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Hydro-geochemical Analysis to Evaluate Groundwater in Sidi-farag Area South of Benghazi, Libya

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ABSTRACT

The irrigation water quality is influenced by the concentration and composition of soluble salts present affecting agricultural production in arid and semiarid regions. this study aimed to evaluate groundwater and determine the sodium adsorption ratio (SAR) and residual Sodium Carbonate (RSC), in the Sidi-Farag area, specifically the police farms (formerly) located south of Benghazi city in July 2024. The study employed the Gibbs diagram and the Piper diagram to characterize the groundwater and demonstrate the hydro-geochemical influence**.** Five groundwater samples were randomly taken from different sites in The area covering approximately 350 hectares in the study area**.** The study's statistical findings demonstrate that all irrigation water values were within the permissible limits outlined in the (FAO) Irrigation Standards (Ayers & Westcot, 1985) and showed the following order: $Na^{+}>Ca^{++}>Mg^{++}>K^{+}$and $Cl^{-} > HCO_3^{-} >SO_4^{2-}$. The agricultural water quality was assessed using SAR and falls into the Excellent category with SAR <10. Based on the negative RSC value (-3.0), it is unlikely that the water is unlikely to lead to sodium accumulation issues in the soil by using these sources. finally, The Gibbs diagram indicates that the occurrence of ion dissolution in groundwater due to evaporation and precipitation is greater than that caused by rock dominance or any other sources. Based on the Piper diagram analysis, the groundwater was classified into Na, Ca, Cl, Mg, and CaHCO3 types**.**

التحليل الهيدروجيوكيميائي لتقييم المياه الجوفية في منطقة سيدي فرج

الواقعة جنوب مدينة بنغازي – شمال ليبيا

إدريس بشير إمنيسي

تتأثر جودة مياه الري بتركيز وتركيب الأملاح الذائبة الموجودة التي تؤثر على الإنتاج الزراعي في المناطق القاحلة وشبه القاحلة. هدفت هذه الدراسة إلى تقييم المياه الجوفية وتحديد نسبة امتصاص الصوديوم (SAR) وكربونات الصوديوم المتبقية(RSC) ، في منطقة سيدي فرج، وتحديدًا مزارع الشرطة (سابقًا) الواقعة جنوب مدينة بنغازي في يوليو 2024. استخدمت الدراسة مخطط جيبس ومخطط بايبر لتوصيف المياه الجوفية وإظهار التأثير الهيدروجيوكيميائي. تم أخذ خمس عينات من المياه الجوفية بشكل عشوائي من مواقع مختلفة في المنطقة التي تغطي حوالي 350 هكتارًا في منطقة الدراسة .أظهرت النتائج الإحصائية للدراسة أن جميع قيم مياه الري كانت ضمن الحدود المسموح بها الموضحة في معايير الري) منظمة الأغذية والزراعة (FAO وأظهرت الترتيب التالي $Na^{+}>Ca^{++}>Mg^{++}>K^{+}$.$Cl^{-}> HCO_3^{-}>SO_4^{2-}$ تم تقييم جودة مياه الري باستخدام SAR كانت تندرج في فئة ممتازة مع .SAR <10 وبناءً على قيمة RSC السلبية (-3.0)، من غير المرجح أن تؤدي المياه إلى مشاكل تراكم الصوديوم في التربة باستخدام هذه المصادر. وأخيرًا، يشير مخطط جيبس إلى أن حدوث ذوبان الأيونات في المياه الجوفية بسبب التبخر والهطول كان أكبر من التاثير الناجم عن هيمنة الصخور أو أي مصادر أخرى في تكوين نوعية المياه . وبناءً على تحليل مخطط بايبر، تم تصنيف المياه الجوفية إلى أنواع Na ,Ca ,Cl ,Mg , Ca-HCO3

INTRODUCTION

Water is the fundamental resource and essential natural element that established the oldest civilizations on Earth. Water represents the largest part of the Earth's surface, as the percentage of fresh water is about 3% and the rest is salt water. Groundwater is considered one of the most important components of the ecosystem. It plays a crucial role in the environment and human activities (Musie and Gonfa, 2023). global agriculture accounts for approximately 70% of annual freshwater consumption and The water demand in irrigation water and agricultural production is a significant strain on freshwater resources (Hüfner, 2010). Numerous researchers worldwide have undertaken investigations into the groundwater quality and the pollution sources influenced by both industrial activities and natural processes (Cheng and Li, 2015). The irrigation water quality is influenced by the concentration and composition of soluble salts present. Salinity, sodality, and ion toxicity are major problems in irrigation waters. The imprudent application of saline or brackish water frequently leads to the emergence of soil salinity, sodality, ion toxicity, and contamination of groundwater. it is crucial to gain a deeper insight into irrigated agriculture, especially in regions characterized by arid and semi-arid climates (Zaman et al., 2018). Irrigated agriculture relies on a sufficient supply of water of usable quality.

