

Assessing water quality is very important to reduce water-borne diseases, thereby improving the health status of the society and the overall quality of life of human population. Various water sources such as river, well, and pipe-borne water stored in tanks can become contaminated with pathogenic microorganisms, some of which are enteric bacteria, especially when the water is not treated periodically. A study conducted by Henok, et al., [2] showed a high bacterial population above international standards encountered from stored drinking water in Jigjiga City, Eastern Ethiopia. High bacterial loads beyond normal standards is highly risky to consumers of such water as pathogenic enteric bacteria could cause tremendous diseases that could even be fatal.

Many institutions of higher learning have plastic tanks as the main water storage facilities in the hostels and staff quarters. The physicochemical parameter such as pH, temperature, conductivity, salinity, biological oxygen demand, chloride, total alkalinity is very important to get exact idea about the quality of water and then compare the obtained results with standard values. The main aim of this study therefore was to examine the physicochemistry and bacteriological quality of water in storage tanks in a tertiary institution.

2. MATERIALS AND METHODS

2.1 Study Area and Duration

A total of 80 water samples were collected from overhead water reservoirs (tanks), through their various outlets (tap), using sterile 150 ml bottles. The sampling involved 16 different locations within the institution premises as shown in Table 1. The water samples from each of the locations were collected for 5 consecutive times for a period of 3 months.

Table 1. Coordinates of study area

Location of study	Coordinates	Location of study	Coordinates
Road A block B	4.7952181, 6.9787599	FCMB PG Building	4.7887334, 6.9838364
Pumping Station	4.7890412, 6.9790971	NDDC hostel	4.7994144, 6.9771218
Hostel E	4.794535, 6.9824934	Clinic	4.7994247, 6.9761146
Bank	4.7918357, 6.9813581	ICTC	4.7962525, 6.9778252
Block F A&B	4.7945355, 6.9824934	Medical College	4.7968519, 6.9810337
Security village	4.8060969, 6.9841722	Block F extension	4.7948125, 6.9868582
Block of flat opposite ICTC	4.7974881, 6.976786	Hall G block 3	4.7948399, 6.9841722
Engineering	4.7952212, 6.9787408	CCE building	4.7977721, 6.980479

2.2 Bacteriological Analysis

2.2.1 Enumeration and isolation of pure cultures

Serial tenfold dilution was carried out by pipetting 1ml of each water sample into 9 ml of already prepared sterile normal saline to obtain dilutions up to 10^{-4}. Aliquots of the diluted samples were cultured, using the spread plate techniques, on Petri dishes containing appropriate bacteriological media such as Nutrient Agar for Total Heterotrophic Bacterial (THB) count; Eosin Methylene blue agar for *Escherichia coli*; Salmonella/Shigella agar for Salmonella/Shigella counts, Thiosulphate-citrate-bile-salts-sucrose agar for Vibrio Counts and MacConkey Agar for enteric bacteria. The inoculated plates were incubated at 37^{o}C for 18 to 24 hours after which growths were counted and analyzed [7].

Pure cultures of bacteria were obtained as described by Obire and Hakam [7], by aseptically streaking representative colonies of different morphological types which appeared on the cultured plates onto freshly prepared nutrient agar plates and incubated at 37^{o}C for 18 to 24 hours.

2.2.2 Method of identification of the bacterial isolates

The isolates were identified in line with standard microbiological procedures reported by earlier researchers [8–12]. This involved spreading aliquots of the serially diluted samples over the surface of solid agar plates and incubated at 37ºC for 24-48 hours. Colonial characteristics such as colour, shape, margin, opacity, surface and size of colony were considered for the identification, while the morphological characteristics was examined following the application of Gram staining technique. The isolates were therefore identified phenotypically based on their classical characteristics.

2.2.3 Storage of pure culture

The pure isolates were stored in a 10% (v/v) glycerol suspension at -4^{o}C which was used as a cryoprotective agent to protect the organisms from damage during freezing, storage and thawing [13]. They were stored in duplicates in McCartney bottles.

