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**RESEARCH ARTICLE** 

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# AN INTEGRATED APPROACH TO GROUNDWATER QUALITY ASSESSMENT IN DETERMINING FACTORS THAT INFLUENCE THE GEOCHEMISTRY AND ORIGIN OF SANDSTONE AQUIFERS, SOUTHERN NIGER DELTA REGION OF NIGERIA

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ARTICLE DETAILS	ABSTRACT
<i>Article History:</i> Received 01 March 2019 Accepted 29 April 2019 Available online 2 May 2019	Rapid industrialization and oil exploration activities are believed to have influence on groundwater quality globally, and Niger Delta Region of Nigeria is no exception. Hence, this research is conducted to evaluate factors that affect groundwater origin and its geochemistry. For the purpose of this study, 20 groundwater samples were collected (4 from borehole and 16 from hand-dug wells). The parameters used in the assessment include physical parameters; pH, total dissolved solid and electrical conductivity and chemical parameters such as; major cations and anions. From the findings it was observed that pH values fell within the slightly acidic range with the exception of sample location HG/08 with value of 7.01 which can be considered as neutral. The dominant factors that influence groundwater origin and geochemistry within the study area are mainly precipitation and weathering. From Gibb's plot ninety percent (90 %) of groundwater chemistry is influenced by precipitation. Soltan classification showed that 98 % of groundwater belongs to $(Na^* - SO_4^2)$ , hence it can be classified as deep meteoric (precipitation influenced), while the remaining two percent (2%) is of $(Na^* - HCO_3)$ and can be classified as shallow meteoric type. Lastly from relationship between $C\Gamma/HCO_3^-$ groundwater was slightly moderately affected by saline water intrusion.
	KEYWORDS

Precipitation, Groundwater, Interaction, Weathering and Source

# 1. INTRODUCTION

The study area is richly endowed with natural resources such as crude oil, water and silica sand among others. The presence of crude oil has resulted in the rapid urbanization and industrialization, which is believed to increase human activities within the area and likewise the generation of various forms of wastes. These wastes are mostly disposed of close to rivers and streams, while the others infiltrate into groundwater which about seventy six percent of the inhabitants of the study area rely on for domestic and other uses. Over 80% of the water abstracted from aquifers finds its way back to the underlying aquifer from septic tanks. [1], further stated that the construction of an onsite sewage system by individuals often lack institutional control and thus quality is compromised, thereby leading to failure. Hence, there is need for constant assessment of water for domestic, irrigation, industrial use and even having prior information as regards groundwater origin, if necessary [2]. Although research has been carried out on hydro geochemistry of groundwater in recent decades, this poses a challenge to the scientific researchers based on hydrology and lithology [2-5, 5-11] due to the complexity of groundwater movement and the fact that it is considered free from pollution compared to surface water [11]. However, that is no longer the case, as anthropogenic activities have also been considered to greatly influence the quality of groundwater for domestic, irrigation and industrial use [5,13]. Human activities such as oil spillage, wrongful disposal of waste and leakage from septic tanks have been major sources of groundwater pollution within the Niger Delta Region [14]. The authors further stated that acid rain and gas flaring within the region, pose threat to the quality of water [13]. Acid rain and its environmental effects within this region have been confirmed by various researchers although no mention was made on the effects of gas flaring on water quality [15-18]. Influence of human activities on water chemistry in the region has also been studied [19]. However, factors that influence the origin of groundwater have not been discussed within the area. Although studies from previous literature has proven that source rock deduction (SRD) and Soltan approach have been used in determining factors that influences groundwater origin and water type [2, 20-12]. SRD is analytical check used in determining origin of groundwater that is not yet known [22]. SRD is derived from simplistic mass balance approach from water quality data. While in some situations source rock minerals may be deduced from the groundwater composition. It is an approach used for explaining groundwater chemistry, as groundwater chemistry plays major role in determining its quality and origin. Therefore, there is the need to evaluate factors that influence the origin of groundwater within the study area.

