Assessment of Quality and Pollution Potential of Groundwater around Dabhaura Area, Rewa District, Madhya Pradesh, India

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Abstract

The present paper deals with quality and pollution potential of Groundwater of Dabhaura area, Rewa District, Madhya Pradesh. The study area is mainly drained by Jatari river which finally meets to Tons river, a life line of Rewa region. Geologically, the area is occupied by shale and Govindgarh sandstone formations of Upper Vindhyan. A total of 22 groundwater samples from shallow aquifer zone collected in June 2011 and analyzed to see their suitability for drinking and irrigation purposes. The analysed data reflect that the groundwater of the area is moderately hard to very hard, higher amount of total dissolved solids as well as higher concentration of sulphate due to lithology of aquifers. A most of samples are within prescribed limits as suggested by World Health Organisation (WHO) and Indian Standard (ISI) for drinking purpose. The groundwater is mainly $Ca-Mg-SO_4-Cl$ and $Ca-Mg-HCO_3$ type. The plot of electrical conductance (EC) vs sodium adsorption ratio (SAR) of analysed groundwater samples in U.S. salinity diagram indicating them to be of medium to high salinity and low sodium hazard type of groundwater. However, for the computation of vulnerability, the DRASTIC Index (DI) modelling has been adopted. The computed Drastic Index suggests that the area is moderate to high susceptible to pollution. Hence, proper attention and water quality monitoring programme has been suggested to check the groundwater pollution.

Keywords: groundwater pollution, DRASTIC index, Dabhaura, Madhya Pradesh India

1. Introduction

The Groundwater is a precious 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 changes are fairly rapid in shallow aquifers because of discharge recharge pattern as well as contaminated activities (Raghunath, 1987). The quality of groundwater is largely controlled by discharge-recharge pattern, nature of host and associated rocks as well as contaminated activities (Walton, 1970). The hydrogeochemical evolution of groundwater is a dynamics process undergoing constant change in space and time (Karanth, 1987). The quality of groundwater is of considerable importance in addition to its quantity for the management of groundwater resource. The study on groundwater quality of Vindhyan region has been performed by few researchers (Tiwari et al., 2009; Tiwari et al., 2010; Mishra, 2010). Hydrogeochemistry and classification of groundwater are carried out in order to evaluate its suitability for municipal, agricultural and industrial uses (Ahmed et al., 2002; Jasrotia & Singh, 2007; Suresh et al., 2010; Purushottam et al., 2011). Realizing the importance of groundwater quality delineation, the present work has been undertaken around Dabhaura area, a tehsil headquarter in Rewa district, Madhya Pradesh (Figure 1).
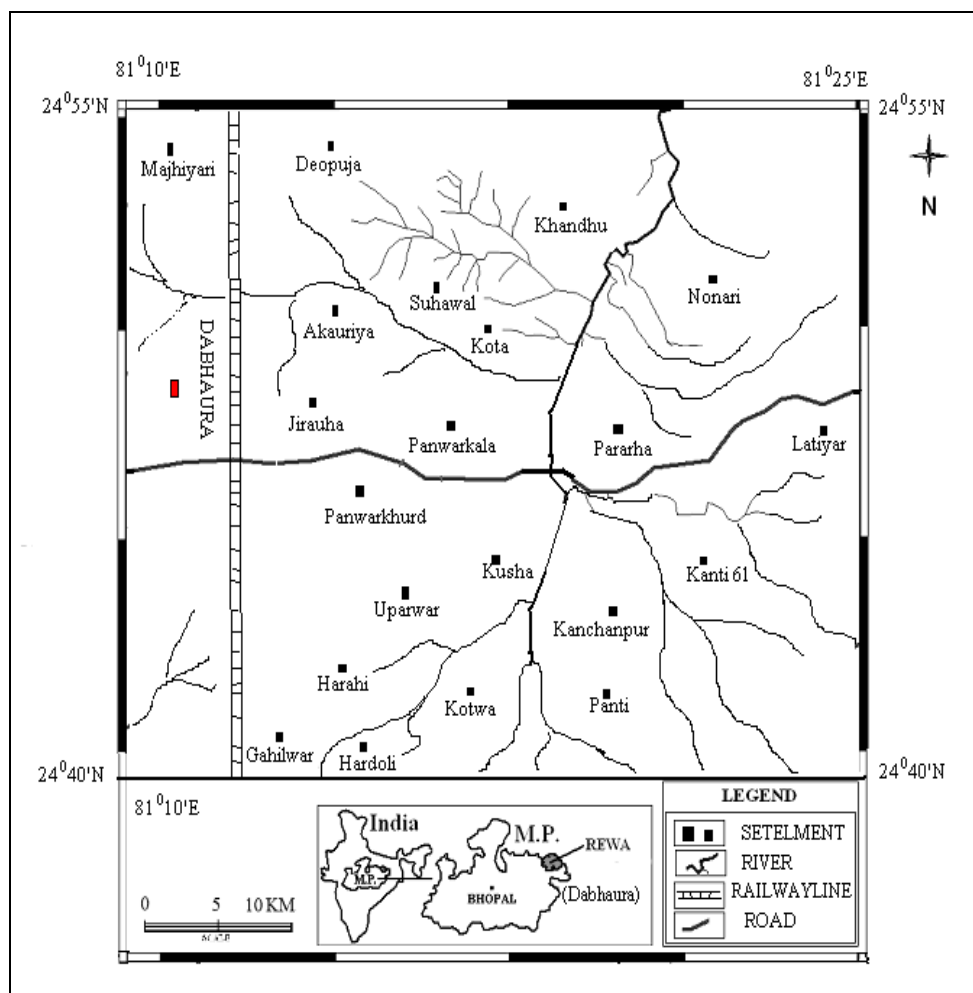
Figure 1. Location map of the Study Area

