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COMPARATIVE ASSESSMENT OF FLUORIDE CONCENTRATION AND HYDROCHEMICAL ANALYSIS OF GROUND WATER OF DUBRAJPUR AND RAMPURHAT-I BLOCK, BIRBHUM, WEST BENGAL, INDIA

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Abstract: **Elevated ground water fluoride concentration and hydrochemical data are presented for groundwater samples, collected from different blocks of Birbhum district, West Bengal, India, belonging to different geological regions. Dubrajpur(unclassified gneiss), Rampurhat-1(Igneous). From Dubrajpur block total 31 samples including hotspring, dugwell and deeptubewell samples were collected during November, 2011 and from Rampurhat-1 block total 63 samples including shallow and deep tubewells were collected during February, 2011 for comparative assessment of the groundwater fluoride status and overall chemical quality and suitability for domestic and agricultural use. Other parameters analyzed for pH ,Total Dissolved Solid (TDS), Electrical Conductivity(EC), Sulphate(SO_4^{2-}), Nitrate(NO_3^-), phosphate(PO_4^{3-}), Fluoride(F^-), Calcium(Ca^{2+}), Magnesium(Mg^{2+}), Sodium(Na^+), Potassium(K^+), Bicarbonate(HCO_3^-), carbonate(CO_3^{2-}), and Total Hardness(TH) using standard techniques. Obtained results show that among both Dubrajpur and Rampurhat-1 samples several parameters were found to be elevated. Sodium adsortion ratio (SAR) values were within the permissible limit in all the Dubrajpur samples but among Rampurhat-1 samples two were elevated (Asanjola and Madhabpur village). Rest of the samples were within the permissible limit. %Na and residual sodium carbonate (RSC) value were within the permissible limit among all the Dubrajpur samples but among the Rampurhat 1 samples %Na was found to be unsuitable (3 samples) and doubtful (3 samples). RSC value was found to be above 1 among 3 Asanjola, 3 Narayanpur and 2 Madhabpur village samples of Rampurhat-1. Birbhum district is a groundwater fluoride affected district and among several samples of both Dubrajpur and Rampurhat-1 block fluoride concentration was found to be elevated. Fluoride concentration seems to have a positive relation to pH, sodium and carbonate whereas a negative relation to magnesium and calcium. The degree of weathering of the silicate minerals as indicated by the sodium acquired by the ground waters may have a decisive role in fluoride enrichment process. The overall obtained results of fluoride and other parameters reveal that Rampurhat-1 block is more worstly affected in comparison to Dubrajpur.**

Keywords**: Ground water quality, Fluoride concentration, related parameters, Dubrajpur and Rampurhat 1 block, Birbhum district, West Bengal, India.**

1. INTRODUCTION

Groundwater is the main source of drinking water and irrigation in rural West Bengal thus is the main source of geogenic fluoride entering our body. An estimated 62 million people of India are chronically exposed to fluoride rich groundwater[1]. Generally groundwater fluoride is introduced through rock-water interaction in the aquifers. The process of dissolution of fluoride from the rocks and soils and its enrichmentn in the ground water depends on interplay of many

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factors [2]. The amount of fluoride occurring naturally in ground water is governed principally by climate, composition of the host rocks and hydrogeology. Areas with a semi-arid climate, crystalline rocks and alkaline soils are mainly affected[3]. Endemic fluorosis has been reported from the Birbhum district of West Bengal since 1996. The occurrence of high concentration of fluoride from an artesian well due to leaching of locally concentrated villiaumite (NaF) minerals has been reported[4]. Birbhum district, West Bengal is mainly a rural area based on agriculture thus groundwater quality is mainly influenced by lithology. The present study was carried out in several villages in the Dubrajpur and Rampurhat-I block of Birbhum district in West Bengal to study the hydrogeochemistry of the ground water.

2. STUDY AREA

Location

Dubrajpur is a rural area located at 23°49′N 87°23′E 23.81°N 87.38°E and has an area of 342.71 km^2. It has an average elevation of 77 metres (252ft). The groundwater samples were collected from Elema (Chinpai), Bakreswar (Gohaliara) and Gopalnagar (LakshmiNarayanpur) villages. The Hotspring is located in Bakreswar. Rampurhat I is also a rural area of Birbhum district, West Bengal, India. The co-ordinates are 24^{0}04'14''N 87^{0}33'25''E having an area of 178.81Km^2. The groundwater samples were collected from Narayanpur, Asanjola, Madhabpur village of Narayanpur and Akhira, Chakaipur, Kusumba and Sandipur village of Kusumba panchayat.

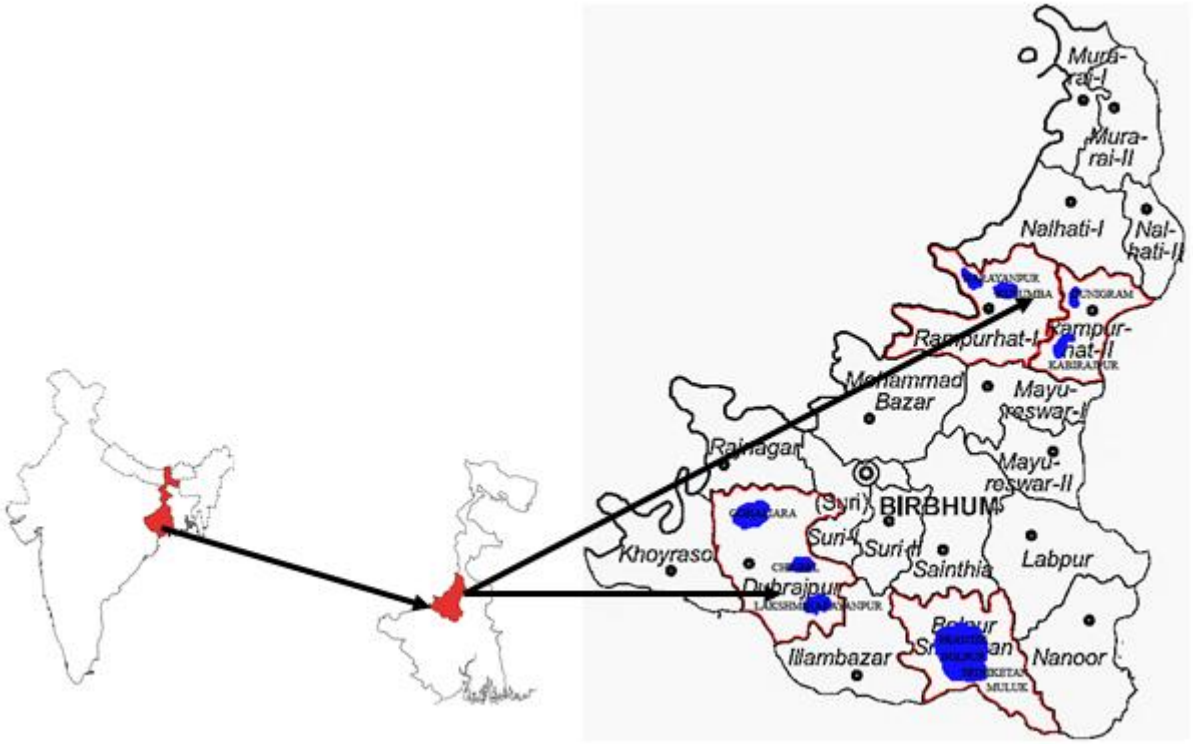

Fig 1: sketch of the study area within Birbhum district, West Bengal, showing the location of Dubrajpur and Rampurhat-1 Block

Population:

As per 2001 census, Dubrajpur block had a total population of 158,968, out of which 81,346 were males and 77,622 were females. Density of population is 464/Km^2. Tribal population numbered 8,358. Dubrajpur block registered a population growth of 17.07 % during the 1991-2001 decade. Decadal growth for Birbhum district was 17.88 %. Decadal growth in West Bengal was 17.84%. Rampurhat I block had a total population of 159,148, out of which 81,292 were males and 77,856 were females. Density of population is 890/Km^2. Tribal population numbered 20,825. During 1991 – 2001 decade population growth rate was 18.48%.

