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Microbial Quality and Physicochemical Properties of Borehole Water Sources in Diobu, Port Harcourt, Rivers State

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ABSTRACT

This study investigated the microbial quality and physicochemical properties of borehole sources in Diobu, Port Harcourt, Rivers State, Nigeria. Water samples were collected at monthly intervals for a period of 12 calendar months (June 2023 to May, 2024), covering both the dry and wet seasons. The physicochemical characteristics of the water samples were determined using standard analytical techniques. Bacterial isolation and total bacterial count was obtained using standard dilution and spread plate method; and bacterial identification was determined using standard microbiological techniques. The results revealed that the borehole water samples had pH values ranging from 6.23 to 6.38, temperatures from 27.15°C to 27.59°C, Electrical conductivity from 26.46 to 96.59µS /cm. Total suspended solids ranged from 2.07 to 2.64 mg/L, Total dissolved solids ranged from 1.64 to 2.06 mg/L, Turbidity from 1.55 to 1.71 NTU, Dissolved oxygen from 5.60 to 5.96mg/L, Biochemical Oxygen Demand from 34.1 to 53.7mg/L, Chemical Oxygen Demand from 61.13 to 92.80mg/L, Chloride ranged from 37.78 to 43.24mg/L, Salinity ranged from 2.51 to 3.51ppt and Total hardness ranged from 6.74 to 7.57mg/L. The mean total coliform counts ranged from $1.04\pm0.57^a \times10^2$ to $8.67\pm4.41^a \times10^2$ CFU/ml. The mean total faecal coliform counts ranged from $4.84\pm2.38^a \times10^2$ to $8.55\pm5.28^a \times10^2$CFU/ml. The mean total *Salmonella-Shigella* counts ranged from $1.02\pm0.74^a \times10^2$ to $2.69\pm1.72^b \times10^2$ CFU/ml. The mean total *Vibrio* counts ranged from $0.98\pm0.76^a \times10^2$ to $1.17\pm0.74^b \times10^2$ CFU/ml. The identification of 14 bacteria genera which included pathogenic and opportunistic strains such as *Klebsiella pneumoniae*, *Vibrio cholerae*, *Salmonella typhii*, and *Escherichia coli* indicated the presence of faecal contamination in the groundwater, rendering it unsuitable for consumption without appropriate disinfection measures. Individuals who consume this water may experience a range of clinical symptoms, including cholera, gastrointestinal disorders, diarrhea, and typhoid fever. Consequently, it is crucial to implement appropriate treatment prior to domestic use to eradicate bacteria associated with waterborne disease outbreaks in Diobu Community.

Keywords: Borehole Water, Enteric Bacteria, *Vibrio cholerae*,physicochemical properties, Water Quality, Public Health.

Introduction

Water is necessary for life, and all living organisms require a sufficient, accessible, and safe supply. Improving access to safe water, for drinking, bathing, food production, or leisure activities, is of significant impact to human health (Eboh *et al.,* 2017; Aleru *et al.,* 2019). Groundwater constitutes a vital source of freshwater for the global population in which one-third of the populace depends on it for drinking water (International Association of Hydro geologists, 2020) besides its utility for domestic, agricultural, and industrial applications. Securing a sustainable and renewable groundwater supply for drinking purposes is essential for a nation's sustainable development. Urbanization, agricultural methods, industrial activities, and climate change pose significant threats to groundwater quality which can be ascertained by its biological, chemical, and physical properties.

Groundwater contamination is a process whereby water progressively or suddenly changes its physical, chemical, or biological properties, rendering it unsuitable for set standards of drinking, irrigation, and other uses. Contaminants such as toxic metals, hydrocarbons, trace organic pollutants, pesticides, nanoparticles, micro plastics, and emerging compounds threaten human health, ecological services, and sustainable socioeconomic development (Li *et al.,* 2021). Groundwater contaminants largely stem from gynogenic sources, specifically the dissolution of natural mineral deposits in the Earth's crust (Rao *et al.,* 2020). The rapid increase in the global population, along with urbanization, industrialization, agricultural expansion, and economic development, has resulted in the emergence of anthropogenic contaminants, posing a significant challenge. The countries most affected by these global changes are those undergoing swift economic development, primarily located in the eastern hemisphere (Lam *et al.,* 2021).

