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Original Article

A Study on the Physico-Chemical Status of Groundwater in Subramaniyapuram Area, Tiruchirappalli District, Tamil Nadu

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ABSTRACT: *Groundwater is an important source of water for drinking, agriculture, and domestic use. In this study, ten groundwater samples were collected from different locations and analyzed for various physico-chemical parameters such as pH, Electrical Conductivity (EC), Total Dissolved Solids (TDS), calcium, magnesium, chloride, sulfate, sodium, potassium, bicarbonate, Dissolved Oxygen (DO), Biological Demand Oxygen (BOD), and Chemical Oxygen Demand (COD). The results were compared with World Health Organization (WHO) standards to determine the suitability of groundwater for drinking. The results show that most parameters are within the permissible limits, while a few samples show slightly higher TDS and chloride levels. Overall, the study indicates that groundwater quality in the study area is generally suitable for drinking and domestic use. However, continuous monitoring and proper management are necessary to protect water resources.*

KEYWORDS: *Physico-Chemical Parameters, Drinking Water Suitability, WHO Standards, Water Quality Assessment, Groundwater Management.*

1. INTRODUCTION

Water is one of the most essential natural resources on Earth and is vital for the survival of all forms of life. It is very important to keep the ecological balance and assist human civilization. Water is essential for drinking, agriculture, industrial activities, sanitation, and power generation. Water is the most fundamentally irreplaceable substance for life up to now in its obvious situations in plants, animals, and humans. The availability of water rules populations and develops cities and countries. Water is found in profusion all over the world, yet only a fraction of it may be used as drinking water (Wellover24, 2011); about 71% of the Earth's surface is covered by water. Over 97 percent of the fresh water is present as groundwater, and it has remained a significant source for drinking purposes, mainly in countries like India, which are still considered developing nations. Water is also a powerful (free) natural solvent that carries nutrients and minerals to living beings. However, rapid urbanization, industrialization, population growth, and improper waste disposal are polluting the water resources. A decline in Water Quality degrades human and agricultural productivity and negatively impacts aquatic ecosystems. Therefore, protection, conservation, and proper management of water resources are of great importance to ensure sustainable development and the well- being of present and future generations. Subramaniyapuram area is a significant residential and commercial district situated in the eastern region of Tiruchirappalli, Tamil Nadu, India. High urbanization and population growth in these zones have increased dependence on groundwater for domestic uses and also small commercial triggers. Thus, it is extremely important to evaluate groundwater quality for drinking and irrigation. The study was carried out at the beginning of the summer season in July 2025; water samples were collected from ten sampling sites different locations within the Subramaniyapuram TVS tollgate of this area, and their comprehensive physico-chemical properties with details.

The parameters analyzed include pH, electrical conductivity (EC), total dissolved solids (TDS), dissolved oxygen (DO), biochemical oxygen demand (BOD), chemical oxygen demand (COD), calcium, magnesium, chloride, sulfate, sodium, and potassium. The results obtained were compared with the standards prescribed by the World Health Organization to evaluate their suitability for drinking purposes. Furthermore, the overall groundwater quality was assessed using the Water Quality Index (WQI), and irrigation suitability was determined through the Wilcox diagram and Piper diagram. Based on these assessments, an attempt was made to ascertain whether the groundwater in the study area is suitable for drinking and agricultural use.

2. MATERIALS AND METHODS

2.1. STUDY AREA

Tiruchirappalli, also known as Trichy, is a major city in Tamil Nadu, India, with rich cultural, historical, and geographical significance. On the banks of the Kaveri River, it has fertile soil and notable plants. The city suffers from a tropical climate with hot summers and, during the monsoon season, fairly moderate rainfall. It is an industrial and educational hub, with several manufacturing units mainly in engineering and textiles, including some reputed institutes such as the National Institute of Technology, Tiruchirappalli. The training data is up to October, 2023. The said destinations could include the heritage sites of the city such as Rockfort Temple, Ranganathaswamy Temple at Srirangam, and many others, which are colonial-era structures. One of the biggest reasons is its beautiful mixture of development, situated at a strategic location where it connects people by all major road and rail networks, making this city a hub for trade, culture, and tourism in central Tamil Nadu.

