# Physico-chemical Study of Subsurface Water from Parts of Taraba State, Nigeria

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***Abstract*– Groundwater is believed to be the safest and purest of all waters and because of these, there is an over exploration and exploitation of groundwater. On irrigation fields, aquifers are dewatered, polluted by herbicide and chemical fertilizers and returned back to the subsurface. These trend posses a great threat to the future of our water resources. Therefore, there is the need to study our water resources in order to guard and manage its future effectively. This study of physico-chemistry of groundwater utilizes a total of eleven groundwater samples collected from boreholes and hand dug wells in and around Mika in Taraba State north-eastern Nigeria in order to appraise its quality for household and irrigation purposes. Sampled points were generated using Spatial Analysis and Decision Assistant (SADA) software. The area sampled falls within latitude 08° 48' to 09° 08' and longitude 11° 27' to 11° 50'. Analysis of the samples collected were carried using HACH model V2000 multi-analyte photometer and Flame photometer while interpretation of the results was carried out using RockWare Aq•QA spreadsheet for water analysis. Two water types were identified; these are Ca-Cl type in seven samples and Na-Cl type in four samples. Results recorded for Sodium Adsorption Ratio (SAR) ranges from 1.01 to 3.1, Exchangeable Sodium Ratio (ESR) 0.44 to 1.96, Magnesium hazard (MH) 5.77 to 47.4, Residual Sodium Carbonate (RSC) 0.00 and Total Dissolved Solids (TDS) ranges from 191 to 308mg/l. All the samples studied had medium salinity hazard which indicates that for farming purposes, the water will have detrimental effects on crops that are sensitive to salinity. The dissimilarity in chemical composition of the studied groundwater samples in the study area may be due to leakage of earthly salts, widespread use of chemical fertilizers and ion exchange between groundwater and the reservoir rocks. The results obtained also indicates that most of the groundwater from the study area is under saturated in calcite and aragonite with exception of sample OW11MK which was slightly saturated in calcite with mineral saturation value of -0.09249 while the determined major anion and cations falls within World Health Organization and Nigerian Standard for Drinking water Values. The studied groundwater samples show that the groundwater quality is generally suitable for household and farming purposes.**

***Keywords*–** Detrimental Effects, Sodium Adsorption Ratio (SAR), Hydro-chemistry, Exchangeable Sodium Ratio (ESR) and Saturation Index (SI)

## I. INTRODUCTION

Hydrochemical data has the potential uses for tracing the origin and history of water. Globally, the quantity and quality of groundwater reserves is diminishing day by day. Therefore any study that can aid in identifying new sources or threats that is associated with groundwater is desirous not only around the study area, but globally. In order to safeguard the future of our water resources, it is essential to study its past and present both quantitative and qualitatively because there is no life without water. This Study of hydrochemistry of groundwater from Mika and environs is mainly based on the results of the chemical analysis for the collected water samples in the study area. The area sampled falls within longitude 11° 27' - 11° 50' and latitude 08° 48' - 09° 08' (fig. 1). The composition of water changes through reactions with the environment and the natural chemistry can have an important bearing on anything living that utilizes this resources and this include human beings. Livestock and even plants, therefore, a detailed analysis of major, minor and trace constituents of groundwater is very important.

The Geology of the area comprises the crystalline basement, represented by migmatite complex comprising of poorly foliated magmatic granite and lenses of banded gneiss. The migmatite gneiss has been intruded by quartz, pegmatite vein and by porphyritic granite.

Groundwater in the crystalline basement rock is confined to pockets and patches of weathered rock and to fractures. Wells usually encounter water at shallow depths but yields are often low and subject to seasonal fluctuations. Boreholes are usually sited on basement along drainage lines where overburden is often thickest. On the basalt capped plateau the weathered zone near some of the larger streams is up to 9m thick and yields moderate amounts of water, usually 2 to 3 liter per second (Nur, et al.)

