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A STUDY ON THE FLUORIDE CONCENTRATION IN GROUNDWATER OF SELECTED LOCATIONS OF ASSAM, INDIA

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ABSTRACT

The present investigation is related to identification of geochemical control and source of fluoride concentration in ground water from different geological settings. Ground water samples were collected from different locations in Kamrup and Goalpara districts of Assam. The results indicate that high fluoride concentration is characteristic of deep thermal wells and indicated by strong alkalinity of prevailing groundwater. The causative factor for elevated fluoride is the dissolution of fluorine – bearing biotite, its occurrence being largely controlled by the bed rock composition. The high Ca^{2+} ion concentration is seen to play a crucial role in controlling the fluoride concentration in deep thermal groundwater wells but the high Ca^{2+} ion concentration is dependent on the availability of Ca-rich plagioclase, a characteristic feature of bed rock composition. Thus, origin and control of high fluoride concentration in groundwater are dependent on the aquifer lithology.

Key words: Groundwater, Fluoride, Biotite, Plagioclase

INTRODUCTION

Safe and pure drinking water is the fundamental need of every human being and in this context ground water is a major source of potable water for most of the communities in different countries. In general, ground water is perceived to be free from pathogenic contamination and hence it is safe for direct consumption. However, ground water is not entirely free from geological contamination caused by addition of toxic elements into aquifer released during dissolution of minerals, rocks and soils of the area (Jadhav and Bogowar, 2014). High concentration of fluoride in ground water is an example of major geological contamination. It is reported that groundwater fluoride concentration (>1.5mg/L) is affecting approximately 260 million people across the world (Banerjee, 2014). This has also become a burning issue of our state due to existence of recently known several fluoride contaminated localities of Karbi Anglong, Nagaon, Kamrup and Golaghat districts (Chakraborti et al., 2000; Das et al., 2003; Kotoky et al., 2008 and Dutta and Barua, 2013).

The occurrence of high fluoride concentration (>1.5mg/l as recommended by WHO, 2004 or >1.0 mg/l as per BIS, 2012) in groundwater and risk of fluorosis associated with using such water for human consumption is an acute problem faced by the people in the affected areas of our state. This needs adequate survey and testing of contaminated ground water to identify the affected areas and to advance some cost effective technologies to eliminate excess fluoride in water. Owing to seriousness of the issue, the present study was undertaken to assess the fluoride concentration in the potable water sources like tube-well and dug-well of various depths and ages in some suspected fluoride contaminated areas in Kamrup and Goalpara districts of Assam and finally to identify the possible sources and control of fluoride concentration in ground water.

Study area

The present investigation includes the already known fluoride contaminated localities of the eastern part of Guwahati city (Narengi, Birkuchi, Satgaon area) and some other suspected but virgin areas in Hajo and Boko Circles in Kamrup district and some localities in Goalpara district (Figure 1).

Both Kamrup and Goalpara districts constitute the southwestern part of Assam covering together an area of 3583 square kilometers. Physiographically, the whole area can be distinguished into three categories – the hills, the alluvial plains and the swampy regions. The climate of the districts is directly characterized by modified tropical monsoon with well marked seasonality. Geologically, the entire region represents the northwestern extension of the Shillong Plateau. The Precambrian rocks of the Goalpara district are dominated by granulite-amphibolite facies mafic rocks interleaved with impure meta-calcareous gneisses, quartzofeldspathic

