Journal of Environmental Protection, 2016, 7, 961-971
Published Online May 2016 in SciRes. http://www.scirp.org/journal/jep
http://dx.doi.org/10.4236/jep.2016.76085

Urban Groundwater Quality in India

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Received 29 February 2016; accepted 21 May 2016; published 24 May 2016

Abstract

The electrical conductivity, alkalinity, salinity, hardness and chemical load of the groundwater in urban area of the country are increased enormously due to excessive urban stresses by making water unsafe for drinking purposes. Therefore, the groundwater quality of Raipur city, capital of Chhattisgarh state, India has been investigated. The physico-chemical characteristic of the groundwater along with the chemical loading variations is described. Various indices were used for rating of groundwater quality for drinking and irrigation purposes. The cluster and factor analysis models were used for source apportion of the contaminants.

Keywords

Groundwater, Quality, Sources, Indices

1. Introduction

The urban groundwater has emerged as one of the world's most challenging issues [1]. The quality of available groundwater resources is being increasingly degraded by geogenic and anthropogenic activities [2] [3]. Asian countries face serious water problems almost everywhere mainly due to explosive population growth, heavy seasonal rains, massive flooding, decreasing of water levels, mixing of waste water, etc. [4]. In India, groundwater is used intensively for drinking, irrigation and industrial purposes. Several land and water-based human activities are causing pollution of these precious resources. India is now the biggest user of groundwater for agriculture in the World [5]. The most dramatic change in the groundwater scenario in India is that the share of tube wells in irrigated areas is rising tremendously. By now, tube wells have become the largest single source of irrigation water in India. Hence, groundwater has a high incidence of water quality problems such as increase in concentration levels of chemical species *i.e.* fluoride, iron, salinity, nitrate, arsenic, etc., may be due to mineralization [6]-[15]. In the present work, the urban groundwater quality of the most industrialized city of the country, Raipur is presented. The variations and sources of contaminants and quality assessment of the groundwater are

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How to cite this paper: Dahariya, N.S., Ramteke, S., Sahu, B.L. and Patel, K.S. (2016) Urban Groundwater Quality in India. *Journal of Environmental Protection*, **7**, 961-971. http://dx.doi.org/10.4236/jep.2016.76085

described.

2. Materials and Methods

2.1. Study Area

Raipur is the capital of the Chhattisgarh state of the country with vast industrial growth having population of >2.0 million habitants. The groundwater is widely used for domestic, agricultural and industrial purposes. Several sponge iron, steel, alloy and cement plants are running using coal as source of energy. The water quality of city is deteriorated tremendously due to over use of groundwater and input of the industrial and sewage wastes in it [16].

2.2. Sample Collection

The sampling locations for the groundwater are presented in **Figure 1**. Fifty six groundwater samples from 28 locations of the city from the residential, urban and industrial area in two seasons (*i.e.* post and pre monsoon) of years, 2012 were collected by using the established methodology [17]. The water was collected into cleaned and rinsed 1 lit polyethylene flask. The physical parameters *i.e.* pH, electrical conductivity (EC), dissolved oxygen (DO) and reduction potential (RP) of the groundwater were measured at the spot. The samples were dispatched to the laboratory by subsequent frizzing at −4˚C.

2.3. Analysis

The total dissolved solid (TDS) value of the filtered samples (through glass fiber filter) was determined by the evaporation method [18]. The total hardness (TH) and total alkalinity (TA) values of the groundwater samples were analyzed by titration methods [19]. The CHNSO-IRMS Analyzer, SV Instruments Analytica Pvt. Ltd. was used for analysis of the dissolved organic carbon (DOC) and dissolved inorganic carbon (DIC). The Dionex DX-1100 Ion chromatograph (Dionex Corporation, Sunnyvale, CA, USA) equipped with anion and cation separation columns and conductivity detector was used for analysis of the ions. The Metrohm-781 ion meter was employed for monitoring of F^- content in the presence of the buffer in 1:1 volume ratio. The buffer was prepared by dissolving sodium citrate (300 g), 1, 2-cyclohexanediamine-N-tetraaceticacid (22 g) and NaCl (60 g) in a volume of 1 lit with the de-ionized water by subsequent adjustment of pH value to 5.2 ± 0.2.