2.3 Physicochemical Analysis

Parameters such as dissolved oxygen, pH, temperature, salinity, bio-chemical oxygen demand (BOD), total alkalinity, conductivity and chloride were determined using the methods from APHA [14]. Extech Instrument was used to measure Electrical Conductivity, Salinity and pH. Argentometric method was used for chloride analysis, while temperature readings were taken in situ, using the thermometer. Titration method was used for total alkalinity evaluation, while Bio-assay procedure was used for BOD.

2.4 Statistical Analysis

Data obtained from all experiments carried out were subjected to statistical analysis using Statistical Package for Social Sciences (SPSS) version 20. Descriptive statistics (mean, standard deviation, etc.) was applied to summarize data for tabulation and graphical representation. Analysis of variance (ANOVA) was used to test for significant difference between counts from various tanks. Where differences exist, Tukey Test was used to separate the means at significant differences ($P< 0.05$) between the various locations.

3. RESULTS

3.1 Physicochemical Analysis of the Water Samples

Results of physicochemical analysis of water samples are shown in Table 2. The pH of the samples ranged from slightly acidic 4.15±0.14 for water from FCMB PG building to neutral 7.16±0.08 for sample from ICTC reservoir tank. The conductivity of the samples was lowest (50.55±0.49 µS/cm) in water from the pumping station and highest in water sample from FCMB PG building reservoir tank (364.00±2.83 µS/cm). The salinity of the samples on the other hand was also highest in samples from FCMB PG building (0.18±0mg/l) and least in samples from Engineering, Clinic and pumping station (0.020 mg/l).

The temperature (^{o}C) of the water samples staggered between 27^{o}C to 28^{o}C for all the samples while the Chloride (Cl) concentrations greatly varied; ranging from 1.03±0.06 mg/l in water from the tank at the Clinic to 10.80±0.79mg/l in Security village. Total Alkalinity in mg/l was highest in samples from NDDC F hostel (11.00±1.41 mg/l) and lowest in samples from security village, Road A Blk B, Hall F hostel extension, FCMB PG building and pumping station (4.00±0 mg/l). The Dissolved Oxygen and Biological Oxygen demand varied slightly for the water samples. The DO (mg/l) ranged from 3.04±.020 (mg/l) from pumping station tanks to 7.36±0.08 (mg/l) from hostel E tanks while the BOD (mg/l) ranged from 0.81±0.00 (mg/l) in Block F (A&B) Hostel, Security Village, Hall G Block 3 Hostel, Hall F Hostel Ext., Blk of Flat OPP ICT and FCMB PG Building to 4.23±0.09 (mg/l) in samples from ICT reservoir tanks.

3.2 Bacterial Population and Identification

Results of Bacterial population obtained from the various water samples are shown in Table 3. The mean Total Heterotrophic Bacterial Counts (THBC) for 80 samples from 16 tanks ranged from 1.03±1.19 x 103 CFU/ml in water from reservoir tanks at the Faculty of Engineering, to 5.89±2.59 x 103 CFU/ml in water from reservoir tanks at Road A, Block B. For Total Coliform Counts (TCC), water from reservoir tanks at Medical Science, Blk of Flat OPP ICT, Security Village, Bank, CCE Building, Engineering and ICT had zero (0.00±0.00 CFU/ml) counts while water from Road A, Block B reservoir tanks with 10.00±2.36 x 102 CFU/ml had the highest count for coliform. There was no statistical difference ($p>0.05$) in the Total Coliform count of the samples. Water from reservoir tanks at Clinic and Hall F Hostel Extension had Salmonella/Shigella counts of 1.00±0.23 x 101 CFU/ml and 0.43±0.36 x 101 CFU/ml respectively. Water obtained from the other sampling stations had zero (0.00±0.00 CFU/ml) counts for Salmonella/Shigella. There was no statistical difference ($p>0.05$) in the Total Salmonella/Shigella count of the samples ($p>0.05$). Zero (0.00±0.00 CFU/ml) Vibrio counts were obtained for samples from 14 stations. Vibrio counts were however obtained for samples from reservoir tanks at Block of Flat OPP ICT (0.42±0.21 x 101 \CFU/ml), Block F (A&B) Hostel (0.44±0.30 x 101 CFU/ml), Hall F Hostel Ext (2.20±3.01 x 101 CFU/ml) and NDDC F Hostel (0.33±0.73 x 101 CFU/ml).

