*FUDMA Journal of Sciences (FJS)*
*ISSN online: 2616-1370*
*ISSN print: 2645 - 2944*
*Vol. 7 No. 6, December (Special Issue), 2023, pp 6 - 13*
*DOI: https://doi.org/10.33003/fjs-2023-0706-2162*

# ASSESSMENT OF POSSIBLE WATER CONTAMINATION IN SHALLOW WELLS OF SULEJA AND ITS ENVIRON NORTH CENTRAL, NIGERIA

***[1]Shuaibu Ahmed Mahi, [2]Bello A. S. and [2]Usman A. A.**

[1]Department of Geology, Faculty of Science, Federal University Gusau, Zamfara
[2]Geography Department, School of Physical Science, Federal University of Technology, Minna

*Corresponding authors' email: mahalkufr@gmail.com

**ABSTRACT**

This research work aimed at assessing the waste dump impacts on shallow groundwater physico-chemical and biological constituents of Suleja area. Groundwater samples were collected monthly at different locations within the study area. Forty-three (43) samples were collected during the dry season while forty-two (42) samples were collected for the wet season at the same samples locations for standard water quality laboratory analysis. The data sets obtained from the laboratory were subjected to descriptive statistics and Anova test to establish their relationship, including water quality index were calculated. The hydrochemical results revealed mean concentrations of physical parameters in the following order: Conductivity > TH > TDS > Alk > T > pH for the dry season while total dissolve solids range higher to that of total hardness concentrations during the wet season (Conductivity > TDS > TH > Alk > Temp. > pH). The minor ionic distributions revealed higher mean concentration of Sulphate ion followed by chloride, bicarbonate, carbon dioxide, and nitrate ions ($SO_4$ > $Cl^-$ > $HCO_3$ > $CO_2$ > $NO_3$) for the both seasons. The major ionic enrichment is in the following order: $Ca^{2+}$ > $Mg^{2+}$ > $Na^+$ > $K^+$) for the both seasons. The heavy metals ions revealed high mean concentration of iron followed by zinc, manganese, and copper during the dry season while concentration of manganese preceded that of zinc during the wet season. Both chemical oxygen demand and biological oxygen demand indicated similar concentrations trends through-out the seasons. Hydrochemical result depict average degree of temperature, sulphate ($SO_4$), iron ($Fe^{2+}$) and manganese ($Mn^{2+}$), total hardness to have range above their standard permissible limit for drinking or domestic water quality by World Health Organisation. There is variability noticed during seasonal parametric comparison which indicate that seasonal variation has significant impact on some ionic enrichment. Correlation matrix revealed strong relationship between pH, TH (total hardness), $SO_4$, $NO_3$, $Cl^-$, $Mg^{2+}$ and $Ca^{2+}$ and positive connectivity between $Na^+$ and $K^+$. All this suggest that major sources of the solute are from weathering of lithological framework and impact from anthropogenic activities. The type of water that predominate the study area is Ca + Mg-$SO_4$ type based on hydrochemical facies classification plot for both dry and wet seasons.

**Keywords**: Hydrochemistry, Water Quality Index, Hydrochemical Facies, Basement Complex, Suleja

## INTRODUCTION

The proliferation of waste dumps in urban and sub-urban areas in Nigeria has become a growing menace to humans and natural ecosystems. Pollution of groundwater has been reported for a number of urban aquifers throughout the world because of its overwhelming environmental significance (Aguwamba, 2003).

Population growth, rising standards of living, rapid pace of urbanization and industrialization pose many environmental challenges for large cities. They have contributed to an increase in the amount and type of solid wastes generated by different human activities. Nigerians, particularly those living in the urban areas, are now having constant memories of huge heaps of garbage in open spaces, as they have to cover their noses against all forms of odor when passing by the heaps. The quality of water and its attendant health implications is also a source of worry for the citizens of such areas (Ikem *et al.,* 2002; Ahmed and Suleiman, 2001; Nkwocha *et al.,* 2011; Fatta *et al.,* 1999; Gallorini *et al.,* 1993; Robinson and Gronow 1992; Khan *et al.,* 1990).

There is a general concern about the rate heterogeneous waste is generated and the volume and types which is on the increase in the country's cities.

Lithological framework, anthropogenic impacts and aquifer solution kinetics are the major factors that influence the constituents of the groundwater chemistry (Shuaibu and Abdullahi, 2015; Abdullahi and Alagbe, 2004). Understanding the quality of groundwater with its temporal and seasonal variation is important because it is the factor that determines the suitability for drinking, domestic, agricultural and industrial purposes (Shuaibu *et al.,* 2020).

Thus, this research work intends to investigate the possible effect of waste dump on the quality of groundwater in Suleja metropolis.

