

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

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### 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  $\text{Cu}^{2+}$ ,  $\text{Zn}^{2+}$ ,  $\text{Mn}^{2+}$ ,  $\text{Fe}^{2+}$ ,  $\text{Pb}^{2+}$ ,  $\text{Cd}^{2+}$ ,  $\text{Cr}^{4+}$ ,  $\text{Mg}^{2+}$ ,  $\text{Ca}^{2+}$ ,  $\text{Na}^+$ ,  $\text{Cl}^-$ ,  $\text{SO}_4^{2-}$ ,  $\text{NO}_3^-$ ,  $\text{HCO}_3^-$  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  $\text{Ca}^{2+} > \text{K}^+ > \text{Na}^+ > \text{Mg}^{2+}$  while the anions are of the order  $\text{HCO}_3^- > \text{Cl}^- > \text{SO}_4^{2-} > \text{NO}_3^-$  during the rainy season. During the dry season cation concentrations are of the order  $\text{Ca}^{2+} > \text{K}^+ > \text{Na}^+ > \text{Mg}^{2+}$  and the anions are of the order  $\text{HCO}_3^- > \text{SO}_4^{2-} > \text{Cl}^- > \text{NO}_3^-$ . 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  $7^{\circ} 44' 33''\text{N}$  and  $7^{\circ} 52'\text{N}$  and longitudes  $6^{\circ} 38' 6''\text{E}$  and  $6^{\circ} 48'\text{E}$  (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  $400\text{km}^2$  [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.

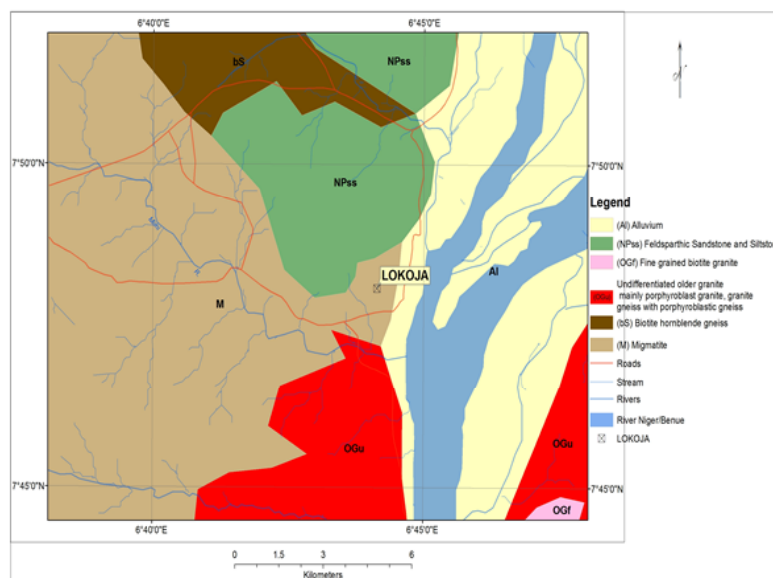


Fig. 1: Geologic Map of the study area

### 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;  $\text{Cu}^{2+}$ ,  $\text{Zn}^{2+}$ ,  $\text{Mn}^{2+}$ ,  $\text{Fe}^{2+}$ ,  $\text{Pb}^{2+}$ ,  $\text{Cd}^{2+}$ ,  $\text{Cr}^{4+}$ ,  $\text{Mg}^{2+}$ ,  $\text{Ca}^{2+}$ ,  $\text{Na}^{+}$  and  $\text{K}^{+}$  were determined using Atomic absorption Spectrophotometer, model 210 VGP.

