International Journal of Microbiology and Applied Sciences
Volume 2 issue 2 Sept, 2023
Research Article

Bacteriological and Physicochemical Qualities of Borehole and Well Water in Bundu Waterside, Port Harcourt

Kpormon, L. B*., Ogbonna, D. N., Wemedo, S.A., Williams, J.O. and Douglas, S. I
Department of Microbiology, Rivers State University,
Nkpolu-Oroworukwo P.M.B 5080,
Port Harcourt, Nigeria
***Corresponding Author:** *Lucky.kpormon@ust.edu.ng*

ABSTRACT

Bacterial contamination of drinking water is a major public health problem worldwide because contaminated water can be an important vehicle of diarrheal diseases. This study was aimed at evaluating the bacteriological and physiochemical qualities of borehole and well water drinking sources. A total of forty eight (48) boreholes and wells water samples were collected from Bundu waterside, Port Harcourt between March - August, 2022 and analyzed using standard analytical procedures. Results showed that mean total heterotrophic bacterial counts for well water and Borehole water samples ranged from $1.30 \pm 0.13 \times 10^6$CFU/ml to$1.73 \pm 0.05 \times 10^6$CFU/ml and from$1.08 \pm 0.21 \times 10^6$CFU/ml to $1.40 \pm 0.11 \times 10^6$CFU/ml respectively. Total coliform counts (TCC) for well water and Borehole water ranged from $2.8 \pm 1.4 \times 10^4$CFU/ml to $4.8 \pm 0.5 \times 10^4$CFU/ml and from $2.1 \pm 1.0 \times 10^3$CFU/ml to $4.0 \pm 1.2 \times 10^3$CFU/ml respectively. Well water samples recorded higher counts compared to borehole water samples, though the counts obtained from the two water sources were higher than the acceptable limit 100CFU/ml of total heterotrophic bacterial counts and 0 CFU/100ml of total coliform, indicating high level of pollution of drinking water sources in Bundu waterside. Percentage occurrence of the bacteria isolated revealed that *Escherichia coli ETEC* (20%), recorded the highest percentage followed by *Escherichia coli 9157:H7* (14%), *Staphylococcus aureus* (12%) *Shigella sonnei* (12%), *Vibrio parahaemolyticus* (12%), *Salmonella enterica* (8%), *Pseudomonas aeruginosa* (7%), *Proteus mirabilis* (6%), *Enterobacter cloacae*, and *Vibrio cholera* (4%). Results of physiochemical parameters of the water samples revealed that Electrical conductivity, Total dissolved solid, sulphate, phosphate and nitrate were above the permissible limit by WHO and Nigerian Standard for Drinking Water Quality while pH, Dissolved Oxygen, Biological Oxygen Demand, and Turbidity were below the permissible limit. Hence, bacteriological and physiochemical characteristics of the borehole and well water sources did not comply with standards which indicates that the water sources are not fit for consumption. Therefore treatment is recommended for the water sources before use for any domestic purposes.

Keyword: Drinking water sources, borehole, well, bacteriological, physico-chemistry, *E. coli*, *Shigella sonnei*

Introduction

One of Nigeria's fastest-growing cities is Port Harcourt, the capital of Rivers State. In quest of work and better opportunities in the city, people are moving from rural to urban areas, contributing to the creation of slum, sometimes referred to as "waterside". In the slum (Informal settlements), many shallow boreholes have been drilled and wells dug into the formation for drinking and domestic water supply. In majority of cases, the water is usually consumed raw without any form of treatment (Ogbonna *et al.*, 2023).

These natural waters contain a myriad of microbial species, many of which have not been cultured, much less identified. The number of organisms present varies considerably between different water types. Improper and indiscriminate dumping of untreated wastes of various kinds around residential areas is common sight in Port Harcourt City (Obire *et al*., 2009).

According to Obire *et al.*, (2009), sources of water pollution include effluents of untreated sewage that are dumped directly into water bodies, runoffs containing faecal materials, leaking pipes run in gutters or drainages, domestic effluents containing large microbial populations that are involved in degradative processes, and hospital effluents (Essien and Bassey, 2012). Other sources of contamination include closeness of borehole to septic tanks especially where space is a constraint and boreholes are drilled around the area (Essien and Bassey, 2012).

Citation: Kpormon *et al*. (2023). Bacteriological and physicochemical qualities of borehole and well water in Bundu waterside, Port Harcourt. *International Journal of Microbiology and Applied Sciences*. *2(2)*: 153 - 161.

Declining water quality has become a global issue of concern as human populations grow, industrial and agricultural activities expand, and climate change threatens to cause major alterations to the hydrologic cycle (Ogbonna and Orinya, 2018). In Nigeria especially Bundu waterside, Port Harcourt Rivers State, a vast majority of people source and drink from borehole and wells irrespective of the state of these water bodies without any form of treatment.

Majority of the human population in semi-urban and urban areas in Nigeria are heavily reliant on well water and borehole as the main source of water supply for drinking and domestic use due to inadequate provision of potable pipe borne water. These ground water sources can easily be contaminated by faecal matter and thus increase the incidence and outbreaks of preventable water-borne diseases (Alonge *et al.,* 2018).