# 2. STUDY AREA

# 2.1 Climate and Topography

The study area lies between longitudes  $5^{\circ}58$ 'E to  $6^{\circ}$  14'E and latitudes  $5^{\circ}24$ 'N to  $5^{\circ}46$ 'N and covers five local government areas (LGAs), namely (Okpe, Ethiope East, Udu, Ughelli North and Ughelli South) in Delta State with Ughelli being the major town (Figure 1). The area experiences subequatorial climate that is now influenced by gas flaring with mean temperature that ranging between 25 °C and 37 °C. The total amount of annual rainfall is over 300 cm without a distinctive dry season, with monthly rainfall (January – December) averaging 20.5 cm. The rainwater according to [17] is acidic in nature and the quality is being threatened because of high level of impurities [18].

The study area is mainly low-lying devoid of hills, with the relief varying from 10 m in the south-western section to 22 m in the northern part.

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Figure 1: Accessibility map of the study area with groundwater sampling points.

### 2.2 Hydrogeology

From the hydrogeological point of view, the aquifer types occurring in the study area are; unconfined, confined and semi-confined aquifers. The aquifers are high yielding and characterized by high specific capacities, as well as high recharge rates [1]. The water-table in the study area is very close to the ground surface, ranging from 0 to 9 m below ground level. The aquifers in the area obtain steady recharge through direct precipitation and from major rivers. Rainfall in the Niger Delta is heavy, varying from about 2400 mm a year inland to 4800 mm near the coast [23]. [1], further stated that the static water level of water bearing unit is on the high side; with value ranging from less than 0.2 to 4m. Fluctuation of water level is influenced by seasonal fluctuation of the wet and dry seasons within the year. The water level is almost at the ground surface during the wet season and decreases during the dry season. The study area is drained by one major river (Ughelli River) with other tributaries that flows throughout the season and, many streams that are perennial in nature. These streams are part of the wetlands and sometimes contribute to the recharge of the aquifers. The aquifers are characterized by grain sizes that range from fine through medium to coarse grained sand.

#### 2.3 Geology

The geology of study area indicates that it is underlain by the Niger Delta Formations (Figure 2). The formations from top to the base are Somebreiro-Warri Deltaic Plain sands (Figure 2). The Benin Formation, Agbada Formation and the Akata Formation have been described in detail [24-27]. According to [27] the Somebreiro-Warri Deltaic Plain sand is about 120 m thick and it is Quaternary to Recent in age. Texturally, the unconsolidated sediments range from fine plastic clay through medium to coarse grain sands and are rarely gravelly. The Benin Formation (Oligocene to Pleistocene) consists predominantly of unconsolidated sand, gravel and occasionally intercalation of shales and with an average thickness about 2000 m. The Agbada Formation (Eocene to Oligocene) is the oil-bearing formation of the Niger Delta sedimentary basin. It consists of shale and alternate sand sequence and is about 3000 m thick. The Akata Formation is the basal units of the Niger Delta sedimentary basin and overlies the basement complex. It is made up of open marine facies and is highly pressured with 1000 km thickness and is of the Ecocene to Oligocene in age.



Figure 2: Geological map of parts of the western Niger Delta (NGSA, 2006).

# **3. METHODOLOGY**

Twenty water samples were randomly collected from six boreholes (BH)

and fourteen hand dug wells (HDW) (Figure 1). Sampling was carried out during the dry season when there was a decrease in the water level and the concentration of cations and anions were more stable. Precautionary

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measures were taken by washing the bottles with clean water, followed by cleaning reagents and finally thoroughly rinsing with distilled, de-ionized water prior to collection of water samples from the site. The samples were analyzed for eleven parameters, namely pH, electrical conductivity, total dissolved solids, magnesium, calcium, chloride, nitrate, sulphate, potassium, sodium and bicarbonate following standard [29] (Table 1).

