Original Research Article

Assessment of Water Quality from Hand-Dug Wells and a River in Oproama Community, Niger Delta Region, Nigeria

ABSTRACT

Aims: assessment of water quality from hand-dug wells and the river in Oproama Community, Niger Delta Region was undertaken.
Study design: For the purpose of the study, ten (10) sampling stations were selected. Seven (7) hand-dug wells are being used extensively for drinking and other domestic purposes and three (3) source points along the Oproama River were sampled monthly.
Place and Duration of Study: The study was carried out in Oproama Community in Asari-toru Local Government Area of Rivers State for twelve (12) months mention year to cover both dry and wet seasons.
Methodology: The parameters assessed were *Vibrio* (bacteria), salinity, calcium, magnesium concentrations as well as saltwater intrusion status employing standard laboratory procedures and estimation model.
Results: The results reveals that *Vibrio* counts ranged from 2 x10^2 to 1.375 x10^4 cfu/100 mL and the bacteria species identified from the water sources were *Vibrio cholera* and *Vibrio parahaemolyticus*. The study also reveals that salinity ranged from 11.97 to 13,772 mg/L, calcium, 0.15 to 126.33 mg/L and magnesium, 0.09 to 43.02 mg/L. All parameters assessed exhibited seasonal variation during the study period; Calcium/magnesium (Ca/Mg) ratios for each well water sample ranged from 1.67 to 12.33 and indicate absence of saltwater intrusion which stands at a Ca/Mg limit of 1.
Conclusion: Salinity (particularly well water samples), calcium and magnesium concentrations were within recommended limit; *Vibrio* counts were high and its presence in drinking water has public health risk. Therefore, there is the need for routine water monitoring, purification design and treatment processes.

Keywords: Calcium, Magnesium, Oproama, Saltwater intrusion, Water Quality

1. INTRODUCTION

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Water is a basic necessity; in its absence, higher animals survive only for a few days [1]. It has several uses such as washing, cooking, food processing, swimming and among others. Out of these uses, drinking of water seems to be the most sensitive as it could have a direct deleterious impact on the health of human beings. Therefore drinking water should be potable, free of diseases, or toxic substance [2].

Lack of safe drinking water and inadequate sanitation measures introduce diseases causing pathogens such as *Escherichia coli*, *Salmonella* species, *Vibrio cholera* into water. These pathogens can cause water-borne diseases like cholera, typhoid, nausea, cramp and diarrhea in either human or animal host [3]. Water-borne pathogens pose special risk for millions of lives especially infants, young children under the age of five and people with severe compromised immune system [4]. Every year millions of lives are claimed in developing countries and death of more than 2 million people per year worldwide is caused by diarrhea, mostly among children under the age of five [4].

Infections caused by pathogenic Vibrios remain a severe threat to the public. Most of these infections result from the consumption of undercooked seafood products or contaminated water [4]. Traditionally, water has been considered to be the most important vehicle for cholera transmission [5] and *Vibrio cholera*, a gram-negative bacterium of the family Vibrionaceae is known worldwide as the etiological agent of cholera [6].

The impact of water on health is associated with unwholesome sources contaminated with faeces (from humans or animals) containing pathogenic microorganisms [7]. The quality of drinking water is closely associated with human health and providing safe drinking water is a major public health priority [8]. In most urban and rural settings in the Niger Delta area, major sources of water for drinking and domestic purposes are: rivers/creeks/streams/ponds, hand-dug wells and harvested rain water [9]. The provision of potable water has been a major problem in Nigeria, a characteristic feature of developing countries [10]. In Oproama, the major drinking water source is hand-dug wells of various depths, depending on availability and the level of groundwater although, centralised water supply may be available. Therefore, villagers use well water as an assumed safe drinking water source as confirmed by Jain et al. [11] that groundwater has unique features, which render it suitable for public water supply. It has excellent natural quality, usually free from pathogens, colour and turbidity and can be consumed directly without treatment.

