Assessment of Groundwater Quality Gurh Tehseel, Rewa District, Madhya Pradesh, India

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Abstract

The paper deals with groundwater quality assessment of Gurh Tehseel, District Rewa, Madhya Pradesh, India. Geologically, the area is occupied by sandstone and shale of Rewa Group belonging to Vindhyan Supergroup. The groundwater occurs in semiconfined to confined conditions. Twenty one groundwater samples from the area were collected in pre-monsoon and post-monsoon seasons of 2011 and were subjected to geochemical analysis. The main hydrochemical facies are Ca-Mg-HCO_3 and Ca-Mg-SO_4-Cl type. The groundwater is hard to very hard in nature. The concentrations of various cations and anions suggest that the groundwater of the area is partially suitable for drinking. The analysis of various parameters like electrical conductivity, sodium percentage, integrated sodium adsorption ratio (SAR) and EC, residual sodium carbonate suggest that groundwater of the area is suitable for irrigation.

Keywords: Groundwater Quality, Gurh, Rewa, Madhya Pradesh, India

Introduction

The groundwater is a precious and reliable natural resource which plays a vital role to cater the demand of water supply arising due to inadequate surface water resources throughout the world. The chemical alteration of the meteoric water depends on several factors such as soil water interaction, dissolution of mineral species, duration of solids – water interaction and anthropogenic impact (Faure, 1998; Subba Rao, 2001). The quality of groundwater is affected by many factors such as physico-chemical characteristics of soil, rainfall, weathering of rocks etc. (Purushotham etal; 2011). Hem (1991) has stated that once the interrelated hydrochemical process are determined, which cause significant variations in groundwater quality, it becomes easy to take necessary further step regarding groundwater quality control and also so suggest alternative water supply schemes. Groundwater quality assessment of different quality parameters has been carried out by various researches (Hegde, 2006; Pandian and Shankar, 2007; Pophare and Dewalkar, 2007; Mishra 2010). The groundwater quality assessment for drinking and irrigation purpose in the Vindhyan region has carried out by few researchers (Tiwari etal; 2009; Tiwari etal; 2010; Mishra et al. 2012). Due to rapid growth of population and expansion of irrigation sectors, demand of groundwater in the study area has been increased exponentially. This paper analyses various chemical parameters of groundwater of the study area to find out its suitability for drinking and irrigation purposes.

Study Area

The study area lies between latitude $24^0 25'$ to $24^0 40'$ N and longitude 81^0 20' to $81^0 40'$E covering a total area of 550 km^2 Fig.1). The area receives about 1100 mm annual rainfall mainly from the southwest monsoon and enjoys subtropical to humid climatic condition. The temperature goes up to 43^{o}C in summer and 4^o C in winter season. Geologically, the study area forms a part of Vindhayn Supergroup. The shale is generally red in colour, thinly laminated and fractured in nature.The main rock types are shale and sandstone of Rewa Group of Vindhyan Supergroup. The sandstone is generally red and purple in colour. They are hard and compact, medium to coarse grained and lack primary porosity. The water circulation occurs through joints and weathered mantle. In the sandstone, the depth of water level varies from 2.68 to 4.50 meters below groundwater level (mbgl) in post-monsoon, 6.50 to 8.10 mbgl in pre-monsoon whereas in shale formation, the depth of water level varies 2.7 to 4.0 mbgl in post-monsoon and 5.5 to7.3 mbgl in pre-monsoon seasons.

