Hydrogeochemical And Water Quality Analysis Of Groundwater In Churu District,Rajasthan

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Abstract
Churu is located in the south eastern part of Rajasthan state between 27º 24' 31.50" to 29º 00' 01.74" North latitudes and 73º 50' 39.45'' to 75º 40' 31.85'' East longitudes. Churu spreads over an area of 13858 sq.km falling within the semiarid region and normally facing water scarcity as well as quality problems. The major sources of occupation are agriculture, horticulture and animal husbandry, engaging almost 80% of the workforce. Evaluation of groundwater quality is an important issue to assure from its safe and stable use. Seven major parameters (via, calcium, magnesium, chloride, sodium, potassium, fluoride, sulphate) were selected to assess the water quality. The samples like G-1, G-3, G-4, G-7, G-8, G-9, G-11, G- 12, G-14, G-16, G-23, G-25 and G-26 were found to be with high fluoride concentration more than permissible value. Eight samples have acceptable water quality for drinking and agriculture purpose but remaining 18 sample were found to be above permissible limits of WHO and BIS. The hydrochemical type in surface water was of CaCl > Mixed Ca Mg Cl > $CaHCO_3$ > NaCl type. The cations and anions in surface water were mainly from weathering and dissolution of carbonate rock. Results showed that the water quality in all 26 sampling sites. Some parameters show average concentration or adequate concentration and some parameters show high concentration. The reason can be attributed to geochemicalinteractions.

Introduction

The quality of water resources is a subject of concern. The health and happiness of the humanbeings are closely tied up with the quality of the water used for consumption where the per capita consumption of water is an index of quality of life of the people as well as their economic and social condition.(Kulshreshtha, 1998).

Two major sources of drinking water are groundwater and surface water. In India groundwater is the major source of drinking water with 85% of the population dependent onit (Patel et al., 2007). The groundwater usually refers to the water below the water tablewhere saturated conditions exist. Under the influence of gravity, infiltrating water slowly percolates through pores in rock such as sand stone. These water bearing layers of the earth's crust are called aquifers and the water in them is known as groundwater. There is no open space under the ground like a river runs on the surface except in cavernous limestonenetworks and some open lava tubes in volcanic terranes. The water travels by twisting through the pore spaces between the sand grains. The smaller the pore spaces and the more difficult it is for fluids to pass through a solid, this property is known as permeability. The permeability depends largely on the amount of pore space between the grains or crystals ofthe rock, the porosity. Thus the ground acts like a sponge, seeking up rain in some places and leaking it out at other places.

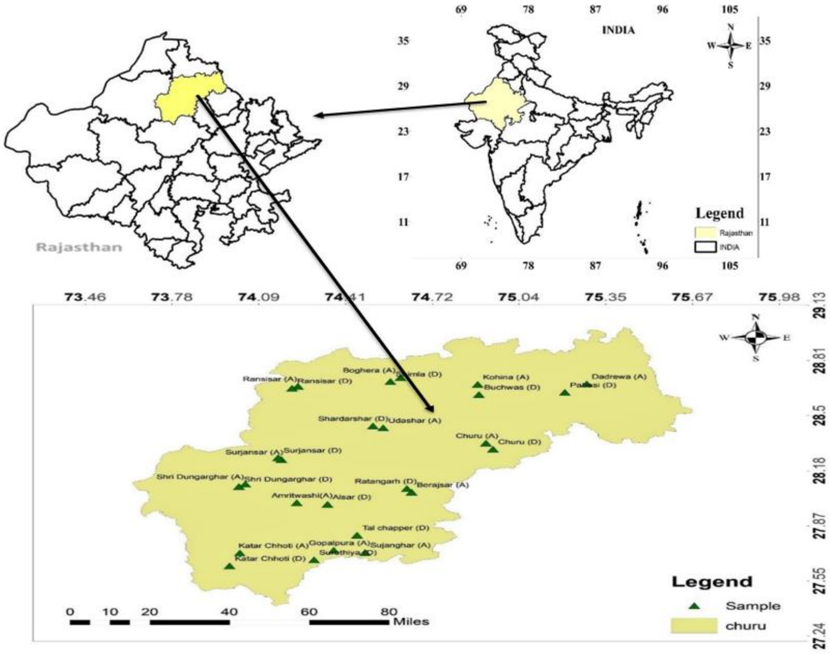
Due to various natural and anthropogenic factors, the groundwater is getting polluted becauseof deep percolation from intensively cultivated fields, disposal of hazardous wastes, liquidand solid wastes from industries, sewage disposal, and surface impoundments. The risk of drinking water is rising rapidly in the developing countries. Millions of people all over the world particularly in the developing countries are losing their lives every year from water borne diseases like cholera, typhoid, bacillary dysentery, infectious hepatitis, leptospirosis, giardiasis, and gastroenteritis (Arnal et al., 2001).

