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THE BACTERIOLOGICAL AND PHYSICOCHEMICAL QUALITIES OF KORU-AMA BONNY (MARINE) AND PENEE (FRESH) RIVERS IN COASTAL AREAS OF RIVERS STATE

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ABSRACT

Water is an important and essential substance used globally and should remain pristine at all times in any place. The essence of this work was to determine and compare the quality of fresh and marine waters used by the people living in the coastal areas of Rivers State. Two Rivers, Koru-ama Bonny (marine) and Penee (fresh) were identified and studied. The sampling sites were located by the Global Positioning Systems (GPS) which are located in Koru-ama Bonny River (N04°28′36.5″) and (E007°06′22.1″) and Penee River (N04°45′36.6″) and (E007°09′77.4″). Surface water samples were collected in clean sterile containers for physicochemical, some heavy metals and bacteriological analyses. The pH, temperature, conductivity and turbidity were determined *in situ* using Horiba Water Checker (Model 11 – 10) instrument. Nitrate, phosphate, chloride, alkalinity and others, including heavy metals and bacteriological analyses were carried out using standard procedures. The results of the physicochemical parameters of the marine water are as follow: pH 7.33±0.18, temperature 29.1±0.99^{O}C, electrical conductivity 32050.0±70.7µS/cm, total dissolved solids 22,935.0±657.6mg/l, salinity 19.1±0.14$^{0}/_{00,}$ chloride 10639.3±655.7mg/l, hardness 3,833.0±1.14mg/l, sulphate 443.8±6.57mg/l and dissolved oxygen 7.50±0.28mg/l. However, the fresh water values for pH, temperature, electrical conductivity, total dissolved solids, salinity, chloride, hardness, sulphate and dissolved oxygen were 7.60±0.28, 27.1±0.42^{O}C, 29.0±0.14µS/cm, 21.0±1.4mg/l, 0.9±0.08$^{0}/_{00,}$ 1.7±0.14mg/l, 4.5±0.14mg/l, 3.6±0.00mg/l and 2.0±0.01mg/l respectively. The heavy metals results showed mercury was 0.079±0.00mg/l for marine water and fresh water 0.261±0.001mg/l while arsenic was 16.385±0.001mg/l for fresh water. The total heterotrophic bacteria count, total coliform count and Most Probable Number (MPN) for marine water were 2.0 x10^{2}cfu/ml, 1.10x10^{2}cfu/ml and 0.90x10^{2}cfu/ml and the fresh water result were also 0.79x10^{2}cfu/ml, 0.90x10^{2}cfu/ml and 0.70x10^{2}cfu/ml respectively while the identified bacteria common to both the fresh and marine waters were *Pseudomonas spp*, *Bacillus spp*, *Escherichia coli* as *Vibrio spp* was found along with others in marine water. It can be inferred that the water sample are not pristine and they could be of health risk to the people and could sometimes result in epidemics in the coastal areas.

KEYWORDS: Water, Fresh, Marine, Bacteriological, Physicochemical, Water Quality.

INTRODUCTION

The coastal area of Rivers State has historically been associated with marine and fresh waters. The marine waters have boundary with the Atlantic Ocean in which they empty into after receiving runoffs and transported sediments from other running waters whereas the fresh water empties into it. The marine and fresh waters do not only provide environment for fishing and hunting activities but also provide platform for industrial activities and source for crude oil. The marine water plays important part as it provides natural harbours for ships to berth. The loading of exporting materials including crude oil and off-loading of imported goods are also handled at the ports in the harbours. There are different rivers, streams, rivulets and creeks in the coastal area and each of them carries its load into the marine and fresh waters.[1] Both the marine and fresh waters support the existence of animals, human and other living things. It is therefore worthwhile to study the quality of the marine and fresh waters because of their usefulness. Water is an essential and necessary substance that supports animal and human lives and their activities; its usefulness is not limited to one activity of man and it therefore needs to be preserved so as to maintain its pristine nature.[2]

Water as stated by the World Health Organization[3] and other organizations in other countries has its quality and standards which must be maintained both in rural and urban areas since they provide support for live. The marine waters in the coastal areas are subjected to water wave action which if harnessed could provide electricity for the people in the coastal area and the whole country at large. The presence of industrial and anthropogenic activities in the coastal area have exposed the marine and fresh waters to different substances entering into them that may have resulted to some changes in them.

