

ASSESSMENT OF GROUNDWATER SUITABILITY FOR IRRIGATION PURPOSES: A CASE STUDY IN MALAJOYE, EPE AREA, LAGOS, NIGERIA.

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ABSTRACT

Proper management of groundwater and surface water resources is crucial for a variety of reasons. The groundwater quality in Malajoye Village in Epe area was assessed by collecting samples from 8 dug wells to determine its suitability for irrigation due to the variability in quantity and quality of water available for irrigation in Nigeria. The fitness evaluation involved determining pH, conductivity, dissolved solids, alkalinity, as well as significant cations (Na^+ , K^+ , Ca^{2+} , Mg^{2+}) and anions (HCO_3^- , Cl^- , SO_4^{2-}). Of the 8 groundwater samples tested, 75% are classified as good water, while the remaining 25% are deemed unsuitable for irrigation. From these assessments, various irrigation quality parameters, including sodium absorption ratio, Kelley's ratio, residual sodium carbonate, and Mg hazard, were computed. Piper, and stiff diagrams shows the water type in the study area is freshwater while shoeller diagram indicates the water type is a combination of freshwater and seawater. The Gibbs diagram indicates water chemistry is primarily influenced by water-rock interaction, including mineral dissolution and chemical weathering. Evaluation of groundwater samples from the study area revealed that most of the water analysed is appropriate for irrigation use without endangering agricultural activities in Malajoye village, Epe, Lagos State.

Keywords: Irrigation Water, Groundwater Suitability, Malajoye Village, Epe.

I. INTRODUCTION

The rising issue of groundwater salinity in coastal areas globally is becoming a significant problem. Even though families rely heavily on this resource for everyday life, the use of irrigation water is essential for sustaining crop production on arable land, particularly during times of low rainfall or in dry seasons. Groundwater plays a significant role in the economic and social activities of the Nigerian population. Despite being widespread, its traits differ by location and extraction is often done without sufficient knowledge of hydrochemical properties, particularly in developing nations, prior to utilization. The mineral composition of the aquifers plays a significant role in determining the chemistry of groundwater. Variation in space and time is also influenced by the rocks and chemical properties [1]. Factors such as ion exchange, dissolution, precipitation, residence time, and downwater path play a significant role in defining the elemental properties of groundwater.

The complexity of groundwater characteristics in coastal communities was documented by [2], attributed to factors including rainfall, saltwater intrusion, geology, groundwater utilization, topography, and contamination rate. Frequent groundwater extraction can lead to depletion of the source and increased levels of specific ions, often making the water unsuitable for its intended purposes.

For centuries, the chemical composition of groundwater has been a key factor in determining its suitability and usability. [3] highlighted the significance of the physical attributes of water when categorizing and evaluating water needs for household and farming uses. The suitability of groundwater for irrigation farming relies on the impact of mineral compositions in both the soil and the crops grown on the farm [4].

Therefore, this research examined the physiochemical, hydrochemical properties and groundwater attributes in specific coastal zones to assess, categorize the appropriateness of groundwater for household consumption, and aid local farmers in effectively scheduling irrigation for increased food yield year-round. Additionally, the primary processes governing the composition of the aquifer were also analyzed.

The aim of this research is to evaluate the suitability of groundwater in the study area for irrigation purposes which will help the stakeholders in the area to take necessary preparations.

II. THE STUDY AREA

The Malajoye village is within the Epe Local Government Area of Lagos State, situated between Latitudes $6^{\circ}33'00''$ and $6^{\circ}35'00''\text{N}$ and Longitudes $3^{\circ}55'30''$ and $3^{\circ}56'30''\text{E}$ on the northern side of the Coastal Lagos Lagoon. The Coastal Plain Sands (CPS) of the Dahomey Basin (Fig.1) underlie it. The geological sequence beneath the research area