### Description of the Study area

The study was conducted in Suleja town, the Headquarters of Suleja Local Government Area of Niger State, Nigeria. It is located specifically on Latitude N 09° 11´ 30 and 09° 06´ 30 with Longitude E 07° 10´ 00 and 07° 13´ 00 and about 20 km north of Abuja the Federal Capital of Nigeria. It is about 100km North East of Minna the administrative headquarters of Niger State (Figure, 1). Suleja enjoys sub-humid climatic condition with annual rainfall of 1640mm and a raining season of over 7 months in a year. There is a single maximum in the rainfall regime usually in the month of August.

Two litho-stratigraphic rock units were identified in Suleja area, which are granite and Gneissic rock units, belong the basement complex rock suits.

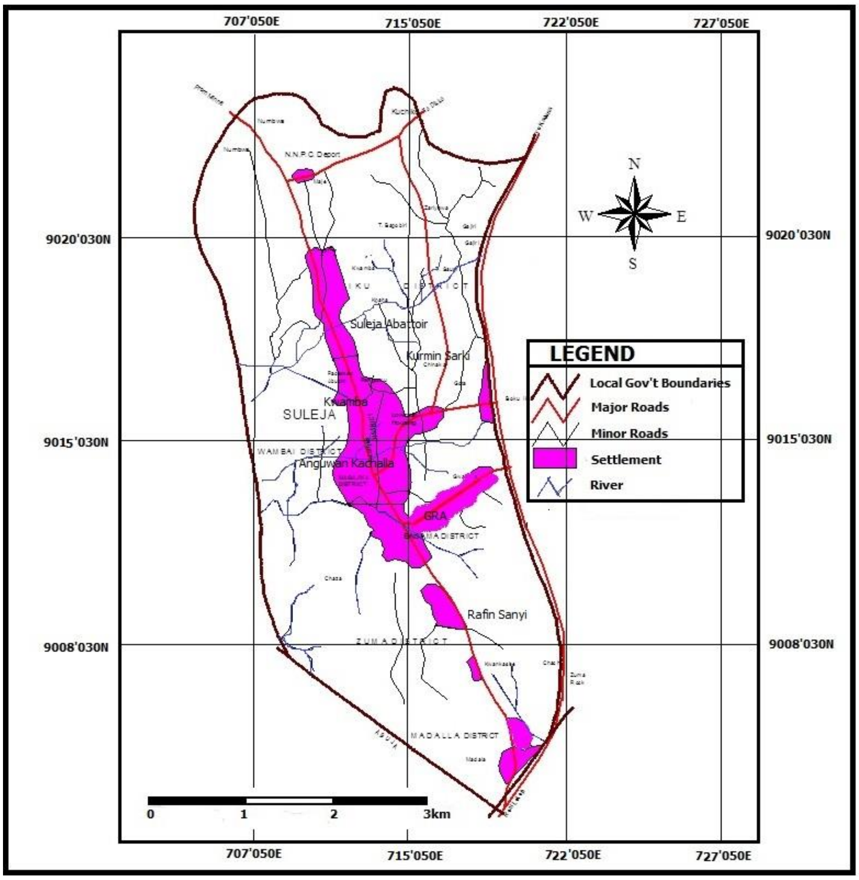


Figure 1: Map of the study Area

## MATERIALS AND METHODS

### Field Sampling Procedure

This research covered both dry and rainy seasons for optimum or maximum results. About 85 representative groundwater samples for both the dry and rainy seasons (43 and 42) respectively from shallow (hand-dug well) in different locations were collected. The targeted wells were the ones that high population of communal inhabitant of the area were concentrated on for their basic water needs. Systematic approach was adopted during the sampling exercise; we commence the field sampling processes in the month of November, and end the whole process October, for each month seven groundwater samples were picked from the field with same or constant locations within the study area (Table 1) in order to monitor complete cycle seasonal variation from those hand-dug wells, the samples collected were prepared with standard necessary procedure for laboratory analysis.

**Table 1: Groundwater Sample Location of the Study Area**

| Sample Locations | | Easting | Northing |
|---|---|---|---|
| Kwamba Maje | 32 | 299147 | 1019149 |
| Kurmin Sarki | 32 | 299347 | 1016747 |
| Angwan Kachala | 32 | 299633 | 1014818 |
| Magajia | 32 | 299820 | 1014994 |
| Rafin Sayin | 32 | 303130 | 1011186 |
| Bagama | 32 | 300698 | 1014586 |
| GRA | 32 | 300443 | 1016510 |

Each sample were analyzed for pH, Ec, TDS, COD, BOD, chloride, nitrate, sulphate, bicarbonate, sodium, potassium, magnesium and calcium. It also included the heavy metals such as iron (Fe), copper (Cu), lead (Pb), zinc (Zn) and chromium. The results obtained from physico-chemical analysis were subjected to critical multivariate statistical analysis.

