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ORIGINAL ARTICLE

Water Quality Evaluation Using Geospatial and WQI Techniques in the Thar Region of India

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ABSTRACT
Suitability of water quality for the drinking purpose and irrigation is essential for the survival of life and sustainability of the Environment. The present study is aimed to evaluate the groundwater quality for suitability of drinking and irrigation purposes in the Thar region (Churu district, Rajasthan), India using the Geospatial and water quality index (WQI) techniques. Groundwater samples were collected randomly from 69variouslocations in the pre-monsoon and post-monsoon season respectively in the year 2019. The different major water quality parameters such as physico–chemical parameters pH, Electrical Conductivity (EC), Total hardness, Calcium (Ca++), Magnesium (Mg++), Sodium(Na+), Potassium (K+), Chloride (Cl-), Carbonate (CO3--), Bicarbonate (HCO3-) and Fluoride (F-) were analyzed using standards methods. Pearson's correlation coefficient was calculated to measure the nature of relation between the groundwater variables. The spatial and seasonal variation maps of these groundwater quality characteristics parameters were generated through inverse distance weightage (IDW) interpolation technique in Arc-GIS software. These results will help planners, decision makers and Government to take necessary steps in planning and management.
Keywords: *IDW, Correlation, WQI, Piper*

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INTRODUCTION

Water is the basic environmental resource on earth. In current times, the water quality is essential for mankind as it is associated to human beings happiness [9 and 19]. In India, 88 percentages of people cannot access the good quality of drinking water [16].

Arithmetical rise in population together with rapid urbanization, industrialization and agricultural growth has resulted in high impact on quality of water in India. Hence, the qualities of the freshwater resources are the majority pressing of the environmental challenges in India [5]. Sums of studies on water quality have been carried out in different parts of India [17, 13, 5, 18, 3 and 2]. These studies revealed that both surface water and groundwater in India are facing deferent type of water quality issues [14]. Groundwater measures in semi-arid regions are restricted by local hydrogeology, topography, geological structures, evaporation, precipitation and rock-water.

The Environment of ground water quality in any region is directly related or influenced by both natural and human induced reasons. The technique of WQI was first recommended by Horton (1965), and henceforth, there has been more adaptation to the preliminary technique [4, 6, 12 and 15].

The present analysis was attempted for investigating the physico-chemical characteristics of the groundwater of Churu districts of Rajasthan, India. The objective of the present work was to figure out the spatial and seasonal variability of the water quality characteristics of different physicochemical parameters of groundwater in the study area. The study region deficient in water is forced to utilize the available water resources. The study will be advantageous to map the groundwater quality characteristics according to BIS standards and the suitability for drinking and irrigation purpose can be ascertained which will in turn be valuable for the regional/master planners and policy makers of this underdeveloped or rising area.

MATERIAL AND METHODS

Site description:

The study area lies between the 27^0 24' 31.50” to 29^0 00' 01.74” North latitudes and 73^0 50' 39.45’’ to 75^0 40' 31.85’’ East longitudes covering around 13,844 sq km of area, situated at an elevation of 250 m to 300 m above the sea level. Seven blocks, namely Sujangarh, Sardarshahar, Rajgarh, Churu, Ratangarh, Taranagar and Bidasar blocks of Churu district were selected to collect the water samples.

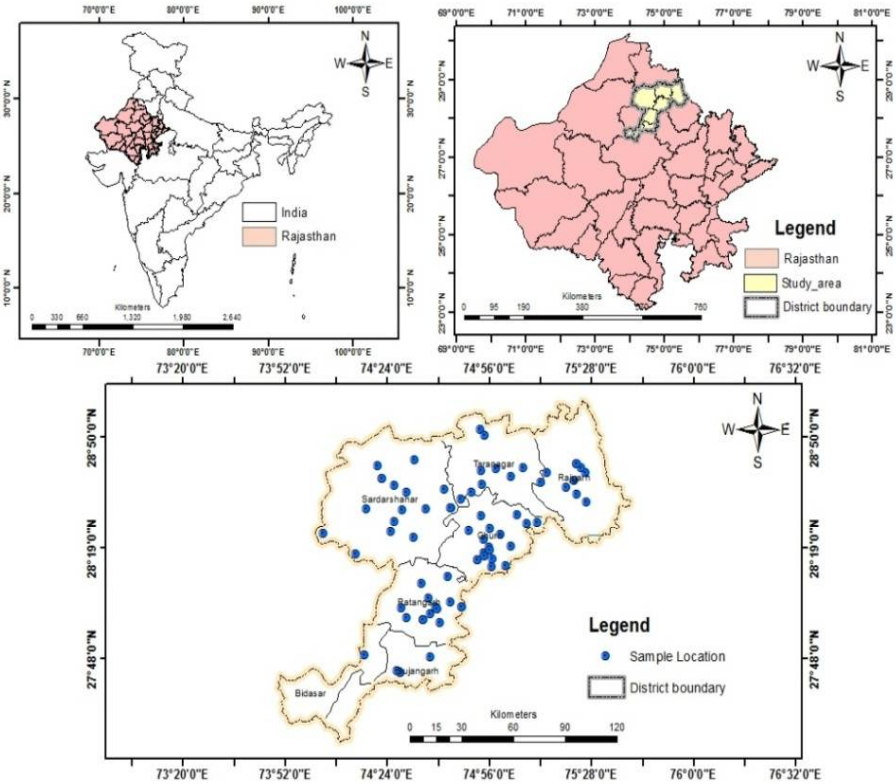

Figure 1: Water Sample Location map of Churu district Rajasthan

Generally, the average annual distribution of rainfall in Churu district ranges from 600 to 700 (mm). The temperature ranges recording below freezing point to over 50 ^{0}C. The study area consists of mainly eolian sand as well as partly by fluvial deposits and the surface soil comprises mostly of sandstone, shales and limestone. Sujangarh block occupies Erinpura granite & gneiss. Pearl millet is the main rainy season crop along with guar, moth, moong and til.

