Study on the significance of ion chemistry in groundwater in Dharmapuri taluk, Dharmapuri District, Tamilnadu, india.

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ABSTRACT

A hydrogeochemical investigation was carried out in Dharmapuri taluk, Dharmapuri district, Tamil Nadu, to assess the suitability of groundwater for domestic and agricultural purposes. The study aimed to understand geochemical processes influencing groundwater quality and the role of natural and anthropogenic factors, which is crucial for sustainable groundwater management in semi-arid regions facing scarcity and degradation. The region is underlain by metamorphic rocks of the Genesis group, including hornblende-biotite gneiss, migmatites, quartzites, schists, amphibolites, ferruginous laterite, and sandy clay. This geological diversity contributes to the complexity of groundwater chemistry. Thirty representative groundwater samples were collected across seasons and locations. Physicochemical parameters were analyzed, including pH, EC, TDS, major cations (Na^+, K^+, Ca^{2+}, Mg^{2+}), and anions (HCO_3^-, Cl^-, SO_4^{2-}). Electrical conductivity values ranged from 1150 to 4098 µS/cm. Higher EC and TDS values were noted in the northern and eastern parts, indicating mineralization and possible saline water intrusion. Hydrogeochemical facies analysis showed seasonal variation, with chloride and sodium being the dominant anion and cation, respectively. Higher bicarbonate concentrations in the southern and western regions are linked to silicate weathering, suggesting active recharge zones with shorter residence time. Groundwater was evaluated for irrigation using standard indices. The Permeability Index (PI) showed groundwater quality to be moderate to good for irrigation. Over extraction for agriculture and urbanization has stressed the aquifer system, increasing susceptibility to salinization and contamination. Despite localized issues, overall groundwater quality was found suitable for drinking and irrigation exception for few locations.

Keywords: Groundwater, Anions, Cations, Water quality, irrigation, Permeability Index

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1. INTRODUCTION

Groundwater is a great source of fresh water existing on earth, increasing industrialization and urbanization coupled with express rise in population despite being an index of progress has been taken its tool on the available natural resources namely water, minerals etc. Since, the quality and quantity of surface and ground water is a vital factor for the expansion of a country, proper attention and evaluation her to be paid for the conserving the natural resources. It is a renewable natural resource having several natural advantages over surface water like wide distribution, negligible evaporation loss and low hazard of contamination. Confidence of groundwater has increased rapidly in many regions because of limited surface water sources, non perennial rivers and frequent failure in monsoon. Therefore, groundwater resources are often over exploited to meet the increasing demand thereby giving a heavy stress to aquifer system. Many studies have been conducted in different parts of the world on groundwater quality by various researchers (Chidambaram et al 2012; Thivya et al., 2013; Singaraja et al., 2013; Anandhan et al., (2016, 2018,2019,2021); Paramaguru et al 2017; Chidambaram 2014, Celik and Yildirim, 2006; Edmunds et al., 2003; Mishra et al., 2005; Leung and Jiao, 2006; Subbarao et al., 2012;). The water quality will also help us to obtain information regarding the environments through which the water has circulated (Janardhana, 2007; Chidambaram et al., 2011; Srinivasamoorthy 2000, 2012). The main purpose of this study is thus to understand the groundwater conditions in the Dharmapuri taluk, Dharmapuri District, Tamil Nadu, India by utilizing more systematic methods. GIS based spatial distribution mapping groundwater suitability evaluation of groundwater quality for domestic and agricultural purposes were carried out Sanjay Kumar et al. 2010, Anadhan 2018. Water is often referred to as the essence of life, and for good reason. Covering about 71% of the Earth's surface and making up roughly 60% of the human body, water is an indispensable resource that sustains life in all its forms. From its role in maintaining ecological balance to supporting human health and industrial activities, water is fundamental to the survival and progress of our planet. The Earth holds an estimated 1.386

billion cubic kilometers (km^3) of water. However, most of this approximately 96.5% is saltwater, brackish water, and other forms such as marshes are found in oceans and seas. This leaves only 2.5% of the Earth's total water as freshwater is glaciers and ice caps, ground water and surface fresh water and other saline water is 0.9% . In turn, the fresh water comprises polar ice caps and glaciers 68.7%, Underground water 30.1% and other fresh water like surface water occurring in lakes, rivers and other surface water is1.2%. The available surface water and other fresh water is excluding atmosphere, swamps, marshes, rivers, lakes, soil moisture and surface water bodies etc. It can be clearly understood from the global water distribution pattern.

2. Study area

Dharmapuri taluk is one of the administrative divisions of Dharmapuri district. Dharmapuri District, officially established on October 2, 1965, after its separation from the larger Salem District, is situated in the northwestern corner of Tamil Nadu, forming a crucial part of the state's interior plateau. It is bounded by Krishnagiri District to the north, which itself was part of Dharmapuri until it was carved out as a separate district in 2004, Salem District to the south, Tiruvannamalai and Villupuram Districts to the east, and the Kaveri River, a major lifeline of southern India, to the west. The dharmapuri taluk spans 785 square kilometers, lying between latitudes 12°0′ N to 12°10′ N and longitudes 78°05′ E to 78°15′ E, encompassing a landscape of rolling hills, and rich forest cover (fig.1). Dharmapuri taluk is recognized as one of the most backward and drought-prone districts in the state due to irregular rainfall, lack of major irrigation infrastructure, and limited industrial development. Nearly 70% of the workforce is dependent on agriculture and allied activities.

