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Assessment of Surface and Ground Water Quality in Ganaja, Lokoja, North-Central, Nigeria

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Abstract
The increasing rise in population, poor sanitation habits, massive flooding and lack of enforcement of environmental Sanitation laws in the study area have contributed immensely to the pollution of water sources. Thus, water samples were obtained from river Niger, hand-dug wells and a bore-hole in Ganaja, Lokoja, north-central, Nigeria for water quality analyses. The hydro-geochemical results showed that the pH values range from 6.70-7.70 indicating alkaline water type. The water hardness of the hand dug wells range from 7.46 - 241.09 with an average value of 110.30 indicating soft to moderately hard water. The hardness value range from 7.47 to 10.78mg/l in the river samples, 56.88 to 207.78mg/l in hand dug wells and 57.35mg/l in borehole sample respectively. The results show values are all above the World Health Organization (WHO) admissive limit and Nigeria Standard for Drinking Water Quality guideline for drinking water. The value of Mg ranges from 1.11 – 10.74mg/l in all the samples, this is above Nigeria Standard for drinking water. The values of the physico-chemical parameters such as the T^oC, Ec, BOD, COD, HCO_3, CO_3, SO_4 Cl, NO_3 Na, Ca, and the heavy metals including Pb, Cd, Cu, Fe, Mn, Ni and Zn as well as the concentration of TDS, Ca and K in all the other waters samples are within the allowable limits. TDS is linked to taste, hardness, corrosion properties and tendency for incrustation by water. Hard water can cause aesthetic problems including include alkali taste (making morning coffee taste bitter), formation of deposit on dishes, utensils, laundry basins, difficulty in getting soup and detergents to lather, formation of insulating precipitate on clothing, characteristic blue-green staining of sinks, household pipes choking, scaling, incrustations on kitchen utensils and increasing soap consumption. Hardness of water can create both nuisance and economic burden to individual and community. It is advisable that the water be treated against hardness, TDS, Ca, Mg and K before consumption or other domestic use. They should be regular routine monitoring by concerned authorities, as this, will ensure compliance and safety.
Keywords: Water quality, Hardness, pH, Hydrochemistry, Heavy Metal and Public Health

1. Introduction

This paper presents an assessment of water quality in Ganaja, Lokoja at the confluence of Niger and Benue Rivers (Fig. 1.). The inhabitant practice random waste disposal and the study area was subjected to unprecedented flooding episodes that occurred in (Sept. 2012 and October 2015) in parts of Nigeria from the overflowing of the Niger and Benue Rivers. This explain the reason for severity of the flooding with the attendant destructions witness in parts of Kogi State and Lokoja metropolis in particular, were thousands of properties were destroyed and hundreds of people displaced and surface and near surface environment submerged

During flood, bowels of septic tanks and the rivers containing all manner of dirt are and poured into the environment deteriorating the water resources and contaminating the environment. Metals for example, can introduced into aquatic system through several ways which include, weathering of rocks and leaching of soils, dissolution of aerosol particles from the atmosphere and from several human activities, including mining, processing and the use of metal based materials (Ipinmoroti and Oshodi,1993; Adeyeye, 1994; Asaolu et al., 1997). The increased use of metal-based fertilizer in agricultural revolution of the government could result in continued rise in concentration of metal pollutions in fresh water reservoir due to the water run-off. Metals entering the water may be taken up by fauna and flora and eventually, accumulated in marine organisms that are consumed by human being (Asaolu et al., 1997).

Indiscriminate faeces and excreter is very prevalent in survey area, particularly, in the stream and river channels as well as their tributaries and this is very worrisome. The overflow of septic tanks as witness in study area is also source of concerned as this will introduce faecal into the water resources. The faecal pollution of drinking water causes water –borne disease which has led to the death of millions of people both in cities and villages (Asaolu et al., 1997). Uncontrolled waste dumping into the discharge of these wastes may affect the aquatic of such river or adversely and alter the chemical composition of the river (Adewoye, 1998). The Water quality characteristic of any environment arise from a multitude of physical, chemical and biological interactions.