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Climate:

Dubrajpur and Rampurhat I blocks climatologically falls under the western semiarid belt of West Bengal. The summer is severe with an average temperature of 40^0C. During the month of May temperature shoots upto 48^0C. The average temperature is 10^0C in winter, but temperature as low as 6^0 C is also recorded. This area receives rainfall from mid June to September and sometimes upto October.

Geology of the study area

Dubrajpur block lies in the South western part of Birbhum district where crystalline metamorphic rocks of Archaean to Proterozoic age including amphibolite, hornblende schist, gabbro, granite gneiss and unclassified pegmatites forming the basement. The Gondwana supergroup overlying this basement, represented by thick piles of pelitic and psamitic sedimentary rocks containing coal seams belonging to Barakar, Barren measure, Raniganj and Dubrajpur Formations ranging from Permian to Jurassic in age. In Dubrajpur block Potential aquifers occur within 140 mbgl and thickness of aquifer increases towards east.

Rampurhat I block lies in the northwest part of Birbhum district. Gondwana overlain by Rajmahal trap (Basalt) occuring in the north and north western part. Rest of the district in north and central part is occupied by Laterite and Lateritic soil. In Rampurhat I block Basaltic rock exposed in most of the western part.

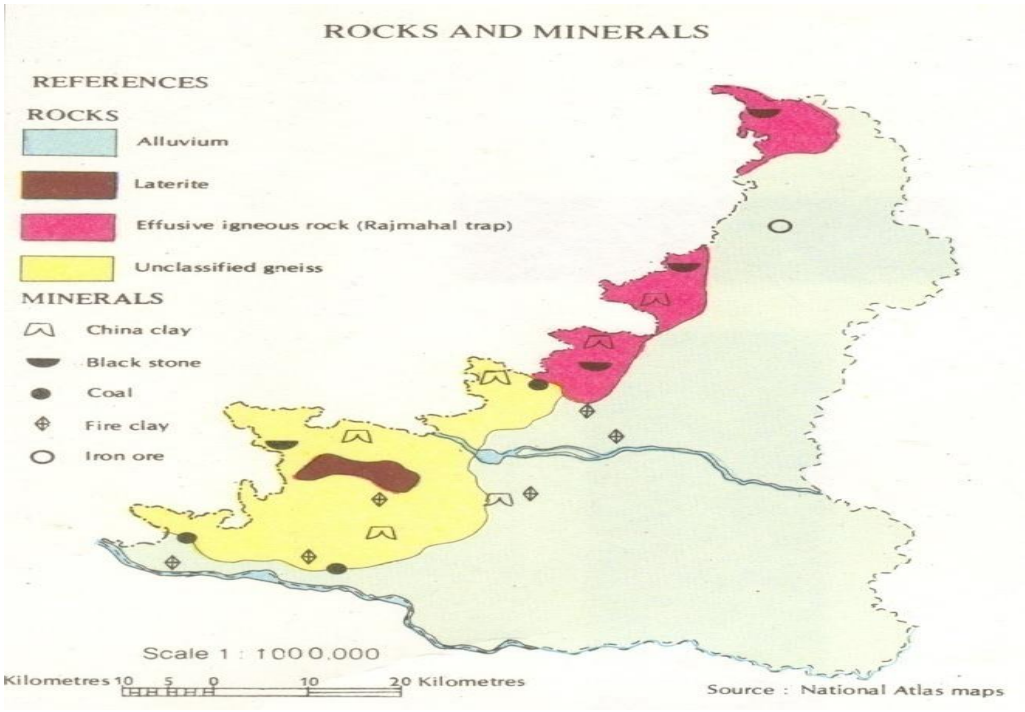

Fig 2: Geological Map of the study area

3. EXPERIMENTAL

In Dubrajpur block groundwater samples were collected from, 4 Hot spring locations, 11 deeptubewells, and 16 dugwells following the standard guidelines [5], [6] during November, 2011 and were analysed for various chemical parameters as described by APHA 1995. The location datas were recorded using GPS covering all the dugwells and deeptubewells of the selected villages. There was no shallow tubewell in the study area of Dubrajpur. From Rampurhat I block 31 deeptubewell and 32 shallow tubewell samples (total 63) were collected from Narayanpur, Asanjola, Madhabpur village under Narayanpur panchayat and Akhira, chakaipur, Kusumba and Sandipur village under Kusumba panchayat with GPS recording during February 2011. The sampling process was similar to Dubrajpur. The parameters include Temperature, pH, EC, Total hardness, TDS, cations like Ca^{2+}, Na^{+}, K^{+}, Mg^{2+} and anions like HCO_3^{-}, CO_3^{2-}, NO_3^{-}, PO_4^{3-}, SO_4^{2-}, Cl^{-}. Temperature, pH was measured in field pH meter and Orion ion selective electrode. EC, fluoride, chloride and nitrate was measured in Orion ion selective electrode (Model Meter 1119000). Ca^{2+}, Na^{+}, K^{+} was measured using ELICO CL 361 Flame Photometer. TDS was measured in SYSTRONICS–TDS meter (Type no. 308). HCO_3^{-}, $CO_3^{2}$was measured using

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titrimetric method. phosphate was measured by stannous chloride method and sulphate by turbidimetric method. Hardness and magnesium was estimated by standard methods recommended by APHA, 1995. SAR (Sodium adsorption ratio), RSC (Residual sodium carbonate) and %Na of all groundwater samples (except hotspring samples, as these are not used for irrigation purposes) was calculated using standard formula recommended by [7],[8],[9] respectively.

$SAR = Na^{+}/\{(Ca^{2+} + Mg^{2+}) \div 2\}^{1/2}$ [10]

$\% Na = (Na^{+}) \times 100/(Ca^{2+} + Mg^{2+} + Na^{+} + k^{+})$

$RSC = (HCO_3^{-} + CO_3^{2-}) - (Ca^{2+} + Mg^{2+})$

All the ionic concentrations are expressed in epm.

Correlation coefficients, mean and standard deviation of the chemical parameters were analysed statistically.

A piper trilinear diagram has been prepared for the study of hydrogeochemical facies.

4. RESULT AND DISCUSSION

The results of the physicochemical analysis of the groundwater samples of Dubrajpur, Rampurhat I are given in Table 12 and 13 respectively. In Table 1 and 2 the minimum and maximum concentration of major ions of the groundwater samples of Dubrajpur and Rampurhat I along with statistical summary and official safe limits for drinking water are given. The classification of water samples based on electrical conductivity recommended by WHO is given in Table 3, classification based on Total dissolved solid is given in Table 4. The classification of water samples on the basis of Total Hardness [11] is given in Table 5 and 6. List of samples having elevated parameters are given in Table 7. Classification of the groundwater samples based on % Na are given in Table 8, 9 and the list of Rampurhat I samples with elevated %Na, RSC and SAR values are given in Table 9.1. Statistical correlation coefficient of major ions of Dujrajpur, and Rampurhat I block groundwater samples (excluding the hotspring samples) are described in Table 10, 11. Table 1, 2, 12 and 13 shows that the physicochemical quality of groundwater varies noticeably among rural habitations of both the blocks. Several samples of both blocks exhibit elevated fluoride levels which was absent in Rampurhat II and Bolpur block [12], [13].

