

Geogenic Fluoride Contamination in Two Diverse Geological Settings in West Bengal

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Abstract Fluoride contamination in groundwater has been studied in two important geological settings of West Bengal, viz. (i) alluvium of Rampurhat–Nalhati area of Birbhum district, and (ii) consolidated formation of Barabazar block of Purulia district. Rampurhat–Nalhati area in Birbhum district is located in ‘basin margin’ area represented by Tertiary sediments overlain by Quaternary deposits. A two aquifer system exists in the area: (i) shallow aquifer in the Pleistocene Older Alluvium in Quaternaries, and (ii) deeper aquifer within the Tertiary sediments. The shallow aquifer has high groundwater potentiality with low fluoride content, while the deeper aquifer system is characterized by comparatively low yield and high fluoride concentration. Maximum concentration of fluoride of 10.7 mg/L has been encountered at Junudpur in Birbhum district. At places, only one continuous aquifer system exists where the groundwater potentiality is high with low fluoride content. The fluoride content of groundwater has, in general, an inverse relationship with calcium and magnesium content and positive relationship with sodium concentration. Barabazar block in Purulia district is situated in the eastern fringe of Chhotanagpur Gneissic Complex, occupied mostly by meta-sedimentaries and a few thin linear patches of alluvium along narrow courses of stream. Groundwater prospect is better in northern parts underlain by gneissic rocks than in the south, which is mainly underlain by phyllites and schists. No relationship could be established between the fluoride content of groundwater with the concentrations of bicarbonate, calcium and sodium. Groundwater is generally potable, except at places near ‘south shear zone’, where groundwater with high concentration of fluoride and iron has been encountered. The concentration of fluoride increases with depth as well as in proximity to shear zone. In both cases, fluoride concentration in groundwater increases with depth.

Keywords Rampurhat–Nalhati · Barabazar · Purulia south shear zone
Aquifer

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1 Introduction

Fluoride is essential for human beings. Drinking water is one of the major pathways for ingestion of fluoride in human body. Fluoride in drinking waters might help prevent tooth decay if the level of fluoride intake is within the permissible limit of 0.5 and 1.5 mg/L (WHO 2004). Considering the climatic condition and other related factors, Bureau of Indian Standards has prescribed 1 and 1.50 mg/L as desirable and permissible limits of fluoride, respectively, for drinking water. Excessive intake of fluoride causes fluorosis, which may lead to serious health hazards. Around 200 million people from 25 nations have health risks because of high fluoride in groundwater (Ayoob and Gupta 2006). Most of the people affected by high fluoride concentration in groundwater live in the tropical countries where the per capita consumption of water is more because of the prevailing climate (Brindha and Elango 2011).

Due to consumption of fluoride-contaminated water in many parts of India, villagers have been found to be suffering from dental, skeletal and non-skeletal fluorosis and various other morphological deformities, and even permanent crippling. Sporadic higher concentrations of fluoride have been reported in groundwater in many parts of the country in both consolidated and unconsolidated deposits. Dental fluorosis is endemic in 14 states and 150,000 villages in India with the problem most pronounced in the states of Andhra Pradesh, Bihar, Gujarat, Madhya Pradesh, Punjab, Rajasthan, Tamil Nadu and Uttar Pradesh (Pillai and Stanley 2002).

Fluoride contamination of groundwater in West Bengal was first detected during 1997 in Nalhati I block in Birbhum district. The occurrence of fluoride in groundwater beyond 1.50 mg/L is in a rather sporadic manner than following a definite pattern in 43 blocks in seven districts in West Bengal. In Purulia district, out of a total 20 blocks, 17 are fluoride infested where out of a total 3304 habitations, 233 are in risk zone. In Birbhum district out of a total 19, seven blocks, viz. Nalhati I, Rampurhat I, Mayureswar I, Sainthia, Siuri II, Rajnagar and Khayrasol have been reported to be fluoride affected by 'Fluoride Task Force', set up by Govt. of West Bengal; in this district, 134 out of a total of 1493 habitations are in the risk zone of fluoride infestation.

In present paper, geogenic fluoride contamination in groundwater has been dealt in two diverse geologic settings: (a) in parts of Rampurhat–Nalhati area of Birbhum district, and (b) in Barabazar block of Purulia district.

Rampurhat–Nalhati area of Birbhum district lies in the north-western part of West Bengal; it represents the marginal part of the 'Bengal Basin' and is fluoride infested (PHE Directorate, Govt. of West Bengal 2008). This terrain is flat and mainly covered by alluvium. Normal annual rainfall is 1601 mm; but, the area faces shortage of drinking water due to topographic undulation and sporadic poor quality of its groundwater due to high fluoride concentration in it.

Barabazar block is situated in the south-eastern part of Purulia district. It covers an area of 418.06 km² and falls in the eastern fringe of Chhotanagpur Gneissic Complex. Barabazar is characterized by undulating topography with denudation

hills, mostly in the southern part, the maximum elevation of which is 331 m above mean sea level (amsl). The present area has a subtropical climate with annual rainfall varying within 1100–1500 mm. Topographic characteristics, hard formation with poor aquifer and erratic rainfall create drought situation.

2 Materials and Methodology

The present study has been carried out in two field seasons. Exploration by rotary rigs in Rampurhat–Nalhati area of Birbhum district has been carried out primarily for delineation of aquifers based on lithological and their characteristics, e.g. ground-water potentiality, its quality including fluoride. The target of exploration by this rotary rig is fixed to 225 m. Electrical logging in boreholes by UPTRON logger has been conducted at three sites, viz. Margram, Tarapur and Nowapara. By e-logging, continuous array of resistivity data, both long-normal (64") and short-normal (16"), and spontaneous potential data of formations in down-log and up-log have been recorded. Clean drill-cutting samples of individual borehole have been kept at 3 m interval and after study of those samples, litho-logs have been prepared. These litho-logs have been compared with respective e-logs; after through correlation, delineation of aquifers in the present area has been made. Then, design of shallow and deep tube wells tapping shallow aquifer and deep aquifer, respectively, has been recommended at different site. After construction of tube wells at different locations, yield tests of tube wells are conducted and water samples from exploratory tube wells are collected for chemical analysis. As the number of exploration is limited in the area, a few other hand pump-fitted and submersible pump-fitted tube wells in and around the Rampurhat–Nalhati area have also been inventoried and water samples from these wells have also been collected for laboratory analysis.

At two places, viz. Margram and Tarapur, both in Rampurhat II block, two-aquifer system occurs; so, tube wells tapping deeper and shallow aquifers, respectively, have been constructed. In Nalhati II block, only one aquifer exists. Groundwater samples collected from deep, shallow and single continuous, from exploratory and other private and government wells representing deep/shallow/single aquifer, are analysed in the laboratory of Central Ground Water Board. Selected drill-cut litho-samples have been sent to Geological Survey of India; those samples are powdered and analysed in their chemical laboratory for determination of F-content in those drill-cut samples.