Different researchers have worked on different types of water in other parts of Nigeria comparing their water qualities such as rivers, springs, stream, boreholes and even underground water. There are works on the qualities of some surface waters in coastal areas which did not separate them into fresh and marine water.[4-7]

Physiochemical and bacteriological analyses of surface water in marine and fresh waters were used to assess their quality as different materials are transported into them. This is because there are polluting agents entering into the marine and fresh waters from uncontrolled disposal of waste such as faecal and sewage from individuals, runoffs, atmospheric disposition, urban and industrial effluents into the water bodies which requires water quality monitoring.[8] The World Health Organization (WHO, 2006)[2] has stated that increase in world and local water scarcity has led to increase search of other sources of water. Globally different parts of the world are witnessing water scarcity. In the developing countries WHO has estimated that about 80% of ill health results from water and sanitation.[9]

In Nigeria water scarcity is a problem especially as it affects the Northern and Southern parts of the country. The available surface water in rivers, streams and others are threaten by waste disposal from increase in population growth, unplanned development, inefficient monitory and insufficient manpower to carry out adequate assessment of the water and sanitation. There are environmental protection laws and policies in place in developing countries, but the enforcement of such laws are difficult and there are continuous dumping of indiscriminate wastes into the water bodies from industrial, domestic wastes and sewage.[10] The marine and fresh waters are experiencing the dumping of sewage from septic tanks and building of make shift toilets on the water leading to direct introduction of faecal matter into the water.

It is in the light of the numerous substances from human, industrial and agriculture materials entering into the marine and fresh waters in the coastal area that their surface water qualities will be determined to know their status and fitness for human use. It was found by[11] that there are seasonal variations in some of the marine and fresh water physicochemical parameters.

The aim of this research work is to assess the levels of the physicochemical parameters, some heavy metals and bacteria present in the marine and fresh water samples. The specific objective is to identify the various physiochemical parameters, some heavy metals and bacteria that are of health risks which could cause epidemic amongst animals and humans living in the coastal areas.

MATERIAL AND METHOD

Study area

The study areas were Koru-ama Bonny River and Penee River which are located in two different Local Government Areas of Rivers State in Nigeria. The water samples represent the marine and fresh water. The Koru-ama Bonny River is located on $N4^{0}28'36.5''$ and $E7^{0}06'22.1''$ and Penee River $N04^{o}45'36.6''$ and $E007^{o}09'77.4''$.

Sample Collection

The water samples from the rivers were collected during the dry season at the designated Global Positioning System (GPS) points. The samples were collected at midstream in sterile universal containers of 25ml capacity for microbiological analysis and in brown bottles of 500ml capacity for physicochemical parameters and were properly labeled and transported to the laboratory in cold chain. The Koru-ama Bonny River (marine) serves as station 1 while Penee (fresh) is station 2.

Sample analysis

The standard analytical methods used for the physicochemical parameters determination in the water were the American Public Health Association Series of Standard Methods of Examination of Water and Effluent.[12]

The pH conductivity salinity and turbidity were determined by using the Horiba Water Checker (Model 11 – 10) after calibrating the instrument with the standard Horiba solution and total dissolved solids with a Lovibond CM-21 Tintometer while the temperature were determined with a mercury thermometer.

The bacteria analyses were carried out by using the standard plate count technique where the water samples were cultured on Nutrient, MacConkey, Salmonella-Shigella and Thioglycholate citrate bile salt sucrose agar culture media.[13] These were incubated at $37^{0}C$ for 24 hours after which bacterial counts were made and sub-cultured. Gram stain, motility and other biochemical tests such as catalase, coagulase, oxidase, citrate ultilization, Voges Proskauer, Methyl red, indole and spore staining were carried out as provided by.[13-18]

Statistical Analysis

The statistical analysis used was the Excel package used to determine the mean and the standard deviation.