The indices *i.e.* sodium hazard (SH), magnesium hazard (MH), sodium adsorption ratio (SAR), permeability index (PI), Kelly's ratio (KR) and water quality index (WQI) were evaluated by using the following equations.

$$\mathrm{SH} = \left(\left\{[\mathrm{Na}]+[\mathrm{K}]\right\} \Big/ \left\{[\mathrm{Na}]+[\mathrm{K}]+[\mathrm{Mg}]+[\mathrm{Ca}]\right\}\right) \times 100$$

$$\mathrm{MH} = \left(\left[\mathrm{Mg}^{2+}\right] \Big/ \left\{\left[\mathrm{Mg}^{2+}\right]+\left[\mathrm{Ca}^{2+}\right]\right\}\right) \times 100$$

$$\mathrm{SAR} = \left[\mathrm{Na}^{+}\right] \Big/ \sqrt{\left\{1/2\left(\left[\mathrm{Ca}^{2+}\right]+\left[\mathrm{Mg}^{2+}\right]\right)\right\}}$$

$$\mathrm{PI} = \left(\left\{[\mathrm{Na}]+\sqrt{\left[\mathrm{HCO}_3^{-}\right]}\right\} \Big/ \left\{[\mathrm{Na}]+[\mathrm{Mg}]+[\mathrm{Ca}]\right\}\right) \times 100$$

$$\mathrm{KR} = \left[\mathrm{Na}^{+}\right] \Big/ \left\{\left[\mathrm{Mg}^{2+}\right]+\left[\mathrm{Ca}^{2+}\right]\right\}$$

where, all ions are expressed in meq/L

Ten parameters *i.e.* pH, EC, DO, TH, TA, Mg^{2+}, Ca^{2+}, Cl^-, NO_3^- and SO_4^{2-} were selected for evaluation of the WQI by using the standard values recommended by BIS and WHO [20] [21]. The weighed arithmetic method was used for calculation of the WQI of the groundwater with the help of following expression.

$$\mathrm{WQI} = \sum q_n W_n \Big/ \sum W_n$$

where:

$$q_n = 100\left(V_n - V_{io}\right) \Big/ \left(S_n - V_{io}\right)$$

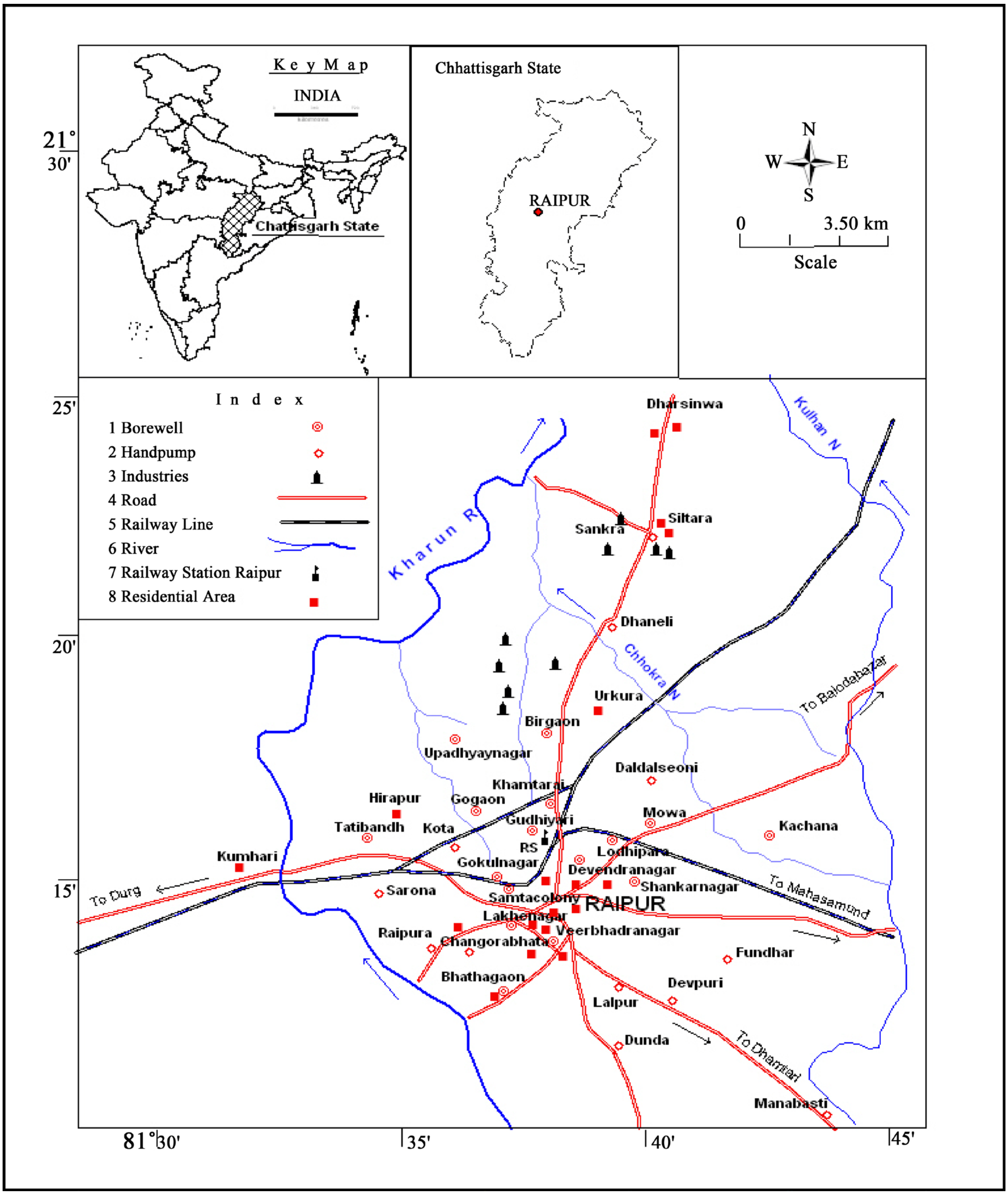

Figure 1. Representation of sampling points in Raipur city, CG, India.

q_n = Quality rating of the nth water quality parameter

V_n = Estimated value of the nth parameter of a given water

S_n = Standard permissible value of the nth parameter

V_{io} = Ideal value of the nth parameter of pure water (*i.e.*, 0 for all other parameters except pH and Dissolved oxygen (7.0 and 14.6 mg/L, respectively)

W_n = Unit weight for the nth parameter

K = Proportionality constant

The Aquachem water quality software was used for the preparation of Piper diagrams. Multivariate statistical analysis *i.e.* hierarchical cluster analysis (HCA) and factor analysis (FA) were used for apportion of contaminant sources [22]-[24]. The windows statistical software STATISTICA 7.1 was employed for the multivariate statistical calculations.

3. Results & Discussion

3.1. Geological Characteristics of Tube Wells

The geological characteristics of the tube wells are presented in **Table 1**. The depth of tube wells was ranged from 30 - 150 m with mean value (p = 0.05) of 90 ± 13 m. The age of tube wells was found in the range of 1.0 - 46 Yr with mean value (p = 0.05) of 10 ± 5 Yr. Generally, younger tube was found to be contaminated with higher content of ions *i.e.* Na^+, K^+, Mg^{2+}, Ca^{2+}, Cl^-, NO_3^-, and SO_4^{2-}, may be due to poor scavenging fluxes. The T value of the groundwater was ranged from 20.1 - 22.9˚C with mean value (p = 0.05) of 21.6 ± 0.3˚C. The slight increase with respect to increasing depth of tube well from 30 - 150 m was observed, may be due to geothermal energy.

Table 1. Geological characteristics of tube wells.

S. No.	Location	Depth, m	Age, Yr	Environment
1	Manabasti	75	11	R
2	Dunda	30	21	R
3	Devpuri	90	6	R
4	Lalpur	105	10	R
5	Fundhar	75	23	R
6	Bhathagaon	75	6	R
7	Changorabhatha	75	11	R
8	Veerbhadranagar	66	8	R
9	Raipura	75	21	R
10	Upadhyay Nagar	84	20	R
11	Lakhenagar	45	11	R
12	Samta colony	105	3	R
13	Sarona	90	7	R
14	Gokulnagar	60	2	R
15	Devendra	72	4	R
16	Lodhipara	75	4	R
17	Shankar Nagar	75	6	R
18	Tatibandh	90	16	R
19	Kota	45	16	R
20	Gudhiyari	90	1	C
21	Mowa	150	2	R
22	Kachana	45	1	R
23	Gogaon	75	3	R
24	Khamtarai	100	1	C
25	Daldalsiwni	90	46	R
26	Birgaon	135	1	I
27	Dhaneli	75	5	I
28	Siltara	90	5	I

C = Commercial, I = Industrial, R = Residential.