2.2. SAMPLE COLLECTION

A total of 30 borewell groundwater samples were collected in and around Tirchirappalli city during july, 2025 for physico-chemical analysis. A total of twenty samples were collected from bore wells and deep hand pumps. The parameters analyzed were pH, EC, TDS, DO, BOD, COD, HCO_3, Ca, Mg, Cl, Na, K, and SO_4. Samples were collected in 2-liter polythene bottles. The bottles were first washed with hydrochloric acid, then with tap water and finally with distilled water and rinsed with the sample water before collection. The bottles were filled leaving a small air gap, tightly closed and sealed to avoid contamination. Separate bottles were used for DO, bod and COD analysis. The samples were analyzed using instruments such as a pH meter, conductivity meter, spectrophotometer, and flame photometer. All analyses were carried out using standard methods, and the results were compared with WHO (2008) drinking water standards.

TABLE 1 Sampling Locations and Sources

Sample no.	Sampling Stations	Source
M1	Jailaniya Main Street	Bore well
M2	NMK Colony Street (cross 8)	Bore well
M3	Iqbal Colony Street	Bore well
M4	Usman Ali Street	Bore well
M5	NMK Colony Street (cross 1)	Bore well
M6	Raja Street	Bore well
M7	MM Complex, Kallukuzlhi	Bore well
M8	Hanifa coloney Street	Bore well
M9	Thanjavur main Road, TVS tollgate	Bore well
M10	Race Course Road Street	Bore well

3. RESULTS AND DISCUSSION

TABLE 2 Physico-Chemical Parameters of Groundwater Samples were Collected in and Around the Subramaniyapuram Area, Tiruchirappalli District. (July -2026)

Parameters	Sample Stations										WHO
	M1	M2	M3	M4	M5	M6	M7	M8	M9	M10	
pH	7.45	7.82	7.99	7.47	7.62	7.92	7.57	7.79	7.64	7.79	6.5-8.5
TDS	518	651	592	621	345	623	595	531	565	603	500
EC	1056	1360	1196	1229	694	1288	1232	1034	1122	1218	600
Ca	132	145	180	114	168	172	167	124	165	189	75-200
Mg	40	60	52	67	43	44	63	81	88	81	30-100
ALKALINITY	56	44	56	23	49	26	43	42	49	51	100-200
SO4	117	98	137	127	152	163	154	172	203	231	200-400
Na	78	69	51	62	72	68	43	56	39	31	50-200
K	09	05	11	08	06	07	12	11	06	09	10-12
HCO3	204	304	216	264	238	313	323	355	308	311	200
Cl	356	396	412	343	372	326	376	319	352	383	250
DO	6.2	5.8	6.5	5.2	5.6	4.8	4.5	5.9	4.2	5.4	5
BOD	1.8	2.4	1.5	3.2	2.7	3.8	4.2	2.1	4.8	2.9	10
COD	12	18	10	22	20	28	32	16	36	21	10

All the values are expressed in ppm, except pH and EC ($\mu mhocm^{-1}$)

3.1. ESTIMATION OF WATER QUALITY INDEX (WQI)

Estimating the Water Quality Index (WQI) involves a technique for rating that amalgamates the influence of individual water quality parameters on the overall water quality. This assessment focuses on human consumption. The average concentration of physico-chemical parameters, including pH, turbidity, total dissolved solids, total alkalinity, total hardness, nitrate, chloride, calcium, magnesium, iron, and fluoride, is utilized in the computation of WQI.

3.2. A CRITICAL POLLUTION INDEX OF 100 IS CONSIDERED UNACCEPTABLE.

The calculation of the water quality index follows the procedure outlined below: An individual quality rating is given by the expression.

$$Qi=100v_i/si$$

Water quality index (WQI) is then calculated as follows: WQI =

$$\sum_{i=1}^{n}(Qi \times Wi)/\sum_{i=1}^{n} Wi$$

Where,

- Q is the sub-index of the i^{th} parameter.
- Wi is the unit weightage for the i^{th} parameter,
- N is the number of parameters considered. Generally, the critical pollution index value is 100.

TABLE 3 Calculation of WQI Values for Ground Water Samples Collected in 2025

Parameters	Mean value (vi)	Who standard (si)	Wi	Qi = (vi/si)×100	Wi × qi
PH	7.71	8.5	0.117	90	10.53
EC	1123	600	0.0016	187	0.30
TDS	564	500	0.002	113	0.23
Ca	155.6	200	0.005	78	0.39
Mg	61.9	150	0.006	41	0.25
ALKALINITY	43.9	200	0.005	22	0.11
SO_4	155.4	400	0.0025	39	0.10
Na	58.2	200	0.005	29	0.15
K	8.4	12	0.083	70	5.81
Cl	384.6	250	0.004	154	0.62
HCO_3	295.6	200	0.005	148	0.74

WQI=53

TABLE 4 Status Categories of WQI

Wqi	Quality of water
0-25	Very good
26-50	Good
51-75	Poor
Above 75	Very poor (unsuitable for drinking)

In the present study, the water quality index is tabulated in Table III. The computed WQI value is 53. This shows that the nature of the water quality of the areas seems to be poor. It is clearly understood that the groundwater of our study area is recommended not for drinking but for other purposes as per the WQI standard values.