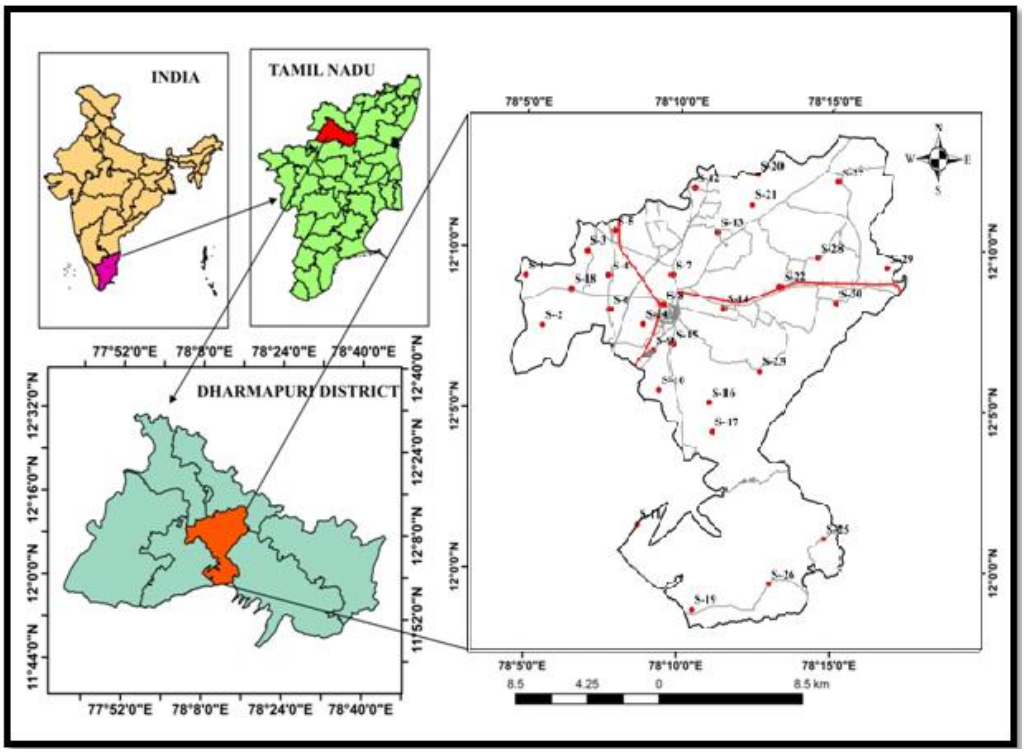


Fig. 1 Study area and sample location map of study area.

3. Geology

In our study area located in the northern part of Tamil Nadu, lies within the Dharwar Craton, one of the oldest geological provinces of India. The region is primarily composed of Archaean to Proterozoic rocks, with minor Quaternary deposits. The oldest formations belong to the Peninsular Gneissic Complex (PGC), comprising highly metamorphosed hornblende-biotite gneisses and migmatites, which form the basement rock. Overlying these are the Dharwar Supergroup rocks, represented by the Sathyamangalam Group, consisting of quartzites, schists, amphibolites, and minor banded iron formations (BIF), indicative of ancient greenstone belts. During the Proterozoic era, the region witnessed the intrusion of Closepet Granite, a pink to gray porphyritic granite that forms prominent hillocks and tors across Dharmapuri. In more recent geological times, lateritic cappings developed due to intense tropical weathering of the granitic and gneissic rocks, resulting in iron-rich duricrusts. The Quaternary alluvial deposits, found along the Ponnaiyar River and its tributaries, consist of unconsolidated sand, silt, and clay, supporting agriculture in the region as shown in Table 1. (References: GSI reports, Krishnan 1982)

Table 1. Geological succession of Study area.

