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ORIGINAL ARTICLE

Groundwater Suitability for Drinking and Irrigation Using Water Quality Indices in Chouthan Tehsil area, District Barmer (Rajasthan)

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ABSTRACT
The present study focused on the hydrochemistry of groundwater of pre and post monsoon in Chouthan tehsil of Barmer District area to assess the quality of groundwater for determining its suitability for drinking and irrigation purposes. Total 20 Ground water samples were collected from the different places in Chouthan tehsil during pre and post monsoon season and were analyzed for physico-chemical parameters like as pH, EC, TDS, Cl^-, SO_4^2, Total Hardness, total alkalinity , Ca^{2+} + Mg^{2+}, Na^+, K^+, CO_3^{2-}+HCO^- , SO^-, F^-, Nitrate , SAR, SSP. Comparison with the standard value with BIS (Bureau of Indian Standard) of drinking water standard and WHO (world health organization). Also represent the piper diagram for both monsoon which showing the cation and anion representative the samples state of holding the pure and impure formation of water. However, the quality of the groundwater in the study area improves with increased rainfall and thus recharging the Quality of water. In conclusion, the combination of physico-chemical parameters that provides a comprehensive graphs and piper diagram of groundwater quality.
Key words: *Ground water Quality, Physico-Chemical, Hydro-Chemical parameter, Piper Diagram.*

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INTRODUCTION

"Water is the foundation, mother, and a venue of all life. Water is necessary for life. Nowadays contemporaneous culture, urbanization, and growing population, along with the resulting industrial activity, have exacerbated the age-old issue of contaminating our lives, mother, and environment. Our life, mother, and a medium are currently being polluted, and to make matters worse, there is a shortage of water that is of this poor quality. Our environment is facing some fundamental difficulties as a result, and we are experiencing issues with both the quality and availability of water [1-4].

On Earth, 96.5% of the planet's crust water is found in seas and oceans, 1.7% in groundwater, 1.7% in glaciers and the ice caps of Antarctica and Greenland, a small fraction in other large water bodies, and 0.001% in the air as vapor, clouds, and precipitation. Only 2.5% of this water is freshwater, and 98.8% of that water is in ice and groundwater. Ground water is a significant water resource in India for domestic, irrigation, and industrial needs. More than 85% of rural and 50% of urban area domestic water requirements are being met from groundwater resources, while irrigation accounts for around 92% of ground water extraction [4].

In India, the major source of drinking water is ground water, and it's more than 92% of the drinking water we get from the groundwater. Since it is directly related to human welfare, water quality is a crucial element to be researched when the overall goal is sustainable development with mankind as the main point. Our land and water resources are under more stress now than they have ever been before because of the expansion of industry, technology, population, and water consumption. A top environmental concern is the preservation and improvement of groundwater quality and resources [4].

The treatment of contaminated groundwater can be expensive, and groundwater quality degradation may be practically irreversible. Numerous pollutants lack color, test differently, and have no odor. According to a general classification, anthropogenic sources of groundwater contamination can be divided into two categories: point sources (localized or individual sources) and non-point sources (activities or processes that introduce contaminants to the groundwater aerially and can include multiple point sources) [5].
One of the key reasons for the requirement for a groundwater quality assessment is the large variety of contamination sources. Fluoride, arsenic, and selenium are three chemical contaminants that pose a very major health danger in this country. It is thought that about 70 million individuals may be at risk from too much fluoride. In addition, an increase in TDS and nitrate concentrations in round water are a major concern for a sustainable supply of drinking water [6].
Portable water is getting worse because of pollution infiltrations from numerous resources (rivers, landfills, drains, agricultural effluents, and city sewage) [7]. Additionally, it is necessary to evaluate the effects on our environment and the general population [8].
Dumping sites are anticipated places for the production and penetration of contaminants. Urban regions have higher levels of harmful chemical pollution than rural areas due to sewage, dumps, factories, and agricultural operations [9]. Leachate from landfills, which comprises a vast array of elements, frequently contains polar and non-polar complex chemical compounds[10].Urbanly polluted soil has a range of negative effects on human health, indirectly [10, 11].