includes the Cretaceous Abeokuta Formation, which is positioned on top of the Precambrian Basement Complex and extends to the Quaternary Coastal Alluvium [5]. Providing additional explanation on the depositional process, [6] pointed out that the ongoing marine transgression in the Paleocene resulted in the formation of shallow marine limestones in the Ewekoro Formation and shales in the Akinbo Formation. Above the Paleocene

sequence are the Eocene shales of the Oshosun Formation and the sandstones of the Ilaro Formation. In terms of chronological order, lithostratigraphic units within the Dahomey Basin were identified to contain formations such as Ise, Afowo, and Araromi within the Abeokuta Group; Ewekoro and Akinbo within the Imo Group; as well as the Ilaro Formation and Coastal Plain Sands [7,8,9] (Fig. 2).

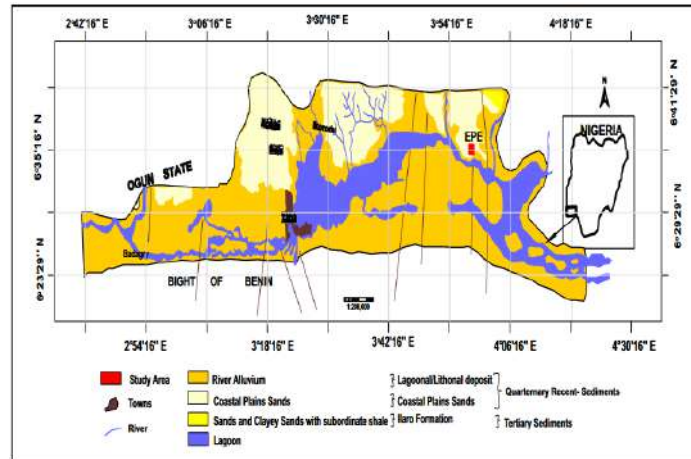


Fig 1: The Study Area on Geological Map of Lagos State.

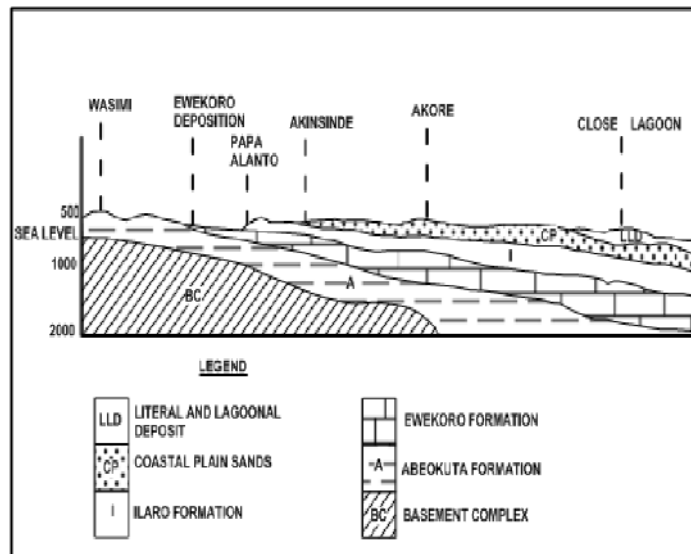


Fig. 2: The Stratigraphic Cross Section (N-S) across the Dahomey Basin [10]

III. METHODOLOGY

In the research area of Epe along Coastal Lagos Lagoon, a combined total of eight (8) groundwater samples were gathered. The pH, Electrical Conductivity (EC), and Total Dissolved Solids (TDS) were measured during the sampling process. Local geology and aquifer type in the study area were also investigated through observations. The laboratory determined concentrations of major anionic (Bicarbonates, Chlorides, and Sulfates) and cationic (Sodium, Potassium, Calcium, and Magnesium) ions, as well as Total hardness,

following standard analytical procedures (Table 1) as suggested by [11]. Using physico-chemical analyses, calculations were performed for irrigation quality parameters such as sodium absorption ratio (SAR), residual sodium carbonate (RSC), and magnesium hazard (MH). The hydrogeochemical parameter were also used to classify the water type in the study area. The assessment of groundwater suitability for irrigation was based on comparing water quality parameters with Indian standards for drinking water [12].