Groundwater

Groundwater is the water that seeps through rocks and soil and is stored below the surface. The rocks in which groundwater is stored are called aquifers. Aquifers are typically made up of gravel, sand, sandstone or limestone. Water moves through these rocks because they have large connected spaces that make them permeable. The area where water fills the aquifer is called the saturated zone. The depth from the surface at which groundwater is found iscalled the water table. The water table can be as shallow as a foot below the ground, or it can be a few hundred meters deep. Heavy rains can cause the water table to rise, and conversely, continuous extraction of groundwater can cause the level to fall. The hydrogeological setting of groundwater defines the potential of this resource and its vulnerability to irreversible degradation.

Location and extent of the Study area Churu district

Churu district is located in the northern part of Rajasthan. It is bounded on the north by Hanumangarh district, in the east by the state of Haryana and Jhunjhunu district, south by Sikar and Nagaur districts and by Bikaner district in the west. It stretches between 27º 24' 31.50” to 29º 00' 01.74” North latitudes and 73º 50' 39.45’’ to 75º 40' 31.85’’ East longitudes.It has six tehsils including Churu, Rajgarh, Ratangarh, Shardarshar, Sujangarh, and Taranagar. The district does not have a properly evolved drainage system, except for a negligible part in the east which is part of Shekhawati River Basin, almost whole of the district is part of an ‘Outside’ Basin. Churu district is administratively divided into six blocks but few year back it will be divided into seven blocks and in this study, Churu divided into seven blocks.



Map of Churu District (in legend sample should be written as sample site)

Sampling, Methodology and Parameter analysis:

Sample location

S. No.	Sample Site	Source of Water	Latitude	Longitude
1	Dadrewa (A)	Bore-well	28.68	75.28
2	Pabasi (D)	Bore-well	28.63	75.20
3	Kohina (A)	Bore-well	28.68	74.89
4	Buchwas (D)	Bore-well	28.62	74.89
5	Boghera (A)	Well	28.72	74.61
6	Shimla (D)	Bore-well	28.69	74.57
7	Ransisar (A)	Well	28.67	74.23
8	Ransisar (D)	Bore-well	28.65	74.21
9	Surjansar (A)	Well	28.25	74.17
10	Surjansar (D)	Well	28.26	74.16
11	Udashar (A)	Well	28.43	74.54
12	Shardarshar (D)	Well	28.44	74.51
13	Churu (A)	Well	28.34	74.92
14	Churu (D)	Bore-well	28.31	74.94
15	Berajsar (A)	Well	28.06	74.65
16	Ratangarh (D)	Hand-pump	28.08	74.63
17	Amritwashi(A)	Well	28.00	74.23
18	Alsar (D)	Hand-pump	27.99	74.34
19	Shri Dungarghar (A)	Well	28.11	74.04
20	Shri Dungarghar (D)	Hand-pump	28.09	74.02
21	Katar Chhoti (A)	Bore-well	27.71	74.02
22	Katar Chhoti (D)	Hand-pump	27.64	73.99
23	Gopalpura (A)	Bore-well	27.73	74.36
24	Surothiya (D)	Hand-pump	27.68	74.29
25	Sujanghar (A)	Well	27.72	74.48
26	Tal chapper (D)	Hand-pump	27.82	74.45

A = Agricultural Land & D= Populated Area.

S. No.	Parameter	Method of Determination
1	pH	Electrometric Method
2	EC	Conductivity Cell Potentiometer
3	TDS	Conductivity Cell Potentiometer
4	Alkalinity	Acid-Base Titration
5	Hardness	EDTA (Ethylene diamine tetra acetic acid) Titrimetric Method
6	Chloride	Argentometric Titration
7	Fluoride	SPADNS (analytical range 0.0 to 2.0 mg/L)
8	Sulphate	Turbidimetric Method
9	Potassium	Flame-photometer Method
10	Sodium	Flame-photometer Method

Results and Discussion

Hydro chemical Properties:

Sample	pH	EC µS	TDS mg/L	Alkalinity mg/L	T. H. mg/L	Ca^{2+} mg/L	Mg^{2+} mg/L	Na^{+} mg/L	K^{+} mg/L	Cl^{-} mg/L	SO_4^{2-} mg/L	F^{-} mg/L
G 1	8.03	8230	3510	900	266.67	46.53	36.53	131	0.16	1712.8	663	13
G 2	7.69	2740	1260	640	173.33	42.53	16.28	49.1	0.17	259.92	339	2
G 3	8.48	1370	570	420	153.33	33.2	17.09	28.3	0.02	36.66	97	12
G 4	7.24	4740	2280	496.67	493.33	114.53	50.3	77.7	0.06	573.16	222	16
G 5	7.38	2030	740	486.67	666.67	118.53	89.99	12.7	8.77	76.64	180	1.6
G 6	7.18	7660	3330	360	746.67	127.87	103.76	282	0.69	1586.18	1150	1.5
G 7	7.9	952	215	133.33	123.33	31.87	10.61	8.6	0.25	53.32	48.5	4
G 8	7.16	9150	3900	323.33	1363.33	238.53	186.38	122	1.01	2156	1320	16
G 9	7.47	4630	1920	766.67	156.67	29.2	20.33	82.9	0.44	756.43	422	5
G 10	7.01	7110	2930	326.67	620	122.53	76.22	99.1	1.18	2051.03	418	0.9
G 11	7.54	5560	2290	276.67	980	171.87	133.73	61.4	0.88	1372.91	1000	13
G 12	7.86	4070	1780	853.33	103.33	19.87	13.04	72.7	0.28	521.5	451	8
G 13	7.31	8490	3630	266.67	1353.33	213	199.34	112	0.75	2264.3	1690	1
G 14	7.3	2360	1030	250	476.67	78.53	68.12	23.2	0.88	566.49	114.5	6
G 15	7.73	3170	1310	743.33	100	29.2	6.56	58.3	0.19	166.62	389	4
G 16	7.84	3110	1250	470	310	55.87	41.39	47.2	0.75	596.48	139	9
G 17	8.23	1360	550	286.67	170	37.2	18.71	20.6	0.22	168.28	109	2
G 18	8.04	1390	590	326.67	220	35.87	31.67	17.8	0.31	189.94	111	0.6
G 19	7.68	2530	1090	703.33	210	46.53	22.76	39	0.28	138.29	243	0.7
G 20	6.76	7730	3220	366.67	1456.67	349.2	141.83	78.8	0.63	411.54	239	2
G 21	7.89	2460	1060	173.33	323.33	50.53	47.87	26.6	0.34	2237.64	147.5	2
G 22	7.45	1150	487	280	230	42.53	30.05	10.1	0.31	156.62	63.5	3
G 23	7.33	87200	32500	300	7733.33	1318.53	1078.19	1590	94.87	1161.31	9010	18
G 24	7.18	4060	1730	170	1436.67	294.53	170.18	15.5	1.18	1216.29	230.5	1
G 25	7.58	2150	910	270	343.33	75.87	37.34	32.8	0.28	1657.82	104.5	11
G 26	7.63	2570	1090	646.67	203.33	49.2	19.52	157	2.87	401.54	167	9

pH: pH in the groundwater of study area is caused by bicarbonate and carbonates. The pH of the groundwater from study area range in between 6.76 to 8.48 and sample G20 found slightly acidic but all samples in prescribed desirable limit given by Bureau of Indian Standard (BIS) is 6.5-8.5 and Of World Health Organization (WHO) is 7.0-8.5 respectively. pH range is normal all over the Churu district.

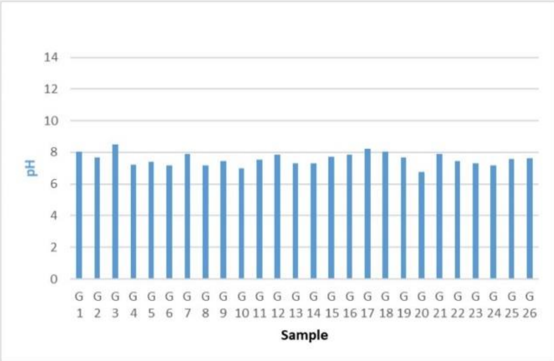


Fig 10: pH range of Churu district

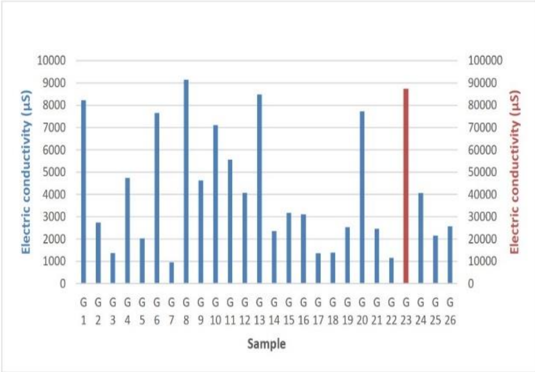


Fig 11: Electric Conductivity of Churu district

Electric conductivity: The electric conductivity of thegroundwater from study area range in between 952 to 87200 µS. Sample G 23 is found with the highest conductivity 87200 µS because many ions present there. Other samples are mostly in a range prescribed by WHO or BIS.

TOTAL DISSOLVED SOLIDS: The range of total dissolved solids from 215 to 32500 mg/L found in the sampling area butthe sample G 23 show total dissolved solids 32500 mg/L. The area with higher TDS was found with lower water quality. Sample G 23 water is very highly polluted. In the groundwater 1000 mg/L is optimum range for the TDS. The rest of the samples fall under the standard of BIS and WHO.