MATERIAL AND METHODS

AREA OF STUDY AND DISCRIPTION

Barmer District is located between 24°58' and 26°32 N latitudes and 70°05' and 72°52' E longitudes. Barmer is located in western Rajasthan, with Jaisalmer to its north,Jalore on its south, Pali and Jodhpur in its east, and Pakistan to its west. Chouthan Tehsil is a large town in the district of Barmer, which is in south-eastern Rajasthan, India. It is located about 22 miles south-east of the city of Barmer. The Chouthan Tehsil is situated about 25°48'N latitudes and 71°07'E longitudes. The proposed study would be carried out in different areas of Chouthan Tehsil in Barmer district of Rajasthan to ascertain the suitability of water for drinking and irrigation purposes.

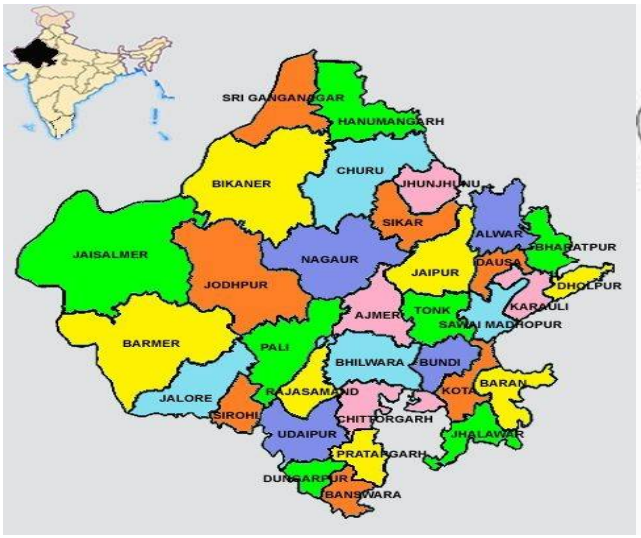

Figure1- Map of Rajasthan.

Figure 2- Map of Chouthan tehsil.

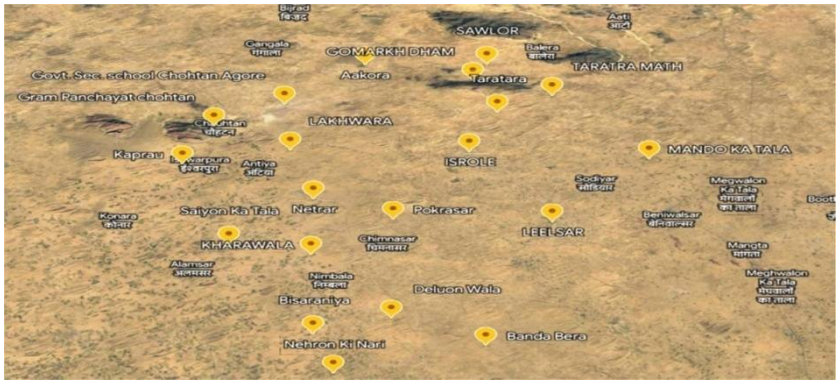

Figure 3- Google map of sample collection places in Chouthan tehsil.

SAMPLE COLLECTION SERIES

SAMPLE NO.	NAME OF PLACE
1.	SAWLOR
2.	GOMARKHDHAM
3.	TARATRA MATH
4.	TATATRA
5.	ISROLE
6.	LEELSAR
7.	LAKHWARA
8.	KHARAWALA
9.	NEHRO KI NARI
10.	MANDO KA TALA
11.	BISRANIYA
12.	DELUONWALA
13.	BANDABERA
14.	SAIYONKATALA
15.	POKRASAR
16.	NETRAR
17.	KAPRAU
18.	GRAM PANCHYAT CHOUHTAN
19.	CHOUTAN AGORE
20.	AAKORE

Table 1. Name of the places from which samples were collected.

SAMPLES COLLECTION AND ANALYTICAL PROCEDURES

In the year 2022, 20 samples of groundwater were obtained from the different places of Chathan tehsil in the post-monsoon season and analyzed and performed the experiments, then obtained the values of physico-chemical parameters. In the earlier month of 2023, 20 more samples of groundwater were collected from the same places as pre-monsoon in Chathan tehsil and again performed the experiments, finally obtaining the values both pre- and post-monsoon data [12].

METHODOLOGY

The present study area is totally depending groundwater for drinking purpose. The assessment of groundwater for drinking purpose depends upon various parameter like as total salinity and sodium adsorption ratio, soluble sodium percentage and MAR also.