RESULTS

The results of the physicochemical parameters obtained from the water samples indicate the pH ranged from 7.33±0.18 in marine water to 7.60±0.28 for the freshwater and they are within the WHO standard values. The temperature of the water samples ranged from 27.1±0.12 to 29.1±0.99^{O}C for fresh and marine water respectively. The results for other parameters as conductivity, turbidity, salinity, total dissolved solids, chloride, total alkalinity, total hardness, calcium, magnesium, dissolved oxygen and sulphate levels of the water samples and the corresponding WHO guideline values for drinking water are all displayed in Table 1.

The presentation of the heavy metals results analysed in the water which are for arsenic, cadmium, chromium, mercury and lead are as shown in the Table 2 with their corresponding WHO recommended levels.

Furthermore, according to the findings the total heterotrophic bacteria count ranged from 0.7 x 10^2 to 2.0 x10^2 cfu/ml, total coliform count from 0.90 x 10^2 to 1.10 x 10^2 cfu/ml while the most probable number (MPN) for faecal coliform ranged from 0.70 x 10^2 cfu/ml to 0.90x10^2cfu/ml respectively for the fresh and marine waters. The values obtained for marine water samples were higher than the fresh water samples (Table 3).

As shown in Table 4, the cultural, morphological and biochemical tests were used to identify the bacteria in the marine and fresh water samples.

Table 1: Physicochemical Parameters in the water samples.

S/N	Parameters	Koru-ama	Penee	WHO Level
1	pH	7.33±0.18	7.60±0.28	6.5-8.5
2	Temperature ^{0}C	29.1±0.99	27.1±0.42	25
3	Conductivity µS/l	32050.0±70.7	29.9±0.14	5.0
4	Turbidity NTU	10.5±0.71	0.8±0.00	5
5	Salinity $^{0}/_{00}$	19.1±0.14	0.9±0.08	5
6	Total Dissolved Solid mg/l	22935.0±657.6	21.0±1.4	500
7	Chloride mg/l	10639.3±645.6	1.7±0.01	0.05
8	Total Alkalinity mg/l	8.5±0.71	10.7±0.14	50
9	Total Hardness mg/l	3833.0±1.14	4.5±0.14	5.0
10	Calcium mg/l	1231.2±6.8	0.85±0.07	7.5
11	Magnesium mg/l	188.3±2.4	4.8±0.14	30
12	Dissolved Oxygen mg/l	7.50±0.28	2.0±0.01	14
13	Sulphate mg/l	443.8±6.57	3.6±0.00	150

Table 2: Heavy Metals in Water Samples.

Sample Name	Arsenic (As)	Cadmium(Cd)	Chromium(Cr)	Mercury(Hg)	Lead (Pb)
Koruama Bonny	-3.064±0.001	-0.008±0.001	-0.006±0.001	0.079±0.00	-0.031±0.001
Penee	16.385±0.001	-0.057±0.0 01	-0.037±0.00	0.261±0.001	-0.261±0.001
WHO STANDARDS	0.00001	0.01	0.0003	0.003	0.001

Table 3: Total Heterotrophic Bacteria Count, Total Coliform, and Most Probable Number.

Parameters	Station 1 Koruama Bonny River (Marine)	Station 2 Penee River (Freshwater)
Total Heterotrophic Bacteria Count (cfu/ml)	2.0 x 10^2	0.79 x 10^2
Total coliform (cfu/ml)	1.10 x 10^2	0.90 x 10^2
Most Probable Number (MPN)	0.90 x 10^2	0.70 x 10^2

Table 4: Identified Bacteria in Marine and Freshwater.