Eleven groundwater samples were collected from boreholes and hand dug wells from the study area (Fig. 1) using a standard sample collection procedures and analyzed for major, minor and trace constituents at the Center for Energy Research and Training, Ahmadu Bello University, Zaria and The Regional Groundwater Laboratory, Gombe using an Atomic Absorption Spectrophotometer and Flame

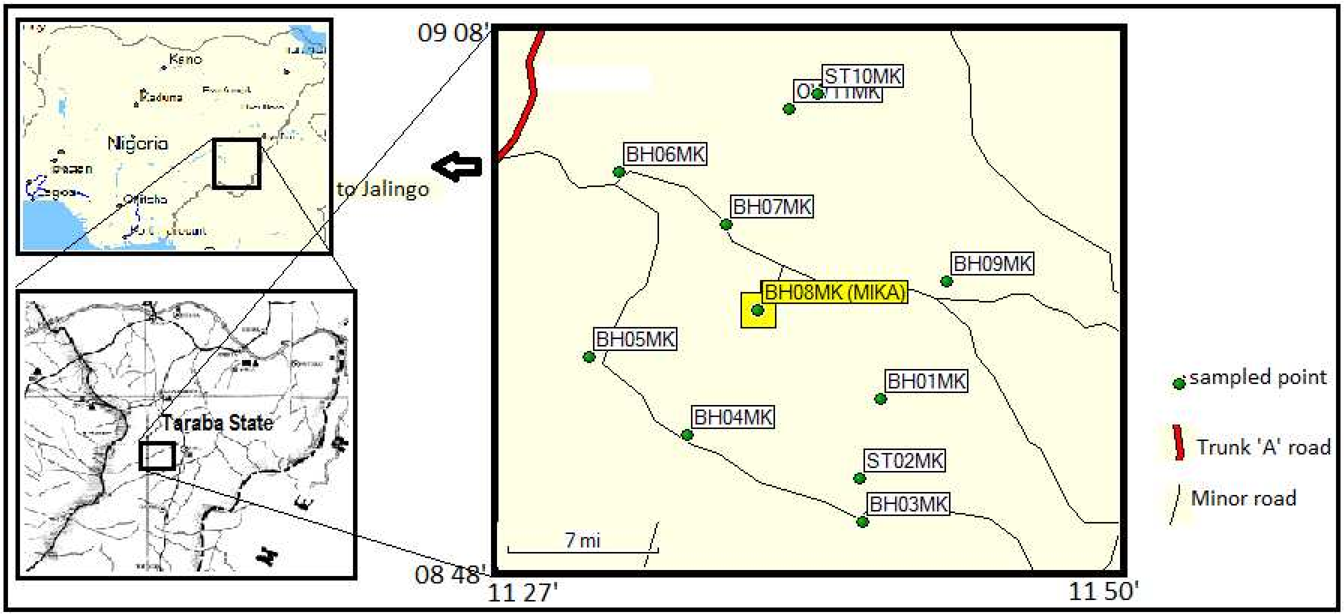


Fig. 1: Location Map of the Study Area Showing Sampled Points (MapSource, 2006)

Photometer and the data was interpreted with the help of software RockWare Aq•QA spreadsheet for water analysis to determine its suitability for use in culinary and agricultural purposes.

From the results of the analysis, two water types were identified; these are CaCl and NaCl. The results of Sodium Adsorption Ratio (SAR), Exchangeable Sodium Ratio (ESR), Magnesium hazard (MH), Residual Sodium Carbonate (RSC), and Total Dissolved Solid (TDS) ranges from 1.01 – 3.1,0.44 – 1.96, 5.77 – 47.4 and 0.00191 – 308mg/l respectively. All the samples analyzed had medium salinity which indicates that for agricultural purposes, the water has detrimental effects on crops that are sensitive to salinity. The observed variation in chemical composition of groundwater in the study area may be due to leaching of terrestrial salts, extensive use of chemical fertilizers and ion exchange between water and the host rock.

The study will be of immense importance to those charged with responsibility of providing safe drinking water to the entire populace around the area and update the knowledge of groundwater from the area for future utilization.

## II. MATERIALS AND METHOD

The water samples were collected in April, 2009 from boreholes and hand dug wells using an environmental sampler in order to have a representative sample that is free from contamination from sampling tool. After each sample was collected an in-situ measurement was made for conductivity, pH, TDS and temperature using Sension Platinum Series portable pH and Conductivity meter (HACH make). Also measured at the field are coordinates, elevation and static water level of each of the locations sampled (Table 1) using GPS and a deep meter. Samples were then stored in a plastic container after acidification with nitric acid before transporting it to the laboratory. The analysis of Si, $O_2$ and P were carried out using V2000 multi-analyte photometer, Na and K were analyzed with a CORNING FLAME PHOTOMETER 410 (after calibrating it with the analyte standard) while the remaining analyte were analyzed with a BUCK SCIENTIFIC 210 VGP ATOMIC ABSORPTION SPECTROPHOTOMETER. The results obtained was then interpreted using RockWare (2006) Aq•QA spreadsheet software for water analysis.