In other field season, hydrogeological investigation has been carried out in fluoride infested parts of Purulia district. Investigations have been conducted both in pre-monsoon and post-monsoon. Sampling has been done following the standard procedure (Central Ground Water Board, Lucknow 1996). Attention was given to collect fresh samples from open wells and hand pump-fitted tube wells so that the samples collected represented the quality of groundwater in the aquifer concerned.

Groundwater samples have been analysed following standard methods (American Public Health association 2012) in the laboratory of Central Ground

Water Board, Kolkata. pH and electrical conductivity in groundwater have been measured, respectively, by potentiometric method using pH metre and electrometric method by a conductivity metre. Among major ions, carbonate (CO_3^{2-}) and bicarbonate (HCO_3^-) in groundwater have been analysed by acid–base titration using H_2SO_4 , and chloride (Cl^-) by titrimetric method using AgNO_3 . UV-spectrophotometer has been used for determination of nitrate (NO_3^-); turbidimetric and molybdophosphoric acid methods by spectrophotometer have been applied, respectively, for determination of sulphate (SO_4^{2-}) and phosphate (PO_4^{3-}) ions. Spectrophotometer has also been used by eriochrome cyanin R as reagent (SPADNS method) for determination of fluoride (F^-) content and ammonium molybdate as reagent for SiO_2 in groundwater. EDTA-titrimetric method has been applied for determination of total hardness (TH), calcium (Ca^{2+}) and magnesium (Mg^{2+}) in water, whereas both sodium (Na^+) and potassium (K^+) in it have been analysed using flame emission method by flame photometer. For determination of total iron, spectrophotometry method has been carried out by using 1,10-phenanthroline as reagent.

3 Rampurhat–Nalhati Area, Birbhum District

Exploration has been carried out at four places: viz. (i) Margram ($24^\circ 09' 02''$; $87^\circ 51' 54''$), about 6 km ESE of Rampurhat, (ii) Tarapur ($24^\circ 06' 26''$; $87^\circ 49' 12''$), 8 km ESE of Rampurhat, in Rampurhat II block, (iii) Lohapur ($24^\circ 17' 31''$; $87^\circ 57' 45''$), 30 km N of Rampurhat and (iv) Nowapara ($24^\circ 16' 56''$; $88^\circ 27''$), about 6 km ESE of Lohapur, in Nalhati II block (Fig. 1). Tertiaries and overlying

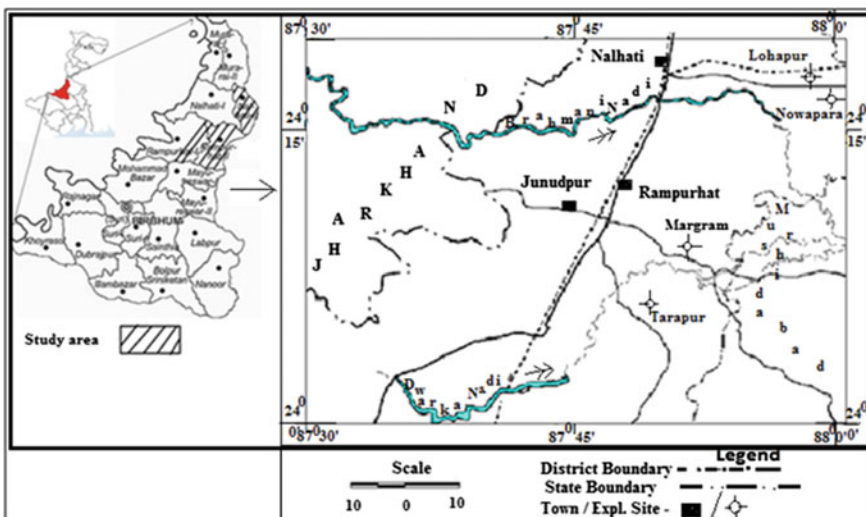


Fig. 1 Rampurhat–Nalhati area, Birbhum district

unconsolidated Quaternaries have been encountered in three boreholes, viz. Margram, Tarapur and Lohapur. At Nowapara, Rajmahal basalts (?) have been encountered beneath Tertiary Formation. Around Rampurhat, the thickness of Older Alluvium, consisting mainly of yellowish to brownish yellow sands, varies between 24 and 40 m. Older Alluvium is underlain by the Tertiaries represented mainly by whitish grey to grey mixtures of sand and clay; greyish clay bed separates the overlying Older Alluvium from the Tertiaries. The thickness of alluvium increases from west to east. In Nalhati II Block, topmost Older Alluvium occurs within 50–60 m. Alluvium is yellowish white to pale yellow. Tertiaries include mixture of grey sands and finer clastics.

3.1 Hydrogeology

At Margram and Tarapur, two-aquifer system has been established. Groundwater under unconfined condition occurs in shallow aquifers of Older Alluvium. The Tertiaries form the deeper aquifer, where groundwater occurs under semi-confined to confined condition. The shallow aquifer corresponds to the thickness of the Older Alluvium. In Nalhati area, however, there is only one continuous aquifer running through both Tertiaries and Quaternaries. Depth to water level (DTW) and discharge of different abstraction structures have been shown in Table 3.1. At Tarapur in Rampurhat II block, historical data of water level in shallow piezometer show falling trend in water level both in pre- and post-monsoon to the tune of 0.49 and 0.43 m/yr, respectively. The depth of submersible pump-fitted tube wells used for

Table 1 Details of tube wells in Rampurhat II and Nalhati II blocks, Birbhum district

S. No.	Location (block)	Well type	Depth to water level (mbgl)	Discharge (lps)	Depth (m)
1	Margram (Rampurhat II)	Deep expl. well	12.40	6.2	160
2	Margram (Rampurhat II)	Shallow expl. well	17.40	26	67
3	Rampurhat (Rampurhat II)	Mark I hand pump-fitted tube well	–	2.5	30
4.	Tarapur (Rampurhat II)	Deep expl. well	14.65	2.6	148
5	Tarapur (Rampurhat II)	Shallow expl. well	17.95	2.1	82
6	Nowapara (Nalhati II)	Expl. well	11.12	35	90
7	Lohapur (Nalhati II)	Expl. well	16.45	22	100
8	Junudpur (Rampurhat I), 9 km <S> of Rampurhat	Mark II hand pump-fitted tube well	–	2.5	61
9	Junudpur (Rampurhat I), 9 km <S> of Rampurhat	Submersible pump-fitted tube well	–	10	21
10	Tarapur	Piezometer	18.12	15.46	50

irrigation generally remains within depth range between 10 and 50 m. The depth of Mark I and Mark II hand pump-fitted tube wells around the area is generally within 30 m and more than 50 m, respectively. The average yield of tube wells varies from 18 to 22.7 m³/hr (Datta and Bandyopadhyay 2006). A perusal of Table 1 indicates that water level in deep exploratory well (DEW) both at Margram and Tarapur is shallower than those in shallow exploratory well (SEW). In Rampurhat area, the discharge of shallow wells including exploratory wells at Margram and Tarapur, shallow tube well of 21 m depth at Junudpur, 9 km SW of Rampurhat, varies within 10–26 lps excepting at Tarapur, where SEW shows discharge of 2.1 lps due to technical reason. But, the discharge of DEWs is low and it ranges between 2.1 and 6.2 lps. So, the potentiality of Older Alluvium is more than that in Tertiaries. In Nalhati II area, water level in Lohapur is deeper than that in Nowapara; the discharge of the well at Lohapur is relatively lower than that at Nowapara.