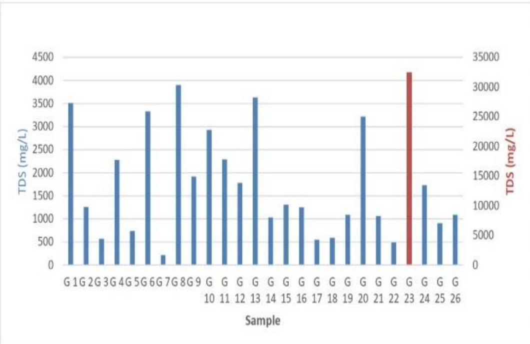


Fig 12: Total Dissolved Solids

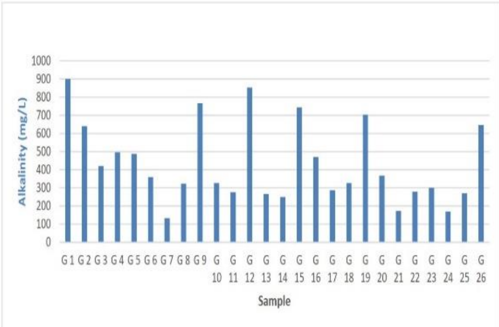


Fig 13: Alkalinity

ALKALINITY: The alkalinity of water may be defined as its capacity to neutralize the acid. Alkalinity in the groundwater of study area is caused by bicarbonate and carbonates. The alkalinity of the groundwater from study area range in between 133.33 to 900 mg/L. Approximately allsample were found in prescribed range of alkalinity for water given by the WHO and BIS.

TOTAL HARDNESS: The determined total hardness in all site is from 100 to 7733.33 mg/L. Permissible limit for total hardness is 500mg/L by WHO and 600 mg/L by BIS. The hardness of the 33% sample isabove the standard level given by the BIS. In all sampling locations, calcium hardness concentration is greater than magnesium hardness concentration. Hardness has got no adverseeffect on human health.

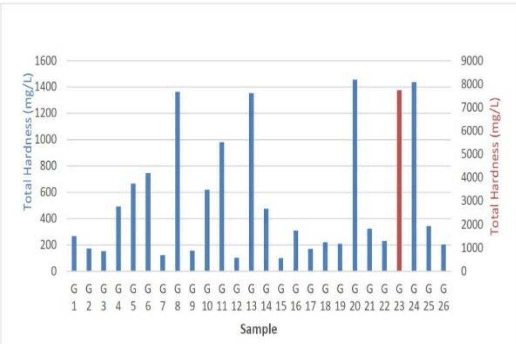


Fig 14: Total Hardness

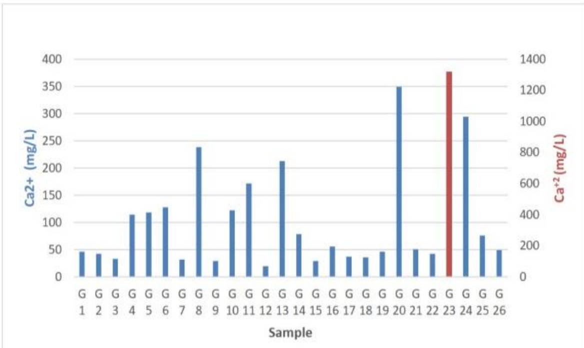


Fig 15: Calcium Concentration

Variation in ions concentration:

In the study area, calcium concentration ranges between 19.87 to 1318.53 mg/L. In some of the blocks, it was above the standards of 75 mg/L. Sample G 23 shows the highest concentration of calcium 1318.53 mg/L. The higher value is mainly attributed due to the abundant availability of lime stone in the area. Magnesium in the sampling area range between 6.56 mg/L to 1078.19 mg/L. Sample G23 show highest magnesium concentration 1078.19 mg/L in the sampling area. Only eight samples are found suitable and within the range of BIS. The concentration of magnesium may be very high due to the dissolution of magnesium, calcite, gypsum and dolomite.

Sodium in the groundwater varies between 8.6 to 1590 mg/L and potassium varies in between 0.02 to 94.87 mg/L. Sample G23 has highest concentration of sodium and potassium. Largeamounts of these salts give a salty taste when combined with chloride. Moderate quantities have little effect on the usefulness of water for most purposes. Higher concentration of sodium is not suitable for irrigation purpose due to sodium sensitivity of crops and plant. Chloride contents in fresh water are largely influenced by evaporation and precipitation**.** Chloride is the most troublesome anion in the irrigation water. They are generally more toxic than sulphate**.** The chlorides value was between 36.66 to 2237.64 mg/L in the groundwater. In chloride concentration, 32% sample were found lower than desirable level (250 mg/L) of BIS, and 34% sample were found higher than the maximum permissible limit (1000 mg/L). Chloride salts in excess of 100 mg/L give salty taste to water. It is recommended that chloride content should not exceed 250 mg/L.The sulphate ion is one of the major anions occurring in natural water. Sulphate in the groundwater ranged between 48.5 to 9010 mg/L. In the study area, most samples are with a high concentration of sulphate according to the BIS standard. Sample G23 have very high concentration of sulphate 9010 mg/L. A higher value of sulphate may cause the intestinal disorder.