Sample Collection and Analysis

Water samples were collected randomly from the dug wells (open well) for pre-monsoon (April-May) and post-monsoon (October-November) season for the year of2019. Water samples were collected from 69 sampling sites (Figure 1). In this study BIS standard (Table 1) has been considered for water quality standard. The samples were tested in Environment laboratory (SHUATS) to obtain the physical and chemical parameters. Fourteen (15) important parameters were applied for the WQI estimate. Overall methodology has been shown in the flow chart figure 2.

Evaluation of Water Quality Index (WQI)

For calculation of water quality index (WQI) the following three steps have been followed [7]. In the first step, each of the fourteen physio-chemical parameters has been assigned a weight (Wi) according to its relative importance in the overall water quality for drinking water. The maximum weight of ‘5’ value has been assigned for its major significance in water quality estimation and the minimum weight of ‘1’ value has been given for its less significance. In the second step, the relative weight is calculated from the following equation:

$$\mathrm{Wi} = \frac{Wi}{\sum_{i=1}^{n} \mathrm{Wi}} \qquad (1)$$

Where, Wi: Relative Weight, wi: Weight of each parameter n = the number of parameters

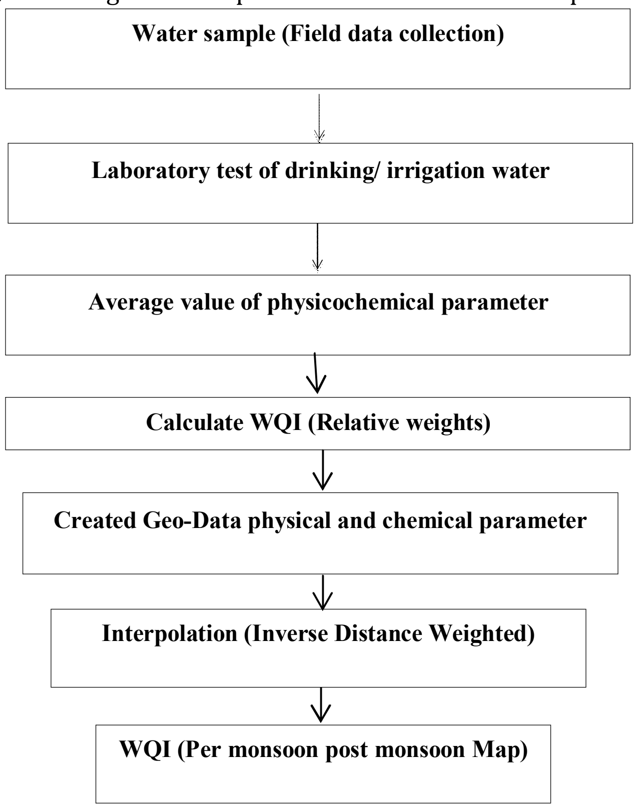

Figure 2: Flow-chart of methodology

In the third step, a *quality rating scale* (*qi*) for each parameter is assigned by dividing its concentration of each water sample by its respective standard according to the guidelines laid down by the BIS and the result is multiplied by 100.

$$qi = \left(\frac{\text{ci}}{\text{si}}\right) \text{x } 100 \qquad (2)$$

Where, q_i = quality rating, C_i= concentration of each chemical parameter in each water sample in mg/l, *Si* = Sub-index of i^t parameter for each chemical parameter in mg/l according to BIS standard that can be calculated as:

$$\text{SI} = W_i \text{ x } q_i \qquad (3)$$

For calculating WQI, SI was determined for each parameter. Finally, WQI can be calculated through sum of SI values for each sample using the equation:

$$WQI = \sum_{i=1}^{n} \text{SI} \qquad (4)$$

Computed WQI values were classified into six categories excellent, good, poor, very poor and unsuitable for drinking as given in Table 2.

TABLE 1: Relative Weights (Wi) Of The Parameters Used For Wqi Determination

Water Quality Classification based on WQI value	
WQI	Water Quality
0-25	Excellent
26-50	Good
51-75	Poor
76-100	Very Poor
>100	Unsuitable for drinking/irrigation

TABLE 2: Water Quality Classification Based On Wqi Value

Relative weights (Wn) of the parameters used for WQI determination				
Parameter	**ICMR/BIS standard (Vs)**	**Weight (wi)**	**Sum of(wi)**	**Relative weight** (Wi)
pH	6.5–8.5	4	42	0.10
Ec	300	4	42	0.10
TDS	500	5	42	0.12
Fe	0.3	2	42	0.05
F	1	3	42	0.07
NO_3	45	3	42	0.07
Ca	75	3	42	0.07
Mg	30	2	42	0.05
CO_3	200	3	42	0.07
HCO3	200	3	42	0.07
CL	250	3	42	0.07
SO_4	200	4	42	0.10
Na	200	3	42	0.07
sum of Wn = 1.00		42		1.00

* All the parameters are in milligrams per litter except pH and EC (uS/cm)

The base map of the Churu district was digitized from the toposheet using ArcGIS software (ver. 10.4). A location map (using pre monsoon and post monsoon points) is prepared based on the sampling points collected through GPSfor years 2019

The geographical distribution of the physico-chemical characteristics of groundwater was executed with the support of spatial analyst in ArcGIS (ver. 10.4) software. Spatial distribution maps of water quality parameters were prepared using ArcGIS (ver. 10.4) with spatial statistical analyst module and the inverse distance weighted (IDW) interpolation technique. The correlation matrix of groundwater parameters has been prepared using to MS Excel software. Aqua Chem (ver. 2012.1) software was used to prepare the data and was plotted Piper diagram.