Table 1. Water quality indices parameters with BIS standards.

S/N	Category of parameter	Characteristics	Analytical method	Unit	BIS Max. Permissible limit (1998)
1	General	pH	Electrode		6.5 - 8.5
2		EC	Conductivity meter	μS/cm	3000
3		TDS	TDS meter	mg/L	2000
4		Total hardness (as CaCO ₃ ⁻)	EDTA titrimetric	mg/L	600
5	Major cations	Sodium (Na ⁺)	Flame photometric	mg/L	200
6		Potassium (K ⁺)	Flame photometric	mg/L	10
7		Calcium (Ca ²⁺)	EDTA titrimetric	mg/L	200
8		Magnesium (Mg ²⁺)	EDTA titrimetric	mg/L	100
9	Major anions	Bicarbonates (HCO ₃ ⁻)	Titrimetric	mg/L	NA
10		Chlorides (Cl ⁻)	Titrimetric	mg/L	1000
11		Nitrates (NO ₃ ⁻)	Titrimetric	mg/L	45
12		Sulfates (SO ₄ ²⁻)	Barium chloride	mg/L	400
13	Irrigation water quality	Salinity		%	NA
14		SAR		%	<10 or 10 - 18
15		RSC		RSC	
15		%Na		%	<20 or 20 - 40
16		MH		%	Below 50%

IV. RESULTS AND DISCUSSION

4.1. Physio-chemical Analysis for Irrigation

a) General Parameters Analysis

The pH levels in the groundwater samples from the study area ranged from 7.6 to 8.4, suggesting they were slightly acidic to slightly basic. Each of the samples exhibited a pH measurement that fell within the acceptable range of 6.5 - 8.5 as specified by [12]. The study area's groundwater samples' analytical results are illustrated in Table 2. In the research area, the electrical conductivity (EC) of groundwater ranges from 220 to 534 μS/cm, indicating that all values are below the allowable limit of 3000 [12]. The total dissolved solids (TDS) range from 132 to 385 mg/L, which is also below the permissible limit of 2000 mg/L [13]. The main reason for water hardness is the existence of cations like calcium and magnesium, as well as anions like carbonate, bicarbonate, chloride, and sulfate in water. The samples from the study area had total hardness

values ranging from 82 to 201 mg/L, with none exceeding the allowable limit of 600 mg/L [12].

The levels of sodium and potassium varied from 53 to 87 and 7 to 16 mg/L, respectively. This shows that all the sodium levels are within the allowed 200 mg/L limit [BIS, 1998], with only four (4) samples having potassium levels within the allowed 10 mg/L limit, except for (KDO 1, KDO 5, KDO 6, and KDO 8). The levels of calcium and magnesium ranged from 14 to 86 mg/L and 9 to 23 mg/L, respectively. The samples all had calcium and magnesium levels below the BIS allowable limits of 200 and 100 mg/L, respectively.

The samples from the study area had bicarbonate anion levels ranging from 86 to 126 mg/L, with chloride concentration exceeding that of bicarbonate. Within the investigation area, chloride levels ranged from 154 to 712 mg/L, with all samples found to have chloride levels below the permitted threshold of 1000 mg/L [12]. The sulfate levels in the groundwater range from 98 to 232 mg/L, falling below the acceptable threshold of 400 mg/L according to [12].