3.1.1 Analytical Data

Groundwater

The quality of groundwater tapped by selected abstraction structures and exploratory wells in Rampurhat II and Nalhati II blocks has been summarized in Table 2. Groundwater in shallow aquifer is potable, but in deeper aquifer is not suitable for drinking. Fluoride and sodium in groundwater of deeper aquifer range between 5.9 and 10.7 mg/L and between 185 and 267 mg/L, respectively; in shallow wells, they range within 0.40–0.84 and 23–46 mg/L. Data show that Ca content is high in groundwater of shallow wells than in deeper wells, and its concentration is indirectly proportional to concentration of both Na and F. The fluoride content of groundwater has an inverse relationship with calcium and magnesium content. Overall high pH, high carbonate plus bicarbonate and low calcium plus magnesium in groundwater lead to leaching of fluoride which results in the concentration of fluoride in groundwater (Brindha et al. 2011).

Deeper aquifer in Tertiaries especially in Rampurhat II block is not potable; but the quality in the shallow aquifer is potable. In Nalhati II area, fluoride content in groundwater is low; it ranges between 0.72 and 0.76 mg/L and it is potable. Chemical facies of groundwater has been studied by plotting chemical parameters in Piper diagram (Fig. 2), which shows that groundwater in shallow aquifer is Ca–HCO₃ type, but in deeper aquifer it is more akin to Na–HCO₃ type. Most of the studies indicate the increase in fluoride composition in groundwater with increase in depth from ground surface (Hudak and Sanmanee 2003; Valenzuela-Va'squez et al. 2006).

Drill-Cut Samples

In Rampurhat area, drill-cut litho-samples up to 64.30 m are yellow sand and are quartzo-feldspathic. Older Alluvium forming the topmost unconfined shallow

Table 2 Quality of groundwater in wells of Rampurhat II and Nalhati II blocks, Birbhum district

Chemical constituents (EC in $\mu\text{S}/\text{cm}$ at 25 °C, others in mg/L)																		
Location	Well type	Type of aquifer	pH	EC	Fe	HCO ₃	CO ₃	Ca	Mg	Cl	SO ₄	F	SiO ₂	NO ₃	Na	K	TH	PO ₄
Margram	Shallow expl. well	Shallow aquifer	8.42	409	0.13	195	12	42	9.72	21	-	0.4	48	0	23	0.9	145	0.18
Rampurhat	Mark I hand pump-fitted tube well	Shallow aquifer	7.76	1210	0.5	348	0	142	45	199	52	0.54	33	25	54	1.6	540	0.01
Tarapur	Shallow expl. well	Shallow aquifer	7.55	397	0.09	226	0	46	12.16	14	-	0.62	36	0	23	1.3	165	0.24
Junudpur	Submersible pump-fitted tube well	Shallow aquifer	7.7	368	3.36	134	0	20	3.64	53	-	0.84	27	2	46	0.8	65	0.01
Margram	Deep expl. well	Deeper aquifer	8.78	1180	0.39	573	36	6	2.43	92	-	6.15	14	-	267	4.9	25	0.65
Tarapur	Deep expl. well	Deeper aquifer	8.8	881	0.67	360	27	6	1.21	71	-	5.9	12	0	203	5	20	4.46
Nowapara	Expl. well	Deeper aquifer	7.19	447	0.06	226	0	20	17	18	-	0.76	32	1	41	1.9	120	-
Lohapur	Expl. well	Deeper aquifer	8.26	586	0.11	366	0	60	24	50	-	0.72	33	-	54	2.9	250	0.13
Junudpur	Deep tube well	Deeper aquifer	8.2	1060	0.12	348	0	30	7.29	209	-	10.7	17	4	185	4.8	105	-

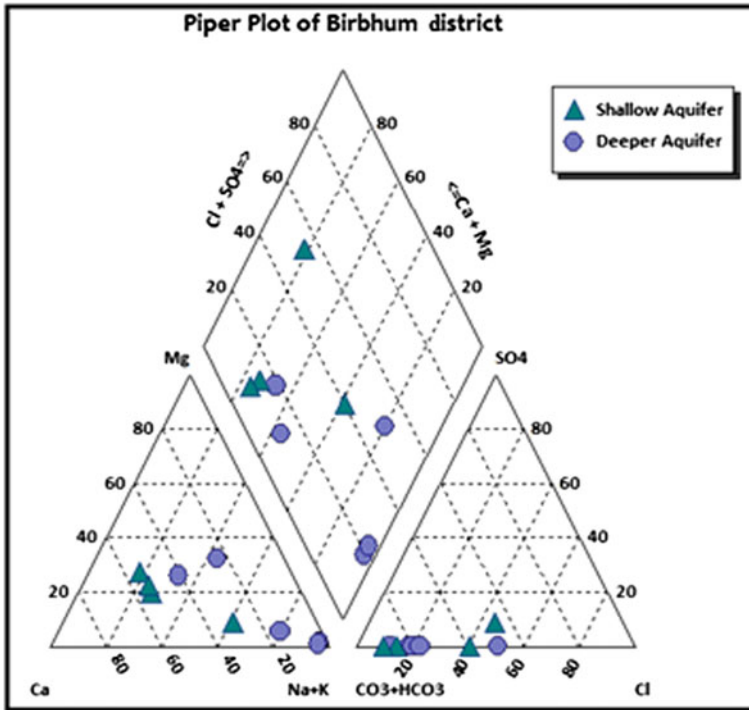


Fig. 2 Chemical facies of ground water of shallow and deeper aquifers

aquifer, analytical data of sample within 51.60–64.30 m contain less than 100 ppm fluoride. Finer clastics are prevalent in deeper aquifer of Tertiaries; sample between 64.30 and 82.20 m contains 315 ppm of fluoride ions (Fig. 3) and below 82.20 m, litho-units contain fluoride ranging from less than 100–164 ppm.

In Nalhati area, Older Alluvium occurs within 88.0 m and is represented by yellow to white, fine to coarse grained material; at Lohapur, sample between 43.90 and 54.10 m contains 120 ppm of fluoride (Fig. 4). Below Older Alluvium, Tertiaries consist mostly of greyish clayey rock fragments and silts; samples at 94.90–98.30, 98.30–101.70 and 162.40–183.00 m litho-samples contain fluorides ranging from 168 to 284 ppm.

