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**Qualitative Evaluation of Groundwater Condition from Part of Gusau  
 Metropolis Zamfara State, Northwestern Nigeria**

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**ABSTRACT**

This research is aimed at assessing the impact of three major waste dumpsites situated within Gusau metropolis on shallow groundwater quality. Fifteen (15) representative groundwater samples were collected from hand-dug well tapping shallow aquifers in different locations within the study area. The results revealed pH values that range between 7.26 to 8.12 with mean value of 7.50, whereas, recorded Total dissolve solid (TDS) range between 377 to 1393mg/L with average concentration of 751.27mg/L. The mean value recorded is > 500mg/L which is the limit set by WHO for drinking water. All the major and minor ions indicate moderate concentration in studied water samples compare to their various WHO, 2011 set up standard, except of sodium (Na<sup>+</sup>) which show elevated values above the threshold of permissible limit for domestic water use. Among the heavy metal, Cr<sup>+2</sup> and Pb<sup>+2</sup> revealed average concentrations higher than the permissible limit set by WHO for drinking water while Fe<sup>+2</sup> and Cu<sup>+2</sup> average concentrations were within the set up limit. The result of the correlation matrix shows that virtually all the major and minor ions are significantly correlated, suggesting similar source of their enrichment, which is not far from the mineral dissolution from the lithological framework due to chemical weathering. Similarly, they equally show significant relationship with total dissolve solids (TDS) and pH indicating their control efficiency of the groundwater within the study area. However, Fe<sup>+2</sup> and Pb<sup>+2</sup> are significantly correlated, this may not be unconnected with anthropogenic inputs, particularly from the waste dumpsites. The well-water samples in the study area are basically 'Alkali waters' that are predominantly SO<sub>4</sub><sup>2-</sup> and Cl<sup>-</sup>. The relative abundance of the three (3) dominant water types are as thus: Na-SO<sub>4</sub>> Na-Ca-SO<sub>4</sub>> Na-SO<sub>4</sub>-Cl. The relative abundance of cations is: Na<sup>+</sup>+K<sup>+</sup>> Ca<sup>2+</sup>> Mg<sup>2+</sup>; while the relative abundance of the anions is: SO<sub>4</sub><sup>2-</sup>> Cl<sup>-</sup>> HCO<sub>3</sub><sup>-</sup>. The Gibb's diagram highlights the supremacy of weathering of rocks, with a slight influence of evaporation-crystallization, in controlling the geochemistry of the well-water samples in the study area.

**Keywords:** Water Quality, Hydrogeochemical Evolution, Geo-statistics, Waste dumpsite, Groundwater

## 1.0 INTRODUCTION

The availability of clean and safe water supply has direct influence on economic well-being, health and quality of life of any society ( Arabi, et al., 2012). 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 (Adams et al., 2001; Amadi and Olasehinde, 2008; Shuaibu and Abdullahi, 2015).

Groundwater is most favored as a source of drinking water in sub-Saharan Africa (Arabi et al., 2010). It is often thought to be cleaner and easier to treat as compared to surface water and as a result, many

wells have either been sunk or drilled. However, groundwater can be contaminated by anthropogenic activities while naturally it contains several chemical components, which can lead to different kinds of health problems (Shuaibu and Bello, 2016). According to (Riemann and Banks, 2004) a groundwater source can potentially contain several naturally occurring chemical elements, many of which are not tested routinely as indices of water quality despite their known toxicity. Despite the lack of alternative water sources, the groundwater hydrogeochemistry of the study area remains poorly understood. Indiscrimination of waste substance and decreasing water levels increase the need for a

comprehensive understanding of the groundwater system that would yield better management of the resource.

The geology of the area studied comprises the crystalline basement made of coarse-medium grained granite and lenses of banded gneiss (Chinwuko, et al., 2018). Groundwater in the crystalline basement rocks is localized in pockets and patches of weathered rock and fractures. Wells usually encounter water at shallow depths but yields are often low and subject to seasonal fluctuations (Arabi, et al., 2012).

This research is aimed at assessing the impact of three major waste dumpsites situated within Gusau metropolis on shallow groundwater quality, which includes communities like Hira Dekodi, GangereYerima and area around Bebeji respectively.

