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HYDROCHEMISTRY AND GROUNDWATER QUALITY IN MERAL -NAGARUNTARI-BHAWANATHPUR AREA, GARHWA DISTRICT, JHARKHAND

Geology

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ABSTRACT

The present paper intends to assess the groundwater quality of Meral –Nagaruntari-Bhawanathpur area in Garhwa district of Jharkhand where higher fluoride concentration has been reported. The area is underlain by metamorphic rocks (Granite and Granitoid gneisses) of Precambrian age in association with sedimentary rocks (limestone, sandstone and shale) in which fluoride occurs as accessory minerals. Altogether 25 representative water samples from dug wells and bore wells were collected in pre- and post- monsoon periods and were analysed for major cations and anions in addition to other parameters.

On and average, the concentration of all the major cations and anions in the groundwater of the area increases in the pre-monsoon period as compared to that in post-monsoon except K^+ and SO_4^{2-}. Plotting of data on Piper Trilinear diagram indicates that alkaline earth (Ca^{2+}+Mg^{2+}) exceeds alkalies (Na^++K^+) in both pre- and post-monsoon periods.

Further, carbonate hardness (secondary salinity) exceeds 50% in the majority samples during post-monsoon. According to USSL classification the quality of water samples belongs to C_2S_1 and C_3S_1 in both pre- and post- monsoon periods indicating low sodium hazard but medium to high salinity hazard. Plot of analytical data on Wilcox's (1995) diagram using Electrical Conductivity versus Sodium percentage shows that the water samples are of excellent to good and good to permissible quality which are suitable for irrigation purpose. Fluoride concentration is above the permissible limit in two places in Bhawanathpur during pre-monsoon whereas during post-monsoon concentration is found beyond the permissible limit in Meral, Nagaruntari, Bhawanathpur and Garhwa areas.

KEYWORDS

Hydrochemistry, Piper's Trilinear diagram, U.S.S.L classification, Wilcox diagram, Sodium hazard, Fluoride

INTRODUCTION

Meral (Lat-24°11'37"N, Long-083°41'02"E), Nagaruntari (Lat-24°17'24"N, Long-083°30'17"E) and Bhawanathpur (Lat-24°22'25"N, Long-083°33'57"E) blocks of Garhwa district comprising the study area located in the north-western part of the Jharkhand state (Fig.1) suffer due to high concentration of fluoride in groundwater The area of Garhwa district primarily comprises metamorphic rocks (granite and granitoid gneisses) of Precambrian age associated with limestone of lower Vindhyan age. The present study carried out in part of Garhwa district aims at evaluation of groundwater quality in terms of drinking and irrigation suitability. Fluoride is the anionic form of the most electronegative element fluorine occurring in the study area, the content of which exceeds the permissible limit at several places, especially in post-monsoon period (Neeta at al 2015, Sinha at al 2008). Excessive fluoride concentration beyond the permissible limit causes various health hazards. According to WHO (1993) the permissible limit of F is 0.5-1.5 mg/l in drinking water whereas Safe limit of fluoride in potable water is considered between 1.0 and 1.5 mg/l (IS10500:2012). Less than 1.0 mg/l of fluoride concentration causes dental caries, while higher concentration results in dental fluorosis.

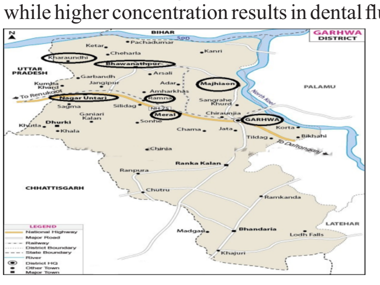

Figure 1a (District Map)

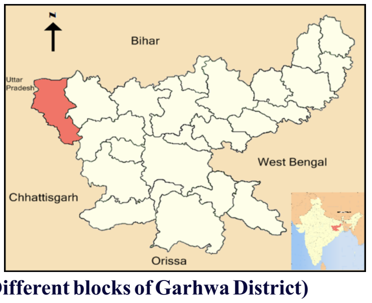

Figure 1b (Different blocks of Garhwa District)

MATERIAL AND METHODS

Representative water samples were collected from dug wells and bore wells of Meral, Nagaruntari, Bhawanathpur and Garhwa Sadar blocks of the district during pre-monsoon (April-May) and post-monsoon (Oct-Nov) periods. The samples were collected in narrow mouthed pre-cleaned acid washed polyethylene bottles and brought to the laboratory for physico-chemical analysis. Samples were analyzed using their standard testing methods such as zirconyl alizarine and ION METER method.

