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Hydrogeochemistry and Groundwater Quality Assessment for Drinking and Irrigation Purpose of Raipur City, Chhattisgarh

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ABSTRACT

Groundwater is an important source of drinking and irrigation purpose and the greater part of the total populace relies on groundwater for survival. Present study investigates the hydrogeochemistry and groundwater quality of the study area for drinking and irrigation purpose. In this study, total 100 numbers groundwater samples were collected and analyzed using standard methods (APHA, 1995) during pre-monsoon period (May, 2016). In the study area, there is occurrence of mainly Ca^{+2}–Mg^{+2}–HCO_3 and Ca^{+2}–Mg^{+2}–SO_4^{-2} water type and the dominant cations and anions are Ca>Mg>Na>K>Fe=HCO_3>Cl>CO_3> SO_4>Fe>F>NH_3. The Gibbs plot shows that, hydrogeochemistry of ground-water is depending upon rock-water interaction. Present study, indicate that groundwater quality in the study area is suitable for irrigation and drinking purpose except some groundwater sample, which are showing high Nitrate, Iron, Sulphate, Ammonia and Calcium concentration.

INTRODUCTION

Ground water pollution is a noteworthy issue in an urban area (Tiwari et al. 2012; Kumar et al. 2015). The usefulness of groundwater to people is based on its quality (WHO,1963; Amadi et al. 1989). Hydrogeochemistry is very important sub-discipline of hydrogeology which depends on climatic, hydrologic, hydro geological and anthropogenic factors (Amadi et al. 1989).

The quality of groundwater, depends on the many factors like lithology, rock water interaction, residence time, sub-surface environment, anthropogenic activity, climatic condition etc. (Freeze and Cherry,1979; Hem, 1989; Freeze and Cherry, 1979; Amadi et al. 1989; Appelo and Postma, 2005; Appelo and Gholam and Azam, 2012). Hydrogeochemical processes like ion exchange, oxidation, reduction, desorption, precipitation and dissolution controls the hydrogeochemistry of groundwater (Gholam and Azam, 2012). The conventional techniques and statistical techniques are generally approved methods to determine the quality of water (Kumar et al. 2015). The main aim of present study was to investigate the hydrogeochemistry and suitability of groundwater for irrigation and drinking purpose of the Raipur city, Chhattisgarh.

The present study has been carried-out in Raipur city which is situated in western part of Raipur district in Chhattisgarh state, India. Study area falls under longitude between 81°35' to 81°40' and latitudes between 21°10' to 21°20' under Survey of India (SOI) toposheet no. 64G/11 and 64G/12 (Fig. 1). It is found that, temperature during April to May sometimes rises above 45 °C in the study area. The annual rainfall of the city is about 1100 mm. Major rock unit of study area are stromatolitic limestone, sandstone, shale and belongs to Chhattisgarh Supergroup of Proterozoic age (Sinha et al. 2002; GSI, 2005).

MATERIAL AND METHODS

In order to effectively carryout present study, systematic methodology adopted is explained as follows.

Collection of Groundwater Sample

Systematic groundwater samples were collected from the study area as per the standard protocol prescribed by APHA-AWWA-WEF (1995) during pre-monsoon periods (May, 2016). The water samples were collected in plastic bottles which are securely corked and sealed with paper and candle wax to prevent oxidations of the water. The locations of different groundwater sample point were collected using global positioning system (GPS) (Fig.1).

Laboratory Analysis of Groundwater Sample and Data Interpretation

Collected samples were analyzed as per the standard protocol given by APHA-AWWA-WEF (1995). Hydrogen ion concentration (pH) and electrical conductivity (EC) were analyzed at site while collecting groundwater sample, whereas ion contents were determined in the laboratory using different techniques such as titration, flame photometer, UV-VIS spectroscopy, atomic absorption spectroscopy (AAS) etc. Statistical analysis has been carried out for the analyzed groundwater quality data (Table 1). The analyzed groundwater quality data were graphically presented and interpreted using AquaChem and Microsoft Excel software.

RESULT AND DISCUSSION

To determine accuracy of analyzed groundwater samples, ion balancing was done in this study. All cations and anions are converted into meq/l for ion balancing and find out that sum value come must be less than 5%. The accuracy of analyzed data is 2.6% which indicates that techniques adopted for groundwater quality analysis was accurate that is why there is a ion balancing between cations and anions.

Multivariate statistical analysis simplifies the huge data set (Fetter 1994; Yidana et al. 2008; Wang et al. 2016). The statistical analysis of the analysed groundwater quality data is givn in Table 1. The correlation matrix was also determined to understand the relationship between two variables (Barzegar et al. 2016; Raju et al. 2016). The correlation matrix of 17 parameters, for 100 water samples is presented in Table 2. There were few significant relationships observed among the measured concentrations. A high correlation observed between EC and TDS (.99). A moderate correlation observed between Ca and EC (.49), Ca and TDS (.5), Na and EC (.49), Cl and EC (.59), Cl and TDS (.59), SO_4 and EC (.43) and SO_4 and TDS (.44) and between K and Mg (.38), low correlation observed between Cl and Na (.38), SO_4 and Ca (.39), HCO_3 and TDS (.35). However, for most ions no significant correlation was found between them. High correlation between EC and TDS reflects the interdependency of the two parameters.