RESULTS AND DISCUSSION

In the current study, the samples from 69 dug wells collected during pre-monsoon and post monsoon for the year 2019. Descriptive statistics of 14 parameters for all samples of pre monsoon and post monsoon were analysed and presented in Table 3 & Table 4.

Table 3: NDVI and NDSI values for the year 1998, 2008 and 2019

Parameters	Ca	Mg	Na	K	CO_3	HCO_3	CL	SO_4	TDS	pH	Fe	F	NO_3	EC
Mean	92.33	90.72	425.79	5.71	15.31	243.06	238.13	394.37	2091.33	7.97	1.02	1.17	194.55	3277.32
StEm	5.19	7.05	60.48	1.07	2.73	28.74	28.68	70.92	165.12	0.06	0.15	0.18	27.96	259.41
Median	92.44	80.81	232.64	3.61	10.39	134.80	130.49	159.80	1811.83	7.95	0.56	0.80	100.06	2641.00
S.D.	43.12	58.54	502.36	8.90	22.69	238.71	238.20	589.08	1371.59	0.46	1.23	1.51	232.27	2154.80
Kurtosis	4.56	8.29	1.94	21.17	6.28	0.88	0.89	6.16	4.00	-0.59	11.18	20.66	6.43	3.16
Skewness	1.50	2.42	1.57	4.52	2.42	1.23	1.24	2.53	1.90	0.05	3.03	4.03	2.40	1.74
Minimum	34.03	18.21	23.84	1.98	0.00	32.67	28.78	7.71	323.65	6.90	0.12	0.08	1.59	376.00
Maximum	268.03	372.59	1875.64	57.53	106.40	1009.10	1002.99	2523.80	6558.40	9.05	7.01	10.28	1126.67	10085.00
95% CI	10.36	14.06	120.68	2.14	5.45	57.34	57.22	141.51	329.49	0.11	0.30	0.36	55.80	517.64

TABLE 4: Descriptive Statistics of Ground Water Variables in Post-Monsoon (2019)

Parameters	Ca	Mg	Na	k	CO_3	HCO_3	CL	SO_4	TDS	pH	Fe	F	NO_3	EC
Mean	89.90	89.61	423.76	5.52	14.45	240.87	236.56	393.20	2089.57	7.82	0.87	1.16	193.03	3268.19
St.Em	5.17	6.97	60.46	1.07	2.69	28.67	28.67	70.89	165.13	0.06	0.15	0.18	27.96	259.25
Median	89.50	79.73	230.54	3.45	8.99	133.40	129.09	159.30	1809.63	7.80	0.41	0.76	98.56	2630.00
St.D.	42.97	57.87	502.21	8.91	22.34	238.14	238.14	588.90	1371.66	0.46	1.23	1.51	232.24	2153.50
Kurtosis	4.63	8.46	1.93	21.15	6.60	0.89	0.89	6.15	4.00	-0.59	11.18	20.55	6.43	3.15
Skewness	1.52	2.45	1.57	4.51	2.50	1.24	1.24	2.53	1.90	0.05	3.03	4.02	2.40	1.74
Minimum	31.03	16.01	22.34	1.83	0.00	31.59	27.28	7.21	322.25	6.75	-0.03	0.04	0.19	365.00
Maximum	265.03	369.39	1873.54	57.38	105.00	1005.90	1001.59	2521.80	6557.00	8.90	6.86	10.26	1124.67	10070.00
95% CI	10.32	13.90	120.64	2.14	5.37	57.21	57.21	141.47	329.51	0.11	0.30	0.36	55.79	517.33

Mean values of all the parameters were found to be higher in pre-monsoon (2019) as compared to the mean values during post-monsoon (2019). As a result of heavy rainfall in the year 2019, the values of all the parameters were found to be lower during post-monsoon than that of pre-monsoon. The 95%Cl values of both pre-monsoon and post-monsoon were observed to be close when compared.

Spatial distribution analysis of water sample of the study area

1. **TDS and pH spatial distribution** – In the study area the amount of TDS which ranges from 950 to 6114 mg/l. It has been found that the amount of TDS in all tehsils, which Ranges from 925 to 2225 (mg/l). It fully extended in Sujangarh, Bidasar and Ratangarh. The highest concentration of TDS is found in the north east direction of study area which is Rajgarh tehsil.
   The pH value in this area has been found to ranges 6.8 to 8.7. The higher concentration of pH was found in Churu, Sardasshahar, Ratangarh and Sujangarh tehsils. However, the lowest concentration of pH was found in Taranagar and Churu tehsils (figure 3).