Accurate and timely information on the quality of water is necessary to shape a sound public policy and to implement the water quality improvement programme efficiently. One of the most effective ways to communicate information on water quality trends is with indices. The water quality index (WQI) is commonly used for the detection and evaluation of water pollution and may be defined as 'a rating reflecting the composite influence of different quality parameters on the overall quality of water' (Mishra, 2005).

The indices are broadly characterized into two parts: the physicochemical and biological (bacteriological) indices. Physicochemical indices are based on the values of various physicochemical qualities in a water sample (Chibuike *et al.*, 2023). These are vital for water quality monitoring (APHA, 2017). A number of scientific procedures and tools have been developed to assess the water contaminants (Dissmeyer, 2000). These procedures include the analyses of different parameters such as pH, turbidity, temperature, dissolved oxygen, alkalinity amongst others. These parameters can affect the drinking water quality if their values are in higher concentrations than the safe limits set by the World Health Organization and other regulatory bodies (WHO, 2011).

Bacterial contamination of drinking water is a major public health problem worldwide; because this water can be an important vehicle of diarrheal diseases, thus the need to evaluate the bacterial quality (Suthar *et al.,* 2009). Monitoring the bacterial quality of drinking water is done through laboratory testing for the coliform groups.

The total coliform refers to a large assemblage of gram-negative, rod shaped bacteria that share several characteristics. This coliform group include *E. coli, Klebsiella, Enterobacter, Streptococcus, Staphyloccocus* spp. Before water can be described as potable, it has to comply with certain physical, chemical and microbiological standards which are designed to ensure that the water is potable and safe for drinking.

Thus studies have been conducted to ascertain these parameters in varying drinking water sources, well water (Aboh *et al.,* 2015; Gambo *et al.,* 2015) borehole water (Ibe and Okplenye, 2005; Isa *et al.,* 2013; Ukpong and Okon 2013, Douglas *et al.*, 2021).

It is on these bases that this research was conducted to determine the physiochemical and bacteriological qualities of borehole and well water sources in Bundu waterside, Port Harcourt, Nigeria.

Materials and Methods

This study was conducted in Bundu Waterside, Port Harcourt, which is in Southern Nigeria's Niger Delta. Around 50 kilometers from the Atlantic coast, the city is located between latitudes 3037' and 3056' N. and longitudes 11010' and 11045' E (Ogbonna *et al.*, 2021). The average annual temperature is 23°C, with 3,030mm of precipitation. Figure 1 is a Map of Port Harcourt with the sampled locations indicated.

Sample collection

According to the Standard Methods adopted by Kpormon *et al.* (2023), a total of forty eight (48) water samples were collected from boreholes and wells located in Bundu waterside, Rivers State between March-August, 2022.

On each sampling occasion, water samples of approximately 600ml were collected aseptically with pre-rinsed 1 litre plastic containers via the running tap connected to the water holding tank for borehole water samples.

Sterile water fetcher was used to obtain water samples from the well from which approximately 600 ml was poured aseptically into sterile pre-rinsed 1 litre plastic containers. All samples were transported to the Laboratory, Microbiology Department of Rivers State University for analyses within 2 hours of collection in a thermos box containing ice packs (APHA, 2017).

Citation: Kpormon *et al*. (2023). Bacteriological and physicochemical qualities of borehole and well water in Bundu waterside, Port Harcourt. *International Journal of Microbiology and Applied Sciences*. *2(2)*: 153 - 161.