TABLE 1: STATISTICAL SUMMARY OF WATER SAMPLES OF DIFFERENT SOURCES OF DUBRAJPUR WITH OFFICIAL ACCEPTIBLE LIMITS

IONS	HOTSPRING SAMPLES(mg/l)				DUGWELL SAMPLES(mg/l)				DEEPTUBEWELL SAMPLES(mg/l)				max.acceptable Limits(WHO)
	MIN	MAX	mean	Std. deviation	MIN	MAX	mean	Std. deviation	MIN	MAX	mean	Std. deviation	
Na^{+}	123.5	157.08	142.34	16.604	2.6	55.9	16.156	16.79	3.1	92.6	17.927	26.7	20
K^{+}	3	5.6	4	1.116	0	283	95.009	105.428	5	262	33.09	76	20
Ca^{2+}	9.38	12.7	11.08	1.371	6.39	345.21	93.885	96.341	41.99	445.47	175.45	133.05	75
Mg^{2+}	0.21	0.61	0.48	0.183	0.59	10.2	2.904	2.564	0.48	17.01	5.15	5.99	50
CO_3^{2-}	4	30	17	13.9	0	28	2.573	7.18	0	24	9.45	9.678	350
HCO_3^{-}	116	140	127.5	9.848	30	470	169.37	138.09	62	576	244.18	145	384
SO_4^{2-}	17.033	27.03	23.268	4.6156	0.549	84.73	37.41	27.49	6.593	99.23	47.63	25.15	400
NO_3^{-}	1.18	3.67	2.5225	1.2406	4.3	25.8	13.62	7.18	6.5	26.4	14.18	7.23	10
PO_4^{3-}	0.115	0.207	0.1572	0.042	0.015	2.996	0.593	0.819	0.142	2.973	0.948	1.014	5
F^{-}	13.7	15.4	14.55	0.7047	0.101	1.84	0.488	0.428	0.309	3.45	1.394	1.014	1.5
Cl^{-}	102	109	106.5	3.3166	19.3	350	144.56	103.42	10.2	756	165.04	242.05	250
EC	621	691	668.25	32.097	238.5	1968	984	600.36	269	2068	969.72	706.75	300
TH	13.2	21.6	17.252	3.972	55	686.5	227.59	174.53	70.2	796	294.7	268.9	500
TDS	311.02	345	333.25	15.142	120	985	473.67	302.88	135	1260	482.23	354.02	1000
pH	7.01	8.04	7.667	0.48	5.65	7.21	6.51	0.43	6.66	7.61	7.054	0.352	6.5-8.5
temp.	41	78	53.25	16.76	24.8	25.4	25.09	0.185	24.8	25.5	25.118	0.121	

EC values are expressed in µS/cm, Temperature in ^{0}C. Rest of the parameters are expreesed in mg/l.

TABLE 2: STATISTICAL SUMMARY OF WATER SAMPLES OF DIFFERENT SOURCES OF RAMPURHAT-I

IONS	RAMPURHAT- I SAMPLES(mg/l)				max.acceptable limits(WHO)
	MIN	MAX	mean	Std.deviation	
Na^{+}	12.3	209.75	42.28	39.25	20
K^{+}	0	2.8	1.25	0.776	20

Ca^{2+}	10	184.75	87.4	41.09	75
Mg^{2+}	0.92	20.6	8.44	4.31	50
CO_3^{2-}	0	84	4.746	15.89	350
HCO_3^{2-}	172	442	293.5	57.5	384
SO_4^{2-}	0.22	129.7	12.25	19.88	400
NO_3^-	0	18.97	6.32	4.41	10
PO_4^{3-}	0.01	5.89	1.127	1.69	5
F^-	0.081	20.9	1.5	4.712	1.5
Cl^-	0.81	252	50.46	58.97	250
EC	516	2341	988.5	471.06	300
TH	15	630	240.95	134.29	500
TDS	268	1171	493.98	240.05	1000
pH	6.42	10.1	7.31	0.719	6.5-8.5
Temp.	24.5	27.1	25.458	0.94	

EC values are expressed in µS/cm, Temperature in ^{0}C. Rest of the parameters are expressed in mg/l

pH

In Dubrajpur samples the pH value ranged from 7.01 to 8.04 in hotspring samples indicating its alkaline nature, elevated pH may be due to plagioclase feldspar releasing sodium and calcium. In dugwell samples pH ranged from 5.65 to 7.21 and in deeptubewell samples it ranged between 6.66 to 7.61 (Table 1). According to WHO standard 25% dugwell samples are acidic (less than 6.5). In Rampurhat I samples the pH value was ranging from 6.42 to 10.1 indicating its highly alkaline nature in several samples and pH was found to be elevated in all fluoride contaminated samples. In 4 deeptubewell samples pH was above maximum permissible limit of 8.5 (Table 2).

Electrical conductivity

For drinking water 300 µS/cm is the permissible limit for EC and it was found to be elevated in all the hotspring samples, 81.25% dugwell and 91% deeptubewell samples (Table 1, 7) in Dubrajpur block. The results are given in Table 12. Among Rampurhat I groundwater samples Electrical conductivity was above 300 µS/cm in all the samples (100%), as shown in Table 2 and 13.

TABLE 3: CLASSIFICATION OF ALL GROUNDWATER SAMPLES BASED ON ELECTRICAL CONDUCTIVITY(WHO) FOR AGRICULTURAL PURPOSES

EC (µS/cm)	Classification	No. of Dubrajpur sample	No. of Rampurhat 1 sample
< 1500	Permissible	27(238.5- 1489 µS/cm)	55(516- 1389 µS/cm)
1500-3000	Not permissible	4(1855-2520 µS/cm)	8(1521- 2520 µS/cm)
>3000	Hazardous	nil	nil
Total sample		31	63

Classification of groundwater samples of Dubrajpur block for agricultural purposes based on Electrical conductivity (Table 3) shows that among total 31 samples 4 samples (DW3, DW16, DTW5 and DTW6) are not permissible. All the rest samples are within permissible limit. Among Rampurhat I samples 12.7% samples were not permissible for irrigation as EC was found to be ranging between 1521 to 2520 µS/cm.

TDS

Total dissolved solid was found to be elevated above 500mg/l, the maximum desirable limit for drinking water in 50% dugwell and 36.36% deeptubewell samples. The classification of groundwater of the study area based on TDS is given in Table 4, which shows among 31 samples of Dubrajpur 2 (DTW 5 and DTW6) fall under brackish water category (Table 7 and 12). Both the samples belongs to Gopalnagar Lakshmi.Narayanpur. Rest 29 samples belong to fresh water category.

Classification of groundwater samples of Rampurhat I block based on TDS showed that 7.94% samples fall under brackish category and rest of the samples were belonging to fresh water category (Table 4). Majority of the elevated TDS samples were belonging from Chakaipur village.

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TABLE 4: CLASSIFICATION OF GROUNDWATER BASED ON TOTAL DISSOLVED SOLID [14]

TDS(mg/l)	Classification	No. of Dubrajpur sample	No. of Rampurhat 1 sample
<1000	Fresh water	29(120- 985 mg/l)	58(259- 885 mg/l)
1000-10,000	Brackish	2(1033 -1260 mg/l	5(1006- 1260 mg/l)
10,000-100,000	Saline	Nil	Nil
>100,000	brine	nil	Nil
Total		31	63

Fluoride

Among all the Dubrajpur samples, fluoride was found to be elevated in 1 dugwell sample (DW1) located in Bakreshwar (Table 12). Fluoride was found to be elevated (above 1.5mg/l) in 100% hotspring samples and 54.54% deeptubewell samples (Table 12). The range is given in Table 1. Among the Rampurhat I samples high concentration of fluoride was observed in 4 deeptubewell samples (Asanjola DTW16, Asanjola DTW21, Madhabpur DTW23, Madhabpur DTW24) where fluoride concentration ranged between 16 mg/l to 20.9mg/l as showed in Table 13. Among the Narayanpur village samples 1 deeptubewell (NT8, primary school) and 1 shallowtubewell sample (Nt7) show elevated fluoride concentration, 1.3mg/l. Rest of the samples were within permissible limit. The overall fluoride concentration was found to be higher in Narayanpur, Asanjola and Madhabpur in comparison to Akhira, Chakaipur, Kusumba and Sandipur.