**2.0 MATERIALS AND METHODS**

In this study, fifteen groundwater samples were collected from hand-dug wells, part of Gusau metropolis Northwestern Nigeria (Fig. 1) and analyzed for major, minor elements and heavy metals for the purpose of comparing its compliance with safe drinking water standards set by World Health Organization (WHO).

**2.1 Sampling Techniques**

This research was carried out during the wet season. Before sampling, the study area was gridded using Spatial Analysis and Decision Assistance (Sada, 2005) software which requires that at least one sample be collected from each grid. Sample collection was based on in EPA’s document on sampling protocol. Fifteen (15) representative groundwater samples were collected from hand-dug wells tapping shallow aquifers in different locations within the study area (Table 1). The targeted wells were the ones that high population of communal inhabitant of the area were concentrated on for their basic water needs; this is to enable evaluation of water quality status of the domestic water use in parts of Gusau metropolis. One litre plastic containers were used to collect the samples, dry washed and rinsed with the water sample before filling it to capacity and then labeled accordingly. Physical parameter was ascertained *in-situ*. The sample from the same source was divided and submits as blind duplicate to access accuracy/precision of the laboratory. After the collection, the various samples were stored in a cool box and taking to the laboratory for investigation at Water Quality Laboratory in Soil Science Department, Faculty of Agriculture, Ahmadu Bello University, Zaria Nigeria.

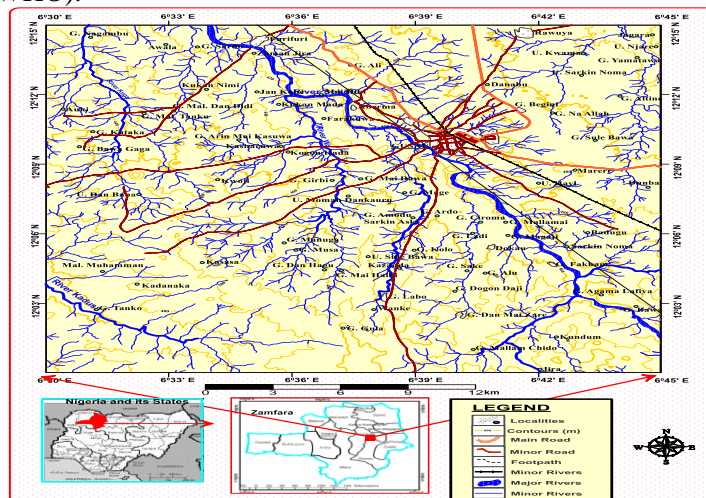


Figure 1: Map of Study Area

### 3.0 RESULTS AND DISCUSSION

Table 1 summarizes the descriptive statistics of analytical results for the fifteen (15) groundwater samples obtained from the studied area.

#### 3.1 Physical parameters Assessment

From table 1 among the physical parameters pH values recorded range between 7.26 to 8.12 with mean value of 7.50, this suggest neutral nature of the studied water samples (in line with WHO, 2011 guideline), which invariably suggesting moderate mineralization of the groundwater with respect to major and minor ions. However, recorded Total dissolve solid (TDS) range between 377 to 1393mg/L with average concentration of 751.27mg/L this shows high level dissolution of

ionic compound due to intense weathering from the lithologic framework within the study area. The mean value recorded is above 500mg/L limit set by WHO for drinking water. Though based on Chebotarev (1955) classification of waters all the water samples falls under fresh category because all the TDS value recorded <1500mg/L. Total hardness measured from the water samples studied range between 60.66 to 253.43mg/L with mean value of 153.38mg/L, though the average concentration is <200mg/L WHO standard, in some instances studied water samples show elevated value above the threshold of permissible limit for drinking water by WHO. This justifies the relative hardness of the groundwater (resistance to foaming against any detergent) within the study area.