Water Types

To assess the hydrogeochemistry of groundwater, Pipers (1944), Stiff (1951), Schoeller (1962) and Gibb's (1970) diagram were used. The geochemical evolution of groundwater can be understood by Piper

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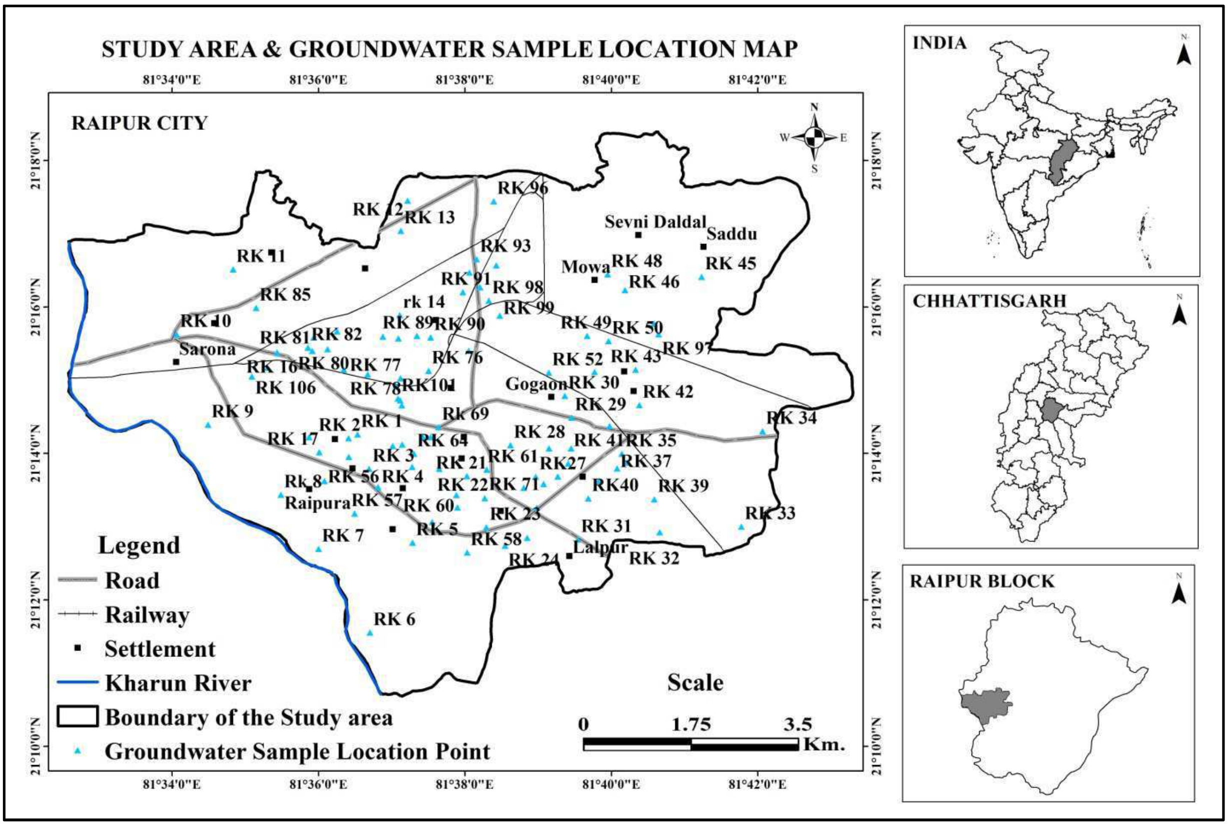

Fig. 1. Location and groundwater samples location map of the study area.

diagram (Wasim et al. 2014; Kumar et al. 2015). Piper and Schoeller diagram were plotted using AquaChem software whereas Gibb's and scatter diagram were plotted using Microsoft Excel.

Piper Diagram

Piper diagram includes three fields i.e. two triangular fields and a one diamond-shaped field. The cations and anion expressed in percentage of meq/l on the left and right (Piper, 1944; Kumar et al. 2015). After plotting points of cations and anions are extend to upper field and where these points intersect indicates the water type with respect to Na^+, K^+, Ca^{2+}, Mg^{2+}, CO_3^-, HCO_3^-, Cl^- and SO_4^{2-} ions. The water type in the study area is mainly of $Ca^{+2} - Mg^{+2} - HCO_3$ type and $Ca^{+2} - Mg^{+2} - SO_4^{2-}$ as per Piper diagram (Fig. 2) in which Ca^{+2} and Na^+/K^+ cations and HCO_3^- and Cl^- are dominant anions in groundwater.

Table 1. Statistical Analysis of the analyzed groundwater quality data

	Min.	Max.	Avg.	Mode	Median	Std. Dev.	Skew-ness	Kurtosis
pH	6.00	9.60	7.30	7.40	7.40	0.45	0.70	5.20
EC	420.00	1661.00	987.11	754.00	964.00	237.26	0.39	0.10
TDS	268.80	1063.04	632.96	482.56	620.16	151.8801	0.374	0.089
Alk	50.00	401.00	222.79	220.00	220.00	69.79	-0.3447	-0.07024
H	30.00	584.30	250.18	330.00	260.00	94.51	-0.024	0.82
Ca	12.50	204.10	87.84	98.50	86.20	40.63	0.95	0.77
Mg	0.30	65.20	27.20	25.30	25.30	14.87	0.53	-0.17
Na	12.00	237.00	76.32	28.70	56.80	54.52	1.18	0.47
K	0.23	80.23	10.06	0.91	2.80	13.45	2.28	7.18
Cl	10.00	270.00	108.83	80.00	100.00	60.89	0.58	0.05
Fe	0.001	1.22	0.11	0.01	0.03	0.21	3.28	12.06
F	0.00	1.10	0.14	0.00	0.03	0.24	2.31	5.27
NO_3	5.80	91.82	25.70	20.00	22.12	14.41	2.02	5.57
CO_3	6.60	84.40	36.48	22.8	31.8	19.13	0.98	0.21
HCO_3	18.30	439.20	171.50	229.36	160.50	67.97	0.58	1.55
SO_4	10.74	415.00	98.21	78.64	87.86	61.88	1.66	6.06
NH_3	0.00	1.00	0.19	0.00	0.00	0.33	1.40	0.75