The study area is drained by Naina river and its tributaries and bounded by latitude $24^0 40'$ to $24^0 55'$N and logitude $81^° 10'$ to $81^° 25'$E covering an area of about 500 km^2. The climate is semi arid to humid type and average rainfall of the area is about 1000 mm however in the year 2010 it was recorded 549 mm. The temperature in summer months goes up to $46^°$C while as low as $2^°$C during peak winter month. The relative humidity is of about 75 percentage.

2. Geology and Hydrogeology

The study area is part of northern extension of Vindhyan sedimentary basin; one of the thickest sedimentary basins of India. The main rock types are Govindgarh sandstone and shale of Rewa Group of Vindhyan Supergroup. Besides these, recent alluviums also present in the area. Sandstone is medium to coarse grained, red and brown in colour and dominated by monocrystalline quartz. It is quartz arenite type (Tiwari & Dubey, 2007) and shows development of cross beds. The shale is thinly bedded and chocolate brown in colour with the development of polygonal mud cracks.

Hydrogeologically, the area is hard rock terrain, lying in Pre-Cambrian sedimentary province (Karanth, 1987). Due to high silica cementation in sandstone, the primary porosity is low. Secondary porosity in the form of joints, fractures, bedding planes and weathered pediments are favourable for the groundwater exploitation. The groundwater occurs in both semi confined and confined conditions.

3. Methodology

The present study is based on 22 groundwater samples which collected from Dugwells during June, 2011. The physico-chemical analysis was performed following standard methods (Ramteke & Moghe, 1986; APHA, 1998). The pH, electrical conductivity and total dissolved solids of the samples were determined in the field using

portable instruments. Calcium, magnesium, total hardness, sodium, potassium, chloride, bicarbonate, sulphate, and fluoride were determined in the laboratory by folowing standard analygtical technique (APHA, 1998).

The total hardness in groundwater in the study area has been calculated using the formula proposed by Raghunath (1987) as under:

$$\text{TH as } CaCO_3 \text{ in mg/l} = (Ca + Mg) \text{ mg/l x } 50$$

For the computation of DRASTIC Index, some hydrogeological parameters as outlined by Aller et al. (1987) have been used, which are given below:

   i.   Depth to water table (D)

   ii.   Net Recharge (R)

   iii.   Aquifer media (A)

   iv.   Soil media (S)

   v.   Topography (T)

   vi.   Impact of vadose zone and (I)

   vii.   Hydraulic conductivity of aquifer (C)

$$D.I. = D_R D_w + R_R R_W + A_R A_w + S_R S_w + T_R T_W + I_R I_W + C_R C_W$$

where R- rating; W- weightage

3.1 Classification of Groundwater

The classification of groundwater is essential to know the suitability of groundwater of an area for domestic, agricultural or industrial uses. In the study area, groundwater are classified based on the total dissolved constituents TDS, Cl^- SO_4^{-2}, HCO_3^- etc. Wilcox (1955) classified groundwater on the basis of concentration of TDS as upto 500 mg/l; desirable for drinking, 500-1000 mg/l; permissible for drinking, upto 3000 mg/l; useful for irrigation and > 3000 mg/l; unfit for drinking and irrigation. Based on the above classification, about 45% of the samples are within the desirable limit and 55% are in permissible limit for drinking purpose.

The maximum sulphate concentration in the water samples is 315.30 mg/l (sandstone) while the concentration in shale formation is 612.00 mg/l in water sample (Table 1). This suggests that 65% of the water sample belong to the "normal sulphate" category (Schoeller, 1962). Based on this classification, the groundwater of the area has maximum concentration of chloride is 85.00 mg/l in sandstone and 212.00 in shale indicates that the groundwater is "normal chloride" water (Schoeller, 1962). The minimum total hardness concentration in groundwater in the study area is 100 mg/l and the maximum concentration is 802mg/l. According to classification based on hardness scale by USGS (Hem, 1985), the groundwater of the area is moderately hard to very hard. The minimum HCO_3^- concentration in groundwater in the study area is 109.00 mg/l in while the maximum concentration is 365.00 mg/l observed in thus, most of the groundwater samples belong to the normal carbonate category (Schoeller, 1962).The analyzed data has been plotted on Chadha's (1999) diagram which is modified version of Piper's (1953) trilinear diagram. It has all the advantage on the diamond shaped field of the Piper's trilinear and can be also used to study various hydro-chemical processes such as base cation exchange, actual ion concentration, mixing of natural waters and sulphate reduction and other related hydro-chemical problems.