Nitrate ( $\text{NO}_3^-$ ) and Sulphate ( $\text{SO}_4^{2-}$ ) ions were determined using spectrophotometer Model Genesys 20. Other anions such as chloride ( $\text{Cl}^-$ ) and bicarbonate ( $\text{HCO}_3^-$ ) were determined by wet chemistry, colorimetry. Chloride ( $\text{Cl}^-$ ) was determined by the argentometry titrimetric method, employing standard silver nitrate solution. 50ml of water samples were titrated with standard  $\text{AgNO}_3$  solution using  $\text{KCr}_2\text{O}_7$  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, methylyated 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°C for 15 minutes. The tubes were allowed to cool to between 47°C – 45°C. 10ml water sample was transferred aseptically 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°C 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 ( $\text{Ca}^{2+}$  –  $\text{Mg}^{2+}$  -  $\text{HCO}_3^-$ ) water type. This represents recently recharged water of meteoric origin that resulted from the dissolution of aluminosilicates.
- ii.) Sodium – Sulphate – Chloride ( $\text{Na}^{2+}$  –  $\text{SO}_4^{2-}$  -  $\text{Cl}^-$ ). This is fossil water whose origin is natural and anthropogenic.
- iii.) Calcium – Magnesium – Sulphate – Chloride ( $\text{Ca}^{2+}$  –  $\text{Mg}^{2+}$  –  $\text{SO}_4^{2-}$  -  $\text{Cl}^-$ ) 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 ( $\text{Ca}^{2+}$  –  $\text{Mg}^{2+}$  -  $\text{HCO}_3^-$ ) water type

