Journal of Basic Physical Research ISSN: 2141-8403 Prints, 2141-8411 Online
Vol.8, No.2 pp. 117- 134, January, 2018. Available online at www.jbasicphyres-unizik.org

SEASONAL VARIATIONS IN THE PHYSICO-CHEMICAL AND MICROBIAL CHARACTERIZATION OF GROUNDWATER IN LOKOJA NORTH CENTRAL NIGERIA

[1]A. O. Omali, [2]B.C.E. Egboka and [1]A. O. Usman
[1]*Department of Earth Sciences, Kogi State University, Anyigba, Nigeria.*
. [2]*Department of Geological Sciences, Nnamdi Azikiwe University, Awka*

Abstract
Physico-chemical and bacteriological characteristics of groundwater in relation to seasonal changes, was carried out *around Lokoja Metropolis with a view of determining its potability. Sixty (60) groundwater samples were collected from both boreholes and hand dug wells. Thirty (30) samples were collected during the rainy season while the remaining thirty (30) samples were collected during the dry season. The pH, Total Dissolved Solid (TDS), Electrical Conductivity (EC) and Dissolved Oxygen (DO) were determined using Hanna HI9813 GROCHEK model. The turbidity of the water samples were investigated with Hach Dr/2000 spectrophotometer. Atomic absorption Spectrophotometer, model 210 VGP was used in analysis of the cation. Results of the geochemical analysis obtained during the wet and dry seasons for physical, chemical and biological analyses reveals that groundwater of the study area is soft to very hard during the wet season and soft during the dry season. On the basis of TDS, groundwater in the area is moderately fresh. The mean concentrations of ions* Cu^{2+}, Zn^{2+}, Mn^{2+}, Fe^{2+}, Pb^{2+}, Cd^{2+},Cr^{4+}, Mg^{2+}, Ca^{2+}, Na^{+}, Cl^{-}, SO_4^{2-}, NO_3^{-}, HCO_3^{-} *are within the World health Organization (WHO) and the Standards Organization of Nigeria (SON) maximum permissible levels for human consumption in both seasons. The biological analysis showed a rise in the number of coliform counts during the rainy season compared with the dry season. Coliform counts in the study area are more in the hand-dug wells than in boreholes. The Piper Trilinear Diagrams constructed indicated Calcium–Magnesium–Bicarbonate, Sodium-Sulphate-Chloride and Calcium-Magnesium-Sulphate-Chloride water types during the wet season and Calcium-Magnesium-Bicarbonate water type during the dry season. The mean concentrations of major cations are of the order* $Ca^{2+}>K^{+}>Na^{+}>Mg^{2+}$ *while the anions are of the order* $HCO_3^{-} > Cl^{-} > SO_4^{2-} > NO_3^{-}$ *during the rainy season. During the dry season cation concentrations are of the order* $Ca^{2+} > K^{+}>Na^{+}>Mg^{2+}$ *and the anions are of the order* $HCO_3^{-}>SO_4^{2-}>Cl^{-} >NO_3$. *The physico-chemical, bacterial and water types are susceptible to seasonal variation. A pre-use treatment for the water is recommended before human consumption.*

Keywords: ***Groundwater, geochemical analysis, piper diagram, water-type, Ionic concentration***

Introduction
The area is located between latitudes 7^0 44' 33"N and 7^0 52'N and longitudes 6^0 38' 6"E and 6^0 48'E (Fig.1). It lies on part of the Basement Complex of Southwestern Nigeria and the Lokoja sub-basin of the middle Niger sedimentary basin, on an area coverage of about 400km^2 [16]. The major settlements in the area include Lokoja, Adankolo, Lokongoma, Kabawa, Ganaja, Zangodaji, Sarkin Noma and Felele. Lokoja, is a city at the confluence of rivers Benue and Niger. The study area falls within two geological domains, namely, the Basement Complex of Southwestern Nigeria and the Lokoja sub-basin of the Mid- Niger Basin.

The unique geology and field relationships, especially the contact between the Basement and the sedimentary rocks make the area a prolific hydrogeological province. However, inadequacy in residential water supply prevails despite its location at the confluence of the Rivers Niger and Benue.

In assessing the quality of potable water, analyses including microbial contamination, heavy metals and substances that are carcinogenic should be considered [6]. However, to ensure regular supply of safe water for public use, routine chemical analysis is recommended periodically to detect if there is any deterioration in the water quality especially in the urban areas prone to industrial pollution [17]. [9] suggested that a legislation be provided for quarterly biological and

physico-chemical examination of borehole water. It is against this background that this study becomes necessary.

Again, the growth in human population has not been complemented with growth in the potable water supply schemes. For instance, the Kogi State Government has been maintaining the water supply scheme introduced during the colonial days (which was enough to take care of the needs of the then smaller population) [15]. The subsequent governments have not built new and larger water supply scheme to take care of the increasing populations over years. Accessibility of the inhabitants of Lokoja to clean water has, therefore, become a problem. However, today, there are several boreholes scattered throughout the metropolis however, these boreholes are not properly built and maintained. This work focuses on the investigation of the physicochemical and bacteriological characteristics of groundwater in the area, to determine its potability with respect to seasonal changes.

Geology of the study area

The study area is dominantly underlain by the Precambrian Basement Complex. However, part of the area is underlain by Cretaceous sediments which unconformably overlie the Basement Complex.

Migmatite covers about half of the study area outcropping at the southwest, west, northwest and central parts of the area. The South and the southeast parts of the area are underlain by undifferentiated older granite, mainly porphyroblastic granite, granite gneiss with porphyroblastic gneiss and fine grained biotite granite. The northern part of the area is made of ridges (Mount Patti) of Cretaceous sediments of the Southern Bida Basin (Lokoja Sub Basin). The ridges are dominantly composed of feldspathic sandstone and siltstone which are separated by the biotite hornblende gneiss. Thick alluvial deposit occurs around the Rivers Niger and Benue drainage system [16].

The groundwater availability in crystalline rocks in the area is greatly dependent on the degree of weathering and fracturing of the rocks and the interconnectivity of the fractures. The area is generally drained by Rivers Niger, Benue and River Mimi, a tributary of River Niger. The mean annual humidity is about 70% [4]. Aquifers found in this area are recharged directly by precipitation but can also be recharged by infiltration from Rivers Niger, Benue and Mimi. Aquifers found within the study area include the fractured basement aquifer and the weathered overburden aquifer. Groundwater abstraction is mainly by hand dug wells, boreholes and from springs.

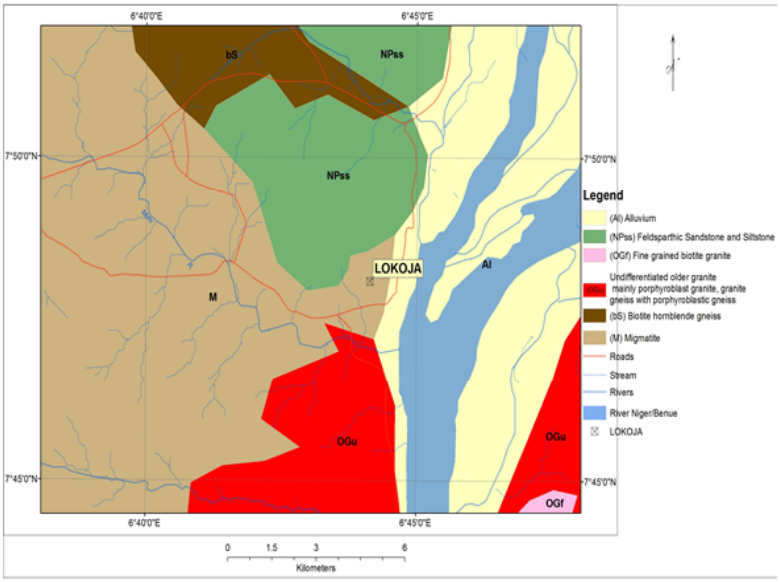

Fig. 1: Geologic Map of the study area

Materials and Methods

A total of sixty (60) representative groundwater samples were collected in 200ml polyethylene plastic bottle. The samples were from boreholes and hand dug wells. Thirty (30) samples were collected during the rainy season while the remaining thirty (30) samples were collected during the dry season. These were to investigate the physicochemical properties of the groundwater in relation to seasonal changes. The pH, Total Dissolved Solid (TDS), Electrical Conductivity (EC) and Dissolved Oxygen (DO) were determined using Hanna HI9813 GROCHEK model. The pH meter used was recalibrated using buffers 4 and 7 to ensure validity of the pH values of the water samples. Readings were taken and recorded one after the other. The stainless sensor was rinsed with distilled water after each reading.