In the Chadha's scheme the difference in milliequivalent (epm) percent between alkaline earth (Calcium + Magnesium) and alkali (Sodium + Potassium) expressed as percentage reacting value is plotted on the X-axis and difference in milliequivalent (epm) percentage between weak acid anion (Carbonate +Bicarbonate) and strong acid anion (Chloride + Sulphate + Nitrate) is plotted on the Y-axis. The milliequivalent percentage difference between alkaline earth and alkaline metals and between weak acidic anions and strong acidic anions would plot in one of the four possible subfields of the diagram. In the study area, out of 22 groundwater samples, 12 sandstone samples and 07 shale samples fall in the subfield -5 of Ca-Mg-HCO_3 type whereas 02 sandstone samples and 01 shale samples fall in the subfield 6 indicating Ca-Mg-Cl-SO_4 type (Figure 2).
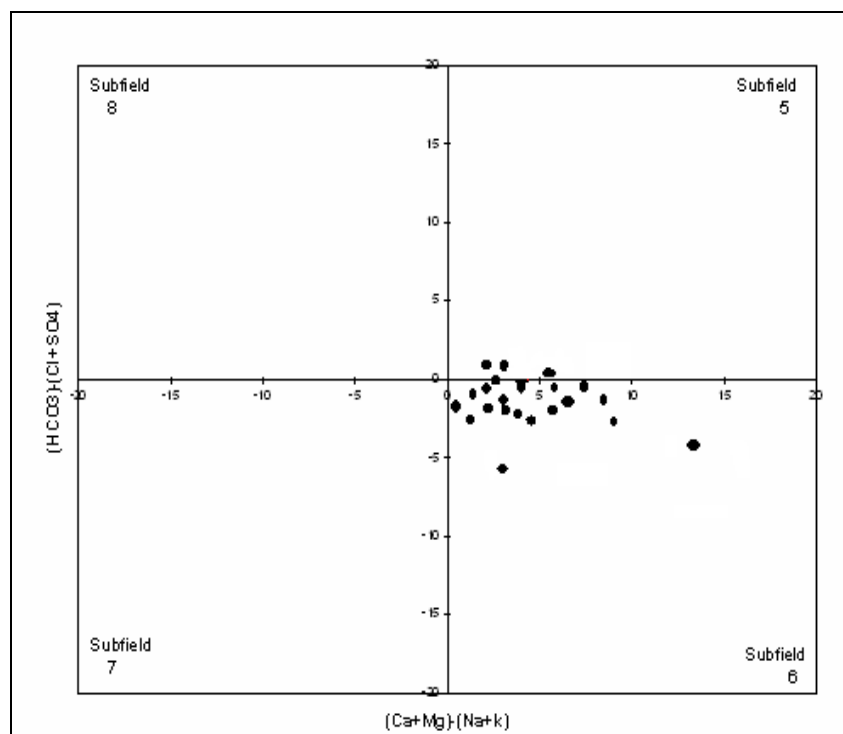
Figure 2. Classification of Groundwater samples as Per Chadha's (1999) Scheme

4. Results and Discussion

4.1 Drinking Water Quality

As evident from Table 1, pH ranges from 7.4 to 8.9 indicating alkaline nature of groundwater. The higher pH values observed in certain samples suggest that carbon dioxide, carbonate-bicarbonate equilibrium is affected more due to change in physico-chemical conditions (Karanth, 1987; Tiwari et al., 2010).

The conductivity of groundwater sample of the study area varies from 500 mg/l to 1867 mg/l in shale. Higher concentration of electrical conductance in shale may be due to the enough time for reaction between groundwater sample and impervious shale. The sandstone litho units have comparatively lesser amount of EC due to its hydrological characters. The total dissolved solids (TDS) varies between 321 mg/l to1197 mg/l. The water with TDS upto 1000 mg/l is considered to be suitable for drinking (Pophare & Dewalkar, 2007; Tiwari & Singh, 2010). The higher amount of TDS may cause gastrointestional irritation in human body.

The total hardness varies between 100 mg/l (Kanchanpur; moderately soft) to 802 mg/l (Pararha; very hard). The possibility of groundwater hardness in the area may be due to calcareous sandstone. The content of calcium in sandstone aquifers varies from 15 mg/l to 109 mg/l while in shale, the range of concentration varies from 30 mg/l to 99.2 mg/l. The magnesium concentration in water sample from sandstone ranges 11.5 mg/l to 75 mg/l while in shales, the concentration varies 16 mg/l to 177 mg/l. The concentration of sodium ranges from 5 mg/l to 104 mg/l in sandstone aquifers whereas it varies from 19.9 mg/l to 70 mg/l in shale lithounit. Similarly, concentration of potassium varies between 1.2 mg/l to 13.6 mg/l in sandstone and 1.1 mg/l to 11.24 mg/l in shale formations. It seems that the clay minerals present in sandstone and shales contributed these two constituents to the groundwater of the area. In the present study, the groundwater sample from sandstone have sulphate concentration ranging from 4.5 mg/l to 315.3 mg/l while in the case of water samples from shaly aquifers, the concentration range of sulphate varies from 20.20 mg/l to 612 mg/l. The higher concentration of sulphate is due to the gypsum and baryte nodules associated with shale.

