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Full Length Research Paper

Groundwater quality and pollution potential studies around Baikunthpur Area, Rewa District, Madhya Pradesh, India

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Hydrogeochemical investigations were carried out in Baikunthpur Area Rewa District Madhya Pradesh. In the study area, Rewa shale and Rewa sandstone of Vindhyan Supergroup are exposed. The groundwater samples were collected from 30 locations during post monsoon season of 2010 and analysed for major cations and anions. The study reveals that groundwater of the area is generally moderately hard to very hard, normal chloride, normal to higher sulphate and normal bicarbonate type. As per Chadha's scheme, the main hydrochemical facies are Ca-Mg-HCO_3 and Ca-Mg-SO_4-Cl types. The concentration of sulphate was higher due to gypsum bonds associated with Shale formation. Nearly on third of the samples have nitrate concentration beyond the permissible limit of 45 mg/L. In few samples concentration of fluoride exceeds the permissible limit of 1.5 mg/L due to the presence of fluoride bearing minerals associated with aquifers. Most of the physico-chemical parameters were within permissible limits of WHO and ISI for drinking purpose. For computation of Pollution potential, DRASTIC modeling has been adopted. The DRASTIC Index ranges from 124 to 203 suggest intermediate to high pollution susceptibility. In the high pollution susceptibility zone, water quality monitoring programme is suggested.

Key words: Groundwater quality, DRASTIC INDEX, Baikunthpur, Rewa Madhya Pradesh.

INTRODUCTION

Water is highly indispensable to life on the planet Earth as well as all human. Surface water becomes deficient due to vagaries of monsoon, improper management, faulty conservation procedure, pollution and growing population. Therefore the importance of groundwater in various fields like domestic, industrial and requirement needs no emphasis. The quality of groundwater is largely controlled by discharge-recharge pattern, nature of host and associated rocks as well as contaminated activities (Raghunath, 1987). The quality of groundwater is of considerable importance in addition to its quantity for the management of groundwater resource (Ackah et al., 2011). The study on groundwater quality of Vindhyan region has been carried out by few researchers (Tiwari et al., 2010; Mishra, 2010; Tiwari, 2011). Realizing the importance of groundwater quality delineation, the present work has been undertaken around Baikunthpur area of Rewa district, Madhya Pradesh (Figure 1).

The study area is drained by Beehar River and its tributaries and bounded by latitude 24°40' to 24°55' N and longitude 81° 15' to 81°30' 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 540 mm. The temperature in summer months goes up to 45°C while as low as 3°C during peak winter month. The relative humidity is of about 75% in monsoon season.

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

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Figure 1. Location map of the study area.

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 and 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 (Tiwari et al., 2010). The groundwater occurs in both semi confined and confined conditions.

MATERIALS AND METHODS

The present study is based on 30 groundwater samples which have been collected from Dugwell, Dug cum bore well during Post monsoon season 2010. The physico-chemical analysis was performed following standard methods (Ramteke and 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, nitrate and fluoride were determined in the laboratory.

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

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.

Classification standard based on TDS

Wilcox, (1955), classified groundwater on the basis of concentration of TDS showing quality standards and limits as given below:

(i) desirable for drinking (<= 500 mg/L)
(ii) permissible for drinking (500 - 1000 mg/L)
(iii) useful for irrigation (500 - 1000 mg/L)
(iv) unfit for drinking and irrigation (> 3000 mg/L).

Based on the above classification, about 90% of the samples of the are within the desirable and permissible limits for drinking purpose.

Classification standard based on SO_4^{-2} concentration

The maximum sulphate concentration in the water samples is 490.90 mg/L (sandstone) while the concentration in shale formation is 868.04mg/l with average 244.21 mg/L (Table 1). This suggests that 66% of the water sample belong to the "normal sulphate" category.

Classification standard based on Cl^- concentration

Based on this classification, the groundwater of the area has maximum concentration of chloride is 30.70 mg/L in sandstone and 99.25 (average 57.63 mg/L) in shale indicates that the groundwater is "normal chloride" water.