One litre plastic rubbers were used to collect the samples, dry washed and rinsed with the water samples before filling it to capacity and then labeled accordingly. The sample from the same source was divided and submits as blind duplicate to access accuracy/precision of the laboratory. The physical parameters (pH, EC, TDS) were determined in the field (*in situ*) using standard equipment. After the collection, the samples were stored in a cool box and taking to the Federal University of Technology, Minna water quality laboratory for the analyses.

### Geo-statistical Techniques

#### *Water Quality Index*

Water quality index (WQI) is one of the most effective tools to communicate information on the quality of water to the concerned citizens and policy makers. It thus, becomes an important parameter for the assessment and management of surface water and groundwater. WQI is a scale used to estimate an overall quality of water based on the values of the water quality parameters (Amadi, 2011). It is a rating reflecting the composite influence of different water quality parameters. WQI is calculated from the point view of the suitability of groundwater for human consumption (Lambarkis *et al*., 2004, Amadi, 2010).

**Calculation of WQI**

The Water Quality Index (WQI) was calculated using the Weighted Arithmetic Index method. The quality rating scale for each parameter qi was calculated by using this expression: qi = (Ci / Si ) x 100

A quality rating scale (qi) for each parameter is assigned by dividing its concentration (Ci) in each water sample by its respective standard (Si) and the result multiplied by 100 Relative weight (Wi) was calculated by a value inversely proportional to the recommended standard (Si) of the corresponding parameter: Wi = 1/Si The Overall Water Quality Index (WQI) was calculated by aggregating the quality rating (Qi) with unit weight (Wi) linearly.

$WQI = \sum_{n=1}^{i=n} qiwi$

Where: qi: the quality of the ith parameter, wi: the unit weight of the ith parameter and n: the number of the parameter considered. Generally, WQI were discussed for a specific and in-tended use of water. In this study the WQI for drinking purposes is considered and permissible WQI for the drinking water is taken as 100. Table 2 shows various ranges of WQI classification scheme.

$$\text{Overall WQI} = \frac{\sum qiwi}{\sum wi}$$

**Table 2: Standard water quality classification scheme based on WQI value**

| Water Quality Value | Water Quality | Water Sample % |
|---|---|---|
| < 50 | Excellent | 12 |
| 50 - 100 | Good Water | 26 |
| 100 - 200 | Poor Water | 35 |
| 200 - 300 | Very Poor | 17 |
| > 300 | Unsuitable for drinking | 10 |

## RESULTS AND DISCUSSION

**Groundwater Quality Assessment for both Wet and Dry Seasons**

The statistical distributions of groundwater physic-chemical and biochemical parameters for the seven point samples location within the study area for the dry and rainy seasons are presented in Tables 3 and 4.

**Table 3: Samples Locations Mean Concentrations of Groundwater Parameters for the Dry Season**

| Parameters/Locality Name | Kwamba | Kurmin Sarki | Agwan Kachala | Magajia | Rafin Saying | Bagama | GRA |
|---|---|---|---|---|---|---|---|
| Temperature | 30.6667 | 31 | 30.8333 | 30 | 30.5 | 30.5 | 30.8571 |
| pH | 6.8833 | 6.9017 | 6.9567 | 6.9867 | 6.8917 | 6.745 | 6.82 |
| TDS | 115.68 | 79.5983 | 115.87 | 128.52 | 33.0733 | 75.1783 | 54.1229 |
| Conductivity | 935 | 636.67 | 831.67 | 1025 | 266.5 | 566.33 | 395.71 |
| TH | 215 | 167 | 283.67 | 369 | 123.67 | 140.58 | 132 |
| Alkalinity | 151 | 77.8333 | 121.33 | 114.17 | 66.3333 | 54.8333 | 58 |
| COD | 7.1667 | 7.1667 | 6.3333 | 7 | 7 | 6.3333 | 8.2857 |
| BOD | 2.1667 | 2.1667 | 2.6667 | 2.5 | 2.1667 | 2 | 3.2857 |
| $Cl^-$ | 126.6 | 125.84 | 128.42 | 187.24 | 66.8333 | 92.2417 | 56.6743 |
| $HCO_3^-$ | 75.5717 | 38.6733 | 60.2167 | 56.44 | 35.1183 | 25.6183 | 27.43 |
| $SO_4^-$ | 160.99 | 98.3467 | 123.57 | 117.91 | 43.38 | 147.28 | 156.08 |
| $PO_4^-$ | 0.0967 | 0.0783 | 0.1267 | 0.1033 | 0.0967 | 0.1167 | 0.1157 |
| $CO_2$ | 9.185 | 9.8983 | 10.865 | 14.1067 | 14.4483 | 32.5433 | 13.5771 |
| $NO_3^-$ | 0.1283 | 0.0933 | 0.0933 | 0.2433 | 0.0883 | 0.1067 | 0.09 |
| $Na^{2+}$ | 12.5633 | 12.0617 | 11.3433 | 12.2767 | 13.21 | 11.495 | 12.5686 |
| $K^+$ | 7.2183 | 6.8867 | 6.125 | 7.6167 | 7.5617 | 9.59 | 9.2971 |
| $Mg^{2+}$ | 52.1733 | 40.695 | 70.0833 | 90.8217 | 31.73 | 33.9883 | 31.6971 |
| $Ca^{2+}$ | 89.5633 | 70.2617 | 116.7 | 153.27 | 57.32 | 61.555 | 54.4314 |
| $Mn^{2+}$ | 0.0167 | 0.015 | 0.0233 | 0.02 | 0.025 | 0.0133 | 0.0129 |
| $Cu^{2+}$ | 0.0083 | 0.01 | 0.0067 | 0.0167 | 0.0067 | 0.01 | 0.02 |
| $Zn^{2+}$ | 0.1833 | 0.145 | 0.1433 | 0.1517 | 0.1583 | 0.1633 | 0.2671 |
| $Fe^{2+}$ | 0.2883 | 0.5283 | 0.4267 | 0.36 | 0.4733 | 0.7683 | 0.6014 |
| $Pb^{2+}$ | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| $Cr^{2+}$ | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