The concentration of chloride in sandstone aquifer varying from 20.2 mg/l to 85 mg/l while the water samples from aquifer in shale have chloride concentration ranging between 36.66 mg/l to 212 mg/l. The water samples from sandstone aquifers have bicarbonate ions ranging between 125 mg/l to 309 mg/l while the shale formation have the range of bicarbonate ions between 109 mg/l to 365 mg/l. Potable water should have 0.6 to 1 mg/l of fluoride for substantial protection against tooth decay. If fluoride is totally absent in drinking water, it causes

dental caries. Continuous high intake of fluoride result in mottled teeth, skeletal fluorosis and sometimes severe osteosclerosis. In the study area, the concentration of fluoride ranges from 0.02 to 1.03 in sandstone aquifer whereas 0.01 to 2.7 in shale aquifers. The higher concentration of fluoride in shale formation is due to the presence of F⁻ bearing minerals (biotitic and clay minerals) in shale formation as well as leaching action from other sources. As evident from Table 1, higher concentration of fluoride is strongly related with pH indicating that higher alkalinity of the water promotes the leaching of F^- and thus affects the concentration of F^- in the groundwater (Chatterjee et al., 2008, Duraiswamy & Patankar, 2011; Saxena & Ahmed, 2001; Madhnure et al., 2007). To ascertain the suitability of groundwater for drinking purpose the geochemical parameters of the study area are compared with the guidelines as recommended by WHO (1984) and ISI (1991) which indicate that groundwater of the study area is more or less suitable for drinking purpose (Table 2).

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

| Lithology	Location	P^H	EC (μs/cm)	TDS	TH	Na	K	Ca	Mg	F	Cl	SO$_4$	HCO$_3$
1	2	3	4	5	6	7	8	9	10	11	12	13	14
SSt./1	DABHAURA	7.6	757	485	352	27.32	12.41	109.00	19.01	1.03	81.02	50.16	309.00
SSt./2	GAHILWAR	8.1	507	325	465	20.00	1.20	63.00	75.00	0.09	85.00	20.00	125.00
SSt./3	HARHAI	7.5	702	450	352	28.30	12.30	108.00	20.00	1.00	80.00	49.10	308.00
SSt./4	MAJHIYARI	7.6	863	553	293	11.50	8.40	98.30	11.50	0.30	20.20	315.30	179.00
SSt./5	KOTWA	8.2	607	389	123	5.00	13.40	27.49	27.49	1.00	27.60	56.90	242.80
SSt./6	KANCHANPUR	8.2	501	321	100	104.00	13.60	15.00	15.09	0.50	33.10	54.50	142.20
SSt./7	DEOPUJA	7.4	605	388	352	37.80	2.50	92.80	29.16	1.01	57.12	6.50	132.00
SSt./8	AKAURIYA	8.1	505	324	241	17.09	3.00	58.00	23.32	0.30	29.70	6.50	176.00
SSt./9	JIRAUHA	8.3	583	374	315	32.00	2.80	85.00	25.00	1.01	40.00	8.90	165.00
SSt./10	KOTA	8.5	1126	722	305	50.00	1.24	76.00	28.05	0.02	70.12	4.50	180.00
Sh/11	SUHAWAL	7.7	934	599	323	33.10	3.08	86.20	23.30	1.40	41.10	19.90	166.10
Sh/12	PANWARKALA	7.6	1026	658	372	51.20	2.10	96.10	57.11	0.06	56.20	21.80	182.10
Sh/13	KHANDHU	8.1	1025	657	388	56.10	2.12	99.20	28.18	0.01	60.10	22.40	156.20
Sh/14	UPARWAR	8.0	554	355	367	47.15	3.20	94.30	24.20	1.00	66.20	20.20	168.30
Sh/15	KUSHA	7.6	472	303	349	35.10	4.15	90.20	34.20	1.80	49.20	20.20	140.40
Sh/16	NONARI	7.8	1221	783	618	19.90	2.00	79.40	102.40	0.90	39.60	407.90	270.00
Sh/17	HARDOLI	8.9	1126	722	305	50.00	11.24	76.00	28.05	2.70	70.12	405.00	188.00
Sh/18	PANWARKHURD	7.7	1248	800	218	20.90	1.10	60.50	29.40	1.40	36.66	490.90	268.01
Sh/19	PANTI	8.2	906	581	271	70.00	11.00	82.10	16.00	1.50	64.00	159.10	365.00
Sh/20	KANTI 61	8.1	663	425	465	20.00	1.20	63.00	75.00	1.60	85.00	250.00	109.00
Sh/21	PARARHA	7.7	1867	1197	802	76.00	3.00	30.00	177.00	0.90	212.00	612.00	178.00
Sh/22	LATIYAR	7.6	1171	751	314	51.40	2.12	76.20	30.05	0.09	72.30	405.00	190.20
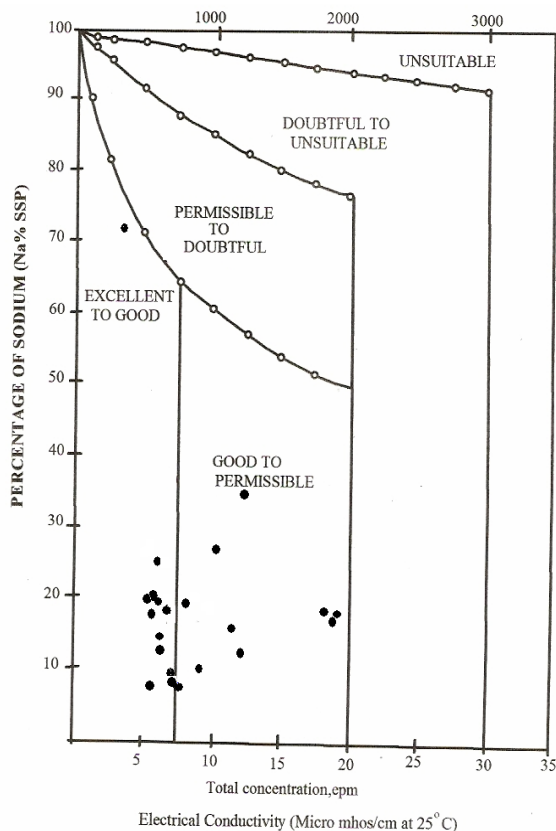
Figure 3. Plot of Sodium percent vs. Electrical conductivity (after Wilcox, 1955)