WILCOX DIAGRAM :

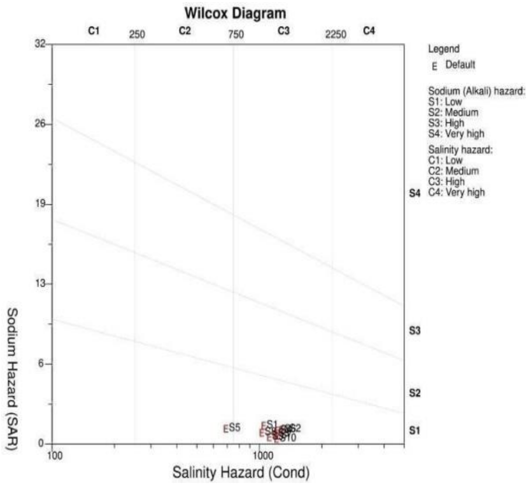

FIGURE 1 Wilcox Diagram for Classification of Irrigation Water Based on Salinity (EC) and Sodium Adsorption Ratio (SAR)

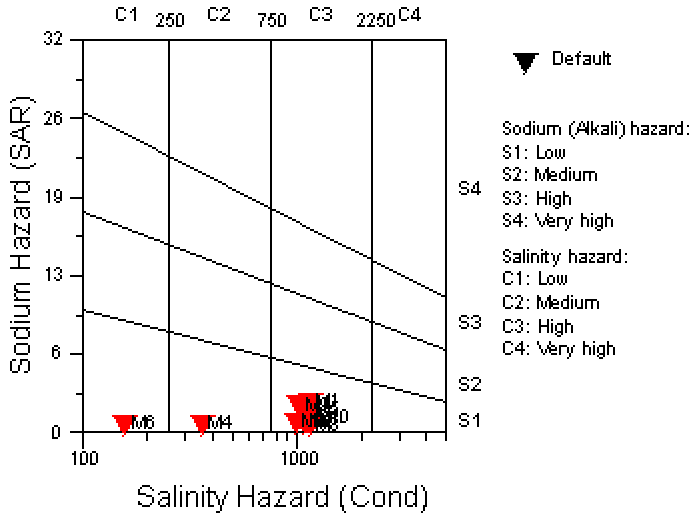

FIGURE 2 **USSL Salinity Hazard (C1–C4) and Sodium Hazard (S1–S4) Classification Diagram**

- The Wilcox (ussl) diagram is a semi-log scatter plot used to evaluate the suitability of groundwater for irrigation by plotting electrical conductivity (EC) on the x-axis (salinity hazard) and Sodium Adsorption Ratio (SAR) on the y-axis (sodium hazard). EC represents the total concentration of dissolved salts in irrigation water and classifies water into four salinity categories: C1 (low salinity), C2 (medium salinity), C3 (high salinity) and C4 (very high salinity). Low salinity water can be used for most crops without problems, while medium salinity requires moderate leaching. High salinity water needs good drainage and salt-tolerant crops, whereas very high salinity water is generally unsuitable for irrigation except under special management conditions.
- Based on SAR values, irrigation water is also classified into S1 (low sodium), S2 (medium sodium), S3 (high sodium) and S4 (very high sodium). Low sodium water can be used safely for most soils, while higher sodium levels may affect soil structure and require special soil management practices.
- In the present study, the calculated SAR values for all groundwater samples (S1–S10) fall within the s1 category, indicating low sodium hazard. When plotted against EC values on the Wilcox (ussl) diagram, most samples fall in the C3 salinity class, while a few belong to C2 and C1 categories. Therefore, the groundwater is mainly classified as C3–S1 type, indicating high salinity but low sodium hazard. This suggests that the water can be used for irrigation with proper drainage, leaching practices, and the cultivation of salt-tolerant crops to prevent soil salinization.
- Based on the calculated EC and SAR values of the groundwater samples (S1–S10), the Wilcox (ussl) diagram shows that all samples fall under the S1 category, indicating low sodium hazard.
- However, the EC values indicate varying salinity levels among the samples. Most of the samples (S1, S2, S3, S5, S7, S8, S9 and S10) fall into the C3 category (high salinity water), while m4 belongs to C2 (medium salinity) and m6 falls under C1 (low salinity). High salinity water may lead to salt accumulation in the soil, which can reduce crop productivity if not properly managed.