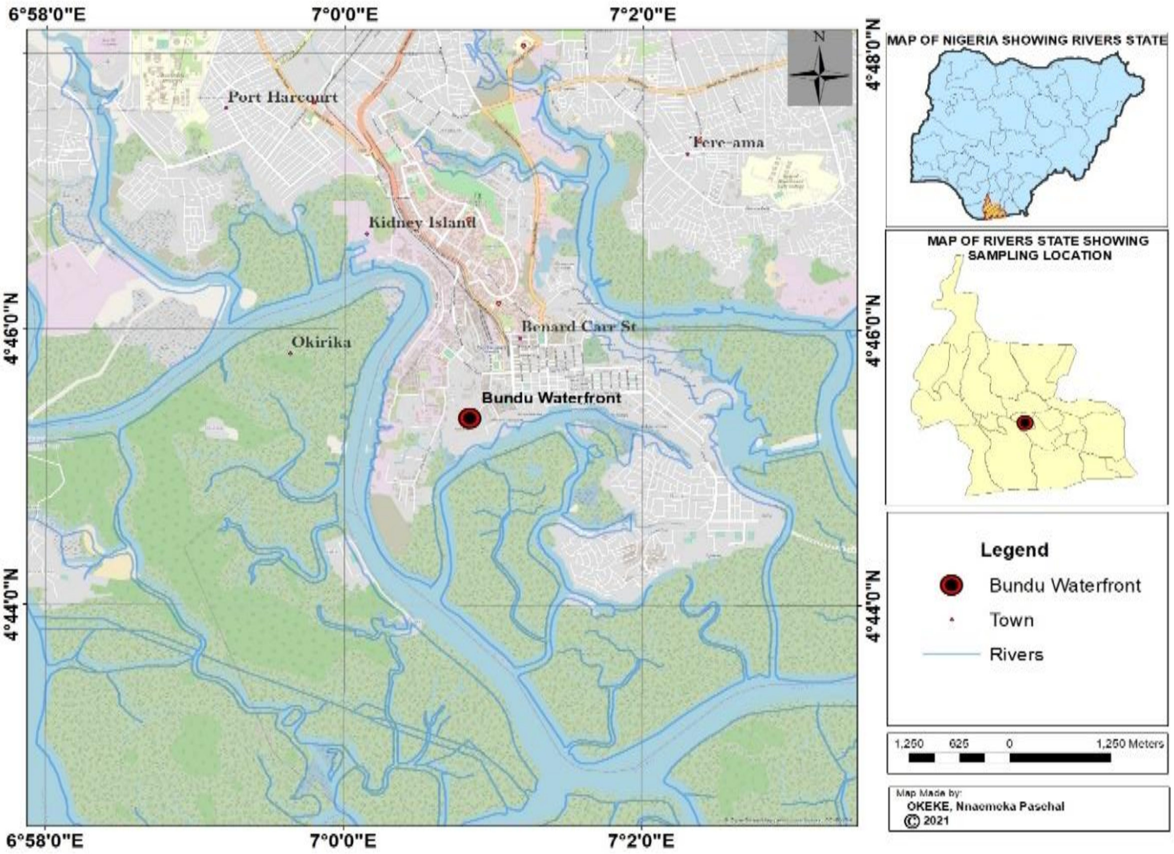

Figure 1: Map of Port Harcourt showing the sampled locations of the study

Bacteriological Analyses

Cultivation and Enumeration of Total Heterotrophic Bacteria (THB)

An aliquot (0.1ml) from 10^{-3} dilution of water samples were inoculated (0.1ml) on the nutrient agar plate in triplicate for isolation and enumeration of total heterotrophic bacteria using standard spread plate methods as described by Prescott *et al.* (2005) and incubated for 24hours at 37.2°C. Bacterial colonies that grew on the cultured plates after incubation were counted and the mean expressed as cfu/ml using the formula below;

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

Cultivation and Enumeration of Total Coliform

An aliquot (0.1ml) from 10^{-2} dilution of water samples were inoculated on the MacConkey agar plates in triplicate for isolation and enumeration of Total coliform using standard spread plated methods as described by Prescott *et al* (2005).

The inocula were spread evenly on the surface of the MacConkey agar media using a sterile spreader and incubated at 37.2ºC for 24 hours, after which the colonies that developed were counted and the mean expressed as colony forming unit per milliliter (Amadi *et al*., 2014).

Purification of Isolates

After incubation, discrete colonies on the respective culture media used were sub-cultured onto freshly prepared nutrient agar plate in order to isolate pure colonies. The cultures pure isolates were obtained by picking (with sterile inoculating loop) distinct culturally and morphologically different colonies from the various plates (Douglas *et al.*, 2022).

Identification of Bacterial Isolates

Pure bacterial isolates were identified phenotypically according to the method described by Cheesbrough (2006). Identification was done by comparison of their cultural, morphological and physiological characteristics with those of known taxa using the Bergey's Manual of Determinative Bacteriology

Citation: Kpormon *et al*. (2023). Bacteriological and physicochemical qualities of borehole and well water in Bundu waterside, Port Harcourt. *International Journal of Microbiology and Applied Sciences*. *2(2)*: 153 - 161.

(Holt *et al*., 1994). Further genotypic identification of pure bacteria isolated was also carried out using molecular approaches which involve extraction of the bacterial DNA by boiling method, the extracted genomic DNA was quantified using the Nanodrop 1000 spectrophotometer. The 16srRNA Amplification was carried out using an ABI 9700 Applied Biosystems Thermal Cycler and method described by Srinivasan *et al*. (2015). Sequencing of the amplified product was carried out using the Big-Dye Terminator kit on a 3510 ABI sequencer by Inqaba Biotechnological, Pretoria South Africa, (Srinivasan *et al*., 2015). The evolutionary history was inferred using the Neighbor-Joining method in MEGA 6.0 (Saitou and Nei, 1987).

Determination of Physicochemical Characteristics

Physicochemical properties such as Temperature, pH, Electrical Conductivity(EC), Dissolved oxygen (DO), Biological Oxygen Demand (BOD), Total Dissolved Solids (TDS), Turbidity, Sulphate, Phosphate, and Nitrate of the borehole and well water samples were measured using their respective meters. pH was measured using a pH meter (HANNA, HI 9125) and conductivity, total dissolved solids using a calibrated Conductivity Meter (HANNA, Conductivity meter). Turbidity measurements was conducted using a portable turbidity meter (APHA, 2017). Total hardness was evaluated by burette titration. Total alkalinity, chloride, nitrate-N, sulfate and major cations were determined according to other standard analytical methods described by APHA (2017).

Statistical Analyses

Analyses of variance of the data obtained were carried out using one ANOVA. Data obtained were compared with the use of Chi square and Fisher's exact test (two tailed) with the all pairs tukey-kramer statistical program. P-value of less than 0.05 was considered to be statistically significant (<0.05).