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 (1984)		ISI (1991)		Concentration in Study Area	Undesirable Effect Produced Beyond Maximum Allowable Limit
		Highest Desirable	Max. Permissible	Highest Desirable	Max. Permissible		
1.	pH	7.0 to 8.5	6.5 to 9.2	6.5 to 8.5	No relaxation	7.4 to 8.9	Taste, effects mucus memberane and water supply system.
2.	TH mg/l	100	500	300	600	100 to 802	Encrustation in water supply and adverse effect on domestic use.
3.	TDS mg/l	500	1500	500	1000	321 to 1197	Gastrointestinal irritation.
4.	Ca mg/l	75	200	75	200	15 to 109	Encrustation in water supply, scale formation.
5.	Mg mg/l	30	150	30	100	11.5 to 177	Encrustation in water supply and adverse effect on domestic use.
6.	Na mg/l	-	200	-	200	5 to 104	--
7.	Cl mg/l	200	600	250	1000	20.2 to 212	Salty Taste
8.	SO$_4$ mg/l	200	400	150	400	4.5 to 612	Laxative effect
9.	F mg/l	0.6 to0.9	0.8 to1.7	1.00	1.5	0.01 to 2.70	Excessive fluoride causes skeletal and dental fluorosis in both children and adult

4.2 Irrigation Water Quality

In the present study the irrigation water quality has been evaluated on the basis of following criteria:

Sodium Percentage (Na%)

It is an important parameter to classify the groundwater samples for irrigation purpose. It is calculated by the formula proposed by Doneen (1962) as under:

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

Sodium along with carbonate forms alkaline soil; while sodium with chloride forms saline soil; both of these are not suitable for the growth of plants (Pandian & Shankar, 2007). The quality classification of irrigation water based on the values of sodium percentage as proposed by Wilcox (1955) suggest that 55% samples are excellent to good category whereas 45% samples are good to permissible category.

4.2.1 Electrical Conductivity (EC)

It measures the capacity of substance or solution to conduct electric current. The EC of groundwater increases with the rise in temperature and varies with the amount of TDS. The conductivity in the groundwater samples of the area ranges from 472 to 1867 μs/cm at 25^0C indicating good category of irrigation water.

4.2.2 Sodium Adsorption Ratio (SAR)

The degree to which the irrigation water tends to enter into cation exchange reaction in soil can be indicated by the sodium adsorption ratio (U.S. Salinity, 1954). Since sodium replaces adsorbed calcium and magnesium in soil, hence it is expressed as:

$$SAR = \frac{Na^+}{\sqrt{Ca^{++} + Mg^{++}/2}} (epm)$$

Excess sodium in groundwater gets adsorbed on soil particles, thus change soil properties and also reduce soil permeability (Ayers & Bronson, 1975). U.S. Salinity Laboratory (1954) proposed to plot SAR against EC for rating irrigation water. The sixteen classes in the diagram indicate the extent that the waters can effect the soil in terms of salinity hazard. These classes are: low salinity (C_1), medium (C_2), high (C_3) and very high salinity (C_4) and similarly sodium hazard as low (S_1), medium (S_2), high (S_3) and very high (S_4). The groundwater samples of the study area fall in C_3S_1 (8 samples) and C_2S_1 (14 samples) categories, hence suitable for irrigation purpose and indicate that most of the groundwater samples of the study area are medium to high saline and low sodium hazard zone. Hence high salinity water should be used only in those soils where adequate drainage is available to leach out the excessive water.

As per classification of Wilcox (1955), water with SAR ≤10 is considered as an excellent quality, between 10 to 18 is good; between 18 to 26 is fair and greater than 26 is said to be unsuitable for irrigation purpose in its natural form. As evident from Table 3, all groundwater samples possess ≤10 SAR; hence excellent for irrigation purpose.

4.2.3 Kelley's Ratio (KR)

It is the ratio of sodium ion to calcium and magnesium ion in epm (Kelley, 1951) and expressed as:

$$K.R. = \frac{Na^+}{Ca^{++} + Mg^{++}} (epm)$$

The Kelley's Ratio (KR) have been computed for all groundwater samples of the study area and presented in (Table 3). In the study area KR ranges from 0.06 to 2.28 indicating that water is suitable for irrigation purpose as the value is less than 2.5.

4.2.4 Permeability Index (PI)

The classification of irrigation waters has been attempted on the basis of permeability Index, as suggested by Doneen (1962). It is defined as:

$$P.I. = \frac{Na^+ + \sqrt{HCO_3^-}}{Ca^{++} + Mg^{++} + Na^+} \times 100 \, (epm)$$