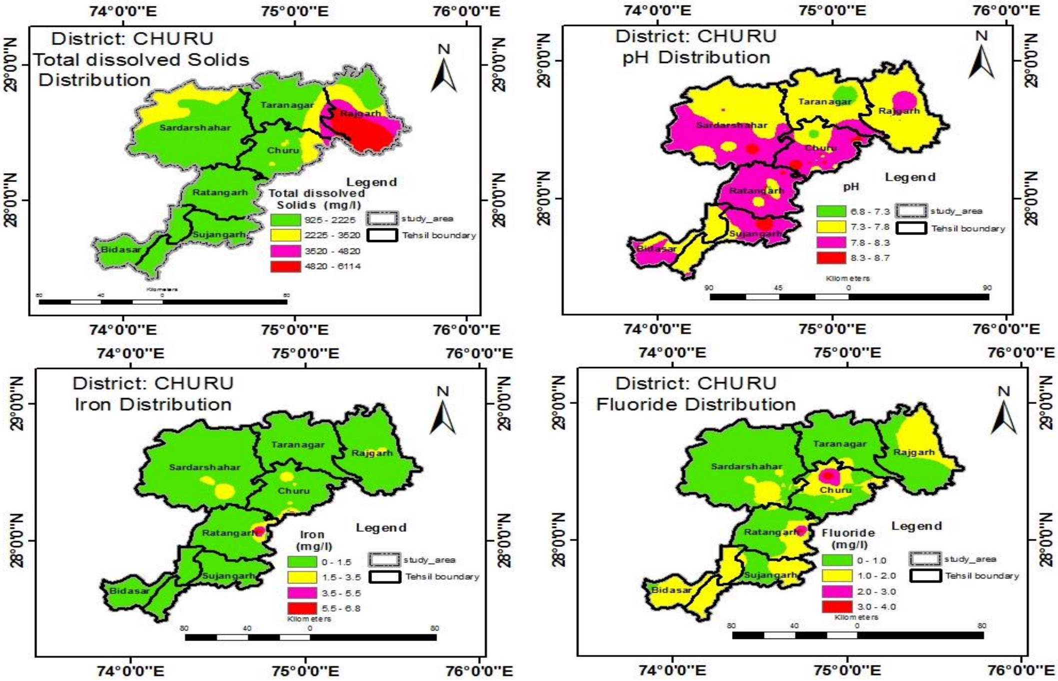

Figure 3: Spatial variation of TDS, pH, Iron & Fluoride

2. **Iron & Fluoride Spatial distribution –** Range of Iron in the study area varies from 0 to 1.5 (mg/l). The highest concentration of iron content has been found in Ratangarh tehsil which ranges from 5.5 to 68 (mg/l). However, range of Fluoride region from 0 to 4.0 (mg/l) shown in figure3. Maximum concentration of fluoride has been found in Churu and Ratangarh tehsils. Fluoride content is being found in the southwest part of study area. The major reason behind the decrease in plant growth is attributed to high concentration of fluoride in the water.
3. **Calcium and Magnesium Spatial distribution –** Range of calcium in the study area varies from 32 to 84 mg/l. The higher concentration of calcium content was found in Sardarsharhar tehsil which is found to be 240 (mg/l). Most part of study area covered 84 to 136 (mg/l).
   Magnesium acts as a growth of plant nutrient. The amount of magnesium in most of the study area ranges from 18 to 106 (mg/l). Therefore, it can be said that the quantity of magnesium in Churu district is very less. Highest concentration of magnesium has been found in the north-west part of Churu district which is Sardarshahar tehsil (figure 4).

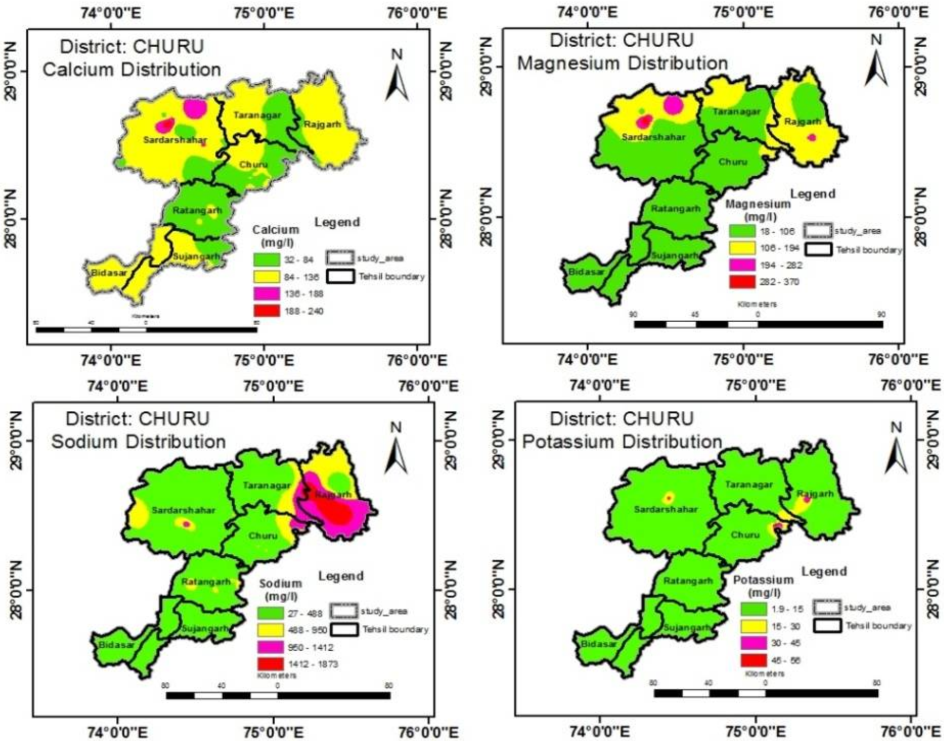

Figure 4: Spatial variation of Calcium, Magnesium, Sodium& Potassium

4. **Sodium & Potassium Spatial distribution –** Higher concentration of sodium was found in the north east part which includes Rajgarh tehsil (figure 4). It has been reported that excessive sodium in water is considered to be the reason behind the lack of plant growth. Potassium distribution ranges from 1.9 to 15 (mg/l) in the entire study area. Potassium content has been found to increase in the north east direction of study area. The amount of potassium found in Sardarshahar tehsil range from 15-56 (mg/l) which is found to be maximum (figure 4).
5. **Carbonate and Bicarbonate Spatial distribution –** The distribution of carbonate range from 0 to 104 (mg/l) in the study area. Most of the areas have covered 0 to 25 (mg/l) which is mostly in north east direction (figure 5). In extent of bicarbonate distribution has been found to be low in concentration in the south west and north east part of study area (as shown in figure 5). Sardarshar and Ratangar tehsil has found to be higher bicarbonate content than other tehsils.