4 Barabazar Block, Purulia District

Detailed hydrogeological investigations have been carried out in perennially drought prone Barabazar block (Fig. 5) of Purulia district. ‘South shear zone’ trending almost NW-SE lies in the southern part of study area. The area belongs to the Precambrian Chhotanagpur Gneissic Complex (CGC) comprising mainly of

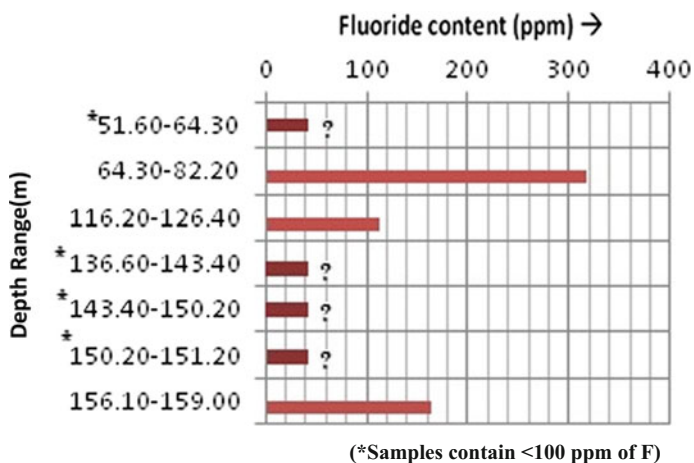


Fig. 3 Fluoride concentration in drill-cut soil samples at Margram, Rampurhat II block

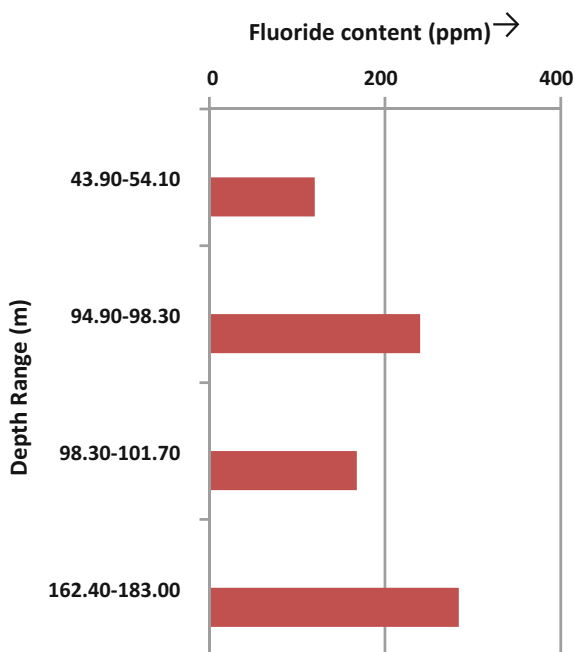


Fig. 4 Fluoride concentration in drill-cut soil samples at Lohapur, Nalhati II block

metamorphics: (i) granite gneisses, with intrusive bodies of granites, in the northern part and (ii) phyllites, slates and mica schists, with enclosures of metamorphosed basic rocks in the southern part of Barabazar block; alluvium is restricted along narrow courses of streams. Mainly three sets of joint, viz. NNE–SSW, NW–SE and

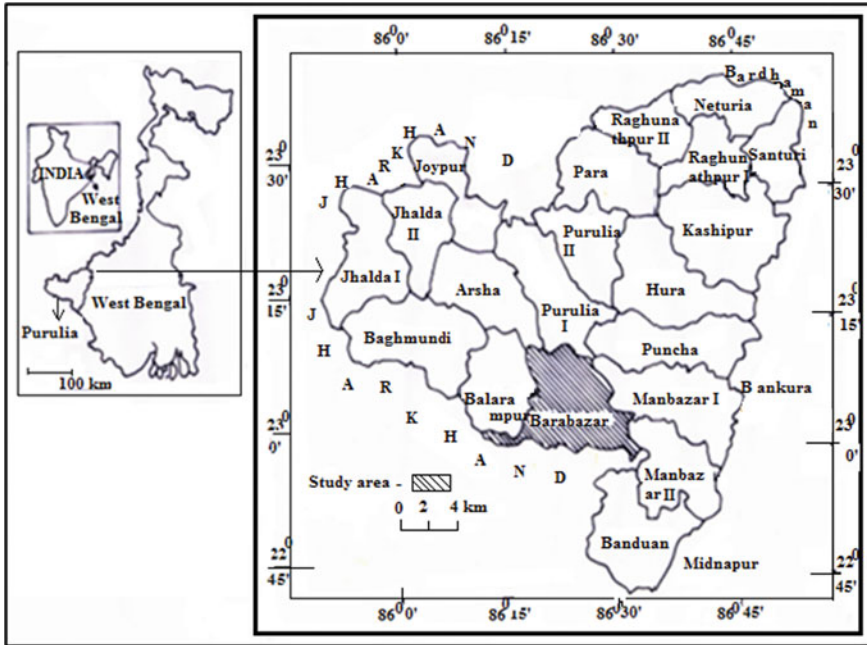


Fig. 5 Barabazar block, Purulia district, West Bengal, India

NE–SW are predominant in the northern granitic part. In the southern part, phyllite and mica schist dominate and NW–SE trending lineaments are relatively persistent in nature.

4.1 Hydrogeology

Groundwater occurs in top weathered mantle ranging up to about 15 m and in the interconnected fractures/joints. The depth to water level in open wells ranges within 5.01–9.82 m below ground level in pre-monsoon and is given in Table 3. The saturated fractures in hard rocks are generally encountered down to 100 m depth (Ghosh and Talukdar 1996); in consolidated formations, groundwater occurs under semi-confined to confined condition (Guha 2009). Deeper potential aquifers in hard rocks are controlled by lineaments (Brahma 2001) of structural elements.

4.2 Analytical Data

The concentration of chemical parameters of groundwater of observation wells, viz. open wells and hand pump-fitted bore wells in villages of eight blocks of Jhalda I,

Table 3 Depth to water level in Barabazar block, Purulia district

Village	Location (coordinates in degree)	Well depth (m)	Depth to water level (m below ground level)	
			(Pre-monsoon)	(Post-monsoon)
Takriya	(23.1693; 86.2688)	15.00	5.98	2.50
Puriara	(23.1562; 86.3564)	9.82	6.98	2.77
Manpur	(23.09194; 86.36556)	7.70	5.01	2.11
Banjora	(23.093889; 86.458338)	9.35	9.19	4.56
Bhabanipur	(23.05139; 86.29444)	8.10	7.85	3.85
Barabazar	(23.01917; 86.347219)	8.40	6.90	4.31
Hizla	(23.03694; 86.41972)	9.00	5.80	2.00
Sindri	(23.03889; 86.48499)	14.00	7.26	2.90
Kukurchanti	(23.58333; 86.29583)	11.22	9.82	5.98

Jhalda II, Joypur, Arsha, Baghmundi, Barabazar, Purulia I and Purulia II falling in western part of Purulia district, has been tabulated in Table 4.