Table 1: Methods used to analyze physicochemical parameters

S/No	Parameters	Units	Analytical Method
1	рН		pH meter Hach sensION + PH1 portable pH meter and Hach sensION + 5050 T Portable Combination pH Electrode
2	Electrical Conductivity (EC)	μS/cm	HACH Conductivity
3	Total dissolved solids (TDS)	mg/L	TDS meters (model HQ14D53000000, USA).
4	Magnesium (Mg <sup>2+</sup> )	meq/L	EDTA titrimetric method
5	Calcium (Ca²+)	meq/L	Titrimetric method
6	Chloride (Cl)	meq/L	Titrimetric method
7	Nitrate (NO <sub>3</sub> )	meq/L	Ion-selective electrode (Orion 4 star)
8	Sulphate (SO <sub>4</sub> <sup>2-</sup> )	meq/L	Turbidimetric method using a UV-Vis spectrometer
9	Potassium (K+)	meq/L	Jenway clinical flame photometer (PFP7 model)
10	Sodium (Na*)	meq/L	Jenway clinical flame photometer (PFP7 model)
11	Bicarbonate (HCO3)	meq/L	Titrimetric method

### **3.1 Rock Source Deduction**

Source rock deduction attempts to determine the possible origin of water samples analyzed. Equations 1 to 7 present a summary of the source rock deduction process on the basis of elemental ratios as proposed by [22].

$Na^++K^+-Cl^-$	
$Na^+ + K^+ - Cl^- + Ca^{2+}$	(1)
$\frac{Na^+}{Na^+ + a^2}$	
	(2)
$\frac{Mg^{2+}}{Ca^{2+} + Ma^{2+}}$	
	(3)

Ca <sup>2+</sup>	
$Ca^{2+} + SO_4^{2-}$	(4)
$\frac{Ca^{2+} + Mg^{2+}}{SO_4^{2-}}$	
Cl <sup></sup>	(5)
Sum of Anions	(6)
HCO <sub>3</sub>	
Sum of Anions	

(7)

The composition and quality of groundwater was used to deduce source rock as shown in Table 2.

Parameters	Value	Conclusion
$\frac{Na^+ + K^+ - Cl^-}{2}$	>0.2 and <0.8	PWP
$Na^+ + K^+ - Cl^- + Ca^{2+}$	<0.2 or >0.8	PWU
Na <sup>+</sup>	>0.5	Sodium source other than halite
$Na^+ + Cl^-$	= 0	HS
	<0.5 TDS >500	Reverse softening, sea water
	<0.5 TDS <500> 50	AE
	<0.5 TDS < 50	Rain water.
$Mg^{2+}$	= 0.5	DW
$Ca^{2+} + Mg^{2+}$	< 0.5	LD
5	>0.5	DD, calcite precipitation or seawater.
Ca <sup>2+</sup>	= 0.5	GD
$\overline{Ca^{2+} + SO_{4}^{2-}}$	< 0.5 PH < 5.5	PO
Ť	<0.5 neutral	Calcium remove-ion exchange
	>0.5	Calcium source other than gypsum
$Ca^{2+} + Mg^{2+}$	>0.8 and <1.2	D
<i>SO</i> <sub>4</sub> <sup>2-</sup>		
TDS	>500	CW or brine, seawater
	<500	SW
	0.0 500	
<u>[]</u>	>0.8 1DS >500	Sea water, or brine or evaporate
LI	>0.8 TDS <100	RW
Sum of Anions	<0.8	RW
	>0.8	Silicate or carbonate weathering
$HCO_3^-$	<0.8 Sulphate High	GW
Sum of Anions	<0.8 Sulphate low	SWB
Conclusion	Aquifer mineralogy	
Conclusion	Reactions	

### Table 2: Source-Rock Deduction Summary of Reasoning

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Where :DW= Dolomite weathering, LD =Limestone Dolomoite, DD = Dolomite Dissolution, **GD** = Gyspum Dissolution, PO = Pyrite Oxidation, **D**= Dedolomitiztion, **CW** = Carbonate weathering, **GW** = Gypsum weathering, **RW** = Rock weathering, **PWP** = Plagioclase weathering possible, **PWU**= Plagioclase weathering unlikely, **SW** = Silicate weathering, SWB = Sea water brine, HS = Halite solution, AE = Analysis error and **RW** = Rain water.