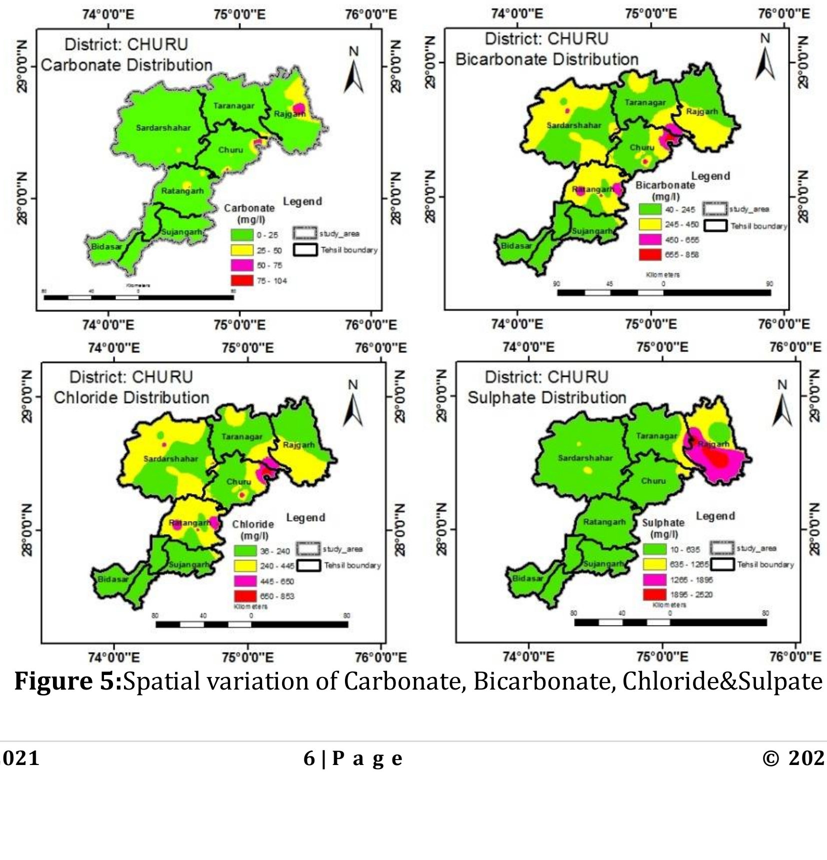

Figure 5: Spatial variation of Carbonate, Bicarbonate, Chloride&Sulpate

6. **Chloride &Sulphate Spatial distribution –**The concentration of Chloride is found to be lower in most part of the study area which is varies from 30-240 mg/l. Higher range has been found in the Churu, Taranager and Ratangarh tehsils (figure 5). The range of sulphate varies from 10 to 635 (mg/l) in most part of study areas. Higher value has been reported in Rajgarh tehsil (figure 5).
7.

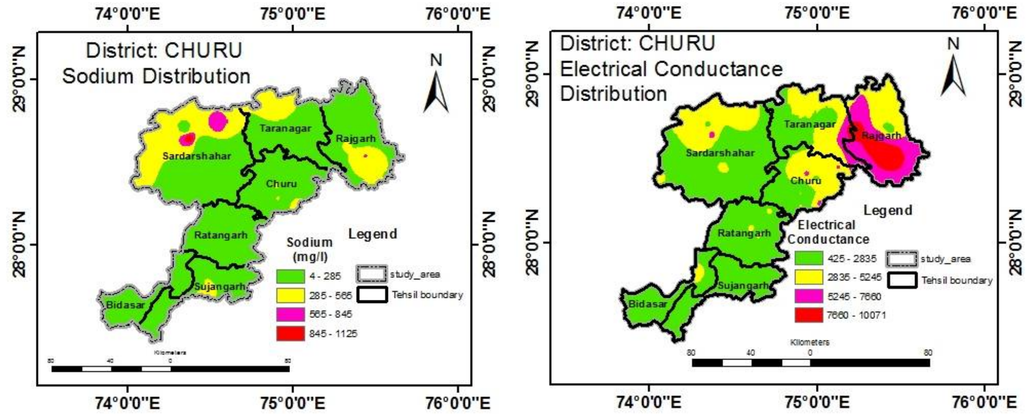

Figure 6: Spatial variation of Sodium and Electrical conductivity

8. **Sodium and Electrical conductivity Spatial distribution –** The amount of sodium in Churu district ranges from 4 to 285 (mg/l). The higher concentration of sodium is found in Sardashahar tehsil, which ranges from 800 to 1125 (mg/l) (figure 6).

   Higher concentration of electrical conductivity was seen in the Rajarh tehsil which is 1000 (us/m)(figure6). High amount of electrical conductivity effects the growth of the vegetation.

   Correlation Analysis (per monsoon and post monsoon)

   The Pearson's correlation coefficient was determined to measure the level of correlation in groundwater quality parameter. The positive value of correlation coefficient is more useful in the regression variables analysis [10].

   In pre monsoon and post monsoon period, both the positive and negative correlation was found in ground water parameter. The positive correlation co-efficient was found in pre monsoon period between Ca and Mg (r=0.74), Na and SO4 (r=0.91), TDS and EC (r=0.94), HCO3 and CL (r=1) at 0.005 level of Significant (table1). The positive correlation co-efficient was observed in post monsoon between Mg and SO4 (r=0.91), HCO3 and CL (r= 1), SO4 and TDS (r = 0.91). The correlation co-efficient among the parameter is shown in table 1.