SODIUM ADSORPTION RATIO:

The sodium or alkali hazard in groundwater for irrigation is determined by the absolute and relative concentration of cations and is expressed in terms of Sodium Adsorption Ratio (SAR). There is a significant relationship between SAR values of irrigation water and the extent to which sodium is absorbed by the soil. If groundwater used for irrigation is high in sodium and low in calcium, the cation-exchange complex may become saturated with sodium.

$$sar = \frac{Na}{\sqrt{\frac{ca+mg}{2}}}$$

(All ions in ppm)

A simple method of evaluating the high sodium in water is the SAR. Calculation of SAR value for a given groundwater provides a useful index of the sodium hazard of that water for soils and crops. Classification of water with reference to SAR is provided by Herman Bouwer (1978). A low SAR of 0 to 6 indicates no problem from sodium; an increasing problem is between 6 and 9, and a severe problem is above 9.

TABLE 5 Sodium Adsorption Ratio (Wilcox Class)

Samples	Ec (µmho/cm)	Sar	Wilcox class (approx.)
M1	0.45	1056	C3–S1
M2	0.29	1360	C3–S1
M3	0.34	1196	C3–S1
M4	0.95	1229	C2–S1
M5	0.21	694	C3–S1
M6	0.35	1288	C1–S1
M7	0.32	1232	C3–S1
M8	0.38	1034	C3–S1
M9	0.72	1122	C3–S1
M10	0.64	1218	C3–S1

The lower the ionic strength of the solution, the greater the sodium hazards for a given SAR.

SCATTER DIAGRAM:

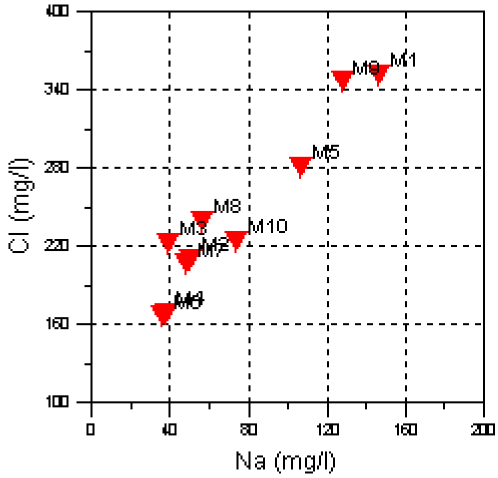

FIGURE 3 Distribution of Sodium and Chloride Concentrations Across Sampling Locations

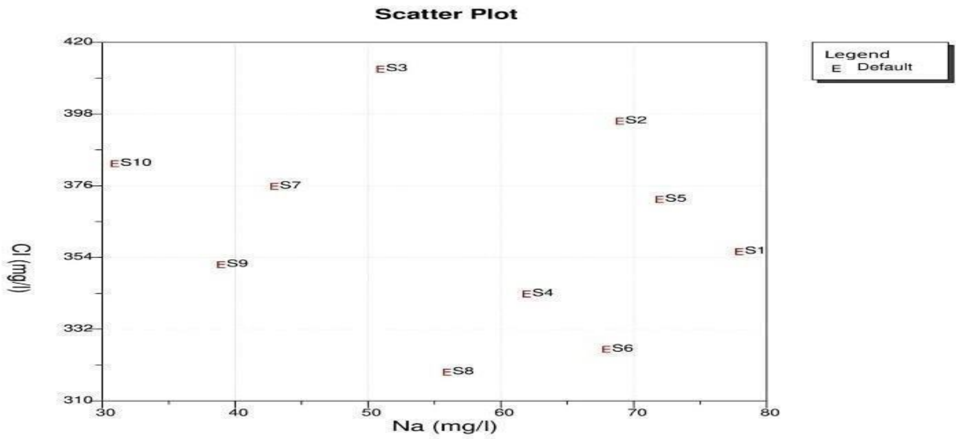

FIGURE 4 Distribution of Water Samples Based on Sodium (Na^+) and Hydroxide (OH^-) Concentrations