### 3.2 Gibb's Plot

Gibb's plot was attempted to obtain knowledge of the separate influences of precipitation, rock-water interaction and evaporation on the groundwater. The formula for cations and anions derived [30-32] by are displayed in equations 8a and 8b.

# For Cations

For Anions

.

$$Na^{+}/(Na^{+} + Ca^{2+})$$
 (8a)

$$Cl^{-}/(Cl^{-} + HCO_{3}^{-})$$
(8b)

# 3.3 Soltan Classification

The sources of groundwater have been classified into two types by [33]. The classifications are based on base-exchange indices (r1) and meteoric genesis indices (r2) as presented in equations 9a and 9b.

$$r1 = (Na^+ - Cl^-)/SO_4^2$$
(9a)

$$r2 = [(Na^{+} + K^{+}) - Cl^{-}/SO_{4}^{2-}])$$
(9b)

### 4. RESULTS AND DISCUSSION

The physicochemical parameters analyzed for both hand-dug wells and borehole samples are shown in Tables 3a and 3b.

Table 3a: Physicochemical result of hand-dug wells samples											
Sample Code	TDS	Electrical Conductivity	рН	Cl.	Na⁺	<b>Mg</b> <sup>2+</sup>	NO <sup>3-</sup>	<b>SO</b> <sub>4</sub> <sup>2-</sup>	Ca <sup>2+</sup>	HCO <sub>3</sub> -	K+
	mg/L	μS/cm		meq/L	meq/L	meq/L	meq/L	meq/L	meq/L	meq/L	meq/L
HG/02	20	39.6	6.58	0.29	0.08	0	0	0.01	0.03	0.1	0
HG/03	68	136.6	6.05	1.09	0.28	0.09	0	0.03	0.47	0.24	0
HG/04	4	8.9	6.73	0.07	0.04	0	BDL	0	0.01	0.01	0
HG/06	18	34.9	6.98	0.25	0.09	0.05	BDL	0.03	0.1	0.07	0
HG/07	51	101.2	6.22	0.56	0.33	0.16	0	0.04	0.55	0.16	0
HG/08	136	271.01	7.01	1.48	0.48	0.18	0	0.09	0.91	0.5	0
HG/09	13	24.77	6.18	0.14	0.05	0.02	BDL	0.01	0.15	0.03	0
HG/10	10	18.96	6.65	0.07	0	BDL	0	0	0.14	0.02	0
HG/12	27	51.33	6.36	0.44	0.27	0	BDL	0.01	0.15	0.15	0
HG/13	23	43.72	6.13	0.31	0.19	0	0	0.01	0.14	0.12	0
HG/15	68	104.6	6.83	0.62	0.42	0.29	0	0.06	0.7	0.2	0
HG/16	7	13.5	6.72	0.08	0	0	BDL	0	0.02	0.04	0
HG/17	24	47.7	6.4	0.3	0.16	0.73	0	0.01	0.19	0.09	0
HG/19	10	20.7	6.45	0.11	0.02	0	0	0	0.03	0.05	0
HG/20	22	44.1	6.53	0.36	0.21	0.1	0	0.02	0.25	0.1	0
Min	4	8.9	6.05	0.07	0	0	0	0	0.01	0.01	0
Max	136	271.01	7.01	1.48	0.48	0.73	0	0.09	0.91	0.5	0
Average	37.7	73.02	6.52	0.45	0.18	0.14	0	0.02	0.28	0.14	0

Where HG = Hand-dug well, Min = Minimum, Max= Maximum and BDL = Below Detective Limit

