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Quantification of Fluoride Contamination of Groundwater sources in parts of Guwahati city, Assam, India: An assessment of hazard to human health

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Abstract: *High concentration of Fluoride in groundwater sources in parts of Guwahati city is a serious threat to the public health and safety. Fluoride (F^-) concentration beyond the permissible limits (1.5 mg/l) in drinking water has lead to human health hazards, including dental and skeletal fluorosis. In order to understand the probable source of fluoride and its concentration, 164 groundwater samples drawn from the affected southeastern part of Guwahati city were collected during December 2008 to December 2009 for evaluation of fluoride contamination. The concentration of fluoride in the groundwater of the study area varies from BDL to 4 mg/l. Among the 164 random samples analyzed, 10 exceeded the maximum permissible limits (above 1.5 mg/l) of fluoride in the study area. From preliminary investigation it has been found that the study area is widely fluoride-affected, having beyond permissible fluoride concentration (maximum of 4 mg/l). The areas viz, Narengi, Bonda, Chandrapur, Mathgharia, Satgaon and Sixmile (Chachal) showed high Fluoride concentration (i.e. more than 1.5 mg/l as recommended by WHO, 1984). There is an increase in the trend of fluoride concentration in groundwater towards the foot hills of Narengi- Mathgharia hill. People inhabiting in these areas who are using raw fluoride contaminated untreated water as a source for drinking water, have started showing initial symptoms of fluorosis. A proper screening and elimination of sources is urgently needed to mitigate the problem for public health safety.*

Keywords: *Fluoride; Ground water; Fluorosis.*

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INTRODUCTION

Water is an essential natural resource for sustaining life and environment. Groundwater forms a major source of drinking water and it plays an important role in all facets of life in urban as well as in rural areas. Groundwater moving through sedimentary rocks and soils pick up a wide range of compounds such as magnesium, calcium, and chloride. The effect of these natural sources of contamination on groundwater quality depends on the type of contaminant and its concentrations. Gaciri *et al.* (1993) stated that fluoride occurs in almost all waters from trace to high concentrations. Utilization of groundwater as a source of drinking water having excess fluoride leads to potential human health hazards known as fluorosis or bone disease. The severity of fluorosis depends on the concentration of fluoride in the drinking water, daily intake, continuity and duration of exposure, and climatic conditions. Globally, around 200 million people from 25 nations have great health risks, with high fluoride in the drinking water (Ayoob and Gupta, 2006). According to UNICEF (1999), nearly 177 districts in almost 20 states of India have been confirmed as fluoride-affected areas. Dental and skeletal fluorosis has affected more than 65 million people including 6 million children. WHO (2006) reported that fluorosis is generally caused by drinking groundwater containing more than the permissible limit of 1.5 mg /l of fluoride. Very low doses of fluoride (<0.6 mg/l) in water promote tooth decay. However, when consumed in higher doses (>1.5 mg/l), it leads to dental fluorosis or mottled enamel and excessively high concentration (>3.0 mg/l) of fluoride may lead to skeletal fluorosis.