3.2. Physico-Chemical Characteristics of Groundwater

The physical characteristics of the groundwater of 28 locations are shown in **Table 2**. The groundwater was colorless when drawn out from the tube well but after some time (≈12 hr) become turbid due to precipitation of the bicarbonates as carbonates. The pH value of the water was ranged from 6.3 - 8.2 with mean value (p = 0.05) of 6.8 ± 0.2. The lowest pH value, 6.3 of the water was observed in the sewage dumping and industrial areas: Kachana and Siltara, due to presence of excessive levels of anions (*i.e.* Cl^-, NO_3^- and SO_4^{2-}). In 92% locations, the pH values of the water were marked in the range of desirable range *i.e.* 6.5 - 9.2 [20]. The DO and RP values were ranged from 3.7 - 7.2 mg/L and 114 - 144 mV with mean value (p = 0.05) of 4.6 ± 0.5 mg/L and 126 ± 0.03 mV. The DO value of the water observed was above the recommended value of 4.0 mg/L [20] [21]. The RP value of the groundwater was found at least 5-folds lower than the recommended value of 650 mV. Extremely high EC values of the water was marked, ranging from 1419 - 6300 µS/cm with mean value (p = 0.05) of 2629 ± 508 µS/cm. The EC value was found to be correlated well (r = 0.92) with the sum of total ionic concentration ions (*i.e.* Cl^-, NO_3^-, SO_4^{2-} and Na^+). The highest EC value of water was marked at the location *i.e.* Kachana, may be due to input of the sewage waste.

Similarly, extremely high TDS, TH and TA values of the water were observed, ranging from 6338 - 14,568, 241 - 1432 and 209 - 878 mg/L with mean value (p = 0.05) of 10,731 ± 603, 519 ± 130 and 319 ± 74 mg/L,

Table 2. Mean value (n = 2) of physical characteristics of groundwater in post monsoon period, January, 2012.

S. No.	pH	DO mg/L	T ˚C	RP, mV	EC, µS/cm	TDS, mg/L	TH, mg/L	TA, mg/L
1	6.7	4.7	21.2	132	2620	10,771	276	411
2	6.5	6.5	20.1	116	3190	8608	989	515
3	6.7	4.8	21.6	132	2380	11,111	431	362
4	6.7	7.2	22.3	123	2600	6338	602	371
5	6.9	4.5	21.4	132	3110	11,204	617	318
6	7.1	4.3	21.6	114	1911	10,667	242	252
7	6.7	4.1	21.6	126	2800	9416	358	345
8	6.7	4.3	21.2	124	2020	11,593	405	209
9	6.9	4.2	22.3	123	1945	9651	241	243
10	6.9	4.3	21.2	134	1557	9950	445	221
11	6.8	4.2	20.4	133	2080	8750	441	256
12	7.0	4.5	22.8	134	2250	12,660	553	211
13	6.8	3.9	21.6	123	2890	9761	402	210
14	6.6	4.6	21.2	132	2640	14,002	529	262
15	7.0	4.6	21.3	124	1419	10,738	474	231
16	6.8	4.4	21.2	127	2290	11,035	341	251
17	6.9	4.2	21.1	121	2020	10,745	446	232
18	7.0	3.7	21.3	123	1970	9747	448	216
19	6.9	4.9	22.4	134	2150	13,039	544	278
20	6.8	5.1	22.2	140	2420	14,568	456	262
21	6.7	4.7	22.9	124	2670	10,770	347	267
22	6.3	6.7	20.4	128	6300	9957	1432	878
23	6.7	3.8	21.2	123	2350	11,708	431	346
24	6.9	4.0	22.6	134	2860	11,463	553	314
25	6.9	4.9	21.5	144	2270	10,268	441	231
26	7.1	4.5	22.7	130	3940	10,667	574	389
27	8.2	4.2	21.4	133	2580	11,043	592	324
28	6.3	3.9	21.9	131	4380	10,248	919	518

respectively. The highest TDS value of the water was seen at the location: Gudhiyari may be due to huge commercial and transportation activities. However, the highest TA and TH values were recorded at location *i.e.* Kachana, may be due to input of the sewage waste.

The chemical characteristics of the groundwater are summarized in **Table 3**. The concentration of DIC and DOC was ranged from 1300 - 7400 and 4500 - 7900 mg/L with mean value (p = 0.05) of 4400 ± 1300 and 6500 ± 900 mg/L, respectively. Similarly, the highest DIC and DOC values were marked in the water at location *i.e.* Gudhiyari. The DOC value of the water was several folds higher than the recommended value of 2 mg/L, may be observed due to percolation of the industrial and municipal waste into the groundwater aquifer. The higher DIC value of the groundwater of this region was marked, may be due to oxidation of the DOC with the microbes.