Polluted waters, irrespective of the pollutants, when consumed, may lead to variety of diseases, such as cholera, typhoid, dysentery, skin and mental disorders (Okolo, et al., 2009). The quality of groundwater resource depends on the management of human waste as well as the natural physio-chemical characteristics of the catchment areas (Efe et al, 2005).

The availability of good water is indispensable feature for preventing disease and improving the quality of life (Oluduro and Aderiye, 2007).The present study has assessed the water quality of hand dug wells, boreholes and river Niger in Ganaja, Lokoja, to ascertain their suitability for human consumptions as well as other domestic uses. This is very necessary because next to air, water constitutes the most essential resource to human existence. Water is needed not only for drinking, but also for cooking, washing and general sanitation. Man can survive longer without food than water.

2. Geology and Hydrogeology of the Study Area

The study area lies between latitude 7°45′N and 7°47′N and longitude 6°43′E and 6°45′E in Ganaja, Lokoja, north-central Nigeria (Fig. 1). Lokoja is located at the confluence of Niger and Benue Rivers and at the contacts between the Precambrian Basement Complex of Nigeria, the Campanian-Maastrichian sedimentary Bida Basin (Omada et al., 2009) and Lower Benue sedimentary inland basin (Benue Trough). The geology comprises of the Precambrian basement complex rocks which are mostly gneiss and migmatite with older granites intrusives. The mineral foliations defined by alternating biotite-rich and quartz-feldspar rich are common in the gneiss (Obaje, 2009). Major foliation and fracture trends are in the N-S and NNE, SSW directions markedly exhibited by the flow direction of the River Niger (Obaje, 2009).

The dominate lithological units in the study area include migmatite, older granite, gneiss (augen gneiss or porphyroblastic and biotite gneiss) intruded by the NE-SW trending pegmatite dykes and covered by the Cretaceous – Recent coarse-medium grained sands to the East forming the bank of River Niger (Fig.1).

Groundwater in the Lokoja area occurs in weathered and or weathered/fractured basement rocks and is recharged by precipitation and by river Niger (Omali, 2014). Two aquifer types have been delineated in the area: weathered layer aquifer and weathered/fractured aquifer (Musa et al., 2014). The Lokoja area is generally drained by rivers Niger, Benue and Meme. Aquifer parameter data of the study area are relatively sparse (Ibrahim, et al., 2014). Based on aquifer test data, the static water level varies between 1.5m and 7.6m; well depth is between 8.2m and 21.8m; and yield is between 70m^3/day and 130m^3/day (Ibrahim, et al., 2014)