Classification standard based on hardness

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

TH as $CaCO_3$ in mg/L = (Ca + Mg) mg/L × 50

The minimum total hardness concentration in groundwater in the study area is 217 mg/L (Kantangi) and the maximum concentration 998 mg/L (Barahatha) with (average value of 427.70 mg/L). According to classification based on hardness scale by USGS (Hem, 1985) the groundwater of the area is moderately hard to very hard.

Classification standard based on HCO_3^- concentration

The minimum HCO_3^- concentration in groundwater in the study area is 108.20 mg/L (Piparaha) while the maximum concentration is 378.20 mg/L (Indaraha Tola). Thus, most of the groundwater samples belong to the normal carbonate category.

Hydrochemical facies

The analyzed data has been plotted on Chadha's (1999) diagram. It 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 alkaline (Sodium + Potassium) expressed as percentage reacting value is plotted on the X-axis and difference in milliequivalent (epm) percentage between weak acid anion (Carbonate + Nitrate) 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 (Figure 2).

In the study area; out of 30 groundwater samples,11 sandstone samples and 8 shale samples fall in the subfield -5 of Ca-Mg-HCO_3 type whereas 2 sandstone samples and 9 shale samples fall in the subfield 6 indicating Ca-Mg-Cl-SO_4 type.

RESULTS AND DISCUSSION

The major anions and cations presents in the groundwater samples of the area given in Table 2. The pH is an important measures of water quality and it represents the chemical nature of water. The pH values vary from 7.5 to 8.5 (average, 8.03), which indicates alkaline nature. The electrical conductivity of groundwater sample of the study area varies from 448 µS/cm (Surwar) to 132 µS/cm (Katangee) in sandstone and 577 µS/cm (Mateema) to 2296 µS/cm (Indaraha Tola) 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 313 mg/L (Surwar) to 849 mg/L (Kantagee) in sandstone whereas in shale from 414 mg/L (Raura) to 1472 mg/l (Indarha Tola).The water with TDS up to 1000 mg/L is considered to be suitable for drinking (Pophare and Dewalkar, 2007). The higher amount of TDS may cause gastrointeqtional irritation in human body.

Calcium and magnesium along with their carbonates, sulphates and chlorides, make the water hard both temporarily and permanent. The total hardness varies between 217 mg/L (Kantgee; moderately hard) to 508 mg/L (Look; very hard) in sandstone while in the shale the total hardness varies between 284 mg/L (Rupauli; hard) to 998 mg/L (Barhatha; very hard). The possibility

Table 1. Geochemical analyses of groundwater samples of the study area (Except pH and EC, all values are in mg/L).