Total Hardness

Among Dubrajpur samples Hardness was found to be low in hotspring samples. Hardness above 500mg/l was found in 1dugwell (DW3) sample of Mukherjipara, Bakreshwar (Table 12) and 2 deeptubewell samples of Gopalnagar habitation, LakshmiNarayanpur (Table7). The classification of Dubrajpur groundwater samples based on hardness [11] is given in Table 5 which shows that 100% hotspring samples and 14.81% groundwater samples (dugwell and deeptubewell) fall under soft category. 33.34% groundwater samples were moderately hard. 22.23% samples were hard and 29.63% samples were found to be very hard. Among Rampurhat I samples the range of TH was 15 to 630 mg/l and it was found to be elevated above 500mg/l in 7.937% samples. TH was elevated above permissible limit(500mg/l) in all the Chakaipur samples and 1 Narayanpur sample(NT14). The classification of the collected samples based on hardness[11] is given in Table 6 which shows that among total 63 samples of Rampurhat I, 6.35% was soft, 12.7% moderate hard, 58.73% fall under hard category and 20.635% was very hard water samples.

TABLE 5: CLASSIFICATION OF DUBRAJPUR WATER BASED ON HARDNESS BY SAWYER & MC CARTHY

HARDNESS AS WATER CLASS ($CaCO_3$ in mg/l)		HOTSPRING SAMPLES	GROUNDWATER SAMPLES
0-75	Soft	4 samples	4 samples
75-150	Moderate hard	0 samples	9 samples (75 – 145mg/l)
150-300	Hard	0 samples	6 samples (167.7 - 269.91mg/l)
>300	Very hard	0 samples	8 samples (350 – 796 mg/l)

TABLE 6: CLASSIFICATION OF RAMPURHAT-I WATER BASED ON HARDNESS BY SAWYER & MC CARTHY

HARDNESS AS WATER CLASS $CaCO_3$(mg/l0		RAMPURHAT I SAMPLES
0-75	Soft	4 samples (15 – 70mg/l)
75-150	Moderate hard	8 samples (105 – 150mg/l)
150-300	Hard	37 samples (152 – 290mg/l)
>300	Very hard	13 samples (325 – 630mg/l)

Sulphate

No sample in Dubrajpur and Rampurhat I study area showed elevated sulphate. The obtained results are given in Table 12 and 13.

Phosphate

Phosphate concentration in all samples of Dubrajpur study area were within permissible limit (Table 12 and 13).

The permissible limit for PO_4^{3-} is 5mg/l(WHO) and among Rampurhat I samples it was found to be elevated in 7.936% (NT8, Nt6, MAT26, MAT27, MAT28) samples belonging to Narayanpur and Madhabpur village.

Magnesium

No sample in the study area showed elevated magnesium content. The obtained results are given in Table 12 and 13.

Chloride

Among Dubrajpur samples Chloride concentration above 250mg/l (permissible limit) was observed in 12.5% dugwell and 18.18% deeptubewell samples (Table1 and 12). No hotspring sample showed elevated Cl^-.

Chloride concentration above permissible limit was only observed in 2 deeptubewell samples of Rampurhat I block. Both the samples belongs to Chakaipur village.

TABLE 7: GROUNDWATER SAMPLES OF THE STUDY AREA EXCEEDING THE DESIRABLE LIMITS PRESCRIBED BY WHO FOR DOMESTIC PURPOSES

Water quality parameters	WHO 1997, desirable limits	No. of Dubrajpur samples exceeding desirable limits	No. of Rampurhat I samples exceeding desirable limits	Undesirable effects
pH	6.5-8.5	2samples below 6.5	4samples above 8.5 AsanT16,AsanT21,MadhabT23, MadhabT24	Taste
EC(µS/cm)	300	4H, 13D, 10DTW	All samples	
TDS(mg/l)	500	8D, 4DTW	9DTW, 8STW	Gastrointestinal irritation
TH(mg/l)	500	1D, 2DTW	3DTW, 2STW	
Na^+(mg/l)	20	4H, 6D, 3DTW	25DTW, 29STW	
K^+(mg/l)	20	8D, 1DTW	Nil	Bitter taste
Ca^{2+}(mg/l)	75	8D, 10DTW	18DTW, 17STW	Scale formation
Mg^{2+}(mg/l)	50	Nil	Nil	
CO_3^{2-}(mg/l)	350	Nil	Nil	
HCO_3^-(mg/l)	384	2D, 1DTW	4DTW, 1STW	
SO_4^{-2} (mg/l)	400	Nil	Nil	Laxative effects
NO_3^- (mg/l)	10	9D, 8DTW	5DTW, 8STW	Blue baby
PO_4^{3-} (mg/l)	5	Nil	4DTW, 1STW	
F^- (mg/l)	1.5	4H, 1D, 6DTW	4DTW	Fluorosis
Cl^- (mg/l)	250	2D, 2DTW	2DTW	Salty taste

H=hotspring sample, D=dugwell sample, DTW=deeptubewell sample, STW=shallowtubewell

Carbonate

CO_3^{-2} concentration in all the Dujrajpur samples were within permissible limit (Table1 and 12). CO_3^{-2} was mainly found to be present in those samples having elevated concentration of Fluoride. CO_3^{-2} concentration in all the Rampurhat I samples were within permissible limit (Table2 and 13). CO_3^{-2} was found to be present in those samples having elevated concentration of fluoride.

Bicarbonate

Among Dubrajpurpur samples HCO_3^- was found to be elevated in 12.5% dugwell and 9.09% deeptubewell samples (Table 7). It was found to be within permissible limit in all hotspring samples (Table 4, 12). Among Rampurhat I samples HCO_3^- was found to be above permissible limit of 384mg/l in 7.93% samples (Akhira t4, T19, T22, T25, T26).

Nitrate

Among Dubrajpur samples NO_3^- was elevated (above 10mg/l) in 56.25% dugwell and 72.73% deeptubewell samples which is may be due to agricultural activities. NO_3^- was within permissible limit in all hotspring samples. Among Rampurhat I samples NO_3^- was elevated above 10mg/l in 20.635% samples with respect to total number of samples.

Calcium

Among Dubrajpur samples Ca^{2+} was found to be elevated above 75mg/l in 91% deeptubewell and 50% dugwell samples and 0% hotspring samples (Table7). Among Rampurhat I samples calcium was found to be elevated in 58.06% deeptubewell samples and 53.125% shallow tubewell samples, i.e, 55.56% of the total samples. The calcium concentration was found to be lowest among the fluoride elevated samples of same habitations which indicates that fluoride concentration is negatively correlated with calcium. Perhaps fluoride binds with calcium through ion exchange.

Sodium

Among Dubrajpur samples Na^+ was found to be elevated in all the hotspring samples (Table 12). In 27.273% deeptubewell and 37.5% dugwell samples sodium was above the desirable limit, 20mg/l (Table7). Among Rampurhat I samples Na^+ was found to be maximum elevated in all the fluoride elevated samples. In 80.645% deeptubewell and 90.625% shallowtubewell samples (85.714% of total samples) sodium concentration was above 20mg/l. Perhaps fluoride tends to bind with Na^+ to form NaF having greater solubility.

Potassium

Among Dubrajpur samples Elevated potassium above desirable limit was observed in 50% dugwell and 9.09% deeptubewell samples. Elevated potassium is likely due to silicate minerals, orthoclase, microcline, hornblende, muscovite and biotite in metamorphic rocks and evaporate deposits. K^+ was within permissible limit in all hotspring samples. Potassium concentration in all samples of Rampurhat I study area was within permissible limit.