Age	**Formation/Group**	**Lithology**	**Key Features**
Quaternary	Laterite & Alluvium	Ferruginous laterite, sandy clay	Weathering product, river deposits
Proterozoic	Closepet Granite	Pink porphyritic granite	Massive intrusions into Dharwar rocks
	Dharwar Supergroup (Sathyamangalam Group)	Quartzites, schists, amphibolites	Metasedimentary rocks, minor iron formations
Archaean	Peninsular Gneissic Complex (PGC)	Hornblende-biotite gneiss, migmatites	Oldest basement rocks, highly metamorphosed
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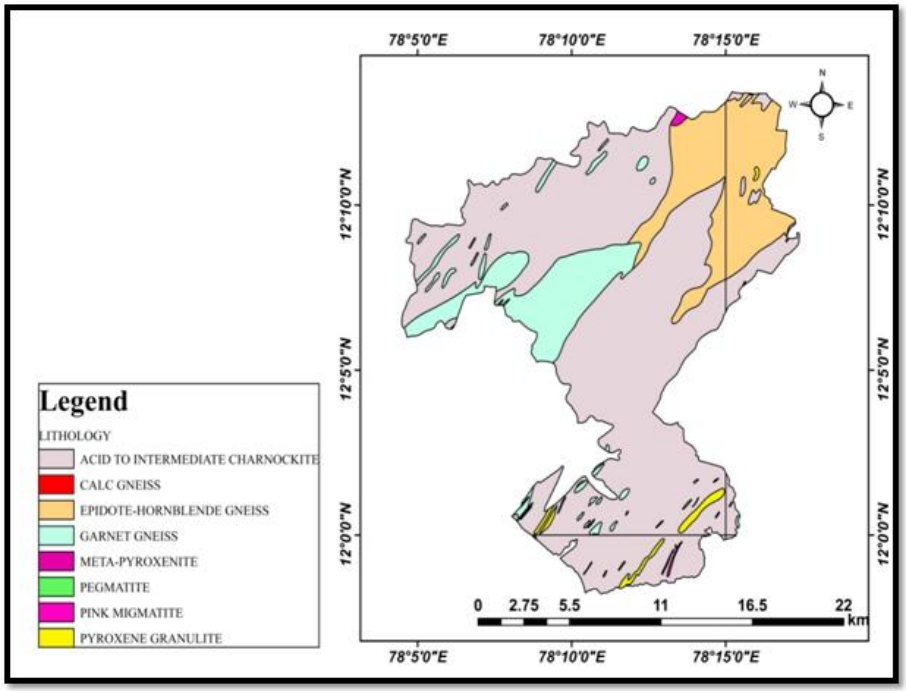


Fig. 2. Geology Map of the Study area.

4. Result and discussion

Hydrogeochemical research requires proper site selection for collection of water samples and appropriate method of analysis. Sampling sites were located taking several factors into considerations like lithology, structure, geomorphology, and river influence, urban, agricultural and availability of wells. Sampling of groundwater has been carried out in Dharmapuri Taluk. The groundwater samples were collected from the premonsoon season. A total of 30 samples were collected (Table 2). Ground water sampling locations are shown in figure 1. One litre of water samples were collected in polyethylene bottle. Then it was sealed and brought to laboratory for analysis and stored properly (4^{o}C) before analysis. Water samples were analysed for major and minor ion concentration by using standard procedures (APHA 1998;Ramanathan 1992; Ramesh and Anbu, 1996, WHO (1984) Groundwater samples were collected in space and time and analysed for major and minor dissolved ions using standard procedures (Anandhan 1998, 2000 and 2016,; Nagarajuna reddy 2023; Chidambaram 2014 and 2015; Singaraja 2014 Ramanathan 2000) (ALPHA 1989, 1995) Groundwater in the study area is generally alkaline in nature with pH varies

Table 2. The chemical concentration of different ions present in the ground water of the area.