Gibb's Diagram

Gibb's diagram (1970) is very important to understand controlling mechanisms of the groundwater chemistry (Gibb's, 1970). According to Gibb's diagram (1970), atmospheric precipitation, rock weathering and evaporation are the natural mechanisms controlling the chemistry of ions in the groundwater (Srinivas et al. 2014). Gibb's (1970) proposed two plots, (i) TDS versus Cl/ $(Cl+HCO_3)$ and (ii) TDS versus (Na+K)/(Na+K+Ca). In present study, it is observed that maximum samples are falling under the rock dominance region which revealed that the rock-water interaction is the dominant chemical process in

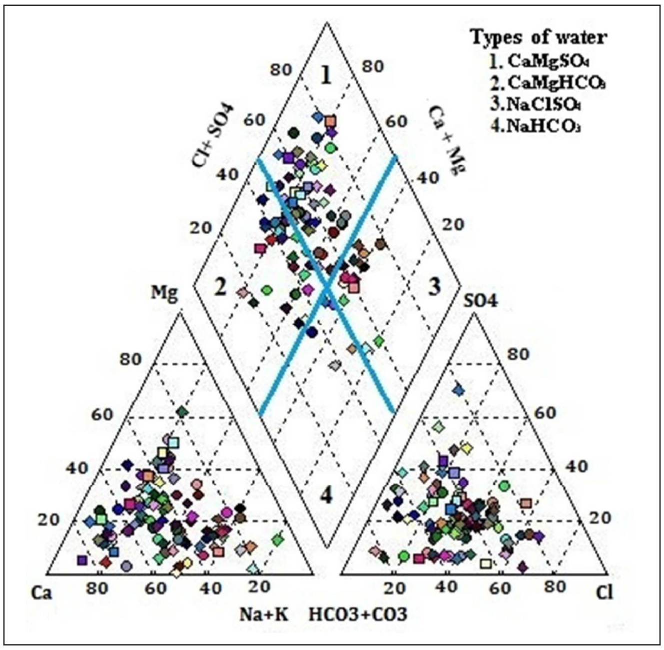

Fig. 2. Piper Diagram.

Table 2. Correlation matrix of the analyzed groundwater quality data

Parameters	pH	EC	TDS	Alk	H	Ca	Mg	Na	K	Cl	Fe	F	NO_3	CO_3	HCO_3	SO_4	NH_3
pH	1																
EC	0.0064	1															
TDS	-0.0005	0.9968	1														
Alk	-0.0865	0.0670	0.0764	1													
H	-0.0460	0.1227	0.1207	0.1967	1												
Ca	-0.0909	0.4916	0.4981	0.1247	0.0812	1											
Mg	0.1218	0.2362	0.2322	0.0101	-0.1236	-0.1125	1										
Na	0.0474	0.4905	0.4810	0.0278	0.1903	-0.1373	-0.2766	1									
K	0.0324	0.1549	0.1493	0.0535	-0.0816	0.0485	0.3574	-0.2633	1								
Cl	0.0323	0.5939	0.5860	0.1640	0.1417	0.2714	0.2719	0.3837	0.2127	1							
Fe	0.1011	-0.0118	-0.0152	-0.1125	-0.0660	-0.0205	0.0061	-0.0265	-0.0894	0.0123	1						
F	-0.0650	-0.0088	-0.0139	-0.3084	0.0608	-0.0647	-0.0608	0.1100	0.0092	-0.0018	-0.1015	1					
NO_3	0.0821	0.1515	0.1535	-0.0045	0.1752	0.1443	0.0381	0.0145	-0.0690	0.1070	0.1158	-0.0949	1				
CO_3	0.1608	0.4690	0.4713	-0.0302	0.0996	0.3047	-0.1401	0.4158	-0.1991	0.1294	-0.0418	0.0830	0.0347	1			
HCO_3	-0.2596	0.3522	0.3451	0.0014	0.0370	0.2100	0.1302	0.0792	0.2147	-0.1100	-0.0990	-0.1014	-0.0481	-0.0082	1		
SO_4	0.1644	0.4338	0.4395	0.0625	-0.0390	0.3866	0.0077	0.3191	-0.0650	0.0117	-0.0178	0.0767	-0.0830	0.2750	-0.0678	1	
NH_3	-0.0422	0.2279	0.2352	-0.0495	-0.0098	0.0833	0.0384	0.0888	-0.0778	0.0738	0.0624	0.0749	0.0241	0.2893	-0.0431	0.0793	1

the study area (Fig.3). Rock-water interaction produces different combination of cations and anions in the groundwater (Garrels and Mackenzie, 1967; Srinivas et al. 2014).

Scatter Diagram

Groundwater quality data were plotted in the scatter diagram {(Ca+Mg) vs. (HCO_3+ SO_4)} and found that, ionic concentration is lie above the equiline and some sample along and below the equiline as shown in Fig. 4(a), which indicate source of calcium ion in the groundwater is due to calcareous rock weathering. Whereas the few points below the equiline indicates silicate weathering. Thus, reaction of carbonic acids and calcium carbonate in soil form bicarbonate and calcium ion as shown in equation 1 & 2. Thus, Calcium is the dominant ion found in the groundwater of the study area. Magnesium is found in considerable amount. Calcium ion present in the groundwater might have come from dissolution of $CaCO_3$ (Eq. 1 and Eq. 2).

$$CO_2+H_2O = H_2CO_3 \quad (1)$$
(Formation of carbonic acid)

$$CaCO_3 + H_2CO_3 = Ca + 2HCO_3 \quad (2)$$
(Calcite dissolution)

Anthropogenic activity also influences the groundwater quality such as NO_3 occurs in groundwater mainly due to agricultural activities and improper sewage disposal (Jalali, 2009; Gillardet et al. 1999). Han and Liu (2004) and Jalali (2009) suggested that the high correlation of TDS and (NO_3+ Cl)/HCO_3 reveals the inûuences of anthropogenic activities on water. There is a less positive correlation between TDS and (NO_3+Cl)/HCO_3{Fig.4 (b)}, suggests that there is a little inûuence of anthropogenic activities on the hydrogeochemistry of the study area.

