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COMPARATIVE STUDY OF THE PHYSICOCHEMICAL AND BACTERIOLOGICAL QUALITIES OF SOME DRINKING WATER SOURCES IN ABUJA, NIGERIA

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ABSTRACT

Diseases caused by contaminated water consumption and poor hygiene are among the leading causes of death in children, the elderly and people with compromised immune system. The present study aims to assess the drinking water quality of some selected drinking water sources in the chosen study area using water quality index (WQI). Samples of drinking waters were collected from four different sources- river, sachet (packaged), borehole and well in Jabi, Abuja, Nigeria for physicochemical and bacteriological analyses using standard methods. With the exception of pH, river water had the highest content of all the physicochemical parameters examined. Excluding dissolved oxygen in river sample, the physicochemical parameters of the water sources were generally within the World Health Organization (WHO) standards. The bacteriological analyses revealed that the highest total coliform counts of 1.03 (0.08) x 10^2 cfu/ml were in the river sample while the least counts of 0.03 (0.00) x 10^2 cfu/ml were in the sachet water. All the bacteriological values did not meet international standard as they were higher than WHO standard of zero per 100ml. Three bacterial isolates *Escherichia coli, Pseudomonas* spp and *Aeromonas* spp*,* were isolated from well water while *Pseudomonas* spp and *Proteus* spp were isolated from borehole water. All other bacteria were isolated from the river. The study demonstrates that the safest drinking water source in Idu district, Jabi, Abuja is the sachet/packaged water while the least safe is the river water due to the presence of opportunistic pathogens. The results of this study are beneficial for water quality management and could be used for low-cost effective water quality assessment in Jabi.

KEYWORDS: Bacterial isolates, Abuja, water sources, physicochemical parameters, bacteriological parameters

INTRODUCTION

Water is an essential element for the survival of all living organisms. In humans, it is shown to make up about 70% of the body mass (Eldon and Bradley, 2004). Many infectious diseases in developing countries are associated with contaminated water (Tar *et al.,* 2009). Thus good drinking water is a luxury but one of the most essential requirements of life (Ajewole, 2005).

Studies have shown that over one billion people in the world lack access to safe drinking water and 2.5 billion people do not have access to adequate sanitation services (Tar *et al.,* 2009). In many developing countries including Nigeria, clean pipe borne water availability is limited and inadequate for the teeming population. Thus, an increasing number of people in semi-urban areas in the country depend on dug wells and water vendors for water supply (Idowu *et al.,* 2011).

Due to the inability of government to meet the ever increasing water demand, people resort to ground water sources such as shallow wells and boreholes as alternative water resources (LAWMA, 2000). Natural groundwater is usually of good quality but this can deteriorate due to inadequate source of protection and poor resource management.

Pollution of ground water stems from different sources that include insanitary condition during borehole construction, splashing of runoff into wells, if left uncovered, flooding at borehole site, leachate from old burned waste pit or latrine into the hole through cracks in aquifer and annular of the hole (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).

Majority of the human population in semi-urban and urban areas in Nigeria are heavily reliant on well water 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).

Packaged water is any potable water that is manufactured or processed for sale which is sealed into food-grade bottles, sachet or other containers and intended for human consumption (Warburton, 2000). Sale of packaged water has exploded all over the world in recent years, largely as a result of public perception that it is safe, taste better and has a better quality

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compared to raw tap water (de França Doria *et al.,* 2009; Fisher *et al.,* 2015).

Packaged water has been implicated as a source of outbreak of cholera and typhoid fever as well as traveller's disease in countries such as Portugal and Spain (Blake *et al.,* 1977; Mavridou, 1992; Bordalo and Machado, 2014). Several studies have shown that packaged water can be contaminated with bacteria at various stages of production (Semerjian 2011; Gangil *et al.,* 2013). Under improper or prolonged storage of bottled water, bacteria can grow to levels that may be harmful to human health (Warburton, 2000).

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. These are vital for water quality monitoring (APHA, 1998). 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 (WHO) 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. These include *E. coli, Klebsiella, Enterobacter, Streptococcus, Staphyloccocus* spp etc.