- The scatter plot illustrates the relationship between sodium (Na^+) and chloride (Cl^-) concentrations (mg/L) for samples E1–E10, allowing evaluation of possible geochemical processes controlling groundwater chemistry. Sodium concentrations range approximately from 30 to 80 mg/L, while chloride concentrations vary from about 310 to 420 mg/L, indicating moderate to relatively high salinity levels.
- Most samples show a general increase in Na and Cl, suggesting a positive correlation and indicating that both ions may originate from a common source. This relationship commonly reflects halite (NaCl) dissolution, saline water mixing, or evaporative concentration effects.
- Samples such as E1, E2, and E5 show relatively higher Na and Cl values, implying stronger mineral dissolution or possible anthropogenic influence (e.g., domestic wastewater or agricultural return flow). Sample E3 displays comparatively high chloride relative to sodium, which may suggest additional chloride sources independent of

sodium, such as industrial discharge or ion exchange processes.

- Conversely, samples like E8 and E6 show moderate sodium but comparatively lower chloride, indicating slight variation in geochemical control mechanisms. The clustering pattern suggests that most samples are influenced by similar hydrochemical processes, with only minor deviations.
- The absence of extreme outliers indicates relatively consistent groundwater chemistry across the sampling area. The overall positive Na–Cl relationship supports the interpretation that salinity is largely governed by rock–water interaction and possibly evaporative enrichment.

If Na and Cl were plotting exactly along a 1:1 line (not shown), it would strongly confirm halite dissolution dominance; however, slight deviations suggest that secondary processes such as cation exchange may also contribute. In conclusion, the scatter plot indicates a moderate positive correlation between sodium and chloride, suggesting that groundwater salinity is primarily controlled by natural mineral dissolution with possible minor anthropogenic inputs**.**

SCHOELLER DIAGRAM:

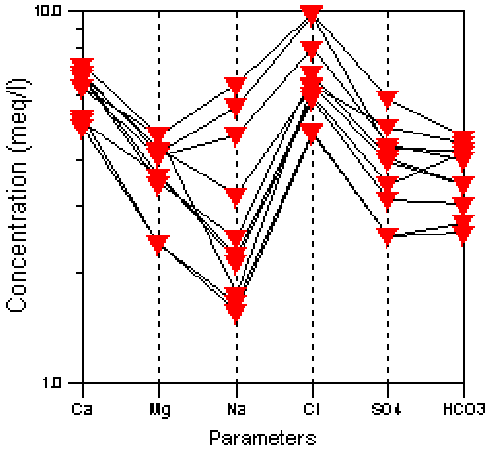

FIGURE 5 Distribution of Sodium and Chloride Concentrations for Water Quality Assessment

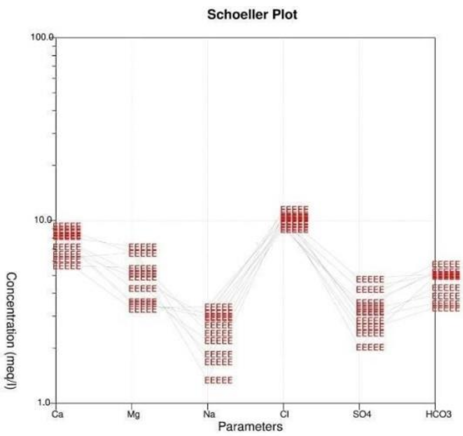

FIGURE 6 Distribution of Major Dissolved Ions in Groundwater Based on the Schoeller Plot

- The Schoeller diagram is a semi-logarithmic graphical representation used to interpret the hydrochemical characteristics of groundwater. In this diagram, the major cations (Ca^{2+}, Mg^{2+}, Na^{+}) and anions (Cl^{-}, SO_4^{2-}, HCO_3^{-}) are plotted on the x-axis, while their concentrations (meq/l) are represented on a logarithmic scale on the y-axis. By connecting the points for each sampling station, the diagram helps in identifying similarities in water chemistry, dominant ions, and possible hydrochemical facies.
- Based on the plotted results for the groundwater samples (m1–m10), the Schoeller diagram shows a similar trend pattern for most samples, indicating that the groundwater in the study area has relatively comparable chemical characteristics. The diagram reveals that chloride (Cl^{-}) and calcium (ca^{2+}) concentrations are relatively higher compared to other ions in many samples, suggesting that these ions dominate the groundwater chemistry. Magnesium (mg^{2+}) and sodium (na^{+}) occur in moderate concentrations, while sulfate (so_4^{2-}) and bicarbonate (hco_3^{-}) show moderate to lower variations among the samples.
- The nearly parallel nature of the plotted lines for different samples indicates that the groundwater likely originates from similar geological formations and undergoes comparable geochemical processes. The dominance of Ca–Cl or Ca–Mg–Cl type water suggests the influence of rock–water interaction, mineral dissolution, and possible mixing