TABLE 5: Pearson's Correlation Coefficient of Groundwater Quality (Pre-Monsoon Period)

Parameters	Ca	Mg	Na	k	CO_3	HCO_3	CL	SO_4	TDS	pH	Fe	F	NO_3	EC
Ca	1.00													
Mg	0.74	1.00												
Na	-0.22	0.28	1.00											
K	-0.19	0.06	0.26	1.00										
CO_3	-0.05	-0.11	-0.18	0.28	1.00									
HCO_3	-0.43	0.01	0.53	0.34	0.01	1.00								
CL	-0.43	0.01	0.53	0.34	0.01	1.00	1.00							
SO_4	0.00	0.47	0.91	0.22	-0.22	0.23	0.23	1.00						
TDS	0.09	0.56	0.87	0.19	-0.15	0.28	0.28	0.91	1.00					
pH	-0.32	-0.24	0.14	0.07	0.23	0.55	0.55	-0.11	-0.07	1.00				
Fe	0.01	-0.09	-0.05	-0.13	-0.03	-0.05	-0.05	-0.06	-0.07	-0.07	1.00			
F	-0.05	-0.09	0.11	-0.04	-0.02	-0.08	-0.08	0.19	0.11	-0.02	0.26	1.00		
NO_3	0.66	0.75	0.14	-0.06	-0.18	-0.03	-0.03	0.29	0.35	-0.06	-0.02	0.00	1.00	
EC	0.15	0.56	0.75	0.17	-0.16	0.15	0.15	0.84	0.94	-0.14	-0.08	0.14	0.30	1.00

TABLE 6: Pearson's Correlation Coefficient of Groundwater Quality (Post-Monsoon Period)

Parameters	Ca	Mg	Na	k	CO_3	HCO_3	CL	SO_4	TDS	pH	Fe	F	NO_3	EC
Ca	1.00													
Mg	0.73	1.00												
Na	-0.23	0.28	1.00											
K	-0.19	0.06	0.25	1.00										
CO_3	-0.04	-0.13	-0.20	0.27	1.00									
HCO_3	-0.43	0.00	0.53	0.34	-0.01	1.00								
CL	-0.43	0.00	0.53	0.34	-0.01	1.00	1.00							
SO_4	0.00	0.48	0.91	0.22	-0.23	0.23	0.23	1.00						
TDS	0.08	0.56	0.87	0.19	-0.16	0.28	0.28	0.91	1.00					
pH	-0.32	-0.25	0.14	0.07	0.23	0.55	0.55	-0.11	-0.07	1.00				
Fe	0.01	-0.10	-0.05	-0.13	-0.03	-0.05	-0.05	-0.06	-0.07	-0.07	1.00			
F	-0.05	-0.08	0.12	-0.04	-0.03	-0.08	-0.08	0.19	0.12	-0.03	0.26	1.00		
NO_3	0.66	0.75	0.15	-0.06	-0.19	-0.03	-0.03	0.29	0.35	-0.06	-0.02	0.00	1.00	
EC	0.15	0.56	0.75	0.17	-0.17	0.15	0.15	0.84	0.95	-0.14	-0.08	0.14	0.30	1.00

Piper Diagram

Piper diagram is also called trilinear diagram [11]. It is a graphical representation of hydro-geological studies (calcium, Magnesium and alkaline metals) with 03 cations and 03 anions (SO4, Cl and Bi-carbonate).

The piper diagram has been shown in figure 7. The diagram describes the variation between cation and anion concentration in the study area. Most of dug-well ground water sample fall in calcium chloride, Cl + SO4 strong acid, Ca + Mg (exceeds the alkaline). Piper diagram of dug-well ground water quality parameters monitored at sampling sites presented an unfavourable condition as shown in figure 7. This diagram indicates the influence of salt due to geological (rocky type) and environment condition.

Water quality index (WQI)

Water quality index (WQI) is an exceptionally important technique for determining the overall quality of water [1] [8]. The calculated values of WQI for pre-monsoon and post monsoon have been shown in Table 7.

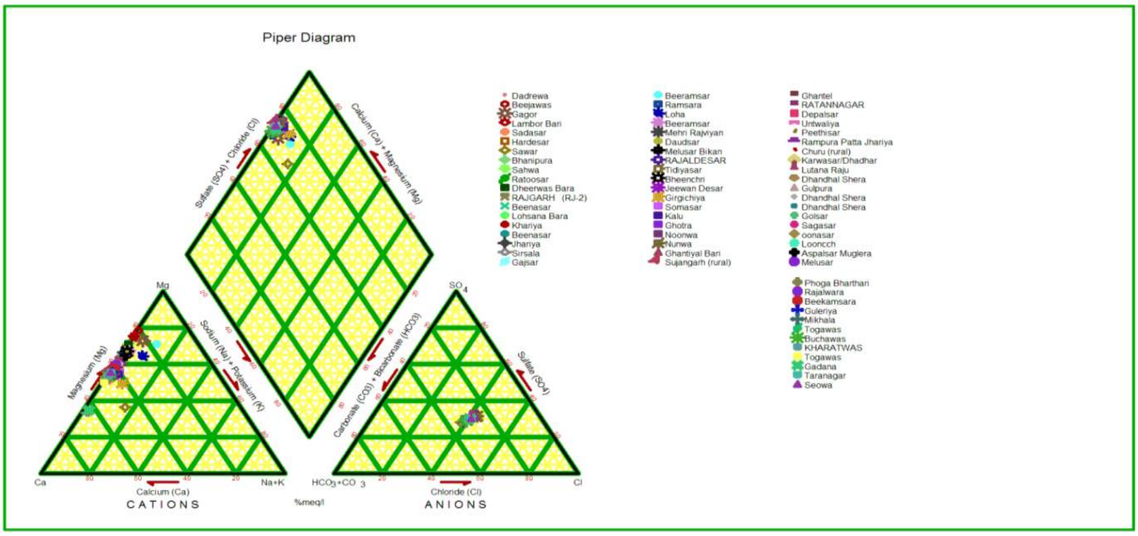

Figure 7: Piper Trilinear Plots for groundwater samples.