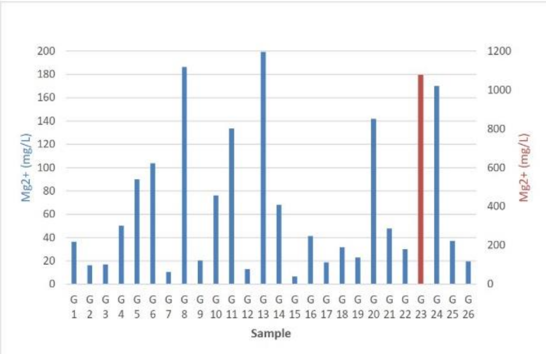


Fig 16: Magnesium Concentration

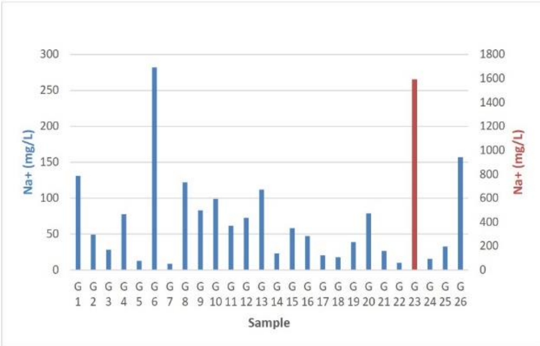


Fig 18: Sodium Concentration

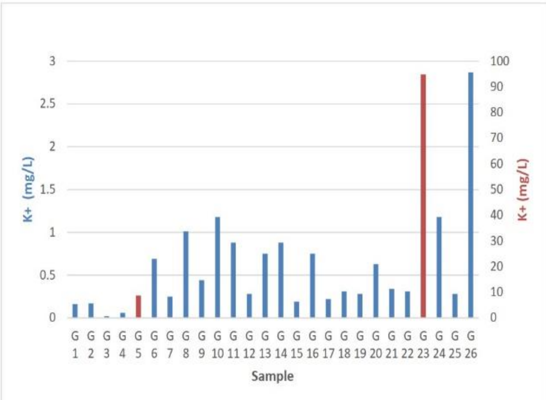


Fig 17: Potassium Concentration

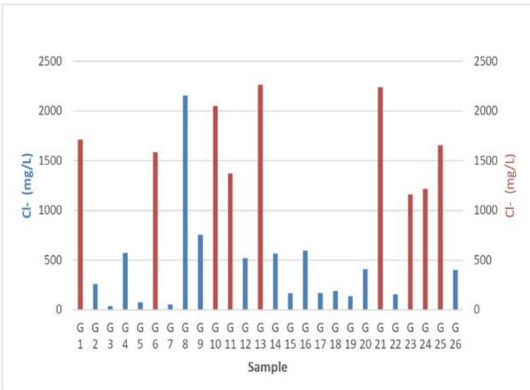


Fig 19: Chloride Concentration

Fluoride, the most commonly occurring form of fluorine, is the natural contaminant of water. The presence of fluorine in groundwater is mainly a natural phenomenon and mainly influenced by local and regional geological conditions, as the fluoride minerals are nearly insoluble in water. Hence fluorine is present in groundwater only when the conditions favour their solution. Fluoride concentration in the sampling area ranges from 0.06 mg/L to 18 mg/L and approximately 68% sample will found with the excessive amount of fluorides. Groundwater usually contains fluoride dissolved by geological formation. Besides these minerals, alkali rocks, hydrothermal solutions may also contribute to the higher concentrationof fluoride in groundwater.

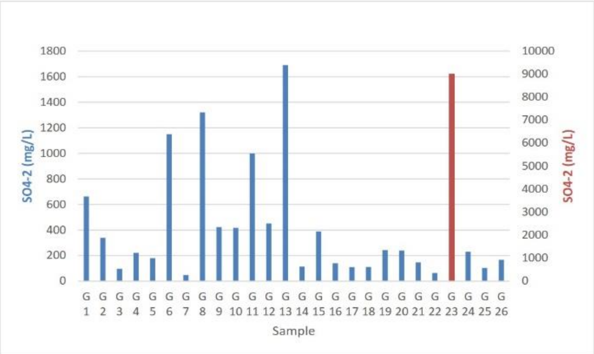


Fig 20: Sulphate Concentration

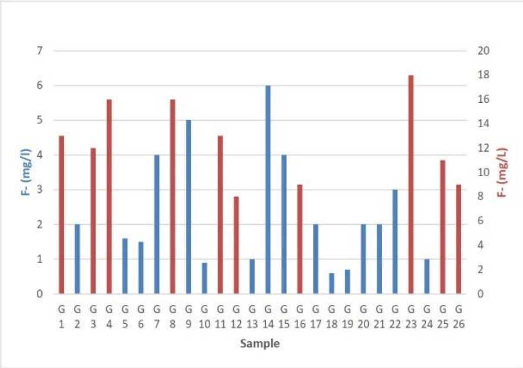


Fig 21: Fluoride concentration

Quality analysis of groundwater:

Variable	Min	Max	Mean	Std. Dev.	WHO STD	BIS STD
pH	6.76	8.48	7.57	0.40	6.5-8.5	6.5-8.5
EC (μS)	952	87200	7229.69	16509.06	-	-
TDS (mg/L)	215	32500	2891.23	6138.44	500	500-2000
Alkalinity (mg/L)	133.33	900	432.18	220.72	-	200-600
Total Hardness (mg/L)	100	7733.33	785.13	1485.8	500	300-600
Ca^{2+} (mg/L)	19.87	1318.53	145.14	254.93	75	75-200
Mg^{2+}(mg/L)	6.56	1078.19	102.60	207.19	50	30-100
Na^{+}(mg/L)	8.6	1590	125.25	304.70	-	-
K^{+}(mg/L)	.02	94.87	4.53	18.50	-	-
Cl^{-}(mg/L)	36.66	2264.3	864.99	770.46	200	250-1000
$SO4^{2-}$ (mg/L)	48.5	9010	733.35	1740.84	200	200-400
F^{-}(mg/L)	0.6	18	6.24	5.59	1.0	1.0-1.5

Variables of groundwater

Descriptive statistics technique is used for hydrochemical characteristics of water as shown inTable. Among the anionic concentrations (mg/L): chloride ranges from 36.66 to 2264.3 mg/L and on an average in Churu district 864.99 mg/L; Sulphate ranges from 48.5 to 9010 mg/L and on an average in Churu district 733.35 mg/L; Fluoride ranges from 0.6 to 18 mg/L and onan average in Churu district: 6.24 mg/L. So the major anions of surface water are dominated by Cl and SO4 (via, Cl>SO4>F).

Among cationic concentrations (mg/L): calcium ranges from 19.87 to 1318.53 mg/L and on an average in Churu district: 145.14 mg/L; magnesium ranges from 6.56 to 1078.19 mg/L and on an average in Churu district: 102.60 mg/L; sodium ranges from 8.6 to 1590 mg/L and on an average in Churu district: 125.25 mg/L; potassium ranges from 0.02 to 94.87 mg/L and on an average in Churu district: 4.53 mg/L. Thus the major cations are dominated by Ca, Na and Mg (via, Ca>Na>Mg>K). Therefore, the analysis results showed that the hydrochemistry types in the water in Churu District are type Cl>SO4>Ca>Na>Mg.

EC ranging from 952 to 87200μS/cm, with an on an average in Churu district of 7229.69μS/cm, all samples exceed the desirable limit for EC. A geochemical process like Evaporation, silicate weathering, sulphate reduction and oxidation process and ion exchange are main contributors for the large variation in EC.

Correlation between different parameters

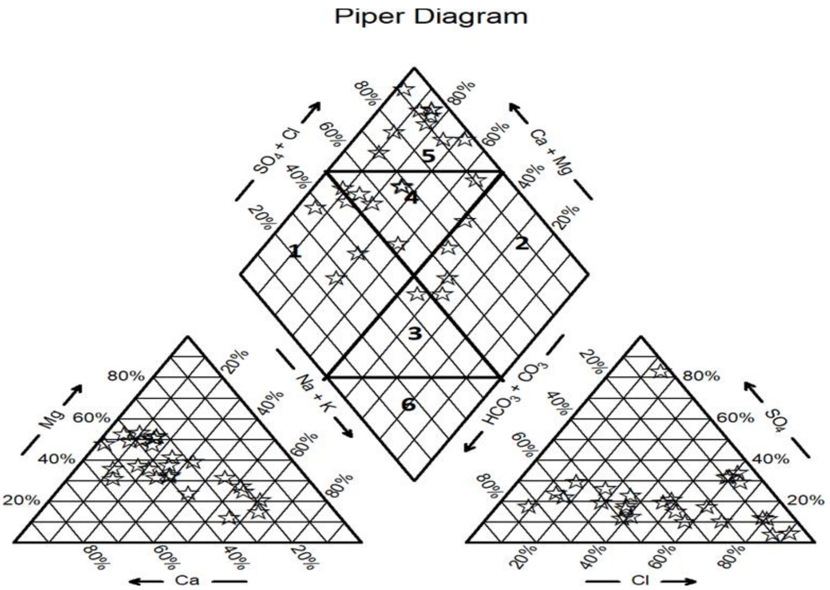
Correlation coefficient describes the relationship between two variables (limit of correlation coefficient **$-1 \leq r \geq +1$**). Correlation coefficient value ±1 is shown perfectly positive/negative correlation; if correlation coefficient value is ±0.75 and above that high correlation between variables; if value is between been ±0.25 to ±0.74 that moderate correlation exists; if correlation coefficient value is 0 to ±0.25 results show low correlation and correlation coefficient the value zero shows no correlation between the variables. Also Correlation coefficient shows the direction of the relationship between the variables like positive and inverse correlation. In the table, EC and TDS show significant strong correlation with $SO4^{2-}$, K^{+}, Na^{+}, Ca^{2+}, and Mg^{2+}. pH and Alkalinity are negatively correlated with approximately all major ions.