# Table 3b: Physicochemical result of boreholes samples

Sample Code	TDS	Electrical Conductivity	рН	Cl-	Na+	Mg <sup>2+</sup>	NO <sup>3-</sup>	<b>SO</b> <sub>4</sub> <sup>2-</sup>	Ca <sup>2+</sup>	HCO <sub>3</sub> -	K+
				meq/L	meq/L	meq/L	meq/L	meq/L	meq/L	meq/L	meq/L
HBG/01	7	14.01	6.41	0.08	0	0	BDL	0	0.25	0.03	0
HBG/05	87	122.8	6.91	1.04	0.41	0.11	0	0.06	0.79	0.21	0
HBG/11	63	119.74	6.17	0.79	0.55	0.07	0	0.03	0.44	0.19	0
HBG/14	142	284.3	6.55	1.85	0.71	0.5	0	0.14	1.19	0.39	0
HBG/18	5	10.6	6.64	0.08	0	0.01	BDL	0	0.01	0.02	0
Min	5	10.6	6 17	0.08	0	0	0	0	0.01	0.02	0
Max	142	284.3	6.91	1.85	0.71	0.5	0	0.14	1.19	0.39	0
Average	64.42	120.9	6.53	0.82	0.34	0.17	0	0.05	0.55	0.17	0

Where HBG = Borehole, Min = Minimum, Max= Maximum and BDL = Below Detective Limit

# 4.1 Source Rock Deduction

It can be understood that there are several possibilities of deciphering the

source rock as shown in Table 2 during the weathering and dissolution processes. The results obtained for the application of Source Rock Deduction is displayed in Table 4.

Table 4: Results obtained from application of Source Rock Deduction within the Study Area

Sample	$\frac{Na^{+} + K^{+} - Cl^{-}}{Na^{+} + K^{+} - Cl^{-} + Ca^{2+}}$	Na *	Mg <sup>2+</sup>	Ca <sup>2+</sup>	Ca <sup>z+</sup> + M	g <sup>z+</sup>	Cl-	HCO3
Code	Ha H G H Ga	Na <sup>+</sup> + Cl <sup>-</sup>	$Ca^{2+} + Mg^{2+}$	$Ca^{2+} + SO_4^{2-}$	SO <sub>4</sub> -		Sum of Anions	Sum of Anions
						TDS		
HBG/1	0.24	0	0	1	0	7	0.72	0.27
HG/02	0.87	0.21	1	0.75	3	20	0.72	0.25
HG/03	-0.63	0.2	0.16	0.94	18.0	68	0.8	0.17
HG/04	-0.75	0.36	0	1	0	4	0.87	0.12
HBG/0	-0.44	0.28	0.12	0.92	15	87	0.79	0.16
- НG/06	0.61	0.26	0.33	0.76	5	18	0.71	0.2
HG/07	0.29	0.37	0.22	0.93	17.7	51	0.65	0.21
HG/08	0.52	0.24	0.16	0.91	12.1	136	0.71	0.24
HG/09	0.37	0.26	0.11	0.93	17	13	0.77	0.16
HG/10	0.08	0	0.14	0.91	0	10	0.77	0.22
HBG/1 1	0.35	0.41	0.31	0.93	17	63	0.78	0.18
HG/12	0.53	0.38	0	1	15	27	0.73	0.25
HG/13	0.46	0.38	0	0.93	14	23	0.7	0.27
HBG/1	0.48	0.27	0.29	0.93	12.0 7	142	0.77	0.16
4 HG/15	0.22	2.47	0.29	0.93	16.5	68	0.7	0.22
HG/16	0.8	0	0	0.89	0	7	0.66	0.33
HG/17	0.42	0.34	0.79	0.92	92	24	0.75	0.22
HBG/1 8	8.88	0	0.5	1	0	5	8	0.2
HG/19	0.75	0.15	1	1	0	10	0.68	0.31
HG/20	0.37	2.71	0.28	0.92	0	22	0.75	0.2

Disintegration of magnesium ions and calcium ion in groundwater play a major role in the understanding of source rock for dolomite under average TDS conditions, however, the magnesium ion to calcium ratio approaches one, it is very likely that calcium could be removed from the solution and this process

is referred to as dedolomitization as shown in Figure 4 [21, 22].