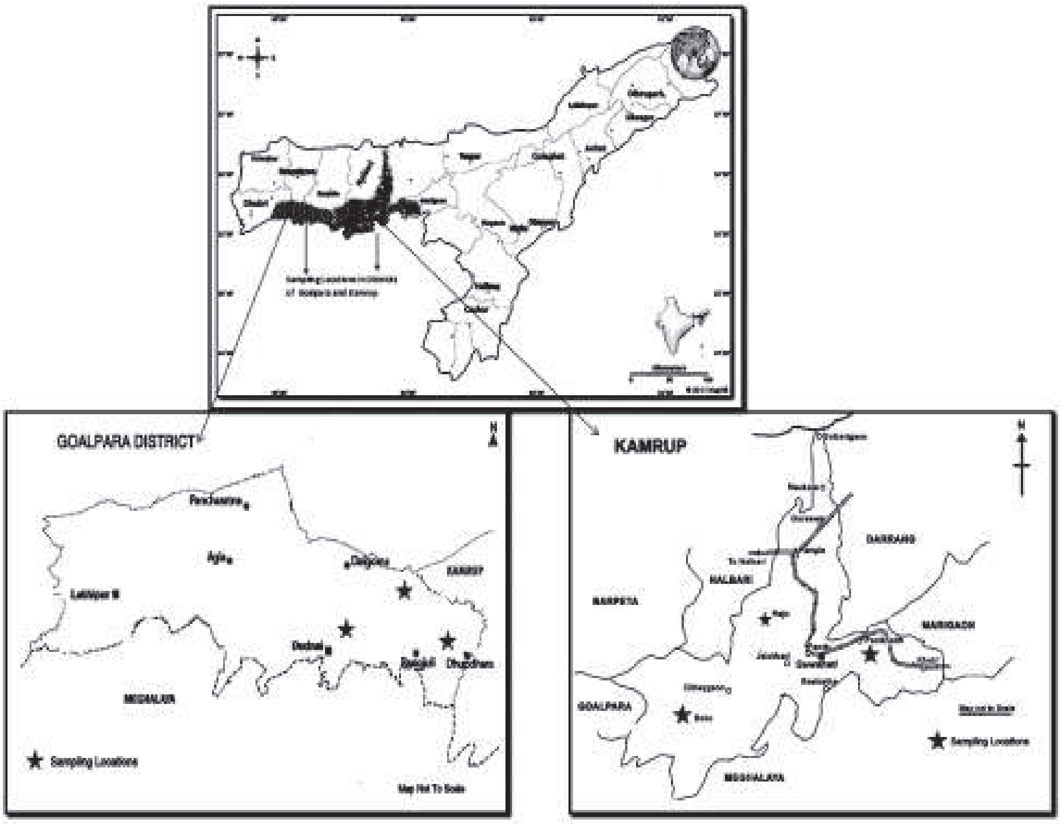

Fig. 1: Map showing different districts of Assam. Star marks indicate different localities of sample collection.

gneisses and banded iron formations. By contrast, hilly areas of Kamrup district are dominated by quartzofeldspathic gneisses with small scale intercalations of amphibolites followed by post-kinematic intrusion of porphyritic granite (Chatterjee et al. 2011). Detailed description of the rock types around the sampling sites in Goalpara district includes presence of intercalated bands of hornblende gneisses/ amphibolites, calc-silicate gneisses and iron formations within poorly exposed quartzofeldspathic gneisses where occurrence of relatively larger dimension of basic granulites in the southern part is a spectacular feature in the geology of the area (Mazumdar, 1996). The compositional continuum of the mineral assemblages particularly in mafic and calc-silicate gneisses indicates that the bed rocks largely consist of Ca-Fe-Mg silicates and Ca-rich plagioclase in the sampling sites. In the present context, the geology of Narengi, Birkuchi, Satgaon area in eastern Guwahati is important since the occurrence of very high fluoride concentration in groundwater was reported from the area. A brief description on lithology of this area was reported by Dutta and Baruah (2013) on the basis of investigation carried out by Dey (1999) which indicates that the most dominant rock type in this area is migmatitic-quartzofeldspathic gneisses. The distinctive mineral assemblage of this rock type is quartz + microcline + plagioclase + biotite ± hornblende ± sphene ± zircon ± magnetite. Biotite is a major constituent in the assemblage ranging in between 3.16% and 12.12% of the total volume of the rock according to Dey (1999).

METHODS AND MATERIALS

Water samples were collected from different sources from a total of 37 locations during the months of March and April, 2015. Collection of samples was made with precise geographical location (latitude and longitude readings by GARMIN-eTrex hand held GPS) and proper description of sources (nature of wells, depth, age etc.) were recorded (Table1). Water samples were directly collected in pre-cleaned PET bottles after allowing the water to pass free from the sampling source for 4-5 minutes. The samples were analyzed for pH, Fluoride (F^-) and Total Hardness (TH) using standard methods (APHA, 2005). Analyses for determining fluoride concentrations in the samples were carried out at the State Water Laboratory of Public Health Engineering Department, Govt. of Assam. To determine the concentration of Fluoride in the water samples, a spectrophotometer [Spectroquant (MERCK kGaA, 64271)] having a measuring range of 0.10 - 20.0 mg/l for fluoride ion was used which functions on the principles analogous to Alizarin visual method of APHA. In this method, fluoride ions react with alizarin complexone and lanthanum(III) to form a violet complex that is determined photometrically by the instrument. pH was estimated using a portable digital system (Systronics pH system 361). TH was estimated using EDTA titrimetric method as per procedures prescribed by the APHA (2005).