**Table 1: Statistical Summary of The Physical, Chemical Analyses of Groundwater Samples From The Study Area**

Parameters	Minimum	Maximum	Mean	Skewness	WHO Water Quality Standard (2011)
TDS	377	1393	751.27	1.044	500
TH	60.66	253.43	153.38	-0.049	200
pH	7.26	8.12	7.50	1.711	7.5
Na <sup>+</sup>	210	900	382.67	2.064	200
K <sup>+</sup>	3.4	86	28.3	1.113	100
Ca <sup>+2</sup>	14.39	88.67	50.46	-0.075	200
Mg <sup>+2</sup>	6.01	7.78	6.65	0.593	150
Cl <sup>-</sup>	3.1	25.5	9.35	2.07	250
SO <sub>4</sub>	56.42	95.69	69.90	0.936	100
HCO <sub>3</sub>	4	14.6	8.67	0.513	100
NO <sub>3</sub>	0.03	0.31	0.09	2.419	50
Cu <sup>+2</sup>	0.29	0.42	0.32	2.882	1
Cr <sup>+2</sup>	0.02	0.81	0.2587	1.344	0.05
Pb <sup>+2</sup>	0.12	0.53	0.3427	-0.12	0.01
Fe <sup>+2</sup>	0.21	0.69	0.3265	2.655	0.3

#### 3.2 Hydrochemical Assessment of the Studied Water Samples

From table 1 major dissolve constituents (Ca, Mg, Na, K, Cl, SO<sub>4</sub>, HCO<sub>3</sub>, NO<sub>3</sub>) were presented, among which Sodium (Na<sup>+</sup>) concentration range between 210 to 900mg/L with average value of 382.67mg/L, which is higher to that of WHO set

standard. The elevated value suggested dissolution of feldspathic minerals within the host rock. Sodium is an essential electrolyte that helps maintain the balance of water in and around the cells of our body. It's important for proper muscle and nerves function, it also help regulating the blood pressure (Arabi, et al., 2012). High concentration of sodium in drinking water can result to hypernatremia, involves

dehydration which can cause lot of problem, include; diarrhea, kidney dysfunction, and diuretics. If it worsens, they may become confused or muscle twitches and seizures.

From the studied water samples potassium (K<sup>+</sup>) concentration range between 3.4 to 8.6mg/L, with mean value of 28.3mg/L, this is lower <100mg/L set up standard by WHO. This suggested that the potassium present in feldspars (Orthoclase and Microcline) are however not very significant to K<sup>+</sup> production. Potassium is a dietary requirement for humans, and we take up to 1 – 60g/day. Potassium in take are relatively rare, but may lead to depression, muscle weakness, heart rhythm disorder and confusion.

However, in the study area the calcium concentration for all the sample measured range between 14.39 to 88.67mg/L with average value of 50.46mg/L (table 1) this is lower to that of WHO standard for drinking water. Low concentration in the body could cause malfunction of neuromuscular excitability, and function of myocardial system, heart and muscle contractibility, including blood coagulation.

Magnesium is usually less abundant in water than calcium. The recommended magnesium daily intake for an adult is about 300 to 400mg/L (Scientific Committee for Food, 1993). The values of magnesium recorded in the studied groundwater range from 6.01 to 7.78mg/L with mean value of 6.65mg/L. All samples studied had magnesium values less than 400mgpd intake for adult as suggested by the Scientific Committee for Food, 1993; Committee on Dietary Reference Intake, 1997. It is worthy to note that magnesium deficiency increases risk to humans of developing various pathological conditions. Such as vasoconstructions, hypertension, atherosclerotic vascular disease, and acute myocardial infection.

The recorded sulphate value in the studied water samples ranged between 56.42 to 95.69mg/L with mean concentration of 69.90mg/L, this suggesting that all the groundwater samples studied had sulphate content below the WHO, 2011 standard. The amount present cannot cause any taste impairment.

The chloride concentration recorded in the studied water samples range between 3.1 to 25.5mg/L with mean value of 9.35mg/L, this suggested low concentration as it is <259mg/L permissible limit for chloride by WHO. Similarly, bicarbonate revealed low concentration against the set standard (table 1). The result of heavy metals such as Cu<sup>+2</sup>, Cr<sup>+2</sup>, Pb<sup>+2</sup> and Fe<sup>+2</sup> as presented in table 1, it very glaring that the average concentration of Pb<sup>+2</sup> and Cr<sup>+2</sup> as measured from the studied water samples are elevated above the threshold of the set up standard by WHO, 2011 for domestic water use. However, Fe<sup>+2</sup> shows moderate concentration while Cu<sup>+2</sup> revealed lower average enrichment as presented in table 1.