The groundwater samples of the study area fall in class-I. As per Doneen chart (Domenico & Schwartz, 1990), the groundwater samples of the study area is of good quality for irrigation (Figure 5). The increased percentage of groundwater samples under class–I is due to dilution subsequent lower values of permeability index.
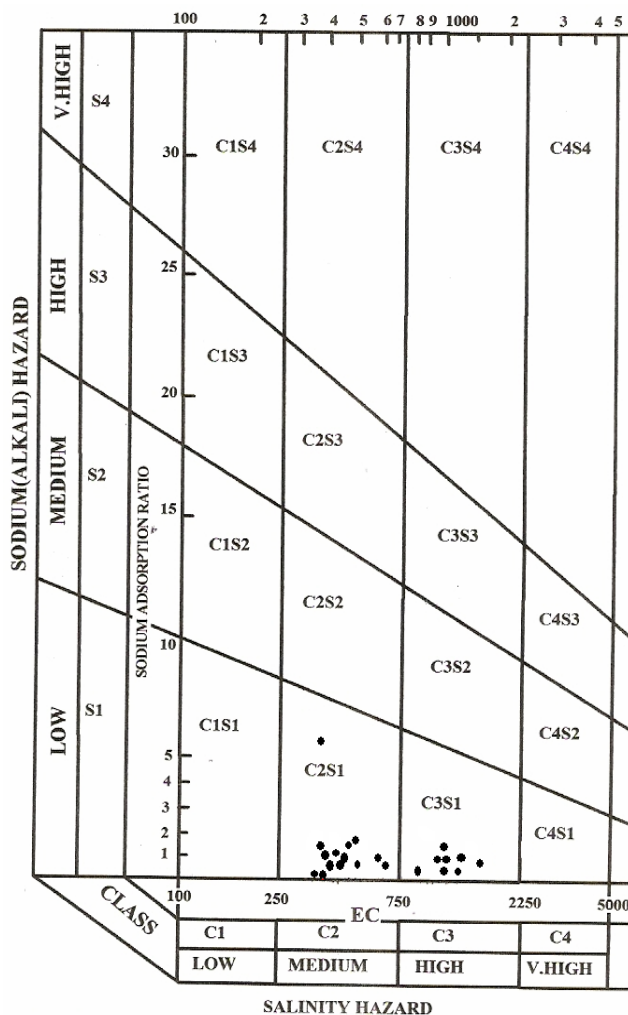

Figure 4. U.S. Salinity Diagram for classification of irrigation groundwater (after Richards, 1954)

Table 3. Ratio and indices of groundwater samples of the study Area

S.No.	No. of Location	SAR	KR	SSP	MR	CR	PI	RSC
1	2	3	4	5	6	7	8	9
1.	DABHAURA	0.90	0.17	17.70	22.33	0.06	42.00	-1.94
2.	GAHILWAR	0.57	0.09	8.82	66.24	0.07	22.59	-7.26
3.	HARHAI	0.93	0.18	18.01	23.39	1.06	42.04	-1.99
4.	MAJHIYARI	0.41	0.09	10.89	16.17	0.02	34.77	-2.92
5.	KOTWA	0.24	0.06	13.72	62.24	0.02	57.64	0.35
6.	KANCHANPUR	6.59	2.28	71.06	62.24	0.03	93.05	0.34
7.	DEOPUJA	1.24	0.23	19.55	34.12	0.05	24.91	-4.87

								
8.	AKAURIYA	0.67	0.15	14.56	39.86	0.02	90.93	-1.93
9.	JIRAUHA	1.11	0.22	18.86	32.65	0.03	39.44	-3.59
10.	KOTA	1.77	0.36	26.57	37.83	1.06	47.07	-3.15
11.	SUHAWAL	1.16	0.23	19.63	30.82	0.03	40.32	-3.50
12.	PANWARKALA	1.44	0.23	19.37	49.49	0.04	33.72	-6.51
13.	KHANDHU	1.82	0.34	25.55	31.89	0.05	41.60	-4.71
14.	UPARWAR	1.58	0.31	24.16	29.73	0.05	42.41	-3.94
15.	KUSHA	1.13	0.21	18.25	38.46	0.04	34.46	-5.01
16.	NONARI	0.49	0.07	6.89	68.01	0.04	22.45	-7.96
17.	HARDOLI	1.77	0.36	28.76	37.83	0.06	47.52	-3.02
18.	PANWARKHURD	0.78	0.17	14.70	44.48	0.03	47.32	-1.04
19.	PANTI	2.62	0.56	38.06	24.32	0.05	64.88	0.57
20.	KANTI 61	0.57	0.09	8.82	66.24	0.07	21.72	-7.51
21.	PARARHA	1.65	0.21	17.37	90.70	0.17	25.87	-13.17
22.	LATIYAR	1.79	0.36	26.74	39.40	1.06	47.07	-3.16
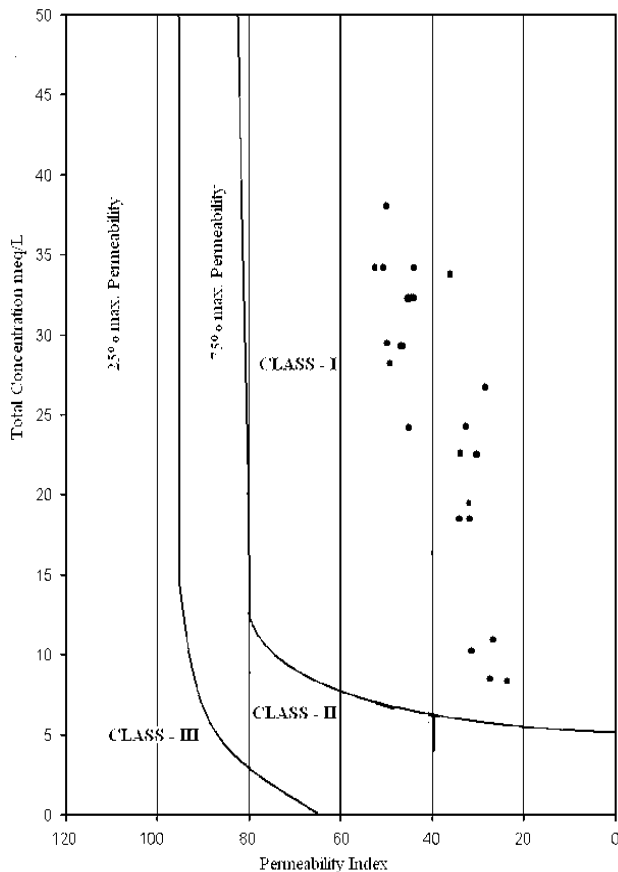
Figure 5. Classification of irrigation water (Doneen, 1962)