(a) Sodium Adsorption Ratio (SAR)

Sodium Adsorption Ratio (SAR) evaluates sodium concentration in relation to calcium and magnesium showing the equation by tood and mays in 2004 [13].

$$\mathbf{SAR=} Na^{+}/\sqrt{((Ca^{2+}+Mg^{2+})/2)} \ldots\ldots\ldots\ldots\ldots\ldots(1)$$

(b) Magnesium Adsorption Ratio (MAR)

MAR is shown as the ratio of magnesium to the sum of calcium and magnesium to multiply with 100.

$$\mathbf{MAR =} (Mg^{2+}/(Ca^{2+}+Mg^{2+}))*100\ldots\ldots\ldots\ldots\ldots(2)$$

(c) Soluble Sodium Percentage (SSP)

Sodium Soluble is indicating to measuring soluble sodium percent (SSP) in groundwater. A comparatively high percent of sodium in groundwater for irrigation may reduce soil permeability [13].

$$\mathbf{SSP=} (Na^{+}+K^{+}/(Ca^{2+}+Mg^{2+}+Na^{+}+K^{+}))*100\ldots\ldots\ldots\ldots\ldots(3)$$

(d) Permeability Index (PI)

PI is shown as the ratio of sodium and HCO_3^- to sum of calcium, Magnesium and Sodium multiplication of 100 [13].

$$\mathbf{PI=} ((Na^{+}+\sqrt{HCO_3^-})/(Ca^{2+}+Mg^{2+}+Na^{+}+K^{+}))*100\ldots\ldots\ldots\ldots\ldots(4)$$

(e) Kelley's Ratio (KR)

KR is expressed between sodium to calcium and magnesium [13].

$$\mathbf{KR =} Na^{2+}/(Ca^{2+}+Mg^{2+}) \ldots\ldots\ldots\ldots(5)$$

(f) Residual Sodium Carbonate (RSC)

RSC is shown as the subtraction of $Co3^{2-}$ and $HCO3^-$ to calcium and magnesium [14].

$$\mathbf{RSC}=(CO_3^{2-} + HCO_3^-)-(Ca^{2+} + Mg^{2+})\ldots\ldots\ldots\ldots(6)$$

RESULT AND DISCUSSION

Parameter	MAXIMUM	MINIMUM	MEAN	ST.DEV.
pH	8.4	7.6	8	0.233734
EC (ds/m)	20.1	1.02	10.56	4.0148482
$Ca^{2+}+mg^{2+}$	46.8	5	25.9	9.0360914
Na^{+}	152.2	5.2	78.7	31.424397
K^{+}	2	0	1	0.5952655
$CO3^{2-}+HCO3^{-}$	12.4	4	8.2	2.1021042
Cl^{-}	153.8	1.4	77.6	31.551702
$-SO_4^{2-}$	40.8	0	20.4	8.7691805
SAR	31.46	2.82	17.14	7.425673
SSP	88	36.73	62.365	13.859992
RSC	3.8	0	1.9	1.1591285
FLORIDE	3.2	0.3	1.75	0.5939165
NITRATE	271	19	145	68.93353
KR	6.78	0.58	3.68	1.617571
MAR	70	11.76	40.88	16.899537
DO	9.6	4.8	7.2	1.5978933
TDS	875	102	488.5	228.18042
PI	91.12	44.05	67.59	11.516307
RSBC	-0.1	-37.6	-18.85	8.1017463

Table 2. Parameter report with mean and standard deviation in Pre-monsoon.

SR.NO.	MAXIMUM	MINIMUM	MEAN	ST. DEV
pH	8.6	7.8	8.215	0.283354
EC (ds/m)	8.22	1.04	3.078	1.906442
$Ca^{2+}+mg^{2+}$	40	5	10.73	8.815841
Na^{+}	199.16	2.6	28.6925	43.31502
K+	2	0.02	0.512143	0.690235
Cl^{-}	61.6	0.2	20.15	15.91251
$CO_3^{2-}+HCO_3^{-}$	15.4	5	7.85	2.694927
SO_4^{2-}	12.2	2.2	3.971429	3.385977
F^{-}	1.6	0.097	0.6319	0.498177
NITRATE	447.8	32.75	105.5955	93.43652
SAR	47.56	1	9.8835	10.01018
SSP	91.48	13.02	59.9555	20.7491
RSC	7.6	0.2	4.15	2.510693
KR	20.32	0.15	3.54225	5.085061
MAR	74.35	10.2	31.5425	18.64022
DO	9.18	2.62	5.7975	1.627393
TDS	870	100	305.85	251.9058
PI	96.17412	18.90747	70.58386	20.10269
RSBC	4.4	-21.6	-2.225	6.220753

Table 3. Parameter report with mean and standard deviation in Post-monsoon.