The TDS in mg/l were recorded after recalibration was done. Electrical conductivity was determined after calibration of the probe was done and readings were taken at micro – sec per centimeter. Temperature was determined with thermometer at the points of sample collection. The Dissolved oxygen, (DO) was determined by electrometric method using oxygen detecting electrode for probing. Salinity was determined by using an oceanographic salinity measuring bridge model MC5 equipped with a platinized electrode.

The turbidity of the water samples were investigated with Hach Dr/2000 spectrophotometer. The following elements; Cu^{2+}, Zn^{2+}, Mn^{2+}, Fe^{2+}, Pb^{2+}, Cd^{2+}, Cr^{4+}, Mg^{2+}, Ca^{2+}, Na^{+} and K^{+} were determined using Atomic absorption Spectrophotometer, model 210 VGP.

Nitrate (NO_3^-) and Sulphate (SO_4^{2-}) ions were determined using spectrophotometer Model Genesys 20. Other anions such as chloride (Cl^-) and bicarbonate (HCO_3^-) were determined by wet chemistry, colorimetry. Chloride (Cl^-) was determined by the argentometry titrimetric method, employing standard silver nitrate solution. 50ml of water samples were titrated with standard $AgNO_3$ solution using KCr_2O_7 indicator. The mixture was titrated until it changed from yellow to brown. Bicarbonate was determined by titrimetric analytical method employing standard HCl using phenolphthalein and bromocressol green indicator.

Bacteriological Analysis

200ml water sample, sterols bottles, conical flask, petridishes, cotton wool, foil paper, methlylated spirit, labeling tape, filter paper, Durham tubes, test tubes, wire loop, Lavryl Tryptose Broth, Brilliant Green Bile Broth, Eosin Methylane Blue Agar, Measuring Cylinder, Pipette, Syringe &

Needle, distilled water, detergents, disinfectants and spatula were used for the bacteriological analyses of water samples collected during the wet and the dry seasons. 200ml double strength and single strength Lavryl Tryptose Broth was prepared. 10ml each was transformed into 5 test tubes for double strength while 5ml each of single strength was distributed into 10 test tubes. Durham tubes were inserted and autoclaved at 121^0C for 15 minutes. The tubes were allowed to cool to between 47^0C – 45^0C. 10ml water sample was transferred aesthetically into 5 tubes containing double strength medium while 1ml and 0.1ml were transferred into 5 tubes each containing single strength medium and autoclaved at 37^0C for 24 – 48 hours. After the incubation period, all the positive tubes were inoculated into a freshly prepared Brilliant Green Bile Broth for confirmatory test after 48 hours. The positive tubes were inoculated by stricken method into a freshly prepared Eosin Methylene Blue Agar for complete test.

Results and Discussion

Physical, chemical and biological analyses are required in assessing the quality of groundwater. Several factors control the chemistry and quality of groundwater. These factors include the origin of water, the nature of soil and rocks in which it is flowing, the nature and duration of contact with the bedrock or soil and anthropogenic activities. The chemical character of the water is also modified by ion exchange reaction during percolation of water and other anthropogenic influence [1] and [9].

Classification of Groundwater (Hydrochemical Facies)

The hydrochemical facies in the study area vary slightly in both rainy and dry season. On the basis of chemical characteristics, anionic and cationic concentrations, the groundwater in the study area is classified using piper trilinear diagrams Figures 2 and 3. The Piper trilinear diagram indicates similarities and differences between groundwater samples. Those with similar qualities plot together as a group. This was done in work of [13] and [7].

From figure 2 and Table 4, the groundwater sampled in the study area during the rainy season is classified as follows;

i.) Calcium – Magnesium - Bicarbonate (Ca^{2+} –Mg^{2+}- HCO_3^-) water type. This represents recently recharged water of meteoric origin that resulted from the dissolution of aluminosilicates.

ii.) Sodium – Sulphate – Chloride (Na^{2+} –SO_4^{2-} - Cl^-). This is fossil water whose origin is natural and anthropogenic.

iii.) Calcium – Magnesium – Sulphate – Chloride (Ca^{2+} – Mg^{2+} – SO_4^{2-}- Cl^-) water type. This is water of intermediate composition that evolved by simple hydrochemical mixing and reverse cation exchange.

iv.) In figure 3 and Table 5, during the dry season, the groundwater is classified as;

v.) Calcium – Magnesium - Bicarbonate (Ca^{2+} – Mg^{2+} -HCO_3^-) water type

Table 1: Summary of physical parameters of Groundwater in Lokoja Area during the Rainy Season

S/N	Sample location	TCH (mg/l)	PH	TDS (mg/l)	EC (μs/cm)	Salinity (mg/l)	Turbidity (mg/l)	Temp. ^{0}C	GPS READING	
									LATITUDE	LONGITUDE
1	Ganaja Village	413	8.7	1215	1869	0.05	49.00	32.10	N 07^0 44' 33"	E 006^0 44' 33"
2	500 Unit	400	8.7	1175	1807	0.08	38.00	33.00	N 07^0 44' 56.6"	E 006^0 44' 24.7"
3	500 Unit	400	8.7	1174	1806	0.07	38.00	33.00	N 07^0 45' 24.7"	E 006^0 44' 24.7"
4	200 Unit	376	8.8	951	1463	0.09	26.00	33.40	N 07^0 45' 33.1"	E 006^0 44' 21.1"
5	200 Unit	120	8.8	915	1407	0.05	38.00	33.00	N 07^0 45' 48"	E 006^0 44' 15.5"
6	Phase I	306	8.8	1104	1698	0.11	56.80	31.80	N 07^0 47' 24.7"	E 006^0 43' 22.3"
7	Phase I	306	8.7	1105	1700	0.11	57.00	31.10	N 07^0 47' 29.3"	E 006^0 43' 33"
8	Phase II	244	8.9	803	1235	0.07	27.00	33.80	N 07^0 48' 4.7"	E 006^0 41' 55.2"
9	Phase II	620	8.4	708	1089	0.06	34.00	34.00	N 07^0 47' 44.3"	E 006^0 42' 18.6"
10	Otokiti Estate	332	8.0	690	1061	0.04	11.20	34.00	N 07^0 48' 18.5"	E 006^0 41' 7"
11	Army Baracks	180	8.3	1217	1872	0.18	42.00	34.10	N 07^0 48' 9.4"	E 006^0 40' 34.5"
12	Roja Table Water	612	8.3	744	1144	0.04	14.50	34.10	N 07^0 48'32.6"	E 006^0 38'41.3"
13	Zangodaji	180	8.2	772	1187	0.10	15.00	33.90	N 07^0 48' 40.6"	E 006^0 38' 26.1"
14	Adankolo	288	8.9	1537	2364	0.15	9.00	34.10	N 07^0 47' 15.6"	E 006^0 44' 16"
15	Adankolo	300	9.0	2000	3076	0.24	121.00	34.00	N 07^0 47'23.5"	E 006^0 44' 28.6"
16	Adankolo	298	8.9	2000	3076	0.16	8.00	34.00	N 07^0 47' 21.6"	E 006^0 44' 17.5"
17	Adankolo	298	8.9	2000	3076	0.16	8.00	34.00	N 07^0 47' 33.9"	E 006^0 44' 29.9"
18	Marine Road	189	8.0	1015	1561	0.21	8.00	30.80	N 07^0 48' 7.1"	E 006^0 44' 54.4"
19	Kasuwa Hotel	384	8.6	1625	2500	0.16	56.00	30.00	N 07^0 47' 50"	E 006^0 43' 55.9"
20	Kenwo Hotel	136	8.1	791	1216	0.09	13.40	32.10	N 07^0 48' 28.9"	E 006^0 44' 55.5"
21	GRA	24	7.9	115	176	0.04	19.00	31.00	N 07^0 48' 24.5"	E 006^0 43' 44.5"
22	New Layout	124	8.7	574	883	0.06	15.00	30.80	N 07^0 48' 37.8"	E 006^0 44' 12.7"
23	New Layout	124	8.7	574	883	0.06	15.00	32.00	N 07^0 48' 37.2"	E 006^0 44' 32.8"
24	Megiri	124	8.6	2000	3076	0.33	102.70	32.00	N 07^0 48' 45.1"	E 006^0 44' 42.1"
25	Kabawa	160	9.0	1796	2763	0.22	19.00	30.00	N 07^0 49' 8.5"	E 006^0 44' 54.7"
26	Sarkin Noma	300	8.9	1459	2244	0.14	30.00	32.20	N 07^0 50' 31.3"	E 006^0 44' 50"
27	Felele	196	8.4	925	1423	0.28	47.00	31.10	N 07^0 51' 6.2"	E 006^0 43' 31.7"
28	Felele	76	8.5	1040	1600	0.18	13.00	32.00	N 07^0 51' 15.8"	E 006^0 43' 21.8"
29	Felele	77	8.4	1040	1600	0.28	47.00	32.00	N 07^0 51' 6.6"	E 006^0 43'24.5"
30	Behind Secretariat	92	8.6	236	362	0.04	9.50	32.10	N 07^0 48' 37.3"	E 006^0 42' 1.5"
	Mean	255.97	8.5	1110	1707	0.01	32.90	32.50		
	W.H.O	-	6.5-8.5	1500	250	-	-	-		
	SON	-	6.5-8.5	500	1000	-	-	Ambient		