	pH	EC	TDS	Alkalinity	Total H.	Ca	Mg	Na	K	Cl	SO4	F
pH	1.00											
EC	-0.21	1.00										
TDS	-0.22	0.99	1.00									
Alkalinity	0.26	-0.10	-0.09	1.00								
Total H.	-0.33	0.97	0.97	-0.24	1.00							
Ca	-0.36	0.96	0.96	-0.25	0.99	1.00						
Mg	-0.30	0.97	0.97	-0.24	0.99	0.98	1.00					
Na	-0.18	0.98	0.98	-0.07	0.94	0.93	0.95	1.00				
K	-0.14	0.98	0.97	-0.12	0.95	0.93	0.96	0.97	1.00			
Cl	-0.35	0.18	0.20	-0.26	0.22	0.20	0.23	0.16	0.06	1.00		
SO4	-0.20	0.98	0.98	-0.11	0.96	0.94	0.97	0.98	0.96	0.23	1.00	
F	0.06	0.45	0.45	0.12	0.40	0.39	0.41	0.44	0.41	0.17	0.44	1.00

Table 5.3 Correlation matrix of different parameter

Piper's Diagram hydrogeochemical Facies:

The Piper's trilinear diagram is valuable for geochemical evaluation, and it is a graphical presentation of the major ions to rapidly determine the hydrochemical facies, of the water. However, the main weakness of the piper's trilinear diagram is that it shows the chemical character of water based on the relative concentration of its constituents rather than the absolute concentrations. In this graph, the major anions are demonstrated in the middle of left triangle and cations are demonstrated in the bottom of the right triangle. It also showed that maximum samples are dispersed between the higher amount of SO4+Cl and Ca+Mg. Therefore, the results of water chemical characteristics showed that the hydrochemistry of water Cl > SO4 > Ca > Na > Mg.



Piper **Diagram** hydrogeochemical Fac

Facies	*Sampling Site*	*No. of Samples*	*Percentage %*
(1) CaHCO3	S-3, S-5, S-7, S-19, S-22	5	19
(2) NaCl	S-1, S-9, S-12, S-26	4	16
(3) Mixed Ca Na HCO3	S-15	1	3
(4) Mixed Ca Mg Cl	S-2, S-4, S-6, S-16,	6	23
	S-17, S-18		
(5) CaCl	S-8, S-10, S-11, S-	10	39
	13, S-14, S-20, S-21,		
	S-23, S-24, S-25		
(6) Na HCO3	-	0	0
Total		26	100

SCHOELLER DIAGRAM

Scholler diagram is a graphical method for drinking water quality classification. The most important water quality parameters for classification in terms of drinking suitability using Scholler diagram are the main water-soluble salts including Anions and Cations, Total Dry Residue and Total Hardness of water resources. The Total Dissolved Solids (TDS) is an effective parameter in the taste of drinking water. The water that has TDS lower than 500 mg/L, in terms of drinking standards, is considered as very good water. TDS between 500 and 1000 is favorable and TDS value from 1000 to 1500 is allowed for drinking but above 1500 mg/L is not suitable.

