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Water quality analysis of various domestic water sources used in Owerri Imo State, Nigeria

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ABSTRACT

The water quality of the various domestic water sources used in Owerri Imo State was monitored. These water sources include the municipal tap water (A1, A2), borehole (B1, B2), Otammiri (C1, C2), Nworie (D1, D2) and rainwater (E1, E2). A total of ten (10) water samples from different sources were analyzed for appearance, odour, pH, electrical conductivity, temperature, total heterotrophic bacterial counts (THBC), total coliform counts (TCC), and total Salmonella Shigella counts (TSSC). The data obtained were compared to WHO and NISDWQ standards for drinking and domestic water. The water samples revealed a slightly acidic pH ranging between 6.43 and 6.96. Electrical conductivity ranged from 42.05 ±1.42 µS/cm - 360.92 ±6.77 µS/cm. The temperature of the water samples between 20.6 °C and 28.8 °C. The water samples revealed an overall low bacterial count. Sample B1 recorded the lowest THBC of $1.0\times10^2 \pm 0.01$ cfu/mL, while sample D2 recorded the highest THBC of $2.1\times10^6 \pm 0.06$ cfu/mL. The highest TCC of $3.7\times10^4 \pm 0.06$ cfu/mL was observed in sample C2, while sample B1 recorded no visible growth for TCC. For TSSC, samples A1, A2, B1, B2, and E1 recorded no visible growth, while sample C1 revealed the highest TSSC of $2.1\times10^2 \pm 0.011$ cfu/mL. This study has revealed that only sample B1 aligned with the stipulated WHO and NISDWQ standards for drinking and domestic water.

Keywords**:** water, bacteria, Owerri, domestic, analysis, quality, sources

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1. INTRODUCTION

The continent of Africa harbors health-related and mineral resources that could contribute significantly to the development of its inhabitants. One such is water, which remains the ultimate basis for sustaining life. Water is a major and essential nutrition requirement for life, both directly as drinking water and indirectly as a food constituent. Water is one of the basic natural resources on which the life of all the organisms on this planet depends and also plays a major role in other applications of life existence [1]. It is used for numerous purposes, including drinking, bathing, washing, agriculture, transportation, etc, the most important of which is drinking. The requirement for domestic water supply is the second basic need of humans after their food needs. The rise in demand for good quality water has been orchestrated by the rapid growth in industrialization, urbanization, and the growing human population [2].

Water supply involves various tightly coupled hydrological components [3]. The water available to humans comes from two sources, surface, and groundwater, but in most developing countries, the quality standard of domestic water supply is often indefensible. Apart from domestic purposes, water is also used for recreational, industrial, and other purposes. Potable drinking water must not contain undue levels of inorganic chemicals, organic chemicals, bacteriological, disinfection byproducts, and radionuclides. Potable water supply is still a major challenge for most developing countries like Nigeria, with urban areas like Owerri relying heavily on both surface water and underground water for their water supply [4]. The rapid urbanization experienced in most developing countries is usually accompanied by health risks from water-borne diseases that emerge from the inappropriate installation and distribution of public water supply systems. Access to safe and clean drinking water is a critical determinant of public health, especially in developing regions where waterborne diseases are prevalent [5]. In urban areas like Owerri, Nigeria, where rapid population growth and urbanization keep increasing without consideration of basic social amenities, the quality of domestic water sources becomes a challenge [6, 7]. With the city experiencing rapid urbanization, the water demand has increased, leading to the utilization of various water sources.

Surface waters are usually susceptible to contamination, unlike underground water sources, which are usually clean and more difficult to pollute. However, regardless of the source of domestic water, a careful evaluation must be made to determine the water quality. These sources include boreholes, rainwater harvesting, rivers, and public water supply systems. Each of these water sources presents its own advantages and challenges regarding availability, quality, cost, and sustainability [1].

Studies have revealed that the microbiological contamination of water sources can lead to severe health challenges, including gastrointestinal infections and other waterborne diseases [8, 9]. For instance, total coliforms and Escherichia coli are common indicators of fecal contamination and potential pathogen presence. This can used as a parameter to assess water quality [10]. Given water quality's critical role in public health, a detailed analysis of water from different domestic sources in Owerri is both timely and necessary.

Although several studies have investigated water quality in various regions of Nigeria [11, 12], there is a notable lack of comprehensive, localized research that considers different parts of Owerri. This study aims to fill this gap by conducting an analysis of water samples from multiple domestic sources, including municipal supplies, private boreholes, and surface water from different areas in Owerri. By evaluating parameters such as total coliforms and other key indicators, this study seeks to compare the data obtained from the different parameters with that of the WHO and NISDWQ [13] stipulated standards across different water sources and assess their implications for public health.