PHYSICAL & CHEMICAL PARAMETER

The maximum temperature was observed as 32^0 in summer whereas 26^0 in monsoon season. As we know that the temperature performed main role in the water. The minimum and maximum value of EC (Electric Conductivity) in pre monsoon is obtained as 1.02 and 20.1 ds/m. whereas its maximum and minimum in post monsoon 8.22 ds/m and 1.04 ds/m. TDS is having Average of 305.85 in post monsoon whereas its having 488.5 in pre monsoon. The maximum pH indicate in post-monsoon as 8.6 and minimum as 7.8 whereas its 8.4 and 7.6 in pre-monsoon. The total average of DO in pre-monsoon is 7.2 and 5.7 In post-monsoon.

The considering all parameter of physical and chemical are compiling in togather in the table.

(1) pH: One of the most needed factor in the groundwater in study the variation in pH from 7.8 to 8.6 in post monsoon whereas its value 7.6 to 8.4 in pre monsoon with an average of 8 in pre and 8.2 in post monsoon [15].

(2) Electrical Conductivity (EC): Generally the main substance work of EC (Electrical Conductivity) to measure the capacity of an substance to observe/ conduct the electric power/current. As per the study the observed value of EC indicating 1.04 ds/m to 8.22 ds/m in post-monsoon whereas its having 1.02 ds/m to 20.1 ds/m in pre-monsoon as compared to the BIS report [16].

(3) Total Dissolve Solid (TDS): The combined effect of the Cation (+) and anion (-) ions in the water is the total dissolve concentration. Total dissolve salts in water are made up of inorganic salt such calcium, Magnesium, Potassium, Sodium, Bicarbonates, Chlorides and Sulphates as well as some trace amount of organic stuff. The TDS varies from 100 to 870 in post monsoon whereas its value 102 to 872 in pre monsoon [17].

(4) Calcium (Ca^{2+}): Water naturally contains calcium. The primary component of igneous rock is it 2+. Insoluble Calcium-carbonate, sulphide and very Sheldon chloride are the forms of calcium that are found in groundwater. The average calcium concentration in groundwater is 7.23 ppm with 2.0 ppm to 25.6 ppm in post monsoon whereas it's values varies from 2 ppm to 40.2 ppm with an average of 21.1 ppm in pre monsoon. All samples in the research region were under the BIS and WQI mandated maximum allowable level [18].

(5) Total Hardness (TH): The hardness of the water causes it to necessitate soap. Magnesium and calcium ions are concentrated to create hardness when heated scale develops significantly more quickly in

hard water. In the study the Total Hardness values from 100 to 870 at an average of 305.85 in post monsoon whereas it's varies from 102 to 875 at an average of 488.5 in pre monsoon [19].

(6) Chloride (Cl^-): Sodium chloride which dissolve in water from rocks and soil is where chlorides first appear it serves as a reliable indicator of the quantity of groundwater and if it combined with sewage or seawater the concentration of the substances in the groundwater will rise in the study report the variation from0.2 to 61.6 at an average of 20.15 in post monsoon whereas it's from 1.4 to 153.8 at an average of 77.6 in pre monsoon as comparing with the statics of BIS parameters values [20].

(7) Sodium (Na^+): The common and Sixth most important element ofthe earth is Sodium. In water samples sodium is a significant cat-ion minerals that includes sodium suchb as albite and various plagioclase feldspars etc. the majority of sodium salts dissolve easily in water. In the study report of groundwater the parameter shows at an average of 28.69 in post monsoon whereas its varies and become 78.7 in post monsoon [21].

(8) Potassium (K^+): Comparing to the sodium potassium is a minor component in groundwater this is because of the way that the potassium minerals are impervious to deterioration by ending. In the study the value of K is from 0.02 to 2 with an average of 0.512 in post monsoon whereas its values rise from 0 to 2 with an average of 1 in pre monsoon [22].

(9) Dissolved Oxygen (DO): The amount of dissolved oxygen in water is used to determine both it's portability and level of pollution in order to manage waste treatment processes and water contamination this serves as a critical test.

In the study report the value of DO varies from 2.6 to 9.18 with an average of 5.76 in post monsoon whereas its varies from 4.8 to 9.6 with an average of 7.2 in pre monsoon [23].