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

| S/N | Sample location    | TCH<br>(mg/l) | PH      | TDS<br>(mg/l) | EC<br>(µs/cm) | Salinity<br>(mg/l) | Turbidity<br>(mg/l) | Temp.<br>°C | GPS READING     |                  |
|-----|--------------------|---------------|---------|---------------|---------------|--------------------|---------------------|-------------|-----------------|------------------|
|     |                    |               |         |               |               |                    |                     |             | LATITUDE        | LONGITUDE        |
| 1   | Ganaja Village     | 413           | 8.7     | 1215          | 1869          | 0.05               | 49.00               | 32.10       | N 07° 44' 33"   | E 006° 44' 33"   |
| 2   | 500 Unit           | 400           | 8.7     | 1175          | 1807          | 0.08               | 38.00               | 33.00       | N 07° 44' 56.6" | E 006° 44' 24.7" |
| 3   | 500 Unit           | 400           | 8.7     | 1174          | 1806          | 0.07               | 38.00               | 33.00       | N 07° 45' 24.7" | E 006° 44' 24.7" |
| 4   | 200 Unit           | 376           | 8.8     | 951           | 1463          | 0.09               | 26.00               | 33.40       | N 07° 45' 33.1" | E 006° 44' 21.1" |
| 5   | 200 Unit           | 120           | 8.8     | 915           | 1407          | 0.05               | 38.00               | 33.00       | N 07° 45' 48"   | E 006° 44' 15.5" |
| 6   | Phase I            | 306           | 8.8     | 1104          | 1698          | 0.11               | 56.80               | 31.80       | N 07° 47' 24.7" | E 006° 43' 22.3" |
| 7   | Phase I            | 306           | 8.7     | 1105          | 1700          | 0.11               | 57.00               | 31.10       | N 07° 47' 29.3" | E 006° 43' 33"   |
| 8   | Phase II           | 244           | 8.9     | 803           | 1235          | 0.07               | 27.00               | 33.80       | N 07° 48' 4.7"  | E 006° 41' 55.2" |
| 9   | Phase II           | 620           | 8.4     | 708           | 1089          | 0.06               | 34.00               | 34.00       | N 07° 47' 44.3" | E 006° 42' 18.6" |
| 10  | Otokiti Estate     | 332           | 8.0     | 690           | 1061          | 0.04               | 11.20               | 34.00       | N 07° 48' 18.5" | E 006° 41' 7"    |
| 11  | Army Baracks       | 180           | 8.3     | 1217          | 1872          | 0.18               | 42.00               | 34.10       | N 07° 48' 9.4"  | E 006° 40' 34.5" |
| 12  | Roja Table Water   | 612           | 8.3     | 744           | 1144          | 0.04               | 14.50               | 34.10       | N 07° 48' 32.6" | E 006° 38' 41.3" |
| 13  | Zangodaji          | 180           | 8.2     | 772           | 1187          | 0.10               | 15.00               | 33.90       | N 07° 48' 40.6" | E 006° 38' 26.1" |
| 14  | Adankolo           | 288           | 8.9     | 1537          | 2364          | 0.15               | 9.00                | 34.10       | N 07° 47' 15.6" | E 006° 44' 16"   |
| 15  | Adankolo           | 300           | 9.0     | 2000          | 3076          | 0.24               | 121.00              | 34.00       | N 07° 47' 23.5" | E 006° 44' 28.6" |
| 16  | Adankolo           | 298           | 8.9     | 2000          | 3076          | 0.16               | 8.00                | 34.00       | N 07° 47' 21.6" | E 006° 44' 17.5" |
| 17  | Adankolo           | 298           | 8.9     | 2000          | 3076          | 0.16               | 8.00                | 34.00       | N 07° 47' 33.9" | E 006° 44' 29.9" |
| 18  | Marine Road        | 189           | 8.0     | 1015          | 1561          | 0.21               | 8.00                | 30.80       | N 07° 48' 7.1"  | E 006° 44' 54.4" |
| 19  | Kasuwa Hotel       | 384           | 8.6     | 1625          | 2500          | 0.16               | 56.00               | 30.00       | N 07° 47' 50"   | E 006° 43' 55.9" |