TABLE 7: Calculated Water Quality Index of Pre-Monsoon and Post Monsoon

ID	Tehsil	Name of Village	Latitude				Longitude				Pre Monsoon	post Monsoon
DW1	Rajgarh	Dadrewa	28°	40'	9.6''	N	75°	14'	0''	E	739.52	744.32
DW2	Rajgarh	Beejawas	28°	32'	0"	N	75°	26'	19.8''	E	862.25	867.05
DW3	Rajgarh	Gagor	28°	36'	4.8"	N	75°	20'	10.2''	E	801.9	806.78
DW4	Rajgarh	Lambor Bari	28°	34'	12''	N	75°	23'	24''	E	787.03	791.91
DW5	Sardarshahar	Sadasar	28°	38'	30''	N	74°	22'	30''	E	51.59	56.45
DW6	Sardarshahar	Hardesar	28°	36'	33.6''	N	74°	26'	22.8''	E	403.19	408.06
DW7	Sardarshahar	Sawar	28°	42'	0''	N	74°	21'	0''	E	52.57	57.29
DW8	Sardarshahar	Bhanipura	28°	38'	30''	N	74°	22'	30''	E	228.53	233.25
DW9	Taranagar	Sahwa	28°	50'	30''	N	74°	54'	30''	E	653.55	658.24
DW10	Taranagar	Ratoosar	28°	43'	40.2''	N	74°	32'	40.2''	E	329.42	333.81
DW11	Taranagar	Dheerwas Bara	28°	50'	30''	N	74°	54'	30''	E	492.01	496.27
DW12	Rajgarh	Rajgarh (Rj-2)	28°	38'	0''	N	75°	22'	30''	E	497.2	501.47
DW13	Churu	Beenasar	28°	15'	45''	N	74°	52'	30''	E	558.86	563.19
DW14	Churu	Lohsana Bara	28°	26'	52.2''	N	75°	7'	30.0''	E	525.55	529.78
DW15	Churu	Khariya	28°	17'	30''	N	74°	54'	15''	E	472.23	476.49
DW16	Churu	Beenasar	28°	15'	45''	N	74°	52'	30''	E	262.73	266.98
DW17	Churu	Jhariya	28°	22'	52.8''	N	74°	59'	30''	E	267.7	271.91
DW18	Churu	Sirsala	28°	26'	0''	N	75°	7'	50.40''	E	53.68	57.89
DW19	Churu	Gajsar	28°	19'	18.6''	N	74°	56'	0''	E	202.24	205.85
DW20	Ratangarh	Beeramsar	28°	2'	300''	N	74°	47'	30''	E	399.95	403.61
DW21	Ratangarh	Ramsara	28°	15'	56.4''	N	74°	57'	6.6''	E	232.43	236.09
DW22	Ratangarh	Loha	28°	0'	300''	N	74°	37'	30''	E	254.38	257.9
DW23	Ratangarh	Beeramsar	28°	2'	300''	N	74°	47'	30''	E	241.92	245.32
DW24	Sardarshahar	MehriRajviyan	28°	30'	15''	N	74°	44'	15''	E	261.56	265.03
DW25	Ratangar	Daudsar	28°	11'	4.8''	N	74°	43'	4.8''	E	259.02	262.55
DW26	Sardarshahar	MelusarBikan	28°	30'	15''	N	74°	44'	15''	E	248.24	251.82
DW27	Ratangarh	RAJALDESAR	28°	2'	15.00''	N	74	28'	34.8''	E	235.4	239.12
DW28	Ratangarh	Tidiyasar	28°	4'	0''	N	74	44'	0''	E	183.83	187.55
DW29	Ratangarh	Bheenchri	28°	5'	300''	N	74	51'	56.4''	E	239.9	243.62
DW30	Sardarshahar	JeewanDesar	28°	22'	0''	N	74	32'	15''	E	286.59	290.14
DW31	Sardarshahar	Girgichiya	28°	26'	19.8''	N	74	26'	19.8''	E	350.97	354.64
DW32	Sardarshahar	Somasar	28°	23'	10.2''	N	74	4'	0''	E	168.2	172.35
DW33	Sardarshahar	Kalu	28°	25'	0''	N	73	52'	36.6''	E	203.98	208.13
DW34	Sujangarh	Ghotra	28°	44'	0''	N	74	7'	0''	E	439.02	443.12
DW35	Ratangarh	Noonwa	28°	59'	0''	N	74	35'	15''	E	280.77	284.87
DW36	Ratangarh	Nunwa	28°	59'	0''	N	74	35'	15''	E	330.87	334.97
DW37	Sujangarh	Ghantiyal Bari	28°	49'	0''	N	74	17'	0''	E	181.42	185.56
DW38	Sujangarh	Sujangarh (rural)	28°	44'	15''	N	74	28'	9.6''	E	445.97	450.12
DW39	Churu	Ghantel	28°	21'	26.4''	N	74	54'	22.2''	E	285.07	289.06
DW40	Churu	RATANNAGAR	28°	12'	13.2''	N	74	54'	48.6''	E	178.18	182.18
DW41	Churu	Depalsar	28°	16'	49.8''	N	74	54'	35.4''	E	231.12	235.12
DW42	Churu	Untwaliya	28°	14'	7.8''	N	75	1'	10.20''	E	246.95	250.87
DW43	Churu	Peethisar	28°	12'	54''	N	74	54'	23.4''	E	259.99	263.92
DW44	Churu	RampuraPattaJ hariya	28°	28'	0''	N	74	53'	34.8''	E	271.83	275.78
DW45	churu	Churu (rural)	28°	18'	20.4''	N	74	56'	22.8''	E	257.92	261.87
DW46	Churu	Karwasar/Dha dhar	28°	21'	38.4''	N	74	58'	28.2''	E	396.87	400.86
DW47	Rajgarh	LutanaRaju	28°	40'	6.6''	N	75	26'	11.4''	E	214.29	218.28
DW48	Rajgarh	Dhandhal Shera	28°	42'	43.8''	N	75	23'	30.6''	E	299.35	303.32
DW49	Rajgarh	Gulpura	28°	41'	25.2''	N	75	24'	51''	E	170.93	174.89
DW50	Rajgarh	Dhandhal	28°	42'	43.8''	N	75	23'	30.6''	E	272.34	276.3

