<u>Original Research Article</u>

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

Abstract

Diseases caused by contaminated water consumption are a serious public health threat. The present study was aimed to assess and compare the physicochemical and microbiological qualities of some drinking water sources in Diobu, Port Harcourt. Samples of drinking waters were collected from two different sources, sachet (packaged) and borehole. Standard analytical procedures were employed for physicochemical and bacteriological analyses. The results of physiochemical parameters showed that the highest pH values were recorded in sachet water samples, while the borehole water samples were slightly acidic with a mean value of 4.37±1.21 which was far below the W.H.O recommended range (6.5 – 8.5). The total suspended solids recorded in this study were within the minimal limits of 30.0mg/l. The highest value of 6.5±4.31mg/l was recorded in the borehole sample while the least value of 2.5±1.5 mg/l was recorded in the sachet water samples. Total dissolved solids were within the range of 15.8±13.5mg/l in sachet water and 55.6±33.4mg/l in the borehole water samples, The electrical conductivity values ranged from 33.5±28.4 μScm^{-1} (Sachet water) to 136.6±73.9 μScm^{-1} (Borehole water), total alkalinity had a mean value of 0.57±0.29mg/l in sachet water and 3.29±1.39 in borehole water. The values of water hardness ranged from 1.95±0.84 mg/l to 10.67±3.21mg/l for sachet water and borehole water respectively. Biological oxygen demand ranged from <1±0.00 (Sachet water) to 2.13±1.38 (Borehole water). Dissolved oxygen ranged from 1.72±0.70 mg/l in sachet water to 1.95±0.62 mg/l in borehole water, Chemical oxygen demand 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). There was no significant difference at $p \geq 0.05$ in values monitored except for chemical oxygen demand. In this research, the mean total bacteria counts were between 9.0×10^4 cfu/ml in borehole water and 2.0×10^4 cfu/ml in sachet water, indicating high level of pollution of the borehole water due to human contamination.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 standards as they were higher than WHO standard of zero per 100ml. The pathogenic bacteria of public health importance isolated from the various water samples were *Salmonella* spp, *Pseudomonas* spp, *Staphylococcus* spp and *Escherichia coli*. A total of five fungi isolates were identified, which include *Penicillium* spp., *Aspergillus niger*, *Aspergillus flavus*, *Trichoderma* spp. and *Mucor spp.* Sachet water samples had the least bacterial contaminants compared to borehole water that had the highest amount of bacterial contaminants. The water sources in this study area are not safe for human consumption; it is therefore recommended that the water sources be treated before use for any domestic purposes.

Keyword: Drinking water sources, Bacteriological, Physico-chemistry, Comparative, Assessment

1.0: Introduction

Clean, safe and adequate freshwater is vital for the survival of all living organisms and proper functioning of ecosystems, communities and economies (Mishra *et al.* 2009). 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 (UN, 2009, Ogbonna and Orinya, 2018). In Nigeria especially Diobu in Port Harcourt Rivers State, a vast majority of people source and drink from boreholes, wells and other water bodies irrespective of the state of these water bodies without any form of treatment. 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, and it is generally accepted that sewage polluted surface waters contain greater number of bacteria than unpolluted waters (WHO, 2003). 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 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)

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 physiochemical and bacteriological qualities of drinking water sources in Diobu, Port Harcourt, Nigeria.

2. Materials and Methods

2.1. Sample collection

Water samples were collected from ten borehole sites and ten popular sachets water popularly referred to as 'pure water' in Nigeria, from 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. 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.

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

The quality of water based on certain physicochemical properties such as pH, Electrical conductivity, Dissolved oxygen, biological oxygen demand; total dissolved solids, etc 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 were conducted using a portable turbidity meter (APHA, 2012). 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 (1995).