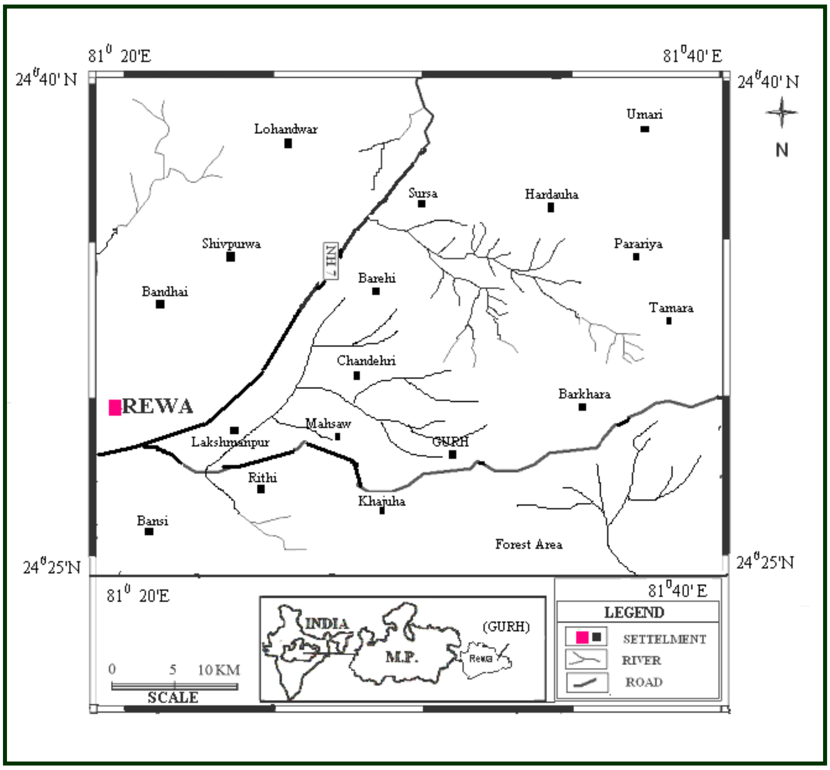


Fig.1 : Location and sampling stations of the study area.

Methodology

Groundwater samples from 21 borewells in different part of the study area were collected during pre-monsoon season and post-monsoon season of 2011 which are extensively used for drinking and irrigation purposes. Electrical conducitivity(EC) and pH of the water have been measured in the field using portable water analysis kit. The groundwater sample are then analyzed for various parameters like calcium (Ca^+), magnesium(Mg^{++}), sodium (Na^+), potassium(K^+), bicarbonate (HCO_3^-), sulphate (SO_4^{--}), nitrate (NO_3^-),chloride (Cl^-) and fluoride(F^-) by following standard analytical techniques (Ramtake and Moghe,1986; APHA,1989) and presented in Table 1.