Table 1: Details of Sampling Location

Sl no.	Sampling Locations	GPS Coordinates (Latitude/Longitude)	Source of Water
1	No.2 Bonda, Amgaon	N 26^0 11.707', E 91^0 50.865'	Ring Well
2	No.2 Bonda, Taribagan Carton Factory	N 26^0 11.668', E 91^0 50.936'	Deep well
3	No.2 Bonda, Taribagan Godown	N 26^0 11.647', E 91^0 50.929'	Deep well
4	No.2 Bonda	N 26^0 11.676', E 91^0 50.996'	Ring Well
5	No.2 Bonda	N 26^0 10.842', E 91^0 50.596'	Ring Well
6	No.2 Bonda	N 26^0 10.836', E 91^0 50.715'	Ring Well
7	Birkuchi Tiniali	N 26^0 10.864', E 91^0 50.357'	Ring Well
8	Birkuchi	N 26^0 10.877', E 91^0 50.310'	Deep Boring well
9	Satgaon, Progoti Nagar	N 26^0 09.748', E 91^0 49.967'	Tube well
10	Satgaon, Kochpara	N 26^0 09.360', E 91^0 50.346'	Deep Boring well
11	Satgaon, Kochpara	N 26^0 09.390', E 90^0 50.315'	Ring Well
12	Satgaon, Puberun Nagar	N 26^0 09.954', E 91^0 49.993'	Deep Boring well
13	Satgaon, Puberun Nagar	N 26^0 09.937' ; E 91^0 49.995'	Ring Well
14	Satgaon, Puberun Nagar	N 26^0 10.062', E 91^0 50.075'	Deep Boring well
15	Satgaon, Puberun Nagar	N 26^0 10.071', E 91^0 50.102'	Deep Boring well
16	Narengi, Patharquary	N 26^0 10.148', E 91^0 49.585'	Deep Boring well
17	Narengi, Patharquary	N 26^0 10.148', E 91^0 49.585'	Ring Well
18	Boko, Dakuwapara	N 25^0 58.345', E 91^0 13.848'	Ring Well
19	Boko, Dakuwapara	N 25^0 58.352', E 91^0 13.832'	Deep well
20	Boko, Dakuwapara	N 25^0 58.263', E 91^0 13.879'	Tube well

(Cont...)

21	Boko, Nowapara	N 25^0 51.785', E 91^0 11.722'	Ring Well
22	Boko, Kothalpara	N 25^0 53.162', E 91^{0}12.798'	Ring Well
23	Boko, Gohalkona	N 25^0 53.171', E 91^0 12.850'	Ring Well
24	Boko	N 25^0 54.846', E 91^0 13.987'	Ring Well
25	Hajo	N 26^0 14' 45.2'', E 91^0 31' 53.7''	Tube well
26	Hajo	N 26^0 14' 45.9'', E 91^0 31' 38.7''	Public well
27	Hajo	N 26^0 14' 25.1'', E 91^0 31' 47.7''	Ring Well
28	Hajo	N 26^0 14' 11.2'', E 91^0 32' 01.6''	Public well
29	Hajo	N 26^0 14' 54.9'', E 91^0 31' 15.4''	Hand pump
30	Hajo	N 26^0 15' 6.8'', E 91^0 31' 47.8''	Hand pump
31	Hajo	N 26^0 15' 2.7'', E 91^0 31' 49.1''	Hand pump
32	Goalpara	N 26^0 10' 32.2'', E 90^0 37'47.0''	Hand tube well
33	Goalpara	N 26^0 10' 54.1'', E 90^0 37' 46.5''	Hand tube well
34	Goalpara	N 26^0 10' 55.3'', E 90^0 37' 43.3''	Ring Well
35	Goalpara	N 25° 59' 9.82", E 90° 47' 11.64"	Deep well
36	Goalpara	N 25°58' 46.07", E 90°47' 39.60"	Deep Boring well
37	Goalpara	N 26° 7' 01.43", E 90° 34' 40.09"	Deep well

RESULTS AND DISCUSSION

The analytical data on water samples are presented in Table 2. It is evident from Table 2 that all the sampling sites in the Narengi, Birkuchi, Satgaon area of Guwahati city are characterized by high level of fluoride concentration, all exceeding the acceptable limit of fluoride (1.0 mg/l as per BIS, 2012).