The hydrochemical data set obtained from studied sampled water were subjected to multivariate statistical analysis, the result of the correlation matrix as presented in table 2 shows that virtually all the major and minor ions are significantly correlated with high level positivity, suggesting similar source of their enrichment, which is not far from the mineral dissolution from the lithological framework due to chemical weathering. Similarly, they equally show significant relationship with total dissolve solids (TDS) and pH indicating their control efficiency of the groundwater within the study area. However, Fe<sup>+2</sup> and Pb<sup>+2</sup> are significantly correlated; this may not be unconnected with anthropogenic inputs, particularly from the waste dumpsites.

**Table 2: Correlation Matrix for the Studied Sampled Water Hydrochemistry**

Parameters	TDS	TH	pH	Na	K	Ca	Mg	Cl	SO <sub>4</sub>	HCO <sub>3</sub>	NO <sub>3</sub>	Cu	Cr	Pb	Fe
TDS	1														
TH	.745**	1													
pH	-0.512		1												
Na	.960**		.625*	1											
K	-0.087		0.099	-	1										
Ca	.731**		1.000**	.591*	.611*	1									
Mg	.935**		.719**	0.466	.873**	0.176	.703**	1							
Cl	.949**		.760**	0.435	.951**	0.159	.750**	.850**	1						
SO <sub>4</sub>	.730**		.543*	0.353	.703**	0.419	.534*	.648**	.698**	1					
HCO <sub>3</sub>	0.212		0.184	0.068	0.335	0.436	-0.193	0.141	0.212	0.323	1				
NO <sub>3</sub>	.879**		.656**	-	.923**	0.061	.645**	.820**	.893**	.808**	0.039	1			
Cu	0.276		0.279	0.351	0.276	0.244	0.275	0.315	0.207	0.089	0.293	0.263	1		
Cr	-0.284		0.193	0.405	-0.266	0.699	-0.185	0.398	0.267	0.276	0.015	0.338	0.286	1	
Pb	0.243		0.206	0.126	0.348	0.599	0.204	0.191	0.362	0.208	.570*	0.153	0.258	0.365	1
Fe	0.045		0.066	0.106	0.088	0.277	0.056	0.166	0.043	0.104	0.093	0.189	.870**	0.42	0.015

\*\* Correlation is significant at the 0.01 level (2-tailed).

**3.3 Groundwater Evolution**

Geochemical models have been applied to study the evolution of groundwater and quantitatively determine the water-rock interaction and mixing between different waters. The well-water samples in the study area are basically ‘Alkali waters’ that are predominantly SO<sub>4</sub><sup>2-</sup> and Cl<sup>-</sup>. The relative abundance

of the three (3) dominant water types are as thus: Na-SO<sub>4</sub> > Na-Ca-SO<sub>4</sub> > Na-SO<sub>4</sub>-Cl (Figure 2). The relative abundance of cations is: Na<sup>+</sup>+K<sup>+</sup> > Ca<sup>2+</sup> > Mg<sup>2+</sup>; while the relative abundance of the anions is: SO<sub>4</sub><sup>2-</sup> > Cl<sup>-</sup> > HCO<sub>3</sub><sup>-</sup> (Figure 3).