3.0 Results and Discussion

3.1 Physiochemical Analyses

The results of the physico-chemical parameters of borehole and sachet water obtained from Diobu, Port Harcourt during the 6-month period are presented in Table 1. The physicochemical parameters determined in this study were, pH, Conductivity, Turbidity, Total Dissolved Solids (TDS), Total Suspended Solids (TSS), Total Hardness, Total Alkalinity, Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Dissolved Oxygen (DO), Phosphate and Ca-Hd. The pH values ranged from 4.37±1.21 to 6.18±2.09 in water samples examined. The highest pH values was recorded in sachet water samples, while the borehole water samples were slightly acidic with a mean value of 4.37±1.21 which was far below the recommended range (6.5 – 8.5) by WHO. There was a 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 borehole water sampled with pH below 6. In this study, excluding pH in the borehole sample which might have a deleterious effect on consumers, physicochemical parameters of all the water samples analysed were within WHO standard. The pH values obtained from sachet sources were within the range reported by Sa'eed and Mahmoud (2014), Allamin *et al.* (2015) and Reda (2016) in well water sampled in Kaduna metropolis.

The total suspended solids recorded in this study were within the minimal limits of 30.0mg/l. The highest value of 6.5±4.31mg/l was recorded in the borehole sample while the least value of 2.5±1.5 mg/l was recorded in the sachet water samples. Similarly, the total dissolved solids were within the range of 15.8±13.5mg/l in sachet water and 55.6±33.4mg/l in borehole water sample. 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

The electrical conductivity values ranged from 33.5±28.4 µScm^{-1} (Sachet water) to 136.6±73.9 µScm^{-1} (Borehole water). These values were significantly different ($p>0.05$) though they were within the recommended limit of WHO standard. 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 within the permissible limit of 500µScm$^{-1,}$ thus the water samples are considered safe in terms of this parameter. The sachet waters sampled in Diobu 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 borehole sample in this study is higher than that reported by Aremu and co-workers (2014

The values of the total alkalinity revealed the mean value of 0.57±0.29mg/l in sachet water and 3.29±1.39 in borehole water samples with significant difference ($p>0.05$). 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)

The values of water hardness ranged from 1.95±0.84 mg/l to 10.67±3.21mg/l for sachet and borehole water respectively. Biological oxygen demand ranged from <1±0.00 (Sachet water) to 2.13±1.38 (Borehole water). 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 soft as the values indicate with sachet water being safer for drinking.

Dissolved oxygen ranged from 1.72±0.70 mg/l in sachet water to 1.95±0.62 mg/l in borehole water, Chemical oxygen demand 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). There was no significant difference at $p\geq0.05$ in values monitored except for chemical oxygen demand. 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 borehole water is consistent with the report of Reza and co-workers (2009). Comparatively, there were significant differences at P≤0.05 in the physicochemical parameters observed in the borehole and sachet water except for few parameters. Physicochemical parameters of the sachet water samples in this study were closer to the range of WHO recommended standards compared to that 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
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

In this research, the mean Total Bacteria Counts (TBC) were between 9.0×10^4 cfu/ml in borehole water and 2.0×10^4 cfu/ml in sachet water, indicating high level of pollution of the borehole water due to human activities (Table 2). These counts are higher than the acceptable counts of 100 cfu/ml for drinking water (WHO 2011). The higher total bacteria count especially in the borehole water samples is an indication of the presence of high organic matter in the water. The main source of these bacteria in the waters can be attributed to both human and animal activities (Allamin *et al.*, 2015). These sources of bacterial contamination include surface runoff, animal waste deposition and pasture are also possible ways of introducing foreign microorganisms in the water thereby making more nutrients available for the microorganisms in the water thus enhancing their growth at all the various water sources. The mean total fungi counts were between 8×10^2 cfu/ml in borehole water and 3×10^2 in sachet water (Table 2). The results of the total coliform counts (TCC) and faecal coliforms were higher in the borehole waters than sachet water which could be attributed to the discharge of sewage into the rivers by the surrounding people and leakage from septic tank.