Table 2: Fluoride concentrations in the sampling locations

Sl. No.	Sample Locations	Depth (in metre)	Well Age (in yrs)	pH	Total Hardness (mg/L $CaCO_3$)	Fluoride (in mg/L)
1	No.2 Bonda, Amgaon	8.84	7	6.0	90	0.38
2	No.2 Bonda, Taribagan Carton Factory	21.33	8	6.0	100	0.42
3	No.2 Bonda, Taribagan Godown	30.48	8	6.5	110	0.18
4	No.2 Bonda	18.29	17	7.0	120	0.31
5	No.2 Bonda	18.29	25	6.5	70	0.1
6	No.2 Bonda	7.62	10	7.0	65	0.33
7	Birkuchi Tiniali	10.9	6	6.0	75	0.1
8	Birkuchi	**30.48**	6	**7.5**	60	**4.7**
9	Satgaon, Progoti Nagar	27.43	15	7.5	70	0.99
10	Satgaon, Kochpara	**79.25**	3	**7.5**	75	**1.79**
11	Satgaon, Kochpara	30.48	5	7.5	45	3.2
12	Satgaon, Puberun Nagar	30.48	3	6.8	75	1.1
13	Satgaon, Puberun Nagar	30.48	15	6.5	75	1.18
14	Satgaon, Puberun Nagar	**73.15**	1	**8.0**	55	**3.6**

(Cont..)

15	Satgaon,					
	Puberun Nagar	27.43	6	**7.5**	75	1.45
16	Narengi, Patharquary	**170.69**	3	**8.5**	45	**3.9**
17	Narengi, Patharquary	15.24	18	6.0	75	0.36
18	Boko, Dakuwapara	**30.48**	60	7.0	75	**1.28**
19	Boko, Dakuwapara	35	1	6.0	90	0.13
20	Boko, Dakuwapara	**30.48**	14	7.5	75	**1.30**
21	Boko, Nowapara	6.10	10	7.0	110	0.19
22	Boko, Kothalpara	9.14	10	6.0	95	0.37
23	Boko, Gohalkona	15.24	30	6.0	90	0.28
24	Boko	3.65	30	6.0	100	0.35
25	Hajo	6.4	10	6.5	120	0.45
26	Hajo	6.4	10	6.5	255	0.88
27	Hajo	9.15	15	7.0	720	0.39
28	Hajo	9.15	8	7.5	210	0.31
29	Hajo	7.62	6	6.5	195	0.81
30	Hajo	9.14	10	6.5	90	0.51
31	Hajo	6.10	5	6.5	135	0.51
32	Goalpara,	14.0	16	6.0	140	0.51
33	Goalpara	36.57	10	6.0	230	0.31
34	Goalpara	15.24	31	6.0	180	0.24
35	Goalpara	39.62	30	6.0	210	0.3
36	Goalpara	60.96	8	6.0	350	0.23
38	Goalpara	24.39	2	6.5	190	0.25

In this region, positive correlation between fluoride and depth of the wells (Figure2) and fluoride and pH (Figure3) indicates a rising trend of fluoride concentration with increasing pH level of groundwater (? 7.00), usually occurring at a well-depth greater than 30.48 meter. This relation is valid for two other localities within the Boko administrative circle which showed higher values of pH at the well depth of 30.48 meter (Table 2). In other areas, fluoride concentration in groundwater is much lower even in the case of very deep wells in some locations of Goalpara district.