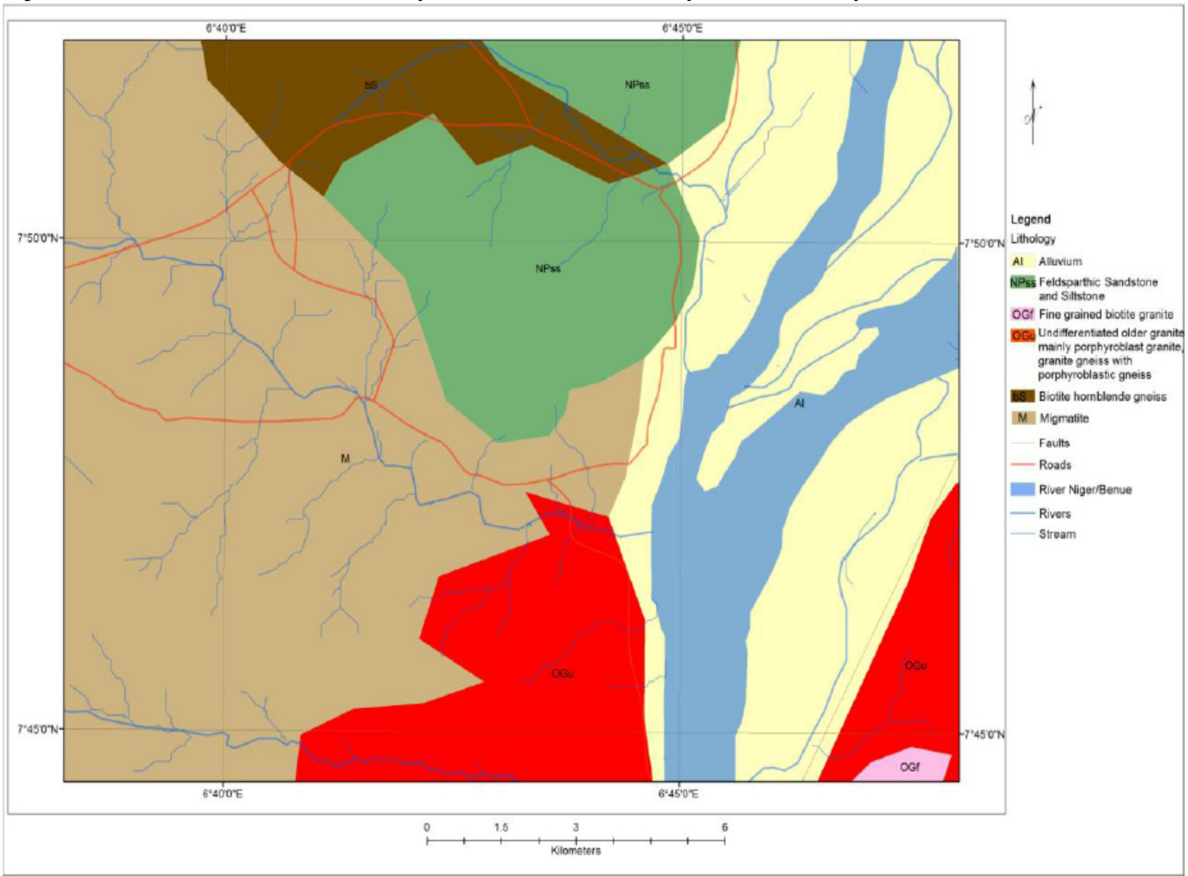

Fig. 1. Geological map of Lokoja and Environs (Source: Omali, 2014)

3. Materials and Methods

Water samples were collected from different sources as indicated in Table 1.0 (three from river Niger, eleven from hand dug wells, and one from a borehole) at different locations in Ganaja. The altitude and cordinates for each sampling point were recorded using a Garmin model 76S GPS. At each sampling location water sample were collected in 1 litre plastic bottles after thorough washing and rinsing with distilled water and the water to be sampled. The samples were preserved airtight in order to minimize oxygen contamination and the escape of dissolved gases. The cations were analyzed by Atomic Absorption Spectrophotometer (model 210 VGP while Anions where analyzed by Spectrophotometer (model Genesys 20), MOHR'S METHOD and the provisional method of Barnes et al, 1981 was used for carbonate and bicarbonate determination at the Geochemistry Laboratory of the Department of Geology of Federal University of Technology, Akure, Nigeria. The quality of the analysis is controlled through the analysis of samples of known compositions along with the unknown.

The analytical results of the hydrogeochemical analyses were compare with World Health Organization (WHO) admissive limit, Nigeria Standard for Drinking Water Quality guideline for drinking water as the water hardness classification of Gary (1994). Piper diagram is used to characterise the water types and their contaminants.

To be able to explain if sources of the contaminants are geogenic or anthropogenic. The anthropogenic factor (AF) is computed using the formula: Concentration of element analyzed/background value (Bn). Where AF > 1, anthropogenic enrichment is indicated; where AF < 1, there is no anthropogenic enrichment of contaminants. For the purpose of calculation of the anthropogenic factor (AF) the average concentration of background value for drinking water is taken from WHO (2011).