**Table 4: Samples Locations Mean Concentration of Groundwater Parameters for the Rainy Season**

| Parameters/Locality Name | Kwamba | Kurmin Sarki | Agwan Kachala | Magajia | Rafin Saying | Bagama | GRA |
|---|---|---|---|---|---|---|---|
| Temperature | 29.5 | 29.8333 | 29.8333 | 29.8333 | 29.8333 | 29.5 | 29.5714 |
| pH | 6.7717 | 6.26 | 6.6233 | 6.58 | 7.1667 | 6.43 | 6.44 |
| TDS | 187.26 | 137.97 | 207.44 | 237.22 | 42.8433 | 173.2 | 136.48 |
| Conductivity | 1112.3 | 747 | 1167.8 | 1128.2 | 172.17 | 763.33 | 733 |
| TH | 213 | 124.33 | 217 | 206.33 | 71.6667 | 152.33 | 113.71 |
| Alkalinity | 146 | 36.8333 | 91 | 138.50 | 55.6667 | 47.8333 | 47.1429 |
| COD | 7.8333 | 8.75 | 8.1667 | 7.5 | 7.1333 | 7 | 7 |
| BOD | 3 | 3.3333 | 2.6667 | 2.15 | 2.8333 | 2.2667 | 2.7857 |
| $Cl^-$ | 90.6 | 63.15 | 65.305 | 45.8533 | 28.1067 | 49.3367 | 68.0129 |
| $HCO_3^-$ | 71.475 | 16.29 | 43.5667 | 67.8233 | 35.0867 | 34.2583 | 26.0843 |
| $SO_4^-$ | 150.97 | 110.87 | 124.13 | 141.03 | 90.5667 | 100.91 | 156.19 |
| $PO_4^-$ | 0.125 | 0.1333 | 0.1367 | 0.1217 | 0.1083 | 0.1267 | 0.2371 |
| $CO_2$ | 6.6317 | 8.2767 | 7.0617 | 10.615 | 5.11 | 5.6133 | 8.7486 |
| $NO_3^-$ | 0.24 | 0.1967 | 0.2183 | 0.1967 | 0.1633 | 0.1667 | 0.2043 |
| $Na^{2+}$ | 8.8817 | 6.7617 | 8.2333 | 7.68 | 9.0667 | 9.29 | 10.5043 |
| $K^+$ | 6.6267 | 7.1567 | 6.12 | 8.5533 | 6.2417 | 10.9883 | 9.6043 |
| $Mg^{2+}$ | 44.16 | 26.9333 | 47.5333 | 44.4167 | 14.3667 | 31.0633 | 23.2257 |
| $Ca^{2+}$ | 77.045 | 46.55 | 82.835 | 76.86 | 26.3583 | 55.9833 | 42.5843 |
| $Mn^{2+}$ | 0.0083 | 0.0117 | 0.17 | 0.18 | 0.51 | 0.5033 | 0.4329 |
| $Cu^{2+}$ | 0.0083 | 0.0067 | 0.0067 | 0.0167 | 0.0033 | 0.0183 | 0.0143 |
| $Zn^{2+}$ | 0.0883 | 0.0967 | 0.0883 | 0.1217 | 0.1267 | 0.1033 | 0.1271 |
| $Fe^{2+}$ | 0.2533 | 0.2733 | 0.315 | 0.255 | 7.115 | 0.36 | 0.3686 |
| $Pb^{2+}$ | 0 | | 0 | 0 | 0 | 0 | 0 |
| $Cr^{2+}$ | 0 | | 0 | 0 | 0 | 0 | 0 |

The degree of temperature ranges above the ideal standard for groundwater temperatures value which supposed to be at 25 C in all the seven wells stations that was sampled for both seasons. There is 1°C indication of temperature variations for the both seasons. This might cause fluctuation in pH value of the groundwater of the area, which is very evident in the minimum and maximum value of pH recorded. However, the general mean average concentration of the pH shows that the groundwater through -out the seven wells station revealed neutrality nature of the aquifer chemistry. There is no significant change in the concentration of pH value from the both seasons.