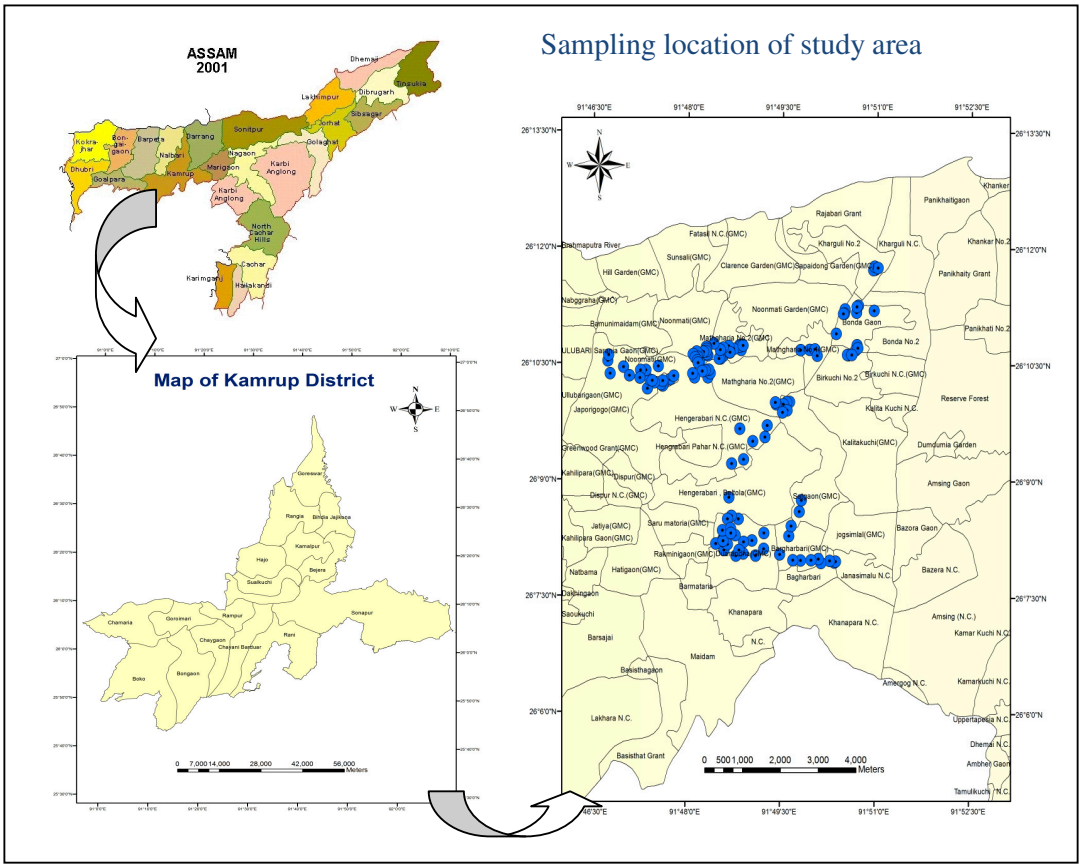
Assam, northeastern province of India, is currently experiencing a widespread problem with fluoride contamination of water. Susheela *et al*. (2001) and Chakraborti *et al*. (2000) reported Karbi Anglong Nagaon and Kamrup districts of Assam of N.E India as fluorosis prone area. Similar studies have been done by Das *et al.* (2003) and Sharma *et al.* (2005) in various parts of the capital city of Guwahati, Assam with special reference to the presence of fluoride. They reported the presence of fluoride up to 6.88 mg/L in drinking water samples. Thus, it is important to evaluate the groundwater quality and there is an urgent need of integrated approach for mitigation of Fluoride contamination in the affected areas of the Guwahati city. In this paper an attempt is made to assess the quality of underground drinking water with respect of Fluoride in the affected area of Guwahati city.

STUDY AREA

Guwahati, the capital of the state of Assam, is one of the most important and rapidly growing cities in North Eastern region of India. Evidences of extensive fluoride contamination in ground water and instances of fluorosis have recently been reported from Birkuchi, Narengi, Satgaon, Chacal and Mathgharia localities of Guwahati. It is located in 26º 05'–26º 15' N latitude and 91º 35'–91 º 55’ E longitudes. The city is situated between the southern bank of the Brahmaputra river. The average annual rainfall occur is 1715.7 mm with tropical climate and average maximum temperature of 29°C and average minimum is 19°C. The basement of the Guwahati city area is formed of Precambrian metamorphic rock complexes (Goswami *et al.*, 1998 and Pathak, 2001). The present study was carried out after proper screening and selections of the affected Zones in the Guwahati city, based upon the available secondary data sources collected from concerned departments (viz., Central Ground Water Board, Public Health Engineering

Department and Central Pollution Control Board). The map of the study area is shown in Figure 1.

Fig.1 Map of study area with sampling location point.