The outcome of this study will provide valuable insights for local authorities, contribute to the development of effective water management strategies, and support efforts to enhance water safety and public health in Owerri. By addressing the current deficiencies in water quality monitoring and management, this study will act as a driving force to significant improvements in water safety standards and inform policy decisions, especially in Owerri Imo State Nigeria.

2. MATERIALS AND METHODS

Water samples were collected from the various domestic water sources used in Owerri. The city of Owerri is the capital of Imo State, South-East Nigeria. It is set in the heart of Igboland with a latitude of 5.48363 and longitude of 7.025853. it has an estimated population of above 1401873, according to the 2016 census [14], and is approximately 100 square kilometers (40 sq mi) in area. Owerri comprises four (4) local government areas: Owerri Municipal, Owerri West, Owerri North and parts of Mbaitoli. The Otammiri River borders Owerri to the east and the Nworie River to the south [15]. The city's average temperature is 26.4^0C, with average precipitation ranging between 18.2 – 2328.2 mm and a relative humidity of between 75.1 % - 90.8 % [16].

Sample collection

Water samples were collected from five different domestic sources popularly used in Owerri using sterile 500 mL screw cap bottles. The first set of samples was collected between November and February to represent the dry season, while the second set was collected between May and August to represent the rainy season.

The water sources are; municipal tap water collected from Aba Road flow station (A1, A2), borehole water collected from Douglas Road (B1, B2), Otammiri river water collected from Wedtheral Road (C1, C2), Nworie river water collected from Amakohia (D1, D2) and rainwater collected from Ikenegbu (E1, E2).

Physicochemical analysis of water samples

Physicochemical parameters such as pH, electrical conductivity, temperature, smell, and appearance were monitored in-situ using standard procedures with appropriate equipment [17]. pH was analyzed using a pH meter HANNA H19723-7 model. Conductivity was measured using a conductivity meter, HANNA H18833, while the temperature was monitored using a mercury-bulb thermometer. The odour and colour of the water samples were also assessed physically.

Bacteriological analysis of water samples

Serial dilution was done by dispensing 1 mL of each water sample in 9 mL of diluent. The mixture was corked and swirled to mix correctly. This represented 10^{-1} dilution. Using a new pipette in each case, 1 mL of the dilution in 10^{-1} was transferred into a second test tube containing 9 mL of diluent to make 10^{-2} dilution. The procedure was repeated up to 10^{-5} for each water sample. 0.2 mL aliquot of each dilution was transferred to the appropriate media using the spread plate technique and incubated for 24 hours at 37 °C in an incubator [18]. The samples were also analyzed using the membrane filtration method. 100 mL of each water sample was swirled thoroughly to mix and allowed to pass through a membrane filter with a pore size of 0.45 µm. The filter paper was carefully and aseptically transferred onto a solidified media using sterile forceps and incubated at 37 °C for 24 hours. All samples were analyzed in duplicates.

The water samples were analyzed for total heterotrophic bacterial count (THBC) using nutrient agar, total coliform counts (TCC) using MacConkey agar, and total Salmonella Shigella counts (TSSC) using the Salmonella Shigella agar. All media were prepared and dispensed following the manufacturer's instructions.

Statistical analysis

Quantitative data obtained in this study are expressed in the mean. The mean values were also subjected to one-way ANOVA, and the results obtained were considered statistically significant at a 95 % confidence interval ($P<0.05$).

3. RESULTS

The physical properties of the water samples, as presented in Table 1, reveal that samples A1, A2, B1, B2, and E1 were colourless, while samples C1, D1, and E2 were slightly cloudy. Samples C2 and D2 were very cloudy in appearance. The water samples were also checked for odour, and samples A1, A2, B1, B2, E1, and E2 were odourless, while there was the presence of objectionable odour in samples C1, C2, D1, and D2.

Table 1. Physical properties of the different domestic water sources used in Owerri.

Samples	Appearance	Odour
A1	clear	odourless
A2	clear	odourless
B1	clear	odourless
B2	clear	odourless
C1	slightly cloudy	odour present
C2	cloudy	odour present
D1	slightly cloudy	odour present
D2	cloudy	odour present
E1	clear	odourless

E2	slightly cloudy	odourless
WHO Standard	clear	odourless
NISDWQ Standard	clear	odourless

The physicochemical analysis on the water samples was pH, conductivity and temperature, as presented in Table 2. The water samples showed an overall slightly acidic to neutral pH. Samples A1 had a pH of 6.91±0.02, A2 6.80±0.11, B1 6.96±0.21, B2 6.94±0.01, C1 6.76±0.01, C2 6.72±0.11, D1 6.81±0.02, D2 6.67±0.12, E1 6.45±0.13 and E2 6.43±0.04. Sample B1 revealed the lowest acidity, while sample E2 had the highest acidity.