Station 1 Koru-ama Bonny River (Marine water)	Station 1 Penee River (Freshwater)
Pseudomonas spp.	*Bacillus spp.*
Bacillus spp	*Pseudomonas spp.*
Escherichia coli	*Escherichia coli*
Vibrio spp	

DISCUSSION

It has been observed that every day and year thousand tons of oil product, raw sewage, faecal matter, chemicals with unpredictable effects get into water be it marine or fresh water in the coastal areas of Rivers State. These waters may indicate elevated levels of different substances such as toxic heavy metals, pesticides, nitrates, phosphates, oil, surfactants and drugs. It is

known that in the Niger Delta of Nigeria and especially the coastal areas of Rivers State, Nigeria over 12 million tons of crude and refined oil get into the water from different activities.[10-11]

There are evidence to show that the coastal areas of Rivers State in the Niger Delta has suffered from debilitating effect of environmental degradation and pollution from anthropogenic activities as oil industry operations, manufacturing and municipal discharges get into the marine and fresh waters. Increase in population resulting from migration, urbanization and different municipal activities have also contributed to the amount of wastes such as solid, liquid, gaseous emissions and heavy metals that are deposited in the water environment resulting in its pollution.[19]

The Table1 shows the physicochemical parameters as obtained from the analyzed water samples; indicating that generally the marine water has higher level of conductivity of 32,050±70.71µS/cm as against 29.9± 0.14µS/cm for freshwater and this indicates that there are different substances carrying charges that are present in the marine water than the fresh water. The levels of conductivity obtained are higher than the WHO recommended standard permissible limit for fresh and marine waters. The turbidity and salinity values as presented in Table 1 were obtained from both marine and fresh water samples. According to the result, the marine water had higher value above the permissible level than the fresh water. The values are below the recommended value of 5NTU and 5% for each of them as recommended by WHO.[3]

The temperature values determined for the marine and fresh waters are as shown on Table 1 and they indicate that the fresh and marine water samples are in the tropical areas where there is shinning of the sun regularly that heat the water surface. The temperature values were 29.1 ± 0.99^0C for marine and 27.1 ± 0.42^0C for the fresh waters. Both temperatures values are higher than the WHO recommended level of 25^0C for water.[3] It means that bacterial that can adapt to this temperature will be the ones that can be found existing in the water samples. These high temperatures could also cause some changes in the bacteria genes since ultraviolet light have been implicated in causing changes in genetic make-up of bacteria.[20-22] The high temperature values could cause change in the taste of the waters.

The total dissolved solid values of 22,935.0±657.6mg/l for the marine water sample is higher than the value for the fresh water and the WHO recommended standard value of 500mg/l. Increase in the level of total dissolves solids decreases the potability of water and it may cause gastrointestinal irritation in the humans and laxative effect upon transits.[23] The measurement of dissolved substances in the water determines the presence of total inorganic materials in the water. Conductivity has been found to be a function of the amount of dissolved solids and it depends on the nature of dissolved solutes. This can be confirmed from the results obtained from the analysed water for conductivity as presented in Table 1.[24-25] The impact of this could be that the water might lose its natural value.

Chloride presence in water occurs as a result of the salts of sodium (sodium chloride, NaCl, potassium (Potassium chloride, (KCl) and calcium (Calcium chloride, $CaCl_2$). The taste produced by the chloride anion in water depends on the associated cation. The taste threshold for sodium and calcium chlorides in water are given to range from 200-300mg/l.[26] The chloride value of 10,639.3±645.6mg/l for marine water is higher than the fresh water value which is 1.7±0.14mg/l. This shows that the marine water receives and mixes with water coming in from the sea and substances from the hinterland. The World Health Organization (WHO) recommends that concentration of chloride in excess of 250mg/l can give rise to detectable taste in water which depends on the associated cation.[27] There is no health based guideline proposed for chloride in water. It is known that when there is increase in chloride in water it causes increase in electrical conductivity of the water which can increase corrosibility as it reacts with metal ions forming soluble salts.[9]