Statistical analysis showed a significant difference ($p<0.05$) in the Total Vibrio counts of the water samples from reservoir tanks at Block F (A&B) Hostel, Clinic, Hall F Hostel Ext., Security Village, and Pumping Station had total faecal counts of 0.20±0.14 x 101 CFU/ml, 1.00±0.23 x 101 CFU/ml, 1.00±0.24 x 101 CFU/ml, 0.20±0.34 x 101 CFU/ml and 1.54±0.66 x 101 CFU/ml respectively. There was also a significant difference ($p<0.05$) in the Total faecal counts of the samples.

3.3 Percentage Occurrence of Isolated Bacteria

A total of 23 isolates were identified in this study. The percentage occurrences of the various bacterial isolates encountered in this study are shown in Fig. 2. *Citrobacter* spp. (26.09%) had the highest percentage of occurrence, followed by *Alcaligenes faecalis* (17.39%) and *Klebsiella* spp. (17.39%). *Tatumella* spp. had percentage occurrence of 8.70% while *Enterobacter* spp., *Edwardsiella* spp., *Erwinia psidii*, *Acinetobacter* spp., *Salmonella* spp., *Pseudomonas* spp., *Providentia* spp. all had percentage occurrences of 4.17% which were the least occurrences encountered in the study.

Table 2. Physicochemical Properties of Water Stored in Reservoir Tanks

Locations	pH	Conductivity (µs/cm)	Salinity (mg/l)	Temp. (^oC)	Chloride (mg/l)	Total Alkalinity (mg/l)	DO (mg/l)	BOD (mg/l)
Block F (A&B) Hostel	5.19±0.04^{d}	109.25±0.49^{e}	0.04±0.00^{b}	27.60±0.14^{ab}	4.53±0.11^{c}	6.00±0.00^{b}	4.46±0.01	0.81±0.00^{a}
Road A Blk B	4.90±0.04^{c}	107.25±1.48^{de}	0.04±0.00^{b}	27.70±0.28^{ab}	4.96±0.03^{cd}	4.00±0.00^{a}	6.51±0.01^{g}	1.62±0.00^{d}
Security Village	4.5±0.16^{b}	229.50±7.78^{h}	0.04±0.01^{b}	27.50±0.00^{ab}	10.80±0.79^{h}	4.00±0.00^{a}	5.66±0.03^{f}	0.81±0.00^{a}
Medical Science	4.87±0.18^{c}	103.50±1.56^{cd}	0.04±0.00^{b}	27.40±0.14^{a}	5.65±0.02^{e}	5.00±1.41^{ab}	5.71±0.06^{f}	0.91±0.03^{b}
CCE building	5.66±0.00^{e}	51.95±0.35^{a}	0.04±0.01^{b}	27.70±0.14^{bc}	5.80±0.04^{e}	6.00±0.00^{b}	3.29±0.04^{c}	1.24±0.06^{c}
ICTC	7.16±0.08^{h}	131.05±0.21^{c}	0.05±0.00^{c}	27.60±0.14^{ab}	8.70±0.03^{f}	8.50±0.71^{c}	3.18±0.01^{b}	4.23±0.09^{f}
Engineering	6.76±0.01^{g}	56.90±0.00^{b}	0.02±0.00^{a}	27.60±0.00^{ab}	1.12±0.01^{a}	8.00±0.00^{c}	5.72±0.01^{f}	1.62±0.01^{d}
Bank	4.85±0.01^{a}	103.75±0.21^{cd}	0.04±0.00^{b}	27.35±0.07^{a}	5.53±0.01^{de}	6.00±0.00^{b}	5.71±0.04^{f}	0.89±0.02^{b}
Hall G Block 3 Hostel	4.89±0.05^{c}	103.10±1.27^{cd}	0.04±0.01^{d}	27.45±0.07^{ab}	3.92±0.05^{b}	8.00±0.00^{c}	5.67±0.01^{f}	0.81±0.00^{a}
Hall F Hostel Ext.	5.26±0.14^{d}	103.10±1.69^{cd}	0.04±0.00^{b}	27.35±0.07^{a}	5.89±0.06^{c}	4.00±0.00^{a}	6.46±0.05^{g}	0.81±0.00^{a}
Blk of Flat OPP ICT	4.82±0.11^{c}	105.00±0.42^{de}	0.04±0.00^{b}	27.45±0.07^{ab}	5.52±0.13^{de}	6.00±0.00^{b}	5.66±0.03^{f}	0.81±0.00^{a}
Clinic	6.95±0.13^{g}	58.50±0.57^{b}	0.02±0.00^{a}	27.40±0.00^{a}	1.03±0.06^{a}	8.00±0.00^{c}	5.69±0.01^{f}	1.62±0.00^{e}
FCMB PG Building	4.15±0.14^{a}	364.00±2.83^{i}	0.18±0.00^{e}	27.45±0.07^{ab}	24.25±0.64^{c}	4.00±0.00^{a}	4.88±0.01^{e}	0.81±0.00^{a}
NDDC F Hostel	7.24±0.02^{h}	148.40±0.85^{g}	0.06±0.00^{d}	27.50±0.00^{ab}	9.43±0.06^{g}	11.00±1.41^{d}	3.21±0.06^{b}	4.06±0.00^{e}
Hostel E	6.33±0.04^{f}	99.40±0.57^{c}	0.04±0.00^{b}	27.90±0.14^{c}	5.89±0.06^{e}	6.00±0.00^{b}	7.36±0.08^{h}	4.06±0.00^{e}
Pumping Station	5.52±0.06^{e}6	50.55±0.49^{a}	0.02±0.00^{a}	27.60±0.14^{ab}	5.53±0.14^{de}	4.00±0.00^{a}	3.04±.020^{a}	1.22±0.00^{c}
WHO Standards	6.50-8.50	200-800	600	24-28	200-600	200	10	6