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Water quality is influenced by rising levels of human activity, as both physical and chemical pollutants modify the properties of the affected water body (Lin et *al.,* 2022). Chemical pollutants are ubiquitous in drinking water worldwide, posing risks to human health. In 2022, approximately 1.7 billion individuals worldwide relied on drinking water sources contaminated with faecal matter. Microbial contamination of drinking water due to faecal pollution poses a significant threat to water safety. Access to safe and adequate water supports hygiene practices are essential for preventing diarrhea diseases, acute respiratory infections, and various neglected tropical diseases (WHO, 2023). Drinking water contaminated with microorganisms serves as a vector for diseases such as diarrhea, cholera, dysentery, typhoid, and polio, resulting in an estimated 500,000 diarrheal deaths annually (WHO, 2023). In Nigeria, boreholes are excavated by individuals as well as public and private organizations to address water scarcity. Consequently, individuals increasingly depend on boreholes as a practical source of water for domestic and potable purposes. Boreholes are sometimes excavated in proximity to pit latrines and septic tanks, potentially resulting in faecal contamination via subsurface infiltration by capillary process (Ewelike *et al.,* 2022). The microbiological evaluation of water is crucial due to the substantial health hazards caused by bacteria in drinking water. Consequently, it is essential to prioritize this health-oriented initiative to protect public health by guaranteeing the quality of accessible water sources. This study assessed the Microbial Quality and Physicochemical Properties of Borehole Water Sources in Diobu, Port Harcourt, and Rivers State, to ascertain the health hazards linked to its consumption.

Materials and Methods

Study area

The study area is Diobu community with coordinates 4°47’24”N, 6°59’36”E (Latitude: 4.772152; Longitude: 6.994514) located in Port Harcourt, Rivers State, Nigeria. The bacteria used for this study were the bacteria that were previously isolated from the borehole water sources and identified in the Rivers State University Microbiology Laboratory by the authors. The bacteria were; *Klebsiella pneumoniae, Klebsiella oxytoca, Vibrio cholereae, Kluyvera ascorbata, Salmonella typhi, Escherichia coli, Shigella dysenteriae, Klebsiella aerogenes, Shewanella putrefaciens, Citrobacter koseri,* and *Yersinia enterocolitica.*

Collection of water samples

Water samples were collected from fifteen (15) different boreholes around the Diobu community, Port Harcourt, Rivers State, in duplicates using sterile containers and labeled 1-30. The sampling protocols previously described by the Clinical and Laboratory Standards Institute (CLSI, 2018) were strictly adhered to during sample collection. Each sample was collected aseptically in screw cap containers after the water was allowed to waste for 3 to 5 minutes. Care was taken not to allow air bubbles into the bottles during collection. The samples were collected aseptically from each sampling point in duplicates into the sterilized container and transported immediately to the Microbiology Laboratory of Rivers State University, Port Harcourt, for bacteriological analysis.

Microbiological Analysis

Determination of Enteric bacterial counts

The total enteric count was carried out using the spread plate technique. A ten-fold serial dilution was carried out by measuring 1 mL of each water sample into nine (9) mL of distilled water in a test tube covered with cotton wool and foil and mixed properly to make a dilution of 10^3. This was used to complete the ten-fold serial dilution. Exactly 0.1 mL of each appropriate diluent was introduced into different sterile Petri dishes containing the various Media (Thiosulphate citrate bile salt and Salmonella-Shigella agar). The plates were incubated at 37^{O}C for 24 hours. An aliquot of 0.1 mL from the appropriate dilution was pipetted and spread on MacConkey agar and Eosine Methylene Blue agar. The inoculated plates were then incubated at 32°C for 18–24 h to determine total coliforms and at 44.5°C for 18–24 h to determine fecal coliform. The physiological characteristics of the colonies and their number on the culture plates were used as basis for the counting, taking into consideration their dilution number. Counts were made from the plates containing 30-300 colonies. The isolates were aseptically sub-cultured into fresh nutrient agar after counting and incubated at a temperature of 37ºC for 24 hours to obtain pure cultures of the isolates.

Isolation of Enteric Bacteria

Discrete colonies obtained from the different agar were counted using the colony counter and recorded appropriately; the colonies were sub-cultured onto nutrient agar. The Petri dishes were placed in an inverted position in the incubator for 24 hours at 37ºC to obtain pure cultures.