During irrigation water evaluation, it is important to consider both the chemical and physical characteristics of the water as well as any other factors that may be associated with the water. (Imneisi, 2022; Wilcox, 1955). The study area is one of the agricultural areas in the Benghazi Plain region. It is called The police farms (formerly) in the Sidi-Farag area located south of Benghazi city. The purpose of the present study was to evaluate groundwater quality and use the important parameters to establish A Gibbs diagram and piper diagram to evaluate the groundwater in study area.

MATERIALS AND METHODS.

Sidi-Farag area is one of the agricultural areas in the Benghazi Plain area. The police farms (formerly) are located south of Benghazi city. The area covers approximately 350 hectares and is considered part of the Sidi-Farag area Table 1 shows the coordinates of the targeted wells in the study area and Figure 1 shows the boundaries of the study area.

Table (1): shows the coordination of the sampling site.

	Latitude	Longitude
Sampling point 1	32. 050 105	20.229 263
Sampling point 2	32.050 824	20.222 909
Sampling point 3	32.043 777	20.230 755
Sampling point 4	32.042 312	20.226 760
Sampling point 5	32.045 337	20.213 187

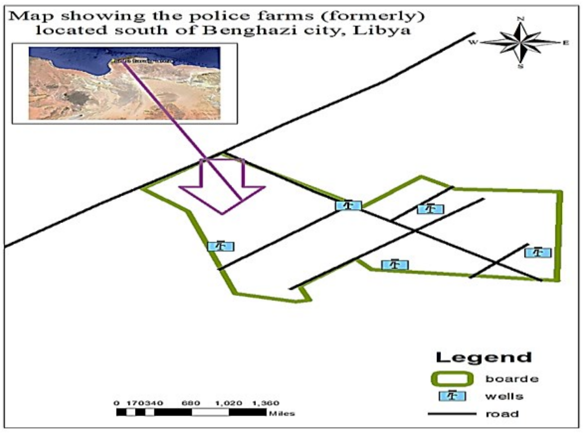

Fig. (1): Study Area Samples Location.

SAMPLE COLLECTION METHOD.

The Groundwater samples for physical and chemical analysis were collected from five locations (wells) in July 2024. The wells were operated for a few minutes to pump out water. The water samples were received in one-liter plastic (polyethylene) bottles that were immediately placed in an ice box and shipped to the laboratory at the agriculture faculty of Benghazi University.

The Physic-Chemical Analysis

Some of the geochemical and physical tests such as electrical conductivity, pH, and temperature were measured in the field. At the same time, chloride (Cl), sodium (Na^{+}), bicarbonate (HCO_3), nitrate (NO_3), calcium (Ca), magnesium (Mg), potassium (K), and sulphate (SO_4) were analysed in the laboratory agriculture faculty of Benghazi University using a HACH-DR 6000 UV-Vis spectrophotometer. All water quality parameters were analysed according to standard methods for examining water and wastewater (APHA, 1989). Statistical analysis such as minimum, maximum, mean, and standard deviation were used SPSS version 24.0 system.

Sodium Absorption Ratio (SAR)

SAR quantifies the relative concentration of sodium ions (Na^{+}) to calcium (Ca^{2+}) and magnesium ions (Mg^{2+}) in the water. The sodium adsorption ratio (SAR) was calculated using the following formula (Ayers and Westcot, 1985; Laboratory, 1954).

$$SAR = \frac{Na}{\sqrt{1/2(Ca^{2} + Mg^{2})}} \quad \ldots\ldots\ldots\ldots. \; eq \; (1)$$

Table (2) Guidelines for Interpretation of Sodium Adsorption Ratio (SAR) in Irrigation Water (Ayers and Westcot, 1985).

SAR	Significance of SAR
SAR (<10)	Indicates that water has a low sodium content relative to calcium and magnesium, making it safe for irrigation with minimal risk of soil structure degradation.