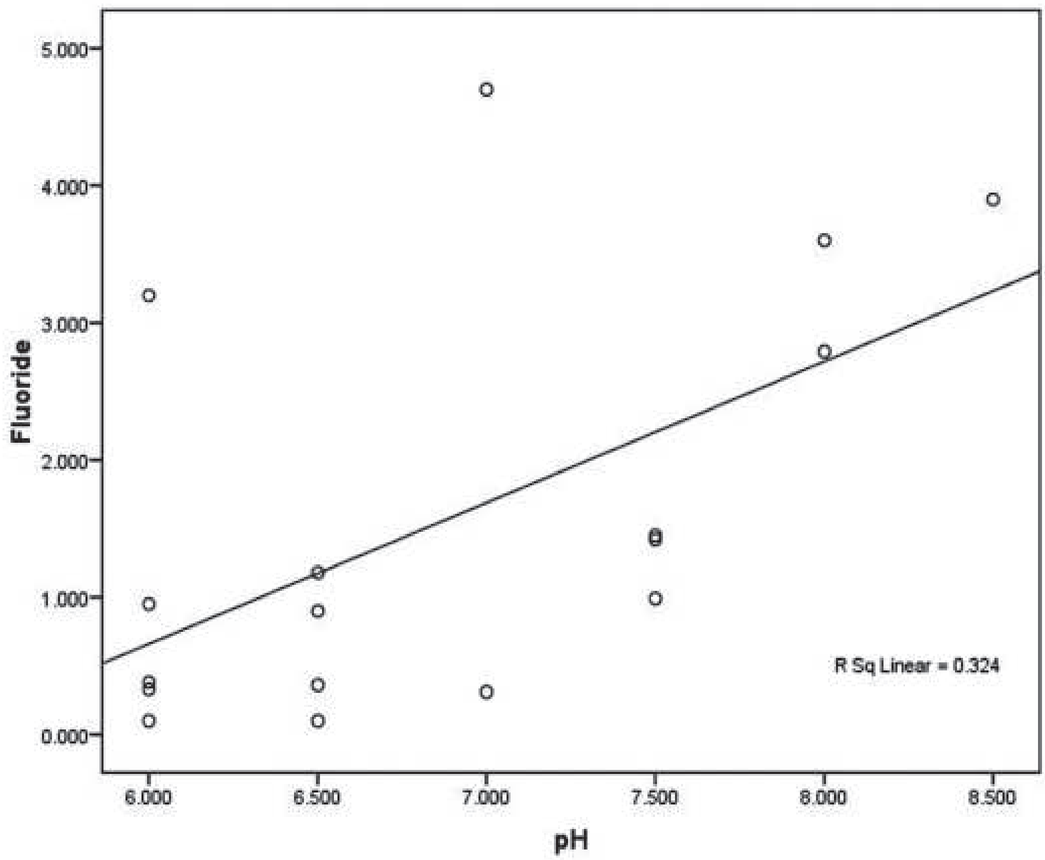

Fig. 2: Variation of fluoride concentration with pH in Narengi-Birkuchi-Satgaon area

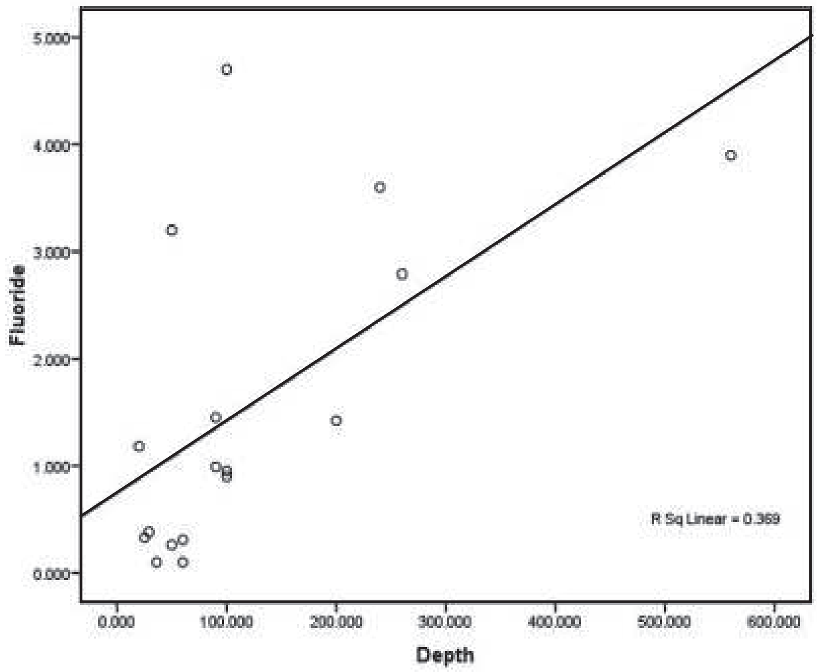

Fig. 3: Variation of fluoride concentration with well depth at Narengi, Birkuchi, and Satgaon area.