4. Result and Discussion

Table 1: The analytical result of the BOD, COD, physico-chemical and heavy metals (mg/l) in different water samples

Sample ID	Locality	Coordinates	pH	Ec (µs/cm)	TDS (mg/l)	Temp (0C)	Mg	Ca	K	Na	Fe	Cu	Zn	Cd	Pb	Mn	Ni	Cl	SO_4	NO_3	HCO_3	CO_3	BOD	Hardness	COD
BH-S1	Ganaja-Ajaokuta road	N7°44'35" 6°44'44"E	7.6	0.73	525	28.5	10.74	4.21	8.2	107.1	BDL	0.01	0.12	BDL	BDL	BDL	BDL	0.16	0.63	0.32	86.64	0.89	0.12	57.35	1.64
RN-S2	Ganaja-Ajaokuta road	N7°44'41" 6°44'47"E	7.5	0.05	47	28.8	1.21	2.17	3.3	18.25	0.02	0.02	1.45	0.02	0.01	0.01	0.02	8.8	12.2	1.87	13	1.66	5.97	10.78	19.74
RN-S3	Ganaja-Ajaokuta road	N7°44'33"6°44'47"E	7.5	0.05	44	29	1.11	1.09	3.5	14.28	0.02	0.02	1.4	0.02	0.01	0.01	0.02	2.68	2.49	0.97	12	0.31	0.19	7.6	20.54
RN-S4	Ganaja-Ajaokuta road	N7°44'28" 6°44'48"E	7.5	0.05	44	29	1.08	1.09	4.7	14.28	0.02	0.02	1.32	0.01	0.01	0.01	0.01	2.68	2.47	0.97	14	0.21	0.18	7.47	11.2
HW-S5	200 Housing Unit	N7°46'48" 6°43'53"E	6.7	0.22	166	29.1	5.46	20.11	5.7	36.28	0.02	0.01	1.01	0.01	BDL	0.01	BDL	0.32	5.09	0.94	73	0.28	0.2	74.98	0.97
HW-S6	200 Housing Unit	N7°46'49" 6°43'52"E	7.7	0.21	153	29.2	4.24	15.09	1.9	34.19	0.01	0.02	0.98	0.02	BDL	BDL	BDL	0.32	4.83	1.01	69	0.25	0.31	56.88	1.82
HW-S7	200 Housing Unit	N7°46'51" 6°43'19"E	7.2	0.34	250	29.3	7.26	31.05	6.3	52.52	0.01	0.02	0.54	0.02	BDL	BDL	0.01	0.21	3.64	0.43	94	0.28	0.51	110.69	1.02
HW-S8	500 housing Unit	N7°45'6' 6°44'29"E	7.1	0.47	337	29.3	5.53	51.5	7.2	55.39	0.01	BDL	0.41	0.01	0.01	BDL	BDL	0.21	4.99	0.36	102	0.65	0.74	155.33	2.13
HW-S9	Ganaja Village	N7°44'32" 6°44'36"E	6.9	0.6	429	29.3	8.61	79.89	8.6	85.69	BDL	0.01	0.66	0.01	0.01	0.01	BDL	0.2	3.64	0.28	183	0.69	0.13	241.09	2.42
HW-S10	Ganaja Village	N7°44'34" 6°44'18"E	7.1	0.49	354	29.3	4.67	52	13	48.8	0.02	BDL	1.24	BDL	0.01	BDL	0.01	0.18	5.16	0.37	98	0.63	0.76	152.87	2.26
HW-S11	Ganaja Village	N7°44'39" 6°4426""E	6.9	0.51	367	29.4	8.82	66.47	7.9	59.27	0.02	0.01	1.07	0.01	BDL	BDL	BDL	0.18	3.96	0.28	86	0.13	0.42	207.78	1.74
HW-S12	Ganaja Village	N7°44'40" 6°44'27"E	6.8	0.45	323	29.1	8.66	46.31	6.1	67.13	0.02	0.01	0.66	0.01	BDL	0.01	BDL	0.19	4.01	0.26	73	0.39	0.43	155.67	1.89
HW-S13	Ganaja Village	N7°44'41" 6°44'31"E	7	0.37	271	28.9	7.93	31.22	5.4	58.8	0.02	0.01	0.47	0.02	BDL	BDL	BDL	0.28	3.98	0.41	81	0.23	0.5	114.03	0.97
HW-S14	Ganaja Village	N7°44'39" 6°44'23"E	6.8	0.52	370	29.1	8.36	45.39	1.3	68.19	0.03	0.02	1.22	BDL	0.01	BDL	0.01	0.14	3.01	0.34	70	0.49	0.43	152.03	2.14
HW-S15	Ganaja Village	N7°44'31" 6°44"25'E	6.8	0.36	258	28.8	6.99	46.97	5.9	34.15	0.01	BDL	1.53	0.01	0.01	BDL	BDL	0.17	4.39	0.36	76	0.51	0.48	150.11	2.29