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 (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; Ukpong and Okon 2013; Sa'eed and Mahmoud, 2014; Ehiowemwenguan *et al.,* 2014), lake (Okorondu and Anyadoh-Nwadike, 2015), packaged water (Ugochukwu *et al.,* 2015; Halage *et al.,* 2015) and stream/river water (Joshi *et al.,* 2009; Lawal and Lohdip, 2015). It is on these bases that this research was conducted to determine the qualities of drinking water sources in Idu district, Jabi, Abuja, Nigeria.

The aim of this study was to determine the bacteriological and physicochemical quality of selected drinking water sources in Idu Industrial District of Federal Capital Territory (FCT) Abuja, Nigeria using some water quality indices (WQI).

MATERIALS AND METHODS

Description of the study area

The study was conducted in Idu Industrial District, Jabi, Federal Capital Territory, Abuja, Nigeria. It is located in the North-Central geopolitical zone of Nigeria known as middle belt region.

Field sampling and analytical procedures

Water samples were collected from ten borehole sites, ten popular sachets water popularly referred to as '*pure water'* in Nigeria*,* ten well water and three points of water from Nile University stream (river). The latter samples were collected from the stream in Nile University and Idu industrial layout. 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.

Water samples were collected and stored in sterile 1500 cm^3 clean polythene bottle containers. Preservation of samples was carried out as prescribed by American Public Health Association APHA (APHA, 1998) methods. They were kept in ice chests and transported to the laboratory where they were further preserved in a refrigerator before analyses.

Physicochemical analysis

The physicochemical parameters were determined in accordance with the method of APHA (1998). The water sample temperature was taken immediately at the site of water collection using a simple thermometer calibrated in degree Celsius. The pH was measured using a veneer pH meter. The pH was determined using the procedure described by APHA (1998).

Electrical conductivity measurement was done using a digital conductivity meter model NATOP PB5 (London, UK). Standardization of the meter was performed using 0.1N KCl at 25°C.

Turbidity measurement was conducted using a digital turbidity meter (2100AN HARCH Model). The meter was standardized with clean deionized water, and this was introduced into the water samples. The turbidity reading of each sample was then recorded.

The total dissolved solid was determined using a conductivity meter, the programme menu of the conductivity meter was switched to total dissolved solid, 100cm^3 of the sample was measured into the beaker and the electrode was introduced into the sample. The results of the total dissolved solid were displayed and recorded (APHA, 1998).

Determination of total hardness was conducted by measuring 10cm^3 of water pipetted into a conical flask. 1cm^3 of buffer solution (NH_4Cl) with pH =10 and 3 drops of Erichrome black T indicator were added to the flask. The mixture was then titrated with 0.01M ethyl diamine tetra acetic acid (EDTA) until the colour changed from wine red to blue. The procedure was repeated two more times to obtain the average liter value (Ademorati, 1996).

The determination of total alkalinity was done by measuring 100cm^3 of water into a beaker where 2 – 3 drops of phenolphthalein indicator was added. Colour change was observed following the titration with 0.1N HCl until the colour changed from pink to colourless (FAO/WHO, 1997).

The Alsterberg (Azide) modification of Winkler method was used to determine dissolved oxygen (DO).

Bacteriological Analysis

Bacteriological assessments were carried out using Total Aerobic Plate Count. All the media were prepared according to the Manufacturer's specification. Total coliform counts were carried out by the standard plate count technique using MacConkey agar. Faecal coliform was determined using Eosin methylene blue medium via pour plate technique. The confirmations of the isolate were done using lactose broth at 44.5^{o}C. Biochemical tests were performed to further identify the isolates and they include the oxidase, motility, catalase, urease, coagulase, indole, methyl red, voges-proskauer and citrate utilization tests.

Data Analysis

All data were presented as mean ± standard error. The data were analyzed using single factor analysis of variance; thereafter individual means were compared using student's-test. Significance differences were considered at 5% probability level.

RESULT

The physicochemical parameters determined in this study were temperature, pH, conductivity, turbidity, total dissolved solid, total suspended solid, total hardness, total alkalinity and dissolved oxygen as presented in Table 1.