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	$5x10^2$	$2x10^2$

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. comparatively, these bacteriological parameters were lower than those reported by other researchers Adegboyega *et al.,* (2015). The coliform counts were also lower in sampled borehole in Samaru, Zaria, Kaduna metropolis and Makurdi town, Benue State (Mile *et al.,* 2012; Aboh *et al.,* 2015; Allamin *et al.,* 2015). These counts recorded in this study were less in sampled sachet water compare to borehole this report is in agreement with observation by (Ehiowemwenguan *et al.,* 2014)

Nine (9) bacterial isolates belonging to the genera, *Pseudomonas, Klebsiella, Bacillus, Shigella, Staphylococcus, Salmonella, Proteus, Bacillus and E. coli* (Figure 1) were isolated and identify using conventional methods. The presence of these microorganisms particularly *E. coli* in the water body is universally accepted to indicate fecal contamination and possible presence of other pathogenic organisms (Reynolds, 2016). *E. coli* is a subgroup of fecal coliforms used as an indicator of fecal contamination. Although vast majority of *E. coli* are completely harmless, some strains of the bacteria have acquired genetic capabilities which enable them to encode virulence factors (Meregini-Ikechukwu *et al.,* 2020). The most public health pathogenic bacteria isolated are the *Salmonella* spp, *Pseudomonas* spp, *Staphylococcus* spp and *Escherichia coli*. A total of five fungi isolates were identified, which include *Penicillium* spp., *Aspergillus niger, Aspergillus flavus, Trichoderma* spp. and *Mucor* (Fig 2)

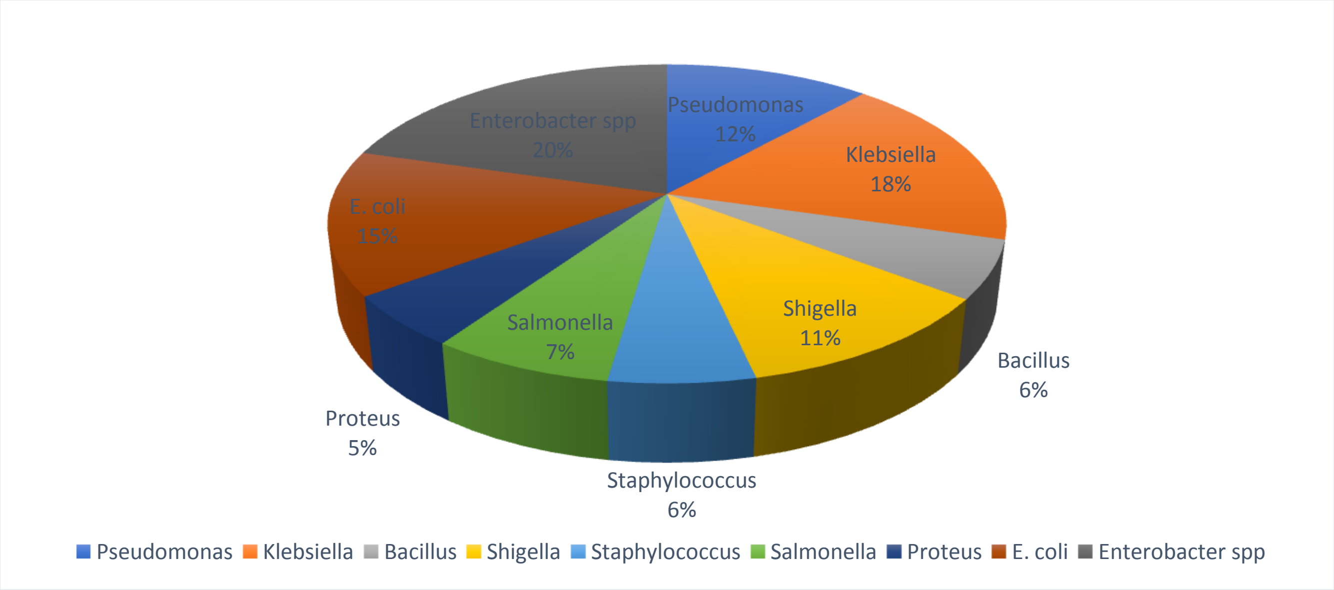

Figure 1. Percentage (%) frequency of distribution of bacteria isolates from the different water sources