The quality parameters of the groundwater samples of open and bore wells of above mentioned eight blocks have been plotted in Piper diagram (Fig. 6); it has been observed: (i) facies characteristics of groundwater in open wells remain Ca-HCO₃-Cl type to Ca-Na-HCO₃-Cl type in both seasons; while the same in bore wells exhibits Ca-HCO₃ to Ca-HCO₃.Cl type facies characteristics in post-monsoon. The quality of groundwater in selected villages of Barabazar block, viz. Beldih, Puriara, Bhabanipur, Roladih, Hizla, Sindri and Murgakocha, has been marked bold in Table 4 in Barabazar block, and groundwater in open wells and bore wells is characterized generally by Ca-HCO₃-Cl type facies both in pre-monsoon and post-monsoon (Fig. 7).

The concentration of chemical parameters in Barabazar block and western part of Purulia district is mostly within BIS permissible limits, excepting occasional cases, when one or two parameters cross the limit. EC of groundwater has often been found high and this may be due to stagnant condition of the concerned wells. The concentrations of fluoride and iron, which are geogenic in origin, in ground water have been found exceptionally high at certain locations. This has resulted contamination of the vital natural resource in the drought prone part of the district and causes serious threat to lives of human beings and cattle of the area.

Analytical data show that fluoride contents in ground water in selected villages of Barabazar block of Purulia district range up to 0.82 mg/L in open well and 1.62 mg/L in hand pump-fitted bore well in pre-monsoon and the same ranges up to 2.6 mg/L in both abstraction structures during post-monsoon; maximum Fe content in groundwater in open well and bore well goes up to 0.39 and 7.03 mg/L, respectively, in pre-monsoon and the same ranges up to 0.07 and 1.97 mg/L in post-monsoon. No relationship could be established between the fluoride content of groundwater with the concentrations of bicarbonate, calcium and sodium.

In seven blocks covering western part of Purulia district excluding Barabazar block, fluoride concentration in groundwater of open well ranges up to 1.4 mg/L in

Table 4 Details of chemical analysis of groundwater samples collected in pre- and post-monsoon period in Purulia district

Chemical constituents (EC in $\mu\text{S/cm}$ at 25 °C, other parameters in mg/L)																		
S No.	Location (coordinates in degrees)	Type	pH	EC	Fe	HCO ₃	CO ₃	Ca	Mg	Cl	SO ₄	F	SiO ₂	NO ₃	Na	K	TH	PO ₄
1	Beldih (23.05087; 86.29683)	Pre-monsoon_Open Well	8.54	393	0.39	85	6	40	16	60	14	0.3	0	33	20	1.4	165	0
2	Ghagra (23.50111; 86.13417)	Pre-monsoon_Open Well	8.2	806	0.08	244	-	-	29	74	42	0.6	28	23	38	1.7	280	0
3	Chakra (23.3806; 86.3113)	Pre-monsoon_Open Well	8.05	498	0.15	128	-	40	13	64	20	0.55	35	5	26	1.5	155	0
4	Puriara Panardia (23.10694; 86.28417)	Pre-monsoon_Open Well	7.69	1410	0.09	366	-	128	23	213	63	0.51	50	40	128	24	415	0.19
5	Bhabanipur (23.05139; 86.29444)	Pre-monsoon_Open Well	8.1	890	0.09	201	-	90	16	96	40	0.75	35	30	32	6.7	290	0.33
6	Hizla (23.03694; 86.41972)	Pre-monsoon_Open Well	7.86	1710	0.09	464	-	122	29	213	57	0.85	42	39	96	99	425	0.34
7	Sindri (23.03889; 86.48499)	Pre-monsoon_Open Well	8.24	261	0.37	91	-	18	3.64	18	1	1.42	59	4	19	1.6	60	0
8	Chipida (23.2337; 86.3674)	Pre-monsoon_Open Well	7.69	2000	0.12	512	-	74	81	319	88	0.64	59	38	207	9.6	520	0.002
9	Thumba Jhalda (23.33444; 86.23472)	Pre-monsoon_Open Well	7.95	1410	0.008	433	-	130	24	121	40	0.31	42	38	80	5	425	0

(continued)

Table 4 (continued)

Chemical constituents (EC in $\mu\text{S/cm}$ at 25 °C, other parameters in mg/L)																		
S No.	Location (coordinates in degrees)	Type	pH	EC	Fe	HCO ₃	CO ₃	Ca	Mg	Cl	SO ₄	F	SiO ₂	NO ₃	Na	K	TH	PO ₄
10	Lohadungri (23.23472; 86.16778)	Pre-monsoon_Open Well	8.2	768	0.08	220	-	68	30	74	32	0.6	34	39	13	2.6	295	0
11	Birgram (23.17194; 85.99745)	Pre-monsoon_Open Well	7.7	3870	0.03	1098	-	348	122	574	107	0.32	42	41	198	2.5	1370	0.01
12	Suisa (23.19527; 85.91861)	Pre-monsoon_Open Well	8.2	448	0.1	140	-	52	9.72	64	7	0.48	41	18	21	1.4	170	0
13	Chakkeyari (23.27444; 85.84499)	Pre-monsoon_Open Well	8.2	236	0.02	73	-	18	7.29	35	1	0.34	11	4	17	2.2	75	0
14	Kolabund (23.4088; 86.3629)	Pre-monsoon_Open Well	8.17	163	0.12	91	-	12	9.72	21	2	1.4	34	1	14	0.9	70	0
15	Hutmura (23.3486; 86.48181)	Pre-monsoon_Open Well	7.78	434	0.16	140	-	34	8.51	60	15	0.34	42	16	46	2.4	120	0.09
16	Talmu (23.54833; 86.1)	Pre-monsoon_Open Well	7.68	2120	0.1	823	-	140	90	181	81	0.52	16	39	101	71	720	0.22
17	Talmu (23.55; 86.10417)	Pre-monsoon_Bore Well	8.34	905	2.75	189	-	90	40	145	76	3.7	39	50	44	2.6	390	0
18	Beldih (23.05078; 86.29697)	Pre-monsoon_Bore Well	8.55	518	0.88	146	-	78	13	71	16	1.62	20	25	8	1.8	250	0
19	Beldih (23.05082; 86.29699)	Pre-monsoon_Bore Well	8.3	1080	7.03	122	-	88	34	266	37	0.63	31	38	87	6.2	360	0
20	Rupapatia (23.082126; 86.37981)	Post-monsoon_Open Well	7.64	1450	-	250	-	92	17	191	56	0.76	56	80	120	7.7	300	0.47

(continued)

Table 4 (continued)