## III. RESULTS

The results of measurements obtained in-situ is presented in Table1. These include pH, conductivity, TDS, static water levels, coordinates of sampled locations, temperature and elevation of each point. Results of analysis of major and minor elements were used to determined water types, Sodium Adsorption Ratio (SAR), Exchangeable Sodium Ratio (ESR), Magnesium hazard (MH), Residual Sodium Carbonate (RSC), and Total Dissolved Solid (TDS). This is presented in Table 2.

A graph of TDS and conductivity is presented in Fig. 2; the plot displays show the relationship between these two parameters.

## IV. DISCUSSION

The results of chemical properties of groundwater in the study area are discussed in the following order:

a) Water types and major and minor constituents
b) Sodium Adsorption Ratio (SAR)
c) Mineral Saturation (MS)
d) Hardness
e) Residual Sodium Carbonate (RSC)
f) Total Dissolved Solid (TDS)

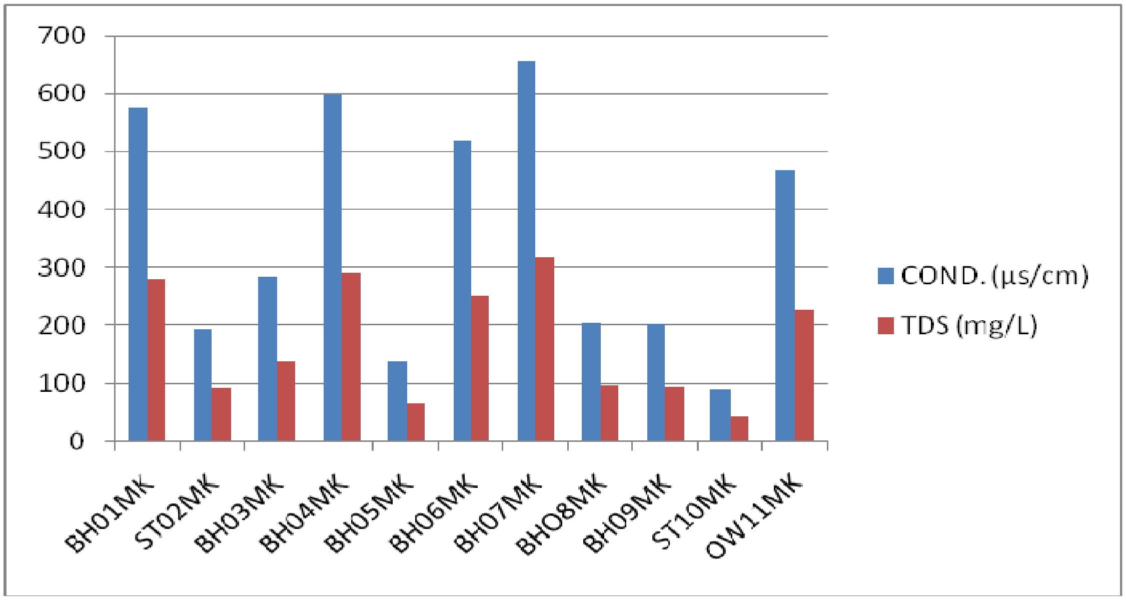


Fig. 2: A Graph of Conductivity and TDS

Table 1: Parameters Measured in-situ During Field Work

(ELEV = elevation, S.W.L =static water level, H-HEAD = hydraulic head, COND = conductivity, TEMP = temperature and TDS = total dissolved solid)