with saline sources in the aquifer system. Overall, the Schoeller diagram indicates that the groundwater chemistry in the study area is mainly controlled by calcium, magnesium, and chloride ions, reflecting the hydrochemical evolution of groundwater in the region.

PIPER DIAGRAM:

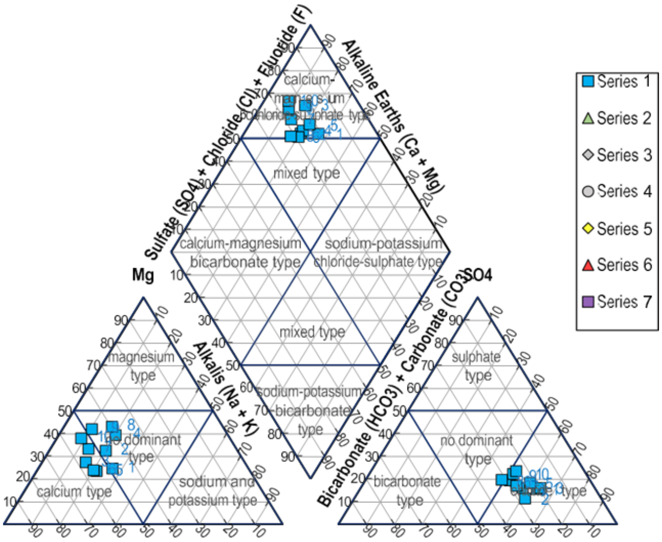

FIGURE 7 Piper Diagram Showing the Hydrochemical Facies of Groundwater Samples

- The Piper plot shows the hydrochemical facies of the collected water samples (labeled E1–E10), illustrating the relative abundance of major cations (Ca^{2+}, Mg^{2+}, Na^{+}+K^{+}) and anions (Cl^{-}, SO_4^{2-}, HCO_3^{-}). In the cation triangle (left), most samples cluster toward the Ca corner with moderate Mg contribution and relatively lower Na+K content, indicating that calcium is the dominant cation in the majority of samples.
- The limited spread toward the Na+K apex suggests minimal alkali metal dominance and indicates that ion exchange processes may not be strongly developed. 4) In the anion triangle (right), the samples are concentrated toward the Cl corner with comparatively lower SO_4 and moderate HCO_3 proportions, demonstrating chloride dominance in the water chemistry.
- The dominance of chloride over sulfate suggests possible influences from evaporation, saline intrusion, or dissolution of chloride-bearing minerals. When projected into the central diamond field, the samples group in the upper central portion, indicating a mixed water type but trending toward Ca–Cl facies.
- The clustering of samples into a tight group implies that similar hydrochemical processes affect all sampling locations. The absence of wide dispersion in the diamond field suggests limited seasonal or spatial variation in groundwater chemistry.
- The overall hydrochemical facies can therefore be interpreted as predominantly calcium–chloride type water with moderate magnesium influence. Such water chemistry may reflect rock–water interaction in sedimentary formations, possible anthropogenic inputs, or evaporative concentration effects depending on the study area's geology and land use. The diagram also indicates that bicarbonate alkalinity is present but not dominant, suggesting that carbonate weathering is occurring but is not the primary controlling process.

4. CONCLUSION

The groundwater in the study area is chemically hard and saline, with high TDS, EC, chloride, bicarbonate, and COD values. Although the groundwater is generally suitable for irrigation due to low sodium hazard, appropriate management practices such as proper drainage, leaching of salts, and cultivation of salt-tolerant crops are recommended to maintain soil health and agricultural productivity. In conclusion, the Piper diagram demonstrates that the groundwater samples share a similar geochemical signature, are mainly Ca– Cl type, and are influenced by mineral dissolution and possibly minor ion exchange processes. Most of the parameters are within WHO limits; the elevated salinity and dissolved solids indicate that the water is not suitable for drinking without treatment but suitable for domestic and other purposes with proper treatment.

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