Table 2: Summary of physical parameters Of Groundwater in Lokoja Area during the dry season

S/N	Sample Location	TCH (mg/l)	pH	TDS (mg/l)	EC	Salinity (mg/l)	Turbidity (mg/l)	Temp. ^{0}C	LATITUDE	LONGITUDE
1	Ganaja	11.9	7.7	1250	1923	0.1	13	30	N 07^0 44' 33"	E 006^0 44' 33"
2	500 Unit	11.76	8.1	1200	1846	0.1	12	31	N 07^0 44' 56.6"	E 006^0 44' 24.7"
3	500 Unit	11.77	8.1	1200	1846	0.1	13	31	N 07^0 45' 24.7"	E 006^0 44' 24.7"
4	200 Unit	14.56	7.7	1010	1553	0.06	13	31	N 07^0 45' 33.1"	E 006^0 44' 21.1"
5	200 Unit	14.57	8.2	1012	1556	0.06	13	30	N 07^0 45' 48"	E 006^0 44' 15.5"
6	Phase I	3.92	8	876	1347	0.1	36	30	N 07^0 47' 24.7"	E 006^0 43' 22.3"
7	Phase I	5.04	8	1001	1540	0.13	22	30	N 07^0 47' 29.3"	E 006^0 43' 33"
8	Phase II	8.44	7.8	800	1230	0.08	27	31	N 07^0 48' 4.7"	E 006^0 41' 55.2"
9	Phase II	8.96	7.5	738	1135	0.04	19	32	N 07^0 47' 44.3"	E 006^0 42' 18.6"
10	Otokiti	1.6	7.5	794	1221	0.03	5	32	N 07^0 48' 18.5"	E 006^0 41' 7"
11	Army	6.72	7.9	1232	1895	0.16	38	32	N 07^0 48' 9.4"	E 006^0 40' 34.5"
12	Roja	6	8	640	984	0.12	16	31	N 07^0 48'32.6"	E 006^0 38'41.3"
13	Zangodaji	6.16	7.5	641	986	0.12	16	30	N 07^0 48' 40.6"	E 006^0 38' 26.1"
14	Adankolo	10.64	8	1690	2600	0.19	10.5	32	N 07^0 47' 15.6"	E 006^0 44' 16"
15	Adankolo	6.72	7.8	1788	2750	0.31	95	32	N 07^0 47'23.5"	E 006^0 44' 28.6"
16	Adankolo	10.62	7.9	1786	2747	0.19	93	31	N 07^0 47' 21.6"	E 006^0 44' 17.5"
17	Adankolo	10.64	7.9	1788	2750	0.19	10.3	32	N 07^0 47' 33.9"	E 006^0 44' 29.9"
18	Marine	6.72	7.4	865	1330	0.13	4	30	N 07^0 48' 7.1"	E 006^0 44' 54.4"
19	Kasuwa	12.88	8.1	1520	2338	0.11	44	30	N 07^0 47' 50"	E 006^0 43' 55.9"
20	Kenwo	6.16	7.7	617	949	0.11	11	29	N 07^0 48' 28.9"	E 006^0 44' 55.5"
21	GRA	6.16	6.6	94	144	0.03	15	29	N 07^0 48' 24.5"	E 006^0 43' 44.5"
22	New	3.92	7.6	418	643	0.06	15	29.9	N 07^0 48' 37.8"	E 006^0 44' 12.7"
23	New Layout	8.85	7.6	400	615	0.31	65	30	N 07^0 48' 37.2"	E 006^0 44' 32.8"
24	Megiri	8.86	8.4	1824	2806	0.35	65	29	N 07^0 48' 45.1"	E 006^0 44' 42.1"
25	Kabawa	5.04	8.1	1281	1970	0.21	10	30	N 07^0 49' 8.5"	E 006^0 44' 54.7"
26	Sarkin Noma	6.72	7.4	922	1418	0.14	6	29.5	N 07^0 50' 31.3"	E 006^0 44' 50"
27	Felele	7.84	7.9	983	1512	0.33	28	29	N 07^0 51' 6.2"	E 006^0 43' 31.7"
28	Felele	7.8	7.9	983	1512	0.32	29	29	N 07^0 51' 15.8"	E 006^0 43' 21.8"
29	Felele	7.84	7.9	981	1509	0.33	28	29	N 07^0 51' 6.6"	E 006^0 43'24.5"
30	Behind Secretariat	3.36	6.9	113	173	0.05	5	30	N 07^0 48' 37.3"	E 006^0 42' 1.5"
	Mean	8.07	7.77	1014.9	1560	0.15	25.89	30.38		
	W.H.O	-	6.5-8.5	1500	250	-	-	-		
	SON	-	6.5-8.5	500	1000	-	-	Ambient		

TCH: *Total carbonate hardness*

Table 3: Summary of the Bacteriological Analysis of Groundwater in Lokoja Metropolis

S/ NO.	Sample location		CFU/100ml		GPS READING	
			Dry Season	Rainy Season	LATITUDE	LONGITUDE
1	Ganaja Village	(BH)	0	0	N 07^0 44' 33"	E 006^0 44' 33"
2	500 Unit	(BH 1)	0	0	N 07^0 44' 56.6"	E 006^0 44' 24.7"
3	500 Unit	(BH 2)	0	0	N 07^0 45' 24.7"	E 006^0 44' 24.7"
4	200 Unit	(BH 1)	0	0	N 07^0 45' 33.1"	E 006^0 44' 21.1"
5	200 Unit	(BH 2)	0	0	N 07^0 45' 48"	E 006^0 44' 15.5"
6	Phase I	(BH 1)	0	0	N 07^0 47' 24.7"	E 006^0 43' 22.3"
7	Phase I	(BH 2)	0	0	N 07^0 47' 29.3"	E 006^0 43' 33"
8	Phase II	(BH 1)	0	0	N 07^0 48' 4.7"	E 006^0 41' 55.2"
9	Phase II	(BH 2)	0	0	N 07^0 47' 44.3"	E 006^0 42' 18.6"
10	Otokiti Estate	(BH)	0	0	N 07^0 48' 18.5"	E 006^0 41' 7"
11	Army Baracks	(BH)	20	25	N 07^0 48' 9.4"	E 006^0 40' 34.5"
12	Roja Table Water	(BH 1)	11	10	N 07^0 48'32.6"	E 006^0 38'41.3"
13	Zangodaji	(BH 2)	11	15	N 07^0 48' 40.6"	E 006^0 38' 26.1"
14	Adankolo(BH 1)		0	0	N 07^0 47' 15.6"	E 006^0 44' 16"
15	Adankolo	(BH 2)	0	0	N 07^0 47'23.5"	E 006^0 44' 28.6"
16	Adankolo	(BH 3)	0	0	N 07^0 47' 21.6"	E 006^0 44' 17.5"
17	Adankolo	(BH 4)	0	0	N 07^0 47' 33.9"	E 006^0 44' 29.9"
18	Marine Road	(BH)	0	0	N 07^0 48' 7.1"	E 006^0 44' 54.4"
19	Kenwo Hotel	(HDW)	130	150	N 07^0 47' 50"	E 006^0 43' 55.9"
20	Kasuwa Hotel	(BH)	0	0	N 07^0 48' 28.9"	E 006^0 44' 55.5"
21	GRAJ(GRA)	(HDW)	550	160+	N 07^0 48' 24.5"	E 006^0 43' 44.5"
22	New Layout	(HDW)	1600	1800+	N 07^0 48' 37.8"	E 006^0 44' 12.7"
23	New Layout	(HDW 2)	550	1600+	N 07^0 48' 37.2"	E 006^0 44' 32.8"
24	Megiri	(HDW)	550	1600+	N 07^0 48' 45.1"	E 006^0 44' 42.1"
25	Kabawa	(HDW)	1600+	1800^+	N 07^0 49' 8.5"	E 006^0 44' 54.7"
26	Sarkin Noma	(HDW)	1800+	1800+	N 07^0 50' 31.3"	E 006^0 44' 50"
27	Felele	(HDW 1)	35	44	N 07^0 51' 6.2"	E 006^0 43' 31.7"
28	Felele	(HDW 2)	40	48	N 07^0 51' 15.8"	E 006^0 43' 21.8"
29	Felele	(HDW 3)	40	65	N 07^0 51' 6.6"	E 006^0 43'24.5"
30	Behind Secretariat	(HDW)	1800+	1800^+	N 07^0 48' 37.3"	E 006^0 42' 1.5"