| S/N | SAMPLE ID | COORDINATES LATITUDE | LONGITUDE | ELEV (m) | S.W.L (m) | H-HEAD (m) | PH | COND. (µs/cm) | TEMPT. (˚C) | TDS (mg/L) |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | BH01MK | 08°54.965′ | 11°42.586′ | 2,378.35 | 10.36 | 2,367.99 | 6.85 | 576.00 | 31.20 | 280.00 |
| 2 | ST02MK | 08°51.728′ | 11°41.741′ | 5,010.00 | - | 5,010.00 | 7.29 | 194.80 | 32.50 | 93.20 |
| 3 | BH03MK | 08°49.989′ | 11°41.869′ | 540.11 | 9.14 | 530.96 | 6.95 | 286.00 | 29.80 | 137.40 |
| 4 | BH04MK | 08°53.486′ | 11°34.673′ | 508.10 | 10.36 | 497.74 | 7.23 | 599.00 | 30.30 | 291.00 |
| 5 | BH05MK | 08°56.649′ | 11°30.701′ | 515.42 | 11.77 | 503.65 | 6.2 | 138.10 | 30.40 | 65.80 |
| 6 | BH06MK | 09°04.129′ | 11°31.910′ | 270.05 | 10.79 | 259.26 | 6.69 | 518.00 | 31.40 | 251.00 |
| 7 | BH07MK | 09°02.000′ | 11°36.299′ | 387.71 | 8.08 | 379.63 | 7.06 | 654.00 | 30.40 | 318.00 |
| 8 | BHO8MK | 08°58.535′ | 11°37.529′ | 446.53 | 8.14 | 438.39 | 6.58 | 203.00 | 30.40 | 96.90 |
| 9 | BH09MK | 08°59.687′ | 11°45.332′ | 500.48 | 8.69 | 491.80 | 6.48 | 201.00 | 29.90 | 96.20 |
| 10 | ST10MK | 09°07.264′ | 11°40.034′ | 361.80 | - | 361.80 | 6.23 | 90.40 | 31.40 | 42.80 |
| 11 | OW11MK | 09°06.675′ | 11°38.846′ | 407.52 | 5.82 | 401.70 | 7.85 | 470.00 | 30.80 | 227.00 |

### *A. Water Type*

The analysis of water samples was used to categorize water from the study area in to two water types with formulae Ca-Cl and Na-Cl indicating Calcium and Sodium water types.

Calcium is the most abundant of alkaline earth metal and a major constituent of common rock forming minerals. Sources of calcium ($Ca^{2+}$) include calcite, aragonite, dolomite, gypsum, anhydrite, fluorite, plagioclase, pyroxene and amphibole ( Brian, et al. 1980). From health point of view, the content of calcium in groundwater is unimportant. Its concentration in natural waters is typically <15mg/l. concentration of calcium in water samples analyzed ranges from 13.2 – 49.33mg/l.

Sources of sodium are halite, sea spray, some silicate and rare minerals such as plagioclase, plagioclase variety of albite and nepheline. Most sodium in groundwater results from natural ion exchange. Sodium and potassium are common constituents of natural waters with sodium being more prevalent than potassium. From health point of view, potassium is unimportant but sodium can have negative effects on people with heart disease. Sodium hydrogen carbonate mineral waters are important for treatment of gastric and biliary tract diseases. The World Health Organization and the Nigeria Industrial Standard's Nigeria Standard for Drinking water Quality has set limit for sodium in drinking water as 200mg/l. The highest value recorded for sodium in the samples analyzed is 56.4mg/l. Except for nitrate which exceeded the limit value of 50mg/l for almost

Table 2: Major, minor elements and some chemically controlled parameters as determined in water samples from the study area