Lithology 1	Location 2	pH	EC (µS/cm)	TDS	TH	Na	K	Ca	Mg	F	Cl	SO_4	NO_3	HCO_3
SSt./1	KARARIYA	8.1	842	540	371	19.10	15.90	30.60	28.60	1.06	56.10	117.80	99	243.00
SSt./2	KHAIRHAN	8.0	763	489	267	23.20	7.40	68.80	18.80	0.40	45.90	167.20	80	121.60
SSt./3	PALHAN	7.8	568	364	347	37.90	3.50	92.80	22.80	1.00	52.13	11.5	46	133.00
SSt./4	SURWAR	7.5	488	313	241	17.10	3.01	57.10	47.60	0.52	30.70	18.80	50	180.00
SSt./5	RAJGARD	7.7	565	362	323	33.10	3.08	86.20	23.30	1.61	41.10	19.90	28	166.10
SSt./6	KYOTI	7.6	671	430	371	51.10	2.10	96.10	57.11	0.35	56.20	21.80	23	182.10
SSt./7	DADAR	8.1	658	422	388	56.10	2.12	99.20	28.18	0.42	60.10	22.40	9	156.20
SSt./8	MALA	8.0	640	410	367	47.15	3.20	94.30	24.20	0.20	66.20	20.20	10	168.30
SSt./9	PIPARAHA	8.2	534	342	341	36.40	3.65	92.10	26.30	0.45	62.10	20.20	45	108.20
SSt./10	HATWA	7.6	560	359	348	35.10	4.15	90.20	34.20	0.54	49.20	20.20	32	140.40
SSt./11	GOHTA	7.8	895	574	305	78.10	2.40	73.22	29.70	1.80	43.80	143.01	16	242.20
SSt./12	LOOK	7.7	1159	743	508	25.40	3.10	109.60	26.90	1.10	57.20	203.40	47	400.00
SSt./13	KATANGEE	7.7	1324	849	217	20.90	1.10	60.50	29.40	0.20	36.66	490.90	18	268.01
Sh/14	DELHI	8.3	688	441	406	16.30	2.60	118.10	27.25	0.08	99.25	16.70	40	179.00
Sh/15	KHAIR	8.0	688	441	444	78.40	3.35	92.20	52.10	0.60	57.00	17.20	42	150.10
Sh/16	BAIKUNTHPUR	8.2	1248	800	313	51.40	2.12	76.20	30.05	0.56	72.30	405.00	49	190.20
Sh/17	MATEEMA	8.4	577	370	431	18.09	4.07	77.00	77.00	0.40	56.20	41.40	42	115.19
Sh/18	UMARI	8.2	652	418	423	18.20	5.10	75.90	75.90	1.57	56.19	41.90	35	215.10
Sh/19	DEWAS	8.1	677	434	447	63.20	2.80	110.12	32.12	1.01	86.20	13.10	42	123.40
Sh/20	RAURA	8.0	646	414	426	59.10	3.10	103.10	32.10	0.50	82.40	13.20	6	132.50
Sh/21	DEUKHAR	7.5	1087	697	457	17.50	4.20	140.20	42.10	0.38	21.26	316.60	119	171.97
Sh/22	KONI	8.3	1913	1226	417	99.10	3.25	124.20	30.10	0.52	96.40	702.10	70	176.15
Sh./23	RAULI	8.1	1158	742	672	12.40	9.60	100.11	41.20	0.52	21.26	316.60	16	175.08
Sh./24	RUPULI	8.4	1218	781	284	76.20	2.60	65.15	30.03	1.60	43.90	345.00	72	242.60
Sh./25	BHAUTHA	8.8	1995	1279	301	67.40	3.05	76.60	26.00	1.10	41.80	868.04	85	193.60
Sh./26	ITMA	8.7	1446	927	303	20.01	2.32	80.20	26.00	2.40	46.66	487.92	72	261.80
Sh./27	PATEHARA	7.9	1839	1179	445	96.80	3.10	133.19	102.90	0.43	86.20	615.04	84	179.20
Sh./28	KHARPATA	8.5	1938	1242	845	75.40	3.40	49.90	27.49	2.60	25.40	676.2	28	298.50
Sh./29	BARHATHA	7.8	1735	1112	998	77.90	2.20	144.40	155.60	1.80	82.70	460.90	85	173.96
Sh./30	INDRAHA TOLA	8.0	2296	1472	825	99.10	3.25	126.80	124.00	1.71	96.40	712.10	75	378.20
AVERAGE		8.03	1048.93	672.40	427.70	47.57	3.83	91.47	44.30	0.91	57.63	244.21	48.83	195.52

of groundwater hardness in the area may be due to calcareous cement in sandstone. The content of calcium in sandstone aquifers varies from 30.60 mg/L (Karariya) to 109.60 mg/L (Look) while in shale, the range of concentration varies from 49.40 mg/L (Kharpata) to 144.40 mg/L (Barahatha). The magnesium concentration in water sample from sandstone ranges 18.80 mg/L (Khairahan) to 57.11 mg/L (Kyoti) while in shales,