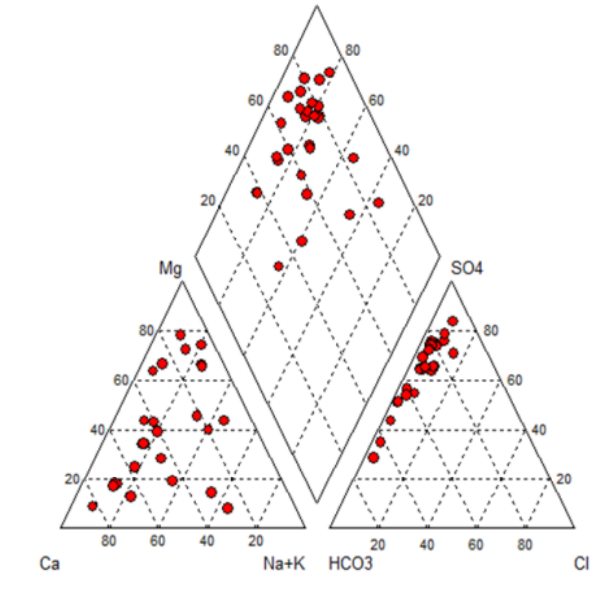

Fig. 2: Piper diagram showing water type in the study area during rainy season

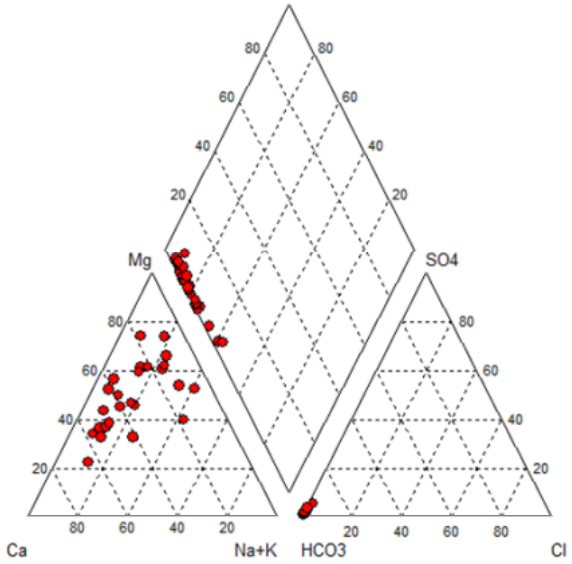

Fig. 3: Piper diagram showing water type in the study area during dry season

Table.4: Summary of Chemical Parameters of Groundwater Samples in Lokoja Area during the Rainy Season

S/ No.	Sample location	Cu^{2+} mg/l	Zn^{2+} Mg/l	Mn^{2+} mg/l	Fe^{2+} mg/l	Mg^{2+} mg/l	Ca^{2+} mg/l	Na^{+} mg/l	Pb^{2+} mg/l	Cd^{2+} mg/l	Cr^{4+} mg/l	K^{+} mg/l	DO mg/l	Redox (mv)	H_2S mg/l	Cl^{-} mg/l	SO_4^{2-} mg/l	NO_3^{-} mg/l	HCO_3^{-} mg/l	GPS READING LATITUDE	LONGITUDE
1	Ganaja Village (BH)	ND	0.030	0.034	0.043	0.940	17.82	10.0	0.000	0.018	0.056	7.55	7.2	246	0.024	99.0	4.46	0.011	110.00	N 07^0 44' 33"	E 006^0 44' 33"
2	500 Unit (BH 1)	ND	0.045	0.007	0.050	4.880	15.53	10.0	0.000	0.000	0.000	6.00	7.3	454	0.010	98.0	4.44	0.016	109.00	N 07^0 44' 56.6"	E 006^0 44' 24.7"
3	500 Unit (BH 2)	ND	0.043	0.007	0.049	4.879	15.53	10.0	0.000	0.000	0.015	6.00	7.2	452	0.010	98.0	4.46	0.016	109.00	N 07^0 45' 24.7"	E 006^0 44' 24.7"
4	200 Unit (BH 1)	0.010	0.066	0.027	0.044	5.560	25.11	7.7	0.010	0.012	0.024	3.00	7.6	307	0.022	42.0	4.28	0.043	121.00	N 07^0 45' 33.1"	E 006^0 44' 21.1"
5	200 Unit (BH 2)	0.002	0.055	0.061	0.010	5.540	25.00	7.5	0.009	0.001	0.000	3.00	8.2	536	0.008	44.0	4.28	0.018	120.00	N 07^0 45' 48"	E 006^0 44' 15.5"
6	Phase I (BH 1)	0.005	0.038	0.110	0.053	2.810	13.67	8.3	0.001	0.001	0.006	8.00	6.5	312	0.012	28.0	4.44	0.921	85.00	N 07^0 47' 24.7"	E 006^0 43' 22.3"
7	Phase I (BH 2)	0.005	0.037	0.110	0.053	4.920	5.40	8.0	0.000	0.000	0.019	7.00	6.5	311	0.012	77.0	4.64	0.920	79.00	N 07^0 47' 29.3"	E 006^0 43' 33"
8	Phase II (BH 1)	ND	0.101	0.006	0.054	2.080	3.42	4.5	0.001	0.000	0.044	12.00	7.5	324	0.019	14.0	4.54	0.027	64.00	N 07^0 48' 4.7"	E 006^0 41' 55.2"
9	Phase II (BH 2)	0.003	0.042	0.005	0.027	2.110	1.28	6.1	0.003	0.007	0.043	11.00	8.3	342	0.042	42.0	4.62	0.028	105.00	N 07^0 47' 44.3"	E 006^0 42' 18.6"
10	Otokiti Estate (BH)	ND	0.034	0.024	0.040	7.350	2.11	4.0	0.000	0.001	0.001	5.00	8.1	365	0.039	14.0	4.71	0.025	55.00	N 07^0 48' 18.5"	E 006^0 41' 7"
11	Army Baracks(BH)	ND	0.071	0.009	0.073	1.900	6.57	7.8	0.007	0.001	0.201	27.00	6.8	544	0.014	42.0	4.52	0.036	102.00	N 07^0 48' 9.4"	E 006^0 40' 34.5"
12	Roja Table Water (BH 1)	ND	0.054	0.081	0.092	5.320	2.90	6.3	0.010	0.003	0.005	13.00	7.8	511	0.013	54.00	4.67	0.012	90.00	N 07^0 48'32.6"	E 006^0 38'41.3"
13	Zangodaji (BH 2)	0.002	0.058	0.213	0.071	5.320	2.91	6.3	0.009	0.001	0.009	12.50	7.5	625	0.036	56.0	4.67	0.014	91.00	N 07^0 48' 40.6"	E 006^0 38' 26.1"
14	Adankolo (BH 1)	0.010	0.047	0.008	0.032	8.240	15.34	10.2	0.006	0.016	0.005	4.00	6.6	298	0.010	161.0	4.67	0.019	54.00	N 07^0 47' 15.6"	E 006^0 44' 16"
15	Adankolo (BH 2)	ND	0.018	0.102	0.039	0.031	27.50	10.2	0.009	0.006	0.059	4.50	5.0	311	0.017	70.0	4.67	0.560	140.00	N 07^0 47'23.5"	E 006^0 44' 28.6"
16	Adankolo (BH 3)	0.010	0.045	0.100	0.040	0.022	25.00	10.2	0.010	0.002	0.040	4.00	5.0	300	0.015	160.0	4.64	0.019	138.00	N 07^0 47' 21.6"	E 006^0 44' 17.5"
17	Adankolo (BH 4)	0.010	0.045	0.100	0.040	0.030	27.00	10.0	0.010	0.001	0.033	4.00	5.0	300	0.015	160.0	4.67	0.019	140.00	N 07^0 47' 33.9"	E 006^0 44' 29.9"
18	Marine Road (BH)	ND	0.021	0.001	0.056	3.000	3.21	7.9	0.010	0.006	0.007	4.00	8.2	527	0.044	147.0	4.65	0.031	95.00	N 07^0 48' 7.1"	E 006^0 44' 54.4"
19	Kasuwa Hotel (BH)	0.001	0.063	0.021	0.085	3.040	16.88	8.5	0.001	0.000	0.004	11.00	7.0	617	0.010	35.0	4.25	0.023	96.00	N 07^0 47' 50"	E 006^0 43' 55.9"
20	Kenwo Hotel (HDW)	0.010	0.017	0.013	0.082	1.830	26.63	7.2	0.016	0.000	0.000	34.00	4.9	639	0.020	42.0	4.67	0.020	72.00	N 07^0 48' 28.9"	E 006^0 44' 55.5"
21	GRA (HDW)	0.020	0.069	0.004	0.011	2.450	30.55	2.2	0.022	0.003	0.002	2.00	5.6	153	0.160	21.0	4.32	0.280	63.00	N 07^0 48' 24.5"	E 006^0 43' 44.5"
22	New Layout(HDW 1)	0.008	0.022	0.012	0.025	2.110	16.86	6.8	0.023	0.008	0.009	4.50	6.0	203	0.029	7.0	4.22	0.240	58.00	N 07^0 48' 37.8"	E 006^0 44' 12.7"
23	New Layout(HDW 2)	0.008	0.023	0.012	0.025	1.210	28.00	13.3	0.023	0.006	0.006	17.00	5.89	202	0.027	160.0	4.80	0.241	72.00	N 07^0 48' 37.2"	E 006^0 44' 32.8"
24	Megiri (HDW)	0.001	0.060	0.003	0.192	1.200	28.00	13.6	0.013	0.019	0.020	17.00	6.2	407	0.005	161.0	4.81	0.810	72.00	N 07^0 48' 45.1"	E 006^0 44' 42.1"
25	Kabawa (HDW)	0.006	0.011	0.034	0.041	3.020	16.56	70	0.023	0.009	0.009	3.00	6.5	206	0.011	7.0	4.44	0.016	28.00	N 07^0 49' 8.5"	E 006^0 44' 54.7"
26	Sarkin Noma (HDW)	0.002	0.044	0.097	0.020	2.140	22.91	11.2	0.042	0.009	0.010	37.00	5.8	370	0.005	42.0	4.65	0.430	48.00	N 07^0 50' 31.3"	E 006^0 44' 50"
27	Felele (HDW 1)	0.002	0.059	0.006	0.042	4.110	18.55	6.0	0.018	0.001	0.001	8.00	6.3	430	0.017	21.0	4.74	0.330	44.00	N 07^0 51' 6.2"	E 006^0 43' 31.7"