| S/N | SAMPLE ID | Na (mg/l) | K (mg/l) | $O_2$ (mg/l) | Fe (mg/l) | $NO_3$ (mg/l) | Mg (mg/l) | P (mg/l) | Si (mg/l) | Ca (mg/l) | $SO_4$ (mg/l) | $HCO_3$ (mg/l) | Cl (mg/l) | Water type | SAR | ESR | MH |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | BH01MK | 29.6±0.07 | 1.2±0.012 | 6.08±0.41 | 0.17±0.18 | 94.3±0.51 | 3.49±0.32 | 0.012±0.003 | 17.4±0.43 | 46.35±0.71 | 0.73±0.01 | 35.00±0.56 | 123.5± 0.91 | Ca-Cl | 1.13 | 0.496 | 11.1 |
| 2 | ST02MK | 56.4±0.02 | 12.6±0.12 | 6.14±0.12 | 0.02±0.001 | 72.4±0.61 | 7.21±0.02 | 0.02±0.001 | 51.2±0.21 | 13.20±1.32 | 1.75±0.021 | 6.08 ±0.02 | 143.00±0.32 | Na-Cl | 3.1 | 1.96 | 47.4 |
| 3 | BH03MK | 37.2±0.025 | 3.5±0.06 | 5.72±0.17 | 0.02±0.003 | 66.32±0.21 | 3.21±0.21 | 0.012±0.001 | 51.7±0.37 | 34.87±0.98 | 0.04±0.001 | 31.00 ±0.61 | 119.0±0.85 | Ca-Cl | 1.63 | 0.824 | 13.5 |
| 4 | BH04MK | 3407±0.04 | 3.8±0.02 | 5.81±0.12 | 0.04±0.001 | 84.3±0.23 | 3.9±0.31 | 0.03±0.001 | 24.5±0.11 | 43.42±1.02 | 0.27±0.01 | 37.00 ±0.21 | 123.5±0.32 | Ca-Cl | 1.35 | 0.607 | 12.9 |
| 5 | BH05MK | 33.5±0.03 | 3.7±0.001 | 6.03±0.23 | 0.37±0.002 | 67.3±0.21 | 4.01±0.12 | 0.05±0.001 | 41.4±0.14 | 27.00±0.64 | 0.04±0.001 | 36.00±0.03 | 109.7 ±0.92 | Na-Cl | 1.59 | 0.869 | 19.7 |
| 6 | BH06MK | 38.9±0.025 | 3.4±0.021 | 5.81±0.011 | 0.02±0.001 | 76.4±0.91 | 3.6±0.10 | 0.02±0.002 | 36.2±0.51 | 27.42±0.76 | 0.23±0.001 | 20.80±0.51 | 118.00 ±0.14 | Na-Cl | 1.85 | 1.017 | 17.8 |
| 7 | BH07MK | 33.4±0.05 | 2.7±0.057 | 5.91±0.12 | 0.013±0.005 | 109.3±0.23 | 3.75±0.54 | 0.02±0.003 | 39±0.22 | 49.33±0.92 | 0.33±0.021 | 56.90 ±0.36 | 110.8 ±0.51 | Ca-Cl | 1.23 | 0.525 | 11.1 |
| 8 | BHO8MK | 27.6±0.031 | 0.9±0.021 | 6.18±0.05 | 0.42±0.03 | 96.2±0.22 | 1.56±0.21 | 0.011±0.001 | 50.3±0.31 | 42.0±1.37 | 0.03±0.001 | 5.60 ±0.51 | 121.7 ±0.36 | Ca-Cl | 1.14 | 0.540 | 5.77 |
| 9 | BH09MK | 38.6±0.051 | 2.6±0.03 | 6.14±0.23 | 0.25±0.011 | 79.31±0.31 | 3.86±0.02 | 0.03±0.002 | 19.7±0.21 | 22.10±0.64 | 0.08±0.01 | 12.9. ±0.08 | 108.3 ±0.28 | Na-Cl | 1.99 | 1.182 | 22.4 |
| 10 | ST10MK | 29.7±0.011 | 2.5±0.10 | 5.95±0.067 | 2.03±0.01 | 76.5±0.22 | 2.46±0.03 | 0.05±0.0021 | 64.4±1.02 | 32.00±0.34 | 0.01±0.001 | 17.80±0.12 | 107.3 ±1.20 | Ca-Cl | 1.36 | 0.718 | 11.3 |
| 11 | OW11MK | 26.5±0.021 | 2.9±0.011 | 6.05±0.21 | 1.15±0.01 | 89.6±0.91 | 3.65±0.21 | 0.07±0.001 | 66.3±0.61 | 46.30±1.51 | 0.15±0.01 | 46.7 ±0.31 | 114.0 ±0.61 | Ca-Cl | 1.01 | 0.441 | 11.5 |