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Presumptive morphological identification of the colonies was done by observing their appearance on the media. The colonies were stored in Peptone water test tubes for cultural/bacteriological identification and biochemical characterization.

Analysis of water samples for physicochemical properties

Temperature (^{0}C), electrical conductivity (µs/cm-^{1}), and pH were analyzed in situ using the Horiba Water Checker (Model U-10). Turbidity was measured using a HACH 2100N Turbidimeter, Total Dissolved Solids (TDS), Total Suspended Solids (TSS), Total hardness, Chemical Oxygen Demand, and the detection of Salinity and Dissolved oxygen in the water samples were determined using standard methods described by APHA (2005) and Ogah and Ukaegbu (2019). Biological oxygen demand (BOD5) after five (5) days of incubation was detected using the digital DO meter HI 9143 Microprocessor and deduced using the methods described by Agbabiaka and Olofintoye (2019). Chloride concentrations of water samples were measured directly by atomic absorption spectrophotometer (Mahmud *et al.,* 2014).

Statistical Analysis

All data generated was analyzed statistically by calculating the mean and comparing the mean value with the acceptable standards. Data collected were statistically analyzed using Statistical Package for Social Sciences (SPSS 20).

Results

Table 1 shows the microbial counts of the borehole water samples. The results revealed a total coliform count of the water samples with range value of 6.59±3.18^a ×10^2 to 10.39±5.67^a ×10^2 CFU/mL. While the total faecal coliform counts ranged from4.84±2.38^a ×10^2 to 8.55±5.28^a ×10^2 the total vibrio counts total shigella-salmonella counts ranged from 0.98±0.76^a ×10^2 to 1.17±0.74^b ×10^2, and the total shigella-salmonella counts ranged from 1.02±0.74^a ×10^2 to 2.69±1.72^b×10^{2}CFU/mL respectively. Mile 2 had the highest counts in TCC, TFC, TSSC and TVC, followed by Mile 1 and Mile 3 with the least counts.

The percentage occurrences of bacterial isolates from water samples are presented in Figure 1. *Enterobacter* spp had the highest occurrence of 1.5%, followed by *Klebsiella* and *Vibrio* spp 11.7%, while Campylobacter *coli* had the least occurrence of 0.9% respectively.

The physicochemical properties of borehole water samples analyzed are presented in Table 2. The result has revealed a slightly acidic pH range of 6.23 to 6.38, with water samples from Mile 2, community recording the highest pH value (6.38) while the Mile 3 community had the lowest pH value (6.23).

The temperature of the samples ranged from 27.15°C to 27.59°C. The pH, Temperature, Electrical conductivity, chemical oxygen demand, total hardness, chlorine, total suspended solids, salinity and turbidity were below the acceptable limits of the World Health Organization (WHO). Biological Oxygen Demand (14mg/L), higher than the acceptable limit of the World Health Organization and Nigerian Standard for Drinking Water Quality from all the Sampling locations in Diobu.

Table 3 shows the water quality index of the borehole water samples in Diobu. The results for the Water Quality Index for Miles 1, 2 &3 shows that Mile 1 had the poorest Water Quality Index of (91.87168) followed by Mile 2 (89.90374) and Mile 3 with the least value (78.19532). This shows the water is unfit for human consumption and should be treated before use.

Table 1: Microbial counts of the borehole water samples in the Diobu Area of Port Harcourt

Sampling Location	Microbial counts (×10^2 CFU/ml) of the borehole water samples			
	Total Coliform	Fecal coliform	Total *Vibrio*	Total *Shigella/ Salmonella*
Mile 1	8.67±4.41^a	6.98±4.38^a	1.16±0.85^{ab}	1.06±0.93^a
Mile 2	10.39±5.67^a	8.55±5.28^a	1.17±0.74^b	2.69±1.72^b
Mile 3	6.59±3.18^a	4.84±2.38^a	0.98±0.76^a	1.02±0.74^a
P-value	0.136	0.109	0.799	0.002

*Means with different superscript shows a significant difference (p≤0.05)
Keys: CFU/ml= Colony Forming Unit per Milliliter.