Conductivity increases during the rainy season in all sample locations, which indicate dilution and dissolution of mineral matter into groundwater as a result of precipitation and run-off during the rainy season.

Total hardness revealed similar trending for both seasons, there is high level hardness noticed through-out the sample stations. Chemical oxygen demand and biological oxygen demand show slight increase in concentrations during the rainy season compared to that of dry season in somewhat all the sample locations.

Chloride ion mean concentration is noticed to be high during the dry seasons through-out the area compare to that of rainy season concentrations, this may be due to high temperature degree witnessed during the season which most have cause the moderate-high evaporate rate of groundwater, resulting to the precipitation effect of chloride ions. Sulphate ion concentrations did reveal much seasonal variations it tends to follow the similar trends during the two seasons. Nitrate concentration for both seasons in virtuously all the sample stations revealed low level presence in the aquifer constituent. Calcium and magnesium concentrations were noticed to be very high during the dry season in virtuously all the sample locations compare to their concentrations during the rainy seasons. Their enrichment is dominantly through natural weathering of lithologic minerals constituents and anthropogenic sources. The hardness of groundwater which may be noticed by the domestic users will be more during the dry season to that of the rainy season, as both ions will react to sulphate ion present in the groundwater aquifer to form $CaSO_4$ and $MgSO_4$ concentration which will precipitate due to high evaporation, thus resulting to high rate of its total hardness.

Generally, there is low level of heavy metals enrichment in all the sample stations except iron concentration. Iron show highest concentration during rainy season particularly in sample location “Rafin Saying” where it rages up to 7.12mg/l this might not be unconnected to the leachate discharges from final open waste dumpsite located in that area.

Table 5 revealed significant effect in the seasonal parametric comparison (season + Month + Parameter) because the P-value is less than (< 0.05). R squared value indicated that the model accounted for 73.7% while the remaining percentage is due to other factors not explained in the model. In nut shell the factors that responsible for the enrichment of solute is primarily lithology and climate condition of the area including some influence from the anthropogenic sources.

**Table 5: Tests of Between-Subjects Effects (Dependent Variables: Observation)**

| Source | Type III Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|
| Corrected Model | 48206242.978a | 280 | 172165.153 | 21.424 | 0.000 |
| Intercept | 8644135.31 | 1 | 8644135.31 | 1075.672 | 0.000 |
| Season | 2077.406 | 1 | 2077.406 | 0.259 | 0.611 |
| Month | 17332.226 | 5 | 3466.445 | 0.431 | 0.827 |
| Parameter | 45417139.57 | 23 | 1974658.242 | 245.725 | 0.000 |
| Season * Month | 78120.229 | 5 | 15624.046 | 1.944 | 0.084 |
| Season * Parameter | 922060.779 | 22 | 41911.854 | 5.215 | 0.000 |
| Month * Parameter | 587310.485 | 115 | 5107.048 | 0.636 | 0.999 |
| Season * Month * Parameter | 1589248.131 | 109 | 14580.258 | 1.814 | 0.000 |
| Error | 14135384.66 | 1759 | 8036.034 | | |
| Total | 71177058.44 | 2040 | | | |
| Corrected Total | 62341627.64 | 2039 | | | |

a. R Squared = .773 (Adjusted R Squared = .737)