RSC (Residual Sodium Carbonate)

However HCO_3^- was found to be elevated above the permissible limit (384mg/l) in 2 dugwell and 1 deeptubewell samples but the RSC value was found to be less than 0.1meq/l indicating no bicarbonate hazard in the study area of Dubrajpur. Classification of Rampurhat I samples based on residual sodium carbonate showed that among total 63 samples, 9.523% samples were unsuitable as RSC value was found to be above 2.5meq/l and 2 samples (NT8 and NT5) were found to be doubtful. Rest of the samples were good. The list of the samples of Rampurhat I showing elevated RSC are listed in Table 9.1. The overall result indicates bicarbonate hazard in some habitation like Narayanpur, Madhabpur and Asanjola .

SAR (Sodium Adsorption Ratio)

Among Dubrajpur samples the range of SAR (sodium adsorption ratio) in dugwells was found to be between 0.217 to 2.14. In deeptubewell samples this range was found to be between 0.443 to 2.595, i.e, much below the permissible limit of 10. Only DW15 showed 2.14 and DTW9 showed 2.595. SAR value in rest of the samples were less than 1.

Among the Rampurhat I samples Asanjola T16 (14.003) and Madhabpur T24 (10.69) showed maximum SAR which is above the permissible limit of 10, indicating sodium hazard. Among the rest samples showing SAR value above 1 are listed in Table 9.1

% Na

% Na of the Dubrajpur samples are given in Table 8, which shows that all the samples are within permissible range. Only 1 deeptubewell sample is permissible i.e, 44.23% (DTW9 of Chinpai elema habitation) and only 1 dugwell sample is good, 22.964%(DW15 of Elema, Majhpara habitation). All the rest samples are excellent.

Classification of Rampurhat I samples based on %Na given in Table 9 shows that among total 63 samples 46.0317% are excellent, 41.27% samples fall under good category, 3.1746% are permissible, 4.762% samples are doubtful and 4.762% samples are unsuitable for irrigation purposes. All the samples showing elevated fluoride exhibit maximum % Na. The list of the samples of Rampurhat I showing elevated %Na is given in Table 9.1

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TABLE 8: IRRIGATION QUALITY OF DUBRAJPUR GROUNDWATER BASED ON % Na

% Na	CLASSIFICATION	NO. OF DUGWELL SAMPLES	NO. OF DEEPTUBEWELL SAMPLES
< 20	Excellent	15	10
20 - 40	Good	1(22.96%)	0
40 - 60	Permissible	0	1(44.23%)
60 - 80	Doubtful	0	0
> 80	Unsuitable	0	0

TABLE 9: IRRIGATION QUALITY OF RAMPURHAT I GROUNDWATER BASED ON % Na

% Na	**CLASSIFICATION**	**NO. OF RAMPURHAT I SAMPLES**
< 20	Excellent	29
20 - 40	Good	26(8 DTW, 18 STW)
40 - 60	Permissible	2(1 DTW, 1 STW)
60 - 80	Doubtful	3 (3 DTW)
> 80	Unsuitable	3 (3DTW)

TABLE 9.1: LIST OF RAMPURHAT I SAMPLES SHOWING ELEVATED %Na, RSC AND SAR

SAMPLE NUMBER	**% Na**	**RSC(meq/l)**	**SAR**
N T4	20.834	< 1	< 1
N T5	64.856	1.522	3.0245
N T6	21.644	< 1	< 1
N T8	48.602	1.914	< 1
N T9	25.17	< 1	< 1
N T10	37.166	< 1	< 1
N T14	16.257	< 1	< 1
Asanjola T16	*92.243*	*4.497*	*14.003*
Asanjola T17	64.262	*3.103*	3.765
Asanjola T19	20.79	< 1	< 1
Asanjola T20	20.975	< 1	< 1
Asanjola T21	*84.46*	*3.0675*	9.034
Asanjola T22	27.365	< 1	< 1
Madhabpur T23	71.502	*2.74*	5.8
Madhabpur T24	*85.8*	*5.447*	*10.69*
Madhabpur T26	16.402	< 1	< 1
Chakaipur T1	24.505	< 1	< 1
Chakaipur T2	21.447	< 1	< 1
N t1	24.13	< 1	< 1
N t2	22.16	< 1	< 1
N t3	22.47	< 1	< 1
N t5	18.147	< 1	< 1
N t7	56.477	*2.644*	2.992
N t8	32.73	0.842	< 1
N t9	34.33	0.913	< 1
N t10	24.026	< 1	< 1
N t11	24.438	< 1	< 1
N t12	23.083	< 1	< 1
N t13	19.802	< 1	< 1
N t14	38.276	< 1	< 1
Asanjola t15	20	< 1	< 1

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Akhira t2	17.54	< 1	< 1
Chakaipur t6	19.6	< 1	< 1
Kusumba t9	20.48	< 1	< 1
Kusumba t10	24.853	< 1	< 1
Sandipur t12	23.733	< 1	< 1
Sandipur t14	29.63	< 1	1.2002
Sandipur t15	28	< 1	< 1
Sandipur t16	25.25	< 1	< 1
Sandipur t17	25.065	< 1	< 1

N=Narayanpur village, T= deeptubewell, t= shallow tubewell

Ground water with a base exchange reaction in which the alkaline earths have been exchanged for Na^+ ions ($HCO_3^- > Ca^{2+} + Mg^{2+}$) may be referred to as base-exchanged-softened water, and those in which the Na^+ ions have been exchanged for the alkaline earths ($Ca^{2+} + Mg^{2+} > HCO_3^-$) may be referred to as base-exchanged-hardened water [15]. In the study area of Dubrajpur , in all the samples $Ca^{2+} + Mg^{2+} > HCO_3^-$ that means base-exchanged-hardened water.

TABLE 10: CORRELATION COEFFICIENTS OF THE CHEMICAL PARAMETERS OF GROUND WATER SAMPLES (DUGWELLS AND DEEPTUBEWELLS) OF DUBRAJPUR BLOCK

	pH	EC	TDS	F^-	TH	SO_4^-	Cl^-	CO_3^-	HCO_3^-	Mg^+	NO_3^-	Ca^+	Na^+	K^+	PO_4^-
pH	1	0.127	0.134	0.707	0.123	0.287	-0.013	0.579	0.336	0.1	0.304	0.257	0.032	-0.057	-0.194
EC		1	0.983	-0.195	0.908	0.698	0.926	-0.141	0.805	0.806	0.496	0.833	-0.048	0.625	0.348
TDS			1	-0.184	0.914	0.69	0.916	-0.146	0.808	0.815	0.461	0.851	-0.114	0.569	0.364
F^-				1	-0.196	0.065	-0.287	0.677	-0.0007	-0.172	0.083	-0.041	-0.047	-0.22	-0.166
TH					1	0.591	0.885	-0.142	0.898	0.943	0.523	0.967	-0.027	0.277	0.49
SO_4^-						1	0.538	0.0.0003	0.607	0.491	0.195	0.605	-0.169	0.408	0.18
Cl^-							1	-0.284	0.679	0.881	0.416	0.808	0.022	0.589	0.413
CO_3^-								1	0.199	-0.18	0.302	0.013	-0.071	-0.113	-0.247
HCO_3^-									1	0.8029	0.595	0.927	-0.04	0.18	0.341
Mg^+										1	0.461	0.933	0.095	0.182	0.475
NO_3^-											1	0.531	0.162	0.182	0.0799
Ca^+												1	-0.056	0.14	0.466
Na^+													1	-0.029	-0.095
K^+														1	-0.018
PO_4^-															1

Among the Rampurhat I groundwater samples 34% samples were base-exchanged-softened water ($HCO_3^- > Ca^{2+} + Mg^{2+}$) and the rest samples were base-exchanged-hardened water ($Ca^{2+} + Mg^{2+} > HCO_3^-$). This base-exchanged-softened water samples were observed in Narayanpur, Asanjola, Madhabpur, Akhira, Kusumba and Sandipur villages of the study area.