Table 1 : Geochemical analyses of groundwater samples of the study area

S.No.	Location	Monsoon	PH	EC (µs/cm)	TDS	TH	Na	K	Ca	Mg	F	Cl	SO_4	HCO_3	NO_3
1.	Gurh	Pre-monsoon	6.8	1281.45	821.44	544.7	75.00	3.00	108.0	67.0	0.50	64.3	116	639.0	30
		Post-monsoon	7.1	1295.50	830.45	611.74	80.00	4.02	119.4	76.4	1.00	76.4	201	703.0	42
2.	Chandehri	Pre-monsoon	7.2	775.66	497.22	426.3	36.00	3.12	100.0	43.00	0.85	42.2	74.2	289.0	41
		Post-monsoon	8.5	847.00	542.95	530.13	41.20	4.70	123.0	54.30	1.85	53.7	81.2	305.0	49
3.	Bandhwa	Pre-monsoon	7.6	762.84	489.00	386.1	51.00	4.21	79.0	46.0	0.89	79.0	89.0	245.0	25
		Post-monsoon	8.0	915.74	587.01	469.92	69.80	5.20	95.8	56.2	1.38	90.3	102.0	278.3	39
4.	Rithi	Pre-monsoon	6.8	856.44	549.00	486.4	87.40	6.23	78.12	71.0	0.90	42.20	99.00	345.0	24
		Post-monsoon	7.3	1033.13	662.26	582.16	91.70	7.30	89.2	87.6	1.56	58.6	107.3	365.0	45
5.	Barkahara	Pre-monsoon	6.8	851.76	546.00	608.37	58.21	4.90	78.2	100.7	0.50	142.3	41.23	241.0	21
		Post-monsoon	7.2	999.34	640.60	671.68	68.50	5.30	88.6	109.8	1.23	163.0	52.5	254.0	35
6.	Nawagaon	Pre-monsoon	6.8	1148.94	736.50	410.23	113.00	5.40	69.3	57.8	0.80	78.30	198.3	356.0	22
		Post-monsoon	7.1	1231.46	789.40	498.8	135.00	6.30	88.00	68.00	1.02	98.00	201.3	398.00	36
7.	Parariya	Pre-monsoon	6.8	776.88	498.00	427.1	74.00	8.10	120.0	31.00	0.23	42.0	101.0	120.00	25
		Post-monsoon	7.4	793.98	508.96	464.28	80.70	9.20	127.0	35.8	0.56	57.9	115.0	138.0	46
8.	Sursa	Pre-monsoon	7.5	864.24	554.00	437.75	69.20	7.30	89.0	52.5	0.80	78.5	42.0	302.0	19
		Post-monsoon	8.9	900.85	577.47	513.59	74.30	8.40	103.1	62.4	1.50	83.7	51.9	321.1	38
9.	Mahshav	Pre-monsoon	7.3	858.59	550.38	413.86	33.20	6.70	47.3	72.1	0.78	176.0	85.30	215.00	23
		Post-monsoon	8.1	886.08	568.00	466.2	52.00	8.20	52.0	82.0	1.90	201.0	95.00	230.00	39
10.	Laxmanpur	Pre-monsoon	7.5	902.18	578.32	518.33	75.1	7.90	102.7	63.8	1.54	84.2	52.1	319.2	10
		Post-monsoon	8.2	1094.06	701.32	585.97	85.0	8.50	112.7	74.2	1.20	102.0	65.00	412.0	25
11.	Purwa	Pre-monsoon	7.6	926.02	593.60	591.02	15.70	3.20	118.0	72.2	0.90	45.0	95.2	405.0	22
		Post-monsoon	8.0	1101.36	706.00	664.4	25.00	5.00	128.0	84.0	1.60	55.0	101.0	501.0	34
12.	Lohandwar	Pre-monsoon	6.9	1164.15	746.25	374.13	25.40	15.30	109.8	24.3	0.80	40.2	415.0	192.0	17
		Post-monsoon	7.5	1251.59	802.30	435.5	31.25	21.00	125.0	30.0	1.45	51.0	502.0	203.0	28
13.	Hatwa	Pre-monsoon	6.8	1117.90	716.60	434.15	73.70	2.40	89.2	51.5	1.00	85.7	162.0	418.5	10

ISSN 2229-5518

S.No.	Location	Monsoon	PH	EC (µs/cm)	TDS	TH	Na	K	Ca	Mg	F	Cl	SO_4	HCO_3	NO_3
		Post-monsoon	7.4	1251.12	802.00	519.82	87.00	4.20	101.0	65.2	1.80	91.0	198.0	532.0	35
14.	Raghurajgarh	Pre-monsoon	6.8	750.36	481.00	519.46	43.20	9.10	174.0	20.6	0.8	54.7	32.3	220.8	14
		Post-monsoon	7.2	860.92	551.87	559.96	52.60	11.20	182.0	25.6	1.40	64.8	47.4	278.0	37
15.	Dihiya	Pre-monsoon	7.5	781.87	501.20	371.92	71.00	3.90	81.20	41.20	0.75	47.20	101.2	203.2	23
		Post-monsoon	8.3	881.17	564.85	419.99	75.20	4.30	87.8	48.9	1.50	57.3	112.5	295.0	45
16.	Atro	Pre-monsoon	7.6	758.74	486.37	426.36	72.90	3.20	89.2	49.6	1.00	45.6	115.7	182.0	13
		Post-monsoon	8.0	783.12	502.00	479.32	89.20	5.20	101.2	55.2	1.50	55.5	123.8	201.2	43
17.	Pipari	Pre-monsoon	6.8	1199.28	768.77	574.28	92.60	3.70	101.3	78.3	1.00	189.2	74.2	321.2	23
		Post-monsoon	7.1	1251.43	802.20	678.43	101.2	5.10	120.0	92.3	1.20	203.0	78.7	350.0	35
18.	Bara	Pre-monsoon	6.2	1124.76	721.00	412.92	70.2	1.90	81.20	51.2	0.70	78.20	205.2	401.5	17
		Post-monsoon	7.2	1289.96	826.90	433.4	74.70	2.60	84.8	54.0	1.10	83.6	278.0	417.5	21
19.	Shivpurwa 1	Pre-monsoon	7.2	628.68	403.00	263.6	30.70	6.00	71.00	21.0	0.8	51.2	72.0	320.0	13
		Post-monsoon	8.2	746.12	478.28	299.02	33.80	6.70	75.0	27.2	1.50	55.7	79.0	332.0	29
20.	Shivpurwa 2	Pre-monsoon	7.4	1796.81	1151.80	612.37	24.30	3.40	108.5	83.2	0.9	92.1	437.1	670.0	12
		Post-monsoon	8.0	3792.36	2431.00	766.37	34.30	5.20	145.5	98.2	1.20	105.2	503.1	702.0	23
21.	Tikuri	Pre-monsoon	7.1	1015.87	651.20	346.41	20.30	16.0	101.5	22.6	0.75	32.2	85.2	502.2	25
		Post-monsoon	8.5	1042.36	668.18	386.41	23.70	18.0	109.3	27.6	1.40	38.7	95.5	585.2	39