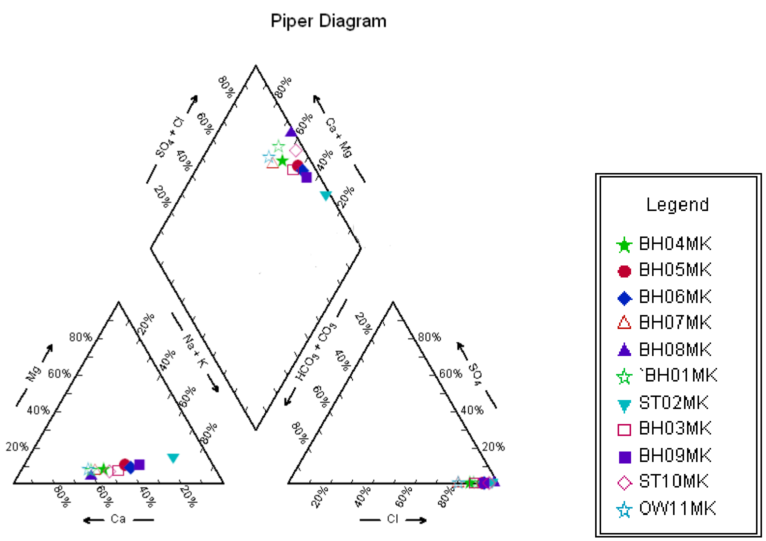


Fig. 3: Piper Diagram for Water Samples from Mika and Environs

Table 3: Sodium and Salinity Control Values (Wilcox, 1955)

| | Salinity status | Sodium status |
|---|---|---|
| <250 µohms | Low salinity water | Low sodium water |
| 250 -750 µohms | Medium salinity water | Medium sodium water |
| 750 -2250 µohms | High salinity water | High sodium water |
| >2250 µohms | Very high salinity water | Very high sodium water |

all the samples analyzed all the other parameters measured (Table 2) complied with the set standard. Nitrate levels exceeding 50mg/l in drinking water have the potential of causing cyanosis, and asphyxia (blue baby syndrome in infants less than 3 months (WHO, 2008).

### *B. Sodium Adsorption Ratio (SAR)*

Sodium Adsorption Ratio (SAR) is used to evaluate the suitability of water for irrigation. It estimates the degree to which sodium will be adsorbed by the soil. High value of SAR means that sodium in the water may replace calcium and magnesium ions in the soil, potentially causing damage to the soil structure (Lloyd, 1985). SAR is calculated from the formula;

$$SAR = \frac{[Na^+]}{\sqrt{\frac{[Ca^{2+}] + [Mg^{2+}]}{2}}}$$

### *C. Mineral Saturation (MS)*

The minerals calcite and aragonite have the same chemical composition ($CaCO_3$), but different chemical structures. The saturation index of these minerals is given as;

SI = log Q/K = log Q – log K, where Q is the ion activity product and K the equilibrium constant and this tells whether they are;

1. supersaturated ( Saturation Index > 1)
2. saturated (Saturation Index = 0) or
3. under-saturated (Saturation Index < 0)

Most of the samples analyzed are under-saturated in both calcite and aragonite with saturation values ranging from -4.34 to -0.71 for calcite and -4.89 to 0.88 for aragonite, except sample OW11MK which is approximately saturated with saturation value of -0.09.

### *D. Hardness*

Hardness is the sum of $Ca^{2+}$ and $Mg^{2+}$ concentrations expressed in terms of mg/l of calcium carbonate: Hardness of water can be determined from the relation:

Hardness = 2.5 X Ca (mg/l) + 4.1 X Mg (mg/l) (Fournier, 1981)

Calcium and magnesium form an insoluble residue with soap. The degree of hardness in water is commonly based on the classification listed in table 5(Sawyer and Mc Carty, 1967).

The analyzed groundwater samples are medium sodium waters meaning that the water is most suitable when used on coarse-textured or organic soil with good permeability and plants with good salt tolerance. The sodium hazard is a function of both SAR and Salinity. Salinity hazard dividing points are 250, 750 and 2250µohms, resulting in four categories as given in Table 3.

Table 5: Classification of Water Hardness (Sawyer and Mc Carty, 1967)

| Hardness range (mg/l of $CaCO_3$) | Water classification |
|---|---|
| 0 – 75 | Soft |
| 75 – 150 | Moderately hard |
| 150 – 300 | Hard |
| >300 | Very hard |

All groundwater samples analyzed recorded hardness value ranging from 9.16 – 93.08mg/l and from this value, ten of the eleven samples analyzed had hardness below 75mg/l indicating that the water in the study area are soft water except sample BH07MK which has hardness value of 93.08mg/l indicating moderately hard water, this sample also has the highest dissolved solids. So, all the samples analyzed passed the hardness limit set by WHO, (2008) and NIS, (2007) Nigeria Standard for Drinking Water Quality.