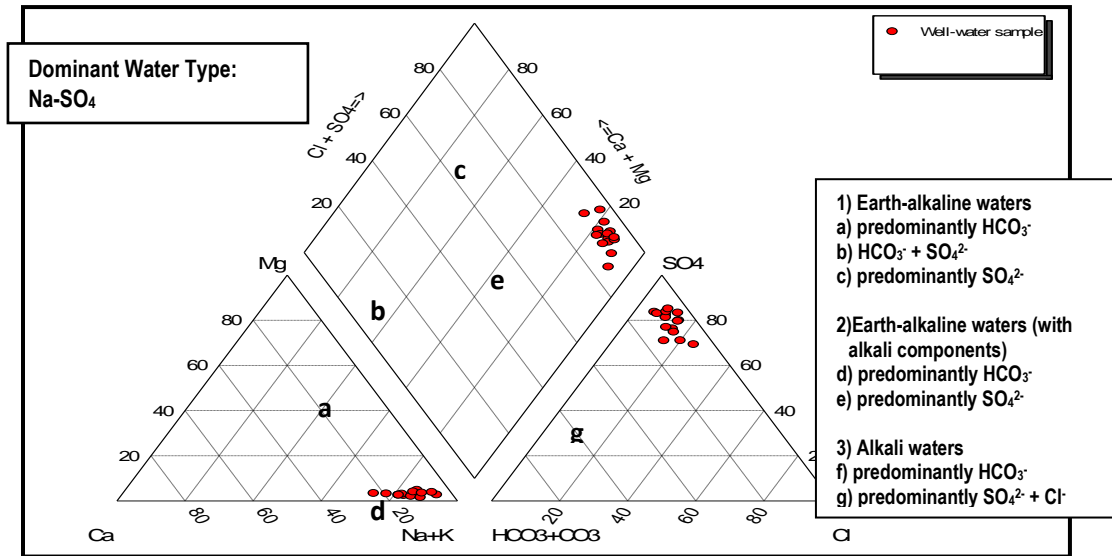


Figure 2: Piper's trilinear plot showing the different hydrochemicalfacies

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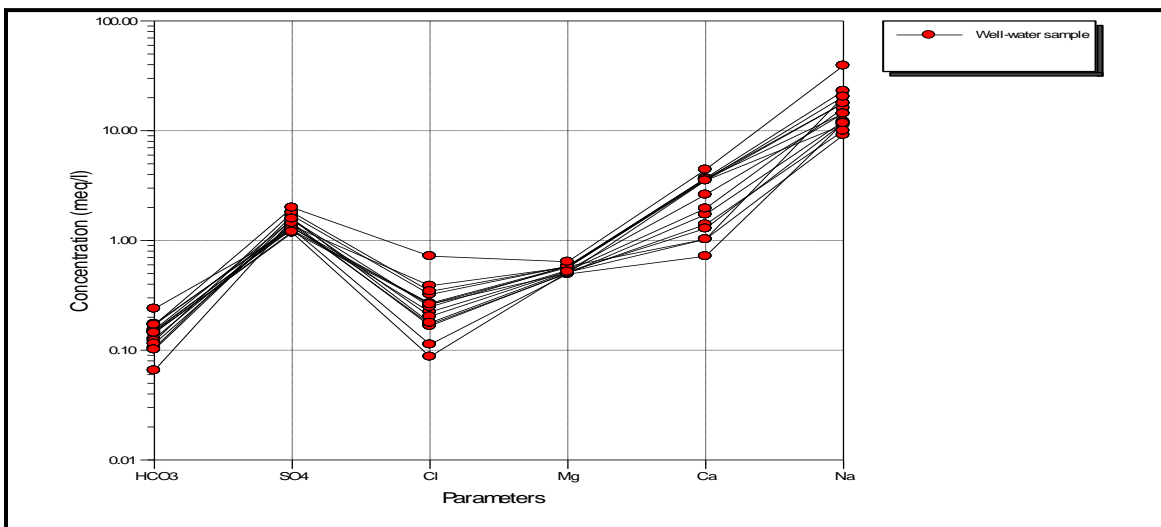


Figure 3: Schoeller's classification of well-water samples

The sodium hazard of the well-water samples in the study area ranges from 'Medium' to 'Very High' while the salinity hazard ranged from 'High' to 'Very High'(Figure 4). Sodium hazard (SAR): 20% of the data plotted in the 'Medium' field; 60%

plotted in the 'High' field; and 20% plotted in the 'Very High' field. Salinity hazard (Electrical Conductivity): 93.33% of the data plotted in the 'High' field; while the remaining 6.67% plotted in the 'Very High' field.