Table 2: Classification use for Water Hardness (Source: Gray, 1994)

Classification use for Water Hardness. **Degree of Hardness**	**Conc. (Mg/l)**
Soft	0-50
Moderately Soft	50-100
Slightly Hard	100-150
Moderately Hard	150-250
Hard	250-350
Excessively Hard	350+

Parameters	WHO (2011)	NSDWQ (2007)	Parameters	WHO (2011)	NSDWQ (2007)
pH	6.50-9.00	6.50-8.50	Cd	0.003-0.03	0.03
Ec (µs/cm)	250	1000	Mn	0.5	0.2
TDS (mg/l)	500.00-1000.00	500	Ni	0.01-0.02	N/A
Temp (°C)	29	Ambient	Cl	250	250
Mg	150	0.2	SO_4	50	50
Ca	75	N/A	NO_3	50.7	50.7
K	12	N/A	HCO_3	600	N/A
Na	200	200	CO_3		
Fe	0.3	0.3	BOD	NA	NA
Cu	2	1	Hardness	150	150
Zn	3	3	COD	NA	NA
Pb	0.4	0.01			

Source: NSDWQ (2007)

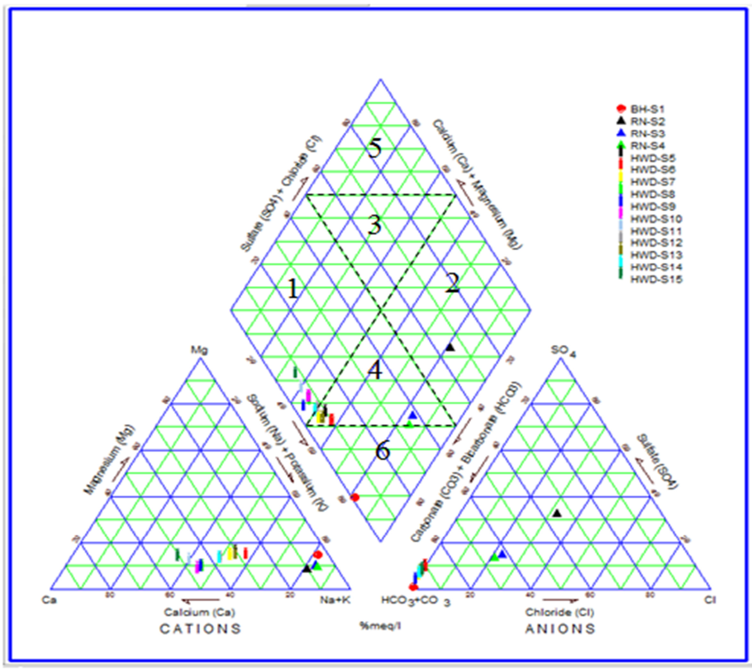

Fig 2: Piper Diagram for Surface and groundwater in the study area

The physico-chemical parameters obtained from analysis of water sample from the river, wells, and the borehole in Ganaja, Lokoja, Kogi State are presented in Table 1. The water hardness value of the hand dug wells rages from 7.47- 241.09 with an average value of 110. 30 indicating soft to moderately hard water (Fig). HW-S8, HW-S9, HW-SW10, HW-S11, HW-S12, HW-S14 and HW-S15 are above WHO (2011) and NSDWQ (2007) admissive limits. The hardness of water recorded in the borehole and the river water samples are all within acceptable limit. Negative association between water hardness and cardiovascular disease have been observe (Kahlown et al., 2006). Hard water can cause aesthetic problems. These problems include alkali taste (making morning coffee taste bitter), formation of deposit on dishes, utensils, laundry basins, difficulty in getting soup and detergents to lather, formation of insulating precipitate on clothing, characteristic blue-green staining of sinks, household pipes choking, scaling, incrustations on kitchen utensils and increasing soap consumption. Hardness of water can create both nuisance and economic burden to community (Kahlown et al., 2006)

In all water samples, the pH values range from 6.70-7.70 with an average value of 7.14 indicating that the water are alkaline. The Ec values rages from 0.21- 0.73 µs/cm with an average value of 0.36 µs/cm. The Temp (°C) values rages from 28.50 – 29.40 °C with an average value of 29.07°C and TDS values ranges of 4-525mg/l with an average value of 262.53mg/l. The results are all within the permissive limits of WHO (2011) and NSDWQ (2007) for drinking water with the exception of the borehole water sample (BH-S1) TDS of 525mg/l, that is above NSDWQ (2007) guideline of 500mg/l. TDS is linked to taste, hardness, corrosion properties and tendency for incrustation by water. TDS and EC are important in quality assessment of water due to their effect on the corrosivity of a water sample and their effect on the solubility of slightly soluble compounds such as CaCO3 (Nas, 2010). Electrical conductivity is an indirect measure of salinity in many areas, which generally affects the taste and thus has significance on the user acceptance of the water as potable (Langenegger, 1990).