SAR (10-18)	Indicates a potential risk of sodium accumulation in the soil, which could lead to reduced soil permeability and aeration over time.
SAR (>18)	Indicates a high risk of sodium accumulation, which can cause soil dispersion, reduce water infiltration, and impair plant growth.

Residual Sodium Carbonate (RSC).

Residual Sodium Carbonate (RSC) is a measure used to evaluate the suitability of irrigation water, its potential to impact soil alkalinity. RSC is calculated based on the concentrations of bicarbonate (HCO_3^-) and carbonate (CO_3^{2-}) ions relative to calcium (Ca^{2+}) and magnesium (Mg^{2+}) ions in water. The Residual Sodium Carbonate (RSC) was calculated using the following formula (Laboratory, 1954).

RSC= ([HCO₃]+ [CO₃])- ([Ca²⁺]+ [Mg2+])….eq (2).

$$RSC = ([HCO_3] + [CO_3]) - ([Ca^{2+}] + [Mg^{2+}]) \quad \text{….eq (2)}$$

Table (3) Guidelines for Interpretation of Residual Sodium Carbonate (RSC) in Irrigation Water.

RSC	Significance of SAR
RSC > 2.5 meq/L	Water with a high RSC is considered unsuitable for irrigation, as it may lead to increased soil alkalinity, which can negatively affect soil structure and reduce crop yield.
RSC 1.25 to 2.5 meq/L	Water with moderate RSC can be marginally suitable for irrigation but may still require management practices to mitigate potential negative effects.
RSC < 1.25 meq/L	Water with low RSC is generally considered safe for irrigation, with minimal risk of adverse effects on soil structure.

HYDRO-CHEMICAL CLASSIFICATION.

The Gibbs diagram and The Piper diagram are used to demonstrate the characterization of the groundwater and signify the influence of hydro-geochemical. Below explained both.

A Gibbs diagram.

The Gibbs diagram is introduced as a plot manifesting of the specific process underlying the water chemistry established in 1970 (Gibbs, 1970).

Piper diagram.

The Piper diagram is highly valuable for interpreting hydro geochemical data and should be carried out with careful attention to detail (Ganvir & Armori, 2023). Piper diagrams offer an insightful way to comprehend the intricate chemistry of water samples and pinpoint the mechanisms that influence their composition.

RESULTS AND DISCUSSION

Water chemistry plays an important role in understanding aquifer hydrogeology and the processes that occur inside it (Glynn and Plummer, 2005). Tables 2,3,4 and 5 show the chemical analysis of water samples for evaluation of irrigation water and calculation of SAR and RSC.

IRRIGATION WATER QUALITY.

Water samples in situ measured temperature values ranged from 20 to 23 degrees C, within the permissible limits. Total dissolved solids in water include all inorganic salts such as carbonate, bicarbonate, chloride, fluoride, sulfate, phosphate, nitrate, calcium, magnesium, sodium, and potassium (VanLoon & Duffy, 2017). The electrical conductivity and dissolved species showed a heterogeneous distribution of groundwater. Total dissolved solids (TDS) in water samples ranged from 570 mg/L to 1700 mg/L while Electrical Conductivity (EC) ranged from 816 µs/cm to 3400 µs/cm at the police farm (formerly) in study area (Fig. 2). However, all TDS and (EC) values of the Ground Water within the permissible limit of Standard of (FAO) Irrigation (Ayers & Westcot, 1985). There is an increasing tendency in the TDS of number 2,3,5 wells compared with the number 4 well, where TDS has a small amount in the number 4. For all wells, no major differences were found in the ions concentration among samples collected, while slight variation was observed for one sample taken from wells as discussed below. Significantly, the pH of groundwater in the study area ranges from 7.88 to 8.4. This indicates that the dissolved inorganic carbon exists almost entirely as the HCO_3 ion. Carbonate is mostly derived from soluble alkaline earth carbonates, including calcite and dolomite. Calcite ($CaCO_3$) is typically the dominating form in developed soils due to their pedogenic origins (Nelson et al., 1998). The concentration of HCO_3 ranges from 1.96 to 3.96 meq/l which indicates more calcite and dolomite have dissolved in the aquifer in the study area.

Table (4). shows the results of the physic-chemical analysis of samples of ground water in the study areas.