Water Quality index	Water Quality Status
0-25	Excellent
25-50	Good
50-75	Poor
75-100	Very poor
>100	Unfit for Consumption

Table 4- WQI Range and the Water Quality status.

SAMPLE	WQI PRE MONSOON	suitability	WQI POST MONSOON	Suitability
S1	88.23	Very poor	95.84	Very poor
S2	71.9	Very poor	104.82	Unfit for Consumption
S3	110.34	Unfit for consumption	81.18	Very poor
S4	97.1	Very poor	86.3	Very poor
S5	108.84	Unfit for consumption	62.17	Poor
S6	108.89	Unfit for consumption	64.39	Poor
S7	96.45	Very poor	71.73	Poor
S8	83.68	Very poor	74.18	Poor
S9	111.02	Unfit for Consumption	94.74	Very poor
S10	85.45	Very poor	90.86	Very poor
S11	110.7	Unfit for Consumption	89.84	Very poor
S12	98.41	Very poor	87.83	Very poor
S13	84.62	Very poor	75.42	Very poor
S14	73.56	Very poor	92.83	Very poor
S15	113.58	Unfit for Consumption	79.09	Very poor
S16	99.61	Very poor	75.97	Very poor
S17	97.6	Very poor	81.15	Very poor
S18	110.16	Unfit for Consumption	82.92	Very poor
S19	98.19	Very poor	54.17	Poor
S20	85.89	Very poor	75.6	Very poor

Table 5- WQI parameter in both pre and post monsoon seasons.

The given report shows the WQI parameters statics under which most of the samples were categorized under 75-100 WQI range which indicating the stats of very poor as per the BIS report.

Parameters	pH	EC	Ca^{2+}	Mg^{2+}	Na^{+}	K^{+}	Cl	SO_4^{-}	CO_3^{2-}	HCO_3^{-}	DO	TDS
pH	1											
EC	0.056	1										
Ca^{2+}	0.060	0.443	1									
Mg^{2+}	0.077	0.430	0.740	1								
Na^{+}	0.073	0.310	0.023	-0.099	1							
K^{+}	0.125	0.844	0.408	0.353	0.170	1						
Cl	0.154	0.984	0.483	0.467	0.324	0.840	1					
SO_4^{-}	0.031	0.977	0.428	0.399	0.328	0.766	0.951	1				
CO_3^{2-}	-0.626	-0.041	-0.250	-0.151	-0.151	0.002	-0.197	-0.043	1			
HCO_3^{-}	-0.453	0.077	-0.250	-0.185	-0.136	0.125	-0.092	0.104	0.915	1		
DO	-0.045	0.045	0.230	0.140	-0.142	0.180	0.015	0.028	0.338	0.302	1	
TDS	-0.065	0.580	0.442	0.221	0.059	0.583	0.543	0.620	0.018	0.231	0.102	1

Table 6. Coefficient Correlation between quality parameter in study area in post monsoon.

Parameters	pH	EC	Ca^{2+}	Mg^{2+}	Na^{+}	K^{+}	Cl	$So4^{-}$	CO^{3}	$HCO3^{-}$	DO	TDS
pH	1											
EC	0.015	1										
Ca^{2+}	-0.205	0.915	1									
Mg^{2+}	0.080	0.703	0.526	1								
Na^{+}	0.072	0.994	0.871	0.711	1							
K^{+}	-0.143	0.788	0.693	0.557	0.784	1						
Cl	0.043	0.997	0.901	0.692	0.994	0.780	1					
So	-0.057	0.992	0.938	0.684	0.979	0.787	0.985	1				
CO_3^{2-}	-0.007	-0.003	-0.003	0.223	-0.014	0.096	-0.065	-0.018	1			
HCO_3^{-}	-0.225	-0.003	0.111	0.138	-0.040	0.019	-0.072	0.009	0.929	1		
DO	-0.268	0.128	0.208	0	0.108	0.009	0.126	0.201	-0.343	-0.234	1	
TDS	-0.247	-0.032	0.116	-0.090	-0.060	-0.019	-0.069	-0.016	0.478	0.551	-0.229	1

Tabel 7. Coefficient Correlation between quality parameter in study areain pre monsoon.