S.NO	LOCATION	pH	EC	Cl	HCO_3	Ca	Mg	H_4SiO_4	PO_4	SO_4	Na	K	TDS
1	SEKKARAPATTI	7.57	2362	212.7	323.3	74	14.4	186.7	1.55	74.4	131.1	9.8	1027.95
2	KUYILANTHOPPU	7.2	1150	97.4	396.5	46	33.6	178.9	1.35	43.5	53.7	13.3	864.25
3	DHOVARANDHATI	7.14	3238	168.3	286.7	78	46.8	94.1	1.2	189.2	229.8	25.4	1119.5
4	SOGATHUR	7.5	1370	79.7	457.5	24	19.8	193.1	2.2	12.7	248.7	201.4	1239.1
5	KADAGATHUR	6.64	1866	150.6	427	98	8	234.2	1.4	36	60.3	6.7	1022.2
6	PAPPINAYAKANALLI	7.89	1872	88.6	878.4	26	10.8	196.7	1.5	8.9	307.4	7.6	1525.9
7	HALE DHARMAPURI	9	1660	168.3	140.3	58	9.6	342.1	3.35	9.1	236	46.1	1012.85
8	KUMARASAMY PETTAI	6.95	1250	221.5	628.3	38	16.8	187	1.85	11.6	96.2	9.2	1210.45
9	BHARATHIPURAM	7.45	1278	62.03	286.7	46	8.4	169.1	1.55	13.8	99.7	7.4	694.68
10	VENKATAMPATTI	6.76	3944	381.08	530.7	70	21.6	159.2	1.45	51	319.5	45.4	1579.93
11	BUHANAHALLI	6.97	1402	124.07	616.1	82	9.6	195.6	1.5	17.8	68.4	9.4	1124.47
12	NALLANALLI	7.28	1252	159.5	329.4	58	15.6	142.5	1.55	15.6	40.5	6.1	768.75
13	KOTTAVUR	7.16	4098	336.7	634.4	78	25.2	161	1.35	42	420	13.5	1712.15
14	SETTIKARAI	7.27	1870	194.9	463.6	66	21.6	123.5	1.2	14	46.4	7.6	938.8
15	ANNASAGARAM	7.02	2200	194.9	555.1	78	6.8	97.8	1.45	12.5	192.8	14.1	1153.45
16	MUKKALANAYAKKANPATTI	6.7	3400	319.05	616.1	90	19.2	111.7	1.45	29.7	261	15.3	1463.5
17	NOOLAHALLI	6.79	2046	150.6	689.3	82	26.4	197.3	1.05	24.9	168.9	7.5	1347.95
18	ADHIYAMAN NAGAR	7.21	1374	79.7	347.7	64	13.2	161.3	1.4	18.6	80.2	6.7	772.8
19	MANGALAKOTTAI	7.3	2368	115.2	817.4	34	20.4	192.8	1.45	32.4	396.7	9.4	1619.75
20	INDAMANGALAM	6.95	2726	117.25	512.4	90	14.4	133.1	1.2	21.8	225.9	8.6	1124.65
21	NAIKANKIOTTAI	7.04	1512	117.25	445.3	88	16.8	125.2	1.2	13.1	60.1	8.4	875.35
22	SOLAIKOTTAI	6.81	3060	292.4	841.8	50	56.4	275.7	1.4	34.4	363.8	7.8	1923.7
23	NARASINGAPURAM	6.86	2726	203.8	884.5	68	30	212.1	1.5	24.6	282.9	14.9	1722.3
24	PIDAMANARI	7.01	2046	115.2	603.9	62	25.2	210.1	2.5	8.7	246.9	8.7	1283.2
25	THIPPIREDDIHALLI	7.07	2046	124.07	567.3	30	39.6	196.7	1.4	23.2	221.8	13.3	1217.37
26	KONDAKARANAHALLI	7.03	1196	106.35	420.9	44	39.6	220.8	1.2	14.8	46.1	12.9	906.65
27	KRISHNAPURAM	7.02	2726	248.15	762.5	58	10.8	328.7	1.7	21.6	310.5	17.9	1759.85
28	AKKAMANAHALLI	6.9	2726	292.4	488	60	31.2	369.8	1.25	13.6	136.5	15.7	1408.45
29	THINNAPATTI	7.52	1400	97.4	494.1	34	34.8	365.1	1.6	17.1	79.5	7.3	1130.9
30	MUKANOOR	7.01	1256	106.3	573.4	56	18	193.7	1.2	11.3	50.8	4.9	1015.6

Table 3. Max, Min, and Average Ions present in the ground water of the study area

	pH	EC	Cl	HCO_3	Ca	Mg	H_4SiO_4	PO_4	SO_4	Na	K	TDS
MAX	9	4098	381.08	884.5	98	56.4	369.8	3.35	189.2	420	201.4	1923.7
MIN	6.64	1150	62.03	140.3	24	6.8	94.1	1.05	8.7	40.5	4.9	694.68
AVE	7.17	2114	170.85	533.953	61	22.15	198.52	1.53	28.73	182.74	19.41	1218.82

from 6.64 to 9 with an average of 7.17. EC is an indirect measure of ionic strength and mineralisation of natural water. EC of pure water is around 0.05 µs/cm (Hem, 1989) EC ranges from 1150 µs/cm to 4098 µs/cm with an average of 2114 µs/cm (Table 3). Total dissolved solids (TDS) which is generally the sum of dissolved ionic concentration varies between 694.68 mgl^{-1} to 1923.7 $mgl^{-1}$with an average of 1218.82 mgl^{-1}.