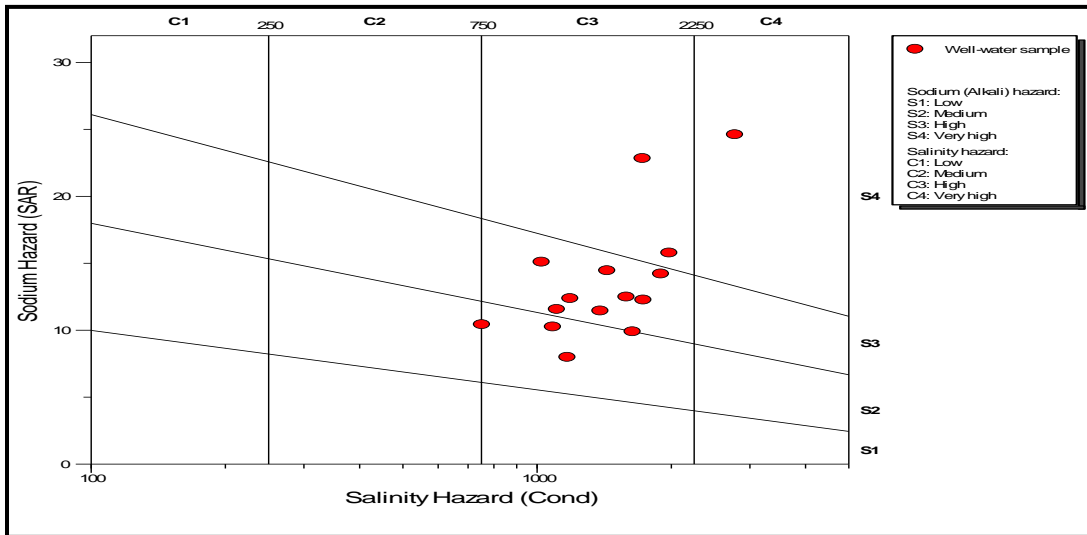


Figure 4: Wilcox plot of well-water samples

Simple mineral dissolution or mixing processes is mainly responsible for the variation in the hydrogeochemistry of well-water samples in the studied area as depicted by the cluster of the data points plotting in the simple dissolution or mixing

rectangle. The cluster of data points represents samples with similar composition of anions and cations. The plot (figure 5) shows a SO<sub>4</sub> dominant (or anion discriminant) and Na<sup>+</sup> dominant water.

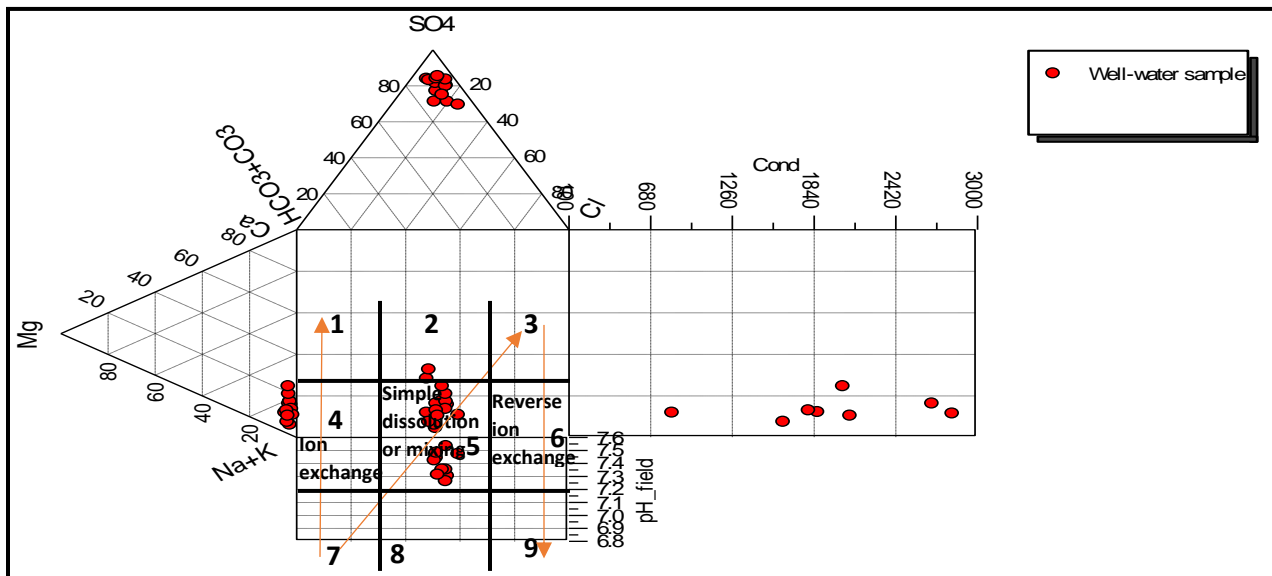


Figure 5: Durov's plot of well-water samples

The Gibb's diagram (Figure 6) highlights the supremacy of weathering of rocks, with a slight influence of evaporation-crystallization, in controlling the geochemistry of the well-water

samples in the study area (Figure 6). It should be noted that no data point plotted below the boomerang, where water composition is dominated by atmospheric precipitation.