Figure 4: Plot of Mg<sup>2+</sup> versus (Ca<sup>2+</sup> + Mg<sup>2+</sup>).

From Figure 5, it can be observed that ten sampling points fall above the equiline while the remaining ten falls below the equiline. This indicates that carbonate and silicate weathering undergo physical action as the source of calcium ion in the groundwater.



Figure 5: Plot of Ca<sup>2+</sup> + Mg<sup>2+</sup> (meq/L) versus HCO<sub>3</sub><sup>-</sup> + SO<sub>4</sub><sup>2-</sup> (meq/L).

It was observed that most of the samples have a Na<sup>+</sup>/Cl<sup>-</sup> ratio value around or above 1, this implies that ion exchange process is more dominant in the study area (Figure 6).



# Figure 6: Plot of Na<sup>+</sup> versus Cl<sup>-</sup>.

Figure 7 shows the ion exchange reactions, where Na<sup>+</sup> is plotted against Ca<sup>2+</sup> in which Ca<sup>2+</sup> levels are ranges from 0.01 to 1.19 (meq/L), while Na<sup>+</sup> levels are ranges from 0.00 to 0.71 (meq/L).



Figure 7: Plot of Na<sup>+</sup> versus Ca<sup>2+</sup>.

# 4.2 Relationship of Cl<sup>-</sup>/HCO<sub>3</sub><sup>-</sup> ratio

The  $Cl^{-}/HCO_{3}^{-}$  ionic ratios were also studied in order to characterize the origin of groundwater salinity in the study area. Ionic ratio is an approach

used to evaluate seawater intrusion especially in coastal regions [34, 35]. The ratios of Cl<sup>-</sup>/HCO<sub>3</sub><sup>-</sup> in the study area ranged between 1.13 and 2.84 (Table 5) and have strong positive and direct relationship with Cl<sup>-</sup> concentrations (Figure 8).

Fable 5: Result of Cl <sup>-</sup> and HCO3 <sup>-</sup> in mg	/L
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Sample No	Cl	HCO <sub>3</sub> -	CI <sup>-</sup> /HCO3 <sup>-</sup>
HBG/1	3.06	1.93	.53
HG/02	10.55	6.49	1.62
HG/03	38.76	15.25	2.54
HG/04	2.78	1.17	2.37
HBG/05	37.04	13.4	2.84
HG/06	9.13	4.52	2.01
HG/07	20.05	10.18	1.97
HG/08	52.56	30.71	1.71
HG/09	5.06	2.15	2.35
HG/10	2.56	1.68	1.52
HBG/11	28.34	11.82	2.39
HG/12	15.6	9.4	1.65
HG/13	11.3	7.51	1.50
HBG/14	65.82	24.12	2.72
HG/15	22.09	12.41	1.78
HG/16	3.12	2.75	1.13
HG/17	10.81	5.5	1.96
HBG/18	2.95	1.54	1.91
HG/19	4.13	3.42	1.20
HG/20	12.78	6.15	2.07
Min	2.56	1.17	1.13
Max	65.82	30.17	2.84

Where parameters are in mg/L, Min =Minimum, Max = Maximum



Figure 8: Relationship between Cl<sup>-</sup>/HCO<sub>3</sub><sup>-</sup> vs Cl<sup>-</sup> concentration in the study area.