The value of the BOD and COD ranges from 0.12 – 5.97mg/l with an average concentration of 0.75mg/l and 0.97 – 20.54mg/l with an average concentration of 4.85mg/l respectively.

The concentration of K in the water samples ranges from 1.3 – 13.0mg/l with an average value of 5.93mg/l and the AF value rages from 0.11 – 1.08mg/l. The value of K in sample (HW-S10) is above the WHO permissive level for drinking water; the AF value of 1.08mg/l indicate anthropogenic source of contamination. Potassium is a soft silvery alkaline metal that occurs naturally bound to other elements in sea water and mineral minerals. It is oxidize rapidly in water, very reactive in water and resemble sodium chemically. The potassium is very important body mineral significant for cellular and electrical functions. The total potassium in the body and blood serum varies between 4-5mg/100ml. Potassium deficiency causes irregular heartbeats, hypertension, muscle weakness, bladder weakness and asthma whereas overdose could lead to irregular/rapid heart beats, cystitis, bladder infections, ovarian, cysts and weakened immune system (ACU-Cell, 2003). An increase potassium in the blood is known as hyperkalemia appears as reduced renal functions, abnormal breakdown of protein and severe infections (Aparna, 2001).

The value of Ca ranges from 1.09 – 79.89mg/l with an average value of 32.97mg/l and the AF value ranges from 0.01 – 1.06 mg/l indicating that the value of Ca in (HW-S11) is above the WHO permissive level for drinking water. The AF value of 1.06mg/l indicate that the source of contamination is anthropogenic. Calcium react with water displacing hydrogen and forming Calcium hydroxide.

Mg concentration rages from 1.11 – 10.74mg/l with an average value of 6.05mg/l is within the permissive limits of WHO (2011) but above NSDWQ (2007) requirement for drinking water in the samples. The AF value ranges from 5.55 – 53.7 mg/l indicating anthropogenic sources of contamination.

The concentration of Na ranges from 14.28 – 107mg/l with an average value of 50.29mg/l. Na is soft, waxy, silvery reactive metal belonging to the akali metals that is abundant in natural compounds. It reacts violently water and oxidizes in air necessitating storage in an inert environment. Sodium are necessary for regulation of blood and body fluids transmission of nerve impulses, heart activity and certain metabolic functions. ACU-Cell (2003) indicated that deficiency of sodium in the body may appear as metal apathy. Low blood pressure, fatigue, depression, seizure, dehydration etc. Similarly, the excess presence as observe cause edema, hypertension, stroke, headaches, kidney damages, stomach problems and nausea.