| 20  | Kenwo Hotel        | 136           | 8.1     | 791           | 1216          | 0.09               | 13.40               | 32.10       | N 07° 48' 28.9" | E 006° 44' 55.5" |
| 21  | GRA                | 24            | 7.9     | 115           | 176           | 0.04               | 19.00               | 31.00       | N 07° 48' 24.5" | E 006° 43' 44.5" |
| 22  | New Layout         | 124           | 8.7     | 574           | 883           | 0.06               | 15.00               | 30.80       | N 07° 48' 37.8" | E 006° 44' 12.7" |
| 23  | New Layout         | 124           | 8.7     | 574           | 883           | 0.06               | 15.00               | 32.00       | N 07° 48' 37.2" | E 006° 44' 32.8" |
| 24  | Megiri             | 124           | 8.6     | 2000          | 3076          | 0.33               | 102.70              | 32.00       | N 07° 48' 45.1" | E 006° 44' 42.1" |
| 25  | Kabawa             | 160           | 9.0     | 1796          | 2763          | 0.22               | 19.00               | 30.00       | N 07° 49' 8.5"  | E 006° 44' 54.7" |
| 26  | Sarkin Noma        | 300           | 8.9     | 1459          | 2244          | 0.14               | 30.00               | 32.20       | N 07° 50' 31.3" | E 006° 44' 50"   |
| 27  | Felele             | 196           | 8.4     | 925           | 1423          | 0.28               | 47.00               | 31.10       | N 07° 51' 6.2"  | E 006° 43' 31.7" |
| 28  | Felele             | 76            | 8.5     | 1040          | 1600          | 0.18               | 13.00               | 32.00       | N 07° 51' 15.8" | E 006° 43' 21.8" |
| 29  | Felele             | 77            | 8.4     | 1040          | 1600          | 0.28               | 47.00               | 32.00       | N 07° 51' 6.6"  | E 006° 43' 24.5" |
| 30  | Behind Secretariat | 92            | 8.6     | 236           | 362           | 0.04               | 9.50                | 32.10       | N 07° 48' 37.3" | E 006° 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. °C | LATITUDE        | LONGITUDE        |
|-----|--------------------|------------|------|------------|------|-----------------|------------------|----------|-----------------|------------------|
| 1   | Ganaja             | 11.9       | 7.7  | 1250       | 1923 | 0.1             | 13               | 30       | N 07° 44' 33"   | E 006° 44' 33"   |
| 2   | 500 Unit           | 11.76      | 8.1  | 1200       | 1846 | 0.1             | 12               | 31       | N 07° 44' 56.6" | E 006° 44' 24.7" |
| 3   | 500 Unit           | 11.77      | 8.1  | 1200       | 1846 | 0.1             | 13               | 31       | N 07° 45' 24.7" | E 006° 44' 24.7" |
| 4   | 200 Unit           | 14.56      | 7.7  | 1010       | 1553 | 0.06            | 13               | 31       | N 07° 45' 33.1" | E 006° 44' 21.1" |
| 5   | 200 Unit           | 14.57      | 8.2  | 1012       | 1556 | 0.06            | 13               | 30       | N 07° 45' 48"   | E 006° 44' 15.5" |
| 6   | Phase I            | 3.92       | 8    | 876        | 1347 | 0.1             | 36               | 30       | N 07° 47' 24.7" | E 006° 43' 22.3" |
| 7   | Phase I            | 5.04       | 8    | 1001       | 1540 | 0.13            | 22               | 30       | N 07° 47' 29.3" | E 006° 43' 33"   |
| 8   | Phase II           | 8.44       | 7.8  | 800        | 1230 | 0.08            | 27               | 31       | N 07° 48' 4.7"  | E 006° 41' 55.2" |
| 9   | Phase II           | 8.96       | 7.5  | 738        | 1135 | 0.04            | 19               | 32       | N 07° 47' 44.3" | E 006° 42' 18.6" |
| 10  | Otokiti            | 1.6        | 7.5  | 794        | 1221 | 0.03            | 5                | 32       | N 07° 48' 18.5" | E 006° 41' 7"    |
| 11  | Roja               | 6.72       | 7.9  | 1232       | 1895 | 0.16            | 38               | 32       | N 07° 48' 9.4"  | E 006° 40' 34.5" |