Chemical constituents (EC in $\mu\text{S}/\text{cm}$ at 25°C , others in mg/L)																		
S No.	Location	Type	pH	EC	Fe	HCO ₃	CO ₃	Ca	Mg	Cl	SO ₄	F	SiO ₂	NO ₃	Na	K	TH	PO ₄
21	Roladh (23.060751; 86.37561)	Post-monsoon_Open Well	7.34	788	-	171	-	70	15	152	43	1.55	48	8	72	2.5	235	0.15
22	Sargo (23.04194; 86.39739)	Post-monsoon_Open Well	7.15	1680	-	268	-	210	49	421	79	0.93	48	42	84	14.5	725	0.17
23	Patharighata (23.102337; 86.47673)	Post-monsoon_Open Well	7.51	145	-	67	-	10	6.08	14	1	0.43	56	3	13	0.2	50	0.11
24	Fatehpur (23.04313; 86.26950)	Post-monsoon_Open Well	6.7	347	0.66	73	-	32	11	21	11	0.26	45	80	17	1.5	125	0.23
25	Beldih (23.05087; 86.29683)	Post-monsoon_Open Well	6.95	240	0.07	61	-	28	4.86	35	7	1.05	19	12	10	0.6	90	0.18
26	Gunja (23.42387; 86.22280)	Post-monsoon_Open Well	7.57	612	-	195	-	64	21	82	25	2.4	3.8	42	36	1.7	245	0.42
27	Ranibandh (22.86528; 86.78297)	Post-monsoon_Open Well	7.77	175	0.008	61	-	14	3.64	18	2	0.9	38	15	14	0.5	50	0.06
28	Dindih (23.38199; 86.26326)	Post-monsoon_Open Well	7.26	290	0.05	104	-	26	8.51	35	22	0.26	4	5	25	8.7	100	0.03
29	Talmu (23.54833; 86.1)	Post-monsoon_Open Well	7.37	1220	0.02	598	-	166	64	85	136	0.86	28	1	63	7.3	680	0.06
30	Kalyanpur(Kasangi) (23.51044; 86.05884)	Post-monsoon_Open Well	7.5	227	-	73	-	14	6.08	21	13	4.5	36	30	29	1.2	60	0.15
31	Jajpur (23.16861; 86.16111)	Post-monsoon_Open Well	7.27	868	0.004	293	-	98	15	117	30	0.73	26	4	59	1.6	564	0.09
32	Mirusaram (23.43897; 86.86.04788)	Post-monsoon_Open Well	7.27	618	-	153	-	64	17	78	41	0.6	33	28	19	5.2	230	0.11

(continued)

Table 4 (continued)

Chemical constituents (EC in $\mu\text{S}/\text{cm}$ at 25° C, others in mg/L)																		
S No.	Location	Type	pH	EC	Fe	HCO ₃	CO ₃	Ca	Mg	Cl	SO ₄	F	SiO ₂	NO ₃	Na	K	TH	PO ₄
33	Sarjemahatu (23.46788; 86.08423)	Post-monsoon_Open Well	7.6	562	-	244	-	88	16	53	45	3.9	39	2	7	1.1	285	0.15
34	Mukundpur (23.39776; 86.14534)	Post-monsoon_Open Well	7.53	654	-	262	-	70	18	43	34	0.74	11	4	35	12	250	0.6
35	Kotshila (23.40694; 86.06667)	Post-monsoon_Open Well	7.38	616	-	110	-	54	12	39	49	0.5	19	4	62	1.4	185	0.1
36	Kulajanga (23.39291; 85.95238)	Post-monsoon_Open Well	7.52	406	-	128	-	38	16	32	32	0.4	28	28	18	1.9	160	0.15
37	Hesalbera (23.42287; 85.95659)	Post-monsoon_Open Well	7.28	910	-	256	-	120	11	96	50	0.64	28	39	34	2.9	345	0.23
38	Murgakocha (23.55478; 86.04623)	Post-monsoon_Open Well	7.01	852	-	256	-	60	17	89	48	2.6	16	28	67	2.7	220	0.53
39	Rupapatia (23.08209; 86.37939)	Post-monsoon_Bore Well	7.29	779	1.97	195	-	64	16	113	38	0.7	42	26	65	3.1	225	0.05
40	Roladh (23.060875; 86.37601)	Post-monsoon_Bore Well	7.44	686	0.83	195	-	76	11	99	29	2.3	45	16	44	1.9	235	0.05
Chemical constituents (EC in $\mu\text{S}/\text{cm}$ at 25° C, others in mg/l)																		
Sl No.	Location	Type	pH	EC	Fe	HCO ₃	CO ₃	Ca	Mg	Cl	SO ₄	F	SiO ₂	NO ₃	Na	K	TH	PO ₄
41	Sargo (23.29722; 86.2125)	Post-monsoon_Bore Well	7.63	270	0.16	110	-	26	3.64	18	2	0.5	48	4	17	0.7	80	0.09
42	Joramohul (23.; 86.)	Post-monsoon_Bore Well	7.31	670	1.04	153	-	44	18	85	32	1.02	38	27	46	2.6	185	0.05
43	Pathariaghata (23.12223; 86.47833)	Post-monsoon_Bore Well	7.61	233	-	22	-	14	7.29	18	3	0.45	56	13	20	1.3	65	0.06
44	Fatehpur (23.04487; 86.25789)	Post-monsoon_Bore Well	7.02	1490	0.44	275	-	184	64	362	53	0.24	30	45	36	5.5	725	0.05
45	Beldih (23.05078; 86.29697)	Post-monsoon_Bore Well	7.18	444	0.12	159	-	68	9.72	67	11	1.85	33	15	15	1.5	210	0.05

(continued)

Table 4 (continued)

Sl No.	Location	Chemical constituents (EC in $\mu\text{S}/\text{cm}$ at 25 °C, others in mg/l)																
		Type	pH	EC	Fe	HCO ₃	CO ₃	Ca	Mg	Cl	SO ₄	F	SiO ₂	NO ₃	Na	K	TH	PO ₄
46	Gunjia (23.42455; 86.22434)	Post-monsoon_Bore Well	7.25	595	0.07	268	–	54	16	53	22	1.06	33	26	60	1.1	200	0.06
47	Alkusha (23.46855; 86.13979)	Post-monsoon_Bore Well	7.18	363	0.95	128	–	34	11	50	37	0.41	45	1	27	1	130	0.09
48	Talmu (23.55; 86.10417)	Post-monsoon_Bore Well	7.67	686	0.57	120	–	96	6.08	14	108	2.6	28	1	1	2	265	0.04
49	Kalyampur (Kasangi) (23.51165; 86.0657)	Post-monsoon_Bore Well	7.33	389	0.01	226	–	50	8.51	14	9	5.8	28	1	25	1.6	160	0.04
50	Jaipur (23.16888; 86.16222)	Post-monsoon_Bore Well	7.25	645	0.15	146	–	82	11	92	38	0.76	28	31	29	2.6	250	0.06
51	Murusaram (23.43279; 86.04644)	Post-monsoon_Bore Well	7.32	796	–	207	–	98	18	99	44	0.5	28	34	22	3.2	320	0.06
52	Sarjemahatu (23.46834; 86.08444)	Post-monsoon_Bore Well	7.51	322	0.1	146	–	44	7.29	11	13	5.8	36	1	11	0.9	125	0.06
53	Mukundpur (23.39605; 86.14611)	Post-monsoon_Bore Well	7.41	449	0.004	183	–	48	11	32	31	2.1	21	4	27	2.2	165	0.18
54	Koishila (23.40446; 86.06638)	Post-monsoon_Bore Well	7.6	339	0.29	73	–	30	2.43	117	11	0.49	36	8	19	1	85	0.1
55	Kuljanga (23.39344; 85.95678)	Post-monsoon_Bore Well	7.2	399	1.2	152	–	36	19	131	26	0.66	23	11	20	8.5	170	0.07
56	Hesalbera (23.42567; 85.95688)	Post-monsoon_Bore Well	6.96	1030	0.1	238	–	150	15	131	64	0.43	28	38	33	5.7	435	0.1
57	Murgakocho (23.55435; 86.046642)	Post-monsoon_Bore Well	6.75	2000	1.58	342	–	206	34	404	82	2.6	21	37	140	5.4	655	0.09