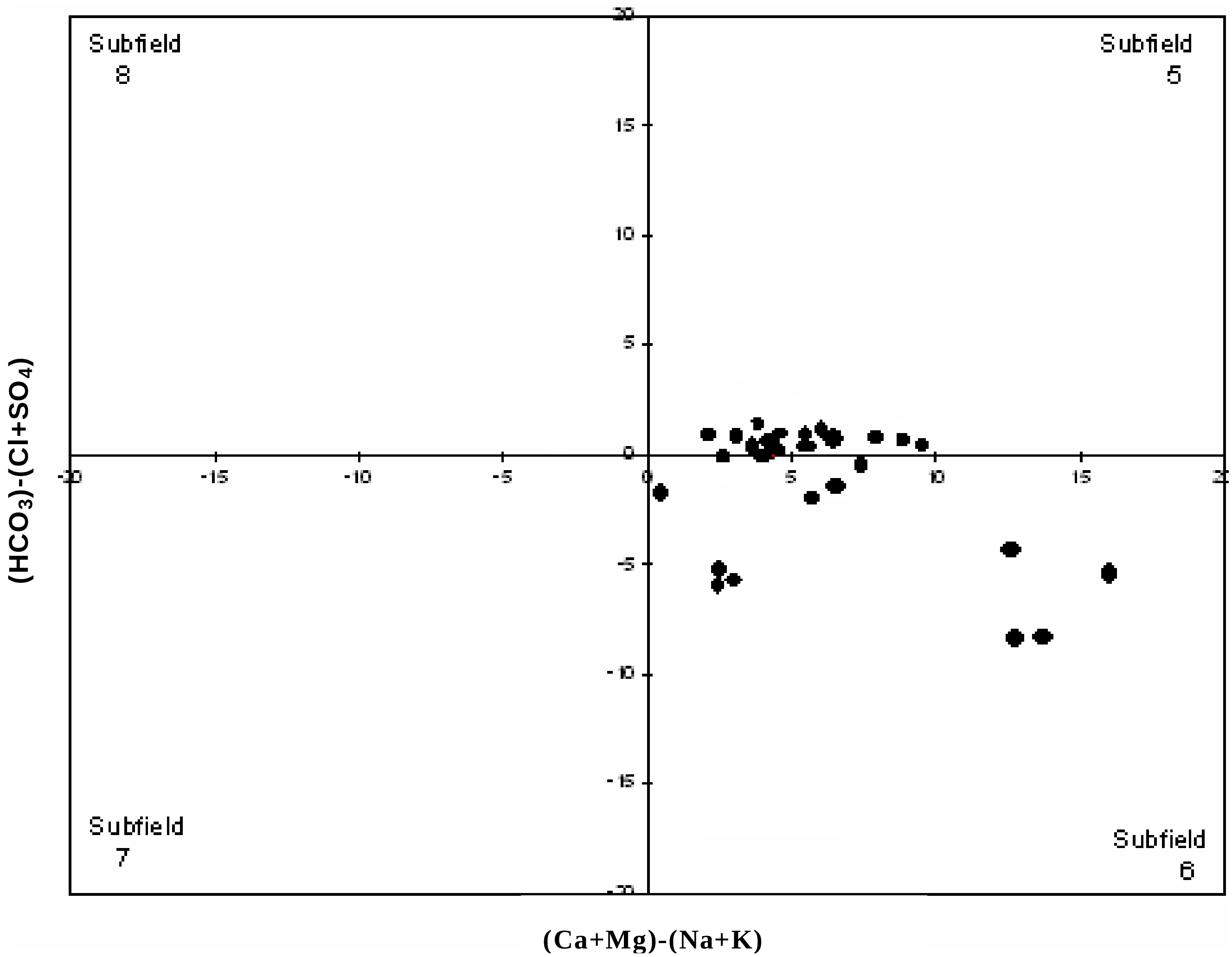

Figure 2. Classification of groundwater samples as per Chadha's (1999) scheme.

the concentration varies 26.00 mg/l (Itma) to 155.60 mg/l (Barahatha). The concentration of sodium ranges from 17.10 mg/L (Surwar) to 78.10 mg/L (Gohata) in sandstone aquifers whereas it varies from 12.40 mg/L (Rauli) to 99.10 mg/L (Koni) in shale lithounit. Similarly, concentration of potassium varies between) 1.10 mg/L (Kantagee) to 15.90 mg/L (Karariya) in sandstone and 2.12 mg/L (Baikunthpur) to 9.60 mg/L (Rauli) 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 11.50 mg/L (Palahan) to 490.90 mg/L (Kantgee) while in the case of water samples from shaly aquifers, the concentration range of sulphate varies from 13.10 mg/L (Devas) to 868.04 mg/L (Indarha Tola). 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 30.70 mg/L (Surwar) to 66.20 mg/L (Mala) while the water samples from aquifer in shale have chloride concentration ranging between 21.26 mg/L (Devkhar) to 99.25 mg/L (Delhi). The water samples from sandstone aquifers have bicarbonate ions ranging between 108.20 mg/L (Piparaha) to 400.00 mg/L (Look) while the shale formation have the range of bicarbonate ions between 115.19 mg/L (Mateema) to 378.20 mg/L (Indarha Tola).