| 12  | Roja               | 6          | 8    | 640        | 984  | 0.12            | 16               | 31       | N 07° 48' 32.6" | E 006° 38' 41.3" |
| 13  | Zangodaji          | 6.16       | 7.5  | 641        | 986  | 0.12            | 16               | 30       | N 07° 48' 40.6" | E 006° 38' 26.1" |
| 14  | Adankolo           | 10.64      | 8    | 1690       | 2600 | 0.19            | 10.5             | 32       | N 07° 47' 15.6" | E 006° 44' 16"   |
| 15  | Adankolo           | 6.72       | 7.8  | 1788       | 2750 | 0.31            | 95               | 32       | N 07° 47' 23.5" | E 006° 44' 28.6" |
| 16  | Adankolo           | 10.62      | 7.9  | 1786       | 2747 | 0.19            | 93               | 31       | N 07° 47' 21.6" | E 006° 44' 17.5" |
| 17  | Adankolo           | 10.64      | 7.9  | 1788       | 2750 | 0.19            | 10.3             | 32       | N 07° 47' 33.9" | E 006° 44' 29.9" |
| 18  | Marine             | 6.72       | 7.4  | 865        | 1330 | 0.13            | 4                | 30       | N 07° 48' 7.1"  | E 006° 44' 54.4" |
| 19  | Kasuwa             | 12.88      | 8.1  | 1520       | 2338 | 0.11            | 44               | 30       | N 07° 47' 50"   | E 006° 43' 55.9" |
| 20  | Kenwo              | 6.16       | 7.7  | 617        | 949  | 0.11            | 11               | 29       | N 07° 48' 28.9" | E 006° 44' 55.5" |
| 21  | GRA                | 6.16       | 6.6  | 94         | 144  | 0.03            | 15               | 29       | N 07° 48' 24.5" | E 006° 43' 44.5" |
| 22  | New                | 3.92       | 7.6  | 418        | 643  | 0.06            | 15               | 29.9     | N 07° 48' 37.8" | E 006° 44' 12.7" |
| 23  | New                | 8.85       | 7.6  | 400        | 615  | 0.31            | 65               | 30       | N 07° 48' 37.2" | E 006° 44' 32.8" |
|     | <b>Layout</b>      |            |      |            |      |                 |                  |          |                 |                  |
| 24  | Megiri             | 8.86       | 8.4  | 1824       | 2806 | 0.35            | 65               | 29       | N 07° 48' 45.1" | E 006° 44' 42.1" |
| 25  | Kabawa             | 5.04       | 8.1  | 1281       | 1970 | 0.21            | 10               | 30       | N 07° 49' 8.5"  | E 006° 44' 54.7" |
| 26  | Sarkin             | 6.72       | 7.4  | 922        | 1418 | 0.14            | 6                | 29.5     | N 07° 50' 31.3" | E 006° 44' 50"   |
|     | <b>Noma</b>        |            |      |            |      |                 |                  |          |                 |                  |
| 27  | Felele             | 7.84       | 7.9  | 983        | 1512 | 0.33            | 28               | 29       | N 07° 51' 6.2"  | E 006° 43' 31.7" |
| 28  | Felele             | 7.8        | 7.9  | 983        | 1512 | 0.32            | 29               | 29       | N 07° 51' 15.8" | E 006° 43' 21.8" |
| 29  | Felele             | 7.84       | 7.9  | 981        | 1509 | 0.33            | 28               | 29       | N 07° 51' 6.6"  | E 006° 43' 24.5" |
| 30  | Behind Secretariat | 3.36       | 6.9  | 113        | 173  | 0.05            | 5                | 30       | N 07° 48' 37.3" | E 006° 42' 1.5"  |
|     | <b>Mean</b>        | 8.07       | 7.77 | 1014.9     | 1560 | 0.15            | 25.89            | 30.38    |                 |                  |
|     |                    | -          | 6.5- | 1500       | 250  | -               | -                | -        |                 |                  |
|     | <b>W.H.O</b>       |            | 8.5  |            |      |                 |                  |          |                 |                  |
|     | <b>SON</b>         | -          | 6.5- | 500        | 1000 | -               | -                | Ambient  |                 |                  |
|     |                    |            | 8.5  |            |      |                 |                  |          |                 |                  |