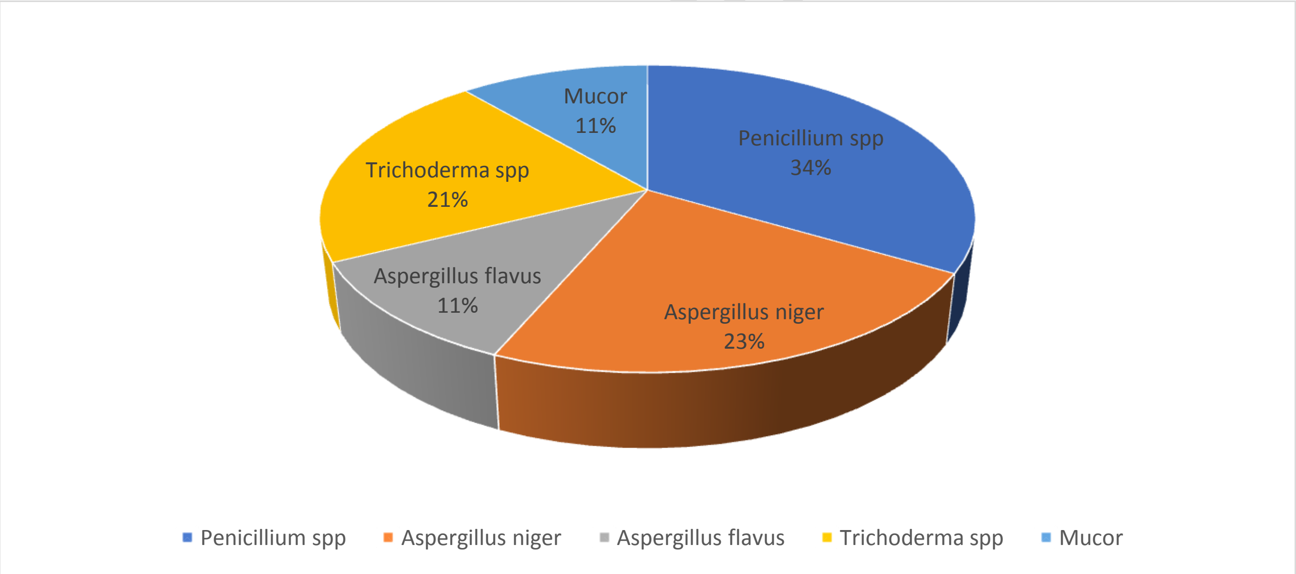

Figure 2: Percentage (%) frequency of distribution of fungi isolates from the different water sources.

4. Conclusion and Recommendation

This study revealed that in all the water samples analysed from Diobu indicate the availability of little contaminants as shown by the level of the determined values of total suspended solids and present of indicator (Feacal coliform). Sachet water samples have the least bacterial contaminants compared to borehole water, the boreholer water had the highest amount of bacterial contaminants. Water sources in the study area are not safer for human consumption compared to the other places in Nigeria.

Therefore high level of treatment is recommended for the water sources before uses of any domestic purposes.

REFERENCES

Aboh, E. A., Giwa, F. J and Giwa, A., 2015. Microbiological assessment of well waters in Samaru, Zaria, Kaduna, State, Nigeria. Ann Afr Med, 14:32.

Adegboyega, A., Olalude, C and Odunola, O., 2015. Physicochemical and Bacteriological Analysis of Water Samples Used For Domestic Purposes in Idi Ayunre, Oyo State, Southwestern Nigeria. IOSR J App Chem, 8.

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.

APHA., 1998. Standard methods for examination of water and waste water. American Public HealthAssociation, Washington, DC.

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.