### *E. Residual Sodium Carbonate (RSC)*

Residual Sodium Carbonate (RSC) value considers the bicarbonate content of the water. High concentration of bicarbonate leads to an increase in pH value of water which aids dissolution of the organic matter. The increase in RSC value leads also to precipitation of calcium and magnesium which can cause an increase in sodium content in the soil. The high concentration of bicarbonate ion in irrigation water leads to its toxicity and affects the mineral nutrition of plants.

According to Eaton's classification, water with RSC greater than +2.5epm is considered unsuitable for irrigation. The water with RSC of +1.25 to +2.5 is considered as marginal and those with a value less than +1.25 are safe for irrigation purpose. All the water samples analyzed had RSC values of less than 1.25 meaning that the water is suitable for irrigation purposes.

### *F. Total Dissolved Solid (TDS)*

The increase in dissolved solids in irrigation water affects soil efficiency and growth and yield of plants. For long term irrigation under average conditions the total dissolved solids should not exceed 2000mg/l. High increase in water salinity increases salts amount in soil and leads to salinization problem. Classification of water according to TDS values (Wilcox, 1955) is given in Table 4.

### G. *Graphical Presentation of Data*

Piper diagram is a combination of anions and cations triangle that lies on a common baseline. It divides waters into basic types according to their placement near the four corners of the diamond. Water that plots at the top of the diamond is high in $Ca^{2+}$ + $Mg^{2+}$ and $HCO_3^-$ and defines the region of waters with temporary hardness. Waters plotted at the lower corner is the diamond is composed primarily of $Na^+$ + $K^+$ and $HCO_3^-$ + $CO_3^{2-}$. The plot according to this arrangement is presented in Figure 3 where three classes of combinations were obtained. The Schoeller diagram represents the combination of major and minor constituents of groundwater in the study area in a diagram (Fig. 4) and the result obtained indicates that Cl is dominant and $SO_4$ as the least in the following order: Cl, Na + K, Ca, Mg, $HCO_3$,+ $Co_2$ then $SO_4$.

The highest TDS value recorded in the examined groundwater samples is 318mg/l and the lowest is 42mg/l which indicates that based on TDS categorization, the water samples analyzed is good for irrigation purpose.

Table 4: Classification of Irrigation Water Base on TDS Value (Wilcox, 1955)

| TDS (mg/l) | Status |
|---|---|
| 200–500 | Best quality water |
| 1000–2000 | Water involving Hazard |
| 3000-7000 | Used for irrigation only with leaching and perfect drainage |

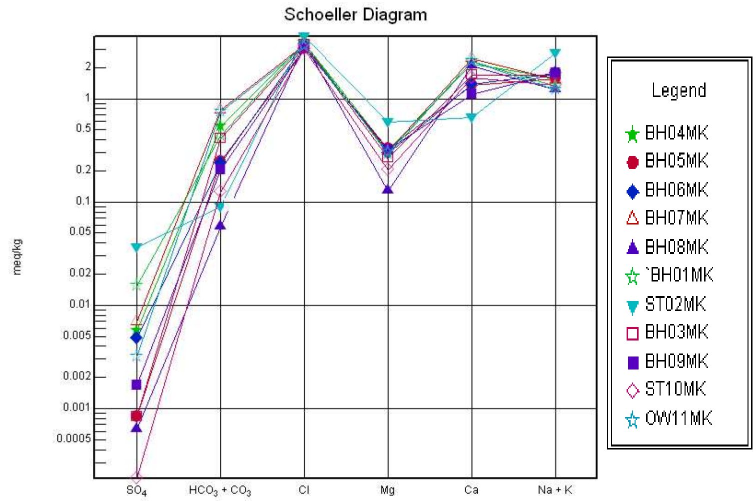


Fig. 4: Schoeller Diagram for Water Samples from Mika and Environs

## V. CONCLUSIONS

The results of analysis and evaluation of groundwater from Mika and environs for culinary and agricultural purpose indicates that whereas the status of the samples based on salinity and sodium hazard (medium) favors most soils and plants with certain properties (coarse-textured or organic soil with good permeability and plants with good salt tolerance). The results of TDS, RSC indicates that the water is good for irrigation purposes and based on WHO, (2008) and NIS, (2007, the water is good for drinking and other culinary purposes except the higher concentration recorded for nitrate which can cause blue baby syndrome in infants less than three months old. Base on these findings, the groundwater samples analyzed is generally suitable for use in homes and for agricultural purposes.

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