As shown in Table 1, the values determined for total hardness in the marine and fresh waters are 383.30±1.14mg/l and 4.5±0.14mg/l. It is an important parameter because it measures the capacity of the water to react with soap as hard water requires more soap to produce lather. The water that is hard produces noticeable deposit of precipitate especially of insoluble metals, soaps or salts in used containers. The hardness of the water is produced by different substances that get into the water such as polyvalent metallic ions of calcium and magnesium cations; although, there are other cations such as aluminum, iron, manganese, barium and zinc. The intake of water that has hardness resulting from calcium and magnesium indicates that these individuals will be increasing their levels of calcium and magnesium with their resultant damages when taking in excess of the two elements. Drinking water that has high magnesium and sulphate present in high concentrations above 250mg/l has been known to produce laxative effect. The intake of excess calcium is a source of concern especially to those who are more prone to milk alkali syndrome with the simultaneous presence of hypercalcaemia, metabolic alkalosis and renal insufficiency.[28]

It has been suggested that exposure to hard water is a risk factor that could cause eczema as a result of increase of soap usage in hard water that causes metal or soap residues on the skin or on clothes that are not easily rinsed off and leads to contact irritation.[29] The calcium concentrations in the marine and fresh water are 1231.2±6.8mg/l and 0.85±0.07mg/l respectively. The marine water value is higher than the WHO recommended standard of 7.5mg/l while the freshwater

value is lower. The excessive intakes of calcium in water has adverse effect as it causes hypercalcemia and might cause impaired kidney function and decreased absorption of other minerals such as iron, zinc, magnesium and phosphorus.[28]

The presence of magnesium in the water was determined for the marine and freshwater respectively. The obtained value of magnesium for marine water was 188.3±2.4mg/l while that of the fresh water was 4.8±0.14mg/l. The presence of magnesium ions in the water are directly related to hardness. The levels of magnesium present in the marine water is higher than the WHO given limit of 30.0mg/l and also higher than the fresh water value; although, the fresh water value is lower than the WHO recommended standard. It has been stated by Kortatsi (2007)[30] that calcium and magnesium ions present in water are essential for human health and metabolism. However, when they are taken in excess there are health associated implications.[28]

Dissolved oxygen in the marine and fresh water samples were determined and presented in Table 1 as 7.50±0.28mg/l marine and 2.0±0.01mg/l fresh water. The determination of the dissolved oxygen in water is an important and required parameter for the assessment of water quality. Dissolve oxygen presence in water reflects the physical and biological processes that prevail in the water system and it indicates the degree of water pollution. The levels of dissolve oxygen in the marine and fresh water were low when compare with the WHO[3] standard of 14.0mg/l. The low level of dissolve oxygen suggests that there are some activities either by the bacteria and some other biochemical activities taking place in the water.[31]

The presence of some heavy metals in marine and fresh waters were analysed. The recorded high level of arsenic (As) at Penee is 16.385±0.001µg/l while mercury (Hg) at Kuro-ama Bonny and Penee are 0.079±0.001µgl and 0.261.0±0,001µg/l respectively and they are both higher than the recommended standard by the WHO of 0.00001µg/l and 0.003µg/l. The high values recorded in both the fresh and marine waters gives the indication that they are entering the waters through runoffs and disposal of different types of waste that contains these heavy metals.

The determination of the total heterotrophic bacteria, total coliform and the most probable number for faecal coliform were carried out to detect if the water samples are free from bacteria and coliform bacteria that could come from the animal and human sources. The determined levels give indication that there are presence of these bacteria and that the water is polluted with faecal and sewage materials from human sources.

The identified bacteria, *Pseudomonas spp. Bacillus spp, Escherichia coli and Vibrio spp* are all bacteria that have potentials of causing infection resulting in diseases and also suggest feacal contamination. This work has shown that there are polluting substances and materials that are gaining entrance into the fresh and marine water.