TABLE 11: CORRELATION COEFFICIENTS OF THE CHEMICAL PARAMETERS OF GROUND WATER SAMPLES (DUGWELLS AND DEEPTUBEWELLS) OF RAMPURHAT I BLOCK

	pH	EC	TDS	F^-	TH	NO_3^-	SO_4^-	PO_4^-	Ca^+	Na^+	K^+	Mg^+	Cl^-	HCO_3^-	CO_3^-
pH	1	-0.357	-0.35	0.935	-0.454	-0.072	-0.063	0.069	-0.44	0.883	0.225	-0.52	0.014	-0.4	0.92
EC		1	0.99	-0.23	0.88	0.099	0.159	-0.175	0.706	-0.115	0.053	0.79	0.759	0.455	-0.25
TDS			1	-0.23	0.887	0.1	0.16	-0.176	0.7	-0.11	0.051	0.792	0.757	0.452	-0.25
F^-				1	-0.38	-0.093	-0.11	0.081	-0.377	0.902	0.267	-0.464	0.086	-0.347	0.963
TH					1	0.174	0.197	-0.125	0.728	-0.267	0.054	0.822	0.724	0.416	-0.404
NO_3^-						1	0.038	-0.107	0.13	-0.139	-0.292	0.202	0.221	0.231	-0.118
SO_4^-							1	-0.134	0.215	0.02	-0.196	0.313	0.186	-0.07	-0.097
PO_4^-								1	0.0177	0.03	0.247	-0.293	-0.112	0.147	0.123
Ca^+									1	-0.348	0.238	0.5	0.713	0.743	-0.423
Na^+										1	0.177	-0.292	0.212	-0.29	0.935
K^+											1	-0.28	0.077	0.517	0.2
Mg^+												1	0.59	0.189	-0.454
Cl^-													1	0.294	0.056
HCO_3^-														1	-0.352
CO_3^-															1

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HYDROCHEMICAL FACIES

The piper diagrams showing the hydrogeochemical facies of groundwater of Dubrajpur, Rampurhat I, blocks are given as Fig.3 and 4 respectively.

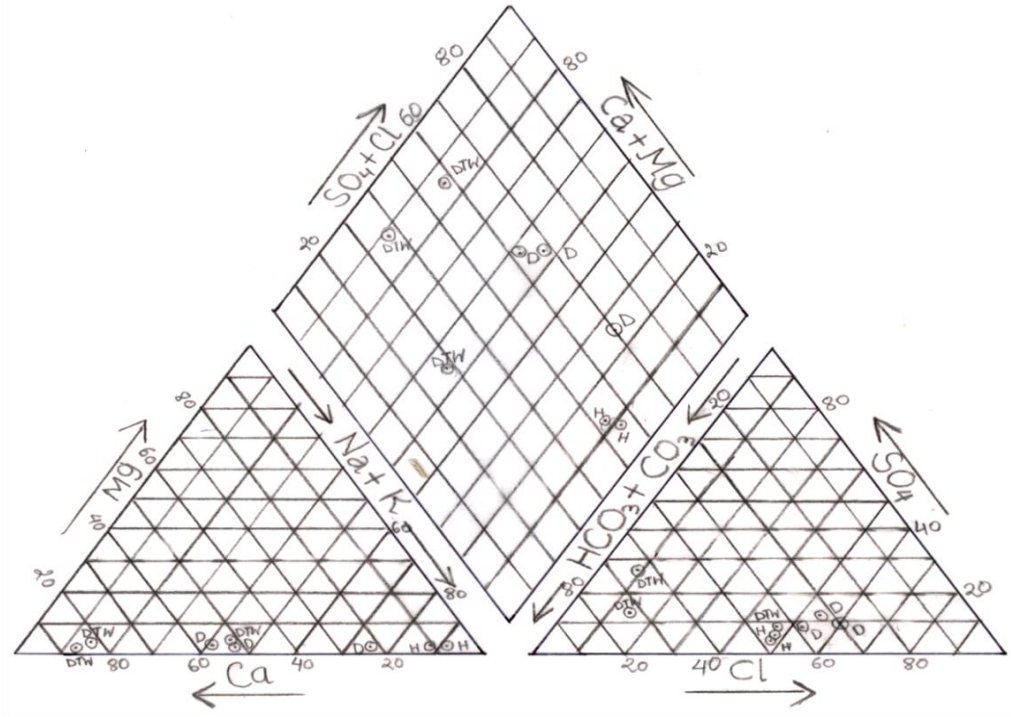

Fig 3: Piper diagram showing the hydrogeochemical facies of Dubrajpur block (H= hotspring sample; DTW=deeptubewell; D=dugwell samples

Fig 3 shows that in Dubrajpur block, the groundwater (dugwell and deeptubewell) is mixed type. The Hotspring samples are HCO_3+ CO_3 type.

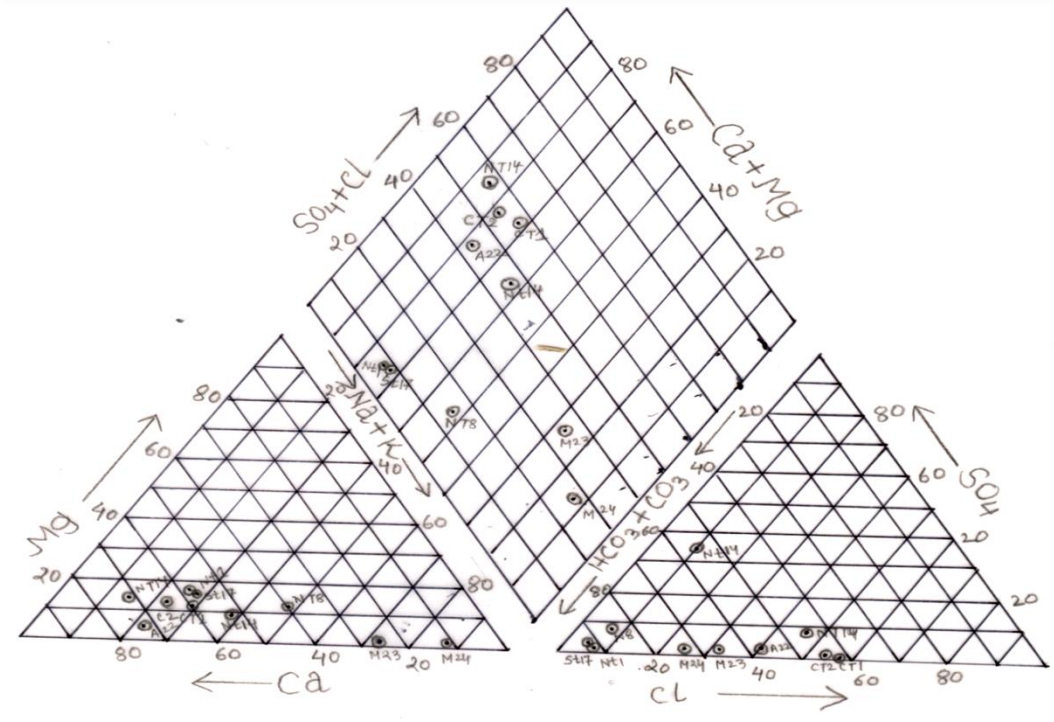

Fig 4: Piper diagram showing the hydrogeochemical facies of Rampurhat I block (T=deeptubewell; t=shallowtubewell samples)

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Fig 4 shows that in Rampurhat I block the fluoride elevated samples are HCO_3+ CO_3 type. Other samples (F^- within permissible limit) are SO_4+ Cl type.

The chief sources of fluoride ion in the natural waters are fluorite, fluoroapatite as well as fluoride replacing hydroxyl in the ferromagnesium silicates. However, the degree of weathering and the amount of leachable fluoride in a terrain is more important in deciding the fluoride content of waters rather than the mere presence of fluoride bearing minerals in rocks or soils [16]. High fluoride and low Calcium in water may be due to prior precipitation of CaCO3 from water with limited incorporation of F- in CaCO3 structure. During the process of chemical weathering, sodium is released into the ground Water which might have replaced by calcium in cation exchange reactions. With increasing concentration of sodium the solubility of fluorite in water also increases [17]. In acidic medium, fluoride is absorbed in clay whereas high pH, alkalinity (CO_3^{-2}) favours the leaching of fluoride from the rocks. Thus, the availability of fluoride in leachable state in soil is more important in deciding the fluoride in water rather than presence of fluoride bearing minerals.