**TCH:** Total carbonate hardness

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

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

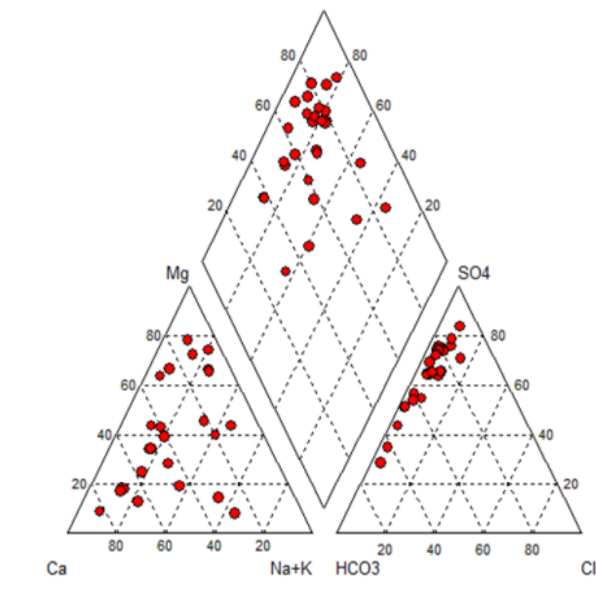


Fig. 2: Piper diagram showing water type in the study area during rainy season

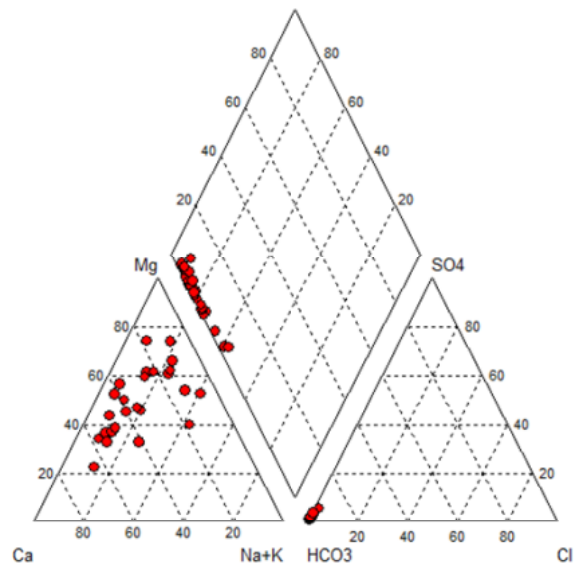


Fig. 3: Piper diagram showing water type in the study area during dry season



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

| S/<br>No. | Sample location         | Cu <sup>2+</sup><br>mg/l | Zn <sup>2+</sup><br>Mg/l | Mn <sup>2+</sup><br>mg/l | Fe <sup>2+</sup><br>mg/l | Mg <sup>2+</sup><br>mg/l | Cd <sup>2+</sup><br>mg/l | Na <sup>+</sup><br>mg/l | Pb <sup>2+</sup><br>mg/l | Cd <sup>2+</sup><br>mg/l | Cr <sup>6+</sup><br>mg/l | K <sup>+</sup><br>mg/l | DO<br>mg/l | Redox<br>(mv) | H <sub>2</sub> S<br>mg/l | Cl <sup>-</sup><br>mg/l | SO <sub>4</sub> <sup>2-</sup><br>mg/l | NO <sub>3</sub> <sup>-</sup><br>mg/l | HCO <sub>3</sub> <sup>-</sup><br>mg/l | GPS READING<br>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° 44' 33"           | E 006° 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° 44' 56.6"         | E 006° 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° 45' 24.7"         | E 006° 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° 45' 33.1"         | E 006° 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° 45' 48"           | E 006° 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° 47' 24.7"         | E 006° 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° 47' 29.3"         | E 006° 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° 48' 4.7"          | E 006° 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° 47' 44.3"         | E 006° 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° 48' 18.5"         | E 006° 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° 48' 18.5"         | E 006° 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° 00' 48.326"       | E 006° 00' 38.413" |
| 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° 48' 40.6"         | E 006° 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° 47' 15.6"         | E 006° 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° 00' 47.235"       | E 006° 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° 47' 21.6"         | E 006° 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° 47' 33.9"         | E 006° 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° 48' 7.1"          | E 006° 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° 47' 50"           | E 006° 43' 53.9"   |
| 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° 48' 28.9"         | E 006° 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° 48' 24.5"         | E 006° 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° 48' 37.8"         | E 006° 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° 48' 37.2"         | E 006° 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° 48' 45.1"         | E 006° 44' 42.1"   |
| 25        | Kabaawa (HDW)           | 0.006                    | 0.011                    | 0.034                    | 0.041                    | 3.020                    | 16.56                    | 7.0                     | 0.023                    | 0.009                    | 0.009                    | 3.00                   | 6.5        | 206           | 0.011                    | 7.0                     | 4.44                                  | 0.016                                | 28.00                                 | N 07° 49' 8.5"          | E 006° 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° 50' 31.3"         | E 006° 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° 51' 6.2"          | E 006° 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<br>(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° 51'<br>15.8" | E 006° 43'<br>21.8" |
| 29 | Felele<br>(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° 51'<br>6.6"  | E 006°<br>43'24.5"  |
| 30 | Behind<br>(HDW)   | 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° 48'<br>37.3" | E 006° 42'<br>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/<br>No. | Sample<br>location      | Cu <sup>2+</sup><br>mg/l | Zn <sup>2+</sup><br>mg/l | Mn <sup>2+</sup><br>mg/l | Fe <sup>2+</sup><br>mg/l | Mg <sup>2+</sup><br>mg/l | Ca <sup>2+</sup><br>mg/l | Na <sup>+</sup><br>mg/l | Pb <sup>2+</sup><br>mg/l | Cd <sup>2+</sup><br>mg/l | Cr <sup>6+</sup><br>mg/l | K <sup>+</sup><br>mg/l | DO<br>mg/l | Redox<br>(mv) | H <sub>2</sub> S<br>mg/l | Cl <sup>-</sup><br>mg/l | SO <sub>4</sub> <sup>2-</sup><br>mg/l | NO <sub>3</sub> <sup>-</sup><br>mg/l | HCO <sub>3</sub> <sup>-</sup><br>mg/l | GPS READING<br>LATITUDE<br>LONGITUDE |
|-----------|-------------------------|--------------------------|--------------------------|--------------------------|--------------------------|--------------------------|--------------------------|-------------------------|--------------------------|--------------------------|--------------------------|------------------------|------------|---------------|--------------------------|-------------------------|---------------------------------------|--------------------------------------|---------------------------------------|--------------------------------------|
| 1         | Ganaja Village (BH)     | ND                       | 0.03                     | 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                                | 101.0                                 | N 07° 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° 44' 56.6"                      |