The concentration of nitrate ranges from 9 to 119 mg/L (average, 48.83 mg/L) in the area. The 30% of samples show concentration of nitrate more than the permissible limit of 45 mg/L. Various researchers have related nitrate in groundwater from different sources namely, leakage from septic tank, leaching from animal waste and nitrogen fertilizers (Pawar and Shaikh, 1995; Pacheco et al., 2001, Bhartiya and Agrawal, 2004; Babu et al., 2007). In the present study chemical fertilizers and pesticides seem to be possible source of nitrate because farmers are excessively using them as confirmed from the Table 3. In the study area the wells located in the area under

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

S. No.	Water quality parameter	WHO (1984)		ISI (1991)		Concentration in study area	Undesirable effect produced beyond maximum allowable limit
		Max. desirable	Max. Per missible	Max. desirable	Max. Per missible		
1	pH	7.0 to 8.5	6.5 to 9.2	6.5 to 8.5	No relaxation	7.4 to 8.2 (Sandstone) 7.6 to 8.6 (Shale)	Taste, effects mucus memberane and water supply system.
2	TH (mg/L)	100	500	300	600	96.89 to 444.11 (Sandstone) 284.64 to 998.96 (Shale)	Encrustation in water supply and adverse effect on domestic use.
3	TDS (mg/L)	500	1500	500	1000	248.91 to 800.27 (Sandstone) 328.28 to 1388.57 (Shale)	Gastrointestinal irritation.
4	Ca (mg/L)	75	200	75	200	15.09 to 118.10 (Sandstone) 32.40 to 144.0 (Shale)	Encrustation in water supply, scale formation.
5	Mg (mg/L)	30	150	30	100	2.6 to 57.10 (Sandstone) 12.40 to 176.0 (Shale)	Encrustation in water supply and adverse effect on domestic use.
6	Na (mg/L)	-	200	-	200	5.40 to 104.60 (Sandstone) 12.40 to 99.10 (Shale)	--
7	Cl (mg/L)	200	600	250	1000	27.60 to 99.25 (Sandstone) 5.40 to 210.10 (Shale)	Salty Taste
8	SO_4 (mg/L)	200	400	150	400	8.80 to 499.9 (Sandstone) 13.10 to 864.04 (Shale)	Laxative effect.
9	F (mg/L)	0.6 to0.9	0.8 to1.7	1.00	1.5	0.02 to 1.03 (Sandstone) 0.01 to 2.70 (Shale)	Excessive fluoride causes skeletal and dental fluorosis in both children and adult
10	NO_3 (mg/L)	45mg/L	100	45	100	9 to 99(Sandstone) 6 to 119 (Shale)	Blue baby disease, carcinogenic diseases

double crop have comparatively higher nitrates than those located near the single coop. Since the water is occurring at higher depth, the denitrification process would not be very effective due to longer residence time of infiltrating water in vadose zone and degradation of organic carbon during the longer course of percolation.

The concentration of fluoride ranges from 0.35 to 1.80 in sandstone aquifer whereas 0.08 to 2.60 in shale aquifers. Continuous high intake of fluorid result in mottled teeth, skeletal fluorosis and sometimes severe osteosclerosis. The higher

Table 3. Use of fertilizers for different crop in the area.