Table 2 Results physicochemical analysis of the water samples

Samples	pH	TH	TDS	EC	RSC	SAR	MAR	Kelly's Index	Na ⁺	K ⁺	Ca ²⁺	Mg ²⁺	Cl ⁻	SO ₄ ²⁻	HCO ₃ ⁻
KDO 1	7.1	167	335	543	-3.3	1.47	18.8	0.57	56	11	86	12	712	123	121
KDO 2	7.6	201	132	276	-0.6	3.15	36.3	1.97	75	8	28	10	642	129	100
KDO 3	8.4	111	246	511	-1.8	1.67	26.3	0.81	54	9	56	11	154	109	117
KDO 4	7.3	98	176	347	-0.3	2.3	50	1.93	54	7	18	10	284	232	103
KDO 5	8.2	104	385	232	-1.8	1.65	20.5	0.75	53	12	62	9	175	167	126
KDO 6	8.3	82	241	220	-3.2	1.94	25	0.78	67	16	72	14	234	127	98
KDO 7	8.0	98	347	309	-1.6	2.69	66.6	2.05	76	8	14	23	230	186	86
KDO 8	8.1	89	333	287	-0.6	3.71	57.1	2.72	87	15	18	14	200	98	90

b) Groundwater Quality Analysis for Irrigation

Irrigation methods primarily rely on the quality of water, the type of soil, and the type of crop. High levels of soluble ions in irrigation water have hindered the efficiency of irrigation, impacting the fertility of both crops and soil. Crop metabolism is disrupted by the biochemical impacts. The key chemical components that impact water's suitability for irrigation, and can be used to assess its suitability, include:

- **SAR**

Water with high sodium content is generally unsuitable for irrigating soil, as excessive sodium deposition can deteriorate the soil's physical properties. Hence, SAR indicates a higher level of sodium risk in irrigation, as the SAR of water is closely linked to the absorption of sodium by topsoil and is an important indicator for determining the suitability of water for irrigation. The SAR is utilized for forecasting the sodium hazard of high carbonate waters, especially those lacking residual alkali. The SAR is calculated as follows.

$$SAR = \frac{Na^+}{\left\{ \frac{Ca^{2+} + Mg^{2+}}{2} \right\}^{0.5}} \text{-----equ (1)}$$

where all levels of cations are indicated in parts per million or milliequivalents per liter. Table 2 depicts the classification of groundwater samples based on SAR in the research region. All samples have SAR values below 10 and are categorized as excellent for irrigation.

- **Residual Sodium Carbonate (RSC)**

Besides SAR, the excess carbonate in groundwater compared to the total of calcium and magnesium also impacts the appropriateness of groundwater for irrigation. Measuring the destructive effects of soils, the high levels of sodium bicarbonate and carbonate cause calcium and magnesium to precipitate as soil water. The amount of sodium in the water is raised through sodium carbonate, and

the extra portion, known as RSC, is computed in this manner:

$$RSC = (CO_3 + HCO_3) - (Ca + Mg) \text{-----Equation (2)}$$

Additionally, when all ionic concentrations are stated in parts per million or milliequivalents per liter. Groundwater in the study region is categorized according to RSC using the method described in [15], with the findings displayed in Table 2. All samples had RSC values below 2.50 epm, indicating they are suitable for irrigation according to RSC values. The 8 samples had negative RSC values because the amount of dissolved Ca²⁺ and Mg²⁺ ions exceeded the levels of CO₃⁻ and HCO₃⁻ ions.

- **Kelly's Index (KI)**

Sodium is compared to calcium and magnesium to determine Kelley's ratio [16,17]. A Kelly's index exceeding 1 indicates high sodium concentration in waters (Table 2). Therefore, groundwater with a Kelly's index below 1 is appropriate for irrigation, whereas groundwater with a ratio above 1 is not suitable. In the current research, Kelly's index ranged from 0.57 to 2.72. The samples KDO2, KDO4, KDO7, and KDO8 are not appropriate for irrigation according to the Kelly index.

- **Magnesium Hazard (MH)**

Calcium and magnesium exhibit different behaviors in soil, with magnesium negatively affecting soil structure, especially in sodium-dominated and highly saline water conditions. The presence of exchangeable Na in irrigated soils often results in elevated levels of Mg. [18] presented a significant ratio named magnesium hazard index. A magnesium hazard value exceeding 50% could harm crop yield by causing the soil to become more alkaline.

$$MH = \frac{Mg^{2+}}{(Ca^{2+} \times Mg^{2+}) \times 100} \text{-----Equation (3)}$$

The MH values range from 18.8% to 66.6% as reported. Of the 8 samples, 75% had a magnesium ratio below 50%, indicating they are suitable, while 25% had a magnesium ratio above 50%, suggesting they may have a negative impact on crop yield (Table 2).