**Water Quality Index Analysis for the Dry Season Analysis**

**Table 6: Computed WQI values of the Dry Season for the study area**

| Parameters | $C_i$ | $S_i$ | $q_i$ | $w_i$ | $q_iw_i$ |
|---|---|---|---|---|---|
| pH | 6.8856 | 7.5 | 91.808 | 0.1333333 | 12.241067 |
| Totatal Disolve Solids (TDS) | 84 | 500 | 16.8 | 0.002 | 0.0336 |
| Conductivity (µs/cm) | 655 | 1000 | 65.5 | 0.001 | 0.0655 |
| Total Hardness (mg/l) | 202.7 | 200 | 101.35 | 0.005 | 0.50675 |
| COD (mg/l) | 6.977 | 10 | 69.77 | 0.1 | 6.977 |
| BOD (mg/l) | 2.326 | 6 | 38.766667 | 0.1666667 | 6.4611111 |
| $Cl^-$ (mg/l) | 111.27 | 250 | 44.508 | 0.004 | 0.178032 |
| $HCO_3^-$ | 48.3 | 100 | 48.3 | 0.01 | 0.483 |
| $SO_4^-$ | 120.57 | 100 | 120.57 | 0.01 | 1.2057 |
| $PO_4$ | 0.10395 | 5 | 2.079 | 0.2 | 0.4158 |
| $CO_2$ | 14.88 | 100 | 14.88 | 0.01 | 0.1488 |
| $NO_3$ | 0.117 | 50 | 0.234 | 0.02 | 0.00468 |
| $Na^+$ | 12.091 | 200 | 6.0455 | 0.005 | 0.0302275 |
| $K^+$ | 7.647 | 100 | 7.647 | 0.01 | 0.07647 |
| $Mg^{2+}$ | 49.97 | 150 | 33.313333 | 0.0066667 | 0.2220889 |
| $Ca^{2+}$ | 85.75 | 200 | 42.875 | 0.005 | 0.214375 |
| $Mn^{2+}$ | 0.01814 | 0.2 | 9.07 | 5 | 45.35 |
| $Cu^{2+}$ | 0.01116 | 1 | 1.116 | 1 | 1.116 |
| $Zn^{2+}$ | 0.1749 | 3 | 5.83 | 0.3333333 | 1.9433333 |
| $Fe^{2+}$ | 0.5033 | 0.3 | 167.76667 | 3.3333333 | 559.22222 |
| $Pb^{2+}$ | 0 | 0.01 | 0 | 100 | 0 |
| $Cr^{2+}$ | 0 | 0.05 | 0 | 20 | 0 |

**Table 7: Computed WQI values of the Rain Season for the study area**

| Parameters | Ci | Si | Qi | wi | qiwi |
|---|---|---|---|---|---|
| pH | 6.5981 | 7.5 | 87.974 | 0.133 | 88.108 |
| TDS | 162.22 | 500 | 32.444 | 0.002 | 32.44 |
| Conductivity | 835.90 | 1000 | 83.59 | 0.001 | 83.59 |
| TH | 157.33 | 200 | 78.665 | 0.005 | 78.67 |
| COD | 7.6738 | 10 | 76.738 | 0.1 | 76.83 |
| BOD | 2.7381 | 6 | 45.635 | 0.166667 | 45.80 |
| $Cl^-$ | 58.3857 | 250 | 23.354 | 0.004 | 23.35 |
| $HCO_3^-$ | 41.9314 | 100 | 41.931 | 0.01 | 41.94 |
| $SO_4^-$ | 124.35 | 100 | 124.35 | 0.01 | 124.36 |
| $PO_4^-$ | 0.1438 | 5 | 2.876 | 0.2 | 3.076 |
| $CO_2$ | 7.3402 | 100 | 7.340 | 0.01 | 7.35 |
| $NO_3^-$ | 0.1988 | 50 | 0.397 | 0.02 | 0.41 |
| $Na^{2+}$ | 8.4831 | 200 | 4.241 | 0.005 | 4.24 |
| $K^+$ | 7.8321 | 100 | 7.832 | 0.01 | 7.84 |
| $Mg^{2+}$ | 33.1433 | 150 | 22.095 | 0.007 | 22.10 |
| $Ca^{2+}$ | 58.3017 | 200 | 29.150 | 0.005 | 29.15 |
| $Mn^{2+}$ | 0.2695 | 0.2 | 134.75 | 5 | 139.75 |

| | | | | | |
|---|---|---|---|---|---|
| $Cu^{2+}$ | 0.0107 | 1 | 1.07 | 1 | 2.07 |
| $Zn^{2+}$ | 0.1052 | 3 | 3.506 | 0.333 | 3.84 |
| $Fe^{2+}$ | 1.2786 | 0.3 | 426.2 | 3.333 | 429.53 |
| $Pb^{2+}$ | 0 | 0.01 | 0 | 100 | 100 |
| $Cr^{2+}$ | 0 | 0.05 | 0 | 20 | 20 |

All the physical, chemical, and biochemical parameters analyzed were used to calculate the WQI in accordance with the procedures explained above and contained in the table 6 and 7. The computed overall WQI value are 4.89 and10.47 for the dry and rainy seasons respectively and this means that the groundwater in the area falls within the excellent quality as contained in table 3.

$$\text{Overall WQI (Dry season)} = \frac{\sum qiwi}{\sum wi} = \frac{636.895}{130.355} = 4.89$$

$$\text{Overall WQI (Wet season)} = \frac{\sum qiwi}{\sum wi} = \frac{1364.498}{130.3553} = 10.47$$

**Hydrochemical Facies Classifications**

The concept of hydrochemical facies was developed to understand and identify the nature of water composition in different classes. Hydrochemical facies are distinct zones of cations and anions concentration categories. The results of cations and anions constituent were subjected to Piper trilinear diagram in Figures 2 and 3, it revealed 90% of the samples plotting under Mg – type for cation concentration while 90% of the samples falling under $SO_4$ – type for anion concentration. Essentially the groundwaters of the study area are Mg-$SO_4$ facies and Ca-Cl facies of water-types, predominantly gypsum groundwater for both dry and wet season samples. This revealed that seasonal variation in the water chemistry has little or no significant impact in the hydrochemical facies of the water types.