The values of HCO_3 and CO_3 ranges from 12 – 183mg/l with an average concentration of 75.38mg/l and 0.13 – 1-66mg/l with an average concentration of 0.51mg/l respectively. On the average the concentration of Cl is 1.12, NO3 is 0.57mg/l while SO_4 is 4.30mg/l as well as the result of the heavy metal obtain for Pb, Cd, Cu, Fe, Mn, Ni and Zn on the average are within the allowable limit for drinking water. The result of the AF value for the each trace element is <1 indicating geogenic source.

4.1 Hydrogeochemical Facies

Characterization of surface and groundwater resource of the study area are presented by plotting them on a Piper-tri-linear diagram (Fig. 2). The diagram reveals the analogies, dissimilarities and different types of waters in the study area. HW-S9, HW-S10, HW-S11, HW-S12, HW-S14 and HW-S15 are Ca-HCO3 water type (Temporary Hardness), RN-S3, RN-S4, HW-S5, HW-S6, HW-S7, HW-S8 and HW-S13 are Ca-Na-HCO3 type (Alkaline earth and Alkali metal water type), RN-S2 is Na-Cl type (Saline) and BH-S1 is NaHCO3 type (Alkali Carbonate water type) (Fig. 2).

5. Conclusion

The water is alkaline with high concentration of Ca in HW-S11; K in HW-S10 and high TDS value in BH-S1. The average hardness of all the water samples indicate that water is soft to moderately hard water. The concentration of Mg in all the samples are above the acceptable limit of NSDWQ (2007). The value of T^oC, Ec, BOD, COD, HCO_3, CO_3, SO_4 Cl, NO_3 Na, Ca, and the heavy metals including Pb, Cd, Cu, Fe, Mn, Ni and Zn are within the allowable limits of WHO 2011 and NSDWQ (2007). Potassium is a soft silvery alkaline metal that occurs naturally bound to other elements in sea water and mineral minerals. It is oxidize rapidly in water, very reactive in water and resemble sodium chemically. The potassium is very important body mineral significant for cellular and electrical functions. The total potassium in the body and blood serum varies between 4-5mg/100ml. Potassium deficiency causes irregular heartbeats, hypertension, muscle weakness, bladder weakness and asthma whereas overdose could lead to irregular/rapid heart beats, cystitis, bladder infections, ovarian, cysts and weakened immune system (ACU-Cell, 2003). An increase potassium in the blood is known as hyperkalemia appears as reduced renal functions, abnormal breakdown of protein and severe infections (Aparna, 2001). TDS is linked to taste, hardness, corrosion properties and tendency for incrustation by water. Negative association between water hardness and cardiovascular disease have been observe (Kahlown et al., 2006). Hard water can cause aesthetic problems. These problems include alkali taste (making morning coffee taste bitter), formation of deposit on dishes, utensils, laundry basins, difficulty in getting soup and detergents to lather, formation of insulating precipitate on clothing, characteristic blue-green staining of sinks, household pipes choking, scaling, incrustations on kitchen utensils and increasing soap consumption. Contaminated water creates both nuisance and economic burden to individual and the community. Availability of good water is indispensable feature for preventing disease and improving the quality of life. The water should be properly treated before consumption as well as other uses because consuming contaminated water will ultimately affect human health.

6. Recommendation

They should be bacteriological analysis to ascertain the level of pollution of both surface and groundwater as this cannot be detected through their physical and chemical analysis.

There is need to regularly conduct water quality tests and verification, sanitary inspections for enforcement of environmental sanitation laws to ensure safe environment and healthy living.