**Means with the same superscript along the column are not significantly different (p>0.05).*
Key: DO (Dissolved oxygen), BOD (Biological oxygen demand)

Table 3. Microbial Population of Water in Storage Tanks

Location	THB (x10^3 CFU/ml)	TCC (x10^2 CFU/ml)	SS (x10^1 CFU/ml)	FCC (x10^1 CFU/ml)	VC (x10^1 CFU/ml)
Blk of Flat OPP ICT	4.32±2.01^{bcd}	0.00±0.00^{a}	0.00±0.00^{a}	0.00±0.00^{a}	0.42±0.21^{a}
Block F (A&B) Hostel	5.15±2.28^{cd}	1.00±0.22^{a}	0.00±0.00^{a}	0.20±0.14^{a}	0.44±0.30^{a}
Clinic	5.32±1.63^{cd}	1.71±0.11^{a}	1.00±0.23^{b}	1.00±0.23^{a}	0.00±0.00^{a}
FCMB PG Building	3.46±1.69^{abcd}	1.00±0.23^{a}	0.00±0.00^{a}	0.00±0.00^{a}	0.00±0.00^{a}
Hall F Hostel Ext.	3.49±2.05^{abcd}	0.41±0.25^{a}	0.43±0.36^{ab}	1.00±0.24^{a}	2.20±3.01^{a}
Medical Science	2.68±1.78^{abc}	0.00±0.00^{a}	0.00±0.00^{a}	0.00±0.00^{a}	0.00±0.00^{a}
Road A Blk B	5.89±2.59^{d}	10.00±2.36^{b}	0.00±0.00^{a}	0.00±0.00^{a}	0.00±0.00^{a}
Security Village	1.88±0.88^{ab}	0.00±0.00^{a}	0.00±0.00^{a}	0.20±0.34^{a}	0.00±0.00^{a}
Bank	3.85±1.68^{bcd}	0.00±0.00^{a}	0.00±0.00^{a}	0.00±0.00^{a}	0.00±0.00^{a}
CCE Building	2.28±1.05^{ab}	0.00±0.00^{a}	0.00±0.00^{a}	0.00±0.00^{a}	0.00±0.00^{a}
Engineering	1.03±1.19^{a}	0.00±0.00^{a}	0.00±0.00^{a}	0.00±0.00^{a}	0.00±0.00^{a}
Hall G Block 3 Hostel	3.68±2.68^{abcd}	1.00±0.24^{a}	0.00±0.00^{a}	0.00±0.00^{a}	0.00±0.00^{a}
Hostel E	1.53±1.20^{ab}	1.41±1.09^{a}	0.00±0.00^{a}	0.00±0.00^{a}	0.00±0.00^{a}
ICTC	3.85±1.76^{bcd}	0.00±0.00^{a}	0.00±0.00^{a}	0.00±0.00^{a}	0.00±0.00^{a}
NDDC F Hostel	3.14±0.49^{abcd}	1.00±0.24^{a}	0.00±0.00^{a}	0.00±0.00^{a}	0.33±0.73^{a}
Pumping Station	2.66±2.18^{abc}	1.54±0.64^{a}	0.00±0.00^{a}	1.54±0.66^{a}	0.00±0.00^{a}

