A COMPARATIVE ASSESSMENT OF THE PHYSICOCHEMICAL AND MICROBIOLOGICAL QUALITIES OF SOME DRINKING WATER SOURCES IN DIOBU, PORTHARCOURT, NIGERIA

Abstract

Diseases caused as a results of drinking contaminated water pose a severe risk to the public's health. In the current study, various drinking water sources in Diobu, Port Harcourt, were evaluated and their microbiological and physicochemical characteristics were compared. Drinking water samples were collected from a borehole and a sachet (packaged) source. The physicochemical and bacteriological investigations were conducted using standard analytical techniques. The results of physiochemical parameters revealed that sachet water samples had the greatest pH readings, but borehole water samples had a mean pH of 4.37±1.21 which was much lower than the W.H.O.-recommended range (6.5-8.5). The study's Total Suspended Solids readings were within the permissible limits of 30.0 mg/l. The borehole sample had the highest concentration of 6.5±4.31mg/l, while the sachet water samples had the lowest concentration of 2.5±1.5 mg/l. Total Dissolved Solids ranged between 15.8±13.5mg/l in sachet water and 55.6±33.4 mg/l in samples from boreholes. Between 33.5±28.4 Scm-1 (sachet water) to 136.6±73.9 Scm-1 (borehole water), the Electrical Conductivity values were recorded. In sachet water, total alkalinity had a mean value of 0.57±0.29mg/l whereas in borehole water, it was 3.29±1.39mg/l. For sachet water and borehole water, the levels of water hardness ranged from 1.95±0.84 mg/l to 10.67±3.21 mg/l, respectively. The range of biological oxygen demand was < 1±0.00 (for sachet water) to 2.13±13 (for borehole water). Dissolved oxygen levels ranged from 1.72±0.70 mg/l in sachet water to 1.95±0.62 mg/l in borehole water. Chemical oxygen demand levels ranged from 2.38±1.18mg/l (Sachet water) to 11.31±9.49 (Borehole water) while Turbidity ranged from <1±0.00 NTU (Sachet water) to 1.1±0.64 NTU (Borehole water). Except for Chemical Oxygen Demand, there was no difference in the values that were observed that was significant at $P \geq 0.05$. In this study, the mean total bacterial counts ranged from 2.0 x 10^4 cfu/ml in sachet water to 9.0 x10^4 cfu/ml in borehole water, demonstrating high levels of contamination in the borehole water from human contamination. Comparatively to the other water sources, sachet water had the lowest overall bacterial and coliform levels. However, because the bacteriological values for total coliform counts above the WHO threshold of zero per 100 ml, they did not comply with international standards. *Salmonella* spp., *Pseudomonas* spp., *Staphylococcus* spp., and *Escherichia coli* were the pathogenic bacteria of public health significance that were isolated from the diverse water samples. Five distinct isolates of fungi, including *Penicillium* spp., *Aspergillus niger*, *Aspergillus flavus*, *Trichoderma* spp., and *Mucor* spp., were found. In comparison to borehole water, which had the most bacterial pollutants, sachet water tests had the fewest. It is advised that the water sources be treated before being used for any domestic purposes as the water sources in this research area are not suitable for human consumption.

Keywords: Drinking water, Bacteriological, Physico-chemistry, Comparative, Assessment

UNDER PEER REVIEW

1.0: Introduction

Freshwater that is clean, safe, and sufficient is essential for human existence as well as the health of ecosystems, communities, and economies (Mishra *et al.* 2009). As human populations increase, industrial and agricultural production increases, and climate change threatens to significantly disrupt the hydrologic cycle, declining water quality has emerged as a major global problem (UN, 2009; Ogbonna and Orinya, 2018). In Nigeria, particularly in Diobu in Port Harcourt Rivers State, the vast majority of people obtain and consume water from boreholes, wells, and other water sources without regard to how clean or unclean these water sources may be. Numerous microbial species, many of which have not been grown or even recognized, are present in these natural waterways. The variety of