DATA ANALYSIS AND GRAPHICAL APPROACH

COEFFICIENT CORRELATION

The reciprocal relationship between two variables knows as Correlation. Correlation Coefficient was used to determine the relationship between the physic-chemical parameter of the water samples and a large number of significant correlation were found. It is a straight forward metric used to demonstrate how accurately one variable predicts the other. Generally it shows the correlation between the quality parameter where the parameter are shown as – pH, Electric Conductivity, Calcium, Magnesium, Potassium, Chloride , SO_4^{2-}, CO_3^{2-}, HCO_3^{-}, Dissolve oxide and Total Dissolve Oxide. Where these are co related to the same parameter and the final stage it's shown the relation like between the pH and TDS is- 0.247, between EC and Cl^{-} is 0.997 and etc.

GIBBS DIAGRAM

The Gibbs plot is frequently used to identify the Chemical Components that are dissolved in the water. The graphic clearly divides the origin of water's chemical makeup in to three district are knowing as precipitation dominance, Rock dominance and evaporation dominance are used in that order.

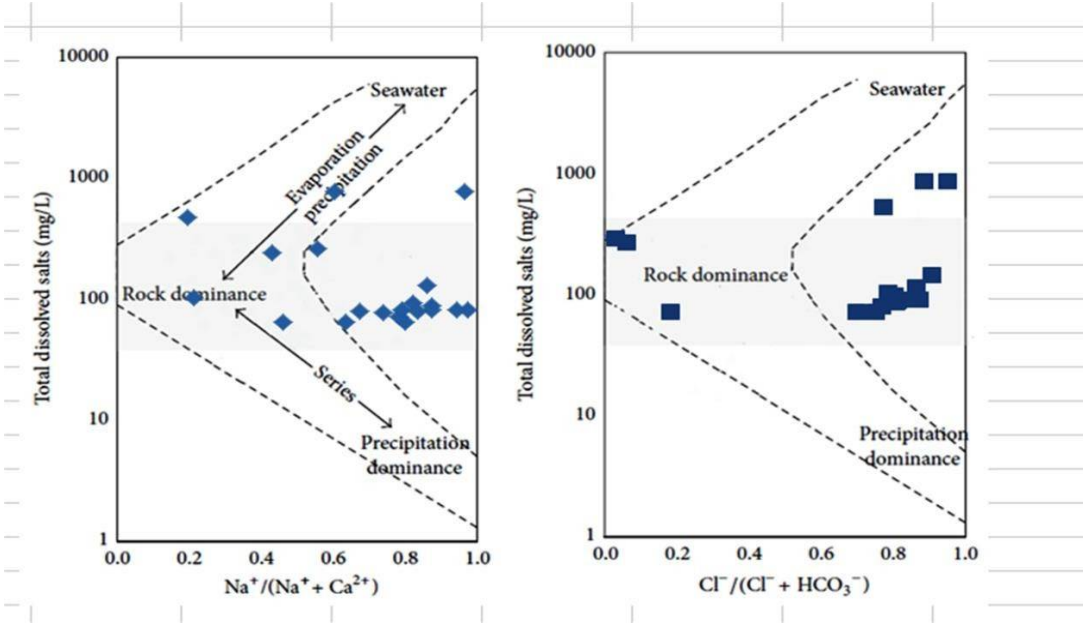

Figure 4- Gibbs Diagram for Post-monsoon.