The concentration of F^-, Cl^-, NO_3^-, SO_4^{2-}, Na^+, K^+, Mg^{2+} and Ca^{2+} in the post monsoon period was ranged from 0.4 - 1.6, 88 - 446, 46 - 991, 45 - 173, 31 - 130, 4 - 56, 16 - 84 and 56 - 256 mg/L with mean value (p = 0.05) of 1.0 ± 0.2, 224 ± 45, 206 ± 101, 105 ± 20, 60 ± 13, 18 ± 5, 28 ± 7 and 92 ± 22 mg/L, respectively. The highest concentration of all ions (except F^- and Na^+) was seen at location *i.e.* Kachana, may be due to input of the sewage waste. At two locations *i.e.* Gogaon and Khamtarai, the concentration of F^- was found to be above the permissible limit of 1.5 mg/L [20] [21].

Table 3. Mean value (n = 2) of chemical characteristics of groundwater during post monsoon period, January, 2012, mg/L.

S. No.	DIC	DOC	F^-	Cl^-	SO_4^{2-}	NO_3^-	Na^+	K^+	Mg^{2+}	Ca^{2+}
1	3900	6600	1.3	266	173	419	34	7	36	120
2	2500	5600	0.9	362	108	221	35	26	48	148
3	5400	5700	1.4	220	110	351	49	10	34	108
4	1500	4500	0.9	255	78	129	52	16	36	104
5	4400	6800	1.4	340	162	223	72	10	32	90
6	4300	6900	0.8	124	63	67	39	14	23	70
7	3500	5900	0.9	276	118	74	87	26	31	104
8	4500	7700	0.8	142	69	116	49	19	16	60
9	4300	5700	1.0	163	86	64	58	15	21	72
10	4500	5900	1.0	132	62	120	37	9	17	57
11	3200	5700	1.5	134	68	193	62	13	23	72
12	5600	7700	0.5	163	74	144	78	23	17	56
13	4400	5600	1.0	266	128	50	94	24	17	56
14	6700	7900	0.8	269	128	115	67	12	24	80
15	4500	6800	1.1	88	45	131	31	14	22	68
16	4700	6800	1.3	170	93	73	65	13	19	76
17	3700	7600	0.9	127	62	87	38	4	24	64
18	4600	5400	1.0	177	86	216	44	16	18	56
19	5700	7700	0.9	177	88	377	50	11	26	80
20	7400	7900	0.9	234	107	115	53	17	22	76
21	4500	6600	0.9	255	116	46	71	10	22	80
22	1300	6800	0.4	446	170	991	82	56	84	256
23	4200	7700	1.6	251	114	216	37	16	30	100
24	5100	6500	1.6	291	145	181	70	16	22	96
25	4700	5900	0.8	134	56	226	48	32	17	64
26	4600	5700	1.2	304	152	420	109	29	36	112
27	4600	6700	1.3	191	110	58	130	29	29	98
28	4400	5400	1.4	324	160	336	35	14	38	160

Chloride in ground water may originate from various sources including: the dissolution of halite. The recommended tolerance limit for Cl^- reported is 250 mg/L [20] [21]. The Cl^- concentration beyond permissible limit was observed in the water of 50% tube wells. The ionic ratio of $[Cl^-]/[Na^+]$ in the water was ranged from 0.9 - 6.8 with a mean value (p = 0.05) of 2.7 ± 0.5 with exceeding of $[Cl^-]$ to $[Na^+]$ in water of the 96% tube wells, may be due to dissolution of halite minerals. The high Na^+ concentration (beyond 20 mg/L) in the water may cause health hazards *i.e.* high blood pressure, heart disease, kidney problem, etc. In the water of all tube wells, the $[Na^+]$ was found above the limit of 20 mg/L. The ionic ratio of $[Na^+]/[K^+]$ in the water was ranged from 2 - 17 with a mean value (p = 0.05) of 7 ± 1 similar to natural water.

High concentration of SO_4^{2-} (150 mg/L) in groundwater of 18% tube wells was marked, ranging from 254 - 2330 mg/L with mean value (p = 0.05) of 1059 ± 392 mg/L. The water of all tube wells was contaminated with NO_3^- above the permissible limit of 45 mg/L [20] [21]. Groundwater of 31% and 62% tube wells of the studied area was found to be contaminated with Mg^{2+} and Ca^{2+} beyond permissible limit of 30 and 75 mg/L, respectively.

The domination of the DOC, DIC and Cl^- in the water was observed. The chemical species *i.e.* carbons and ions in the water was found to occur in following decreasing order: DOC > DIC > Cl^- > NO_3^- > SO_4^{2-} > Ca^{2+} > Na^+ > Mg^{2+} > K^+.