One of the most important environmental issues today is ground water contamination [12] and between the diversity of contaminants affecting water resources, heavy metals receive particular concern considering their strong toxicity even at low concentrations [13]. Some of the metals are essential to sustain life – calcium, magnesium, potassium and sodium must be present for normal body functions. Also, cobalt, copper, iron, manganese, molybdenum and zinc are needed at low levels as catalysts for enzyme activities [14].

Another contaminant of source of groundwater source is saltwater intrusion. Saltwater intrusion is the movement of salt water into freshwater aquifers. Most often, it is caused by groundwater pumping from coastal wells, or from construction of navigation channels or oil-field canal. The channels and canal provide conduits for saltwater to be brought into freshwater marshes. But saltwater intrusion can also occur as the result of a natural process like a storm surge from a hurricane [15].

Sea water intrusion is a natural process, but it becomes an environmental problem when excessive pumping of groundwater from the aquifer reduces the water pressure thereby drawing salt water into new areas [16]. In any coastal environment, it is necessary to understand the pattern of movement and mixing between freshwater and saltwater as well as the factors that can influence these processes. When freshwater is withdrawn at a faster rate than it can be replenished, the water is drawn down as a result; the draw-down also reduces the hydrostatic pressure. When this happens near an ocean coastal area, saltwater from the ocean is pulled into the freshwater aquifer. The result is that the aquifer becomes contaminated with salt water. This is happening to many coastal communities [17, 18]. Generally, there are documented groundwater pollutions. An example of widespread groundwater pollution is the Ganges Plain of Northern India and Bangladesh where severe contamination of groundwater by naturally occurring arsenic affected 25% of water wells in shallower of two regional aquifers aided by the action of microbes [15].

The only drinking water source in Oproama Community is the hand-dug wells which are of various depths; therefore, to establish the baseline status of the quality of the well water and the river, the present study was carried to ascertain the *Vibrio* spp., salinity, calcium, magnesium concentrations and saltwater intrusion status of the hand-dug wells and the river water in Oproama Community.

2. MATERIAL AND METHODS

2.1 The Study Area

The study was carried out in Oproama Community in Asari-toru Local Government Area of River State. The community lies on latitudes 4o 47' and 4o 56' North and longitudes 6o 50' and 6o 41' East. Oproama Community lies in a combination of tropical rain and mangrove forest zone, with the mangrove forest as the dominant vegetation. Generally, the study area has clay-sandy soil texture, the study area falls within the tropical equatorial zone dominated by dry season (November-March) and rainy seasons (April-October). The inhabitants are predominantly fisherman, which is their basic source of livelihood.

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2.2 Sampling Stations and Duration

For the purpose of this study, ten (10) sampling stations were selected which include seven (7) hand-dug wells which are used for drinking and other domestic purposes and three (3) points along the Oproama River were sampled monthly for *Vibrio* spp., salinity, calcium, magnesium concentrations and saltwater intrusion status twelve (12) months to cover both dry and rainy seasons.

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2.3 Collection of Water Samples

Seven (7) clean plastic buckets were used to collect well water samples from each of the seven hand-dug wells in the community using ‘okowa’ (stick with hook) and transferred immediately into already labelled 2 litre plastic containers. River water samples were collected by wading to slightly above knee depth and plunging the neck of the already labelled clean and sterile 2 litre plastic containers downward to about 30 cm below the water surface and tilted slightly upward towards upstream to let it fill and a space of 1.5 cm left in each plastic container to facilitate mixing before carefully replacing the cap under water. Samples were collected in triplicate for microbiological, salinity and metal analysis. All the samples were then taken to the laboratory in a cold box for analysis within 2 hours.

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2.4 Microbiological Analysis

2.4.1 Isolation of *Vibrio* spp. in Water Samples

Membrane filtration technique was employed as described in 9260H (APHA, 1998). Ten milliliters (10 mL) of 10-1 dilution (from a ten-fold serial dilution) of each water sample was used. After the filtration, the filter (membrane filter of 0.45 µm, HAWG, Millipore Corporation, Bedford, USA) was then placed on Thiosulphate Citrate Bile Salts Sucrose (TCBS) Agar which was prepared according manufacturer’s instruction. All the plates in duplicates were incubated at 35 ^{o}C for 24 hours.