Results and Discussion

Hydrochemical Facies

Groundwater samples of the study are have been plotted on Chadha's diagram (1999). In this scheme the difference in milliequivalent (epm) percent between alkaline earth (calcium + magnesium) expressed as percentage reacting value is plotted on the x-axis and the difference in milliequivalent (epm) percentage between weak acid anions (carbonate +bicarbonate) and strong acid anions (chloride, sulphate and nitrate) is plotted on the y-axis. The milliequivalent percentage difference between alkaline earth and alkalies and between weak acidic anions and strong acidic anions is plotted on one of the four possible sub fields of the diagram. In both premonsoon and postmonsoon seasons 55% samples are Ca-Mg-HCO_3 type and 45% samples are Ca-Mg-Cl -SO_4 type(Fig. 2).

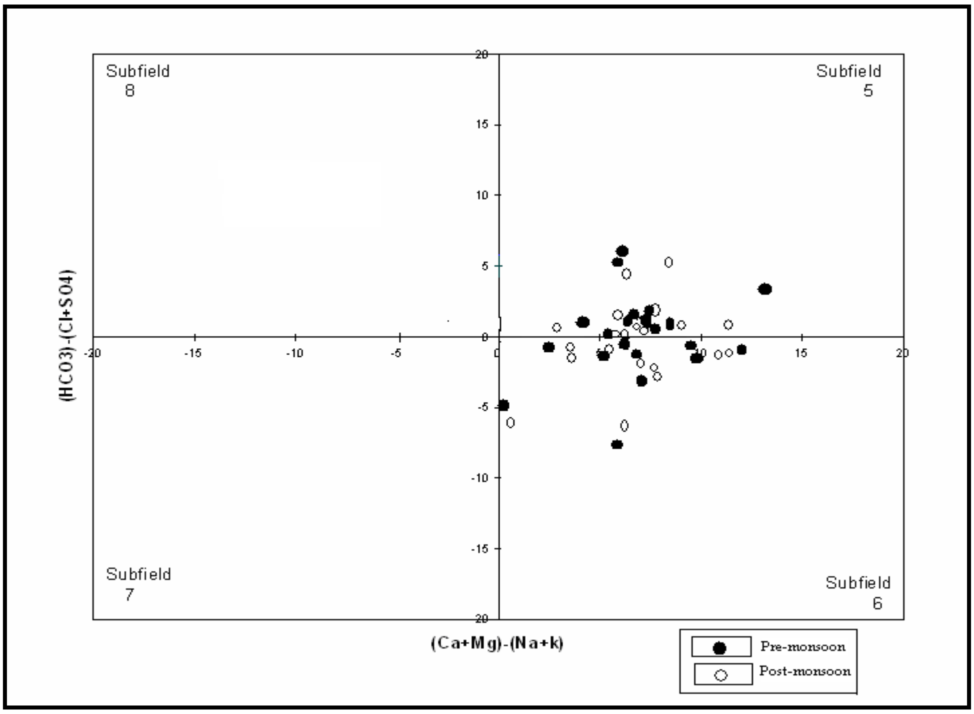


Fig.2 : Classification of Groundwater samples as per Chadha's (1999) Scheme.