		Shera										
DW51	Rajgarh	Dhandhal Shera	28°	42'	43.8''	N	75	23'	30.6''	E	379.67	383.67
DW52	Ratangarh	Golsar	28°	4'	52.80''	N	74	37'	51''	E	188.57	192.53
DW53	Ratangarh	Sagasar	28°	2'	38.40''	N	74	39'	11.4''	E	213.66	217.59
DW54	Ratangarh	oonasar	28°	3'	45.60''	N	74	38'	31.2''	E	183.89	187.82
DW55	Ratangarh	Looncch	28°	2'	36.0''	N	74	39'	52.2''	E	223.64	227.56
DW56	Sardarshahar	Aspalsar Muglera	28°	29'	47.4''	N	74	28'	41.4''	E	287.75	291.68
DW57	Sardarshahar	Melusar	28°	30'	9''	N	74	43'	57.6''	E	149.6	153.47
DW58	Sardarshahar	Phoga Bharthari	28°	29'	58.2''	N	74	36'	19.2''	E	221.54	225.4
DW59	Sardarshahar	Rajalwara	28°	17'	19.8''	N	74	14'	10.2''	E	213.55	217.48
DW60	Sardarshahar	Beekamsara	28°	23'	39''	N	74	25'	15''	E	217.94	221.97
DW61	Sujangarh	Guleriya	28°	44'	43.2''	N	74	27'	14.4''	E	205.39	209.42
DW62	Taranagar	Mikhala	28°	8'	34.20''	N	74	22'	13.2''	E	146.31	150.34
DW63	Taranagar	Togawas	28°	32'	47.4''	N	74	47'	9.6''	E	183.66	187.75
DW64	Taranagar	Buchawas	28°	36'	46.2''	N	74	53'	39.6''	E	171.16	175.25
DW65	Taranagar	Kharatwas	28°	40'	12.6''	N	74	58'	24.6''	E	160.51	164.6
DW66	Taranagar	Togawas	28°	34'	46.8''	N	74	50'	24.6''	E	153.33	157.37
DW67	Taranagar	Gadana	28°	40'	39.6''	N	74	53'	22.8''	E	129.89	133.89
DW68	Taranagar	Taranagar	28°	39'	5.4''	N	75	2'	49.20''	E	154.55	158.59
DW69	Taranagar	Seowa	28°	37'	31.2''	N	75	12'	15.6''	E	153.55	157.58

The results of this study showed that most of the water samples are unsuitable for drinking purpose. Majority of the Highest WQI values were recorded during post monsoon season. The values ranged from 52.57 (Sawar) to 867.05 (Beejawas). However, the highest WQI value that is 867.05(Beejawas) was recorded in post-monsoon. Seasonal WQI values revealed that the well waters of Dadrewa, Beejawas, Gagor and Lambor Bari were unsuitable for irrigation and drinking purpose. This is also the result of high EC and TDS content throughout the study area. The map on spatial distribution of WQI for dug well ground water sample is shown in the figure 8.

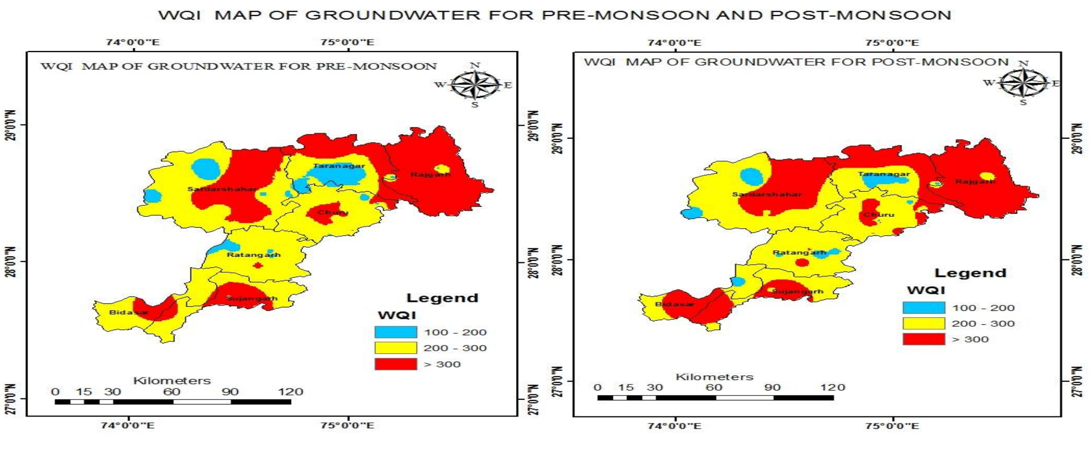

Figure 8:WQI Map of ground water for per monsoon and post monsoon

CONCLUSION

The study was carried out in Churu district, which is facing water insufficiency for irrigation purposes, by using suitable ground and geo-statistical techniques. The quality of water (irrigation) in the study area was assessed using ground-based sampling and geospatial techniques. The results of physico-chemical analysis of water indicate that most of the water quality parameters (Ca Mg Na k CO3 HCO3 CL SO4 TDS pH EC exceeded permissible limits according to BIS standards. The water quality in the study area was also mapped spatially using the Water Quality Index (WQI). The WQI results (WQI > 100) indicated that, for the most part, water in the study area is below irrigation standards. The WQI outcome specifies that most of the water in the study area is unsuitable for drinking and irrigation purposes. The Trilinear diagram revealed the geological structure with chemical reactions having a major impact on this area.

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