The major cations Ca^{2+},Mg^{2+},Na^+,K^+ and anions F^-,Hco_3^-,Co_3^{2-},Cl^-,So_4^{2-} were analyzed in addition to EC and pH . EC and pH values were measured in the field using portable conductivity and pH meter respectively. Major anions (F^-,Hco_3^-,Co_3^{2-},Cl^-,So_4^{2-}) and cations (Ca^{2+},Mg^{2+},Na^+,K^+) were measured by Ion-Chromatograph. All the concentrations are expressed in mg/l except pH and EC. EC is expressed in micro mho/cm at 25°C. Table-1 and Table-2 show the result of analytical data of groundwater of the study area during pre- and post- monsoon periods.

Table 1 Major Ions (mg/l) Concentrations Of Groundwater Of Garhwa District.(pre-monsoon)

Sl. No.	Location	pH	EC	TH	TDS	Ca^{2+}	Mg^{2+}	Na^+	K^+	HCO_3^-	Cl^-	F^-	SO_4^{2-}	SAR
1	Neoua more	7.72	611	510	311.3	108.2	12.07	59.27	0.84	76	124	1.3	33.86	1.22
2	Meral	7.88	1832	1200	1173	152.2	14.51	82.49	2.13	60	602.6	1.5	55.3	1.12
3	Meral	7.70	1568	600	1004	149.2	16.34	84.04	1.86	78	496.3	0.6	56.2	0.78
4	Meral	7.77	729	240	450.8	104.4	13.78	83.68	1.65	64	106.4	0.5	35.86	1.08
5	Meral	7.66	717	360	453.4	145	18.90	60.64	0.78	56	88.6	0.6	52.61	0.98
6	Nagaruntari	7.39	664	280	426.8	95.2	25.2	103.01	102.43	120.2	70.9	0.5	79	1.83
7	Nagaruntari	7.91	711	360	451.1	84	9.7	42.63	0.7	52	70.9	1	88.2	1
8	Nagaruntari	7.64	821	400	508	72	30	43.27	1.03	85.0	70.9	0.8	53.2	0.83
9	Nagaruntari	7.78	1234	440	790	115	22.1	103.01	102.43	64	177.2	0.8	82	1.50
10	Nagaruntari	7.57	1453	560	930.7	102	37	116.62	119.23	89.2	212.7	0.6	110	1.96
11	Bhawanathpur	7.80	993	320	575.5	119	37.5	82.8	117.76	78.5	141.8	3	113	1.70
12	Bhawanathpur	7.61	851	440	545.2	78	34	74.18	0.76	94.0	141.8	3.1	61.2	1.84
13	Bhawanathpur	7.66	798	440	480.6	89	10.3	51.14	1.19	62.5	70.9	0.6	98.7	1.06
14	Bhawanathpur	7.80	697	320	447.0	107	19.2	60.1	1.81	51.3	70.9	0.6	71.3	1.38
15	Bhawanathpur	7.91	835	440	522	153	17.2	63.89	1.49	87	70.9	1.4	63.7	0.78
16	Garhwa	7.71	978	520	593	174	13.2	86.05	1.1	79	141.8	0.6	83.2	1.25
17	Garhwa	7.65	1084	400	694.5	103	12	102.93	0.7	58	177.2	0.7	51.2	1.01
18	Garhwa	6.86	1485	280	951.7	111	12.02	101.35	1.2	72	283.6	0.6	26.5	1.11
19	Garhwa	7.28	1304	520	835.8	69	42	99	1.6	119	177.2	0.5	84.2	2.10
20	Garhwa	7.51	865	320	554.3	180	18.2	107.85	6.12	82	159.5	0.6	88.2	0.98
21	Town hall Garhwa	7.53	1307	530	837.9	75	31.1	83.2	1.8	47	152.7	0.4	51.3	2.32
22	Chinia more	7.36	1300	465	832.0	85.4	11.2	81.36	1	39.8	154.6	2	73.5	1.00
23	Sahajna more	6.98	1365	325	874.0	150	20.2	82.9	1.2	54	174.5	0.8	93.2	1.01
24	Chinia more	7.25	1232	488	789	136	18.2	78.2	0.9	85	173.2	0.9	42.2	0.85
25	Bus stand Garhwa	7.65	1403	547	898.0	61	47	73.7	0.8	53.2	178.2	1.5	88.9	1.85