2.4.2 Purification and Storage of isolates

Discrete colonies were picked and subcultured onto Nutrient Agar plates using streak plate method. Stock cultures were prepared on sterile Nutrient Agar in Bijou bottles, coded for ease of identification and stored in the refrigerator (4 ^{o}C) until needed for further tests.

2.4.3 Characterisation and Identification of Bacterial Isolates.

The isolates were identification on the basis of their cultural, morphological and physiological characteristics in accordance with schemes and methods described by Cheesborough [19]. Microscopic examination of isolates was carried out using oil immersion objectives (x100). The following tests were carried out: Gram staining and Biochemical tests which were catalase, oxidase, coagulase, citrate utilisation, indole, methyl red, Voges Proskauer, Hydrogen Sulphide, Urease, motility, salt tolerance and sugar fermentation test.

2.5 Determination of Salinity

Salinity of the water samples was determined using a digital meter (consort p107). The probe end of the meter was dipped into the water sample while the value at the pointer was read off and recorded.

2.6 Metal Analysis

The water samples were analysed for the presence of magnesium and calcium using atomic absorption spectrophotometer (AAS) (HACH DR 2400). The method involves direct aspiration of the water sample into an air/acetylene or nitrous oxide/acetylene flame in the presence of energy at specific wavelength generated by hollow cathode lamp peculiar only to the metal under investigation. Prior to analysis, the AAS was calibrated with standards of known concentrations to obtain a calibration curve for the individual metal.

2.7 Statistical Analysis

The data obtained from this study were subjected to statistical analysis using two factors analysis of variance (ANOVA) and Pearson moment correlation.

3. RESULTS AND DISCUSSION

3.1 *Vibrio* sp. Counts

There were seasonal changes in *Vibrio* counts of the different sampling stations (wells and rivers) in Oproama Community (Figure 1). Generally, apparent seasonality was shown in *Vibrio* counts especially in well water sources (stations 1-7). Station 6 (well) and station 9 (river) recorded the highest value of $1.53x10^{1}$ cfu/mL (log_{10} 2.1846) and $8.99x10^{1}$ cfu/mL (log_{10} 1.9537) for wet season amongst the well and rivers samples respectively, while dry season values shows that station 6 (well) and station 8 (river) recorded the highest values of $1.66x10^{1}$ cfu/mL (log_{10} 1.2201) and $2.32x10^{2}$ cfu/mL (log_{10} 2.3654) for well and river samples respectively. With the analysis of variance (ANOVA), it was observed that there was significant difference in the counts obtained within stations and months (wet and dry seasons) over the monitoring period at $p<0.05$. The bacterial isolates identified from water samples include *Vibrio cholerae* and *Vibrio parahaemolyticus*.

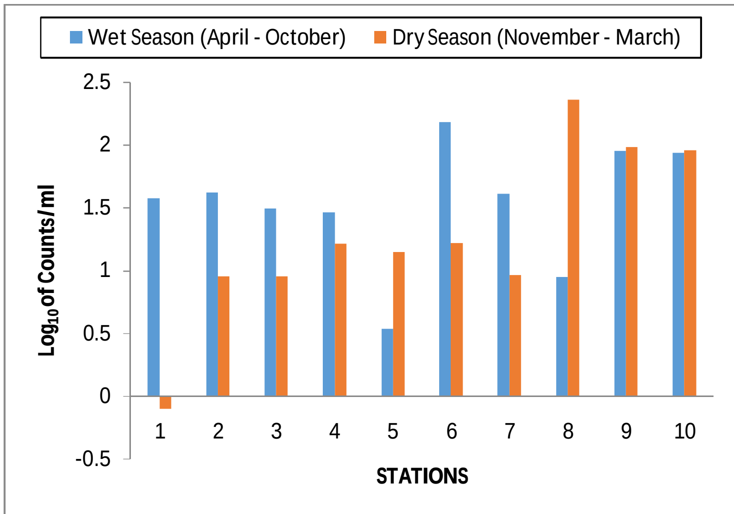

Figure 1 ***Vibrio*** **sp. Counts of Water Samples from Oproama Community covering the wet and dry seasons**