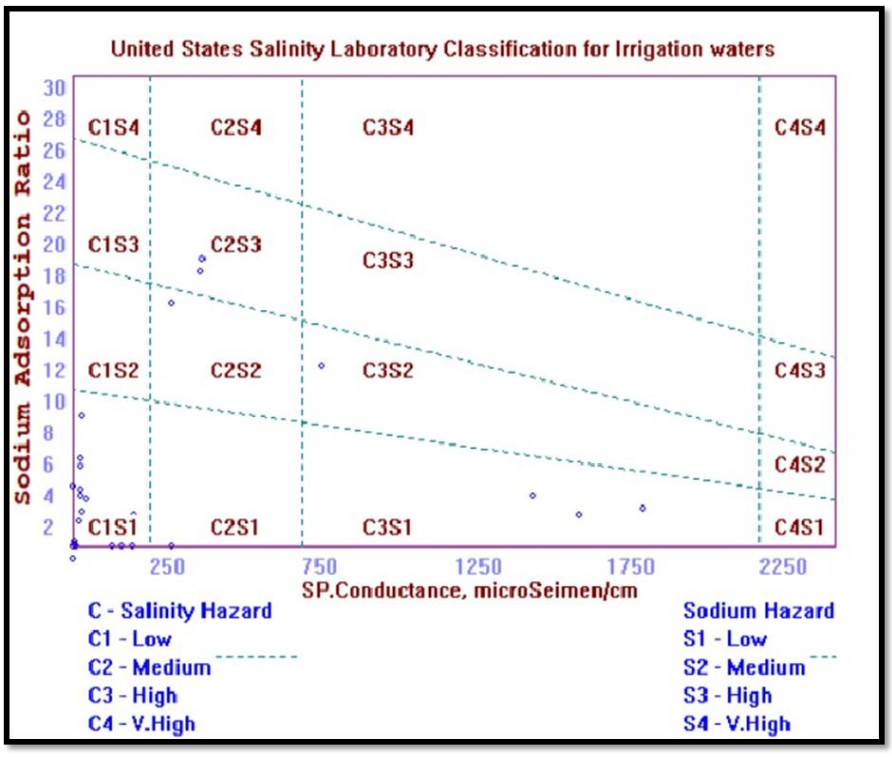


Fig. 3 Classification of groundwater samples for irrigation purpose using USSL diagram

When SAR (alkali hazard) and specific conductance (Salinity hazard) is plotted in USSL diagram USSL (1954) classification of water for irrigation purpose can be determined. Majority of samples fall in C1S1 zone indicating low salinity and low sodium hazard, satisfactory for plants having moderate salt tolerance on soils (Fig 3). Minor representation of samples is also noted in C2S3 and C3S1 zones indicates medium to high salinity waters.

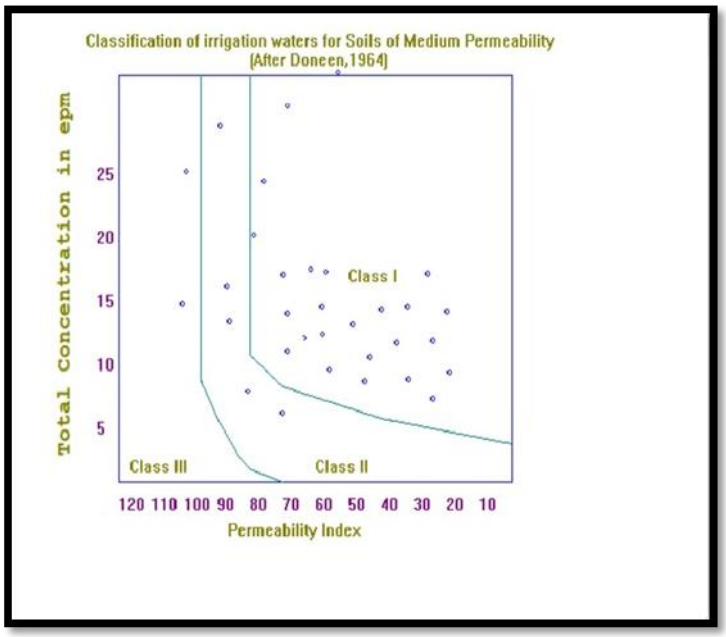


Fig. 4 Doneen's permeability index plot

Permeability index is an important factor which influences quality of irrigation water, in relation to soil for development in agriculture. Based on permeability index Doneen (1948), classified the groundwater as class I, class II and class III to find out suitability of groundwater for irrigation purpose (Fig 4). Most of the samples fall in class I indicating water is good for irrigation purpose. Certain samples was noted class II indicates water is unfit for irrigation purpose.

The chemical facies of groundwater in the study was obtained by plotting the values in the Piper diagram (Piper 1954)(Fig.5). The position of the points reveals that in the cation plot, most water samples falls in calcium-magnesium facies type and few samples fall in calcium-sodium facies type, whereas in the anion plot chloride-sulfate-bicarbonate facies type contains most samples.

In Piper diagram (fig. 5) the sample fall into three major segments, representing three types of water i.e.,Na-Cl, mixed Ca-Na-HCO and mixed Ca-Mg-Cl. Majorities of the samples fall in Ca–Mg and Na-Cl, which indicates salinity nature in the groundwater.