The relationship between Cl<sup>-</sup>/HCO<sub>3</sub><sup>-</sup> and Cl<sup>-</sup> shows the mixing of fresh groundwater with saline water. Based on Cl<sup>-</sup>/HCO<sub>3</sub><sup>-</sup> ratios groundwater can be classified into unaffected (< 0.2), slightly or moderately affected (0.4 – 4.1), and strongly affected (> 4.1) by salinization process. [36, 37]. On the basis of the ratio of Cl<sup>-</sup>/HCO<sub>3</sub><sup>-</sup>, groundwater was moderately affected by seawater intrusion probably because the study area is distant from the sea and groundwater exists in sandstone aquifer at great depths. A combined effect of seawater and urban wastewaters may also be attributed to the poor quality of groundwater, which is influenced by low relief close to the coastal area [38]. It was also interesting to note that 6.2% of the samples unaffected by salinization were located near Perumal Lake in the study area, which may be due to the dilution effect from the surface water recharged into the aquifer or lesser extraction of groundwater due to the increased usage of surface water.

### 4.3 Soltan classification

[20] classified groundwater into two types, which are base-exchange indices (r1) and meteoric genesis indices (r2) as shown in equations 9a and 9b, where Na<sup>+</sup>, K<sup>+</sup>, Cl<sup>-</sup> and SO<sub>4</sub><sup>2<sup>-</sup></sup> concentrations are expressed in meq/L (Table. 2a and 2b). If r1<1 and r2<1, the groundwater sources are of Na<sup>+</sup>– SO<sub>4</sub><sup>2<sup>-</sup></sup> and deep meteoric type, respectively, while r1>1 and r2>1 indicates the sources are of Na<sup>+</sup>– HCO<sub>3</sub><sup>-</sup> and shallow meteoric type, respectively [20], and also presented in Table 6. Based on Soltan classification 98 % of groundwater belongs to Na<sup>+</sup> – SO<sub>4</sub><sup>2<sup>-</sup></sup> and are classified as meteoric type. This implies that groundwater is greatly influenced by precipitation process, as shown in Table 5, with the exception of samples HGB/05 and HG/06 that belong to shallow meteoric type.

Table 6: Groundwater classification according to base-exchange (r1) and meteoric genesis index (r2) criteria modified after [20]

Sample code	<i>r</i> 1	Water Type	r2	Water Type
HBG/1	0	Na+ - SO42-(DM)	0	Na+ - SO42-(DM)
HG/02	-21	Na+ - SO42-(DM)	-21	Na+ - SO42-(DM)
HG/03	-27	Na <sup>+</sup> - SO <sub>4</sub> <sup>2-</sup> (DM)	-27	Na <sup>+</sup> - SO <sub>4</sub> <sup>2-</sup> (DM)
HG/04	0	Na+ - SO42-(DM)	0	Na+ - SO <sub>4</sub> <sup>2-</sup> (DM)
HBG/05	10.5	Na+ - HCO <sub>3</sub> -(SM)	10.5	Na+ - HCO3-(SM)
HG/06	5.33	Na+ - HCO <sub>3</sub> -(SM)	5.33	Na+ - HCO3-(SM)
HG/07	-5.75	Na+ - SO42-(DM)	-5.75	Na+ - SO42-(DM)
HG/08	-11.11	Na <sup>+</sup> - SO <sub>4</sub> <sup>2-</sup> (DM)	-11.11	Na <sup>+</sup> - SO <sub>4</sub> <sup>2-</sup> (DM)
HG/09	-0.1	Na <sup>+</sup> - SO <sub>4</sub> <sup>2-</sup> (DM)	-9	Na <sup>+</sup> - SO <sub>4</sub> <sup>2-</sup> (DM)
HG/10	0	Na+ - SO42-(DM)	0	Na+ - SO <sub>4</sub> <sup>2-</sup> (DM)
HBG/11	-8	Na <sup>+</sup> - SO <sub>4</sub> <sup>2-</sup> (DM)	-8	Na <sup>+</sup> - SO <sub>4</sub> <sup>2-</sup> (DM)
HG/12	-17	Na+ - SO42-(DM)	-17	Na+ - SO <sub>4</sub> <sup>2-</sup> (DM)
HG/13	-12	Na+ - SO <sub>4</sub> <sup>2</sup> -(DM)	-12	Na+ - SO <sub>4</sub> <sup>2-</sup> (DM)
HBG/14	-8.14	Na+ - SO <sub>4</sub> <sup>2</sup> -(DM)	-8.14	Na+ - SO <sub>4</sub> <sup>2-</sup> (DM)
HG/15	-3.33	Na <sup>+</sup> - SO <sub>4</sub> <sup>2-</sup> (DM)	3.33	Na <sup>+</sup> - HCO <sub>3</sub> (SM)
HG/16	0	Na <sup>+</sup> - SO <sub>4</sub> <sup>2-</sup> (DM)	0	Na <sup>+</sup> - SO <sub>4</sub> <sup>2-</sup> (DM)
HG/17	-14	Na <sup>+</sup> - SO <sub>4</sub> <sup>2-</sup> (DM)	-4	Na <sup>+</sup> - SO <sub>4</sub> <sup>2-</sup> (DM)
HBG/18	0	Na+ - SO42-(DM)	0	Na+ - SO <sub>4</sub> <sup>2-</sup> (DM)
HG/19	0	Na+ - SO <sub>4</sub> <sup>2-</sup> (DM)	0	Na+ - SO <sub>4</sub> <sup>2-</sup> (DM)
HG/20	0	Na+ - SO4 <sup>2-</sup> (DM)	0	Na+ - SO <sub>4</sub> <sup>2-</sup> (DM)