**Means with the same superscript along the column are not significantly different (p>0.05).*

Key: THB (Total Heterotrophic Bacteria), TCC (Total Coliform Count), SS (Salmonella/Shigella Counts), FCC (Faecal Coliform Count), VC (Vibrio Count)

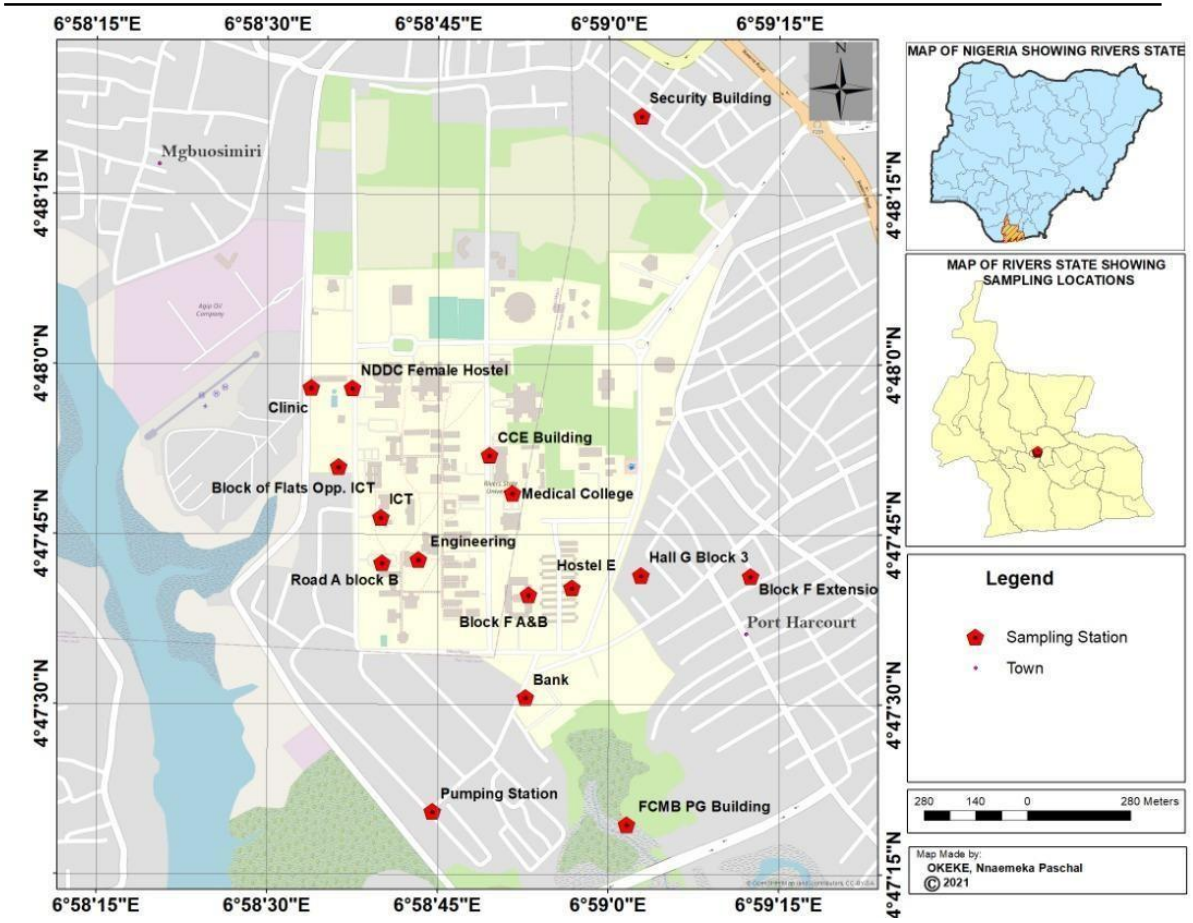

Fig. 1. Map of the study area

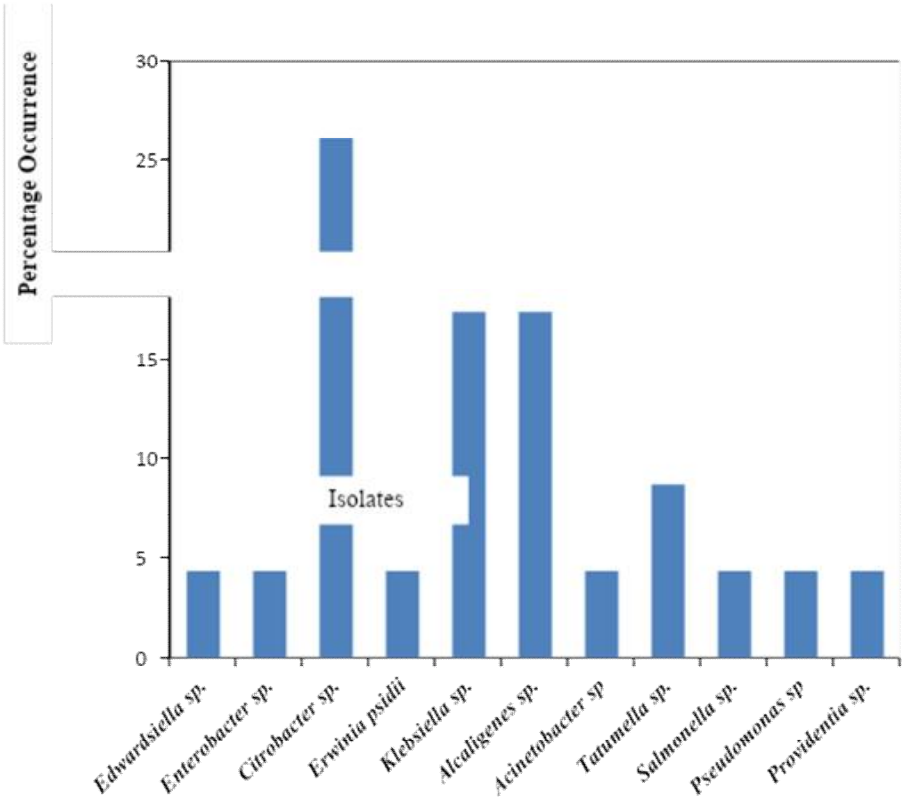

Fig. 2. Percentage occurrence of bacterial isolates from the water stored in plastic tanks

4. DISCUSSION

The physicochemical test results obtained for water samples from the present study has revealed the basic physicochemistry of drinking water stored in plastic tanks. The results obtained for pH which was mostly neutral to slightly acidic for most of the samples is in agreement with the results from the work of Chalchisa, et al. [15]. The pH is an important parameter in evaluating the acid–base balance of water. It is also the indicator of acidic or alkaline condition of water samples. The implications as well as factors influencing the pH of a water source has been elaborated by Wemedo et al [16]. They evaluated the Nitrate to Phosphate Ratio and Other Physicochemical Characteristics of Different Water Sources in Yeghe Community, Rivers State, Nigeria, and observed that the pH values of all the water sources were within the acidic range, with that of the river water samples being significantly higher than the well and tap water sources. They consequently stated that different factors are known to influence the pH of water, including man-made and natural conditions, and further implicated storage conditions as one of the factors contributory to the difference in pH. However, the difference in the pH readings in this study could be attributed to difference in location as well as other chemical properties of the water such as chlorine concentration.