BH = Borehole HDW = Hand-dugwell

Table.4: Summary of Chemical Parameters of Groundwater Samples in Lokoja Area during the Rainy Season (Contd)

28	**Felele**	**(HDW 2)**	0.020	0.052	0.019	0.071	4.000	18.53	6.0	0.023	0.005	0.001	8.00	6.4	394	0.016	23.00	4.72	0.038	44.00	N 07^0 51' 15.8"	E 006^0 43' 21.8"
29	**Felele**	**(HDW 3)**	0.002	0.057	0.017	0.072	3.950	18.53	5.8	0.013	0.015	0.000	8.00	6.4	393	0.016	21.00	4.72	0.331	44.00	N 07^0 51' 6.6"	E 006^0 43'24.5"
30	**Behind (HDW)**	**Secretariat**	0.004	0.071	0.016	0.081	4.950	3.54	3.8	0.000	0.001	0.001	1.00	6.4	465	0.177	35.0	4.62	0.013	64.00	N 07^0 48' 37.3"	E 006^0 42' 1.5"
	Mean		0.01	0.05	0.04	0.05	3.11	14.66	7.88	0.010	0.005	0.020	9.74	6.66	384.20	0.03	66.03	4.57	0.18	83.73		
	W.H.O		2.0	3.0	0.4	0.03	50	75	200	0.01	0.03	0.05	-	-	-	-	250	250	50	-		
	SON		1.0	3.0	0.2	0.3	50	-	200	0.01	0.03	0.05	-	-	-	-	250	100	50	200		

BH = Borehole HDW = Hand-dugwell

Table 5: Summary of Chemical Parameters of Groundwater Samples in Lokoja Area during the Dry Season

S/ No.	Sample location	Cu^{2+} mg/l	Zn^{2+} Mg/ l	Mn^{2+} mg/l	Fe^{2+} mg/l	Mg^{2+} mg/l	Ca^{2+} mg/l	Na^{+} mg/l	Pb^{2+} mg/l	Cd^{2+} mg/l	Cr^{4+} mg/l	K^{+} mg/l	DO mg/l	Redox (mv)	H_2S mg/l	Cl^{-} mg/l	SO_4^{2-} mg/l	NO_3^{-} mg/l	HCO_3^{-} mg/l	GPS READING LATITUDE	LONGITUDE
1	Ganaja Village (BH)	ND	0.031	0.036	0.045	0.92	17.82	5.50	0.000	0.016	0.040	7.54	7.00	ND	0.011	0.030	0.91	0.017	101.00	N 07^0 44′ 33″	E 006^0 44′ 33″
2	500 Unit (BH 1)	0.08	0.02	0.022	0.08	3.51	11.28	6.92	0.000	0.000	0.000	9.18	5.90	523	0.010	0.043	0.77	0.006	88.00	N 07^0 44′ 56.6″	E 006^0 44′ 24.7″
3	500 Unit (BH 2)	0.08	0.01	0.023	0.08	2.59	11.30	6.90	0.000	0.000	0.015	9.16	5.91	521	0.010	0.048	0.77	0.006	88.00	N 07^0 45′ 24.7″	E 006^0 44′ 24.7″
4	200 Unit (BH 1)	3.27	0.04	ND	0.05	2.70	21.34	6.12	0.009	0.002	0.023	9.64	7.90	310	0.022	0.049	0.75	0.030	68.00	N 07^0 45′ 33.1″	E 006^0 44′ 21.1″
5	200 Unit (BH 2)	3.25	0.04	0.007	0.07	3.56	3.58	4.72	0.007	0.000	0.000	8.56	7.89	312	0.022	0.031	0.73	0.031	78.00	N 07^0 45′ 48″	E 006^0 44′ 15.5″
6	Phase I (BH 1)	0.13	0.08	0.005	0.06	1.21	6.68	5.90	0.000	0.001	0.006	10.46	5.50	481	0.002	0.062	0.78	0.017	99.00	N 07^0 47′ 24.7″	E 006^0 43′ 22.3″
7	Phase I (BH 2)	1.51	0.04	0.061	0.16	1.22	6.67	5.91	0.000	0.000	0.017	10.48	6.80	402	0.001	0.062	0.79	0.650	99.00	N 07^0 47′ 29.3″	E 006^0 43′ 33″
8	Phase II (BH 1)	1.32	0.04	0.004	0.15	1.67	1.44	3.36	0.000	0.000	0.043	8.04	6.80	409	0.006	0.044	0.80	0.020	42.00	N 07^0 48′ 4.7″	E 006^0 41′ 55.2″
9	Phase II (BH 2)	1.42	0.06	0.002	0.00	1.67	2.12	4.14	0.003	0.005	0.040	5.72	5.30	310	0.010	0.034	0.91	0.014	75.00	N 07^0 47′ 44.3″	E 006^0 42′ 18.6″
10	Otokiti Estate (BH)	2.13	0.09	0.008	0.16	4.01	1.02	4.94	0.000	0.000	0.001	4.78	7.20	402	0.011	0.028	0.85	0.010	49.00	N 07^0 48′ 18.5″	E 006^0 41′ 7″
11	Army Baracks(BH)	1.24	0.04	0.004	0.01	1.76	4.92	4.96	0.005	0.001	0.200	8.82	4.30	600	0.002	0.097	0.77	0.013	84.00	N 07^0 48′ 9.4″	E 006^0 40′ 34.5″
12	Roja Table Water (BH 1)	1.46	0.20	0.080	0.01	2.89	2.36	4.25	0.009	0.000	0.005	8.34	3.40	572	0.008	0.023	0.82	0.016	61.00	N 07^0 48′32.6″	E 006^0 38′41.3″
13	Zangodaji (BH 2)	1.48	0.20	0.080	0.00	3.18	1.74	3.84	0.009	0.001	0.007	4.63	3.40	572	0.007	0.056	0.79	0.016	56.00	N 07^0 48′ 40.6″	E 006^0 38′ 26.1″
14	Adankolo (BH 1)	2.44	0.05	0.008	0.10	5.12	13.50	8.06	0.004	0.014	0.005	6.66	3.30	277	0.002	0.094	0.63	0.008	44.00	N 07^0 47′ 15.6″	E 006^0 44′ 16″
15	Adankolo (BH 2)	2.62	0.06	0.210	0.11	0.67	21.50	7.24	0.008	0.003	0.056	4.56	6.00	214	0.003	0.136	1.25	0.095	156.00	N 07^0 47′23.5″	E 006^0 44′ 28.6″