Results

Results of the mean counts of bacteria of borehole and well water sampled in Bundu waterside, Port Harcourt is shown in Table 1. The result revealed that the mean total heterotrophic bacteria counts for well water samples ranged from 1.30±0.13x10^6 CFU/ml (March) to1.73±0.05x10^6 CFU/ml (June) while Total heterotrophic bacteria counts for Borehole water ranged from1.08±1.21x10^6 CFU/ml (April) to 1.40±0.11x10^6 CFU/ml (June), indicating high level of pollution of the water sources in Bundu waterside (Table 1). The results of the total coliform counts (TCC) ranged from 2.8±1.4x10^4 CFU/ml to 4.8±0.5x10^4 CFU/ml for well water samples and TCC for Borehole water samples ranged from 2.1±1.0x10^3 CFU/ml to 4.0±1.2x10^3 CFU/ml. The results of the phenotypic and genotypic identification of the bacterial species are presented in (Table 2.). Five out the total number ten bacterial species isolated and identified had percentage similarity of 100% while others had 99%. The results of the molecular analysis demonstrated a wide range of bacteria with varying percentages (Figure 1), present in the borehole and well water sources in Bundu waterside Port Harcourt.

Table 1: Mean counts of bacteria of borehole and well water sampled in Bundu Waterside, Port Harcourt

	Total Heterotrophic Bacteria counts (CFU/ml)		Total Coliform Counts (CFU/ml)	
Month/Sample	**Well Water**	**Borehole Water**	**Well Water**	**Borehole Water**
March	1.30±0.13x10^6	1.15±0.5x10^6	3.5 ±0.1x10^4	2.1±1.0x10^3
April	1.50±0.08x10^6	1.08±1.21x10^6	2.8±1.4x10^4	2.5±0.7x10^3
May	1.61±1.0x10^6	1.15±0.54x10^6	5.9±0.5x10^4	4.2±0.5x10^3
June	1.73±0.05x10^6	1.40±0.11x10^6	7.0±0.7x10^4	2.0±0.6x10^3
July	1.66±1.5x10^6	1.32±0.15x10^6	3.4±0.8x10^4	34±1.4x10^3
August	1.43±1.2x10^6	1.38±0.05x10^6	4.8±0.5x10^4	4.0±1.2x10^3
NSDWQ 2008	1x10^2 CFU/ml	1x10^2 CFU/ml	0 CFU/100ml	0 CFU/100ml

Citation: Kpormon *et al*. (2023). Bacteriological and physicochemical qualities of borehole and well water in Bundu waterside, Port Harcourt. *International Journal of Microbiology and Applied Sciences*. *2(2)*: 153 - 161.

Table 2: Phenotypic and genotypic identity of the bacteria isolated from borehole and well water sampled in Bundu Waterside Port Harcourt

ISO code	Phenotypic Identity	Genotypic identity	Similarity (%)	NCBI Genebank Accession Number
ISO 1	*Escherichia coli*	*Escherichia coli ETEC*	99	MF 919609.1
ISO 2	*Proteus* sp	*Proteus mirabilis*	99	LC728309.1
ISO 3	*Escherichia coli*	*Escherichia coli 9157:H7*	100	EU871626
ISO 4	*Salmonella* sp	*Salmonella enterica*	100	AF170176.1
ISO 5	*Staphylococcus* sp	*Staphylococcus aureus*	100	AH013003.2
ISO 6	*Enterobacter* sp	*Enterobacter cloacae*	100	NR 102794.2
ISO 7	*Pseudomonas* sp	*Pseudomonas aeruginosa*	100	FJ972527.1
ISO 8	*Shigella* sp	*Shigella sonnei*	99	NR 104826.1
ISO 9	*Vibrio* sp	*Vibrio parahaemolyticus*	99	HG999479.1
ISO 10	*Vibrio* sp	*Vibrio cholerae*	99	KU981188.1