The result of the present study reflects upon the geochemical behavior of groundwater from the fluoride contaminated regions. The groundwater in such regions are characterized by higher values of pH (Figure 2, Table 2), thereby indicating more alkalinity, with higher fluoride concentration. Although the value of correlation co-efficient in this case is low to strongly establish such a point, yet this fact has been established by other workers elsewhere. The results of Kumar (2011) strongly establishes that the fluoride-bearing water in deep aquifers are usually high in alkalinity. It is expected that if larger numbers of samples are tested, the results would yield similar interpretations and show higher R^2 values. The geochemical behavior such as high alkalinity with rising fluoride concentration as reflected from this study is also related to low Ca^{2+} concentration in groundwater (Meenakshi and Maheswari, 2006). Further, in this contaminated area, the fluoride concentration is also a function of the depth of wells. High fluoride concentration is typically observed in deep wells (~ 30.48 meter) where high temperature and long residence time in aquifer with fluorine-bearing minerals of the bed rock augments the fluoride concentration (Nordstrom et al., 1989; Saxena and Ahmed, 2003). This is indicated from the positive correlation between fluoride concentration and the depth of wells (Figure 3) which corroborates with the findings of other researchers from the same area (Das et al 2003). Here also the correlation co-efficient value is low and signifies poor correlation. But as stated earlier, this low value is particularly due to lower number of samples. In contrast to this, the fluoride concentration of some of the deep wells from Goalpara district (36.5 – 60.96 meter) displays insignificant fluoride - content in groundwater (Table 2) and this rules out the possibility of the depth of wells as a significant criterion for elevated fluoride level in the area. According to some workers, presence of different fluorine bearing minerals such as fluorite, fluorapatite, cryolite, amphiboles and biotite in bed rocks are causative factors for high fluoride concentration in groundwater (Handa, 1975; Pickering, 1985; Subba Rao and Devadas, 2003). Many authors have considered that fluorite (CaF_2) is the most dominant source of fluoride in groundwater (Deshmukh et al., 1995; Shah and Danishwar, 2003). However, in the Narengi-Birkuchi-Satgaon area fluorite was not likely a candidate for contributing excessive fluoride ion in groundwater because of its low solubility in fresh water and very slow dissolution rate (Nordstrom and Jenne, 1977). Further, fluorite is only an accessory mineral in the metamorphic rocks found in the area. The bedrock compositions confirm biotite as a major mineral in this region which generally contains significant fluorine at the OH^- sites of their octahedral sheet (Nordstrom et al. 1989). Again, according to some authors a high fluorine concentration of biotite is related to the partial melting (Li et al., 2003) which is consistent with a migmatitic terrain like the present area (Dey, 1999). Also, dissolution of biotite is a governing process for high fluoride concentration in regions having granitic bedrock (Chae et al. 2006). Therefore, we strongly suggest biotite as the potential source of high fluoride concentration in groundwater in this region. However, insignificant fluoride concentrations in the deep wells (36.5 – 60.96 meter) of Goalpara district were caused due to contrasting bed rock composition. In this region, low alkalinity (low pH values ~6,00) and very high values of hardness (measured as $CaCO_3$) (Table 2) indicates a high concentration of Ca^{2+} ion in groundwater as a result of Ca^{2+} supply from dissolving Ca-bearing plagioclase from more mafic and calcic composition of the bed rocks (Mazumdar,1996). As a matter of fact, in this area, dissolution of Ca-rich plagioclase released sufficient Ca^{2+} ions in groundwater

(Chae et al., 2006) and hence Ca^{2+} concentration was negatively correlated with fluoride concentration. Thus, in the light of present study we would like to propose that high fluoride concentration in groundwater largely depends upon lithology of the aquifer while Ca^{2+} concentration in groundwater is a dominant factor for controlling fluoride concentration regardless of the depth of wells. Therefore, this study suggests that the origin and control of high fluoride concentration in groundwater are largely depending upon the aquifer lithology. Further extensive studies with larger number of sampling sites must be carried out in order to re-establish the co-relation among pH, depth of water extraction and fluoride concentration.

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