3.2 Salinity Concentration

The salinity of the water bodies during the sampling period are presented in Figure 2. Stations 8, 9 and 10 (river sources) exhibited the highest salinity levels both for the wet and dry seasons. Stations 1-7 which are well water sources were generally low compared to the river stations all through the seasons. During the wet season, the salinity of stations 1-7 ranges from 12.60-31.24 mg/L and 11.97-35.9 mg/L for the dry season. Generally, higher values were recorded in dry season than the rainy season especially with the stations 8, 9, and 10 which are river water. Statistically there was significant difference ($P<0.05$) observed in salinity values obtained for the stations, while there was no significant difference within the months (wet and dry seasons) during the study period.

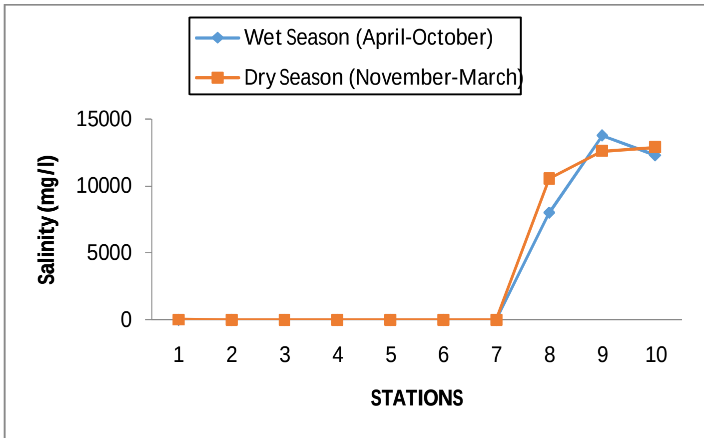

Figure 2 **Salinity of Water Samples from Oproama Community covering wet and dry season**

3.3 Calcium Concentration

The results of Magnesium concentrations of the water samples are presented in Figure 4. Magnesium concentration in stations 8, 9, and 10 showed higher values compared to that in other stations for both wet and dry seasons. Station 10 recorded the highest value of 43 ppm while stations 4 and 7 recorded the lowest value of 0.09 ppm for the wet season. During the dry season, station 8 recorded the highest value of 31.18 ppm while station 7 recorded the lowest value of 0.09 ppm. The values recorded for stations 1-7 for the dry season were generally higher than those recorded for wet season. However, for stations 8-10, higher values were recorded for wet season than dry season and there is apparent seasonal variation. With the analysis of variance (ANOVA), there was significant difference ($P<0.05$) in magnesium concentration for the stations and months (wet and dry seasons) during the study period.

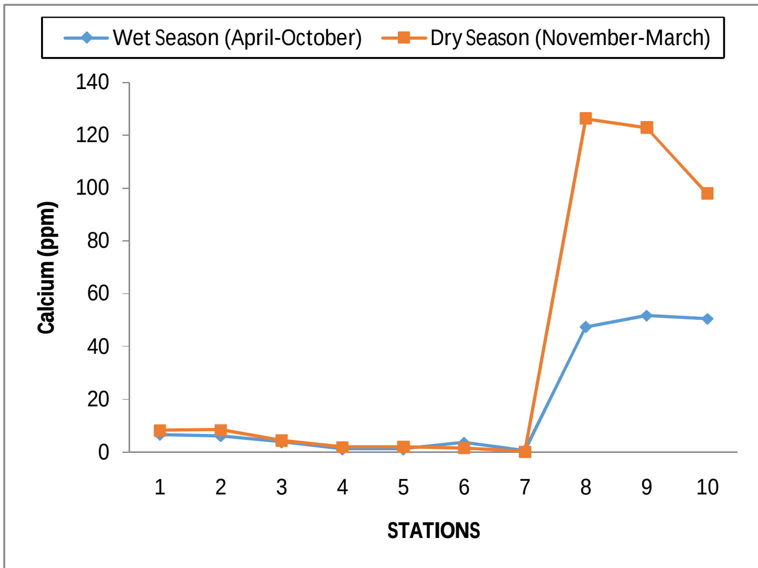

Figure 3 **Calcium Concentration of Water Samples from Oproama Community covering wet and dry seasons**