METHODOLOGY

Secondary data sources

The secondary data was used to identify the affected areas of Guwahati city with significantly high concentration of fluoride in ground water. Altogether eight affected zones of Guwahati city viz; Zone A (Mathgharia), Zone B (Bonda-Narengi), Zone C (Panjabari), Zone D (Khanapara), Zone E (Satgaon), Zone F (Chachal- Sixmile), Zone G (Gitanagar- Zoo Tinali) and Zone H (VIP Road- Patharquary) have been chosen for a detailed study of fluoride in groundwater after proper screening of the affected areas based upon secondary data collected from various organizations such as PHED, CPCB, CGWB and published research findings.

Sampling and Analysis

The water samples were collected from Tube Wells, Deep Tube wells (DTW) and open ring wells from house to house at approximately100 meter distance during December 2008 to

December 2009. Selected Water Quality parameters like pH, Conductivity, Total Dissolved Solids (TDS) were measured using WAGTECH portable pH, EC and TDS meters at every source. GPS survey was made simultaneously for recording the locations of the sampling points. GARMIN GPS (model: 76 CSx) was used and the locations of the samples are shown in Figure 1. In the field, the bottles were rinsed three times with the water to be sampled and then filled to the top. Both acidified and non acidified samples were taken for analysis of different parameters. The collected water samples were then carried to the laboratory at IIT Guwahati and analyzed for presence of fluoride and other hydro geochemical parameters were measured using standard methods (APHA, WEF, AWWA, 1998).

RESULTS AND DISCUSSION

Physico-chemical analysis

The chemical analysis of groundwater samples collected from the affected areas of Guwahati city was done. The pH varied from 7.66 to 5.5 in Zone A, 7.52 to 5.6 in Zone B, 7.1 to 5.72 in Zone C, 6.9 to 6.2 in Zone D, 8.24 to 6.85 in Zone E, 7.11 to 5.66 in Zone F, 7.31 to 5.62 in Zone G and 7.61 to 6.09 in Zone H. Similar results on water quality parameters viz; pH, Electrical conductivity (EC), Total dissolved solids (TDS), Turbidity and Fluoride in ground water of Guwahati city were reported earlier by Nesa *et al.* (2010). The pH value in most of the groundwater samples collected from the study area indicates slightly alkaline condition which favors the solubility of fluorine- bearing minerals. However, only few samples showed acidic pH which exhibits lower concentrations of Fluoride. Fluoride is adsorbed in clay in acidic medium, but in alkaline medium, it is desorbed, and thus alkaline pH is more favorable for fluoride dissolution activity (Saxena *et al.* 2001). EC values ranged from lowest (65.1 µS/cm) to maximum of (1027 µS/cm) in all the groundwater samples. The EC concentration in all the groundwater samples were less than 1000 µS/cm except in sample no.56 collected from Zone A (Mathgharia area) having EC of 1027 µS/cm which contains high amount of total dissolved solids (TDS) such as Calcium, Magnesium and Fluoride ions (Table 1). Data emerging from water quality analysis were categorized as safe or unsafe based on amount of fluoride content in groundwater samples. The concentration of fluoride in the groundwater samples of the study area varies from below detectable level (BDL) to maximum of 4 mg/l. The water samples collected from the areas like Zone A, Zone B, Zone E and Zone F showed high Fluoride concentration beyond 1.5 mg/l as recommended by WHO (1984). The concentration of Fluoride was found to be generally in increasing trend from dry (October to March) to wet seasons (April to September) in ground water samples collected from almost all the affected Zones of Guwahati city (Fig.2). However, in contrast, few samples collected from Zone A (Mathgharia), Zone B (Bonda-Narengi), Zone H (VIP Road- Patharquary), Zone F (Chachal- Sixmile) and Zone G (Gitanagar-Zoo Tinali) showed decreasing trend from dry (October to March) to wet seasons (April to September). These wells were primarily with low Fluoride concentrations and they generally tapped shallow aquifers. Deeper wells in the same locations still exhibited higher Fluoride concentrations as well as they demonstrated similar concentration fluctuations. Thus, there appear to be at least two different aquifers zones with variable contamination possibly due to variable proximity to Fluoride bearing horizons. Contrasting seasonal variability of concentration may also be attributed to advection and dispersion of two distinct Fluoride bearing groundwater parcels affected by variable transport and fate mechanisms.