Parameter	Standard (FAO)	unit	station 1	station 2	station 3	station 4	station 5
pH	6.5-8.4	pH	7.9	8.4	8	7.9	7.88
Temperature (C)	25	C	23	20	22	23	23
Electro-conductivity (EC)	3000	µS/ cm	3110	3400	2830	816	2720
Total Dissolved Soiled	0-2000	mg/l	1560	1700	1420	570	1320
Calcium (Ca^{+2})	0-20	meq/l	4.33	3.69	4.43	1.20	3.91
magnesium (Mg^{+2})	0-5	meq/l	3.75	3.22	3.86	1.07	3.90
sodium (Na^-)	0-40	meq/l	8.78	9.57	9.39	1.34	9.00
potassium (K^+)	0-40	meq/l	0.14	0.15	0.15	0.03	0.14
Cl – chloride (Cl^-)	0-30	meq/l	16.38	17.94	14.75	4.38	14.35
Carbonate ($Co3^{2-}$)	0-0.1	meq/l	-	-	-	-	-
Bicarbonate ($HCO3^-$)	0-10	meq/l	3.61	3.61	3.11	1.97	3.03
Sulfate (So4)	0-20	meq/l	2.92	4.16	4.16	0.83	4.02
Nitrate (N-NO3)	0-10	mg/l	4.8	2.2	3.2	4.5	4.9
Phosphate (PO4-P)	0-2	mg/l	20	32	36	12	34
Iron (Fe)	0.3	mg/l	0.05	0.05	0.05	0.05	0.06

Table (5). Shows The Statistical analysis of the Physical-Chemical Analysis of the Study Area and The Permissible Limit According to the Standard of (FAO) Irrigation.

Parameter	Standard (FAO)	unit	min	max	Average	St.div
pH	6.5-8.4	pH	7.88	8.4	8.016	0.21
Temperature (C)	25	C	20	23	22.2	1.30
Electro-conductivity (EC)	3000	µS/ cm	816	3400	2575.2	1018.207
Total Dissolved Soiled	0-2000	mg/l	570	1700	1314	439.97
Calcium (Ca^{+2})	0-20	meq/l	1.19	4.42	3.51	1.32
magnesium (Mg^{+2})	0-5	meq/l	1.07	3.90	3.16	1.19
sodium (Na^{+})	0-40	meq/l	1.34	9.56	7.61	3.52
potassium (K^{+})	0-40	meq/l	0.03	0.14	0.11	0.05
Cl – chloride (Cl^{-})	0-30	meq/l	4.37	17.93	13.55	5.32
Carbonate ($Co3^{2-}$)	0-0.1	meq/l	-	-	-	-
Bicarbonate ($HCO3^{-}$)	0-10	meq/l	1.96	3.60	3.06	0.66
Sulfate (So4)	0-20	meq/l	0.83	4.16	3.218	1.43
Nitrate (N-NO3)	0-10	mg/l	2.2	4.9	3.92	1.17
Phosphate (PO4-P)	0-2	mg/l	12	36	26.8	10.35
Iron (Fe)	0.3	mg/l	0.05	0.06	0.052	0.004

meq/L =miliequivalent per litre.

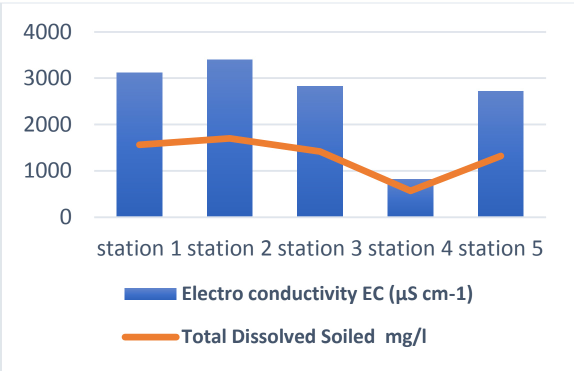

Fig. (2): EC and TDS values for five stations of groundwater in study area.