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References

ACU-Cell, (2003). Bismuth and lithium http://www.ace-cell.com/bili.html

Adewoye RA, 1998. Saving and Oceans; Opportunity for Nigeria Chemist: Plenary Address at the 21st Annual Int. Conf. Chemical Society Nig. at Conf. Centre, Univ. Ibadan p. 12

Aparna, (2001). Iron in diet information. Department of community medicine, University of Connecticut School of Medicine, Farmington, CT. *http://www.1uphealth/health/iron_in_diet_sideeffects.html*

Asaolu, S. S., Ipinmoroti. K. O., Adeyinowo. C. E., Olaofe. O. (1997). Interrelationship of heavy metals concentration in water, sediment as fish samples from Ondo State coastal Area, Nig. Afr. J.Sci, 1: 55-61

Efe, S. I., Ogban, F. E., Horsfall, M., & Akporhonor, E. E. (2005). Seasonal variation of Physico-chemical characteristics of water resources quality in western Niger Delta region, Nigeria. Journal of Applied Science and Environmental Management, 191-195.

Gray N.F. (1994). Drinking Water Quality Problems and Solutions. John Wiley and Sons: London, UK. 43-63.

Ibrahim, Y., El-Ladan, and Maiwada N.A. (2014). An Assessment of some Water Quality Properties of Groundwater in Dutsin-Ma Metropolis, Nigeria. International Journal of Current Microbiology and Applied Sciences, 3 (5), 644-649.

Ipinmoroti, K and Shodi, O.O. (1993). Determination of Trace Metals in fish, associated Water and Soil sediments of fresh fish ponds. Disc Innov, 5:138-143.

Langenegger, O. (1990) Ground water quality in rural areas of western Africa, UNDP project INT/81/026:10.

Jones, H.A., Hockey, R. D. (1964). The Geology of part of south western Nigeria. Geol Survey Bull 31:2

Kahlown, M. A., Ashraf, M., Hussain, M., Salem, A.B., and Bhatti, A.Z. (2006). Impact Assessment of Sewerage and Industrial Effluent on Water Resources, Soils, Crops and Human Health in Faisalabad. Pakistan Council of Research in Water Resources (PCRWR), Khyaban-e-johar, H-8/1, Pakistan. Retrieved from htt://www.pcrwr.gov.pk

Musa, O.K., Kudamnya, E.A., Omali A.O., and Akuh T.I. (2014). Physico-chemical Characteristics of Surface and Groundwater in Obajana and its Environs in Kogi State, Central Nigeria. African Journal of Environmental Science and Technology, 8 (9) 521-531.

Nas, B. and Berktay, A. (2010). Groundwater quality mapping in urban groundwater using GIS, Environ.moni. Assessment.160:215–227.

Nigerian Standard for Drinking Water Quality (2007). Approved by Standards Organization of Nigeria: Nigerian Industrial Standard NIS 554: 2007.

Obaje, N.G. (2009). Geology and Mineral Resources of Nigeria. Springer Dordrecht Hudelberg London New York, 221 pp. http://dx.doi.org/10.1007/978-3-540-92685-9

Kolo, B., Dibal, J.M., Ndakawa, I. I. (2009). Elemental Analysis of Tap and Borehole Waters in Maiduguri. Semi-Arid Region, Nigeria. European Journal of Applied Sciences I (2): 26- 29.

Oluduro. A. O., Adewoye. B. I. (2007). Efficiency of moringa Oleifera Seed extract on the micro flora of surface and ground water J. plant Sci. 6: 453-438

Omada, J.I., Omali, A.O. and Awodi, J.O. (2009). Physio – Chemical Characteristics of Surface Water in parts of Lokoja Metropolis, central Nigeria. Journal of the Nigerian Association of Hydgrogeologists (NAH), 19, 56 – 62

Omali, A.O. (2014) Hydrogeophysical Investigation for Groundwater in Lokoja Metropolis, Kogi State, Central Nigeria. Journal of Geography and Geology; 6 (1) 81.

WHO, 2011. World Health Organization's Drinking Water Standard. www.WHO.int/water...health/in/2011

WHO, 2006. World Health Organization's Drinking Water Standard. *www.lenntech.com*