3.3. Seasonal Variation

The variation of ion concentration during post (January, 2012) and pre monsoon (May, 2012) periods is presented in **Figure 2**. The T value of the groundwater (n = 28) was increased during the pre monsoon period (*i.e.* May, 2012) in the range of 26.0 - 28.0˚C with mean value (p = 0.05) of 27.3 ± 0.2˚C. The value of pH, EC, TDS, TH, TA, DOC, DIC, F^-, SO_4^{2-}, Na^+, Mg^{2+} and Ca^{2+} of the water was found to be increased in the pre-monsoon

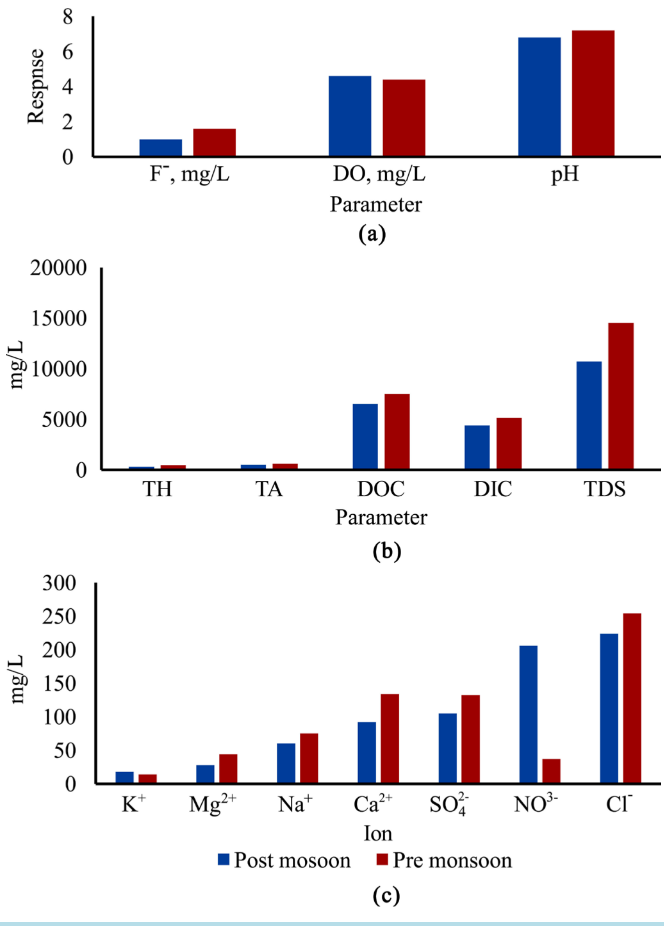

Figure 2. Parameters of groundwater during post and pre monsoon period (*i.e.* January, 2012 and May, 2012).

period, may be due to increase in the water temperature, ≈4˚C and shrinking of the water Table up to ≈30 m. However, the concentration of ions *i.e.* NO_3^- and K^+ was found to decrease, may be due to decrease of the anthropogenic activities.

3.4. Sources

In the present study, HCA was used to classify the sample sites into hydrochemical groups in the post monsoon period. The Ward's linkage method was used by using Euclidean distance for similarity measurement in the classification scheme. The result obtained by HCA detected the similar groups, yielding a dendrogram into three statistically significant clusters such as Group-I, -II and -III in the post monsoon period (**Figure 3**). The Group-I presented groundwater sample of location: Kachana which showed the highest values of parameters *i.e.* EC, TA, TH, NO_3^- and major cations (*i.e.* K^+, Mg^{2+} and Ca^{2+}) become as an outlier. The Group-II and Group-III were characterized by moderate and high pollution load of the chemicals in the groundwater, respectively.

The factor analysis (FA) derived a subset of uncorrelated variables called factors that explained the variance observed in the original dataset. In FA, all the variables were standardized at the z-scale (mean and variance set to zero and one, respectively) to minimize the effects of different units and variance of variables [25]. The FA was performed for the set of 28 sample locations with 20 variables in order to establish the association between the chemical and physical variables of the groundwater. Factor extraction was carried out by using principal components based on Kaiser Criterion [26]. Factors with eigenvalues higher than 1 were retained and presented in **Table 4**. Six factors explaining 84.62% of the total variance were retained after normalized varimax rotation. Factor-1 accounted for 44.18% of the total variance, revealed strong associations (high positive loadings) with TDS, EC, TH, Ca^{2+}, Mg^{2+}, Cl^-, NO_3^-, SO_4^{2-} and TA. This factor was characterized by complex processes derived from anthropogenic sources. Factor-2 explained 11.81% of the total variance, had strong positive loadings on pH and Na^+. Factor-2 could represent weathering of Na-bearing minerals. Factor-3 accounted for 9.69% of the total variance, had a negative loading on RP, which confirmed that RP in the groundwater did not contribute significantly to the hydrochemistry. Factor-4 accounted for 8.67% of the total variance, had a negative loading on F^-. This factor did not contribute significantly to the variation of the groundwater hydrochemistry. In the same order, Factor-5 which accounted for 5.26% of the total variance, had a negative loading on depth and did not contributed significantly to the groundwater hydrochemistry. At last, factor-6 accounted for 5.01% of the