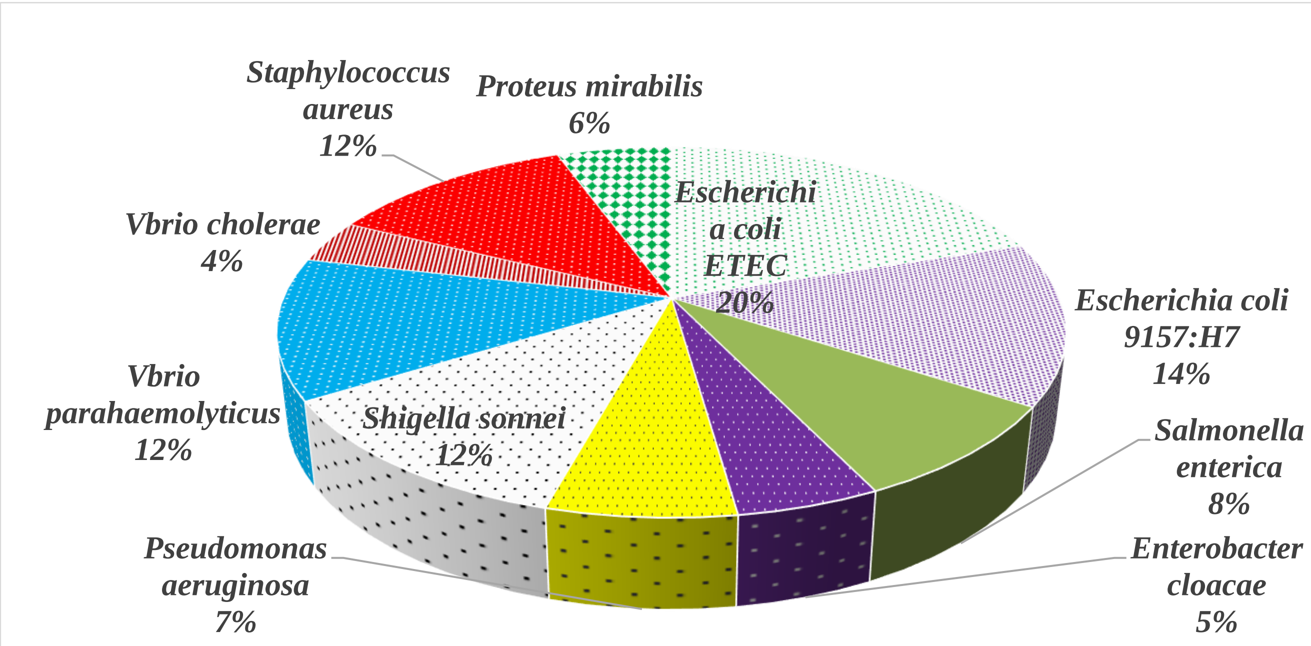

Figure 1: Frequency (%) of bacteria isolated from borehole and well water sampled in Bundu Waterside Port Harcourt

The results of the physicochemical parameters of well water and borehole water collected from Bundu waterside during the study are presented in Table 3. The results of Temperature for the waters ranged from 25ºC in the Well water to 26.5ºC in the Borehole water. The value of pH ranged from 5.45±0.14 in Well water to 6.45±0.14 in Borehole water. Turbidity 2.38±0.38 NUT in Borehole to 3.38±0.38 NUT in Well.

Values of Electrical conductivity ranged from 422.25±50.43µs/cm in Borehole to 522.25±50.43 µs/cm in Well water. Total dissolved solid 703±2.32 mg/L (Borehole) to 1034±2.32 mg/L (Well), Dissolved Oxygen 2.42±0.14 mg/L (Borehole), to 4.12±0.14 mg/L (Well) while the Biological Oxygen Demand ranged from 1.2±0.33mg/L in Borehole to 1.8±0.12 mg/L in Well water.

Citation: Kpormon *et al*. (2023). Bacteriological and physicochemical qualities of borehole and well water in Bundu waterside, Port Harcourt. *International Journal of Microbiology and Applied Sciences*. *2(2)*: 153 - 161.

Table 3: Mean values of physicochemical parameters of borehole and well water sampled in Bundu Waterside Port Harcourt

Parameter	Well water	Borehole Water	NSDWQ (2008)	WHO (2012)
Temperature (ºC)	25.5±0.5 [a]	26.5±0.5 [a]	20-33 °C	ND
Turbidity (NUT)	3.38±0.38 [a]	2.38±0.38 [a]	5.00 NTU	5.00 NTU
EC (µs/cm)	522.25±50.43 [ab]	422.25±50.43 [ab]	500 µs/cm	250 µs/cm
TDS (mg/L)	1034±2.32 [ab].	703±2.32 [ab].	1000mg/l	500mg/l
pH	5.45±0.14 [ab]	6.45±0.14 [ab]	6.5-8.5	7.0 to 8.5
DO (mg/L)	4.12±0.14 [a]	2.42±0.14 [a]	14 mg/l	14 mg/l
BOD (mg/L)	1.8±0.12 [a]	1.2±0.33 [a]	<5 mg/l	<5 mg/l
Sulphate (mg/L)	252.5±23.63 [a]	242.5±23.63 [a]	300 mg/l	250 mg/l
Phosphate (mg/L)	10.47±0.43 [a]	6.47±0.43 [a]	5mg/l	2 mg/l
Nitrate (mg/L)	64±3.40 [a]	54±3.40 [a]	50 mg/l	45 mg/l

Discussion

The results of this present study reveal the population (counts) of total heterotrophic bacteria and total coliform in both borehole water and well water sampled from Bundu waterside in Port Harcourt. The counts are higher than the acceptable counts of 100 cfu/ml for drinking water (WHO 2011 and NSDWQ, 2008). The higher total heterotrophic bacterial counts especially in the Well water samples in the month of June can be attributed to several anthropogenic activities around the waterside such as indiscriminate dumping of untreated wastes and surface runoffs containing faecal materials, leaking pipes run in gutters or drainages, domestic effluents. Other sources of bacterial contamination may include, animal waste deposition and pasture are also possible ways of introducing foreign micro-organisms in the water thereby making more nutrients available for the microorganisms in the water thus enhancing their growth at all the various water sources according Obire *et al*., (2009).