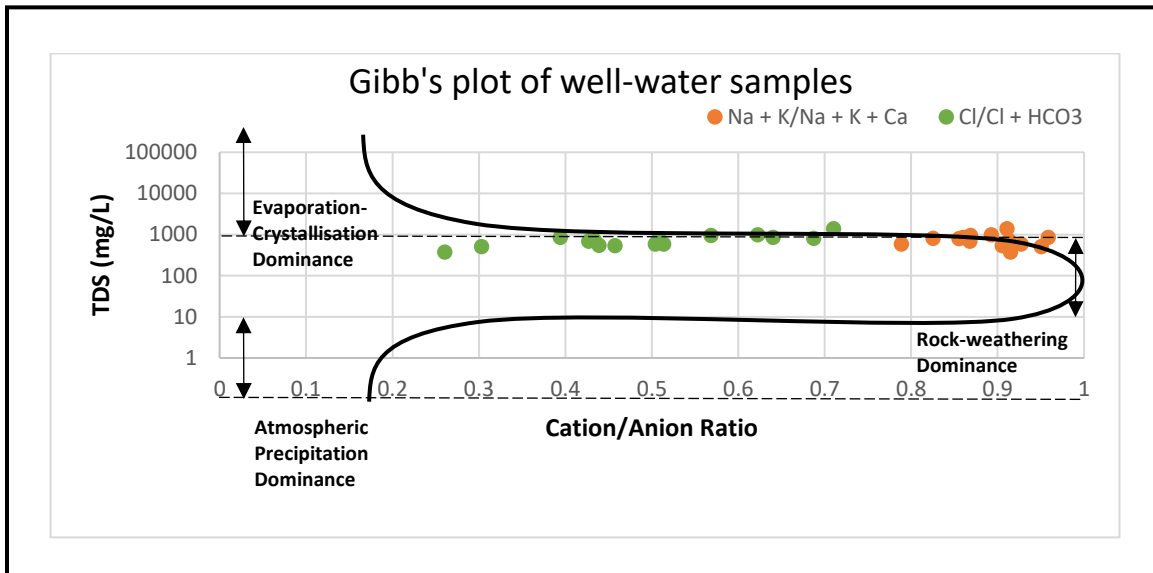


Figure 6: Gibb's plot of well-water samples

#### 4.0 CONCLUSION

All the major and minor ions indicate moderate concentration in studied water samples which are lower than WHO, 2011 set up standard, except of sodium ( $\text{Na}^+$ ) which show elevated values above the threshold of permissible limit for domestic water use.

Among the heavy metal  $\text{Cr}^{+2}$  and  $\text{Pb}^{+2}$  depict average concentration higher than the permissible limit set by WHO for drinking water while  $\text{Fe}^{+2}$  and  $\text{Cu}^{+2}$  average concentrations were within the set up limit.

The result of the correlation matrix shows that virtually all the major and minor ions are significantly correlated, suggesting similar source of their enrichment, which is not far from the mineral dissolution from the lithological framework due to chemical weathering. Similarly, they equally show significant relationship with total dissolve solids (TDS) and pH indicating their control efficiency of the groundwater within the study area. However,  $\text{Fe}^{+2}$  and  $\text{Pb}^{+2}$  are significantly correlated, this may not be unconnected with anthropogenic inputs, particularly from the waste dumpsites.

The well-water samples in the study area are basically 'Alkali waters' that are predominantly  $\text{SO}_4^{2-}$  and  $\text{Cl}^-$ . The relative abundance of the three (3) dominant water types are as thus:  $\text{Na-SO}_4 > \text{Na-Ca-SO}_4 > \text{Na-SO}_4\text{-Cl}$ . The relative abundance of cations is:  $\text{Na}^+ + \text{K}^+ > \text{Ca}^{2+} > \text{Mg}^{2+}$ ; while the relative abundance of the anions is:  $\text{SO}_4^{2-} > \text{Cl}^- > \text{HCO}_3^-$ .

The Gibb's diagram highlights the supremacy of weathering of rocks, with a slight influence of evaporation-crystallization, in controlling the geochemistry of the well-water samples in the project area

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