Schoeller Diagram

Schoeller (1962) proposed the use of semi logarithmic graph paper to plot the concentration of anions and cations. The concentrations are plotted in milli equivalent per liter (meq/l). Data are plotted on six equally spaced logarithmic scales in the arrangement. The points plotted are joined by straight line. This type of graph shows not only the absolute value of each ion but also the differences in concentration. Na, Ca, HCO_3 and Mg are the dominant ions in the groundwater as per the Schoeller diagram (Fig.5).

Suitability of groundwater for drinking purpose

To assess the suitability of groundwater for drinking purposes

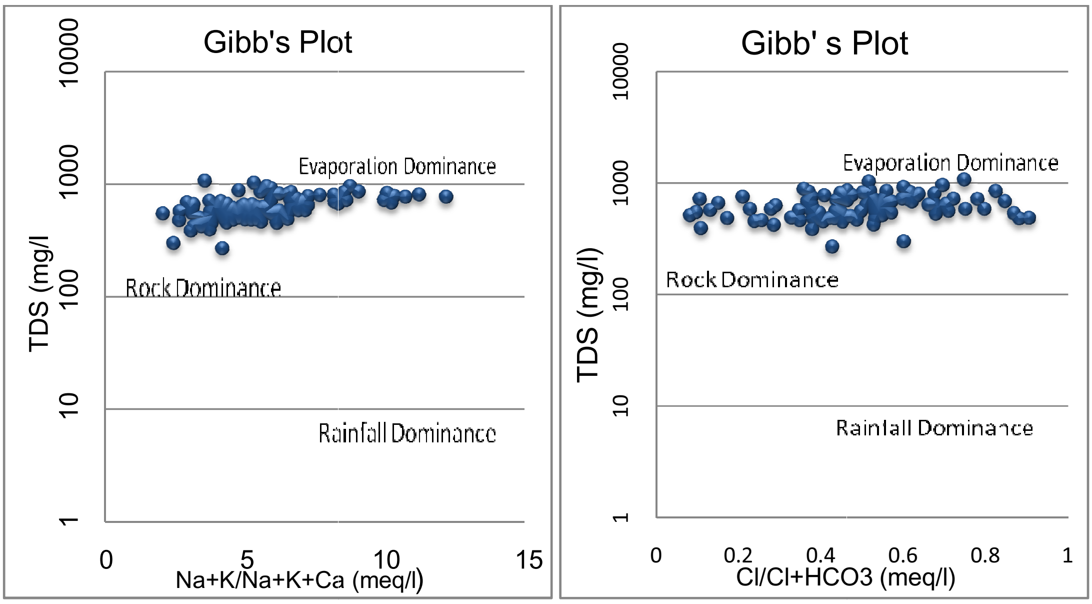

Fig.3. Gibb's Diagram for **(a)** cations and **(b)** anions.

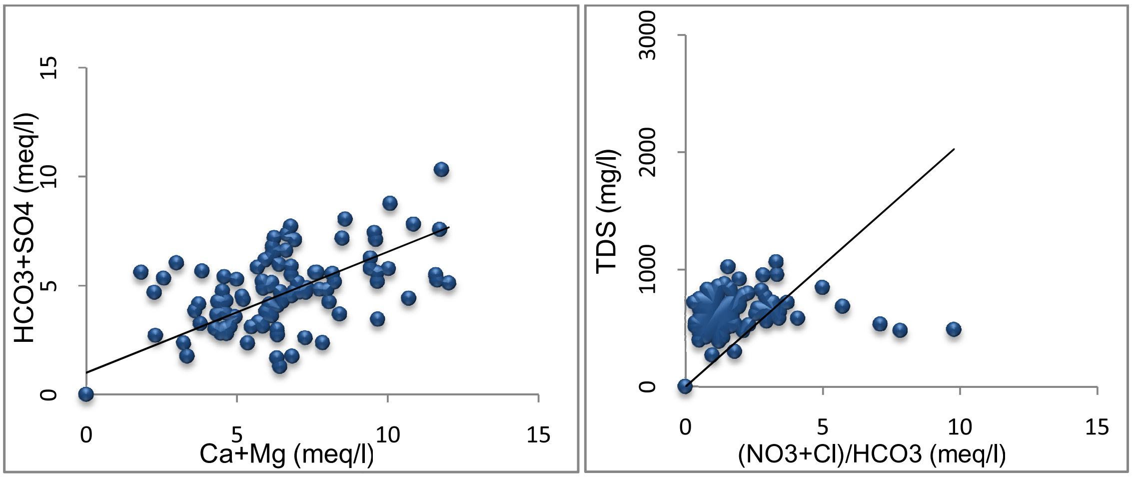

Fig.4. Scatter Diagram **(a)** (Ca+Mg) vs. (HCO_3+ SO_4); **(b)** TDS vs. (NO_3+ Cl)/HCO_3.

a comparison of the analyzed values with the WHO (2003) and BIS (2012) standards which are discussed below.

pH: pH is the concentration of H^+ in the water. More H^+ ions indicate acidic nature of fluid and OH^-ion indicates basic nature of water. Thus, pH is classified from 1 to 14, pH value less than 7 is acidic, 7 is neutral and value more than 7 is basic. pH plays important role in chemistry of groundwater (WHO, 2003; Jalali, 2008). In the study area pH ranges from 6.01 to 8.42 which is within acceptable limit 6.5 – 8.5 (BIS 2012) (Table 3).

Temperature: According to WHO (2003), warm water is not acceptable for drinking purpose. If water temperature is high there is chance of increased growth of microorganisms that leads to undesired taste, odour, colour and dissolution of rock. In the present study, minimum temperature recorded of groundwater sample is 22°C and maximum temperature is 29°C (Table 3).

Total Dissolved Solid (TDS): TDS is the total dissolved solid of inorganic salts and according to the solubility of minerals concentration TDS varies. WHO has not proposed any standard limit for TDS for drinking purpose. BIS (2012) proposed 200 mg/l as acceptable limit whereas 2000 mg/l permissible limit. In the study area, TDS ranges from 268.3 to 1063 mg/l. In study area 79 groundwater samples show TDS value above the acceptable limit (500 mg/l). It is found that all sample are within permissible limit (2000 mg/l) as per BIS (2012) standard (Table 3), thus, groundwater is suitable for drinking purpose.