Different types of water harboured a wide range of organisms, however it is generally acknowledged that surface water that has been contaminated by sewage has a higher bacterial content than unpolluted surface water (WHO, 2003). Ground water contamination can come from a variety of sources, such as unsanitary conditions during borehole construction, runoff splashing into wells if left uncovered, flooding at borehole sites, and leachate from old buried waste pits or latrines that seeps into the hole through cracks in the aquifer and annular of the hole. Other sources of pollution include borehole proximity to septic tanks, particularly in areas with limited space and borehole drilling nearby (Essien and Bassey, 2012). Due to the insufficient supply of potable pipe-borne water, the majority of the population in semi-urban and metropolitan areas of Nigeria significantly relies on well and borehole water as the main source of water supply for drinking and household usage. The prevalence and epidemics of avoidable water-borne diseases rise as a result of these ground water. In nations like Portugal and Spain, packaged water has been linked to cholera, typhoid fever, and traveler's disease outbreaks (Blake *et al.,* 1977; Mavridou, 1992; Bordalo and Machado, 2014). According to several studies (Semerjian 2011; Gangil *et al.* 2013), packaged water can become contaminated with germs at different phases of manufacture. Bacteria can develop to levels that could be dangerous to human health when bottled water is improperly or indefinitely stored (Warburton, 2000). To effectively implement the water quality improvement program and to create solid public policy, accurate and timely information on water quality is required. Indicators are one of the best tools for conveying data on trends in water quality. The water quality index (WQI), which can be defined as "a rating reflecting the composite influence of different quality parameters on the overall quality of water" (Mishra, 2005), is frequently used for the identification and evaluation of water pollution. The physicochemical and biological (bacteriological) indices are two broad categories used to describe the indices. The values of numerous physicochemical characteristics of a water sample serve as the basis for physicochemical indices. These are essential for monitoring water quality (APHA, 2017). To evaluate the water pollutants, a variety of scientific techniques and instruments have been created (Dissmeyer, 2000). In these methods, many factors, including pH, turbidity, temperature, dissolved oxygen, and alkalinity, among others, are analysed. If these factors have values that are greater than the safe limits established by the World Health Organization (WHO) and other regulatory agencies, the drinking water quality may be impacted (WHO, 2011). Drinking water contamination by bacteria is a significant public health issue that affects people all over the world; as a result, it is vital to assess the bacterial quality of the water (Suthar *et al.,* 2009). Using coliform group testing in the lab, the bacterial quality of drinking water is monitored. The term "total coliform" refers to a sizable collection of rod-shaped, gram-negative bacteria that exhibits a number of similar traits. These include Staphylococcus *spp*., *E. coli, Klebsiella, Enterobacter, Streptococcus,* and others. Water must meet specific physical, chemical, and microbiological requirements before it can be referred to as potable. These requirements are intended to make sure the water is suitable for drinking. Therefore, research has been done to determine these parameters in a variety of drinking water

UNDER PEER REVIEW

sources, including well water (Ezeribe *et al.,* 2012; Mile *et al.*, 2012; Aboh *et al.,* 2015; Gambo *et al.,* 2015; Allamin *et al.,* 2015), borehole water (Ibe and Okplenye, 2005; Onwughara *et al.,* 2013; Isa *et al.,* 2013 as well as water from streams and rivers (Joshi *et al.,* 2009; Lawal and Lohdip, 2015). This study was done to find out the physiochemical and bacteriological characteristics of the drinking water sources in Diobu, Port Harcourt, Nigeria.

2. Materials and Methods

2.1. Sample collection

Ten borehole sites and ten of the popular sachets of water sold in Nigeria under the name "pure water" were sampled in Diobu, in Port Harcourt. Two sachet water packs of the same brand bought at different points were analyzed and the average values obtained represented the value for each parameter determined in the brand. The 1500 cm^3 clean polythene bottle containers used for collection and storage of the water samples were sterile. As instructed by American Public Health Association APHA (APHA, 2017) methods, sample preservation was completed. They were brought to the lab in ice chests, preserved there in a refrigerator, and then subjected to analyses.

2.3: Microbiological analyses

Microbiological analysis of the water samples included isolation and characterization of total cultural aerobic heterotrophic bacteria using nutrient agar (Oxoid) media and total coliforms and faecal coliforms using standard analytical methods according to methods prescribed by Prescott *et al* (2005).