BH = Borehole HDW = Hand-dugwell

Table 5: Summary of Chemical Parameters of Groundwater Samples in Lokoja Area during the Dry Season (Contd)

S/ No.	Sample location	Cu^{2+} mg/l	Zn^{2+} Mg/l	Mn^{2+} mg/l	Fe^{2+} mg/l	Mg^{2+} mg/l	Ca^{2+} mg/l	Na^{+} mg/l	Pb^{2+} mg/l	Cd^{2+} mg/l	Cr^{4+} mg/l	K^{+} mg/l	DO mg/l	Redox (mv)	H_2S mg/l	Cl^{-} mg/l	SO_4^{2-} mg/l	NO_3^{-} mg/l	HCO_3^{-} mg/l	GPS READING LATITUDE	LONGITUDE
16	Adankolo (BH 3)	2.53	0.03	0.210	0.10	5.11	13.70	8.04	0.010	0.001	0.040	6.66	3.50	276	0.003	0.140	0.63	0.095	154.00	N 07^0 47' 21.6"	E 006^0 44' 17.5"
17	Adankolo (BH 4)	2.60	0.04	0.200	0.11	5.11	13.70	8.04	0.009	0.000	0.031	6.66	6.00	277	0.002	0.140	0.63	0.090	154.00	N 07^0 47' 33.9"	E 006^0 44' 29.9"
18	Marine Road (BH)	1.10	0.14	ND	0.22	1.30	5.30	3.74	0.009	0.006	0.007	7.48	5.20	411	0.020	0.117	0.97	0.020	92.00	N 07^0 48' 7.1"	E 006^0 44' 54.4"
19	Kasuwa Hotel (BH)	0.26	0.22	0.013	0.03	2.14	17.62	6.00	0.000	0.000	0.002	8.70	6.50	514	0.004	0.088	0.54	0.024	77.00	N 07^0 47' 50"	E 006^0 43' 55.9"
20	Kenwo Hotel (HDW)	0.53	0.17	0.010	0.03	1.51	20.61	4.16	0.014	0.000	0.001	19.02	4.20	490	0.010	0.053	0.81	0.030	60.00	N 07^0 48' 28.9"	E 006^0 44' 55.5"
21	GRA (HDW)	4.17	0.01	0.012	0.02	4.92	22.16	7.13	0.012	0.003	0.000	15.09	3.80	226	0.009	0.028	0.86	0.099	34.00	N 07^0 48' 24.5"	E 006^0 43' 44.5"
22	New Layout (HDW 1)	3.47	0.06	0.012	0.14	1.36	13.68	4.14	0.023	0.006	0.000	5.10	8.40	234	0.003	0.046	0.81	0.095	63.00	N 07^0 48' 37.8"	E 006^0 44' 12.7"
23	New Layout (HDW 2	3.49	0.06	0.012	0.00	1.36	13.70	4.14	0.023	0.005	0.000	5.10	5.80	437	0.005	0.046	0.80	0.629	63.00	N 07^0 48' 37.2"	E 006^0 44' 32.8"
24	Megiri (HDW)	2.48	0.25	0.002	0.00	1.24	28.40	7.98	0.040	0.017	0.001	15.88	5.80	438	0.005	0.183	1.41	0.631	88.00	N 07^0 48' 45.1"	E 006^0 44' 42.1"
25	Kabawa (HDW)	2.36	0.06	0.005	0.35	1.90	19.80	8.06	0.022	0.005	0.000	15.60	4.40	114	0.010	0.126	0.84	0.018	32.00	N 07^0 49' 8.5"	E 006^0 44' 54.7"
26	Sarkin Noma (HDW)	2.67	0.06	0.007	0.10	1.07	28.40	6.74	0.040	0.008	0.000	21.88	5.00	278	0.003	0.079	0.82	0.033	45.00	N 07^0 50' 31.3"	E 006^0 44' 50"
27	Felele (HDW 1)	0.19	0.04	0.012	0.14	1.84	24.22	4.36	0.016	0.001	0.005	8.91	5.90	337	0.006	0.171	0.88	0.216	18.00	N 07^0 51' 6.2"	E 006^0 43' 31.7"
28	Felele (HDW 2)	0.20	0.04	0.010	0.14	1.89	9.62	5.46	0.021	0.003	0.000	24.82	6.00	335	0.006	0.101	0.85	0.216	44.00	N 07^0 51' 15.8"	E 006^0 43' 21.8"
29	Felele (HDW 3)	0.19	0.04	0.012	0.14	1.83	24.20	4.36	0.010	0.005	0.000	8.90	6.10	333	0.006	0.103	0.88	0.214	42.00	N 07^0 51' 6.6"	E 006^0 43'24.5"
30	Behind Secretariat (HDW)	2.24	0.05	0.009	0.01	4.03	1.72	1.32	0.000	0.000	0.000	2.40	4.40	524	0.025	0.027	1.36	0.009	41.00	N 07^0 48' 37.3"	E 006^0 42' 1.5"
	Mean	1.76	0.08	0.04	0.10	2.44	12.80	5.45	0.010	0.003	0.020	9.63	5.40	383.76	0.01	0.08	0.85	0.09	73.17		
	W.H.O	2.0	3.0	0.4	0.03	50	75	200	0.01	0.03	0.05	-	-	-	-	250	250	50	200		
	SON	1.0	3.0	0.2	0.3	50	-	200	0.01	0.03	0.05	-	-	-	-	250	100	50	-		

BH = Borehole HDW = Hand-dugwell

Total Hardness

Results of the total carbonate hardness analyzed in Tables 3 and 4 show that the total hardness for the rainy season ranges from 24mg/l to 620mg/l with an average of 256mg/l. For the dry season it ranges from 3.36mg/l to 14.57mg/l with an average of 8mg/l. On the basis of [5], groundwater classification, Tables 1 and 2 indicate that groundwater in Lokoja area during the dry season is classified as soft water while groundwater during the rainy season is classified as soft to very hard water. Hardness of water in the area during the wet season could be attributed to the geologic materials such as dissolved carbonates of calcium and magnesium. Hardness induced by calcium and magnesium is usually shown by precipitation of soap scum, hence the need to use excess soap to achieve cleaning. Hardness also causes yellowing of fabrics, toughens vegetables during cooking, forms scales in boilers, hot water heaters, pipes and cooking utensils. Due to their adverse effect with soap, hard water is unsatisfactory for household cleaning. Water softening processes for removal of hardness are needed. However, there are indications that very soft water may have an adverse effect on mineral balance, but detailed studies are not available for evaluation [19].

pH

pH values measured during the rainy season in the study area varies from 7.9 to 9.0 with an average of 8.6. During the dry season the pH ranges from 6.6 to 8.4 with an average of 7.8. Generally, the pH values within the two seasons indicate alkaline water type, except for the slight acidity (Table 1 and 2) recorded in GRA and the hand- dug well behind the secretariat during the dry season. The increment in alkalinity recorded during the rainy season is an indication of an increase in the rate of dissolution of the hydroxyl ions due to a rise in the volume of groundwater in the area. Several factors can also cause fluctuations or extremes in pH, including bedrock degradation, acid rain, wastewater discharge and carbondioxide (CO_2) [10]. Samples collected during the dry season yielded values within the Standards Organization of Nigeria [18] and World Health Organization [19] permissible limit of 6.5 – 8.5. Nineteen out of thirty samples collected during the rainy season exceeded the WHO and SON standards. According to WHO, health effects are more pronounced in pH extremes. Drinking water with an elevated pH above 11 can cause skin, eye and mucous membrane irritation. Although pH usually has no direct impact on groundwater, values found in the area are below those at which toxic effects may occur.