According to the WHO standard, the total heterotrophic bacteria count should not exceed 100 colony forming unit per milliliter (cfu/ml). The detected bacteria count in the water sample exceeding the WHO standards indicates that the water sample contained bacteria that make the water unsafe for human use for drinking and other domestic uses[3] while the fresh water heterotrophic level was below the WHO value. The recorded high value of heterotrophic bacteria for the marine and the fresh water could be due to the human disposal of faecal and sewage materials directly into the water and also from runoffs entering into the water. The poor sanitary habits of the people living in the coastal area could have contributed to it too. The Table 3 shows the total coliform count which ranged from 0.90×10^2 to 1.10×10^2 cfu/ml and the most probable number (MPN) for facial coliform ranged from 0.70×10^2 to 0.90×10^2 cfu/ml; they are above the WHO standard for potable water as it states that no coliform should be present in any drinking water and this makes the water samples unacceptable for use and it shown that anthropogenic activities are close to the water samples.

CONCLUSION

The obtained results from physicochemical and bacteriological analyses of these waters suggests that both the marine and fresh water samples are not free from depositions of materials and substances from runoffs, animal and human activities, industrial and municipal wastes. It indicates that the water environment is not being monitored as different discharges are sent into it and this has made the water a source of health risk to human and animal lives.

REFERENCES

1. Fubara, D.M.J. (2014). River Hydrodynamics and Sea Level Monitoring for Flood Impact Control in the Niger Delta Proceedings of the 2nd International Conference on Flood and Erosion Prevention, Protection and Mitigation 3rd-5th November, 2014. Amphitheatre, Rivers State University of Science and Technology, Nkpolu, Port Harcourt, Rivers State, Nigeria.
2. Cunningham, W.P. & Cunningham, M.A. (2008). Water use and management, environmental science: A global concern. New York, United States of America: McGraw-Hill Companies International.
3. World Health Organization (WHO), (2006). Guidelines for drinking water quality (3rd edition): Incorporation of the first and second addenda volume 1 recommendations WHO, Geneva, Switzerland.
4. Ukpaka, C.P., & Chuku, J. Investigating the physiochemical parameters and the potability of some river water in Rivers State of Nigeria. *Journal*