Suitability of Groundwater for Drinking

It is observed that the p^H varies between 6.8 to 8.5 indicating alkaline nature of groundwater. The concentration of total dissolved solids varies from 550.3 mg/l to 2431 mg/l, nearly 5% samples exceed the permissible limit (1000 mg/l, WHO; 1993). The intake of higher TDS in human body may cause gastrointestinal problem (Jasortia and Singh,2007). Total hardness of groundwater samples varies between 263.6 to 766.37 mg/l. About 60% of the samples are hard to very hard in nature due to calcite associated with sandstone aquifer as cementing material. The groundwater samples of the area are characterized by Ca>Na>Mg:HCO3>$S0_4$>Cl > NO_3>F type. The concentration of sulphate lies between 42 to 503.1 mg/l, nearly 10% samples exceed the maximum permissible limit (400 mg/l; BIS, 1991). The $CaSO_4$ $2H_20$ associated with shale formation seems to be responsible for higher amount of sulphate. The potassium concentration varies between 1.90 to 21.0 mg/l, and higher concentration is attributed due to K feldspar (orthoclase, microcline) minerals associated with aquifers. The consumption of higher concentration of potassium in human body may cause nervous and digestive disorders. The bicarbonate concentration varies between 120 to 702 mg/l. Fluoride concentration varies between 0.50 to 1.8 mg/l and 15% of samples exceed the permissible limit of 1.5 mg/l (BIS 1991). The higher concentration of fluoride may cause dental and skeletal fluorosis (Madhunure etal., 2007). High concentration of fluoride in groundwater may be due to phosphatic fertilisers used by farmers. The concentration of nitrate varies between 10 to 49 mg/l in which two samples exceed the limit of 45 mg/l. The higher concentration of nitrate may cause methamogbinemia in infants. The sodium calcium, chloride and magnesium ions are with in permissible limit as per standard fixed by WHO (1993) and BIS (1991). To ascertain the suitability of groundwater for drinking, hydrochemical parameters of the study area are compared with standards as per world Health organization (WHO, 1993) and Bureau of Indian standards (BIS, 1991) (Table 2), which shows that the groundwater of the area is partially suitable for drinking because the concentration with respect to TDS, TH, SO_4, Cl and NO_3 in few groundwater samples are higher than the recommended limit for drinking .

Table 2: Comparison of the quality parameters of groundwater of the study area with WHO and ISI for drinking purpose.

S.No.	Water Quality Parameters	WHO (1993)		BIS (1991)		No. of locations which exceed max. permissible limit (WHO)	Concentration in Study Area	Undesirable Effect Produced Beyond Maximum Allowable Limit
		Max Desirable	Max. Permisible	Max. Desirable	Max. Permisible			
1.	pH	7.0	8.5	6.5	8.5	-	6.8-8.2	Taste, effects mucus memberane and water supply system.
2.	TH mg/l	100	500	300	600	17	263.6 to 766.37	Encrustation in water supply and adverse effect on domestic use.
3.	TDS mg/l	500	1500	500	1000	2	403 to 2431	Gastrointestinal irritation.
4.	Ca mg/l	75	200	75	200	-	47.3 to 182.0	Encrustation in water supply, scale formation.
5.	Mg ml/l	30	150	30	100	-	20.6 to 109.8	Encrustation in water supply and adverse effect on domestic use.
6.	Na mg/l	-	200	-	200	-	15.70 to 135.0	Hypertension
7.	K mg/l	-	12	-	-	4	1.90 to 21.0	Nervous disorder
8.	Cl mg/l	200	600	250	1000	-	32.2 to 203.0	Salty Taste