Where; **SM** = Shallow Meteoric Type and **DM** = Deep meteoric.

# 4.4 Hydrogeochemical Analysis

The attribute of anions and cations in groundwater denotes the aspect of physicochemical quality caused by the groundwaters interaction with soil and rock, while flowing in the aquifer [29]. Water bearing formation show the attributes of water bodies with various chemical compositions; therefore, such attributes can be referred to hydrochemical facies of groundwater. Most times hydrochemical facies is usually affected by the rocks of the water bearing formation and the flow patterns of groundwater. The distribution of anions (Cl<sup>-</sup>, HCO<sub>3</sub>) and cations (Na<sup>+</sup>, Ca<sup>2+</sup>) as well as the TDS value as shown in (Eqn, 8a and 8b) were used to plot the Gibbs diagram in other to show the dominant processes that have

effect on groundwater within the study area such as; evaporation dominance, rock dominance, precipitation dominance. Gibbs diagram helps in interpreting the effect of hydrogeochemical processes such as; rock-water interaction mechanism, precipitation and evaporation on groundwater geochemistry. The chemical data of groundwater samples were plotted in Gibbs diagram (Figure 8). From Figure 8, ninety percent 90% of groundwater fell within the precipitation dominance region indicating that groundwater chemistry in the study area is highly controlled by precipitation. [39] stated that calcium-chloride type facies could be attributed to a combination of atmospheric precipitation charged with chloride ion, leachates from surrounding dumpsites.



Figure 8: Gibb's Plot of Water Sampled Location of the Study Area

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# 5. SUMMARY AND CONCLUSION

From detailed studies, pH value within the study area fell within the slightly acidic range with the exception of sample location HG/08 with value of 7.01. It was observed that from source rock deduction groundwater chemistry is influenced by the following; dolomite type weathering, gypsum type weathering, alkaline and alkaline type weathering. It was also observed that weathering has great influence on groundwater within the study area. From Gibb's plot ninety percent (90%) of groundwater quality chemistry is influenced by precipitation. From Soltan classification, 98 % of groundwater belongs to (Na<sup>+</sup> - SO<sub>4</sub><sup>2-</sup>), hence it can be classified under deep meteoric, while the remaining (2 %) is of (Na<sup>+</sup> - HCO<sub>3</sub><sup>-</sup>) can be classified under shallow meteoric type. Groundwater was slightly affected by seawater intrusion from relationship of Cl<sup>-</sup>/HCO<sub>3</sub><sup>-</sup>.

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