S. No.	Crop	fertilizer kg/acre and pesticides liter/acre used			
		Mix Super Urea Pesticides (N:K:P) Phosphate			
		N	K	P	
1.	Wheat	50		50	2 L 2 times
2.	Gram		50		
3.	Pea	50			1 L
4.	Mustard			25	
5.	Jawar	45		25	1 L
6.	Tur	45		50	2 L 2times
7.	Soya bean		75		2-4 L 2-4 times

Source:(Informationscollected from Farmers).

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 fluorite 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 (Saxena and Ahmed, 2001; Madhnure et al., 2007; Chatterjee et al., 2008; Duraiswamy and Patankar, 2011; Zhang et al., 2011). To ascertain the suitability of groundwater for drinking purpose the geochemical parameters of the study area were compared with the guidelines as recommended by WHO (1984) and ISI (1991) (Table 2) which indicate that groundwater of the study area is more or less suitable for drinking purpose.

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.

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

If D.I.>199; Very high, between 160 and 199; High, between 120 and 159; Intermediate, lower than 120; Low pollution susceptibility.

The various parameters are discussed below:

(i) Depth to water table: In the unconfined aquifers of the area, the water table varies between 02 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.

(ii) Net recharge: 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.

(iii) Aquifer media: 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 to7 in sandstone and 08 to 10 in shale. The ratings for aquifer media depend upon the type of consolidated and unconsolidated medium which serves as an aquifer.

(iv) Soil media: 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.

(v) Topography: 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.

(vi) Impact of Vadose Zone: 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.

(vii) Hydraulic conductivity of the aquifer: It refers to the ability of the aquifer to transmit water under a given hydraulic gradient. The rate of flow within an aquifer controls

Table 4. DRASTIC INDEX (Pollution Potential) of the study area.

Lithology	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
SSt./1	KARARIYA	6x5=30	6x4=24	6x3=18	6x2=12	10x1=10	3x5=15	6x3=18	127
SSt./2	KHAIRHAN	5x5=25	3x4=12	7x3=21	8x2=16	10x1=10	5x5=25	5x3=15	124
SSt./3	PALHAN	8x5=40	5x4=20	5x3=15	5x2=10	10x1=10	3x5=15	6x3=18	128
SSt./4	SURWAR	6x5=30	3x4=12	6x3=18	8x2=16	10x1=10	6x5=30	6x3=18	134
SSt./5	RAJGARD	6x5=30	7x4=24	9x3=27	10x2=20	9x1=9	6x5=30	7x3=21	140
SSt./6	KYOTI	8x5=40	5x4=20	5x3=15	5x2=10	10x1=10	3x5=15	6x3=18	128
SSt./7	DADAR	8x5=40	5x4=20	7x3=21	6x2=12	10x1=10	3x5=15	8x3=24	142
SSt./8	MALA	8x5=40	6x4=24	6x3=18	6x2=12	10x1=10	3x5=15	6x3=18	137
SSt./9	PIPARAHA	6x5=30	3x4=12	6x3=18	8x2=16	10x1=10	6x5=30	6x3=18	134
SSt./10	HATWA	8x5=40	5x4=20	7x3=21	6x2=12	10x1=10	3x5=15	8x3=24	142
SSt./11	GOHTA	6x5=30	6x4=24	7x3=21	9x2=18	9x1=9	5x5=25	8x3=24	151
SSt./12	LOOK	8x5=40	5x4=20	5x3=15	5x2=10	10x1=10	3x5=15	6x3=18	128
SSt./13	KATANGI	6x5=30	6x4=24	7x3=21	9x2=18	10x1=10	5x5=25	8x3=24	152
Sh./14	DELHI	8x5=40	6x4=24	6x3=18	6x2=12	10x1=10	3x5=15	6x3=18	137
Sh./15	KHAIR	6x5=30	6x4=24	7x3=21	9x2=18	10x1=10	5x5=25	8x3=24	152
Sh./16	BAIKUNTHPUR	5x5=25	3x4=12	7x3=21	8x2=16	10x1=10	5x5=25	5x3=15	124
Sh./17	MATEEMA	10x5=50	6x4=24	9x3=27	6x2=12	10x1=10	4x5=20	8x3=24	167
Sh./18	UMARI	8x5=40	7x4=28	8x3=24	6x2=12	10x1=10	6x5=30	8x3=24	168
Sh./19	DEWAS	9x5=45	9x4=36	8x3=24	7x2=14	10x1=10	8x5=40	8x3=24	193
Sh./20	RAURA	10x5=50	6x4=24	9x3=27	6x2=12	10x1=10	4x5=20	8x3=24	167
Sh./21	DEUKHAR	7x5=35	7x4=28	8x3=24	6x2=12	10x1=10	6x5=30	8x3=24	163
Sh./22	KONI	9x5=45	9x4=36	8x3=24	7x2=14	10x1=10	8x5=40	8x3=24	193
Sh./23	RAULI	10x5=50	6x4=24	9x3=27	6x2=12	10x1=10	4x5=20	8x3=24	167
Sh./24	RUPULI	9x5=45	9x4=36	10x3=30	8x2=16	10x1=10	6x5=30	10x3=30	197
Sh./25	BHAUTHA	8x5=40	7x4=28	8x3=24	6x2=12	10x1=10	6x5=30	8x3=24	168
Sh./26	ITMA	10x5=50	6x4=24	9x3=27	6x2=12	10x1=10	4x5=20	8x3=24	167
Sh./27	PATEHARA	9x5=45	9x4=36	10x3=30	7x2=14	10x1=10	8x5=40	8x3=24	199
Sh./28	KHARPATA	9x5=45	9x4=36	10x3=30	8x2=16	10x1=10	6x5=30	10x3=30	197
Sh./29	BARHATHA	8x5=40	9x4=36	10x3=30	9x2=18	10x1=10	9x5=45	8x3=24	203
Sh./30	INDRAHA TOLA	9x5=45	9x4=36	8x3=24	7x2=14	10x1=10	8x5=40	8x3=24	193