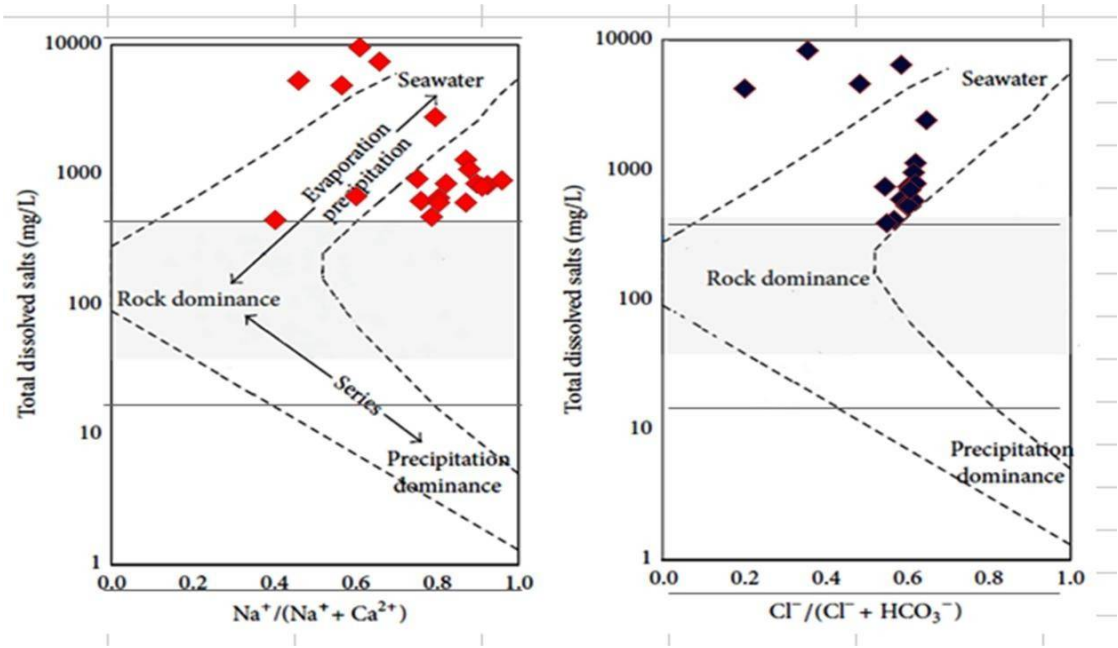

Figure 5- Gibbs Diagram for Pre-monsoon.

PIPER CHART

The Piper plot proposed by Piper (1944) illustrates it's indicating the comprehensive relationship between the hydro-chemical factors and groundwater types (Gao et al. 2020). The hydrochemistry of the groundwater of the DFD was evaluated using the piper diagram. The X-axis of the diagram comprising milliequivalent percentage diference between alkaline earth and alkali metals is plotted against the Y-axis containing milliequivalent percentage diference between weak and strong acidic anions.

This diagram accounts for eight classes of groundwater. The cation plot depicts that most of the samples are located in the center (zone B) revealing that there is no dominance of any cations in the groundwater. Similarly, the anion plot suggests that most of the parameters are con centrated in the left

(zoneE) indicating the dominancy of $HCO3^-$ and implying the weathering of carbonate-dominated rocks [22].