Groundwater's appropriateness for irrigation was assessed using irrigation quality parameters such as boron, SAR, RSC, Kelley's Index, and magnesium hazard. Of these factors, SAR, Kelly's ratio, and

MH indicate that the water samples are categorized as excellent, suitable, unsuitable, and excellent for irrigation, respectively. RSC values indicate which categories water samples belong to.

4.2 Hydrogeochemical facies evaluation

The water samples were characterized hydrogeochemically by being plotted on Piper's, Stiff, Gibbs and Shoeller diagrams.

Table 3. Results of the Hydrogeochemical of groundwater in the study area

Samples	Cations	Mg/l	Meq/l	Anions	Mg/l	Meq/l
H	Ca ²⁺	86	4.3	Cl ⁻	712	20.1
	Mg ²⁺	12	1	HCO ₃ ⁻	121	2
	Na ⁺ +K ⁺	67	2.7	SO ₄ ²⁻	123	2.6
I	Ca ²⁺	28	1.4	Cl ⁻	642	18.1
	Mg ²⁺	10	0.8	HCO ₃ ⁻	100	1.6
	Na ⁺ +K ⁺	83	3.5	SO ₄ ²⁻	129	2.7
J	Ca ²⁺	56	2.8	Cl ⁻	154	4.3
	Mg ²⁺	11	1	HCO ₃ ⁻	117	2.3
	Na ⁺ +K ⁺	63	2.5	SO ₄ ²⁻	109	2
K	Ca ²⁺	18	1	Cl ⁻	284	8
	Mg ²⁺	10	1	HCO ₃ ⁻	103	1.7
	Na ⁺ +K ⁺	61	2.5	SO ₄ ²⁻	232	4.8
L	Ca ²⁺	62	3.1	Cl ⁻	175	5
	Mg ²⁺	9	0.8	HCO ₃ ⁻	126	2.1
	Na ⁺ +K ⁺	65	2.6	SO ₄ ²⁻	167	3.5
M	Ca ²⁺	72	3.6	Cl ⁻	234	7
	Mg ²⁺	14	1.2	HCO ₃ ⁻	98	1.6
	Na ⁺ +K ⁺	83	3.4	SO ₄ ²⁻	127	2.6
N	Ca ²⁺	14	1	Cl ⁻	230	6.5
	Mg ²⁺	23	2	HCO ₃ ⁻	86	1.4
	Na ⁺ +K ⁺	84	3.5	SO ₄ ²⁻	186	3.9
O	Ca ²⁺	18	0.9	Cl ⁻	200	5.6
	Mg ²⁺	14	1.2	HCO ₃ ⁻	90	1.5
	Na ⁺ +K ⁺	102	4.2	SO ₄ ²⁻	98	2

• Shoeller diagram

Schoeller diagram shows the concentration of the main ionic constituents in water in milliequivalent per liter (meq/L), using a semi-logarithmic scale, including SO₄²⁻, HCO₃⁻, Cl⁻, Mg²⁺, Ca²⁺, Na⁺+K⁺. Points on six evenly spaced lines represent the concentration of each ion in each sample, with lines connecting the points. The graph provides the exact amount of concentration and the curve also shows the proportion between two ions in the identical

specimen [20]. The Shoeller diagram displays the major ion distribution of the water samples in (Fig. 3). It is evident that the cation distribution follows the order Na⁺+K⁺>Ca²⁺>Mg²⁺, while the anions follow the order Cl⁻>SO₄²⁻>HCO₃⁻. This suggests that the water samples in the study area are freshwater, making them suitable for irrigation.