In overall the obtained result indicates that not only fluoride several other parameters are elevated in both the study as per the standard guidelines [18], [19].

TABLE 12: WATER QUALITY PARAMETERS OF DUBRAJPUR BLOCK, BIRBHUM

Samples	pH	TEMP	EC	TDS	F-	Hardness	SO_4^-	Cl^-	CO_3^-	HCO_3^-	Mg^{2+}	NO_3^-	Ca^{2+}	Na^+	K^+	$PO^3{}_4^-$
HS		(^{0}C)	(µs/cm)	(mg/l)	(mg/l)	(mg/l)	(mg/l)	(mg/l)	(mg/l)	(mg/l)	(mg/l)	(mg/l)	(mg/l)	(mg/l)	(mg/l)	(mg/l)
GBH1	7.61	48	685	339	15.4	21.6	22.527	102	6	128	0.58	1.18	9.38	133.3	5.6	0.13
GBH2	8.01	41	691	345	14.4	20.1	27.03	106	28	140	0.61	3.67	11.37	157.08	3.7	0.207
GBH3	8.04	46	676	338	14.7	15.2	26.483	109	4	126	0.21	1.76	10.87	155.5	3.7	0.115
GBH4	7.01	78	621	311.02	13.7	13.2	17.033	109	30	116	0.52	3.48	12.7	123.5	3	0.177
DW																
GBDW1	7.21	25	1359	681.1	1.84	470	46.374	198	8	332	7.41	21.7	235.5	12.4	10.2	0.338
MBDW2	6.68	25	1489	745	0.225	368.2	64.176	179	28	430	3.21	22.1	194	3	186	0.251
MBDW3	6.59	25.4	1968	985	0.303	686.5	84.73	275	0	470	10.2	21.9	345.21	3.7	0	2.996
CEDW4	6.62	25.1	587	293.7	0.564	145	23.736	91.1	0	70	1.61	7.87	78.2	6.1	2.7	0.142
CEDW5	5.72	24.8	288.5	144.25	0.144	55	5.824	16.5	0	64	0.74	12.3	6.39	33.3	2.8	1.85
CEDW6	5.81	25.2	254	128	0.537	75	0.549	20	0	72	0.62	8.95	25.9	3.2	6.1	1.05
CEDW7	6.54	25.4	238.5	120	0.101	48.6	1.758	19.3	0	30	0.59	11.8	13	4.6	7.4	0.246
CEDW8	6.61	24.9	340	170	0.102	102.5	12.97	34.5	0	78	2.16	9.02	9.8	27.7	31.45	0.1
CEDW9	6.42	25.2	417	209	0.198	121.3	19.89	54.5	0	80	2.02	12.1	26.5	33.5	5.5	0.188
MEDW10	5.65	25.2	488	244	0.123	98.4	7.802	75.2	0	28	1.89	4.3	18.9	31.9	13	0.015
MEDW11	6.84	25	1076	539	0.444	167.7	38.57	143	0	82	1.18	6.1	44.76	2.9	152	1.296
MEDW12	6.59	25.2	1343	671.5	0.525	208.5	64.505	207	0	200	2.61	5.42	107.08	2.6	192	0.162
MEDW13	6.85	25	1440	720.1	0.637	251.1	66.593	230	0	188	2.72	7.89	79.08	3.4	247	0.227
MEDW14	6.87	25.1	1415	707.7	0.614	269.91	46.593	241	0	170	3.02	25.8	108	31.4	163	0.138
MEDW15	6.61	24.8	1186	293	0.639	189.65	44.396	179	6	168	2.16	19.7	48.2	55.9	218	0.335
MEDW16	6.56	25.3	1855	927.51	0.822	384.1	70.109	350	0	248	4.33	21.1	161.65	2.9	283	0.165
DTW																
MBDTW1	6.97	24.9	786	363.2	0.757	250	43.297	101	14	212	3.52	19.04	177.6	10.8	7.8	0.319
BLnDTW2	7.61	25	526	263	2.14	126.5	6.593	19.4	22	230	1.56	26.4	105.56	6.1	2.7	0.142
BLnDTW3	6.74	24.8	1064	532	0.535	350	44.945	179	0	232	5.45	11.03	182.96	4.8	5	0.2
BLnDTW4	6.98	25.1	1137	569	0.901	405	37.912	152	4	352	3.62	6.5	209.4	5.5	8	1.927
GLnDTW5	6.59	25.2	2520	1260	0.425	789	59.45	756	0	380	17.01	18.3	402.47	23.5	262	2.973
GLnDTW6	6.92	25.3	2068	1033	0.309	796	77.912	495	0	576	16.86	24.6	445.47	35	13.2	1.173
CEDTW7	7.45	25.5	591	295.5	2.67	120	31.978	20.3	24	220	2.94	9.81	102	3.4	14.9	0.116
CEDTW8	6.89	25.2	566	283.2	1.12	105	99.23	43.2	2	120	2.01	3.04	89.45	8.3	17.5	0.338
CEDTW9	7.54	25.3	591	296	1.89	135	30.44	26.3	12	184	2.56	13.7	92.37	92.6	10.2	0.292
MEDTW10	6.66	24.9	269	135	1.14	70.2	34.725	13.1	4	62	0.65	10.92	41.99	4.1	8.8	2.35
MEDTW11	7.25	25.1	549	274.7	3.45	95.1	57.5	10.2	22	118	0.48	12.7	80.71	3.1	13.9	0.6

GB= Gohaliara, Bakreshwar; MB=Mukherjipara, Bakreswar; CE=Chinpai, Elema; ME=Majhpara, Elema; BLn= Belbuni, Lakshminarayanpur; GLn= Gopalnagar, LN pur : DW=Dugwell sample; DTW= Deeptubewell sample; HS= Hotspring sample