The temperature of the sampled waters ranged from 27.51 (3.34)$^°$C to 30.62 (0.46)$^°$C in water samples examined. The highest and least pH values of 7.89 (1.45) and 5.96 (0.43) were recorded in well and river water samples, respectively. The only slightly acidic water sample was the river water. The only water sample pH outside the recommended range by WHO was the river water sample. However, there was no significant difference (p>0.05) in the values of pH obtained from the water samples.

The total suspended solids recorded in this study were within the minimal limits. The highest value of 8.37 (0.45 mg/l) was recorded in the river sample while the least value of 2.25 (0.11 mg/l) was recorded in the sachet water samples. Similarly, the total dissolved solids were within the range of 146.54 (2.45 mg/l) in sachet water and 187.29 (12.34 mg/l) in river water sample.

The electrical conductivity values ranged from 123.69 (10.56 µScm^{-1}) to 186.00 (12.84 µScm^{-1}) in sachet water sample and the river water sample. These values were not significantly different (p>0.05) as they were within the recommended limit of WHO standard.

The values of the monitored total alkalinity revealed the following order of magnitude: river>well>borehole>sachet waters; thus 119.42 (12.65)>116.32 (17.92)>101.05 (11.01)> 80.31 (0.21) with no significant difference (p>0.05).

The values of water hardness recorded revealed that three of the water samples were grouped into moderate hardness, thus, the river, well and borehole with the following values 136.72 (13.93 mg/l), 112.30 (8.45 mg/l) and 72.45 (1.39 mg/l) respectively and the hardness of 49.17 (1.82 mg/l) recorded in the sampled sachet water was grouped as soft hardness.

Table 1: Mean Standard error of the physicochemical parameters of sampled drinking water sources in Jabi District of FCT, Abuja. NS- not stated.

Parameters	WHO Standard	Drinking water sources			
		River	Sachet	Borehole	Well
Temperature (^{o}C)	30.00 – 32.00	30.62 (0.46)	29.45 (1.22)	27.51 (3.34)	29.86 (2.19)
pH	6.50 – 8.50	5.96 (0.43)	6.87 (0.41)	7.43 (1.12)	7.89 (1.45)
Electrical Conductivity (µScm^{-1})	500.00	186.00 (12.84)	123.69 (10.56)	167.30 (11.09)	172.87 (4.87)
Total dissolved solid (mg/l)	259.00 – 500.00	187.29 (12.34)	146.54 (2.45)	167.89 (2.86)	174.67 (14.81)
Total suspended solid (mg/l)	30.00	8.37 (0.45)	2.25 (0.32)	2.45 (0.11)	4.61 (1.02)
Turbidity (NTU)	5.00	4.67 (0.54)	2.25 (0.21)	2.87 (0.43)	3.43 (1.02)
Total hardness (mg/l)	200.00	136.72 (13.93)	49.17 (1.82)	72.45 (1.39)	112.30 (8.45)
Free carbon (iv) oxide	NS	1.45 (0.43)	0.09 (0.00)	0.11 (0.01)	0.31 (0.02)
Total alkalinity (mg/l)	120	119.42 (12.65)	80.31 (0.21)	101.05 (11.01)	116.32 (17.92)
Dissolved oxygen	7.50	12.45 (1.48)	6.32 (1.04)	5.44 (0.31)	5.86 (0.22)

The viable and total coliform counts of bacteria in the different water samples are presented in Table 2. The total coliform counts were highest in river sample with a value of 1.03 (0.08) x 10^2 cfu/ml while the least counts of 0.03 (0.00) x 10^2 cfu/ml were recorded in sachet water. All the values for total coliform counts were higher than WHO standard of zero per 100ml. However for total viable counts, sachet water was 0.98 (0.02) x 10^2 cfu/ml approximately within the WHO standard of 1.0 x 10^2 cfu/ml (Table 2)

Table 2: Total Aerobic Plate Count Mean (Standard error) of bacteriological analyses (coliform count) sampled drinking water sources in Jabi, Abuja.