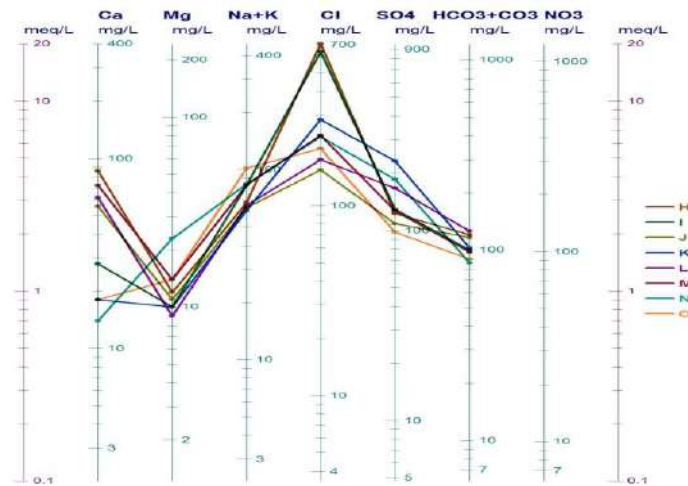


Fig 3. Shoeller pattern distribution of analyzed water samples [19].

• **Stiff diagram**

These are visual depictions of water chemical tests initially created by [21]. A polygonal form is formed by three or four horizontal axes running parallel on each side of a vertical axis. Cations and anions are shown in milliequivalent per litre, with cations on the left side of the zero axis and anions on the right side [20]. (Fig. 4) displays the rigid pattern diagram of

the water samples. Half of the samples (H, J, L, M) show Ca^{2+} as the main cation, while the remaining half (I, K, N, O) have $\text{Na}^+ + \text{K}^+$ as the primary cations. Cl^- is the prevalent anion present in all water samples. The water samples from the study area indicate that there is no risk to the water supply for irrigation as they contain a mixture of both freshwater and seawater.

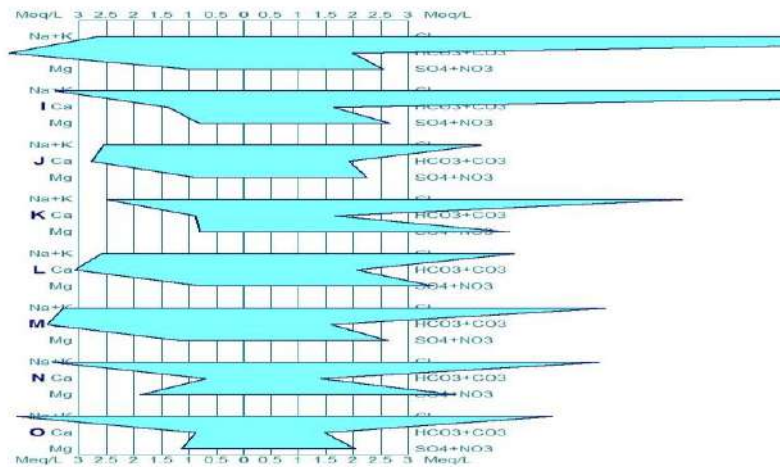


Fig 4. Stiff diagram showing the pattern distribution of major ions in the water samples [21].

• **Piper diagram**

The piper diagram illustrates how water samples are distributed (Fig. 5), showing that 62.5% of the samples are in the $\text{Na}^+ + \text{K}^+$ dominant region, while the remaining 50% are in the non-dominant cation field. 62.5% of the anion ternary falls under the

dominant $\text{Ca}^{2+} - \text{HCO}_3^-$ field, while the remaining 37.5% is classified in the non-dominant anion field of the anion ternary. This indicates that the water samples are from inland sources and do not threaten the plants in the research area.