| 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° 45' 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° 45' 24.7"                      |
| 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° 45' 48"                        |
| 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° 47' 15.5"                      |
| 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° 47' 29.3"                      |
| 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° 48' 4.7"                       |
| 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° 47' 44.3"                      |
| 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° 48' 18.6"                      |
| 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° 48' 9.4"                       |
| 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° 48' 34.5"                      |
| 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° 48' 40.6"                      |
| 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° 47' 15.6"                      |
| 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                                | 156.0                                 | N 07° 47' 23.5"                      |
|           |                         |                          |                          |                          |                          |                          |                          |                         |                          |                          |                          |                        |            |               |                          |                         |                                       |                                      | 0                                     | 47° 23.5' 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/<br>No. | Sample<br>location       | LATITUDE                 |                          |                          |                          |                          |                          |                         |                          |                          |                        |            |               |                          |                         |                                       |                                      | GPS<br>READING |                                       |                              |
|-----------|--------------------------|--------------------------|--------------------------|--------------------------|--------------------------|--------------------------|--------------------------|-------------------------|--------------------------|--------------------------|------------------------|------------|---------------|--------------------------|-------------------------|---------------------------------------|--------------------------------------|----------------|---------------------------------------|------------------------------|
|           |                          | Cu <sup>2+</sup><br>mg/l | Zn <sup>2+</sup><br>Mg/l | Mn <sup>2+</sup><br>mg/l | Fe <sup>2+</sup><br>mg/l | Mg <sup>2+</sup><br>mg/l | Cd <sup>2+</sup><br>mg/l | Na <sup>+</sup><br>mg/l | Pb <sup>2+</sup><br>mg/l | Cd <sup>2+</sup><br>mg/l | K <sup>+</sup><br>mg/l | DO<br>mg/l | Redox<br>(mv) | H <sub>2</sub> S<br>mg/l | Cl <sup>-</sup><br>mg/l | SO <sub>4</sub> <sup>2-</sup><br>mg/l | NO <sub>3</sub> <sup>-</sup><br>mg/l |                | HCO <sub>3</sub> <sup>-</sup><br>mg/l |                              |
| 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                                | E 006°<br>N 07°<br>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                                | E 006°<br>N 07°<br>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                                 | E 006°<br>N 07°<br>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                                 | E 006°<br>N 07°<br>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                                 | E 006°<br>N 07°<br>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                                 | E 006°<br>N 07°<br>43° 44.5" |
| 22        | New Layout (HDW)         | 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                                 | E 006°<br>N 07°<br>44° 12.7" |
| 23        | New Layout (HDW)         | 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                                 | E 006°<br>N 07°<br>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                                 | E 006°<br>N 07°<br>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                                 | E 006°<br>N 07°<br>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                                 | E 006°<br>N 07°<br>44° 50"   |
| 27        | Felele 1 (HDW)           | 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                                 | E 006°<br>N 07°<br>43° 31.7" |
| 28        | Felele 2 (HDW)           | 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                                 | E 006°<br>N 07°<br>43° 21.8" |
| 29        | Felele 3 (HDW)           | 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                                 | E 006°<br>N 07°<br>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                                 | E 006°<br>N 07°<br>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<sub>2</sub>) [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 ( $^{\circ}\text{C}$ )