The calcium content of the Ground Water samples varied from 1.19 meq/L at well number 4 to 4.42 meq/L at well number 3 (Fig. 3). The calcium concentration in ground water samples was significant, which is mainly due to the release of calcium from sedimentary carbonate rocks and soil aquifer materials into ground water as a result of precipitation infiltration. (Magaritz et al., 1989). Sodium concentrations in the collected water samples ranged from 1.34 meq/L at station number 4 well to 9.56 meq/L at station number 2 well all the samples showed a sodium concentration within the permissible limit of (0-40 meq/l) in this study. Increasing of sodium concentration is mainly attributed to the use of water in irrigation purposes. On the other hand, the decreasing of sodium concentrations in water sample number 4 reflect the dilution by rainwater to well (Zaman et al., 2018). Figure 3 shows the average concentration of calcium, magnesium and sodium of irrigation water in the study area.

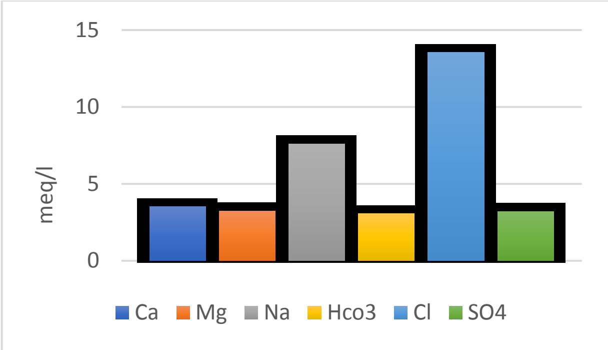

Fig. (3): The average concentration of calcium, magnesium and sodium of irrigation water in the study area. (the concentration in the water (meq/L).

The Chloride is a significant inorganic anion in water. The chloride (Cl) anion is present in all types of water; chlorides are soluble and easily leach into drainage water. While chlorides are essential for plant growth, elevated concentrations can hinder growth and may be extremely toxic to certain plant species (Zaman et al., 2018). in this study, the chloride (Cl)content of the Ground Water samples ranged from 4.38 meq/l at station number 4 well to 17.94 meq/l at station number 2 well with the highest value measured. Table 2,3 and figure 3 illustrates the levels of Cl in irrigation water.

1.1. SODIUM ADSORPTION RATIO (SAR).

The chemical suitability of the groundwater of the study area for irrigation water was judged mainly by its sodium adsorption ratio (SAR) and residual Sodium Carbonate (RSC). It is advisable to steer clear of water containing high residual sodium carbonate (RSC) levels and sodium adsorption ratio (SAR) (Minhas et al., 2021).
Table (6) shows The average calcium, magnesium, and sodium in irrigation water to calculate SAR in the study area.

ion	Ca	Mg	Na
element	calcium	magnesium	sodium
Equivalent weight mg/meq	20.04	12.15	22.99
mg/l	70.4	39.36	175.18
meq/l	3.51	3.23	7.61
SAR		5.87	

The sodium adsorption ratio (SAR) is one of the most serious salinity indices that are considered for determining the suitability of irrigation water. Higher sodium adsorption ratios make water less suitable for irrigation. Irrigation with high sodium adsorption ratios may require soil amendments to prevent long-term harm (Michael et al., 2008; Moasheri et al., 2012). In table 5, It was evident from the analysis of the Sodium Adsorption Ratio (SAR) that the total samples of our study area fall under the category of low sodium hazards (in the excellent category i.e. <10), which reveals that the groundwater of sidi- Faraj is free from any sodium hazard.

Residual Sodium Carbonate (RSC).

Table (7) shows The average calcium, magnesium, Bicarbonate, and carbonate in irrigation water to calculate RSC in the study area.

ion	Ca	Mg	Hco3	CO_3
element	calcium	magnesium	bicarbonate	Carbonate
Equivalent weight mg/meq	20.04	12.15	60.02	30.00
mg/l	70.4	39.36	225	0
meq/l	3.51	3.23	3.74	0
RSC		-3.0		

A negative RSC value indicates that the water is unlikely to cause sodium accumulation problems in the soil, as the calcium and magnesium concentrations are sufficient to counteract any potentially harmful effects of bicarbonate.

HYDRO-CHEMICAL CLASSIFICATION.

The hydro-geochemical study offered valuable insights into the groundwater resources of the former police farms in the Sidi-Farage area, situated to the south of Benghazi. The study focuses on understanding the primary processes influencing the mineralization of the groundwater and evaluating its suitability for irrigation purposes. The Gibbs diagram and The Piper diagram were used to demonstrate the characterization of the groundwater and signify the influence of hydro-geochemical. Below explained both.

A Gibbs diagram.