9.	SO_4 mg/l	200	400	150	400	4	32.3 to 503.10	Laxative effect.
10.	F mg/l	1	1.5	1	1.5	5	0.50 to 1.85	Dental Problem in children and adults causes Fluorosis

Suitability of Groundwater for Irrigation

Sodium Percentage (Na%)

Sodium concentration in groundwater is important since increase of sodium concentration in water affect deterioration of soil properties reducing permeability (Kelly, 1951; Tijani, 1994). The sodium in irrigation water is usually denoted as percent sodium and denoted by the following formula (Wilcox, 1955)

$$\text{Na\%} = \frac{\text{Na}^{+} + K^{+}}{\text{Ca}^{++} + Mg^{++} + \text{Na}^{+} + K^{+}} \times 100$$

where all the concentrations are expressed in epm

The classification of groundwater samples with respect to sodium percentage and electrical conductivity is presented in Fig. 3 (Wilcox,1955). It is observed that during pre-monsoon season 4% of groundwater is excellent to good while 92% fall in good to permissible and another 4% sample are unsuitable. In post-monsoon season all samples are of good to permissible category.

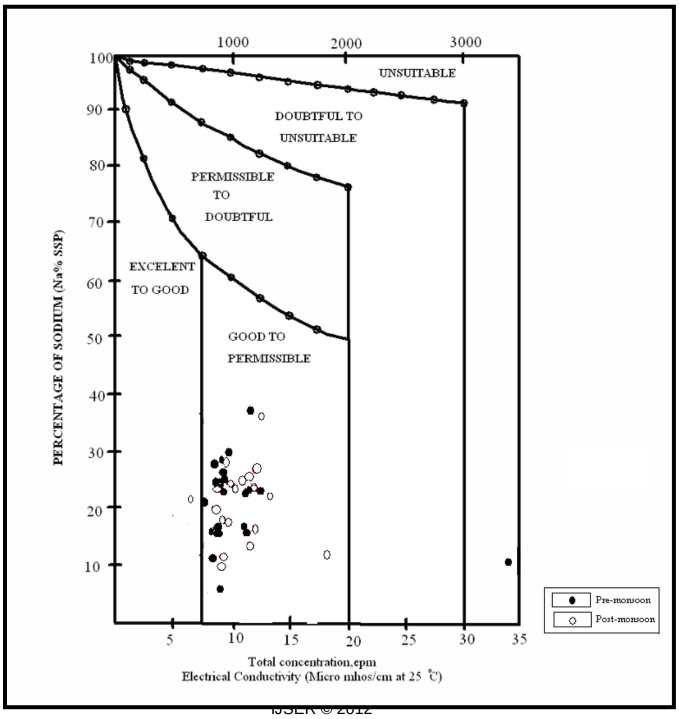


Fig. 3 : Classification of groundwater based sodium percentage vs. electrical conductivity (after Wilcox 1955).

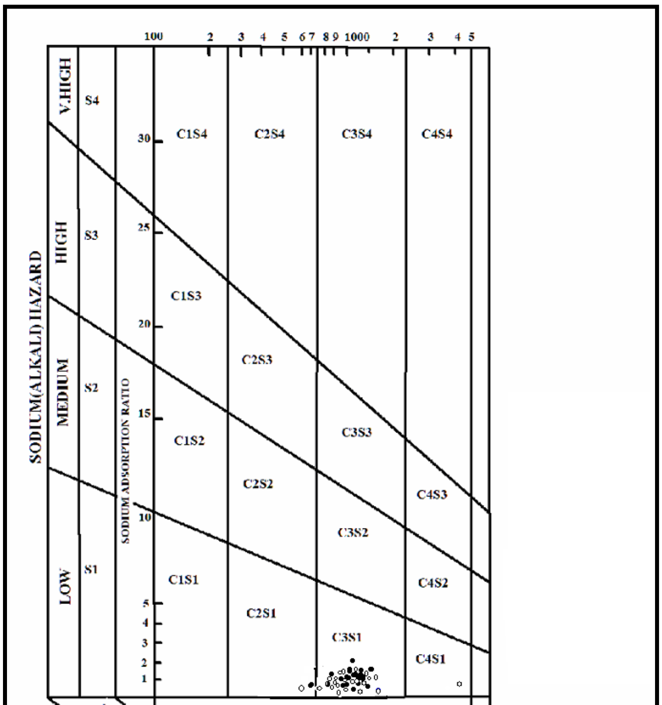
Sodium Adsorption Ratio (SAR)