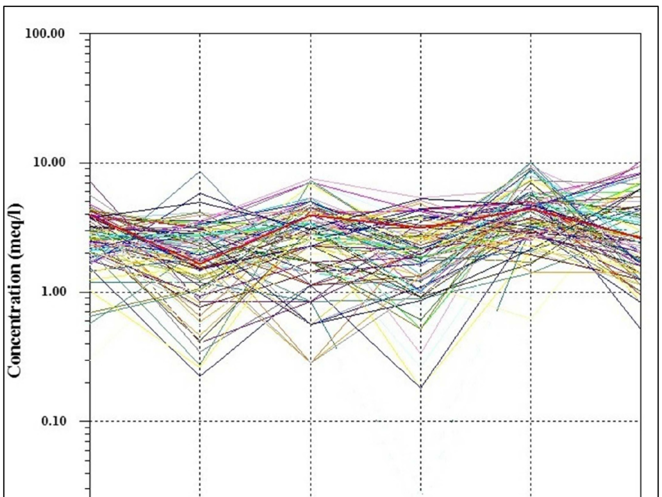

Fig.5. Schoeller Diagram.

Electrical conductivity (EC): Electrical conductivity is an important property to measure ion present in the water. There is strong relationship with TDS and EC, if TDS is high than electrical conductivity will be high. Electrical conductivity in study area is varying from 420 to 1661 µs/cm which is within permissible limits as per the drinking water standard (WHO, 2003 BIS, 2012) (Table 3).

Alkalinity: The alkalinity plays an important role in the characteristics of natural and polluted waters. The alkalinity has property of water to react with solute it contains and neutralize acid. Alkalinity in groundwater is due to the dissolved carbon dioxide species, bicarbonate and carbonate. In study area alkalinity is varying from 50 to 401mg/l which is within permissible limits as per the drinking water standard (WHO, 2003; BIS, 2012) (Table 3).

Sulphate (SO_4): Sulphate occurs naturally in various minerals. The acceptable limit is 200 mg/l and permissible limit is 400 mg/l according to BIS (2012) standard. In the study area, Sulphate concentration is ranging from 10.7 to 415 mg/l. Most of the groundwater samples of study areas are falling under safe limit of sulphate concentration except samples numbers RK 97, RK 28 and RK 50 (Table 3).

Calcium (Ca): In sedimentary rock calcium carbonate also present in the pores fully or partially. In present study area calcium concentration is ranging from 12.5 to 204.5 mg/l. BIS (2012) has given drinking standard limit 5 to 200 mg/l. In study area, 55 groundwater samples have calcium concentration above acceptable limit whereas in 2 groundwater samples have concentration above permissible limit (Table 3). The elevated concentration of calcium is due to rock water interaction in the Limestone terrain.

Magnesium (Mg): Concentration of magnesium in the study area ranges from 0.30 mg/l to 65.20 mg/l. In study area total 39 samples have value above 30 mg/l which is acceptable limit as per BIS (2012) (Table 3).

Sodium (Na): Sodium is very essential ion and it is found in all food and water (WHO, 2003). In study area concentration of sodium ranges from 1.2 to 237 mg/l.

Potassium (K): In groundwater, the amount of potassium is much lower than the amount of sodium, calcium and magnesium (Kumar et al. 2015). In study area potassium concentration ranges from 0.3 to 65.2 mg/l.