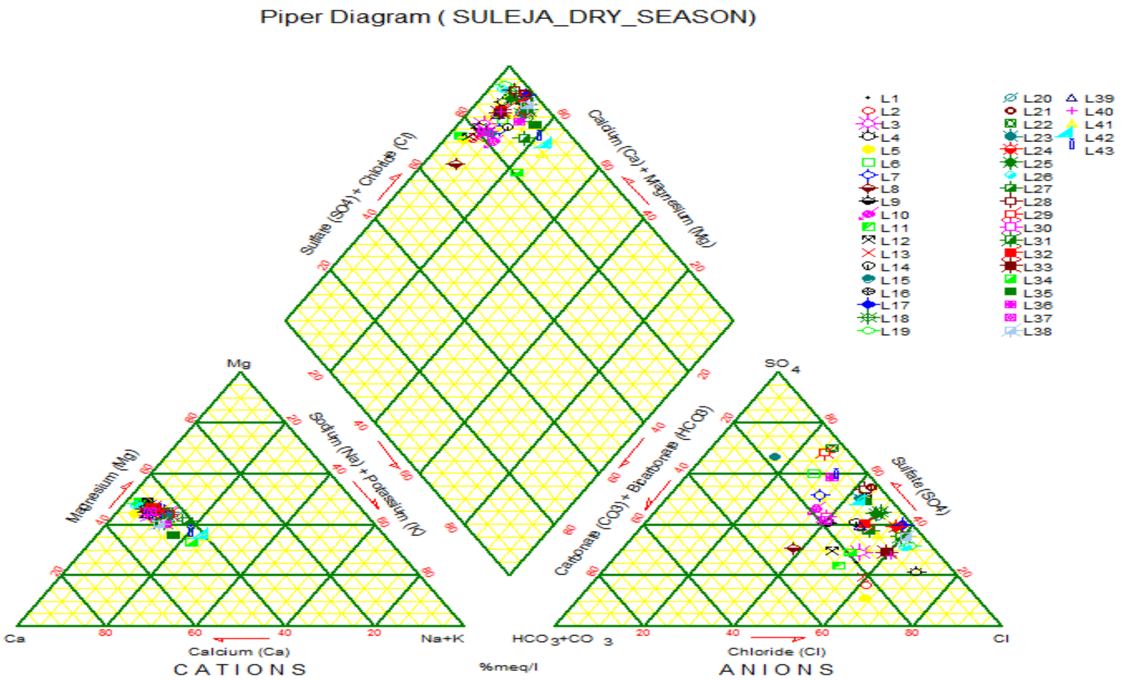

Figure 2: Hydrochemical Characterization of groundwater of Suleja Plotted on Piper Trilinear diagram for the dry season.