3.3 Magnesium Concentration

The results of Magnesium concentrations of the water samples are presented in Figure 4. Magnesium concentration in stations 8, 9, and 10 showed higher values compared to that in other stations for both wet and dry seasons. Station 10 recorded the highest value of 43 ppm while stations 4 and 7 recorded the lowest value of 0.09 ppm for the wet season. During the dry season, station 8 recorded the highest value of 31.18 ppm while station 7 recorded the lowest value of 0.09 ppm. The values recorded for stations 1-7 for the dry season were generally higher than those recorded for wet season. However, for stations 8-10, higher values were recorded for wet season than dry season and there is apparent seasonal variation. With the analysis of variance (ANOVA), there was significant difference ($P<0.05$) in magnesium concentration for the stations and months (wet and dry seasons) during the study period.

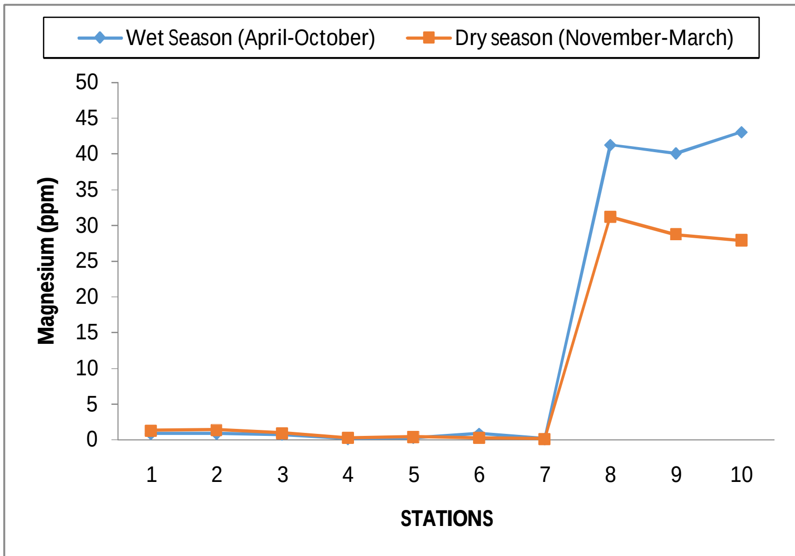

Figure 4 **Magnesium Concentration of Water Samples from Oproama Community covering wet and dry seasons**

3.4 Calcium/Magnesium Ratio for Well Water Samples

The Calcium/Magnesium ratio for well water samples (Stations 1, 2, 3, 4, 5, 6 and 7) indicating saltwater intrusion is presented in Table 1. The ratio obtained for all the stations revealed a range of 4.95-12.33 and 1.67-8.54 for wet and dry season, respectively. All the ratios obtained were above 1.

Table 1: Mean Seasonal Ratio of Calcium/Magnesium (Ca/Mg) for Well Water Samples

	Wet Season			Dry Season		
Station	**Ca**	**Mg**	**Ratio**	**Ca**	**Mg**	**Ratio**
1	6.56	0.82	8	8.26	1.25	6.55
2	6.05	0.82	7.37	8.4	1.35	6.26
3	3.78	0.68	5.55	4.31	0.89	4.84
4	1.11	0.09	12.33	1.88	0.22	8.54
5	1.09	0.22	4.95	1.97	0.40	4.93
6	3.53	0.86	4.10	1.57	0.24	6.54
7	0.54	0.09	6	0.15	0.09	1.67