Nitrate (NO_3): In Nitrogen cycle, nitrate is naturally occurring

Table 3. Suitability of Groundwater for Drinking purpose

S. No.	Water Quality Parameter	WHO (1985)	BIS Acceptable limit	Permissible limit	No. of Groundwater samples exceeding acceptable limit	No. of Groundwater samples exceed max. permissible limit	Concentration in the study area
1	pH	6.5-9.5	6.5 - 8.5		-	-	6.01 - 8.42
2	EC	-	-		-	-	420 - 1661
3	Alkalinity	-	-		-	-	50 - 401
4	Hardness	NHBVP	200	600	RK 52, RK 43, RK 97, RK 94, RK 15, RK 52, RK 53, RK 30, RK 103, RK 18, RK 55,RK 6, RK 50, RK 45, RK 2, RK 17, RK 18, RK 8, RK 72, RK 87, RK 86, RK 91, RK 12, RK 11, RK 83, RK 16, RK 13, RK 73, RK 74, RK 75, RK 5, RK 7, RK 60, RK 22, RK 21, RK 70, RK 24, RK 58, RK 33, RK 32, RK 36, RK 37, RK 42, RK 41, RK 35, RK 38, RK 68, RK 64, RK 3, RK 1, RK 48, RK 39, RK 31, RK 26, RK 104, RK 78, RK 79, RK 81, RK 85, RK 80, RK 77, RK 14, RK 76, RK 93, RK 99, RK 98, RK 49, RK 65, RK 28, RK 27, RK 71, RK 23, RK 61, RK 82, RK 105, RK 67.	-	30 - 584.3
5	Cl	NHBVP	250	1000	RK 52, RK 96, RK 42, RK 39 and RK 77	-	10 - 270
6	TDS	NHBVP	500	2000	RK 51, RK43. RK97, RK46, RK94, RK92, RK52, RK53, RK30, RK103, RK18, RK8, RK72, RK87, RK86, RK56, RK57, RK26, RK 20, RK88, RK90, RK95, RK12, RK96, RK11, RK83, RK16, RK73, RK75, RK7, RK60, RK22, RK21, RK69, RK70, RK25, RK24, RK58, RK33, RK32, RK36, RK34, RK37, RK41, RK40, RK35, RK38, RK 40A, RK39, RK31, RK26, RK79, RK81, RK85, RK77, RK14, RK100, RK93, RK99, RK49, RK65, RK28, RK71, RK23, RK61, RK29, RK82, RK105, RK10, RK106, RK9, RK 67, RK68, RK64, RK3, RK1, RK48, RK50, RK45.	-	268.8 - 1063
7	Ca	NHBVP	75	200	RK 51, RK 97, RK 46, RK 15, RK 52, RK 30, RK 103, RK 56, RK 57, RK 88, RK 91, RK 95, RK 12, RK 96, RK 11, RK 83, RK 16, RK 73, RK 75, RK 22, RK 69, RK 24, RK 58, RK 32, RK 36, RK 34, RK 42, RK 41, RK 35, RK 38, RK 31, RK 26, RK 78, RK 79, RK 81, RK 77, RK 14, RK 76, RK 100, RK 93, RK 99, RK 98, RK 49, RK 28, RK 71, RK 23, RK 29, RK 82, RK 105, RK 106, RK 67, RK 64, RK 1, RK 50 and RK 45.	RK 68 and RK 87	12.5 - 204.1
8	Mg	NHBVP	30	100	RK 43, RK 97, RK 46, RK 94, RK 92, RK 52, RK 56, RK 57, RK 26, RK 4, RK 20, RK 89, RK 12, RK 96, RK 19, RK 74, RK 22, RK 21, RK 69, RK 25, RK 33, RK 34, RK 37, RK 40, RK 39, RK 31, RK 104, RK 79, RK 85, RK 76, RK 100, RK 93, RK 28, RK 23, RK 61, RK 10, RK 1, RK 6 and RK 50.	-	0.3 - 65.2
9	Na	NHBVP	NHBVP		-	-	1.2 - 237
10	K	NHBVP	NHBVP		-	-	0.23 - 80.23
11	Fe	NHBVP	0.3		RK 3, RK 64, RK 29, RK 99, RK 79, RK 78, RK 20, RK 62 and RK 4	-	0.001 - 1.22
12	F	1.5	1	1.5	RK 63, RK 39 and RK 31	-	0 - 1.1
13	NO_3	50	45		RK 83, RK 74, RK 32, RK 79, RK 81 and RK 85	-	5.8 - 91.82
14	CO_3	-	-		-	-	
15	HCO_3	-	-		-	-	18.3 - 439.2
16	SO_4	200	200	400	RK 97, RK 28	RK 50	10.7 - 415
17	NH_3	-	0	0.5	-	RK 92, RK 30, RK 18, RK 86, RK 56, RK 90, RK 7, RK 22, RK 69, RK 24, RK 58, RK 33, RK 36, RK 39, RK 36, RK 79, RK 85, RK 14, RK 29, RK 10, RK 68 RK 64, RK 45	0-1.0

substance (WHO, 2003). The nitrate concentration is high in groundwater and surface water mainly due to anthropogenic activity. According to WHO (2003) the primary health problem due to high nitrate concentration in groundwater is methemoglobinemia. In the study area, the nitrate concentration is ranges from 5.8 to 91.82 mg/l. In the study area 6 groundwater samples i.e. RK 83, RK 74, RK 32, RK 79, RK 81 and RK 85 have high nitrate concentration which is above the acceptable limit 45 mg/l which is hazardous for health according to BIS (2012) and WHO (2003). In present study, maximum groundwater samples are suitable for drinking purpose except some which are showing high nitrate concentration (>45 mg/l).

Chloride(Cl): According to WHO (2003) Chloride in water comes from natural and anthropogenic sources. Excessive chloride concentrations may increase the metal concentration in the water due to corrosion. The acceptable limit of chloride is 250 mg/l and permissible limit is 1000 mg/l according to BIS (2012). In study area chloride concentration ranges from 10 to 270 mg/l. In the study area 5 groundwater samples (RK 52, RK 96, RK 42, RK 39 and RK 77) showing chloride concentrations value above acceptable limit i.e. 250 mg/l and no one sample exceeding concentration above permissible limit i.e. 1000 mg/l.

Fluoride (F): Fluoride occurs in groundwater as geogenic sources, it is found mainly in the acidic plutonic rock that have fluoride can contribute fluoride in groundwater (WHO, 2003; Jhariya and Dewangan, 2013). Long term ingestion of fluoride can cause adverse effects on skeletal tissues and also influence morbidity (WHO, 2003; Jhariya and Dewangan, 2013). According to WHO and BIS its acceptable limit is 1.0 mg/l and permissible limit is 1.5 mg/l. In the study area fluoride concentration is ranging from 0 to 1.1 mg/l and it is found that only three groundwater samples have fluoride value above acceptable limit (RK 63, RK 39 and RK 31). Thus, groundwater of the study area is safe for drinking purpose as per BIS and WHO guidelines.

Hardness (H): Divalent ions (Ca and Mg) are main cause of hardness in water. If hardness of water is above 200 mg/l than causes scale deposition. The acceptable limit is 200 mg/l and permissible limit is 600 mg/l according to BIS drinking water standard. In the study area, the concentration of hardness is ranging from 30 to 584.3 mg/l. In study area, total 76 numbers groundwater samples have concentration above acceptable limit i.e. 200 mg/l according to BIS guidelines (Table 3). The high hardness in the study area is due to rock-water interaction in the Limestone terrain.

Iron (Fe): Iron is good for health but high concentration may cause unacceptable taste and staining in utensils & clothes. According BIS (2012) drinking water guidelines Fe concentration should not exceed above 0.3 mg/l. In the study area, concentration of iron is ranging from 0.001 to 1.22 mg/l. Total 9 samples have concentration above acceptable limit (0.3 mg/l) as per BIS guidelines which are unsuitable for drinking purpose (Table 3).

Bicarbonate (HCO_3) and Carbonate (CO_3): Alkalinity in water is mainly due to bicarbonate and carbonates ions. These concentration in water is due to the action of carbon dioxide upon basic materials in the soil. The concentration of bicarbonate in study area, is varying from 18.3 to 439.2 mg/l and concentration of carbonate is 6.6 to 84.4 mg/l.