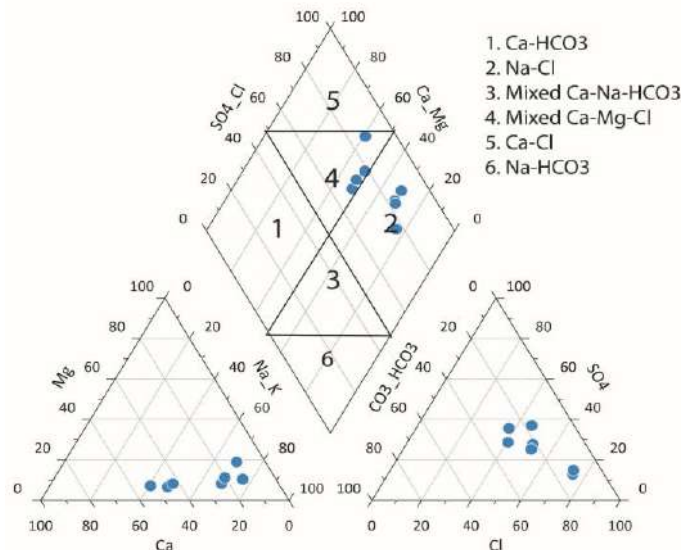


Fig 5. Piper diagram of the water samples showing the distribution of water facies type [22].

• *Gibbs Diagram*

The purpose of the Gibb's diagram is to analyze the primary process (either precipitation, evaporation, or rock weathering) that influences water chemistry.

The diagram in (Fig.6) illustrates that rock weathering is the main factor influencing the chemistry of water samples.

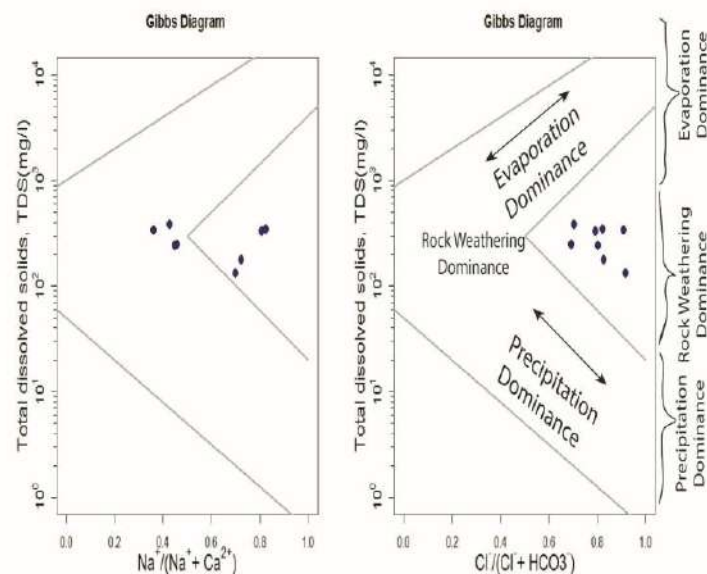


Fig 6. Gibbs digram showing the dominant processes that contol water chemistry [23].

V. CONCLUSION

Groundwater quality and its suitability for agricultural uses at Malajoye in EPE environment were evaluated since it is a major source of water for domestic and agricultural activities in the study area. The physio-chemical analysis for Irrigation purpose shows that all the water samples analyzed is good for agricultural purposes. Hydrogeochemical analysis uses many criteria to study and reveal the properties and conditions the water passes through to reach the state and

composition it has presently. This analysis was done to the samples collected at Malajoye, Epe in Lagos state. The sampling was done carefully following every precaution that has to be taken and taking into consideration situation that can lead into having an incorrect result. The analysis serves as means of checking the quality of the water people of the area are using for irrigation purposes. The results from Piper's diagram, Shoeller diagram, shows that the water type is from freshwater environment which is good for irrigation purpose.

The stiff diagram shows the water type in the study area is a combination of freshwater and seawater.

The gibbs diagram of the water samples shows that rock weathering in the major process controlling water chemistry. The gibbs diagram of the water samples shows that rock weathering in the major process controlling water chemistry. Kelly's ratio, sodium absorption ratio, residual sodium carbonate and magnesium hazard results indicate the water samples are good for irrigation.

It is recommended that the community and stakeholders should properly monitor the groundwater for a healthy irrigation processes in the study area.

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