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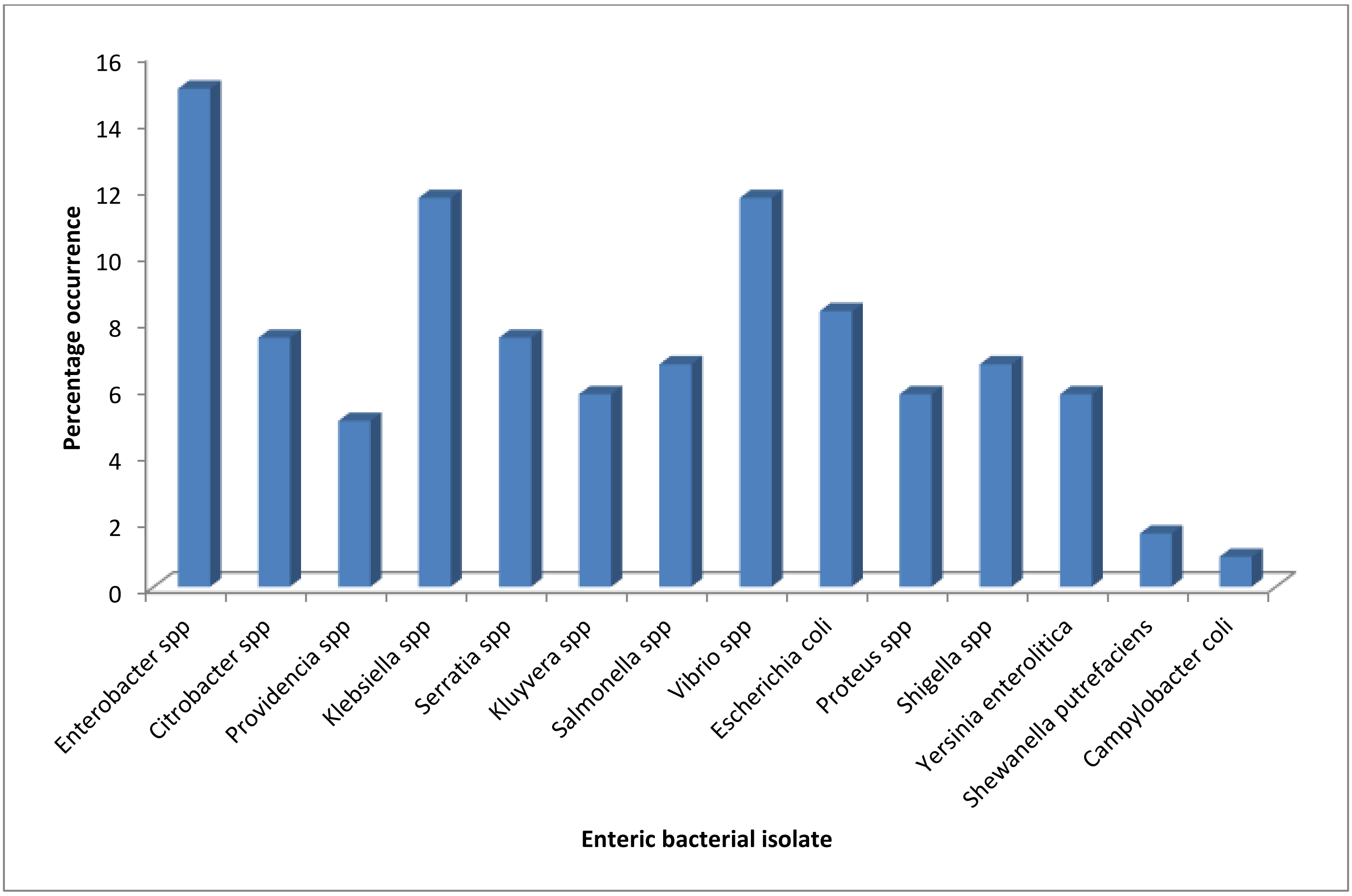

Fig. 1: The percentage (%) occurrence of enteric bacteria isolated from borehole water samples

Table 3 Water Quality Index of the Borehole Water Samples for the Study Period

Parameters	**Location of Diobu Borehole water sample**		
	Mile 1	**Mile 2**	**Mile 3**
pH	6.24	6.38	6.23
Temperature (ºC)	27.15	27.59	27.17
Electrical Conductivity (*µS/cm*)	96.59	26.46	58.03
Total Suspended Solid (mg/l)	2.64	2.32	2.07
TDS (mg/l)	2.06	1.67	1.81
Turbidity (NTU)	1.69	1.55	1.71
Dissolved Oxygen (DO) (mg/l)	5.71	5.66	5.96
Biological Oxygen Demand (BOD) (mg/l)	51.89	53.79	34.14
Chemical Oxygen Demand (COD) (mg/l)	92.8	76.77	61.13
Chlorine (mg/l)	43.24	37.78	42.83
Salinity (mg/l)	3.51	3.34	2.51
Total Hardness (mg/l)	7.57	7.02	6.74
∑WnQn	91.87168	89.90374	78.19532
Wn	1.00	1.00	1.00
WQI=∑WnQn/Wn	91.87168	89.90374	78.19532