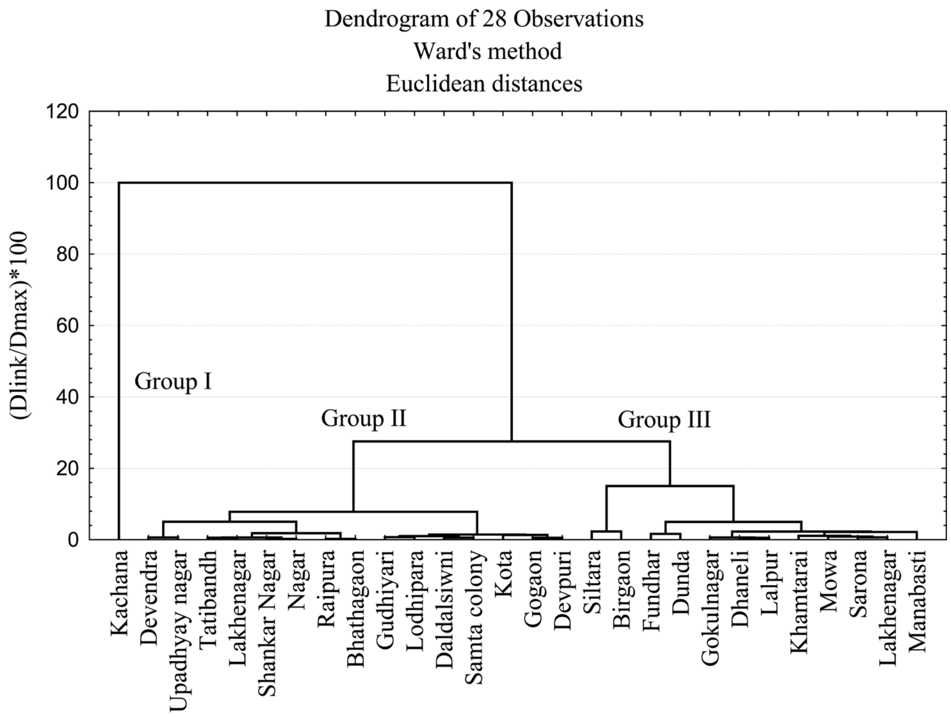

Figure 3. Dendrogram of groundwater samples in the post monsoon period, January 2012.

Table 4. Factor analysis of variables of groundwater during post monsoon period, January, 2012.

Parameter	Factor-1	Factor-2	Factor-3	Factor-4	Factor-5	Factor-6
Depth	−0.15	0.12	−0.01	−0.02	**−0.91**	0.03
Age	−0.22	−0.00	−0.10	0.06	0.27	**−0.74**
T	−0.21	−0.10	−0.62	0.15	0.03	−0.08
pH	−0.44	**0.78**	0.04	−0.10	0.10	0.00
DO	0.49	−0.21	−0.01	0.55	0.03	−0.31
RP	0.00	0.00	**−0.89**	−0.14	0.01	0.14
EC	**0.95**	0.09	0.15	0.06	−0.12	0.04
TDS	**0.96**	0.09	0.15	0.08	−0.10	0.05
Alk	**0.79**	0.06	0.07	0.43	0.23	0.07
TH	**0.94**	−0.09	0.19	0.09	0.14	−0.06
CC	−0.41	0.14	−0.57	−0.21	−0.14	0.47
OC	−0.13	0.04	−0.29	0.17	0.33	**0.81**
F^-	−0.02	0.01	0.00	**−0.93**	0.00	−0.12
Cl^-	**0.89**	−0.05	0.09	−0.13	−0.21	0.02
SO_4^{2-}	**0.79**	0.07	−0.03	−0.44	−0.24	0.17
NO_3^-	**0.85**	−0.06	−0.09	0.12	0.23	−0.04
Na^+	0.25	**0.86**	0.02	−0.01	−0.29	0.09
K^+	0.61	0.47	0.21	0.46	0.08	−0.12
Mg^{2+}	**0.92**	−0.07	0.18	0.15	0.19	−0.07
Ca^{2+}	**0.94**	−0.09	0.18	0.05	0.13	−0.03
Eigen value	8.36	1.72	1.80	1.97	1.44	1.63
Explained Variance %	44.18	11.81	9.69	8.67	5.26	5.01
Cumulative Variance %	44.18	55.99	65.68	74.34	79.61	84.62

Significant loadings > 0.7 (in italic and bold) at $p < 0.05$.

total variance, had a positive and negative loading on DOC and age which did not contribute statistically.