2.4: Identification of Bacterial Isolates

Morphological characteristics (pattern of growth, pigmentation and appearance/sizes and shapes on plates) were observed after 18-24 hours of incubation at 37°C; Cell morphology (Gram reactions) and other biochemical tests of the isolates were done. Further identification was made by comparison of their cultural, morphological and physiological characteristics with those of known taxa using the Bergey's Manual of Determinative Bacteriology (Holt *et al*., 1994).

2.5: Physico-chemical Characteristics

Using the appropriate meters, the physicochemical qualities of the water, such as pH, electrical conductivity, dissolved oxygen, biological oxygen demand, total dissolved solids, etc., were assessed. Total dissolved solids (TDS) were determined using a calibrated Conductivity Meter (HANNA, Conductivity meter) and pH was determined using a pH meter (HANNA, HI 9125). A portable turbidity meter was used to measure the turbidity (APHA, 2012). Burette titration was used to determine the total hardness. APHA (1995) presented additional common analytical procedures for determining total alkalinity, chloride, nitrate-N, sulphate, and main cations.

UNDER PEER REVIEW

3.0 Results and Discussion

3.1 Physiochemical Analyses

Table 1 displays the results of the physico-chemical parameters of borehole and sachet water collected from Diobu, Port Harcourt during a 6-month period. The following physicochemical parameters were measured in this study: pH, Conductivity, Turbidity, Total Dissolved Solids (TDS), Total Suspended Solids (TSS), Total Hardness, Total Alkalinity, Dissolved Oxygen (DO), Phosphate, and Ca-Hd. In the water samples analyzed, the pH ranged from 4.37±1.21 to 6.18±2.09. The sachet water samples had the highest pH readings, while the borehole water samples had a mean pH of 4.37±1.21, which was much lower than the WHO-recommended range of 6.5–8.5. The pH readings obtained from the water samples varied significantly (p 0.05). Plumbing and faucets are often corroded by acidic water, especially if the pH is below 6. Therefore, this might apply to the borehole water sampled with a pH under 6. The physicochemical parameters of all the water samples analyzed in this study, with the exception of pH in the borehole sample, which could have a negative impact on consumers, were within WHO standards. The pH readings from the sachet sources fell within the range that Sa'eed and Mahmoud (2014), Allamin *et al.* (2015), and Reda (2016) reported for well water samples taken in Kaduna city.

The total suspended solids measured in this investigation were under the 30.0 mg/l minimum threshold. The borehole sample had the highest concentration of 6.5±4.31mg/l, while the sachet water samples had the lowest concentration of 2.5±1.5mg/l. Similar to this, the total dissolved solids in the sampled borehole water were between 55.6 ± 33.4 mg/l and 15.8 ± 13.5 mg/l in sachet water. Total suspended solids (TSS) measurements from all water samples reveal that there aren't many pollutants present. All metrics fell within the WHO-acceptable range. Similar to this, the total dissolved material levels in the water samples were similarly under the 500 mg/l WHO guidelines. According to Harrison (2007), higher total dissolved solids are known to lower water clarity, which could result in decreased photosynthetic activity and possibly raise water temperature. However, this was not the case in this investigation.

Between 33.5±28.4 Scm-1 (sachet water) to 136.6±73.9 Scm-1 (borehole water), the electrical conductivity values were measured. These readings were within the acceptable range of the WHO norm, however they were significantly different (p>0.05). According to Sa'eed and Mahmoud (2014) and Aremu *et al*. (2014), electrical conductivity is the capacity of a solution to carry an electrical current. It is controlled by solution migration, which is reliant on the types and quantities of ionic species present in the solution. It is a helpful instrument for determining the water's purity. The water samples are deemed safe in terms of this characteristic because their electrical conductivity was below the allowed level of 500 Scm-1. In terms of conductivity, the sachet waters sampled in Diobu appear to be superior to the research done by Sa'eed and Mahmoud (2014) in the Fagge Municipality of Kano

UNDER PEER REVIEW

State, Nigeria. However, compared to Aremu and colleagues' (2014) findings, the electrical conductivity from the borehole sample in this investigation is higher. Total alkalinity measurements showed a significant difference between borehole water samples with 3.29±1.39 mg/l and sachet water samples with a mean value of 0.57 ± 0.29 mg/l, respectively ($p>0.05$). The capacity of water to neutralize acids is measured by its total alkalinity. According to Raju et al. (2009), carbonates and bicarbonates play a major role in the alkalinity of groundwater. Alkalinity levels that are considered to be appropriate range from 120 mg/l to about 500 mg/l (Raju *et al.,* 2009; WHO, 2000, 2011). It can be concluded that the water is safe to drink based on the total alkalinity readings of the sampled waters. Furthermore, the levels of total alkalinity seen in this study were higher than those reported by Sa'eed and Mahmoud (2014).