Ammonia (NH_3): Ammonia in water is a good indicator of bacterial, sewage and animal waste pollution. According to BIS guideline the ammonia concentration should be 0.5 mg/l. The concentration of ammonia in study area is varying from 0 to 1 mg/l.

Suitability of groundwater for irrigation purpose

The groundwater quality for irrigation purpose is very important, because it influences both the plant and the soil (Richard, 1954; Todd and Mays, 2013; Singh et al. 2015; Shah and Mistry, 2013; Aref and Roosta, 2016). Higher salt in groundwater causes changes in the permeability of soil, soil structure and aeration (Thorne and Peterson, 1954; Todd and Mays, 2013; Singh et al. 2015). An important factor for good crop growth is drainage, if well drained the crop growth will be good and if poorly drained then crop growth will be poor (Raju et al. 2011; Todd and Mays, 2013; Singh et al. 2015). To assess the suitability of groundwater for irrigation usages, the different irrigational water quality such as sodium absorption ratio (SAR), permeability index (PI), electrical conductivity (EC), total dissolved solid (TDS) and US salinity diagram were computed and interpreted. Irrigation water quality standard which is prescribed by BIS (1988) is given in Table 4.

Electric Conductivity (EC): Electrical conductivity gives information about the dissolved solids in the water. In case of high EC there will be high chances of salinity hazard, which influences the water quality for irrigation purposes (Nag and Das, 2014; Ahamed et al. 2013; Brhane, 2016). According to BIS standard as given in Table 5, only groundwater sample no. RK 58 and RK 39 have EC more than 1500 which are unsuitable for irrigation purpose. Present study indicates that groundwater of the study area is good and permissible (Table 5).

Table 4. Irrigation water quality guidelines according to BIS (1988).

S.no.	Parameter	BIS Standard
1.	pH	6.5-8.5
2.	Chloride	1000
3.	Electrical Conductivity	1500
4.	Total Dissolved Solid	2000
5.	Total Hardness	600
6.	Calcium	200
7.	Magnesium	100
8.	Sodium	200

Table 5. Irrigation water quality on the basis of Electric Conductivity (EC).

S. No.	Parameter	Range	Water class	No. of samples
		<250	Excellent	-
		250-750	Good	RK 55, RK 2, RK 63, RK 4, RK 89, RK 19, RK 74, RK 104, RK 78, RK 76, RK 27, RK 106, RK 66 and RK 48
1.	Electric Conductivity (EC)	750-2000	Permissible	RK 51, RK 43, RK 97, RK 46, RK 44, RK 94, RK 15, RK 92, RK 52, RK 30, RK 103, RK 18, RK 17, RK 8, RK 72, RK 87, RK 86, RK 56, RK 57, RK 20, RK 88, RK 90, RK 91, RK 95, RK 12, RK 96, RK 11, RK 83, RK 16, RK 13, RK 73, RK 75, RK 5, RK 7, RK 60, RK 22, RK 21, RK 69, RK 70, RK 25, RK 24, RK 58, RK 33, RK 32, RK 36, RK 34, RK 37, RK 42, RK 41, RK 35, RK 38, RK 40, RK 39, RK 31, RK 26, RK 79, RK 81, RK 85, RK 80, RK 77, RK 14, RK 100, RK 93, RK 99, RK 98, RK 49, RK 65, RK 28, RK 71, RK 23, RK 61, RK 29, RK 82, RK 105, RK 10, RK 9, RK 67, RK 68, RK 64, RK 3, RK 1, RK 6, RK 50, RK 45 and RK 100.
		2000-3000	Doubtful	-
		>3000	Unsuitable	-

Table 6. Irrigation water quality on the basis of TDS.

S. No.	Parameter	Range	Water class	No. of samples
		<450	Good	RK 55, RK 63, RK 4, RK 89, RK 19, RK 27, RK 106 and RK 66
1.	TDS (mg/l)	450-2000	Permissible	RK 51, RK 43, RK 97, RK 46, RK 44, RK 94, RK 15, RK 92, RK 52, RK 30, RK 103, RK 18, RK 2, RK 17, RK 8, RK 72, RK 87, RK 86, RK 56, RK 57, RK 62, RK 20, RK 88, RK 90, RK 91, RK 95, RK 12, RK 96, RK 11, RK 83, RK 16, RK 13, RK 73, RK 74, RK 75, RK 5, RK 7, RK 60, RK 22, RK 21, RK 69,RK 70, RK 25, RK 24, RK 58, RK 33, RK 32, RK 36, RK 34, RK 37, RK 42, RK 41, RK 35, RK 38, RK 40, RK 39, RK 31, RK 26, RK 104, RK 78, RK 79, RK 81, RK 85, RK 80, RK 77, RK 14, RK 76, RK 100, RK 93, RK 99, RK 98, RK 49, RK 65, RK 28, RK 71, RK 23, RK 61, RK 29, RK 82, RK 105, RK 10, RK 9, RK 67, RK 68, RK 64, RK 3, RK 1, RK 48, RK 6, RK 50, RK 45, RK 100
		>2000	Unsuitable	-

TDS: TDS is very important in terms of irrigational quality of water (Ahamed et al., 2013). Groundwater quality of the study are falling under good and permissible range as per TDS concentration in different groundwater sample (Table 6).