The results of FA in the pre monsoon period are shown in **Table 5**. Three factors explaining 79.37% of the total variance were extracted. Factor-1 accounted for 56.67% of the total variance, described complex processes such as mineralization and dissolution of evaporate in the water. Factor-2 represented 13.44% of the total variance, had positive and negative loading on NO_3^- and pH, which did not contribute statistically to the hydrochemistry. Factor-2 was related to anthropogenic activities (*i.e.* runoff and waste water). Factor-3 was accounted for 9.26% of the total variance, had a positive and negative loading on T (˚C) and F^-. Factor-3 characterized the importance of temperature on the dissolution of evaporate.

3.5. Water Quality Assessment

As per Piper diagram, the groundwater in the post monsoon season was mostly classified into two types: Ca-Cl-SO_4-NO_3-HCO_3 and Ca-SO_4-NO_3-HCO_3 of water. The most dominating type of water was Ca-Cl-SO_4-NO_3-HCO_3. In the pre monsoon season, only Ca-SO_4-NO_3-HCO_3 water was observed. The WQI of the water in the post and pre monsoon period was ranged from 218 - 846 and 321 - 889 with mean value ($p = 0.05$) of 361 ± 45 and 504 ± 56, respectively. The value of TDS, TH, TA, F^-, NO_3^-, Cl^-, SO_4^{2-}, Mg^{2+} and Ca^{2+} in the pre monsoon period was found above the recommended values of 500, 200, 120, 1.5, 45, 200, 150, 30 and 75 mg/L, respectively [20] [21]. These data showed that the groundwater of Raipur city was found to be unsuitable for the drinking purposes.

The values of SAR, KR, SH, MH and PI values of the groundwater in the post monsoon period were ranged from 1.3% - 6.2%, 0.3% - 2.0%, 26% - 70%, 28% - 38% and 47% - 87% with mean value ($p = 0.05$) of 3.0 ± 0.5, 0.9 ± 0.2, 48 %± 4%, 33% ± 1% and 71% ± 4%, respectively. Generally, the MH, SAR, KR and PI value of <50,

Table 5. Factor analysis of variables of groundwater during pre monsoon period, May, 2012.

Parameter	Factor-1	Factor-2	Factor-3
T (˚C)	0.05	0.11	**0.75**
pH	−0.26	**−0.80**	−0.14
EC	**0.93**	0.07	−0.08
Alk	**0.84**	0.29	0.21
TH	**0.84**	0.33	0.12
F^-	0.09	0.06	**−0.81**
Cl^-	**0.95**	0.17	−0.09
SO_4^{2-}	**0.92**	−0.22	−0.13
NO_3^-	−0.02	**0.81**	−0.06
Na^+	**0.90**	−0.03	−0.04
K^+	**0.85**	0.17	0.02
Mg^{2+}	**0.73**	0.55	0.05
Ca^{2+}	**0.82**	0.46	0.04
Eigenvalue	6.85	2.13	1.34
Explained Variance %	56.67	13.44	9.26
Cumulative Variance %	56.67	70.11	79.37

Significant loadings > 0.7 (in italic and bold) at $p < 0.05$.

<10, <1 and <25 were considered good for the irrigation purposes [21] [27]-[29]. The SH value in the water of all tube wells was found in the range of 26% - 70%, indicating permissible water quality for the irrigation purpose [29].

4. Conclusion

The water of Raipur city is found to be very hard with high EC and TA values. The domination of Ca-Cl-SO_4-NO_3-HCO_3 type water was observed, may be due to huge industrial and urban activities. The quality of water was found to be deteriorated due to excessive mineralization of species *i.e.* DOC, DIC, Cl^-, NO_3^-, SO_4^{2-}, HCO_3^-, Na^+, K^+, Mg^{2+} and Ca^{2+}, and not found to be suitable for drinking purposes.

Acknowledgements

We are thankful to the UGC, New Delhi for awarding the RG scholarship to one of the author, NSD for doing this work.

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