Table 2 Major Ion (mg/l) Concentrations Of Groundwater Of Garhwa District (post-monsoon)

Sl.No.	Location	pH	EC	TH	TDS	Ca^{2+}	Mg^{2+}	Na^{+}	K^{+}	HCO_3	Cl	F	SO_4^{2-}	SAR
1	Nezua more	7.20	857	280	596	56	34	41	2	280	66.5	2.1	49.6	0.871
2	Meral	6.88	1294	426	870	138.4	21.6	86	5	338	114.5	2.3	105.8	1.340
3	Meral	7.19	816	308	556	102.4	12.6	52	1	270	53.8	2.0	46.9	0.953
4	Meral	7.25	830	246	536	69.6	17	44	1	222	49.9	2.2	36.8	0.937
5	Meral	7.40	625	234	408	56	17.9	48	2	300	35.2	2.0	8.1	1.111
6	Naparuntari	7.20	757	298	444	75.2	26.7	52	2	326	17.6	2.1	21.1	1.027
7	Naparuntari	7.06	642	288	362	73.2	26.7	39	1	320	17.6	2.5	8.7	0.786
8	Naparuntari	7.69	606	252	324	83.2	10.7	26	1	254	22.5	0.6	23.8	0.528
9	Naparuntari	7.19	688	330	488	98.4	20.4	31	1	284	40.1	0.62	22.6	0.562
10	Naparuntari	7.17	655	334	460	94.4	18.9	29	2	332	24.4	0.6	11.8	0.538
11	Bhawanathpur	7.45	618	188	436	49.6	15.5	66	1	332	8.9	2.0	10.4	1.627
12	Bhawanathpur	6.68	412	146	286	42.4	9.7	32	1	238	4.9	1.0	10.7	0.878
13	Bhawanathpur	7.33	1730	718	1120	193.6	56.8	135	2	320	228.9	0.8	158.2	1.700
14	Bhawanathpur	7.86	649	232	458	64	17.5	30	2	250	32.3	0.8	12.5	0.657
15	Bhawanathpur	7.63	668	306	466	96.8	15.5	33	1	294	30.3	0.9	18.9	0.613
16	Garhwa	7.45	1309	476	790	117.6	44.2	71	7	376	62.6	2.4	109.5	1.113
17	Garhwa	7.46	1139	268	792	61.6	27.7	88	5	290	86	2.3	71.1	1.865
18	Garhwa	7.85	423	174	290	47.2	13.6	10	2	154	7.8	0.6	13.4	0.254
19	Garhwa	7.26	992	452	692	135.2	27.7	33	4	404	67.5	1.0	41.6	0.511
20	Garhwa	7.15	1048	632	854	176	43.8	188	7	388	279.8	1.0	162.7	2.524
21	Town hall Garhwa	7.01	1420	554	990	182.4	23.8	126	2	330	176.1	0.5	118.1	1.726
22	Chinia more	7.35	1048	422	636	130.4	23.3	65	4	240	119.4	0.4	97.1	1.034
23	Sabejna more	7.35	1334	494	932	124.8	44.2	125	12	410	155.5	0.4	82.6	1.917
24	Chinia more	7.45	1036	264	726	61.6	26.7	96	5	210	92.9	0.7	64.9	2.045
25	Bus stand Garhwa	7.82	887	186	622	46.4	16.9	101	2	206	112.5	1.0	79.1	2.533