of Research Environmental Science and Technology, 2012; 1(7): 168-185.
5. Etim, E.E., Odoh, R., Itodo, A.U., Umoh, S.D., & Lawal, U. Water quality index for assessment of water quality from different sources in Niger Delta Region of Nigeria. *Frontiers in Science*, 2013; 3(3): 89-95.
6. Olorode, O.A., Bamigbola, E.A., & Ogba, O.M. Comparative studies of some river waters in Port Harcourt based on their physicochemical and microbiological analyses, Niger Delta, region of Nigeria. *International Journal of Basic and Applied Science*, 2015; 3(3): 29-37.
7. Raji, M.I.O., Ibrahim, Y.K.E., Tytler, B.A., & Ehinmidu, J.O. Physicochemical characteristics of water samples collected from Rivers Sokoto, Northern Western Nigeria. *Atmospheric and Climate Sciences*, 2015; 5: 194-199.
8. Onojake, M. C., Ukerun, S.O., & Iwuoha, G. A statistical approach for evaluation of the effects of industrial and municipal wastes on Warri Rivers, Niger Delta, Nigeria. *Water Quality Exposure Health*, 2011; 3: 91-99.
9. World Health Organisation (WHO), (1998). Guidelines for water quality. (3rd Edition), Incorporating the first and second addenda volume 1, recommendations. World Health Organization, Geneva, Switzerland.
10. Oguzie, F.A. Heavy metals in the sediments of the Lower Ikpoba River, Benin City, Nigeria. *Sri Lanka Journal of Aquatic Science*, 2002; 7: 35-44.
11. Onojake, M.C., Sikoki, F.D., Omoklayeke, M.O., & Akpiri, R.U. Surface water characteristics and trace metals level of the Bonny/New Calabar River Estuary Niger Delta, Nigeria. *Applied Water Science*, 2017; 7: 951-959.
12. American Public Health Association (APHA), (2005). American Water Works Association and Water Environmental Federation. Standard methods for the examination of water and waste water (21st Edition), Washington DC, United States of America: Port City Press.
13. Cheesbrough, M. (2004). *District Laboratory Practice in Tropical Countries* Part 2. Cambridge, United Kingdom: Cambridge University Press.
14. Singleton, P. (1999). Bacteria in Biology, Biotechnology. The Identification and Classification of Bacteria. 4th Edition, England, United Kingdom: John Wiley & Sons.
15. Benson, H.J. (2002). Microbiological Applications Laboratory Manual in General Microbiology Short Version, 8th Edition, New York, NY, United States of America: McGraw-Hill Companies.
16. Barrow,G. I., & Feltham, R.K.A. (2003). *Cowan and Steel's Manual for the Identification of Medical Bacteria* 3rd Edition. Cambridge, United Kingdom: Cambridge University Press.
17. Forbes, B.A., Sahm, D. F., & Weissfeld, A.S. Laboratory Methods and Strategies for Antimicrobial Susceptibility Testing. In: Bailey & Scott's Diagnostic Microbiology. 12th ed. Mosby, St. Louis, 2007; 187-214.
18. Hatcher H, Planalp R, Cho J, Torti FM, Torti SV. Curcumin: From Ancient Medicine to Current Clinical Trials. *Cell Molecular Life Science*, 2008; 65: 1631-1652.
19. Chakraborty, S., & Pal, N. K. (2011).*Manual of Practical Microbiology and Parasitology*. 2nd Edition. Kolkata, India: New Central Book Agency (P) Limited.
20. Onojake, M.C., & Frank, O. Assessment of Heavy Metals in Oil Contaminated by Oil Spill: ACase Study in Nigeria. *Chemical Ecology*, 2013; 29(3): 246-254.
21. Schlegel, H. G. (2002). General Microbiology Cambridge Low Price Edition, 7th Edition London, United Kingdom: Cambridge University Press.
22. Childress, H., Sullivan, B., Kaur, J., & Karthikeyan, R. Effect of ultraviolet light disinfection an tetracycline resistant bacteria in waste water effluents. *Journal Water Health*, 2014; 12(3): 404-409.
23. Rammelsberg, A. (2017). How does ultraviolet light kill cells? Scientific American A Division of Nature America, Inc. https://www.scientiricamerican.com/article.how_does_ultraviolet_light
24. World Health Organization (WHO), Guideline for Drinking Water Quality, (2nd Edition), Vol.2 Health Criteriaand other supporting information, World Health Organization, Geneva, 1997; 940-949.
25. Ademoroti, C, M. A. (1996). Environmental Chemistry and Toxicology. Foludex Press Ibadan, Nigeria: 111-204.
26. Sharma, R. K., & Sharma, T. K. A textbook of hydrology and water resource engineering, 5th Edition, India, Ishi Kapur for Dhanpat Rai Publications, 2000; 615-786.
27. Zoeterman, B.C.J. (1980). Sensory assessment of water quality. New York, USA: Pergrom Press.
28. World Health Organization (WHO), Guidelines for drinking water quality. 2nd Edition, vol. 2, Health criteria and other supporting information, World Health Organization Geneva, 1996.
29. World Health Organization (WHO), (2009). Calcium and Magnesium in Drinking Water; Public Health Significance. Geneva WHO http://whoguidbdoc.who.int/publications/2009//9821/56
30. Thomas, K.S., & Sach, T.H. A multicenter randomized controlled trial of ion-exchange water sogthers for the treatment of exzema in children, protocol for the softened water. Eczema Trial (SWET) *British Journal of Determatology*, 2000; 159(3): 1561-3667.
31. Kortatsi, B.K. Groundwater quality in Wassa West District of the Western Region of Ghana. *West African Journal of Applied Ecology*, 2007; 11: 1-10.
32. Obeta, M.C., & Ocheje, F.J. Assessment of groundwater quality in Ankpa urban, Kogi state,

Nigeria. Nigerian Association of Hydrological Sciences (NAHS) Proceedings of the NAHS. 5th Annual National Conference. October, 2013; 21-24. University of Nigeria, Nsukka.