Note: Very poor water quality; wi; Wi; Unit weight, Qi; Quality rating, WiQi; Unit Weight X Quality Rating.

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Table 1 Physicochemical Parameter Obtained from Mile 1, 2 and 3 for the Study Period

Sampling location	pH	Temp	E.C	TSS	TDS	Tur	DO	BOD	COD	Chl	Sal	TH
Mile 1	6.24±0.96[a]	27.15±1.02[a]	96.59±39.76[c]	2.64±0.64[a]	2.06±0.91[a]	1.69±0.67[a]	5.71±1.60[a]	51.89±54.53[a]	92.80±3.38[a]	43.24±40.29[a]	3.51±4.22[a]	7.57±4.16[a]
Mile 2	6.38±0.88[a]	27.59±1.18[a]	26.46±12.12[a]	2.32±0.76[a]	1.67±0.59[a]	1.55±0.57[a]	5.66±1.17[a]	53.79±56.89[a]	76.77±45.51[a]	37.78±35.29[a]	3.34±4.02[a]	7.02±4.75[a]
Mile 3	6.23±1.03[a]	27.17±0.83[a]	58.03±4.71[b]	2.07±0.38[a]	1.81±0.72[a]	1.71±0.82[a]	5.96±2.17[a]	34.14±30.98[a]	61.13±19.84[a]	42.83±39.99[a]	2.51±2.99[a]	6.74±4.35[a]
WHO standard	6.5-8.0	15.5-32 (^{O}C)	250 (µs)	15-25 mg/l	500 mg/l	5 NTU	5 mg/l	14 mg/l	200 mg/l	100-250 mg/l	30-60 mg/l	50-100 mg/l
NSDWQ	6.5-8.5	Nil	1000 (µs/cm)	10mg/l	1000mg/l	5NTU	5mg/l	5mg/l	10mg/l	100mg/l	Nil	100mg/l
P-value	0.950	0.664	0.000	0.240	0.624	0.896	0.940	0.713	0.148	0.957	0.871	0.938

***Means with similar superscript shows no significant difference ($p \geq 0.05$)**

Key: Temp; Temperature, E.C; Electrical Conductivity, TSS; Total Suspended Solid, TUR; Turbidity, DO; Dissolved Oxygen, BOD; Biochemical Oxygen Demand COD; Chemical Oxygen Demand, CHL; Chlorine, SAL; Salinity, TH; Total Hardness, TDS; Total Dissolved Solid, WHO; World Health Organization. NSDWQ: Nigerian Standard for Drinking Water Quality.

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Discussion

The high microbial count obtained from the borehole water samples indicated that the borehole waters are polluted. Several studies have been conducted to determine the microbial quality of water from boreholes in Kurnar Asabe Quarters, Kano Metropolis and Okorenkoko, Delta State in Nigeria (Adeiza *et al.,* 2018; Asionye *et al.,* 2023). These findings also corroborate the report of Nnadozie (2016) that reported the presence of significant coliforms in the ground and surface water sources in Port Harcourt Metropolis. The activities such as defecation, dumping of domestic waste and channeling of effluents including grey water have been identified as a remote challenge to surface water while with respect to ground water these can be traced to decades of seepages into the water bed (Sasakova *et al.,* 2018). The study identified the presence of pathogenic and opportunist organisms such as *Salmonella typhimurium*, *Vibrio cholerae*, *Escherichia coli, Enterobacter aerogenes*, *Enterococcus faecalis*, *Klebsiella* spp., *Citrobacter* spp., and *Shigella* spp. The presence of these pathogens suggests faecal contamination and this agrees with the findings of Douye et al. (2018) who assessed the bacteriological quality of water from boreholes in Otuoke Community, Bayelsa State; Aleru et al. (2019) who studied the Bacteriological assessment of borehole water in some communities in Owerri West, Southeastern Nigeria. *Escherichia coli* is an indicator of fecal pollution. *Shigella* and *Salmonella* are enteric organisms responsible for Shigellosis and Salmonellosis which may cause life-threatening diseases (Asionye *et al.,* 2023).