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TABLE 13: WATER QUALITY PARAMETERS OF RAMPURHAT-I BLOCK, BIRBHUM

sample	Temp	PH	F^-	EC	TDS	Cl^-	TH	Mg^{2+}	HCO_3^-	SO_4^-	NO_3^-	PO_4^-	Ca^{2+}	Na^+	K^+	CO_3^{2-}
DTW	(^{0} C)		(mg/l)	(µs/cm)	(mg/l)	(mg/l)	(mg/l)	(mg/l)	(mg/l)	(mg/l)	(mg/l)	(mg/l)	(mg/l)	(mg/l)	(mg/l)	(mg/l)
NT1	24.9	7.38	0.154	876	438	10	152	8.5	280	21.21	2.63	0.028	74.71	21.3	0.4	0
NT2	24.8	6.99	0.112	896	448	42	235	8	240	45.93	3.15	0.69	93.98	18.4	0.2	0
NT3	25	6.85	0.138	846	423	110	185	8.5	280	25.83	13.04	0.079	144.0	12.3	1.1	0
NT4	24.7	6.83	0.081	829	415	15	175	6.8	260	7.7	11.74	3.1	69.97	24.6	0.6	0
NT5	25	7.29	0.145	774	388	15	185	8.5	172	20.99	4.15	0.075	11.9	56.0	0.9	0
NT6	24.9	7.36	0.245	802	402	25	205	7.2	270	5.83	3.23	0.29	71.6	26.5	0.3	0
NT7	25	7.09	0.209	793	397	40	210	9.72	284	6.27	14.23	0.62	87.8	22.8	0	0
NT8	24.8	7.4	1.3	814	407	15	105	8.5	270	18.9	3.34	5.1	49.68	69.2	0.2	20
NT9	24.7	7.61	0.197	854	427	35	235	8.5	240	12.30	8.37	0.02	65.04	30.8	1.5	0
NT10	24.9	7.11	0.159	771	386	20	195	12.15	220	11.76	6.74	0.24	37.05	38.8	0.2	0
NT11	24.7	7	0.191	889	445	45	265	7.3	280	16.38	3.78	0.78	97.03	19.2	0.7	0
NT12	24.5	6.99	0.108	1521	761	90	410	14.59	300	65.83	4.93	0.31	134.4	22.6	1.2	0
NT13	24.9	7.19	0.046	1768	885	105	470	12.15	300	37.7	14	0.025	138.7	21.8	0.8	0
NT14	24.8	7.05	0.113	2012	1006	210	501	19.44	360	46.26	16.37	0.009	186.5	48.8	1.1	0
NT15	24.5	7.35	0.122	652	326	55	120	7.52	270	11.21	8.45	0.026	89.6	28.6	0.7	0
AST16	24.9	9.49	16	534	269	12	15	1.4	200	13.73	0	0.035	10.0	178.3	1.5	55
AST17	24.9	7.79	0.803	634	317	15	115	7.3	300	15.60	1.74	0.01	31	89.68	0.8	10
AST18	24.7	7.04	0.344	716	359	0.81	105	4.16	340	0.33	5.12	3.21	90.76	20.1	2.3	0
AST19	24.9	7.08	0.298	801	401	21.2	245	7.1	400	1.65	4.15	2.3	103.2	35.1	3.1	0
AST20	24.8	6.95	0.322	1389	695	0.02	424	14.77	320	0.22	4.48	2.58	62.7	26.9	2.4	0
AST21	24.7	10.0	20.8	836	419	85.1	70	0.92	180	2.75	4.1	1.54	24.5	167.3	1.6	60
AST22	24.9	7.49	0.869	1578	769	179	345	8.02	440	12.2	3.23	1.29	184.7	62.5	2.2	0
MAT23	24.7	10.1	19.61	535	268	91.2	56	0.96	220	2.75	8.12	1.91	49.00	150	2.7	50
MAT24	24.9	9.82	20.9	516	259	85.7	50	0.891	250	1.11	7.37	2.34	27.6	209.7	2.2	84
MAT25	25.2	7.21	0.589	1187	594	158	325	7.5	440	7.37	1.07	3.95	194.9	36.3	2.8	0
MAT26	24.9	7.31	0.372	1211	606	50	389	4.8	442	0.77	5.15	5.2	139.7	33.7	4	0
MAT27	24.9	7.03	0.623	661	332	10	175	3.6	330	0.33	2.45	5.25	97.00	17.3	1.8	0
MAT28	25.1	6.92	0.254	731	366	8.02	215	4.13	320	1.12	3.61	5.89	91.53	18.3	1.9	0
MAT29	24.7	6.96	0.569	676	339	10	210	3.11	300	0.82	2.23	2.89	90.15	13.4	1.4	0
CHT30	26.9	6.75	0.066	2341	1171	250	630	20.6	310	0.88	6.79	0.056	151.06	69.1	1.1	0
CHT31	26.7	6.8	0.11	2096	1048	252	595	19.45	345	3.31	6.24	0.051	171.18	63.8	0.9	0
STW																
N-t1	24.9	7.16	0.075	692	347	10	150	7.3	210	0.88	14.23	0.27	48.03	22.1	1	0
N-t2	24.8	7.19	0.083	708	355	12	156	7.2	250	2.75	14.07	0.21	61.52	24.1	0.8	0
N-t3	24.8	7.25	0.092	693	347	11	161	6.8	200	13.96	16.3	2.96	54.1	21.9	1.1	0
N-t4	25.3	7.2	0.111	1016	508	64	290	9.72	290	17.69	11.04	0.69	107.7	21.6	0.7	0
N-t5	24.9	7.11	0.165	1008	504	52	250	8.5	284	9.45	11.52	2.63	94.69	26.7	0.4	0
N-t6	24.8	7.19	0.117	1012	507	60	256	9.7	260	28.8	6.8	6.2	100.13	24.5	0.2	0
N-t7	25	8.01	1.3	742	372	20	161	4.86	280	3.08	0.93	2.74	44.33	78.6	0.9	20
N-t8	25.1	6.99	0.217	531	266	20	180	8.5	264	5.72	10.37	0.24	55.83	39.1	0.4	0
N-t9	25	6.93	0.148	672	336	15	176	10.94	248	6.043	5.15	3.11	45.12	37.9	0.1	0
N-t10	24.9	7.61	0.115	637	319	10	185	10.15	222	6.703	4.93	0.025	45.78	22.9	1.2	0
N-t11	24.5	7.65	0.146	757	379	65	260	8.5	260	6.813	13.3	0.64	83.64	36.4	0.9	0
N-t12	24.8	7.27	0.201	769	385	20	185	8.5	280	7.143	4.7	0.64	68.79	28.7	1.1	0
N-t13	24.8	7.44	0.106	1072	536	115	454	10.37	286	21.32	18.97	0.08	122.2	39.6	1	0
N-t14	24.8	7.39	0.164	605	303	30	200	9.74	284	129.7	1.93	0.08	88.71	75	1.3	0
As-t15	24.9	7.41	0.182	882	442	80	425	10.16	230	5.95	3.45	0.021	82.36	28.5	1.2	0
AKH t16	27.1	6.95	0.26	819	410	11	240	9.72	302	0.33	1.04	0.03	73.63	17.9	1.8	0
AKH t17	26.8	6.93	0.24	817	409	10	228	3.65	300	0.22	2.6	0.035	79.9	21.2	1.9	0
AKH t18	26.6	6.85	0.326	1248	624	59.9	278	9.7	360	11	0.92	0.036	119.5	24.1	1.6	0
AKH t19	27	7.1	0.377	1369	685	60.1	285	12.10	384	18.7	1.15	0.028	130.6	19.5	2.2	0
AKH t20	26.9	7.01	0.293	909	455	30	211	8.49	320	0.44	3.14	0.042	89.2	22.4	1.7	0
CH t21	26.7	6.42	0.24	2011	1006	130	512	16.19	300	24.7	6.17	0.05	121.1	41.5	1.2	0
CH t22	26.8	6.77	0.21	2520	1260	128	571	19.1	340	22.9	6.71	0.052	130	38.9	1.1	0
K t23	26.7	7.16	0.373	883	442	10	148	3.61	310	0.81	5.6	0.034	86.9	18.3	2.3	0
K t24	26.8	6.93	0.345	869	435	12	136	4.95	290	1.01	7.12	0.038	74.68	24.7	1.5	0
K t25	27	7.13	0.317	844	423	11	150	4.86	320	0.52	6.52	0.025	77.09	32.5	1.1	0
K t26	27	7.05	0.375	994	498	10	250	6.07	360	0.22	5.9	0.032	126.31	28.4	1.2	0
S t27	26.9	7.11	0.403	951	476	10	206	7.63	320	0.76	6.11	0.035	73.47	30.9	1	0
S t28	26.6	7.15	0.378	973	487	12	208	8.02	340	0.78	3.89	0.024	83.29	26.7	1.3	0
S t29	27	7.12	0.384	987	494	11	110	4.86	324	1.01	4.8	0.041	72.48	39.1	0.9	0
S t30	27	7.05	0.391	936	469	10	170	7.3	320	0.33	6.31	0.022	69.03	36.4	1.1	0
S t31	26.8	6.94	0.318	875	438	10	180	8.51	300	2.2	5.8	0.042	65.81	31.1	0.8	0
S t32	27	6.92	0.307	883	442	10	196	10.13	290	1.1	2.76	0.032	59.57	29.5	1.2	0

DTW= deeptubewell samples: STW= shallowtubewell samples; AS=Asanjola; CH= Chakaipur; K= Kusumba; S= Sandipur; AKH=Akhira; N= Narayanpur; MA= Madhabpur.

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