Sodium Absorption Ratio (SAR)

Sodium absorption ratio (SAR) is recommended by the salinity laboratory of the U.S. Department of Agriculture (Todd and Mays, 2013; Nagaraju et al. 2014; Ogunfowokan et al., 2013). SAR indicate sodium absorption by soil particles, may increases with the amount of soluble sodium, this may cause alkali hazard in soil which hinders successful crop production (Islam and Shamshad, 2009; Islam et al. 2013; Shah and Mistry, 2013). Sodium hazard are less where calcium and magnesium ions have high concentration. Higher value of SAR affects the permeability of the soil (Ackah et al., 2011; Singh et al., 2015; Ogunfowokan et al. 2013). SAR is defined by following formula (Eq.3).

$$SAR = \frac{Na}{\sqrt{Ca + Mg}/2} \quad 3$$

If Na concentration is high in water it becomes deflocculated (Singh and Khare, 2008; Ackah et al. 2011; Singh et al. 2015). The sodium adsorption ratio (SAR) is classified into five categories such as, low (<10), medium (S10 to 18), high (18 to 26) and very high (>26) (Rao, 2006; Ackah et al. 2011; Ogunfowokan et al. 2013; Singh et al. 2015; Singh et al. 2016).

In this study, it is found that in the groundwater samples, SAR value ranges from 0.44 - 2.9 and average value is 1.4. Sodium adsorption ratio (SAR) is less than 10 thus can be considered as excellent for irrigation purpose (Table 7).

Permeability index (PI): Permeability index is based on the cation exchange reaction taking place in soil (Nag and Das, 2014; Singh et al., 2013), which is defined by equation number 4. It has been observed that continuous irrigation influences the permeability of the soil (Singh and Khare, 2008; Ahamed et al. 2013). It is inûuenced by Na, Ca, Mg and HCO_3 contents in soil.

$$\text{Permeability index (PI)} = \frac{(Na + \sqrt{HCO3})}{Na + K + Ca + Mg} * 100 \quad 4$$

Where, all ionic concentration is expressed in meq/liter.

In this study it is found that, most of the groundwater samples are falling under class II (25–75 %) and few groundwater samples under Class III (Table 8) indicating that groundwater is suitable for irrigational purpose.

US Salinity Laboratory Diagram: A graphical classification of water which is given by the U.S. Salinity Laboratory is used for classification of irrigation water (Wilcox, 1958; Richards, 1954). It is based on SAR and electrical conductivity.

In the present study it is found that, maximum samples are falling under high-salinity hazard and low-sodium hazard (C3–S1) class, some under high-salinity hazard and medium-sodium hazard (C3–S2) class, one sample fall in medium-salinity hazard and low-sodium hazard (C2–S1) class (Fig. 6). The groundwater samples which are coming in C3–S1 and C3–S2 are moderate quality to irrigate semi-tolerant crops.

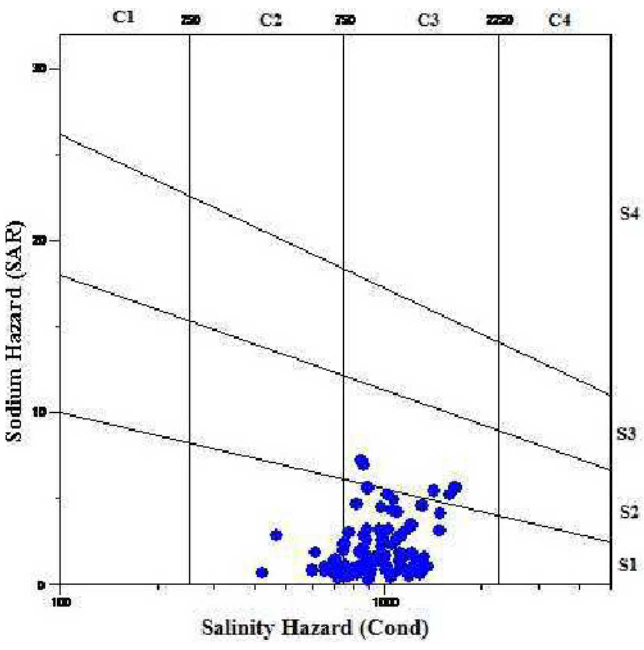

Fig.6. US Salinity laboratory diagram (USSL).

Table 7. Irrigation water quality on the basis of Sodium Absorption Ratio (SAR)

S. No.	Parameter	Range	Water class	No. of samples
1.	Sodium Absorption Ratio (SAR)	<10	Excellent	All samples fall under excellent range
		10 – 18	Good	-
		18 – 26	Doubtful	-
		>26	Unsuitable	-

Table 8. Irrigation water quality on the basis of Permeability Index (PI)

S. No.	Parameter	Range	Water class	No. of samples
1.	Permeability Index (PI)	Class I (>75%)	Good	-
		Class II (25 % - 75%)	Suitable	-
		Class III (<25%)	Unsuitable	RK 87, RK 96, RK 21, RK 34, RK 50 and RK 45

CONCLUSION

Present study has been carried-out to investigate the hydrogeochemistry and suitability of groundwater for irrigation and drinking purpose of the Raipur city, Chhattisgarh. The hydrogeochemical study of the Raipur city reveal that the Groundwater type is mainly Ca^{+2} – Mg^{+2} – HCO_3 Type and Ca^{+2} – Mg^{+2} – SO_4^{-2} in the study area. In which Ca^{+2} cation and HCO_3^- are dominant anions in groundwater in the study area, which indicates water is alkaline. The order of dominance cations and anions in the study area are as following $Ca>Mg>Na>K>Fe=HCO_3>Cl>CO_3>SO_4>Fe>F>NH_3$. Rock-interaction is the dominant activity produces different combination of cations and anions in the groundwater. It is observed that, groundwater is suitable for drinking purpose in the present study area except some groundwater samples, which are showing high Nitrate, Iron, Sulphate, Ammonia and Calcium concentration. To find out irrigation water suitability different irrigational quality parameter such as Sodium Absorption ratio (SAR), Permeability Index (PI), Electrical Conductivity (EC), Total Dissolved Solid (TDS) and US salinity Diagram were computed and interpreted which revealing that groundwater is suitable for irrigation purpose. Raipur city is very fast-growing city, where urbanization and Industrialization are influencing groundwater quantity and quality. Therefore, there is strong need of proper management and development of groundwater resource for future perspective. This study will be helpful to solve problem related to drinking and irrigation in the study area.

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