Wells recorded the higher counts compared to borehole waters, though the counts obtained from the two water sources were higher than the acceptable limit 100CFU/ml of total heterotrophic bacterial counts and 0 CFU/100ml of total coliform. Well recorded the higher counts compared to borehole waters, though the counts obtained from the two water sources were higher than the acceptable limit, These high counts could be attributed to the discharge of sewage into the rivers by the surrounding people and leakage from septic tank (Obire *et al*., 2009).

In this study, the total bacterial and coliform counts were lowest in borehole water relative to the other water sources.

However, the bacteriological values for total coliform counts did not meet international standard as they were higher than WHO standard of zero per 100ml. comparatively, these bacteriological parameters were higher than those reported by other researchers Adegboyega *et al.*, (2015). The difference in the counts obtained in this study could be attributed to the nature of the Bundu waterside. The coliform counts were also higher compare to the report of other researchers (Mile *et al.*, 2012; Aboh *et al.*, 2015, Douglas *et al.*, 2021).

Molecular analysis demonstrated a wide range of bacteria with varying percentages, present in the borehole and well water sources in Bundu waterside Port Harcourt. Among the bacterial species were various strains of *Escherichia coli*, including *ETEC* (MF 919609.1) and the highly pathogenic *E.coli 9157:H7* (EU871626). The presence of these pathogenic *E. coli* strains indicates that the borehole and well water sources in Bundu waterside contamination with faecal materials which may poses a significant risk of gastrointestinal infections, particularly in areas where sanitation facilities are lacking or inadequate. The presence of *E.coli* 9157:H7 in this study corroborates the study of Ngwa *et al.*, (2013) and Abdulkadir *et al.*, (2016) who in their respective studies were able to isolate the highly pathogenic organism from water sources in their respective study locations.

Several waterborne pathogens, including *Salmonella enterica* (AF170176.1), *Shigella sonnei* (NR 104826.1), *Vibrio cholerae* (KU981188.1), and *Vibrio parahaemolyticus* (HG999479.1), were also identified in the water samples. These organisms are known to cause severe diarrheal diseases, with potentially fatal outcomes if left untreated.

Citation: Kpormon *et al*. (2023). Bacteriological and physicochemical qualities of borehole and well water in Bundu waterside, Port Harcourt. *International Journal of Microbiology and Applied Sciences*. *2(2)*: 153 - 161.

Their presence in the water sources highlights the urgent need for immediate public health interventions to prevent waterborne disease outbreaks. Our study also agrees with Douglas *et al.*, (2021) that also identified the following organisms from Abonnema community: *Vibrio* sp, *Enterobacter* sp. *Salmonella* sp. *Shigella* sp. *Bacillus* sp. *Staphylococcus* sp.

The isolation of opportunistic pathogens, such as *Staphylococcus aureus* (AH013003.2), *Enterobacter cloacae* (NR 102794.2), *Pseudomonas aeruginosa* (FJ972527.1), and *Streptococcus agalactiae* (CP010867.1), raises concerns about the potential impact on vulnerable populations. These microorganisms can cause infections, especially in individuals with weakened immune systems or underlying health conditions. Adequate water quality and sanitation are crucial to protecting the health of these susceptible groups.

Water physicochemical properties, which serve as a measure of water contamination, are usually evaluated to determine the water quality for different purposes. Management of water is done to ensure that contaminants that get into it do not exceed the permissible or standard limits. Thus, the quality of water is related to the expected use of the water for fishing, recreation, or wild life (Amaku and Akani, 2016).

This present study also reveals the physicochemical properties of both borehole water and well water sampled from Bundu waterside in Port Harcourt as presented in Table 3. Values of the Electrical conductivity, Total dissolved solid, sulphate, phosphate and nitrate were above the permissible limit recommended by World Health Organization and Nigerian Standard for Drinking Water Quality while pH, Dissolved Oxygen, Biological Oxygen Demand, and Turbidity were below the permissible limit. The pH values of the well water samples tends to more acidic than the boreholes water samples, though the pH of both samples were below the recommended range (6.5 – 8.5) by WHO. There were significant difference ($p \geq 0.05$) in the values of pH obtained from the water samples. Drinking water with pH range of 6.5 to 8.5 is generally considered satisfactory (WHO, 2011). Acid water tends to be corrosive to plumbing and faucets, particularly, if the pH is below 6.

Consequently, this could be the case for the well water sampled with pH below 6. Low pH observed in this study may be attributed to organic pollution and waste discharge from the various activities within the Bundu waterside into the river systems, river water intrusions and other flourishing photosysnthetic activities of the aquatic plants as corroborated by other workers (El-Bouraie *et al.*, 2011). However, the pH of a water body is known as one of the important factors in the determination of water quality as it affects other chemical reactions such as solubility and metal toxicity (Agbaire and Obi, 2009).