Total Dissolved Solids (TDS)

The concentration of the total dissolved solids (TDS) measured for the water samples collected during the rainy season ranges from 115mg/l to 2000mg/l with a mean of 1110mg/l while that obtained during the dry season ranges between 94mg/l and 1824mg/l with an average of 1015mg/l. The mean TDS for groundwater in both seasons are below the WHO maximum permissible level of 1500mg/l but above the SON maximum permitted level of 500mg/l. However, for boreholes located at Megiri, Adankolo, Kabawa and Kasuwa, the TDS are above the WHO maximum permitted level for drinking water in both seasons. The anomalous concentrations of the TDS in these areas reflect the high intake of effluents the groundwater receives possibly from human activities.

From Table 3, on the basis of TDS, groundwater in the study area is classified as fresh. The presence of a high level of TDS may be objectionable owing to excessive scaling in water pipes, heaters, boilers and household appliances as reported by some inhabitants at the course of oral interview. In addition, high concentrations of TDS can cause water to taste bad. Highly mineralized water also deteriorates plumbing.

Turbidity

Turbidity in water is a function of the suspended inorganic or organic materials found in such water. The turbidity of groundwater samples during the rainy season is within the range between 8mg/l and 121mg/l with an average of 33mg/l while those of dry season range from 4mg/l to 95mg/l with an average of 26mg/l. The higher turbidity value recorded during the rainy season is attributable to the inflow of clay materials into the wells from the sedimentary environment and the weathered feldspar (clay) from the basement terrain.

Temperature (^{0}C)

The temperature of groundwater samples collected during the rainy season ranges from 30^0C to 34.1^0C with a mean value of 32.45^0C while those collected during the dry season have a range of 29^0C to 32^0C with an average of 30.38^0C. The values measures for all samples in both seasons are above the World Health Organization standard (WHO) while Standards Organization of Nigeria (S0N) has an ambient temperature. The temperature of water is a function of the season and the time of the day when the samples are collected.

According to Meteorological Department of Federal Ministry of Aviation (2007), Lokoja area has high temperatures ranging between 33^0C and 36^0C, hence, the high temperature of the groundwater. Cool water is more palatable than warm water, as the temperature will impact on the acceptability of a number of other inorganic constituents and chemical contaminants that may affect taste. High water temperature enhances the growth of micro-organisms and may increase taste, odour and corrosion [19].

Trace Elements

The concentration of lead (Pb^{2+}) from water samples analyzed during the rainy season ranges from 0.00 to 0.042mg/l with a mean value of 0.01mg/l while that of dry season varies from 0.00 to 0.040mg/l with an average value of 0.01mg/l. Most of the values are within the SON and WHO maximum limits of 0.01mg/l except the values for samples from GRA, New Layout, Kabawa, Sarkin Noma and Felele that are slightly higher. High concentrations of lead in some of the samples may have arisen from plumbing system containing lead in pipes and/or fittings and lead batteries from mechanic workshops.

Health impact associated with high contents of lead in human body are cancer, interference with vitamin D metabolism, affect mental development in infants and toxic to the central and peripheral nervous systems [18].

Cadmium (Cd^{2+}) content in the water samples ranges from 0.00 to 0.018mg/l with an average of 0.005mg/l during the wet season and 0.00 to 0.017mg/l and a mean value of 0.003mg/l during the dry season. Both seasons recorded values below SON and WHO permissible level of 0.03mg/l. The presence of cadmium in the groundwater could be attributed to leachate from refuse dumps in the study area. Cadmium, according to [18], is said to be toxic to kidney.

Chromium (Cr^{+4}) content varies between 0.00 to 0.05mg/l with a mean of 0.020mg/l during the wet season while the dry season recorded a range of 0.00 to 0.040mg/l and a mean value of 0.020mg/l. These values are below the SON and WHO permissible value of 0.05mg/l. health impact associated with chromium in the body is cancer.

Bacteriological Parameters

The organisms most commonly used as indicators of faecal pollution are the coliform group as a whole. However, coliform bacteria are not a single species of bacteria rather they are a group of bacteria. They make up about 10% of the intestinal microflora of the human and animal intestines. Coliforms are defined as any bacteria capable of fermenting lactose (milk sugar) with the production of acid and gas in 48 hours at 25^0C under aerobic conditions. This group of bacteria may contain several genera and species of bacteria including Enterobacter, Klebsiella, Aeromonas and Escherichia coli (E.Coli) [10, 11].

The total coliform counts of the groundwater in the area studied ranges between 0 and 1800/100ml in both seasons (Table 3). Abundant coliform counts are found in the hand-dug wells within a range of 40 and 1800cfu/100ml. The coliform counts in water samples collected from boreholes range from 0 to 20cfu/100ml during the dry season and 0 to 25cfu/100ml during the wet season. The values of coliforms bacteria measured in water samples obtained from boreholes during both seasons are within the Standards Organization of Nigeria (SON) maximum permissible levels of 10cfu/100ml (2007) except at Zangodaji and Army Barracks, where water samples have higher counts attributed to leakages from nearby septic tanks, cesspools and other natural and anthropogenic activities into the

aquifers supplying the boreholes. On the basis of presumptive coliform counts, all the water samples from boreholes are safe (<25cfu/100ml) (Table 3).

The values of coliform bacteria in water samples from hand-dug wells are above the Standards Organization of Nigeria (SON) level (10cfu) for drinking water. The standard by the World Health Organization (WHO) is nil. The relatively higher values of coliform bacteria in samples from hand-dug wells are reflective of the reckless faecal dumps due to the unplanned nature of the settlement pattern of these areas. The presence of these bacteria could be the result of exposure of these wells to the surface and other anthropogenic activities. Some of these bacteria are excreted in the faeces of humans and animals, but many coliforms are heterotrophic and able to multiply in water and soil environment (WHO, 2006). Health impact associated with high counts of bacteria is an indication of faecal contamination. Figures 4 and 5 show the distribution of coliform bacteria during the wet and dry seasons in the study area. They indicate areas with coliform counts higher than the permissible limit as stated by SON. Wells contaminated with the coliform bacteria include the hand-dug wells located at New Layout, Megiri, Kabawa, Sarkin Noma, Felele and behind the state secretariat. The presence of this coliform group of bacterial shows the water sources are biologically polluted. Biological pollution has serious health implication.

Table 6: Groundwater classification based on hardness ($CaCO_3$ + $MgCO_3$)mg/l [5]

0 – 75	Soft
75 – 150	Moderately hard
150 – 300	Hard
Over 300	Very hard

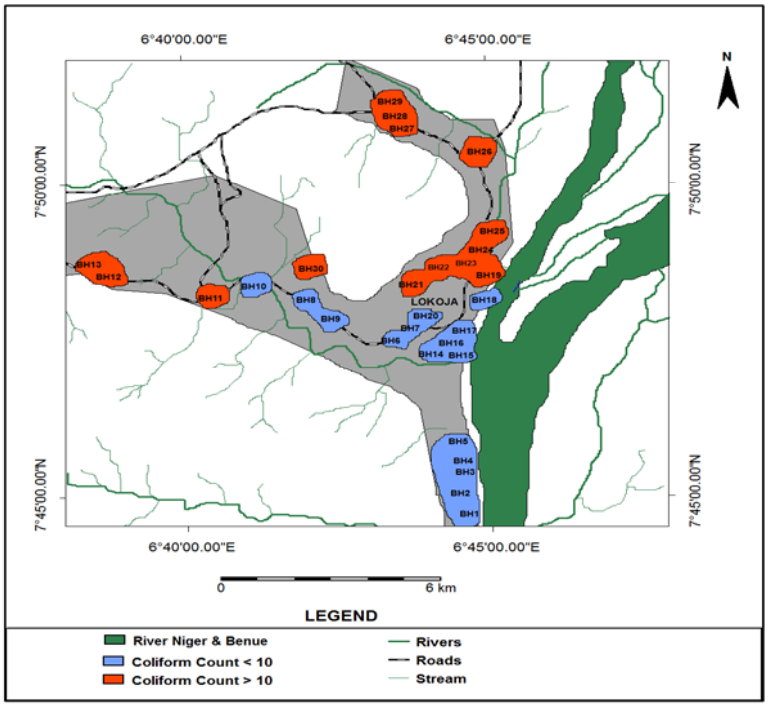

Fig.4: Distribution of Total Coliform Bacteria during the Dry Season in the study Area