Blake, P. A., Rosenberg, M. L., Florencia, J., Costa, J. B., do Prado Quintino, L and Gangarosa, E. J., 1977.

Bordalo, A. A and Machado, A., 2014. Water bags as a potential vehicle for transmitting disease in a Cholera in Portugal, 1974. II. Transmission by bottled mineral water. Am J Epidemiol, 105:344-348.

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. Afr J Food Sci, 7:9-13.

Durfor, C. N and Becker, E., 1964. Public water supplies of the 100 largest cities in the United States, 1962. vol 1812. US Government Printing Office

Ehiowemwenguan, G., Iloma, A and Adetuwo, J., 2014. Physico-Chemical and Bacteriological Quality of Borehole Water in Eyaen Community Area of Edo State, Nigeria. IJBAS,3:60-68.

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

Ezeribe, A., Oshieke, K and Jauro, A., 2012. Physico- chemical properties of well water samples from

Gambo, J., James, Y and Yakubu, M., 2015. Physico– Chemical and Bacteriological Analysis of Well Water at Crescent Road Poly Quarters, Kaduna. Int J Eng Sci, 4 (11):11-17.

Gangil., R., Tripathi, R., Patyal, A., Dutta, P and Mathur, K., 2013. Bacteriological evaluation of packaged bottled

Halage, A. A., Ssemugabo, C., Ssemwanga, D. K, Musoke, D., Mugambe, R. K., Guwatudde, D and Ssempebwa. J. C., 2015. Bacteriological and physical quality of locally packaged drinking water in Kampala, Uganda. J Environ Public health.

Ibe, S and Okplenye, J., 2005. Bacteriological analysis of borehole water in Uli, Nigeria. Afr J. Appl Zool. Environ. Biol, 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. 3 (5-1).

Joshi, D. M., Kumar, A and Agrawal, N., 2009. Studies on physicochemical parameters to assess the water quality of river Ganga for drinking purpose in Haridwar district. Rasayan J Chem, 2:195- 203.

Lawal, R and Lohdip, Y., 2015. Physicochemical and Microbial Analysis of Water from Mimyak River in Kanke LGA of Plateau State, Nigeria. Afr J Nat Sci, 1119-1104. Mavridou, A., 1992. Study of the bacterial flora of a non- carbonated natural mineral water. J. Appl. Microbiol,73:355-361.

Mile, I., Jande, J and Dagba, B., 2012. Bacteriological contamination of well water in Makurdi town,Benue State, Nigeria. Pakistan journal o

Ogbonna, David & Orinya, Obande. (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. 10.9734/MRJI/2018/44112.

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

Proceedings, May 27-June 1, 2012, Bari, Italy, American Society of Agricultural and Biological Engineers, p 1.

Raju, N. J., Ram, P and Dey, S., 2009. Groundwater quality in the lower Varuna river basin, Varanasi district, Uttar Pradesh. J Geol Soc India, 73:178.

Reda, A. H., 2016. Physico-Chemical analysis of drinking water quality of Arbaminch Town. J

Reza, R., Jain, M and Singh, G., 2009. Pre and Post Monsoon variation of heavy metals concentration in Ground water of Angul-Talcher region of Orissa, India. Nat Sci, 7:52-56.

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 J Anal Chem, 2:42-46.

Semerjian, L. A., 2011., Quality assessment of various bottled waters marketed in Lebanon. *Environmental Monitoring Assessment*, 172:275-285.

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

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. IJAST, 3.

United Nations Economic and Social Council, Progress towards the Sustainable Development Goals. 2009. Retrieved from https://unstats.un.org/ sdgs/files/report/2020/secretary-general-sdg-report-2020–EN.pdf.

Warburton, D. W., 2000. The microbiological safety of bottled waters. Food science and technology-New York-Marcel Dekker-:479-518.

World Health Organization. World Health Statistics Report-2011. Geneva: WHO (2011) Egunjobi, L (1999). Our gasping cities: an inaugural lecture. Ibadan, Nigeria: University of Ibadan, 1999.