The electrical conductivity values ranged 422.25±50.43 us/cm (Borehole) to 522.25±50.43 us/cm (Well). These values were above the recommended limit of WHO standard of 250 µs/cm. Electrical conductivity is the ability of a solution to conduct an electrical current that is governed by the migration of solutions which is dependent on the nature and numbers of the ionic species in that solution (Sa'eed and Mahmoud, 2014; Aremu *et al.*, 2014). It is a useful tool to assess the purity of water. The electrical conductivity of the water were above the permissible limit of $500\mu Scm^{-1,}$ thus the water samples are considered not safe in terms of this parameter. The high electrical conductivity content may be as a result of land runoff which contains large amounts of cations and anions as averred by Ezzat *et al.* (2012). Also certain levels of TDS are essential for aquatic organisms and high level of TDS may be unfavourable for aquatic life (Akpan *et al*, 2015). In the case of turbidity, the values were high but not greater than the limit set by WHO thus they were assumed to be adequate. The turbidity levels of the water sources suggest that the high suspended materials, bacteria, planktons and dissolved organic and inorganic materials (Reza *et al.*, 2009). The higher but not above recommended limit of turbidity recorded in well and borehole water is consistent with the report of Reza and co-workers (2009). Comparatively, there were significant differences at $P \leq 0.05$ in the physicochemical parameters observed in the borehole and well water except for few parameters. Physicochemical parameters of the borehole water sampled in this study were closer in the range of WHO recommended standards compared to that of the borehole water.

In conclusion, the bacteriological characteristic of the borehole and well water samples from the Bundu waterside revealed that well water had the highest heterotrophic bacteria and total coliform counts compared to the borehole, though the counts in both well and borehole water sources were above the Standards recommended by Nigeria Standard of

Citation: Kpormon *et al*. (2023). Bacteriological and physicochemical qualities of borehole and well water in Bundu waterside, Port Harcourt. *International Journal of Microbiology and Applied Sciences*. *2(2)*: 153 - 161.

Drinking Water Quality and World Health Organization. Also, the physiochemical characteristics of both the borehole and well water sources did not comply with regulatory standards which indicate that the sources of water are not fit for consumption. Therefore, treatment is recommended for the water sources before use for any domestic purposes. Government through relevant agencies should set up water treatment plants in the slums to increase the bacteriological and physiochemical quality of water around waterside especially Bundu.

References

Abdulkadir, A., Ahmed, Z., Ahmad, H. and Khalid, N. (2016). Estimates and burden of foodborne pathogens in RTE beverages in relation to vending practices. *Food Quality and* Safety, 3, 107–115.

Aboh, E. A., Giwa, F. J and Giwa, A., (2015). Microbiological assessment of well waters in Samaru, Zaria, Kaduna, State, Nigeria. *Annual African Medical Journal*. 6(4) 14-32.

Agbaire, P. O. and Obi, C. G. (2009). Seasonal variations of some physico-chemical properties of River Ethiope water in Abraka, Nigeria. *Journal of Applied Science and Environmental Management,* 13(1),55-57.

Akpan, O.P. Adeneye, A.K. Musa, A.Z, and Adeneye, A.A (2015). Living conditions and public health status in three urban slums of Lagos, *Nigeria South East Asia Journal of Public Health*. 3(1),36-41.

Alonge, O., Wakkala, F., Ogbaga, C and Akindele, K., (2018). Bacterial Analysis of Barbecued Meat (Suya) From Selected Locations within Abuja, Nigeria. Paper presented at the 13th International Conference on Electronics, Computer and Computation (ICECCO), Abuja. 23-51.

Amadi, E.N, Kiin K.D**.,** Lucky Barinedum Kpormon and Robinson, V.K.K. (2014) Microbial flora and nutritional composition of adult palm-wine beetle. *International Journal of Current Microbiology and Applied Science*. 3 (11), 189-192.

Amaku, G. E. and Akani, N. P. (2016). Physicochemical properties of the effluents of Forcados Terminal in Warri, Delta State. *Journal of Environmental Chemistry and Ecotoxicology*. 24(23), 21-32.

APHA., (2017). Standard methods for examination of water and waste water. American Public Health Association, Washington, DC.211-342.

Aremu, M., Majabi, G., Oko, J., Opaluwa, O., Gav, B and Osinfade, B., (2014). Physicochemical Analyses of Different Sources of Drinking Water in Okene Local Government Area of Kogi State, Nigeria.

Cheesebrough, M. (2006). District Laboratory Practices in Tropical Countries (Second Edition ed.). Cambridge: Cambridge University Press. 34-45.

Chibuike, P. M. Williams, J.O. and Ajah, E. Q. (2023). Microbiology and Physicochemical Characteristics of Surface Water from a Local Refinery Site in Port Harcourt, Nigeria. *Journal of Advances in Microbiology*. 23(9), 1-8.

Dissmeyer, G. E., (2000). Drinking water from Forests and Grasslands. USDA Forest Service General drinking water from wash boreholes in Maiduguri Metropolis, Borno State, Nigeria. *African Journal of Food Science*, 7,9-13.

Douglas, S.I, Williams J.O, and Onyedibia, G.C. (2022). Isolation of biofilm producing bacteria from stool samples and their Antibiogram. *Microbiology and infectious Diseases*, 6(1),1-9.