3. RESULTS AND DISCUSSION

The logarithm of the reciprocal of the hydrogen ion concentration (pH) in the pre-monsoon water samples varies from 6.86 to 7.91 with an average of 7.58 and in the post- monsoon water samples it varies from 6.68 to 7.86 with an average of 7.33 indicating its alkaline nature. As per ISI (2012) standards, all the samples in the pre-and post- monsoon seasons are within the recommended limits (6.5 to 8.5) for human consumption. The specific conductance values are found in the range of 611-1832 micro mho/cm at 25°C with an average of 1073.48 micro mho/cm at 25°C in the pre-monsoon period and in the range of 412-1730 micro mho/cm at 25°C with an average of about 891.32 micro mho/ cm at 25°C in the post-monsoon period. The total dissolved solids were computed from electrical conductivity (Hem 1985). The concentration of total dissolved solids ranges from 311.3 to 1173 mg/l with an average of 693.2 mg/l in the pre monsoon samples and 286 to 1120 mg/l with an average of 605.36 mg/l in the post monsoon samples. Higher concentrations of calcium are found to be in the central and Southeastern parts of the basin in the pre-monsoon season whereas calcium ion concentration is more than the permissible limit of 75 mg/l for drinking water in the sample no.2,3,6,8,9,10,13,15,16,19,20,21,22 and 23 in the post monsoon period. During pre-monsoon period magnesium concentration is within the permissible limit in the northern part of the study area. Mg content ranges from 9.7 to 47 mg/l and 9.7 to 56.8 mg/l in the pre and post monsoon seasons respectively. Sodium concentration varies from 42.63 to 116.62 mg/l and 10 to 188 mg/l in both pre- and post-monsoon seasons respectively. Potassium content ranges from 0.7 to 119.23 mg/l and 1 to 12 mg/l in pre- and post- monsoon seasons respectively.

Bicarbonate ion varies from 39.8 to 120.2 mg/l and 154 to 410 mg/l in pre- and post- monsoon seasons respectively. During pre- and post-monsoon periods, higher concentration of HCO_3 occur in the north-western part of the study area.

Chloride concentration ranges from 70.9 to 602.65 mg/l and 4.9 to 279.8 mg/l in the groundwater samples during pre- and post- monsoon seasons respectively. Low chloride occurs in north-western part of the study area, during post monsoon season, while high chloride values are present in sample no.2,13,20,21,22,23,24 &25.

Fluoride content ranges from 0.4 to 3.1 mg/l and from 0.4 to 2.5 mg/l during pre and post monsoon periods respectively. Fluoride contamination in drinking water is a public health problem in many areas around the world and excess contamination (> 1.5 mg/l) may cause dental, skeletal or non-skeletal fluorosis along with secondary neurological complications. About 96% of fluoride in the human body is found in bones and teeth. Fluorine is essential for the normal mineralization of bones and formation of dental enamel. Tooth enamel is principally made up of hydroxyapatite (87%) which is crystalline calcium phosphate. Fluoride which is more stable than hydroxyapatite replaces the hydroxide ions from hydroxyapatite to form fluoroapatite. The local population of the area at many places of Meral and Bhawanathpur have been affected by dental fluorosis.

The overall ionic concentration of groundwater in the study area is more due to rock-water interaction during the pre-monsoon season. It is controlled by contamination from extraneous sources. The concentration of these ions are less during post- monsoon period as a result of dilution.

Plot of the groundwater samples in Piper's Trilinear diagram (piper 1944) of pre- monsoon data falls in the field 1 and 4 suggesting alkaline earth ($Ca^{2+}+Mg^{2+}$) exceeds alkalies ($Na^{+}+K^{+}$) and strong acids ($SO_4^{2-}+Cl^{-}+F^{-}$) exceed weak acids ($CO_3^{2-}+HCO_3^{-}$) respectively. Samples of post- monsoon data fall in field 1,3 and 4. Plot in field 3 (more than 50%) indicates that weak acids exceed strong acids (Fig.2a & 2b).