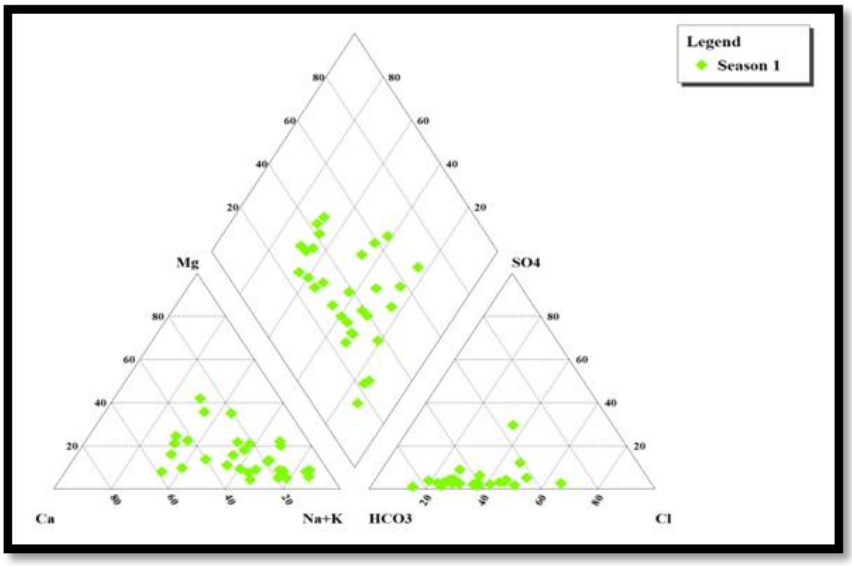


Fig.5 Piper Trilinear plot for the study area

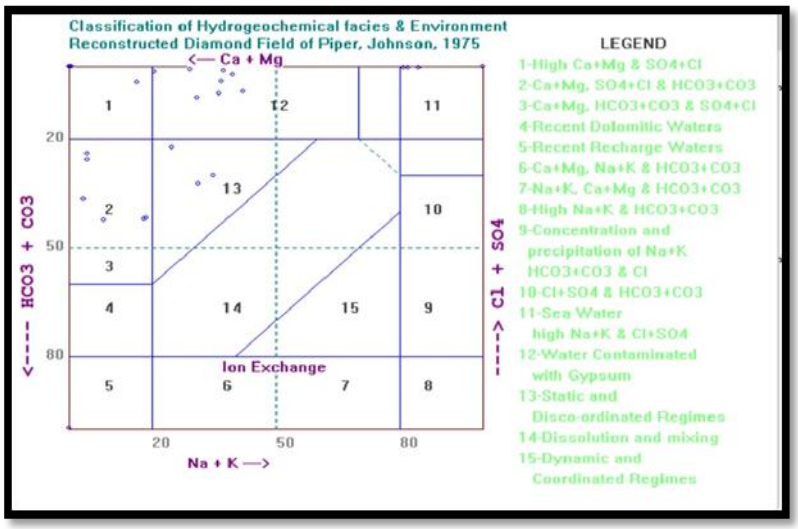


Fig.6 Johnsons plot (Modified Piper) for the study area

The modified Johnson's (Diamond) plot, Geochemistry of groundwater is influenced by geochemical reaction and mixing. Here cation is dominated by Na>Ca>Mg and anions by $Cl>HCO_3>SO_4$. Evolution of water is chiefly dependant on this relationship between rock types and water composition of anions and cations (Fig 6) (Jhonsons 1974). In figure samples fall in water contaminated by secondary precipitation and in static and dis-coordinated regimes and also noted in high $Ca+Mg+SO_4+Cl$ zone and HCO_3+CO_3 zones indicating weathering impact. In general alkali exceeds alkaline earth on trolled by strong and weak acids. Mechanism controlling chemistry of groundwater in the study area (Gibbs, 1970). In the study area, the ratios of (Na+K) /(Na+Ca+K) of the groundwater samples have been plotted against TDS. Similarly the ratios of $C1/(C1 + HCO_3)$ have been plotted against TDS and is shown in Fig 6, show the similar nature of water. The density of the distribution of points is maximum in the centre and this indicates that mechanism controlling of groundwater is predominately due to water rock interaction.

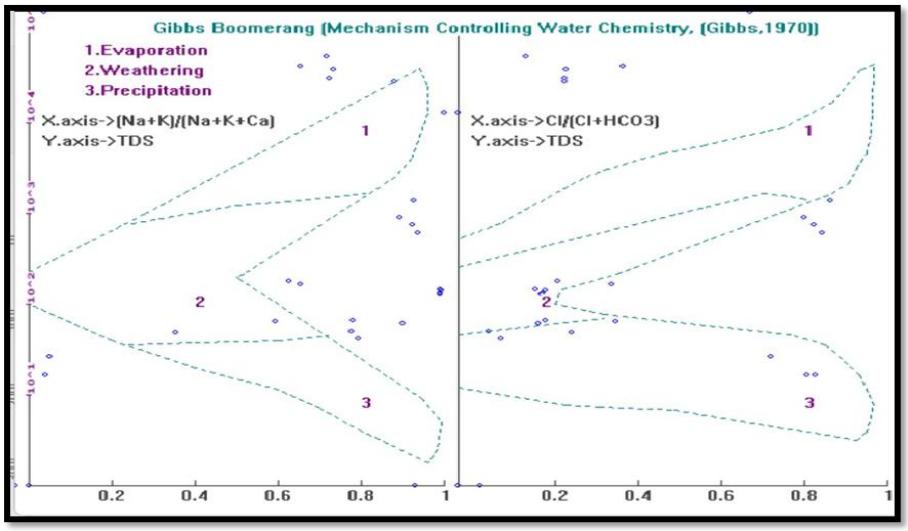


Fig.7 Gibbs Diagram for the study area

Mechanism controlling chemistry of groundwater in the study area (Gibbs, 1970). In the study area, the ratios of (Na+K) / (Na+Ca+K) of the groundwater samples have been plotted against TDS. Similarly the ratios of $C1/(C1 + HCO_3)$ have been plotted against TDS and is shown in fig 7, show the similar nature of water. The density of the distribution of points is maximum in the centre and this indicates that mechanism controlling of groundwater is predominately due to water rock interaction.