the movement of contaminants from one place to another.

From the computed values, it is observed that the DRASTIC Index varies between 124 to 152 in sandstone aquifer whereas 124 to 203 in shale aquifer (Table 4). The values suggest the sandstone aquifer have intermediate pollution susceptibility whereas shale aquifer is highly susceptible to pollution.

Conclusion

The result of geochemical analyses of groundwater samples indicate overall alkaline nature of groundwater. The higher values of electrical conductance in shale aquifer may be due to enough time for recetion between groundwater and impervious shale whereas sandstone aquifer has comparatively lesser amount of EC are due to its hydrological characters. As per classification, most of the samples are normal chloride, normal carbonate, normal to high sulphate and moderate to very hard in nature. The samples plotted on Chadha's diagram indicate that 60% are Ca-Mg-HCO_3 type whereas 40% are Ca-Mg-Cl-SO_4 type. A most of the sample exceed the desirable limit of total dissolved solids may cause gasterointestinal problem. The concentration of sulphate associated with shale aquifer is high due to gypsum ($CaSO_4.2H_2$) and baryte ($BaSO_4$) nodules present in shale.

The source of high nitrates in groundwater seem to be nitrogen rich fertilizer and pesticides used by the farmers in their crops. Denitrification process may be ineffective due to deeper aquifers in the study area, so by involving agriculture experts and NGOs and creating awareness among farmers about the optimum use of chemical fertilizers as well as maximum use of biofertilizers the problem can be minimised. The higher concentration of fluoride is due to presence of higher F^{-} bearing minerals. To Combat this problem, defluridation and ion exchange techniques may be of adopted. The analysed data with the standard limits recommended by World Health Organization (1984) and Indian Standard Institute (1991) reveals that the groundwater in general, is suitable for drinking purpose. The computed Drastic Index (Index of Vulnerability) varies between 124 to 152 in sandstone aquifer whereas 124 to 203 in shale aquifer. The values suggest that the sandstone aquifer have intermediate pollution susceptibility whereas shale aquifer is highly susceptible to pollution. In the high pollution susceptibility zone, the unused or dry dug wells should not be used as dumping pits by the nearly habitants and the waste materials should be managed properly. The condition of pollution for the waterwell in use should be checked at regular interval. Besides these, proper attention and water quality monitoring programme is needed to check the groundwater pollution.

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