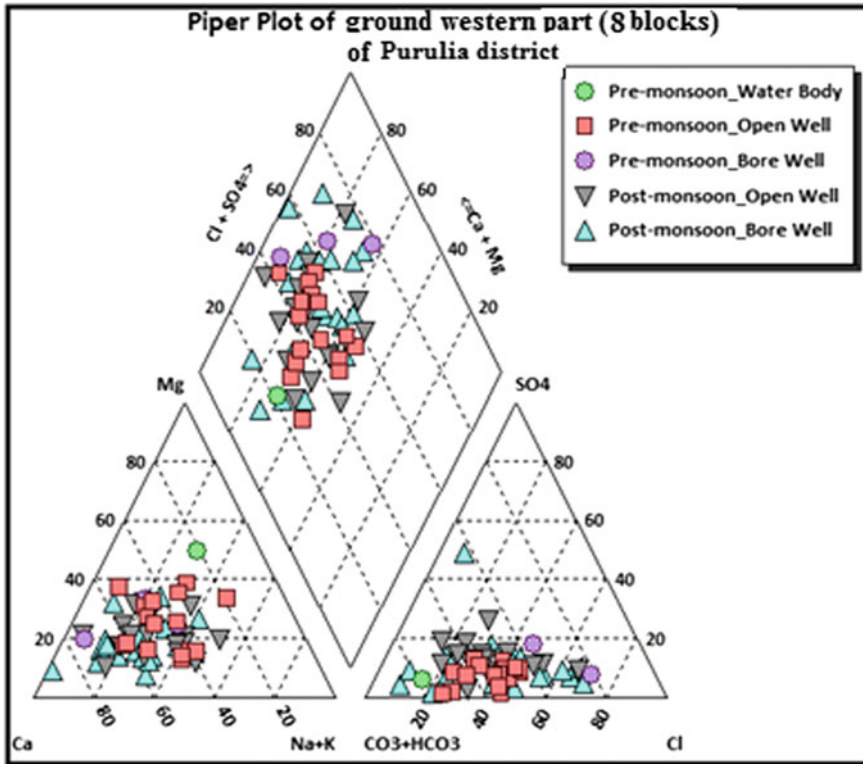


Fig. 6 Facies plot of chemical parameters of groundwater in eight blocks of Purulia district

pre-monsoon and 4.5 mg/L in post-monsoon, whereas in bore well it ranges up to 3.7 mg/L in pre-monsoon and 5.8 mg/L in post-monsoon; NE–SW trending ‘north shear zone’ of Purulia district passes through the northern part of this area.

A perusal of data (**Annexure I**) shows that in Barabazar block, high fluoride and iron concentration in groundwater have been encountered, in general, at villages, e.g. Beldih, Murgakochoa, Roladih and Rupapatia, which are located at the proximity of ‘south shear zone’ (Fig. 10). Also, in this area the concentration of fluoride increases with the depth of the abstraction structures (Figs. 8 and 9).

5 Discussion and Conclusion

5.1 Rampurhat–Nalhati Area, Birbhum District

In Rampurhat area, presence of two-aquifer system has been established in Rampurhat area: shallow aquifer, conforming to the thickness of Older Alluvium of the Quaternaries, occurs under unconfined condition and the deeper aquifer in the

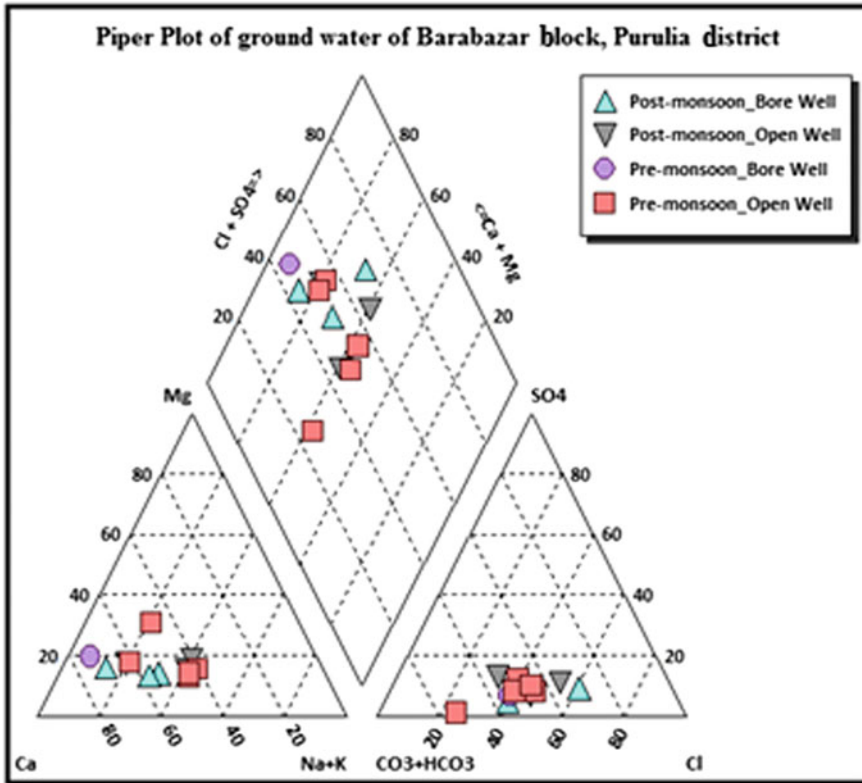


Fig. 7 Facies plot of groundwater in Barabazar block

Tertiaries, under semi-confined to confined condition. Hydrogeologically, these two aquifers are quite different from each other and are separated by a thick clay. Depth to water level (DTW) in deep exploratory well (DEW), both at Margram and Tarapur, is shallower than that in the shallow exploratory well (SEW). Potentiality of Older Alluvium, mainly tapped in SEW, is more than that of the Tertiaries, tapped in DEW. Groundwater in deeper aquifer is characterized by high fluoride and high sodium content, whereas these constituents are quite low in groundwater of shallow aquifer. In Nalhati II block, however, there is only one aquifer continuously from the Tertiaries at the bottom to the overlying Quaternaries; fluoride and sodium content in groundwater is low and groundwater in this part is potable.