The Gibbs diagram was used to demonstrate the characterization of the groundwater and signify the influence of hydro-geochemical in study area. In Figure 4, the Gibbs diagram illustrates the relationship between TDS and the concentration of cations and anions in groundwater.

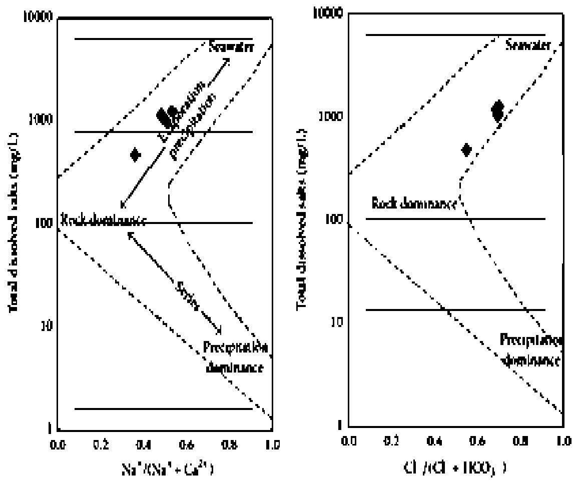

Fig. (4): Gibbs diagrams using cations and anions of groundwater in the study area.

The diagram indicates that the majority of cations and anions in the groundwater originate from evaporation and precipitation processes. The analysis indicates that the occurrence of ion dissolution in groundwater due to evaporation and precipitation is greater than that caused by rock dominance or any other sources.

Piper diagram.

The plotted position of the analyses on a Piper diagram allows us to draw preliminary conclusions about the source of the water being analysed. Based on the Piper diagram analysis, the groundwater was classified into Na, Ca, Cl, Mg, and Ca-HCO3 types. For the classifications of the groundwater by Piper's diagram, samples were classified for agriculture usage shown in Figure 5.

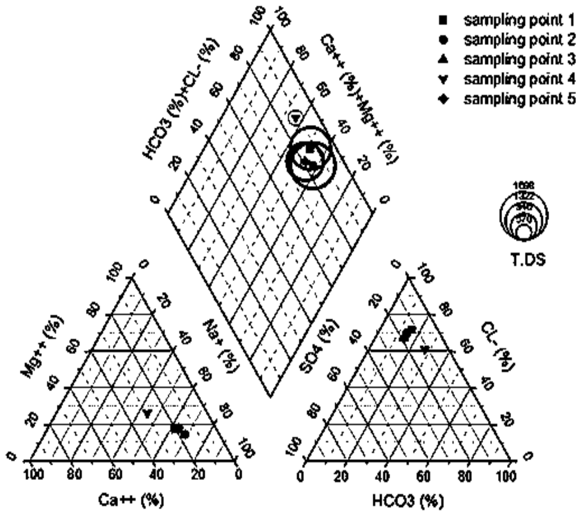

Fig. 5 Chemical analyses of the groundwater as the percentage of total equivalents per litre on the Piper diagram for the study area.

CONCLUSION AND RECOMMENDATION.

The study focuses on understanding the primary processes influencing the mineralization of the groundwater and evaluating its suitability for irrigation purposes.

- Total dissolved solids (TDS) in water samples ranged from 570 mg/L to 1700 mg/L while Electrical Conductivity (EC) ranged from 816 µs/cm to 3400 µs/cm at The police farms (formerly) in study area. However, all TDS and (EC) values of the Ground Water within the permissible limit of Standard of (FAO) Irrigation.
- The dominance of the cations and anions showed the following order: Na+>Ca++>Mg++ >K+. as anions Cl- > HCO3 - >SO4 2-.
- in this study, the highest value of the chloride (Cl) anion was 17.93 meq/l. While the highest value of Na cation was 9.56 meq/l in the study area.
- Based on the analysis of the Sodium Adsorption Ratio (SAR), it is clear that all the samples in study

area pose low sodium hazards, falling within the excellent category (<10).

- The negative RSC value suggests that the water is unlikely to lead to sodium accumulation issues in the soil. This is because there are adequate calcium and magnesium concentrations present to neutralize any potential harmful effects caused by bicarbonate.
- The Gibbs and Piper diagrams were employed to illustrate the groundwater's characteristics and show hydro-geochemical influence. According to the Gibbs diagram, groundwater is sourced from rainfall and evaporation. The Piper diagram indicates that calcium bicarbonate is a common component of groundwater.

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