Table 1. Physico-chemical analysis of collected groundwater samples

Zone	Total samples	pH mg/l Max - Min	EC µS/cm Max - Min	TDS mg/l Max - Min	F^- mg/l Max - Min	Ca^{2+} mg/l Max - Min	Mg^{2+} mg/l Max - Min	Na^+ mg/l Max - Min	K^+ mg/l Max - Min	$HCO3^-$ mg/l Max - Min	SO_4^{2-} mg/l Max - Min	Cl^- mg/l Max - Min	TH mg/l Max - Min
Zone A	33	7.66-5.5	1027-111	790-100	1.89 - 0	30.76 - 4.31	6.51 - 0.58	42.87 - 7.26	10.78 - 0.27	198 - 76	34.12 - 0.14	53.3-0.07	103 - 17.3
Zone B	25	7.52-5.6	673-126.8	480-120	4.00 - 0.08	32.79 - 4.54	8.7 - 0.22	44.73 - 2.58	10.25 - 0.09	204 - 56	35.9 - 0.33	72.02 - 0.01	117 - 12.3
Zone C	19	7.1-5.72	694-269	640-180	0.93 - 0.08	19.64 - 6.75	6.17 - 0.24	29.58 - 2.25	10.87 - 0.095	216 - 88	32.47 - 0.39	45.13 - 0.04	68.5 - 24.3
Zone D	10	6.9-6.2	611-340	300-110	0.81 - 0	20.9 - 5.32	3.83 - 1.28	42.86 - 11.5	2.99 - 1.29	236 - 82	2.9-1.2	22.8 - 1.57	61.7 - 19
Zone E	9	8.24-6.85	672-195	380-180	2.22 - 0	21.98 - 5.36	2.83 - 0.55	35.21 - 12.4	10.46 - 1.27	258 - 90	22.8 - 1.25	45.89 - 1.77	61.9 - 20.6
Zone F	18	7.11-5.66	792-65.1	340 - 80	1.76–0	22.05 - 5.12	44.4 - 1.37	41.7 - 8.62	10.46 - 1	216 - 76	22.35 - 1.25	22.9 - 0.06	73.4 - 19.3
Zone G	29	7.31-5.62	730-139.3	510 - 130	0.88 - 0	19.3 - 5.01	4.57 - 0.82	22.77 - 5.14	10.29 - 1.03	214 - 80	4.84 - 1.01	45.64 - 0.08	67.1 - 21.2
Zone H	21	7.61-6.09	743-176.8	480 - 160	1.24 - 0.05	21.9 - 5.64	4.54 - 1.26	41.87 - 7.36	5.26 - 1.05	218 - 80	24.35 - 1.02	45.86 - 0.09	72.5-20.2