Water sample	Total viable counts (cfu/ml)	Total coliform counts (cfu/ml)
River	1.54 (0.12) x 10^2	1.03 (0.08) x 10^2
Sachet	0.98 (0.02) x 10^2	0.03 (0.00) x 10^2
Borehole	1.01 (0.14) x 10^2	0.79 (0.10) x 10^2
Well	1.06 (0.23) x 10^2	0.95 (0.07) x 10^2
WHO standard	1.0 x 10^2	Zero per 100ml

The different bacterial isolates identified from the water sources sampled in this study are presented in Table 3. Three bacterial isolates *Escherichia coli*, *Pseudomonas* spp and *Aeromonas* spp were isolated from well water while the bacterial isolates *Pseudomonas* spp and *Proteus* spp were isolated from the borehole water. All other bacteria were isolated from the river. The most public health pathogenic bacteria isolated are the *Salmonella* spp, *Aeromonas* spp and *Escherichia coli* (Table 4).

Table 3: Bacterial isolates from the different sampled drinking water sources in Jabi District of FCT, Abuja

Isolates	Sampled drinking waters			
	River	Sachet	Borehole	Well
Salmonella spp	+	-	-	-
E. coli	+	-	-	+
Pseudomonas spp	+	-	+	+
Aeromonas spp	+	-	-	+
Proteus spp	+	-	+	-

+ Present, - Absent

Table 4: Cell Morphology and Biochemical Characteristics of Isolates from drinking water sources in Jabi District of FCT, Abuja

Isolate code	Cell Morphology	Gram Stain	Motility	Catalase	Oxidase	Citrate	Urease	Indole	Glucose	Sucrose	Lactose	Dextroses	Organism
WS1	Rod	G-	+	+	-	+	-	-	G	A	-	A	*Salmonella* spp
WS2	Rod	G-	+	+	-	+	+	+	G	A	-	A	*Aeromonas* spp
WS3	Rod	G-	+	+	+	+	-	-	-	-	A	A	*Pseudomonas* spp
WS4	Rod	G-	M	+	-	-	+	+	G	A	AG	AG	*Escherichia coli*
WS5	Rod	G-	+	+	-	-	+	-	G	A	A	A	*Proteus* spp

Key: + = Positive; - = Negative; A= Acid production; G= Gas production; G- = Gram negative; AG=Acidic and gas production; M = Moderate

DISCUSSION

Bacteriological analyses:

In this study, the total bacterial and coliform counts were lowest in sachet 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. Despite the high values in other water sources, these bacteriological parameters were lower than those reported by (Adegboyega *et al.,* 2015) in sampled wells of Idi Ayunre community, Oyo State. The coliform counts were also higher in sampled wells in Samaru, Zaria, Kaduna metropolis and Makurdi town, Benue State (Mile *et al.,* 2012; Aboh *et al.,* 2015; Allamin *et al.,* 2015). An indication that the water sources in Abuja are safer for drinking compared with aforementioned states of the country.

These counts were less in sampled borehole water in Abuja than that reported by (Ehiowemwenguan *et al.,* 2014) in Eyaen community Area of Edo State, Nigeria; (Ibe and Okplenye, 2005) in Uli, Nigeria. In this study, few pathogens of public health such as *Salmonella typhii, Aeromonas* spp and *Escherichia coli* were isolated from river, borehole and well water sources. This is consistent with the work of Ehiowemwenguan *et al.* (2014) in Eyaen community Area of Edo State, Nigeria were pathogens such as *Salmonella, Shigella* and *Vibrio cholera* were isolated. The *Pseudomas* spp is perhaps widely distributed in soil and water (Schlegel, 2002; Alonge *et al.,* 2018). Hence, was isolated from all the ground water sources in this study. However, despite the high level of pathogenic bacteria isolates from river sample in Jabi, Abuja, it cannot be compared with the Mimyak river in Kanke LGA of Plateau State with even higher level of pathogenic bacteria (Lawal and Lohdip, 2015).

Physicochemical parameters:

The value of borehole temperature recorded was within the range reported by Obi and Okocha (2007), Chukwu (2008) and Onwughara *et al.* (2013). Cool water is more potable for drinking purposes, because high water temperature enhances the growth of microorganisms. Thus, taste, odour, colour and corrosion problems may increase (Okoye and Okoye, 2008).