For sachet and borehole water, the corresponding water hardness readings ranged from 1.95±0.84 mg/l to 10.67±3.21mg/l for sachet and borehole water respectively. F Biological oxygen demand ranged from <1±0.00 (Sachet water) to 2.13±1.38 (Borehole water). According to Raju *et al.* (2009), calcium and magnesium are the main ions that cause hardness, and the allowable limit of overall hardness can reach 500 mg/l. Durfor and Becker (1964) divided hardness into four categories: gentle (0–60 mg/l), moderate (60–120 mg/l), hard (121–180 mg/l), and very hard (180 mg/l and above). Similar to this, according to the WHO International Standards for Drinking Water, water that has a total hardness of $CaCO_3$ less than 50 mg/l is classed as soft water, 50–150 mg/l as moderately hard, and more than 150 mg/l as hard water. This classification suggests that sachet water is more palatable and that the total hardness of the drinking fluids that were examined may be characterized as soft, as the figures show. Dissolved oxygen levels ranged from 1.72±0.70 mg/l in sachet water to 1.95±0.62 mg/l in borehole water. Chemical oxygen demand levels ranged from 2.38±1.18mg/l (Sachet water) to 11.31±9.49 (Borehole water). Turbidity ranged from <1±0.00 NTU (Sachet water) to 1.1±0.64 NTU (Borehole water). The only result that differed significantly at $p\geq0.05$ was the chemical oxygen demand. When it came to turbidity, the numbers were below the WHO-set standard, thus it was deemed that they were sufficient. The water sources' turbidity values indicate that they are devoid of highly suspended particles, bacteria, planktons, and dissolved organic and inorganic compounds (Reza *et al.,* 2009). The report by Reza and coworkers (2009) is consistent with the greater level of turbidity observed in borehole water, but it is not above the suggested limit. Except for a few measures, the physicochemical parameters found in the borehole and sachet water differed significantly at P0.05. In this investigation, the physical-chemical characteristics of the sachet water samples were closer to the WHO recommended requirements than those of the borehole water.

Table 1: Mean Standard error of the physicochemical parameters of sampled drinking water sources in Diobu Port Harcourt

Parameters	Unit	Borehole Water	Sachet Water	WHO Standard

UNDER PEER REVIEW

pH		4.37±1.21	6.18±2.09	6.50 – 8.50
Cond	**µScm-1**	136.6±73.9	33.5±28.4	500.00
TDS	mg/l	55.6±33.4	15.8±13.5	259.00 – 500.00
TSS	mg/l	6.5±4.31	2.5±1.5	30.00
COD	mg/l	11.31±9.49	2.38±1.18	NS
BOD	mg/l	2.13±1.38	<1±0.00	10
Turb	NTU	1.1±0.64	<1±0.00	5
DO	mg/l	1.95±0.62	1.72±0.70	7.5
Alkalinity	mg/l	3.29±1.39	0.57±0.29	120
PO4	mg/l	0.56±0.21	<0.1±0.00	10
T-Hd	mg/l	10.67±3.21	1.95±0.84	200
Ca-Hd	mg/l	8.26±2.61	<0.1±0.00	NS

3.2 Microbial Analyses

The mean Total Bacteria Counts (TBC) in this study ranged from 2.0 x10^4 cfu/ml in sachet water to 9.0 x10^4 cfu/ml in borehole water, showing a high level of contamination of the borehole water from human activities (Table 2). The recommended limit for cfu/ml in drinking water is 100, and these numbers are higher (WHO 2011). The greater total bacterial count, particularly in the borehole water samples, is a sign that the water contains a lot of organic debris. According to Allamin *et al.* (2015), both human and animal activities might be considered the primary source of these bacteria in the waters. These bacterial contamination sources, such as surface runoff, animal waste buildup, and pasture, can also introduce foreign microorganisms into the water, increasing the nutrients available to them and promoting their growth in all kinds of water sources. In sachet water, the mean total fungus counts ranged from 3 102 to 8 102 cfu/ml (Table 2). The results of the Total Coliform Counts (TCC) and faecal coliforms were higher in the borehole waters than in the sachet water, which may have been caused by septic tank leaks and sewage discharge into the rivers by the neighbourhood's residents.