The amount of chlorine in water from the present study is on the average higher than those reported by Sule et al., [17] who carried out a study on the bacteriological quality of water stored exteriorly in storage tanks in Ilorin, Nigeria. This variation can be explained by the peculiarities of the environments where these

stored waters are obtained from; the Niger Delta Region is mostly surrounded by the salty Atlantic Ocean while the North Central Nigeria is a less water surrounded region. The temperature values recorded in this study ranged between 27 and 28^{o}C for all samples. Despite this unique trend, there was significant difference in the temperature of the water obtained from the various reservoir tanks attributable to positioning and exact location of the tanks within the institution. The temperature observed were slightly higher than those obtained in similar studies by Chalchisa, et al., [15] in which temperature values between 21 and 24°C were recorded. Temperature in this study was found to be within permissible limit of World Health Organization (30°C).

The electrical conductivity of water samples varied greatly across the various locations. The highest electrical conductivity of 364.00±2.83µS/cm was observed in water from the FCMB PG hostel reservoir tanks. Generally, the amount of dissolved solids in water determines the electrical conductivity. Electrical conductivity (EC) actually measures the ionic process of a solution that enables it to transmit current [16]. High electrical conductivity of water can occur when water contains heavy metals and metal ions in solution [18]. The conductivity of normal drinking water ranges from 200 to 800 µS/cm and According to WHO standards, EC value should not exceed 400 µS/cm [19]. The current investigation indicated that EC value was between 50.55±0.49 to 364.00±2.83µS/cm. The least EC values obtained in this study measures close to EC values of seawater of 50.00 µS/cm.

The dissolve oxygen (DO) of the water samples examined was highest in hostel E samples (7.36±0.08mg/l) and lowest in water from pumping station (3.04±.020mg/l) while the biological oxygen demand (BOD) of all samples were all below 4.00mg/l which is within the World Health Organization's permissible limit of 6.00mg/l. The results of DO and BOD in the present study is in agreement also with results from the work of Olukosi et al., [20].

The study also revealed that out of 80 water samples from 16 tanks sampled, the total heterotrophic bacteria counts was highest in samples from tanks at Road A Block B (5.89±2.59 × 10^3 CFU/ml) and lowest in water from reservoir tanks at the Faculty of Engineering (1.03±1.19 × 10^3CFU/ml). There was a significant difference in the Total heterotrophic bacterial count of the samples ($p<0.05$). Most of the counts obtained for aerobic plate count (APC) were considerably high for drinking water. Results of heterotrophic plate count were similar to those obtained by [21]. In this present study, coliform bacteria were present in nine (9) of the sixteen (16) water samples, and therefore indicative of presence of other potentially harmful bacteria and a threat to water quality. Sule et al., [17] also reported coliform bacteria in stored drinking water from reservoir tanks in their study, and therefore in agreement with results from this study.

The other samples were free of coliform bacteria hence, relatively safe. Salmonella/Shigella counts of 1.00±0.23 x 10^1 CFU/ml and 0.43±0.36 x 10^1 CFU/ml were recorded for water samples from the clinic tanks and hall F hostel extension respectively. Their presence, although in only two samples from this study portends danger for consumers and users of the water sources. Al-Bahry et al., [21] encountered Salmonella counts in the inner surface of tanks as well as water obtained from the tanks in their study. Chalchisa et al., [15] compared the bacteriological contamination of drinking water among samples taken from water tanks before and after storage and revealed that for the bacteriological contamination, the number of total coliforms increased after storage. Vibrio counts were observed for samples from Blk of Flat OPPICT (0.42±0.21 × 10^1 CFU/ml), Block F (A&B) Hostel (0.44±0.30 x 10^1 CFU/ml) and Hall F Hostel Ext (2.20±3.01 × 10^1 CFU/ml). The presence of coliform, Salmonella/Shigella and Vibrio in water sampled in this study could be as a result of infiltration from the nearby septic tanks situated around most of the primary source of the water collected into the tanks for storage and subsequent use. They could also have emanated from poor sanitary condition on the part of users of these reservoir tanks who unconsciously introduce microbes into reservoir tanks.