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 river water sampled with pH below 6. In this study, excluding dissolved oxygen in the river sample which might have a deleterious effect on consumers, physicochemical parameters of all the water samples analyzed were within WHO standard. The pH values obtained from other sources were within the range reported by Sa'eed and Mahmoud (2014), Allamin *et al.* (2015) and Reda (2016) in well waters sampled in Kaduna metropolis.

In the case of turbidity, the values were less than the limit set by WHO thus they were assumed to be adequate. The turbidity levels of the water sources suggest that they lack 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 river water is consistent with the report of Reza and co-workers (2009) that turbidity is associated with surface water sources.

All water samples indicate the availability of little contaminants as shown by the level of the determined values of total suspended solids (TSS). All measurements were within the permissible limits of WHO. Similarly, the total dissolved solid values of water samples were also within the WHO guideline values of 500 mg/l. Higher total dissolved solids are reported to reduce water clarity, which could contribute to reduced photosynthetic activities and possibly lead to an increase in water temperature (Harrison, 2007), which is not the case in this study.

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 was within the permissible limit of 300μScm^{-1}, thus the water samples are considered safe in terms of this parameter. These waters sampled in Abuja are apparently better in terms of conductivity in comparison with the work by Sa'eed and Mahmoud (2014) in Fagge Municipality in Kano State, Nigeria. However, the electrical conductivity from the river sample in this study is higher than that reported by Aremu and co-workers (2014) who sampled streams and rivers in Okene, Kogi State.

The total alkalinity of water is its acid neutralizing capacity. The alkalinity of groundwater is mainly due to carbonates and bicarbonates (Raju *et al.,* 2009). The acceptable limit of alkalinity is 120mg/l and can be up to approximately 500mg/l (Raju *et al*., 2009; WHO, 2000, 2011). Based on the values of total alkalinity of the sampled waters, it can be inferred that the water is safe for drinking. In addition, the total alkalinity levels observed in this study were better than those reported by Sa'eed and Mahmoud (2014) in Fagge Municipality of Kano State, suggesting a better soil environmental condition.

The principal hardness-causing ions are calcium and magnesium and the acceptable limit of total hardness can be up to 500 mg/l (Raju *et al.,* 2009). According to Durfor and Becker (1964) hardness can be classified into four; soft (0 - 60mg/l), moderate (60 - 120mg/l), hard (121-180mg/l) and very hard (180mg/l and above). Similarly, the WHO International standards for drinking water classified water with a total hardness of $CaCO_3$ less than 50mg/l as soft water, 50-150mg/l as moderately hard and water hardness above 150mg/l as hard water. Based on this classification, the total hardness of the sampled drinking waters could be grouped as moderate as the values indicate with sachet water being safer for drinking.

Generally, the physicochemical parameters observed in this well water is consistent with the report of Gambo and co-workers (2015) on well waters in Crescent Road, Poly Quarters in Kaduna, while those from the sampled sachet water was within the range reported by Rahmanian *et al.* (2015) in Malaysia, an indication that the sachet water sampled in Abuja is the closest in terms of international best practice. Also, the physicochemical parameters of water sampled from the river in this study was closer in the range of WHO recommended standards compared to that reported by Joshi *et al.* (2009) in river ganga, India.

Overall, the different sources of drinking water sampled in this study revealed more healthy water sources than those reported by Nduka *et al.* (2008) in Warri, Delta State; Agwu and Avoaja (2013) in Aba, Abia State and Ogunlana *et al.* (2010) in Ota, Southwest, Nigeria. No bacterial isolates were isolated from the sampled sachet water in the study area compared to the different bacterial isolates, isolated from sachet water in local areas in Eastern Nigeria (Nwachukwu and Ume, 2013), Samaru-Zaria, Kaduna State (Ugochukwu *et al.,* 2015) and even in neighbouring Kampala, Uganda (Halage *et al.,* 2015), an indication that the sampled sachet water in this study is safer for drinking and better for domestic water purposes.

CONCLUSION

This study revealed that in all the water samples analysed, sachet water samples have the least bacterial contaminants followed by the borehole water and the well water. The river water had the highest amount of bacterial contaminants. Also, water sources in the study area are safer for human consumption compared to the other places in Nigeria. However, the bacteriological values from total coliform count did not meet international standard as they were higher than WHO standard of zero per 100ml.

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