Table 2: Mean Microbial counts of sampled drinking water sources in Diobu Port Harcourt

Parameters	Unit	Borehole	Sachet
Total Heterotrophic Bacteria Counts	cfu/ml	9.0×10^4	2.0×10^4
Total Fungal Counts	cfu/ml	8×10^2	3×10^2
Total coliform counts	cfu/ml	1.3x10^3	9x10^2
Feacal Coliform Counts	cfu/ml	5x10^2	2x10^2

UNDER PEER REVIEW

In this study, compared to the other water sources, sachet water had the lowest total bacterial and coliform counts. However, because the bacteriological readings for total coliform counts above the WHO limit of zero per 100 ml, they did not meet the international standard. These bacteriological values, in comparison, were lower than those mentioned by Adegboyega et al. (2015). The coliform counts in the sampled borehole in the cities of Samaru, Zaria, and Kaduna were likewise reduced. and the town of Makurdi in the Benue State (Mile *et al.*, 2012; Aboh *et al.*, 2015; Allamin *et al.*, 2015). These counts were lower in the analyzed sachet water compared to the borehole water in this investigation, and this report is consistent with the finding of Ehiowemwenguan *et al.*, (2014).

Conventional techniques were used to collect and identify nine (9) bacterial isolates from the genera *Pseudomonas*, *Klebsiella*, *Bacillus*, *Shigella*, *Staphylococcus*, *Salmonella*, *Proteus*, *Bacillus*, and *E. coli* (Figure 1). It is widely acknowledged that the presence of these microbes, especially E. coli, in a body of water indicates fecal pollution and the potential presence of other dangerous organisms (Reynolds, 2016). A subclass of fecal coliforms called E. coli is utilized to detect fecal contamination. While the majority of *E. coli* are absolutely innocuous, some strains of the bacterium have developed the genetic capacity to encode virulence factors (Ogbonna *et al.*, 2020). *Escherichia coli*, *Salmonella* spp., *Pseudomonas spp.*, *Staphylococcus* spp., and other important pathogenic bacteria were isolated. Five distinct isolates of fungi, including *Penicillium* spp., *Aspergillus niger*, *Aspergillus flavus, Trichoderma* spp., and *Mucor*, were found (Fig. 2).