The data obtained from electrical conductivity analysis revealed a conductivity value of 42.05±1.42 µS/cm for sample A1, 43.00±1.03 µS/cm for A2, 85.22±2.04 µS/cm for B1, 91.07±4.09 µS/cm for B2, 347.06±11.01 µS/cm for C1, 358.73±10.07 µS/cm for C2, 355.31±9.21 µS/cm for D1, 360.92±6.77 µS/cm for D2, 138.41±4.41 µS/cm for E1 and 141.22±2.38 µS/cm for E2. The highest conductivity of 360.92±6.77 µS/cm was recorded in sample D2 while sample A1 recorded the lowest conductivity of 42.05±1.42 µS/cm.

The temperature of the individual samples showed that sample A1 had a temperature of 28.1±2.04 °C, A2 28.3±1.11 °C, B1 28.0±4.01 °C, B2 27.9±3.30 °C, C1 27.6±2.02 °C, C2 28.8±2.02 °C, D1 28.2±2.82 °C, D2 28.9±1.01 °C, E1 20.4±4.04 °C and E2 20.6±1.11 °C. Sample D2 recorded the highest temperature of 28.9±1.01 °C, while sample E1 recorded the lowest temperature of 20.4±4.04 °C.

Table 2. Physicochemical Analysis of the different domestic water sources used in Owerri.

Samples	pH	Conductivity (µS/cm)	Temperature (°C)
A1	6.9±0.02	42.05±1.42	28.1±2.04
A2	6.80±0.11	43.00±1.03	28.3±1.11
B1	6.96±0.21	85.22±2.04	28.0±4.01
B2	6.94±0.01	91.07±4.09	27.9±3.30
C1	6.76±0.01	347.06±11.01	27.6±2.02
C2	6.72±0.11	358.73±10.07	28.8±6.06
D1	6.81±0.02	355.31±9.21	28.2±2.82
D2	6.67±0.12	360.92±6.77	28.9±1.01
E1	6.45±0.13	138.41±4.41	20.40±4.04
E2	6.43±0.04	141.22±2.38	20.6±1.11
WHO Standard	6.50 – 8.50	250	27 – 28
NISDWQ Standard	6.50 – 8.50	100	-

Values represent the mean of duplicate analysis ± standard deviation

The total heterotrophic bacterial count (THBC) conducted on the individual samples revealed a THBC of 1.0×10^3 ±0.14 cfu/mL in sample A1, 1.5×10^3 ±0.13 cfu/mL in A2, 1.0×10^2 ±0.01 cfu/mL in B1, 1.2×10^2 ±0.01 cfu/mL in B2, 3.0×10^5 ±0.21 cfu/mL in C1, 3.6×10^5 ±0.23 cfu/mL in C2, 1.07×10^6 ±0.14 cfu/mL in D1, 2.1×10^6 ±0.06 cfu/mL in D2, 3.0×10^5 ±0.14 cfu/mL in E1 and 3.5×10^6 ±0.11 cfu/mL in E2. Sample C2 recorded the highest THBC while sample B1 had the lowest as presented in Table 3.

The total coliform counts (TCC) revealed a TCC of 0.3×10^2 ±0.002 cfu/mL in A1, 1.3×10^2 ±0.012 cfu/mL in A2, 0.2×10^2 ±0.001 cfu/mL in B2, 2.1×10^4 ±1.22 cfu/mL in C1, 3.7×10^4 ±0.06 cfu/mL in C2, 2.8×10^4 ±1.36 cfu/mL in D1, 3.6×10^4 ±1.27 cfu/mL in D2, 2.1×10^3 ±0.97 cfu/mL in E1 and 2.9×10^3 ±0.88 cfu/mL in E2. Sample B1 recorded no growth while sample C2 recorded the highest TCC of 3.7×10^4 ±0.06 cfu/mL as presented in Table 3.