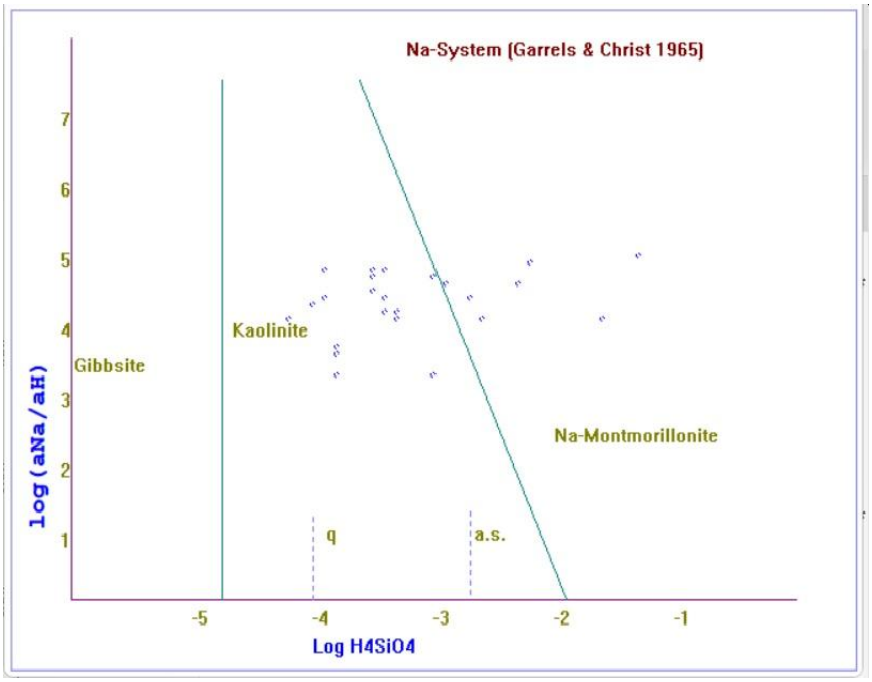


Fig.8 Thermodynamic stability For Na System for the study area

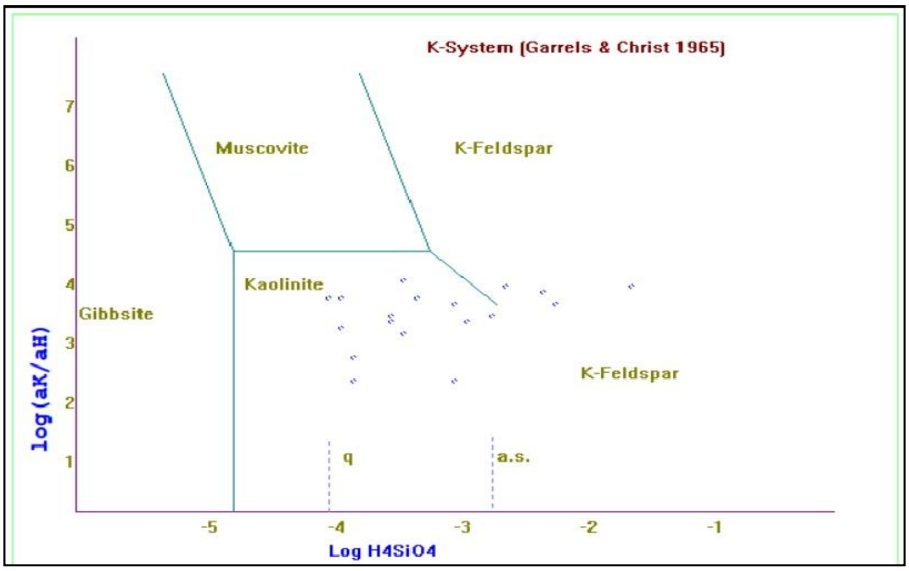


Fig. 9 Thermodynamic stability For K System for the study area

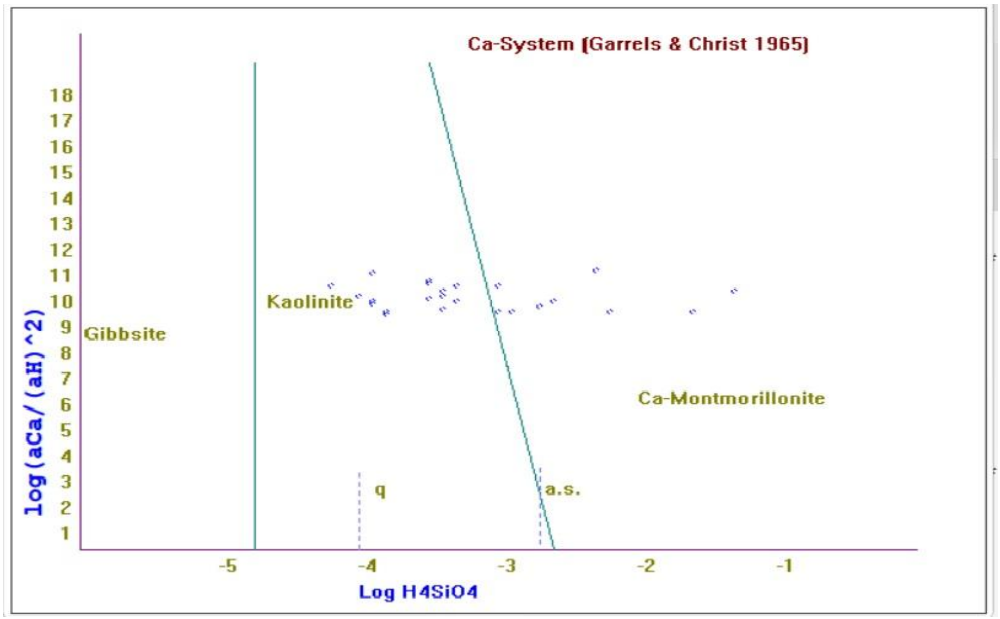


Fig. 10 Thermodynamic stability For Ca System for the study area

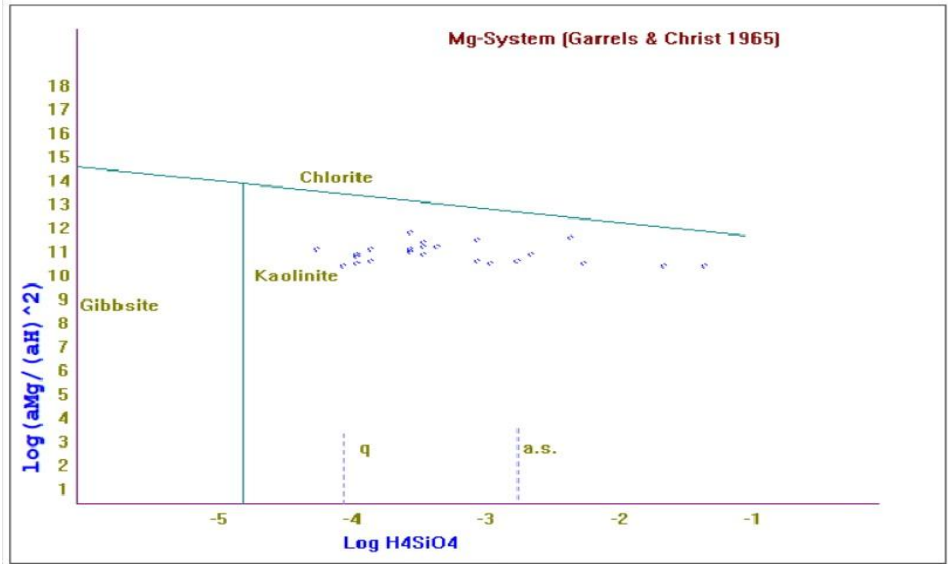


Fig. 11 Thermodynamic stability For Mg System for the study area

Thermodynamic stability Diagram for Na system, initially samples stable with Kaolinite field and further it tend to move towards Montmorllinite due to the excess supply of cations and silica (Fig.8). In K system, movement of ions is well noted (Fig.9). Ca system, cluster of samples are stable with Kaolinite and it tends to move to Montmorllinite field indicates the movement of in OS along the groundwater flow path (Srinivasamoorthy 2011, Chidambaram 2013) (Fig 10). In Mg system, most of the samples stable with Kaolinite indicates incongruent dissolution of feldspar with minor representation in chlorite field (Fig.11).

5. Conclusion

Groundwater in the study area is generally acidic to alkaline in nature with pH ranging from 6.64 to 9 with an average of 7.17. EC ranges from 1150 µs/cm^2 to 4098 µs/cm^2 with an average of 2114 µs/cm^2. Total dissolved solids (TDS) which is generally the sum of dissolved ionic concentration varies between 694.68 to 1923.7 mg/1 with an average of 1218.82 mg/1. USSL diagram, classification of water for irrigation purpose can be determined. Majority of samples fall in C1S1 zone indicating low salinity and low sodium hazard, satisfactory for plants having moderate salt tolerance on soils. Minor representation of samples is also noted in C2S3 and C3S1 zones indicates medium to high salinity waters. Doneen Permeability index classification of groundwater shows most of the samples fall in class I indicating water is good for irrigation purpose. Certain samples was noted class II indicates water is unfit for irrigation purpose. Gibbs boomerang shows that majority of samples falls in weathering dominant zone but few representations fall away from boomerang zone shows impact of secondary salt precipitation. Thermodynamic stability diagram for Ca system, cluster of samples are stable with Kaolinite and it tends to move to Montmorllinite field indicates the movement of in OS along the groundwater flow path. In Mg system, most of the samples stable with Kaolinite indicates incongruent dissolution of feldspar with minor representation in chlorite field. In Na system, initially samples stable with Kaolinite field and further it tend to move towards Montmorllinite due to the excess supply of cations and silica. In K system, movement of ions is well noted.

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