4.2.5 Magnesium Ratio (MR)

It is expressed as:

$$M.R.. = \frac{Mg^+}{Ca^{++} + Mg^{++}} \times 100(epm)$$

If the Magnesium Ratio is greater than 50%; it is considered as suitable for irrigation purpose (Palliwal, 1972). In the present study 70% samples are good for irrigation whereas 30% samples are unsuitable (Table 3).

4.2.6 Residual Sodium Carbonate (RSC)

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

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

The RSC values >1.25 mg/l are considered as safe for irrigation while those from 1.25 mg/l to 2.5 mg/l are marginally suitable for irrigation. If RSC values are > 2.5, the groundwater is unsuitable for irrigation (Eaton, 1950; Richards, 1954). The RSC values of groundwater samples of the study area ranges from -13.17 mg/l (Pararha) to +0.57 mg/l (Panti); hence suitable for irrigation purpose.

4.2.7 Corrosivity Ratio (CR)

It is defined as alkaline earth and alkalies and expressed as:

$$C.R. = \frac{Cl^-/35.5 + 2\left(\dfrac{SO_4^{--}}{96}\right)}{2\left(\dfrac{HCO_3^- + CO_3^{--}}{100}\right)}$$

The groundwater with corrosivity ratio < 1 is considered to be safe for transport of water in any type of pipes, whereas >1 indicate corrosive nature and hence not to be transported through metal pipes (Ryner, 1944, Raman, 1985). The calculated values of groundwater samples of the study are presented in Table-1.3, which suggests that 19 samples are safe whereas 3 samples are corrosive in nature and need non-corrosive pipe for transporting and lifting of groundwater.

4.3 Pollution Susceptibility

For the estimation of pollution susceptibility, DRASTIC modelling proposed by Aller et al. (1987) has beed adopted. The DRASTIC approach takes into account seven hydrogeologic parameters which influence pollution of the area. The index of vulnerability is computed through multiplication of the value attributed to each parameter by its relative weight and adding up all seven products (Table 4).

$$DRASTIC\ INDEX = 5 \times D + 4 \times R + 3 \times A + 2 \times S + 1 \times T + 5 \times 1 + 3 \times C$$

Table 4. DRASTIC INDEX (pollution potential) of the study area

S.N.	Location Weightage	Depth to water table 5	Recharge 4	Aquifer Media 3	Soil Media 2	Topography 1	Impact of vadose zone 5	Hydraulic conductivity 3	Total Drastic Number
1.	DABHAURA	9x5=45	9x4=36	8x3=24	7x2=14	9x1=9	8x5=40	8x3=24	192
2.	GAHILWAR	8x5=40	6x4=24	6x3=18	6x2=12	10x1=10	3x5=15	6x3=18	137
3.	HARHAI	5x5=25	3x4=12	7x3=21	8x2=16	10x1=10	5x5=25	5x3=15	124
4.	MAJHIYARI	8x5=40	5x4=20	5x3=15	5x2=10	10x1=10	3x5=15	6x3=18	128
5.	KOTWA	6x5=30	3x4=12	6x3=18	8x2=16	10x1=10	6x5=30	6x3=18	134
6.	KANCHANPUR	8x5=40	7x4=28	8x3=24	7x2=14	10x1=10	6x5=30	8x3=24	170
7.	DEOPUJA	6x5=30	7x4=24	9x3=27	10x2=20	9x1=9	6x5=30	7x3=21	140
8.	AKAURIYA	10x5=50	6x4=24	9x3=27	6x2=12	10x1=10	4x5=20	8x3=24	167
9.	JIRAUHA	8x5=40	5x4=20	5x3=15	5x2=10	10x1=10	3x5=15	6x3=18	128
10.	KOTA	6x5=30	3x4=12	6x3=18	8x2=16	10x1=10	6x5=30	6x3=18	134
11.	SUHAWAL	10x5=50	6x4=24	9x3=27	6x2=12	10x1=10	4x5=20	8x3=24	167
12.	PANWARKALA	2x5=10	9x4=36	10x3=30	10x2=20	9x1=9	6x5=30	8x3=24	159
13.	KHANDHU	9x5=45	9x4=36	8x3=24	7x2=14	10x1=10	8x5=40	8x3=24	193
14.	UPARWAR	10x5=50	6x4=24	9x3=27	6x2=12	10x1=10	4x5=20	8x3=24	167
15.	KUSHA	8x5=40	7x4=28	8x3=24	6x2=12	10x1=10	6x5=30	8x3=24	168