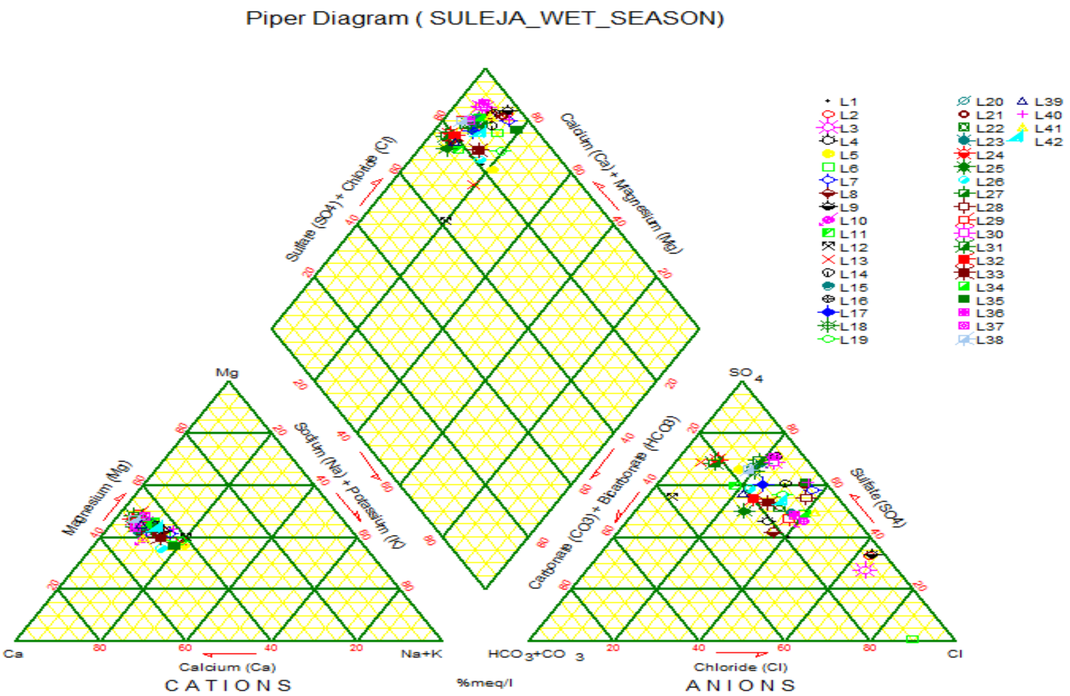


Figure 3: Hydrochemical Characterization of groundwater of Suleja Plotted on Piper Trilinear diagram for the wet season.

**CONCLUSION**

The result of statistical analysis as applied to the hydrochemical data set in the crystalline aquifer of Suleja area provides an insight in to the underlying factors controlling hydrochemical process in the area as discussed.

The observed wide range of standard deviation and variance in some of the parameters are indications that there is substantial difference in the groundwater chemistry within the study area.

Hydrochemical result depict high level average concentration of sulphate ($SO_4$), iron ($Fe^{2+}$) and total hardness to have range above their permissible limit for drinking water. There is variability noticed during seasonal parametric comparison which indicate that seasonal variation has impact on some ionic enrichment (Such as $Cl^-$, $SO_4$, $Mg^{2+}$ and $Ca^{2+}$) and revealed negligible impact on others. The WQI values for both dry and rainy seasons are 4.89 and 10.47 respectively which indicate that the groundwater in the area is excellent in quality. Essentially the groundwaters of the study area are Mg-$SO_4$ facies and Ca-Cl facies of water-types, for both dry and wet season. This revealed that seasonal variation on the groundwater chemistry has little or no significant impact in the hydrochemical facies of the water types.

**REFERENCES**

Abdullah, M.H., Musta, B., & Aris, A.Z. (2004). Groundwater Resources of Mabul Island,

Sempoma, Sabah: Quality Monitoring and management. Proceedings of the Second International Conference on Water and Wastewater Management and Technologies, 117-120.

Aguwamba JC 2003. Optimization of solid waste collection system in Onitsha, Nigeria. J. Envt.,
ss1(1): 124-135.

Ahmed, A.M. and W.N. Sulaiman, 2001. Evaluation of groundwater and soil pollution in a landfill area using electrical resistivity imaging survey. Environ. Manage., 28: 655-663.

Amadi, A.N (2010): Effects of urbanization on groundwater quality: A case study of Port-Harcourt, Southern Nigeria. Natural and Applied Sciences Journal, 2010, 11(2): 143 – 152.

Fatta, D., A. Papadopoulos and M. Loizidou, 1999. A study on the landfill leachate and its impact on the groundwater quality of the greater area. Environ. Geochem. Health, 21: 175-190.

Gallorini, M., M. Pesavento, A. Profumo and C. Riolo, 1993. Analytical related problems in metal and trace elements determination in industrial waste landfill leachates. Sci. Total Environ., 133: 285-298.

Khan, R., T. Husain, H.U. Khan, S.M. Khan and A. Hoda, 1990. Municipal solid waste management-A case study. Municipal Eng., 7: 109-116.

Ikem, A., O. Osibanjo, M.K.C. Sridhar and A. Sobande, 2002. Evaluation of groundwater quality characteristics near two waste sites in Ibadan and Lagos, Nigeria. Water Air SoilPollut., 140: 307-333.

Lambarkis, N, A. Antonakos, G. Panagopoulos (2004). The use of multi-component statistical analysis in hydrogeological en-vironmental research. Water Res. 2004, 38(7):1862-1872.

Nkwocha, E E and Emeribe A.C. (2008) Proliferation of unsanitary solid waste dumpsites in urban and suburban areas in Nigeria: Need for the Construction of Regional Sanitary.

Robinson, H. and J. Gronow, 1992. Groundwater protection in the UK: Assessment of the landfill leachate source-term. Inst. Water Eng. Managers, 6: 229-236

Shuaibu A.M, Murana, K.A and Ajibade I.I (2020): Qualitative Evaluation of Groundwater Condition from Part of Gusau Metropolis Zamfara State, Northwestern Nigeria. *IJSGS FUGUSAU 6*(2): 2020.

Shuaibu, A. M and I. N. Abdullahi (2015): Hydrochemical characterization of groundwater aquifer using multivariate analysis, Minna, North Central Nigeria. Nigerian journal of technological research, 10(1): 25:31, Doi:http://dx.doi.org/10.4314/njtr.vl10i1.5.