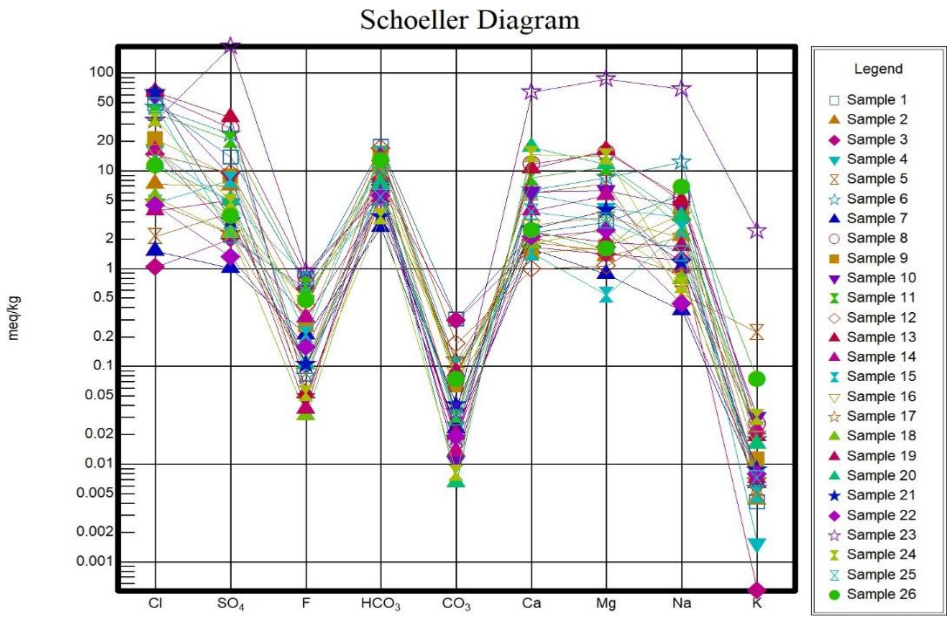


Fig 34: Scholler Diagram

DUROV DIAGRAM

Durov, (1948) introduced another diagram which provides more information on the hydrochemical facies by helping to recognize the water types and it can display some probable geochemical processes that could help in understanding quality of groundwater and its evaluation. The diagram is a composite plot consisting of 2 ternary diagrams where the cations of interest are plotted against the anions of interest; sides form a binary plot of total cation vs. total anion concentrations; pH and TDS data also added to the sides of the binary plot to allow further comparisons.

The Duorv plot for groundwater samples indicates that most of the samples are in the phaseof mixing and others are in ion exchange.

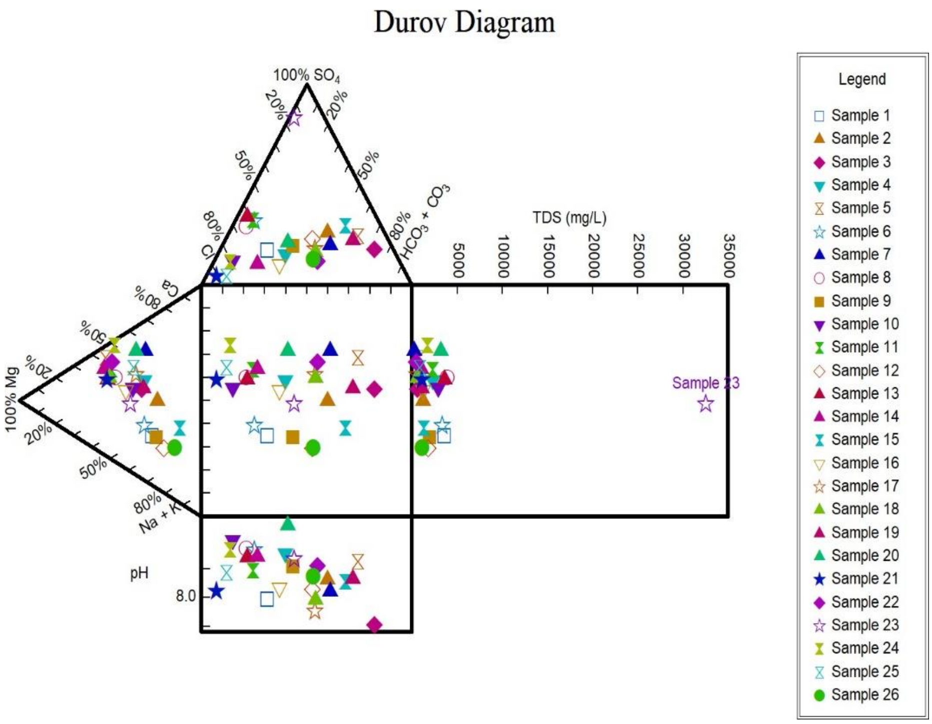


Fig 35: Durov Diagra

Conclusions

1. In the present study, some parameters show average concentration or adequate concentration and some parameters show high concentration. The reason can beattributed to geochemical interactions.
2. Eight samples (G-2, G-5, G-17, G-18, G-19, G-20, G-22, and G-24) have acceptable water quality for drinking and agriculture purpose, remaining 18 sample were found to be above permissible limits of WHO and BIS.
3. The spatial representation of groundwater quality in the study area of Churu district indicates variable groundwater quality in the study area and needs treatment before consumption.
4. The samples like G-1, G-3, G-4, G-7, G-8, G-9, G-11, G-12, G-14, G-16, G-23, G-25 and G-26 were found to be with high fluoride concentration more than permissible value given by BIS and may lead to diseases like dental fluorosis and skeletal fluorosis with a long run usage.
5. Some major facies of the hydrochemistry in Churu district shows dominance of following facies in the order; CaCl > Mixed Ca Mg Cl > $CaHCO_3$ > NaCl.
6. In Churu district, high ion concentration shows less groundwater recharge because of low rainfall and high temperature.

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