One of the prevalent diseases in the region is typhoid fever caused by *Salmonella* sp. Possible sources of contamination of boreholes are septic tanks, livestock yards, septic leach fields, petroleum tanks, liquid-tight manure storage, fertilizer storage, and manure stacks (Aleru *et al.,* 2019). The unhygienic and poor sanitary environment surrounding some of the boreholes also could be responsible for the contamination (Ewelike *et al.,* 2022). The safety and effectiveness of a borehole depend greatly on its location. For this reason, it is necessary to maintain safe distances between boreholes and possible contamination sources.

The mean values of all the physicochemical properties (pH, temperature, electrical conductivity, turbidity, total dissolved solids, total suspended solids, dissolved oxygen, and total hardness) of the borehole water samples from all selected communities were within the acceptable limits set by the WHO. This corroborates Asionye et al. (2023), Muhammed et al. (2023), and Aleru et al. (2019), who reported that the physicochemical properties of borehole water samples in Delta, Kano, and Rivers State of Nigeria, respectively, also adhered to the World Health Organization's acceptable limits. The pH of water indicates the characteristics of chemical processes and biological systems present in it (Muhammed *et al.,* 2023). Temperature is a critical ecological and physical factor that significantly impacts both biotic and abiotic components of the environment, consequently influencing organisms and ecosystem functionality (Adeiza *et al.,* 2018). Electrical conductivity reveals the overall ionic concentration in water, serving as indicator of its capacity to conduct electricity and potentially reflecting the concentration of dissolved salts. Turbidity is a quantification of suspended particles and is directly correlated with the electrical conductivity values recorded during the investigation. Turbidity may result from sediments accumulating at water distribution points due to ageing infrastructure and the manner in which water is channeled to these locations (Muhammed *et al.,* 2023). Total Dissolved Solids (TDS) in water indicates the presence of both organic and inorganic substances. Elevated levels can impart an unpleasant aroma and distasteful flavor to the water (Adegboyega *et al.,* 2015). Total hardness in water results from the concentrations of calcium, magnesium, and carbonates present in the water sample. The water samples in the Diobu area are categorized as not hard according to the categorization by Tiwari and Bajpai (2012), with values ranging from 5.34 mg/L to 12.50 mg/L, which comply with the WHO maximum limit of 100 mg/L. Adequate levels of dissolved oxygen reflect high water quality, effective aeration, and reduced pollution levels. Aeration improves the neutral taste and mitigates odour in water. Chemical oxygen demand (COD) quantifies the quality of water and wastewater by measuring the oxygen required to chemically oxidize organic contaminants into inorganic products.

Despite the borehole water sample exhibiting a low COD concentration, it is imperative to treat any drinking water with a COD exceeding 8 mg/l with appropriate caution (Imoh *et al.,* 2021).

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All borehole water samples didn't comply with the recommended limits for biological oxygen demand which exceeded the acceptable limit set by the WHO. The amount of dissolved oxygen utilized by microorganisms during the oxidation process of organic materials is termed biological oxygen demand (BOD5), measured after a five-day incubation period in darkness (Maddah, 2022). A high BOD value signifies considerable water pollution and represents the level of degradable organic matter present, as microorganisms consume dissolved atmospheric oxygen to oxidize this organic matter, thus, presents significant health hazards to consumers.

Conclusion

A microbial quality and physicochemical properties of borehole water samples from Diobu, Port Harcourt in Rivers State, revealed that the borehole water did not meet the standard criteria for drinking and domestic purposes. The poor water quality index is of public health importance. Therefore, this study recommends implementing measures to protect communities from the risks associated with contaminated water. Continuous monitoring of water quality and consistent sanitation around borehole sites is necessary. Additionally, the presence of *Escherichia coli*, an indicator of faecal contamination reveals that sewage disposal systems located at close distances to the location of the boreholes. The content of septic tanks must have leached into the subsoil. The presence of pathogenic bacteria such as *Escherichia coli*, *Salmonella, Klebsiella, Enterobacter, Vibrio* and *Shigella* species is of major public health concern.

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