5.2 Barabazar Block, Purulia District

In the northern, granite gneisses predominate, whereas in the southern part slates, phyllites and mica schists are prevalent. The effect of deformation activities on

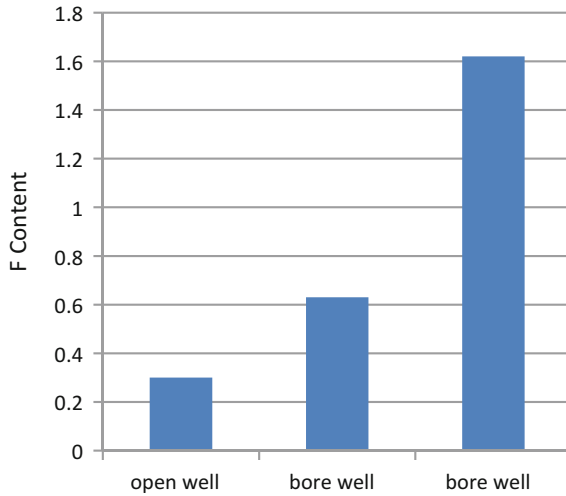


Fig. 8 Increase in fluoride content in groundwater in pre-monsoon at Beldih, Barabazar block

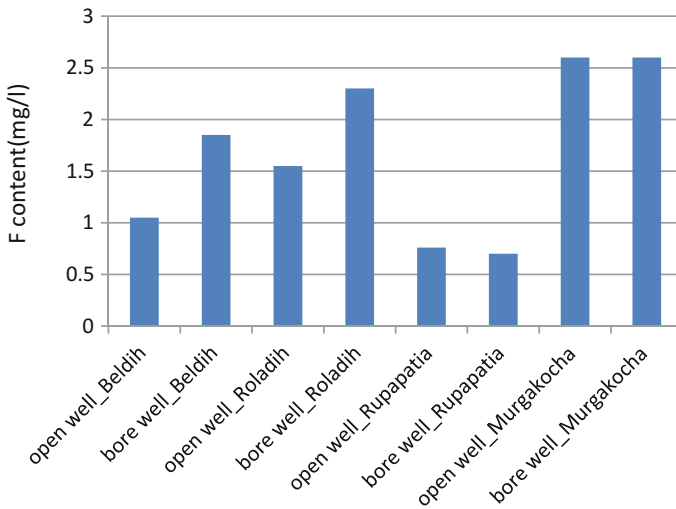


Fig. 9 Increase in fluoride content in groundwater in post-monsoon in different villages, Barabazar block

granite gneisses of the north is more pronounced than that in slates and phyllites. As a result, former type is more permeable than the latter. Hence, groundwater prospect is relatively better in the northern part.

Many granitic rocks have elevated fluoride concentration (World Health Organization 1970). The main source of fluoride in groundwater is considered to be

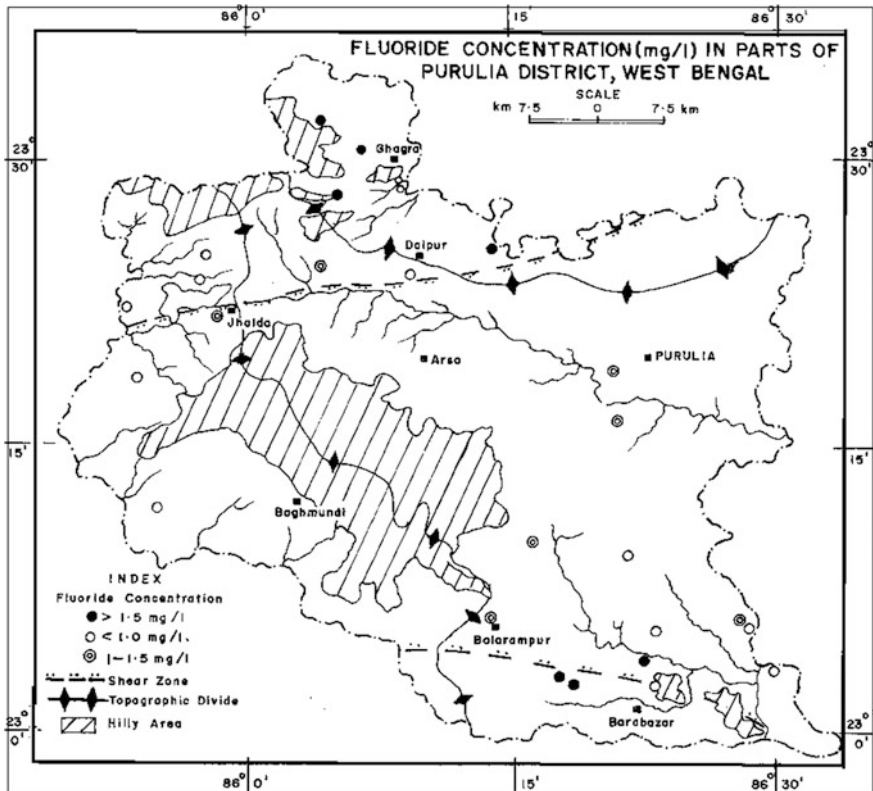


Fig. 10 Fluoride concentration in groundwater in parts of Purulia district

fluoride-bearing minerals such as fluorspar (CaF_2), fluorapatite [$\text{Ca}_5(\text{PO}_4)_3\text{F}$], cryolite, and hydroxylapatite in rocks (Farooqi et al. 2007). Overall, the natural concentration of fluoride in groundwater depends on the geological, chemical and physical characteristics of the aquifer, the porosity and acidity of the soil and rocks, the surrounding temperature, the action of other chemical elements, depth of the aquifer and intensity of weathering (Feenstra et al. 2007).

The chemical parameters of groundwater are mostly within BIS limits, but at places in the southern part of Barabazar block especially near the 'south shear zone', its quality is bad due to high fluoride and iron concentration. Both iron and fluoride contents in groundwater increase with depth and towards the proximity to shear zone. Saxena and Ahmed (2001) put forth that alkaline conditions with pH ranging between 7.6 and 8.6 are favourable for dissolution of fluorite mineral from the host rocks. Very deep aquifers are safer than shallow aquifers. (Shashank et al. 2012). The fluoride content of groundwater has no relation with the concentrations of bicarbonate, calcium and sodium.

In both these terrains, though diverse in nature, fluoride concentration in groundwater increases with depth.

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