Ravi and Krishna (1996) Standard Ratio: <1 indicates Salt water Intrusion

3.4 Discussion

In developing countries, majority of the population is not adequately supplied with drinking water from protected and managed water supply network and are forced to use unprotected water from wells, springs and streams that may be unsafe for domestic application as a result of contamination through natural and anthropogenic interferences [20].
The isolation of *Vibrio* sp. showed seasonal variation except at stations 8, 9 and 10 throughout the study period. The *Vibrio* sp. was found more frequently at higher concentrations in the well water samples (stations 1-7) during the wet season, which is in agreement with earlier studies [21, 22], however, were less than the $6.0x10^2$ cfu/ml reported by Osarenminda and Idaehor [23]. The overall reduction in *Vibrio* count during the dry seasons particularly in the month of November, December and January was noted at stations 1-7 (well water), this can be due to the fact that the organisms may enter the viable but nonculturable (VBNC) state, a survival strategy used to counter temperature stress [24]. However, their presence in drinking water has public health risk as the WHO [25] reported that, of the estimated 3-5 million cholera cases that occur globally every year, about 100,000 to 120,000 die.

Salinity concentration of the water samples was observed with apparent seasonality in occurrence as higher values were recorded during the dry season than the wet season. The result showed that for both seasons, the well water samples were within the acceptable limits of 250 mg/l [26]. It has been reported that the amount of a substance entering a water body depends on land or geology and rainfall and release of substances from underlying sediment into the water [27]. This may be responsible for salinity levels recorded in the drinking water wells (Station 1 – 7) in Oproama. However, very high salinity was recorded in both seasons for the river water samples (station 8-10). This is because they are seawater in origin. The lower values recorded during the wet season may be due to dilution. Similarly, [28] reported that rainfall could cause dilution of estuaries and hence cause reduction in salinity, while heat generated by sunlight in dry season months would cause evaporation of the surface water making it saltier and hence more saline. Akinrotim et al. [29] reported that the highest values (16.18-21.11%) were recorded during the dry months while sampling the Buguma Creek.

Metal ions such as Mg2+ and Ca2+ are naturally present in groundwater, and they appear at unusually high concentrations as a result of contamination by natural and anthropogenic inputs [30]. Calcium and Magnesium concentration exhibited the same trend in the water samples analysed. Generally, the dry season samples had higher values of these parameters for all the water samples. This probably may be due to decrease in well water level following extended period of sunshine which resulted in increased concentration of calcium level while the low concentrations during the wet season may be attributed to the dilution effect of rain water. The higher values observed in both wet and dry seasons were in the river samples (Stations 8, 9 and 10), while the lower values were observed in the well water samples (Stations 1, 2, 3, 4, 5, 6 and 7). However, samples from the wells (Stations 1, 2, and 3) closer to the river were higher than other well samples for both seasons. This might be as a result of their proximity to the river bank. Also [31] reported that calcium and magnesium salts which are generally highly soluble in water are leached from the terrestrial environment to ground and surface water. It is known that calcium and magnesium along with their carbonates sulphates and chlorides naturally confer temporary and permanent hardness. However, the concentrations of these parameters in the water samples analysed were found to be below the acceptable limit of 75-200mg/l for calcium and 30-150mg/l for magnesium recommended by [26] for drinking water as well as the 183.75 mg/l and 91.30 mg/l average values for calcium and magnesium reported by [32].

Studies of sea water intrusion in coastal aquifers have assumed greater importance in recent decades because of the increased demands placed on subsurface water to meet the growing needs of water in large urban areas and agricultural practices located in the coastal regions in the world [33]. For assessing saltwater intrusion into the Oproama aquifer, the ratio of calcium/magnesium (Ca^{2+}/Mg^{2+}) was used. Since magnesium is present in seawater in much greater concentration than calcium, Ca/Mg is recommended as a parameter for determining the saltwater contamination. A low Ca/Mg ratio may also be indicative of saltwater contamination [34]. If the ratio is less than 1, then the area is considered to be highly affected by saltwater intrusion. From the study, none of the Ca/Mg ratio of well (groundwater) water sample is indicative of saltwater intrusion which can be confirmed by the local dwellers. The result of the study is in agreement with [33].