Douglas, S. I. Alambo, A.A. and Obire, O. (2021). Bacteriological and Physicochemical Quality of Mono-pumps and Boreholes used as Sources of Domestic Water Supply in Abonnema Rivers State, Nigeria. *South Asian Journal of Research in Microbiology. 9(4): 44-55.*

Essien, O. E and Bassey, E. D., (2012). Spatial variation of borehole water quality with depth in Uyo Municipality, Nigeria. In: 21st Century Watershed Technology: *Improving Water Quality and Environment Conference*. 22-28.

Gambo, J., James, Y and Yakubu, M., (2015). Physico– Chemical and Bacteriological Analysis of Well Water at Crescent Road Poly Quarters, Kaduna. *International Journal of Engineering and Science*, 4 (11),11-17.

Holt, J. G., Krieg, N. R., Sneath, P. H. A., Staley, J. T. and Williams, S. T. (1994) Bergey's Manual of Determinative Bacteriology.12-18.

Ibe, S and Okplenye, J., (2005_. Bacteriological analysis of borehole water in Uli, Nigeria. *African Journal of Applied Zoology and Environmental Biology*, 7,116-119.

Isa, M. A., Allamin, I. A., Ismail, H. Y and Shettima, A., (2013). Physicochemical and bacteriological analyses of Oguta Lake Water, Imo State, Nigeria. *Journal of Applied Microbiology*.73, 355-361.

Kpormon, L. B. Ogbonna, D. N. Wemedo, S. A. Williams, J. O. and Douglas, I. 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.* e 12(6), 37-45.

Kpormon, L. B. and Douglas, S. I., (2018). Comparative Ecotoxicological Assay of E- waste (Phone Batteries) on Some Aquatic Micro Flora. *Journal of Advances in Biology & Biotechnology* : 17(2), 1-10.

Mishra, D.Iyama, W. A. and Edori, O. S. (2009). Comparative analysis of the water quality status of the Bassanrivers in Bayelsa State, Nigeria. *International Journal of Chemistry and Chemical Engineering*, 6 (1), 59-69.

Ngwa, S. Baumler, A. and Lucky, J. (2013). Evolution of the chaperone/usher assembly pathway: Fimbrial classification goes Greek. *Microbiology Molecular Biology Revision*, 71(4), 551-575.

Nigeria standard for drinking water quality. (2008). Nigeria Industrial Standard, Approve by Standard Organization of Nigeria Governing Council, 15-19.

Obire, O. Ramesh, R.P. and Igoni, O.A. (2009). Bioburden (Quality) of Different Drinking Water Sample. *Rasāyan Journal of Chemistry*. 2 (4), 1007-1011.

Ogbonna, D. N. Anthony, E. M. and Kpormon, L. B. (2023). Physiochemistry and Microbiological Quality of Surface Water Body around Port Terminals in Southern Nigeria. *Microbiology Research Journal International.* 33(2), 54-60.

Ogbonna, D.N; Ogbuku,J.O; Ngah, S.A and Ayotamuno, A (2021). Public Health Problems associated with informal Settlements around Waterfronts Communities in Port Harcourt, Nigeria. *Current Journal of Applied Science and Technology.* 26(21),23-29.

Ogbonna, David and Orinya, Obande, S. (2018). Physico-chemical and Microbiological Characteristics of a River Mud as substrate for Biological Generation of Electricity in the Niger Delta, Nigeria. *Microbiology Research Journal International*. 25. 1-14.

Prescott, L.M., Harley, J.P. and Klein, D.A. (2005) Microbiology. Sixth International Edition. Mcgraw-Hill Publishing Company, UK, 652-668.

Raju, N. J., Ram, P and Dey, S., (2009). Groundwater quality in the lower Varuna river basin, Varanasi district, Uttar Pradesh. *Journal Geology and Social Science India*, 73:178.

Sa'eed, M and Mahmoud, A., (2014). Determination of Some Physicochemical Parameters and Some Heavy Metals in Boreholes from Fagge L.G.A of Kano Metropholis Kano State- Nigeria. *World Journal Anal Chemistry*, 2,42-46.

Saitou, N. and Nei, M. (1987). The neighbor-joining method: A new method for reconstructing phylogenetic trees. *Molecular Biology and Evolution*, 4, 406-425.

Srinivasan, R., Karaoz, U., Volegova, M., MacKichan, J., Kato-Maeda, M., Miller, S., Nadarajan, L., Brodie, E. L. and Lynch, S. V. (2015). Use of 16S rRNA Gene for Identification of a Broad Range of Clinically Relevant Bacterial Pathogens. *Plos One*, 10 (2), 1 – 22.

Suthar, S., Chhimpa, V and Singh, S., 2009. Bacterial contamination in drinking water: a case study in Technical Report SRS-39, Asheville, North Carolina. 23-37.

Ukpong, E and Okon, B., (2013) Comparative analysis of public and private borehole water supply sources in Uruan Local Government Area of Akwa Ibom State. *International Journal of Advance Science and Technology. 3, 12-23.*

World Health Organization. (2011) *Global status report on noncommunicable diseases. Geneva, Switzerland*: 234-321.

Citation: Kpormon *et al*. (2023). Bacteriological and physicochemical qualities of borehole and well water in Bundu waterside, Port Harcourt. *International Journal of Microbiology and Applied Sciences*. *2(2)*: 153 - 161.