The temperature of groundwater samples collected during the rainy season ranges from  $30^{\circ}\text{C}$  to  $34.1^{\circ}\text{C}$  with a mean value of  $32.45^{\circ}\text{C}$  while those collected during the dry season have a range of  $29^{\circ}\text{C}$  to  $32^{\circ}\text{C}$  with an average of  $30.38^{\circ}\text{C}$ . The values measures for all samples in both seasons are above the World Health Organization standard (WHO) while Standards Organization of Nigeria (SON) 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  $33^{\circ}\text{C}$  and  $36^{\circ}\text{C}$ , 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 ( $\text{Pb}^{2+}$ ) 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 ( $\text{Cd}^{2+}$ ) 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 ( $\text{Cr}^{+4}$ ) 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  $25^{\circ}\text{C}$  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       |

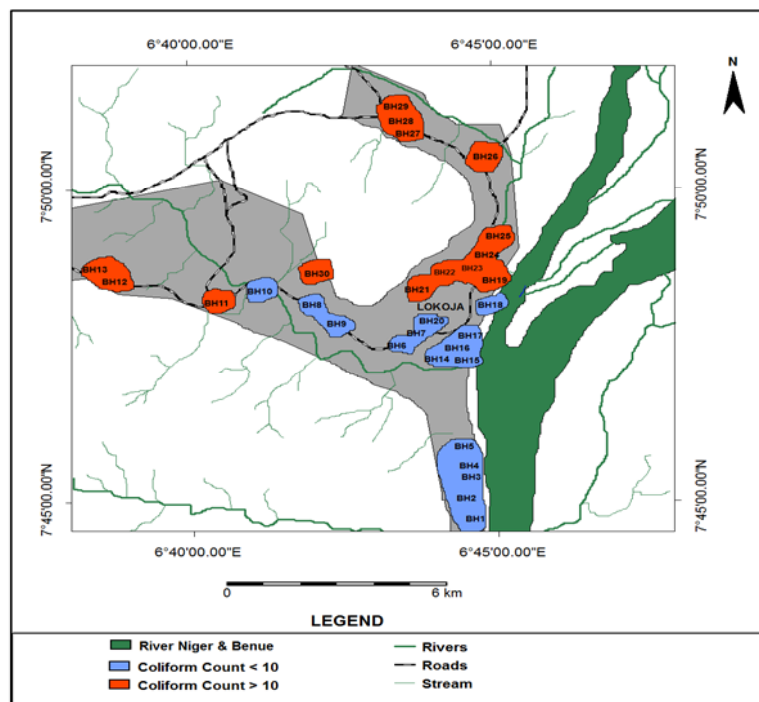


Fig.4: Distribution of Total Coliform Bacteria during the Dry Season in the study Area

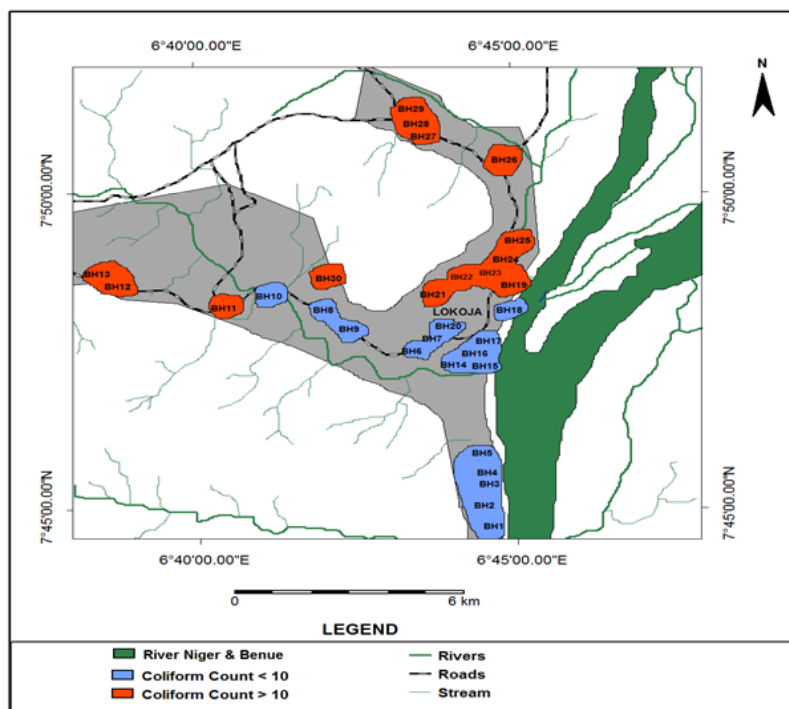


Fig.5: Distribution of Total Coliform Bacteria during the Dry Season in the study Area

## 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  $HCO_3^- > SO_4^{2-} > Cl^- > NO_3^-$ .



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