Piper Chart for Post- Monsoon

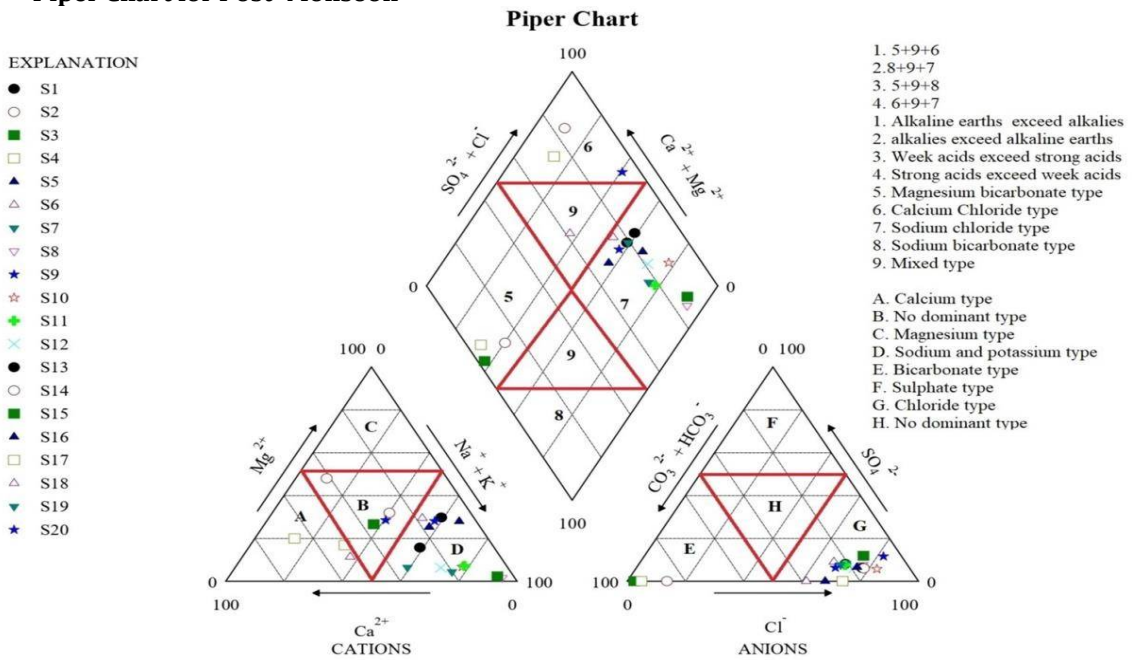

Figure 6- Piper chart for post monsoon

Piper Chart for Pre- Monsoon

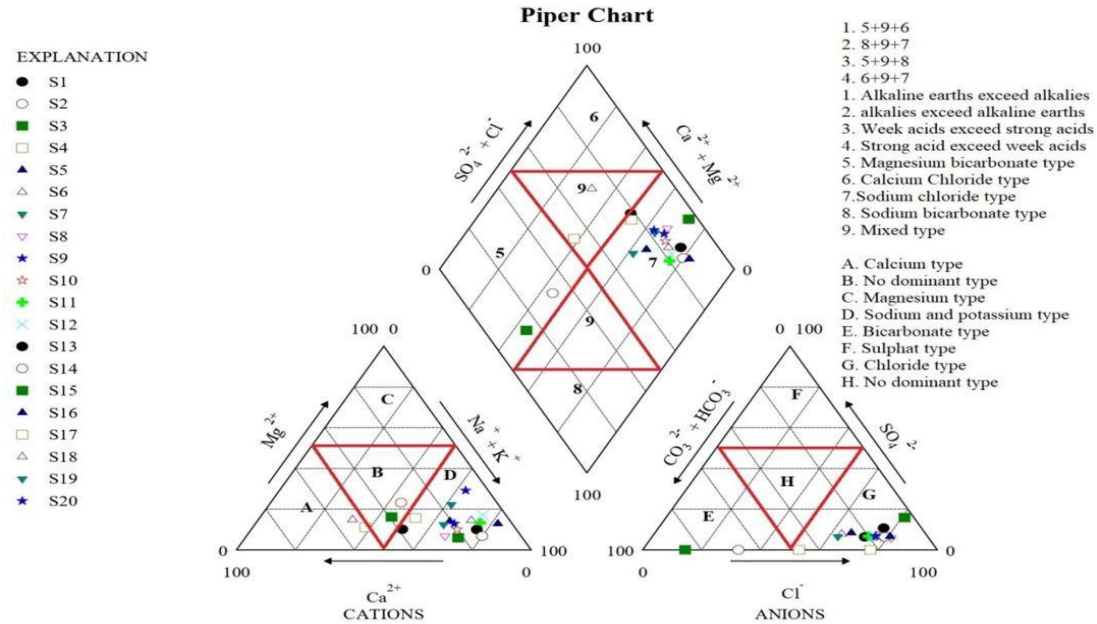

Figure7- Piper chart for post monsoon

CONCLUSION

This study examined the suitability of groundwater in the Chouthan tehsil of Barmer district for drinking and irrigation purposes. The result indicates that EC, TDS, Cl^- and Na^+ were the most significant parameters of groundwater samples which were also confirmed by the analysis of Gibb's plot.

The ground water in Chouthan Tehsil region is fresh to salinity and acidic in character, according to the interpretation of the Hydro-chemical analysis. According to all evaluation criteria, long-term irrigation and drinking from the area's groundwater would be safe. Regarding the Physico-chemical characteristics of water as well as SAR, SSP, EC, PI, KR, and MAR. In general, the water in these research areas is safe for people to drink. The majority of areas have high study area difficulty. Water should be purified using anionic exchangeresinto eliminate hardness before being used for drinking or cooking, in addition to boiling the water first and letting it cool. A high concentration of EC, Cl− and Na+ resulted from the increasing salinity due to high evaporation and anthropogenic activities. As per the data indicating in the report following parameters like total dissolved solids (TDS), Magnesium absorption ratio (MAR), sodium absorption ratio (SAR), and residual sodium carbonate (RSC) showed the mean values of respectively. 305.85, 31.54, 9.8835 and 4.15 in post monsoon whereas its having 488.5,40.8, 17.14 and1.9inpre monsoon.

The given report shows the WQI paramters statics under which most of the samples were categorized under 75-100 WQI range which indicating the stats of very poor as per the BIS report.

The increased frequency of severe rainfall events, which is a result of climate change and global warming, has an impact on the processes of pollution accumulation and infiltration from soil to groundwater. To ensure the sustainability of future groundwater supplies, it is crucial to comprehend how rainfall, climate change, and topography affect groundwater quality. The future pollution of groundwater quality must thus be evaluated and predicted.

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