16.	NONARI	3x5=15	6x4=24	4x3=27	7x2=14	10x1=10	6x5=30	8x3=24	144
17.	HARDOLI	10x5=50	6x4=24	9x3=27	6x2=12	10x1=10	4x5=20	8x3=24	167
18.	PANWARKHURD	9x5=45	9x4=36	10x3=30	8x2=16	10x1=10	6x5=30	10x3=30	197
19.	PANTI	8x5=40	7x4=28	8x3=24	6x2=12	10x1=10	6x5=30	8x3=24	168
20.	KANTI 61	5x5=25	3x4=12	7x3=21	8x2=16	9x1=9	5x5=25	5x3=15	123
21.	PARARHA	9x5=45	8x4=32	8x3=24	7x2=14	9x1=9	4x5=20	10x3=30	174
22.	LATIYAR	10x5=50	9x4=36	10x3=30	8x2=16	10x1=10	6x5=30	9x3=27	199

If D.I.>199; Very high, Between 160 and 199; High, Between 124 and 197; Intermediate, Lower than 124; Low pollution susceptibility.

The various parameters are discussed below:

In the area, the water table varies between 03 to 10 meters, hence the rating should be between 02 to 08 in sandstone and 08 to 10 in shale and the weight parameter is 05. It indicates the amount of water per unit area of land that penetrates the ground surface and reaches water table. The assigned weight for this parameter is 4. The net recharge in the area as determined by the water table fluctuation method is. The rating for this recharge is 3. The bedding planes, joint planes and fractures developed in sandstones and shale. Primary porosity and permeability are insignificant. The rating may be assigned a value of 2 to 5 in sandstone and 06 to 09 in shale. The ratings for aquifer media depend upon the type of consolidated and unconsolidated medium which serves as an aquifer.

In general, the less the clay shrinks and swells, and the smaller the grain-size, the less the pollution potential. The weight assigned to this grain-size, the less the pollution potential. The weight assigned to this parameter is 2. Thickness and types of soils in the area vary from place to place. There are areas where soil thickness is negligible while in others it goes up to 2 meters. The soil type varies from sandy loam to salty or clayey loam. Hence ratings may be taken as 10, 6, 5 and 4 for computing pollution index. The hilly tracts have slopes greater than 20 for which the rating is 01. However, in most places have slopes varying between 2 to 6 degrees for which the rating may be 10 in sandstone and shale and assigned weight for this parameter is 01.

The material present in this zone either facilitate pollution are helps in its attenuation. It also controls the time and distance taken by the pollutants to reach the zone of saturation. In the area, the vadose zone is mainly composed shales and sandstone. Jointing and fracturing are present in rocks. For this the rating may be 3 for shale and 6 for jointed sandstone and assigned weight is 5.It refers to the ability of the aquifer to transmit water under a given hydraulic gradient. The rate of flow within an aquifer controls the movement of contaminants from one place to another. From the computed values, it is observed that the DRASTIC Index varies between 124 to 192 in sandstone aquifer whereas 123 to 199 in shale aquifer. The values suggest the sandstone aquifer have intermediate pollution susceptibility whereas shale aquifer is highly susceptible to pollution.

5. Conclusion

The result of geochemical analyses of groundwater samples indicate overall alkaline nature of groundwater. The groundwater with pH above maximum desirable limit can affect the mucous membrane. The higher values of electrical conductance in shale aquifer may be due to enough time for reaction between groundwater and impervious shale whereas sandstone aquifer has comparatively lesser amount of EC are due to its hydrological characters. About 90% of samples have TDS less than 1000 mg/l; hence suitable for drinking. As per classification, most of the samples are normal chloride, normal carbonate, normal sulphate and moderate to very hard in nature. The samples plotted on Chadha's diagram indicate that 55% are Ca-Mg-HCO$_3$ type whereas 45% are Ca-Mg-Cl-SO$_4$ type. The concentration of sulphate associate with shale aquifer is high due to gypsum (CaSO$_4$·2H$_2$O) and baryte (BaSO$_4$) nodules present in shale. The source of sodium and potassium ions may be the feldspar and clay minerals associate with aquifers. In few samples, concentration of fluoride is high due to presence of F$^-$ bearing minerals (muscovite, biotite and clay). The deflouridation and ion exchange techniques may be adopted in high fluoride localities. The comparison of analysed data with WHO (1984) and ISI (1991) indicate that groundwater samples of the area are more or less suitable for drinking.

The groundwater samples have also been evaluated for their irrigation quality. The plot of sodium percentage vs electrical conductance of groundwater samples of the study area suggest that 55% samples are excellent to good category whereas 45% samples are in good to permissible category. The samples plotted in U.S. salinity diagram suggest medium to high saline and low alkaline nature. The water having high salinity should be used only in

those soils where adequate drainage is available. The calculated values of corrosivity ratio suggest that 84% samples are safe whereas 16% samples are corrosive in nature and need non-corrosive pipe for transporting and lifting of groundwater. The other parameters such as Kelley's Ratio, Residual sodium carbonate, Magnesium Ratio, Permeability Index suggest that groundwater of the study area are suitable for irrigation purpose.

The computed Drastic Index (Index of Vulnerability) varies between 124 to 192 in sandstone aquifer whereas 123to 199 in shale aquifer. The values suggest the sandstone aquifer have intermediate pollution susceptibility whereas shale aquifer is highly susceptible to pollution. In the high pollution susceptibility zone, the dug well need to have properly constructed which will present waste water from percolating into the well. The use of pesticides and insecticides in agriculture sector should be avoided. Besides these, proper attention and water quality monitoring programme is needed to check the groundwater pollution.

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