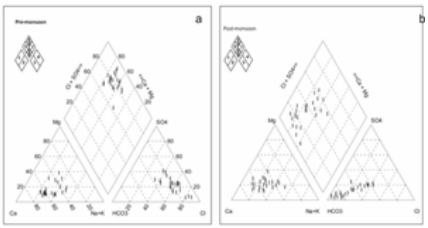

Figure 2 Piper trilinear showing chemical characters of ground water (a) Pre- Monsoon and (b) Post- Monsoon

Table 3 The Quality Of Groundwater Based On Piper Trilinear Diagram

Various segments of the diamond Shaped field	Characteristics of corresponding each small part of diamond field
1	Alkaline earth ($Ca^{2+}+Mg^{2+}$) exceeds alkalies ($Na^{+}+K^{+}$)
2	Alkalies exceeds alkaline earths
3	Weak acids ($CO_3^{2-}+HCO_3^{-}$) exceeds strong acids ($SO_4^{2-}+Cl^{-}+F^{-}$)
4	Strong acids exceeds weak acids
5	Carbonate hardness (secondary salinity) exceeds 50%
6	Non-Carbonate hardness (secondary salinity) exceeds 50%
7	Non-Carbonate alkali (Primary alkalinity) exceeds 50%
8	Carbonate alkali (Primary alkalinity) exceeds 50%
9	None of the cation or anions pairs exceeds 50%

Hydrochemical facies of groundwater is classified following Back (1961) in the present study area. Almost all the samples of pre- and post- monsoon periods fall in the field of Calcium-Sodium facies. For anion facies all the plots of pre- monsoon data fall in Chloride-Sulphate-Bicarbonate facies, while plots of post-monsoon data fall in Chloride-Sulphate-Bicarbonate (36%), Bicarbonate-Chloride-Sulphate (44%) and Bicarbonate (20%) Facies fields (Fig.3).

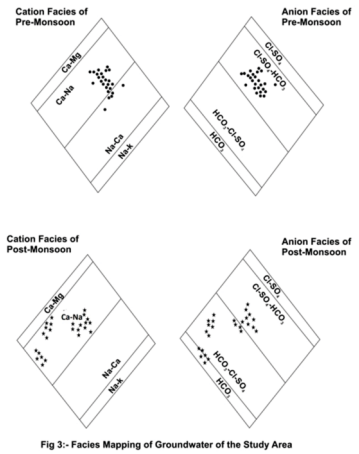

Fig 3:- Facies Mapping of Groundwater of the Study Area

Groundwater can be classified based on distribution of the total dissolved solids following ICMR (1975), Wilcox (1955) and WHO (1993) such as up to 1500 mg/l (permissible for domestic use) 1500 to 3000 mg/l (useful for irrigation) and >3000 mg/l (unsuitable for domestic, industrial and irrigation purposes) Hundred percent of the pre- and post- monsoon samples are within permissible limits for domestic, industrial and agricultural uses.

3.1 PERCENTAGE OF SODIUM

In all natural waters, percent of sodium content is a parameter to assess its suitability for agricultural purposes (Wilcox 1948). Sodium combining with carbonate can lead to the formation of alkaline soils, While, sodium combining with chloride forms saline soils. Both these soils do not help growth of plants. A maximum of 60% sodium in groundwater is allowed for agricultural purposes. Plot of sodium Vs Specific Conductance on the Wilcox diagram shows that almost all the samples in the pre- and post- monsoon seasons fall in excellent to good and good to permissible categories. (Fig.4)

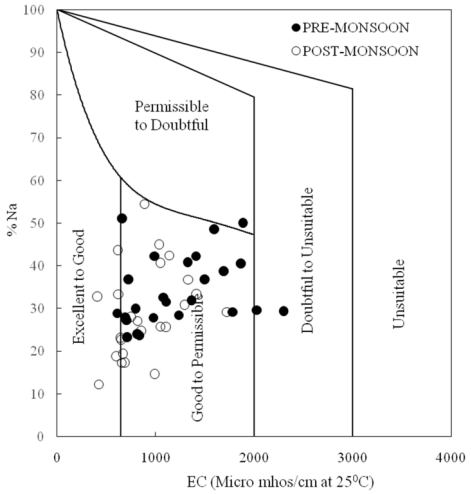

Figure 4 Wilcox (1955) diagram of groundwater of the study area based on EC and % Na

3.2 SODIUM ABSORPTION RATIO (SAR)

Sodium concentration in groundwater is important as increase of sodium concentration in water affects the soil properties reducing permeability, Kelly (1951) and Tijani (1994). The process leading to the cation exchange reactions in soil may be studied from sodium absorption ratio (SAR) (U. S. Salinity laboratory, 1954)

SAR is expressed as: -

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

Where the concentration are expressed in meq/l

Classification of water with reference to SAR (Herman Bouwer, 1978) is presented in Table 4. All the samples of water of pre and post monsoon seasons fall under no problems category.