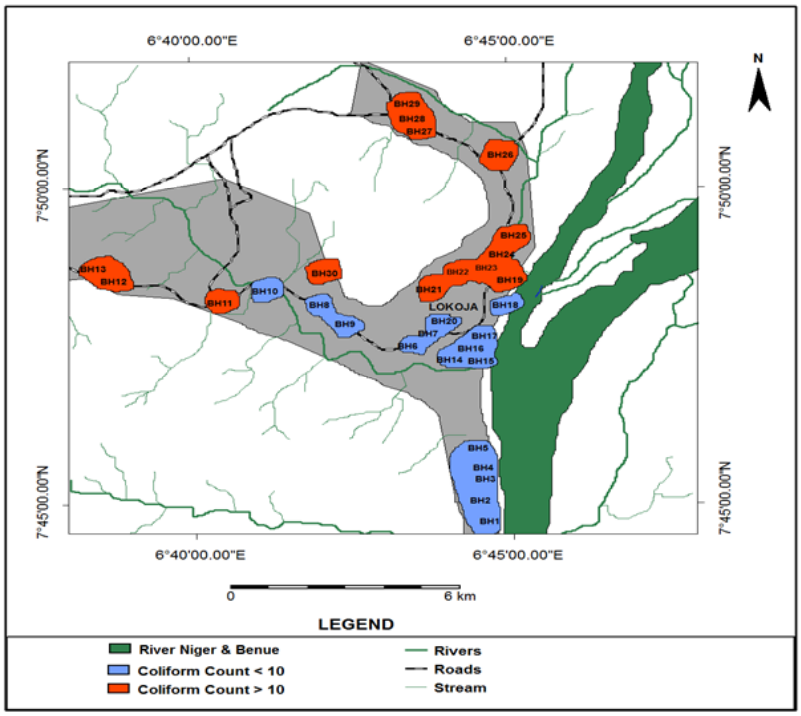

Fig.5: Distribution of Total Coliform Bacteria during the Dry Season in the study Area

Conclusions

The results of the physicochemical and biological analyses reveal that there is seasonal variation in these parameters. The water types are also affected by season. The geochemical analysis of the water samples obtained during the wet and dry seasons for physical, chemical and biological analyses revealed that groundwater of the study area is soft to very hard during the wet season and soft during the dry season. On the basis of TDS, groundwater in the area is moderately fresh. The mean concentrations of ions including Cu^{2+}, Zn^{2+}, Mn^{2+}, Fe^{2+}, Pb^{2+}, Cd^{2+},Cr^{6+}, Mg^{2+}, Ca^{2+}, Na^{+}, Cl^{-}, SO_4^{2-}, NO_3^{-}, HCO_3^{-} are within the World health Organization (WHO) and the Standards Organization of Nigeria (SON) maximum permissible levels for human consumption in both seasons.

The biological analysis showed a rise in the number of coliform counts during the rainy season compared with the dry season. Coliform counts in the study area are more in the hand-dug wells than in boreholes. Most boreholes (BH) recorded values of coliform counts within the Standard Organization of Nigeria (SON) permissible limits for drinking water except for the boreholes in the Army Barracks and Zangod+aji. All water samples collected from hand-dug wells (HDW) have coliform counts that did not meet both WHO and SON requirements indicating biological pollution.

The Piper Trilinear Diagrams constructed indicated Calcium–Magnesium–Bicarbonate, Sodium-Sulphate-Chloride and Calcium-Magnesium-Sulphate-Chloride water types during the wet season and Calcium-Magnesium-Bicarbonate water type during the dry season. The mean concentrations of major cations are of the order $Ca^{2+}>K^{+}>Na^{+}>Mg^{2+}$ while the anions are of the order $HCO_3^{-} > Cl^{-} > SO_4^{2-} > NO_3^{-}$ during the rainy season. During the dry season cation concentrations are of the order $Ca^{2+} > K^{+}>Na^{+}>Mg^{2+}$ and the anions are of the order $HCO_3^{-}>SO_4^{2-}>Cl^{-}>NO_3^{-}$.

References

[1] Abimbola, A.F., Odukoya, A.M., and Olatunji, A.S. (2002). Influence of bedrock on the hydrogeochemical characteristics of groundwater in northern part of Ibadan metropolis SW Nigeria. Journal of the Nigerian Association of Hydrogeologists. (NAH), 13, pp. 1 – 6.

[2] Abimbola, A.F., Laniyan, T.A., Okunola, O.W., Odewande, A.A., Ajibade, O.M and Kolawole, T. (2005). Water quality test of areas surrounding selected refuse dumpsites in Ibadan, Southwestern Nigeria. Journal of the Nigerian Association of Hydgrogeologists (NAH), 16, pp. 39 – 48.

[3] Agbazue, A V.E and Akpanisi, L.E.S. (2012). Fundamentals of environmental chemistry. Welfare and Industrial Promotions (WIPRO) International. 205p.

[4] American Public Health Association. APHA, 1975. Standard Method as for the Examination of waste water (American Public Health Association, Washington, DC), 14th edition, pp14 – 150.

[5] Egboka, B.C.E. (1986). Hydrogeochemistry of shallow wells and surface waters of Owerri and its environs. Proc. 1st symposium, NIWASA, pp. 305-328.

[6] Ehinola, A.O. (2006). Hydrochemical characteristics of groundwater in parts of the Basement Complex of southwestern Nigeria. Journal of Mining and Geology, 38(2), 125 – 133.

[7] Ige, O.O., Bale, R.B., and Olasehinde, P.I. (2008). Physico Chemical characteristics of water sources in Imeko, southwestern, Journal of the Nigerian Association of Hydgrogeologists (NAH), (18), pp. 32 – 36.

[8] Nton, M.E., Adejumo, S.A. and Elueze, A.A. (2007). Hydrogeochemical assessment of surface water and groundwater quality in Agbowo – Orogun Area of Ibadan, southwestern Nigeria. Global Journal of Geological Sciences, Vol. 5 (1 and 2), pp. 13 – 23.

[9] Ofoma, A.E., Omologbe, D.A. and Aigberua, P. (2005). Physico – chemical quality of groundwater in parts of Port Harcourt City, Eastern Niger Delta, Nigeria. Journal of the Nigerian Association of Hydgrogeologists (NAH), 16, pp. 18 – 24.

[10] Offodile M. E. (2002). Groundwater study and development in Nigeria. 2nd edition. Published by Mecon geology and engineering services L.t.d. 452p.

[11] Olarewaju, V.O, Olorunfemi, M.O., and Alade, O. (1997). Chemical characteristics of groundwater from some parts of the Basement Complex of central Nigeria. Journal of Mining and Geology, 33(2), pp. 135 – 139.

[12] Olatunji, A.S., Abimbola, A.F., Oloruntola, M.O. and Odewande, A.A. (2005). Hydrogeochemical evaluation of groundwater resources in shallow coastal aquifers around Ikorodu Area, southwestern Nigeria. Journal of the Nigerian Association of Hydgrogeologists (NAH), 16, pp. 65 – 71.

[13] Olobaniyi S.B., Ogala, J.F. and Nfor, N.B., (2007). Hydrochemical and bacteriological investigation of groundwater in Agbor area, southern Nigeria. Journal of Mining and Geology, 43(1), pp. 79 – 89.

[14] Omada, J.I., Omali, A.O. and Awodi, J.O. (2009). Physico – Chemical Characteristics of surface water in parts of Lokoja Metropolis, central Nigeria. Journal of the Nigerian Association of Hydgrogeologists (NAH), (19), pp. 56 – 62.

[15] Omada J.I., Omatola, D.O., and Omali, A.O. (2011). Physico – Chemical characteristics of surface and groundwater in Anyigba and its environs, Kogi State, Nigeria. Journal of the Nigerian Association of Hydgrogeologists (NAH), 21, pp. 18 – 24.

[16] Omali A.O and Egboka B.C.E (2011). Physico chemical assessment of water around Okaba Coal mine, Kogi State, Nigeria. Natural and Applied Sciences Journal, 12. (2), Available online at www. Naasjournal-ng.org.

[17] Onugba, A. and Eduvie, M.O. (2005). The hydrogeochemistry and environmental isotopes of the aquifer systems in the Upper Benue Area, Nigeria. Journal of the Nigerian Association of Hydrogeologists (NAH), 16, pp. 80 – 89.

[18] Standards Organization of Nigeria (SON). (2007). Nigerian Standard for drinking water quality. Nigerian Industrial Standard NIS 554: 2007.

[19] World Health Organization (WHO). (2006). Guideline for drinking water Quality First Addendum to Third Edition. Vol. 1

[20] Yaya, O.O., Edet J.N., Nwude, M.O. and Eduvie M.O. (2008). Sanitary Inspection of Boreholes and Dug Wells in Armed Forces Command and Staff College, Jaji Kaduna State. Journal of the Nigerian Association of Hydrogeologists (NAH), 18, pp. 41-49.