4. CONCLUSION

The microbiological investigation reveals that *Vibrio cholera* and *Vibrio parahaemolyticus* were isolated from the water sources which could be potential pathogens and harmful to human health. Salinity, magnesium and calcium values of the samples, particularly the water samples from the wells were within the WHO or? recommended range for drinking water. However, the samples from the river were above the recommended levels for the parameters analysed during the study period. The calcium/magnesium ratios obtained from this study revealed that they are above 1. This suggests that there is no saltwater intrusion in the study areas. The study revealed an apparent seasonal influence on the microbiological and physicochemical parameters of the various water samples. Open defecation by humans (including use of jetty latrines) and animals, and dumping of waste close to these water-points should be discouraged. Proper drainage channels should be constructed around these water-points to keep away stagnant water that may contribute to the pollution of the wells. Also, the use of sanitary buckets and point-of-use (households use) treatment and safe storage practices of water should be advocated.

REFERENCES

1. Amira, AA, Yassir ME. Bacteriological quality of drinking water in Nyala, South Darfur, Sudan. Environ Monit Assess 2011;175:37-43.
2. Bove F, Shim Y, Zeitz P. Drinking Water contaminants and adverse pregnancy outcomes: A Review. Environ Health Perspectives. 2002;110(1):61-74.
3. Hogan CM. (2010). Water Pollution. Encyclopedia of Earth; National Council on Science and the Environment: Washington, DC, USA, 2010; Accessed: 12 March 2021. Available: http//www.oearth.org/article/Water_pollution.
4. World Health Organisation, WHO (2014). The United Nations International Children's Emergency Fund (UNICEF).Joint Monitoring Programme for Water Supply and Sanitation. In Progress on Drinking Water and Sanitation:2014 Update; UNICEF: New York, NY, USA.
5. Centre for Disease Control and Prevention (CDC). Laboratory Methods for the Diagnosis, Control and Prevention of *Vibrio cholerae*. http://www.cdc.gov/cholera/pdf/Laboratry-Method-for-the-diagnosis-of-vibrio-cholerae-chapter-6, pp 27-36. 1994.
6. Willey JM, Sherwood LM, Woolverton CJ. Prescott, Harley, and Klein Microbiology. Seventh Edition: McGraw Hill New York. pp40-983. 2008.
7. Mara D, Horan D. Handbook of Water and Wastewater Microbiology, First Edition. Academic Press. p832. 2003.