Table 4 Classification Of Sodium Absorption Ratio In Ground water

SAR	Water quality	Post-monsoon (no. of samples)	Pre-monsoon (no. of samples)
0-6	No problem	25	25
6-9	Increasing problem	0	0
>9	Severe problems	0	0

U.S. Salinity Laboratory diagram based on Sodium Absorption Ratio (SAR) Vs Specific Conductance Values, the two most significant parameters of Sodium and Salinity hazards indicate usability for agricultural purposes.

Sixteen categories are demarcated in the diagram in terms of salinity hazards as low (C_1), medium (C_2), high (C_3), very high (C_4) and also in terms of sodium hazards as low (S_1), medium (S_2), high (S_3) very high (S_4).

SAR ranges from 0.78 to 2.32 and 0.254 to 2.533 during pre and post monsoon periods. About 30% and 70% of the groundwater samples fall within C_2S_1, C_3S_1 in pre-monsoon season respectively and 40% and 60% of the groundwater samples fall within C_2S_1, C_3S_1 respectively in post monsoon season.(Fig.5)

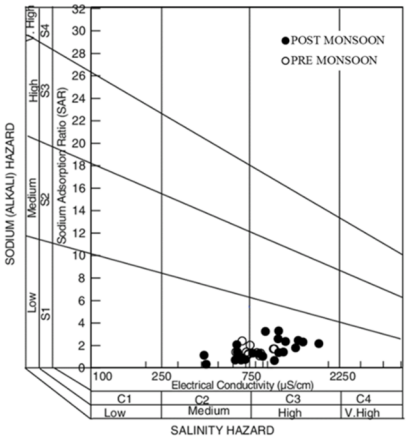

Figure 5: U.S. Salinity diagram for classification of irrigation water after Richards (1954)

4. CONCLUSIONS

The groundwater in the investigated area shows limited seasonal variations in quality. In the pre-monsoon water samples pH ranges from 6.86 to 7.91 and in the post-monsoon water samples pH ranges from 6.68 to 7.86 indicating the alkaline nature. As per ISI (2012) standards all the samples of the study area during pre- and post-monsoon seasons are within the recommended limits (6.5 to 8.5) for human consumption. The average specific conductance values are found about 1073.48 micro mho/cm at 25°C in the pre-monsoon period and about 891.32 micro mho/cm at 25°C in the post-monsoon period. The average concentration of total dissolved solids ranges from 677.21 mg/l in the pre-monsoon samples and 609.36 mg/l in the post-monsoon samples. During pre-monsoon period Magnesium (Mg) concentration is normal in the northern part of study area while its concentration is beyond the permissible limit of 30 mg/l in Nagaruntari, Bhawanathpur and Garhwa. Sodium (Na) concentration varies from 42.63 to 116.62 mg/l (average 80.29 mg/l) and 10.0 to 188.0 mg/l (average 65.88 mg/l) in pre- and post- monsoon seasons respectively. Potassium (K) contents range from 0.7-119.23 mg/l and 1 to 12 mg/l in pre- and post-monsoon seasons respectively within the permissible limit of 1 to 7 mg/l in the post- monsoon while its concentration is beyond the permissible limit in the pre monsoon period.

Bicarbonate ion varies from 39.8 to 120.2 mg/l and 154-410 mg/l in pre- & post- monsoon seasons respectively. During pre- & post-monsoon period high Hco_3 is found in the north western part of the study region. Chloride concentration ranges from 70.9-602.65 mg/l and 4.9-279.8 mg/l in the groundwater samples during pre- and post-monsoon seasons respectively.

Groundwater can be classified based on distribution of the total

dissolved solids following ICMR (1975) WILCOX (1955) and WHO (1993) such as upto 1500 mg/l (permissible for domestic use) 1500-3000 mg/l (useful for irrigation) &>3000 mg/l (unsuitable for domestic industrial & irrigation purposes)

Percentage of sodium and Sodium Absorption Ratio (SAR) has also been calculated during pre- and post- monsoon seasons respectively.

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