The total Salmonella Shigella counts (TSSC) was also monitored and it revealed a TSSC of 2.1×10^2 ±0.011 cfu/mL in C1, 1.7×10^2 ±0.011 cfu/mL in C2, 1.3×10^2 ±0.84 cfu/mL in D1, 1.1×10^2 ±0.02 cfu/mL in D2 and 1.0×10^2 ±0.001 cfu/mL in E2. Samples A1, A2, B1, B2 and E1 recorded no visible growth after 24 hours of incubation. Sample C1 recorded the highest TSSC of 2.1×10^2 ±0.011 cfu/mL as presented in Table 3. Overall, the samples recorded very low TSSC.

Table 3. Bacterial counts of the different domestic water sources used in Owerri.

Samples	THBC (cfu/mL)	TCC (cfu/mL)	TSSC (cfu/mL)
A1	1.0×10^3 ±0.14	0.3×10^2 ±0.002	NG
A2	1.5×10^3 ±0.13	1.3×10^2 ±0.012	NG
B1	1.0×10^2 ±0.01	NG	NG
B2	1.2×10^2 ±0.01	0.2×10^2 ±0.001	NG
C1	3.0×10^5 ±0.21	2.1×10^4 ±1.22	2.1×10^2 ±0.011
C2	3.6×10^5 ±0.23	3.7×10^4 ±0.06	1.7×10^2 ±0.011
D1	1.07×10^6 ±0.14	2.8×10^4 ±1.36	1.3×10^2 ±0.84
D2	2.1×10^6 ±0.06	3.6×10^4 ±1.27	1.1×10^2 ±0.02
E1	3.0×10^5 ±0.14	2.1×10^3 ±0.97	NG
E2	3.5×10^6 ±0.11	2.9×10^3 ±0.88	1.0×10^2 ±0.001
WHO Standard	-	0.00	0.00
NISDWQ Standard	-	0	0

NG = No growth.
Values represent the mean of duplicate analysis ± standard deviation

4. DISCUSSION

The different domestic water sources used in Owerri include the municipal tap water, which the government provides through the Imo State water cooperation, private boreholes provided by individuals in their various homes, river water from Nworie and Otammiri rivers and rainwater, which many dwellers collect through the roofs or from constructed water collector pipes once there is rainfall.

The physical properties of these water samples analyzed revealed that the municipal tap water and borehole water maintained a clear and odourless appearance corresponding to the WHO and NISDWQ standards for domestic water, unlike the river water and rainwater samples, which did not align with these standards.

The pH of the water samples ranged from 6.43 – 6.96, which also falls within the stipulated pH range for domestic water according to the WHO [19] standards. This pH range also corresponds to the pH recorded by Bello et al. [20] and Agbo et al. [21], who reported a slightly acidic to alkaline pH in boreholes and well water for domestic use.

The temperature recorded for the water samples ranged between 20.6 °C and 28.8 °C. This temperature range aligns with the stipulated WHO and NISDWQ standards for domestic water. Temperature is an important parameter in water because it significantly impacts the growth and pH of the ecological environment. It also plays an important role in water's oxygen solubility rate. The water's pH reduces at high temperatures, making it acidic, favouring the rapid growth of microbes. The temperature range obtained in this study is also in line with the study of Oparaocha et al. [22], who reported the maximum water temperature of 28 °C from different water sources in Imo State, Nigeria.

The electrical conductivity of the water samples was also measured to detect the degree of ions in the water. This is important because a water sample's conductivity affects the water's taste and general acceptance. Electrical conductivity ranged from 42.05±1.42 µS/cm - 360.92±6.77 µS/cm. This result revealed that some water samples, like the municipal borehole and rainwater, were within the permissible limit of WHO and NISWQ, while the river water was above the electrical conductivity limits as stipulated by WHO. The high electrical conductivity observed in the river water samples could have resulted from high total dissolved solids, low dissolved oxygen, and the presence of impurities in the water, which was evident in the physical appearance of the water [23].

The bacterial counts of the different water samples revealed an overall low bacterial load except for the Otammiri (C1 & C2) and Nworie (D1 & D2) water, which recorded higher bacterial counts. The total coliform counts revealed that samples A1 & A2, the municipal tap water, recorded very low coliform counts while the rest recorded higher coliform counts. This result does not correspond with the coliform count stated by the WHO for drinking water. As a result, it can be noted that these water samples might be unfit for consumption without proper water treatment. The only sample that satisfied the WHO and NISDWQ standards for drinking water is sample B1, a borehole water sample.

5. CONCLUSION

This study has revealed the physicochemical properties and bacteriological quality of the different domestic water sources used in Owerri, Nigeria. The findings of this study, when compared to the stipulated standards for drinking and domestic water, have shown that only the borehole water met all the standards. Therefore, it can be safe to say that only the borehole water out of all the water sources analyzed is fit for consumption, while the others must be properly treated before use.

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