8. Semenza J, Robert L, Henderson AK, Bogan J, Rubin CH. Water Distribution System and Diarrheal Disease transmission: A case study in Uzbekistan. Am J Trop Med Hgy.1998;59(6): 941-946.
9. Federal Government of Nigeria (FGN). Annual report on water resources in Nigeria. A yearly publication of Federal Ministry of Water Resources. 2000.
10. Ashbolt NJ. Microbial contamination of drinking water and disease outcomes in developing region. Toxicol 2004;20:229 – 238.
11. Jain CK, Omkar, Sharma MK. Groundwater Quality Technical Report, C S (AR) 196. National Institute of Hydrology, Roorkee, 1995 – 1996. 1996.
12. Vodela JK, Renden JA, Lenz SD, Mchel Henney WH, Kemppainen BW. (1997). Drinking Water contaminants. Poult Sci 1997;76:1474-1492.
13. Marcorecchio JE, Botte SE, Frejie RH. Heavy metal, major metals, trace elements. In: Vollet LM, editor. Handbook of water analysis (Ed.). 2nd Edition. CRC Press, London. 2007.
14. Adepoju-Bello AA, Ojomolade OO, Ayoola GA, Coker HAB. Qualitative Analysis of some metals in domestic water obtained from Lagos Metropolis. The Nig J Pharm 2009;42(1):57-60.
15. Wikipedia. Saltwater Intrusion. Wikipedia, the free Encylopedia. 2009. Accessed 10 August 2019. Available: http://www.en.wikipedia.org/wiki/saltwaterintrusion.
16. Amadi AN, Nwankwoala HO, Olasehinde PI, Okoye NO, Okunlola IA, Alkali YB. (2012). Investigation of Aquifer Quality in Bonny Island, Eastern Niger Delta, Nigeria using Geophysical and Geochemical Techniques. J. Emerg. Trends Eng Appl Sci 2012;3(1):180-184.
17. Delleur JW. The Handbook of Groundwater Engineering. Second Edition. CRC Press. pp1320. 2006.
18. Frank-Briggs IN. The Hydrogeology of some Island Towns in the Eastern Niger Delta. A Ph.D Thesis, submitted to the University of Port Harcourt, Choba. pp238. 2003
19 Cheesbrough M. (2006). District Laboratory Practice in Tropical Countries. Second edition, Cambridge University Press, United Kingdom. pp 143-157. 2006.
20. Amanial H. Assessment of physicochemical quality of spring water in Arbaminch, Ethiopia. J Environ Anal Chem 2015;2:2380–2391. 1000157. https://doi: 10.4172/2380- 2391.1000157.
21. Feachem RG, Bradley DJ, Garelick H, Mara DD. Sanitation and Disease Health Aspects of excreta and waste water management. World Bank studies in water supply and sanitation, No. 3. John Wiley and Sons, New York. pp501. 1983.
22. Chowdhury MAR, Yamanaka H, Miyoshi S, Aziz KMS, Shinoda S. Ecology of *Vibrio mimicus* in Aquatic Environments. Appl Environ Microbiol 1989;55:2073-2078.
23. Osarenminda OO, Idaehor AG. Bacteriological and Physicochemical analyses of well water used for drinking in Ekpoma-Edo State, Nigeria. J Microbiol Exp 2019;7(6):280-284.
24. Oliver JD, Hite F, Mc Dougald D, Andon NL, Simpson LM. Entry into and resuscitation from, the viable but nonculturable state by *Vibrio vulnifi*cus in an estuarine environment. Appl Environ Microbiol 1995;61:2624-2630.
25. World Health Organisation and United Nations Children's Emergency Fund. Progress on Sanitation and Drinking Water; update. Joint Monitoring Programme for Water Supply and Sanitation. 2010.
26. World Health Organisation. *Guideliness for Drinking-water quality*. Volume 1 Recommendations. 3rd Ed. World Health Organisation, Geneva. 2004.
27. Brian M. Ecology of Freshwater. 1^{st} edition. Blackwell Scientific Publications, London. pp312. 1980.
28. Mclusky DS. The Estuarine Ecosystem. 2nd Ed. Chapman and Hall, New York. pp214. 1989.

29. Akinrotim OA, Abu OMG, Bekibele DO, Uedema-Naa B. Occurrence and Distribution of Grey Mullets *Liza falcippinis* and *Liza grandisquamis* from Buguma Creek, Niger Delta, Nigeria. Res J Biol Sci. 2011;5(1):1-5.
30. Barbieri M, Ricolfi L, Vitale S, Muteto PV, Nigro A, Sappa G. Assessment of groundnut quality in the buffer zone of Limpopo National Park, Gaza Province, Southern Mozambique. Environ Sci Pollut Res. 2019;26(1):62-77.
31. World Health Organisation. Guidelines for Drinking Water Quality (Vol. 2): Health Criteria and Other Supporting Information, Geneva, Switzerland. 1996.
32. Xu X, Wang Z, Wang S, Liu W, Su Q, Tong H. et al. Hydrochemical Characteristics and IrrigationSuitability Evaluation of Groundwater with Different Degrees of Seawater Intrusion. *Water*. 2020:12(3460):1-20.
33. Babu MM, Viswanadah GK, Rao SV. Assessment of Saltwater Intrusion Along Coastal Areas of Nellore District, A.P. Int J Sci Eng Res. 2013;4(7):173- 178.
34. Ravi PS, Krishna RG. Delineation of salt water contamination zones by Chemical Parameters in Parvada Aream, Vishakapattnam, AP. J Indian Water Res Soc. 1996;2:63–38.