The relative activity of sodium ion in the exchange reaction with soil is expressed in terms of sodium adsorption ratio (SAR). It is processed as -

$$\mathrm{SAR} = \frac{\mathrm{Na}^{+}}{\sqrt{\mathrm{Ca}^{++} + Mg^{++}/2}}$$

where all the concentrations are expressed in epm

The U.S.Salinity Laboratory (Richards,1954) proposed a diagram for suitability of groundwater for irrigation purpose based on sodium adsorption ratio (SAR) and electrical conductivity(EC) (Fig.4). Sixteen categories are demarcated in the diagram in terms of salinity hazard as low (C_1), medium (C_2), high (C_3), very high (C_4) and also in terms of sodium hazard as low (S_1), medium (S_2), high (S_3), very high (S_4). About 5% samples of pre-monsoon season fall under C_2 S_1 class indicating medium salinity and low alkaline; 90% under C_3 S_1 class indicating high salinity and low alkaline nature and 5% samples under C_4 S_1 having high salinity. During post-monsoon season, it is observed that 5 % of groundwater samples fall under C_2 S_1 and 95% of samples fall under. C_3 S_1. It can be inferred from the Fig. 4 that 97% of groundwater samples for both pre-monsoon and post-monsoon season fall in the field C_2 S_1 and C_3 S_1 indicating medium to high salinity and low alkaline in nature which can be used for irrigation with little care of exchangeable sodium.



ISSN 2229-5518

Fig. 4 : U.S. Salinity Diagram for classification of irrigation water [after Richards (1954)]

Residual Sodium Carbonate (RSC)

It refers to the residual alkalinity and is calculated for irrigation water by the following formula:

$$RSC = (HCO_3^{\ -} + CO_3^{\ --}) - (Ca^{++} + Mg^{++})$$

where all the concentrations are expressed in epm

The RSC values >1.25 epm are considered as safe for irrigation while those from 1.25 to 2.5 epm are marginally suitable for irrigation. If RSC values are > 2.5 epm, the groundwater is unsuitable for irrigation (Eaton, 1950; Richards, 1954). According to Eaton (1950) scheme, all groundwater samples are marginally suitable for irrigation.

Conclusion

Chemistry of the groundwater of the area indicates that the alkaline earth (Ca^{++} and Mg^{++}) exceeds alkalies (Na^{+}+ K^{+}), weak acid (HCO_3^{-}) exceeds strong acid (Cl^{-}, NO_3^{-} and $SO_4^{\ --}$). The concentration of p^H (6.5- 8.5) in the area suggests alkaline nature of groundwater. The total dissolved solids increase in the post-monsoon season as a result of dissolution of minerals from the overlying layers and weathered zones by water percolation. The over all characteristics of groundwater in the study area in post-monsoon season, where majority of the cations and anions are high due to the rock water interaction. About 40% of the samples exceed the maximum permissible limit of hardness. This type of water should be used for drinking after chemical treatment. Nearly 10% of the samples exceed the maximum limit of sulphate which may cause laxative effect. Higher concentration of sulphate is attributed to gypsum associated with aquifer. The higher concentration of fluoride in 15% of the samples of the study area may be due to the phosphatic fertilizers. Except two samples nitrate concentration is within permissible limit. Hence groundwater of the area is partially suitable for drinking purpose. The values plotted on USSL diagram suggest that 97%

ISSN 2229-5518

of the samples are C_2S_1, and C_3 S_1 category in pre-monsoon and post-monsoon seasons indicating medium to high salinity and low sodium hazard. The plot of sodium percentage vs electrical conductivity suggest good to permissible category of groundwater for irrigation. Residual sodium carbonate values denote that all sample are of safe and marginal types. So it can be concluded that groundwater of the area is suitable for irrigation.

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