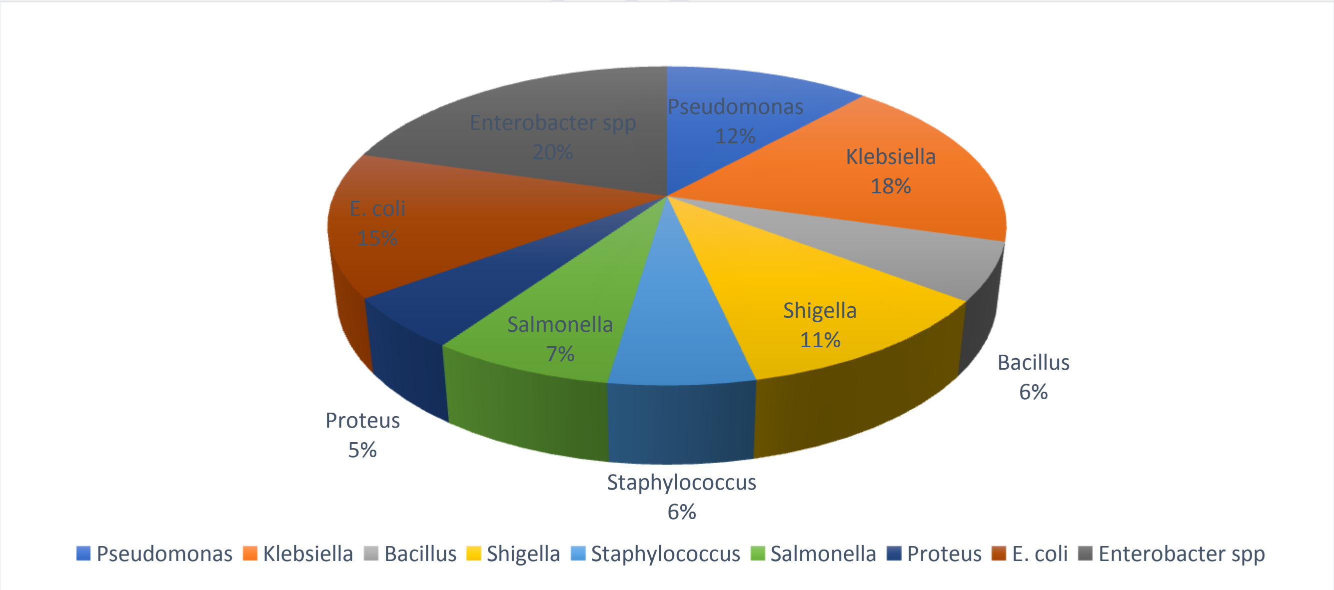

Figure 1. Percentage (%) frequency of distribution of bacteria isolates from the different water sources

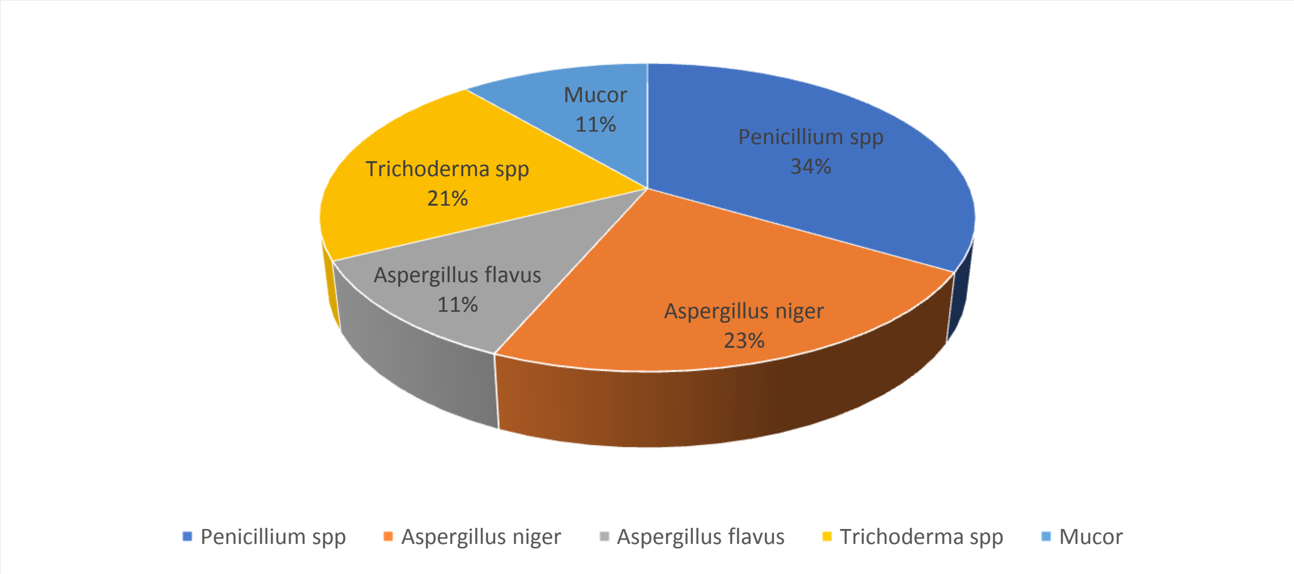

Figure 2: Percentage (%) frequency of distribution of fungi isolates from the different water sources.

UNDER PEER REVIEW

4. Conclusion and Recommendation

The results of this investigation showed that all of the water samples examined were contaminated, as evidenced by the amount of total suspended particles values measured and the presence of indicator organisms (Feacal coliforms). Compared to the borehole water, which had the most bacterial pollutants, the sachet water samples included the fewest. It is advised that the water sources be treated before being used for any domestic purposes because the water sources in the research region are not suitable for human consumption.

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UNDER PEER REVIEW

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UNDER PEER REVIEW

UNDER PEER REVIEW