In this study, feacal counts were encountered in five (5) stations (pumping station, clinic, security village, hall F hostel extension and Block F (A&B) Hostel. Novak et al., [22] reported that the presence of opportunistic and pathogenic feacal bacteria in drinking water can pose a health risk to consumers due to daily contact with water, via several exposure points, such as drinking and showering.

This study has revealed that enteric bacteria are prevalent in stored drinking water. Amongst the

organisms isolated in this study were those in the genus Citrobacter, Klebsiella, Tatumella, Alcaligenes, Salmonella, Edwardsiella, Erwinia, Acinetobater, Pseudomonas, Providentia and Enterobacter. Al-Bahry et al., [21] reported similar isolates such as *Pseudomonas* spp., *Salmonella* spp. and *Enterobacter* spp. from their study of stored drinking water. Pathogenic Pseudomonas, Pasteurella, Salmonella, Serratia and Tatumella, Yersinia in biofilms varied in the three tanks examined by Al-Bahry et al., [21]. This is in agreement with results from this study. Sule et al., [17] also isolated *Pseudomonas aeruginosa* from stored drinking water in Ilorin, Nigeria. Poonia et al., [23] isolated 19 species of bacteria in the genera Escherichia, Klebsiella, Proteus, Salmonella, Shigella, Enterobacter, Citrobacter, Morganella, Pseudomonas, Acinetobacter, Flavobacterium, and Serratia in their study of water from stored water in rural communities. Most of these organisms were also isolated in this study.

The presence and persistence of Salmonella have been reported in surface waters such as rivers, lakes, and ponds, while ground water in general offers better water quality [24]. The presence of Salmonella in this study could therefore be as a result of externally introduced contaminants by reservoir tank users and handlers. Some of these tanks, especially those within the hostel premises are located near the toilets and septic tanks. In general terms, the greatest microbial risks are associated with ingestion of water that is contaminated with human or animal faeces [25]. Pindi, et al., [26] isolated organisms in the genus Citrobacter and Acinetobacter while trying to identify opportunistic pathogens present in stored drinking water in rural health centers. Their findings are in agreement with those from this study.

Otorkpa, [27] in a study of the major bacterial contaminants of drinking water in Nigeria, revealed the presence of *Escherichia coli*, *Klebsiella* spp, *Pseudomonas aeruginosa, Enterobacter aerogenes*, *Salmonella typhi*, *Vibrio cholerae* and *Shigella* spp.in the water samples. Some of these isolates were also found in the present study, though were however not as prevalent as those encountered in his study. Most isolates from this study are as opportunistic pathogens; their presence is dangerous mostly to immune suppressed individuals who consume water from sources where they are present [28].

The World Health Organization (WHO) reports that *Klebsiella* spp. are not considered to represent a source of gastrointestinal illness in the general population through ingestion of drinking-water. *Klebsiella* spp. detected in drinking-water are generally biofilm organisms and are unlikely to represent a health risk. Henriot et al., [29] also reported the prevalence of Klebsiella in water. The detection of *Edwardsiella* spp., although with a very low prevalence in this study portends danger as some species of Edwardsiella such as Edwardsiella tarda have been found to be pathogenic to humans [30]. The most frequently occurring organisms in this study (Citrobacter spp.) are known drivers of opportunistic infections in human.

5. CONCLUSION

This study was centered on ascertaining the physicochemical and bacteriological quality of drinking water stored in storage tanks with particular interests in enteric bacteria in a tertiary institution. These are areas of utmost importance to public health microbiology. The study has been able to determine the population of microorganisms (Total heterotrophic bacteria, Total Coliform counts, Total Salmonella/Shigella, Total Vibrio counts and Total feacal counts) of water stored in reservoir tanks at the institution with prevalence of some enteric bacteria such as Citrobacter, Klebsiella and Alcaligenes faecalis which occurred in higher frequencies than the others. The microbial populations especially for coliform bacteria encountered for some of the samples analyzed were above the limits for drinking water and portable water set by the world health organization. These organisms are opportunistic organisms that can be harmful to individuals with underlying health conditions and immune compromised individuals. This calls for improved sanitary conditions of reservoir tanks as well as water sources in these locations. Potable water should be relatively free from such contaminants. Water samples tested are used mainly for domestic purposes making its microbiological safety very important.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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