EC = Electrical conductivity; TDS = Total dissolved solids; TH = Total Hardness

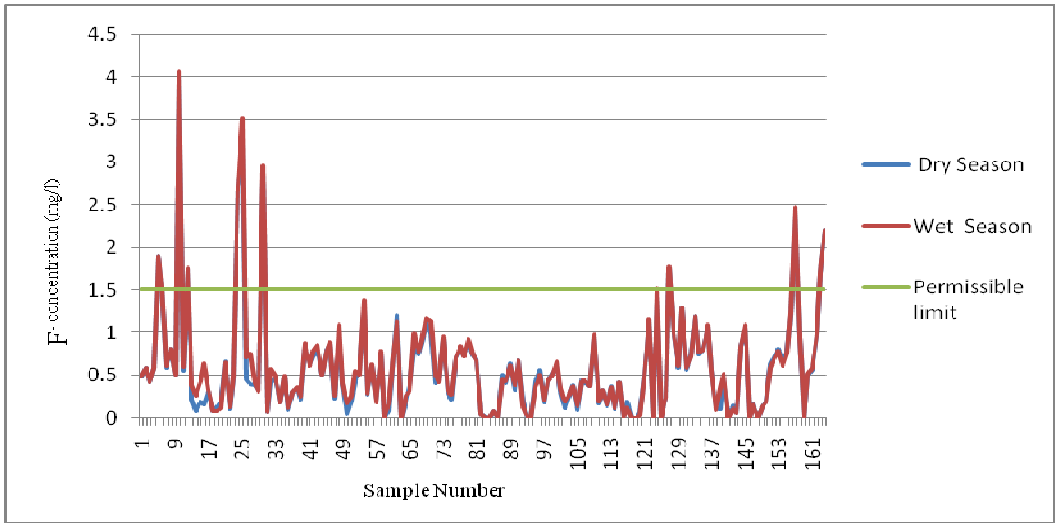


Fig.2. Variation in Fluoride concentration at Dry and Wet Seasons

To observe the relationship among various physico-chemical parameters, correlation analysis was performed and correlation matrix calculation is given in Table 2. The values of correlation coefficient were found positive as well as negative. Analysis revealed that fluoride has a good positive correlation with pH which indicates an alkaline environment as a dominant controlling mechanism for leaching of fluoride from the source material as reported by Rao *et.al.* 2008. High positive correlation found is of 0.951 (Ca^{2+} and TH), 0.652 (F^- and Na^+) and 0.539 (Ca^{2+} and Na^+). Similar kind of report was earlier reported by Das *et.al* (2003) stating positive correlation of fluoride (F^-) with sodium ion (Na+). Ramesam and Rajagopalan (1985) reported that higher concentration of sodium is an indicative of weathering of minerals. High concentration of sodium will increase the solubility of fluoride- bearing minerals in the waters. This may be the cause for the higher levels of fluoride in the groundwater of the study area. The other alkaline earth metal viz; Ca^{2+}, Mg^{2+} and the total hardness showed moderate to low positive correlation with fluoride content. The correlation coefficients were 0.443, 0.162 and 0.422 respectively. The concentration of Ca, Na, hydroxyl ion and certain complexing ions can alter the concentration of fluoride in the groundwater (Raju *et al.*, 1993). A strong negative correlation between Ca and F in the ground waters that contain Ca in excess of that required for the solubility of fluoride minerals has been observed by many researchers (Hem *et.al.,* 1991; Boyle *et.al.,* 1992; Babulal *et.al.,* 2003). Chakraborti *et al*. (2000) reported positive correlation of fluoride with Ca^{2+} in groundwater in parts of Nagaon and Karbi Anglong districts of Assam.The percentage of occurrence of fluoride in groundwater of the affected areas of Guwahati city showed that out of a total of 164 samples, 3.66% has fluoride concentration above 2 mg/l, 3.05% between 1.5 to 2 mg/l and 6.05% between 1 to 1.5 mg/l, whereas 54.88% of the samples are deficient (below 0.5 mg/l) in fluoride (Table 3).

Table 2. Correlation between water samples collected from affected areas of Guwahati.

	pH	EC	TDS	F^-	Ca^{2+}	Mg^{2+}	Na^+	K^+	$HCO3^-$	SO_4^{2-}	Cl^-	TH
pH	1											
EC	0.182	1										
TDS	0.091	0.774	1									
F^-	0.353	0.025	0.079	1								
Ca^{2+}	0.236	-0.018	0.013	0.443	1							
Mg^{2+}	0.111	-0.091	-0.02	0.162	0.361	1						
Na^+	0.299	0.069	0.042	0.652	0.539	0.182	1					
K^+	-0.05	0.033	0.061	0.039	0.158	0.139	0.06	1				
$HCO3^-$	0.119	-0.051	-0.02	0.197	0.024	-0.007	0.17	0.016	1			
SO_4^{2-}	0.035	0.0004	0.158	-0.02	0.137	0.151	0.02	0.095	0.17	1		
Cl^-	-0.13	0.111	0.162	0.088	0.179	0.083	0.12	0.199	0.02	0.39	1	
TH	0.233	-0.045	0.005	0.422	0.951	0.632	0.51	0.178	0.02	0.16	0.18	1

Table 3: Percentage of occurrence of Fluoride in groundwater samples.

Range (mg/l)	Number of Samples	Percentage of occurrence (%)
0-0.50	90	54.88
0.51-1.00	53	32.32
1.01-1.50	10	6.09
1.51-2.00	5	3.05
above 2	6	3.66

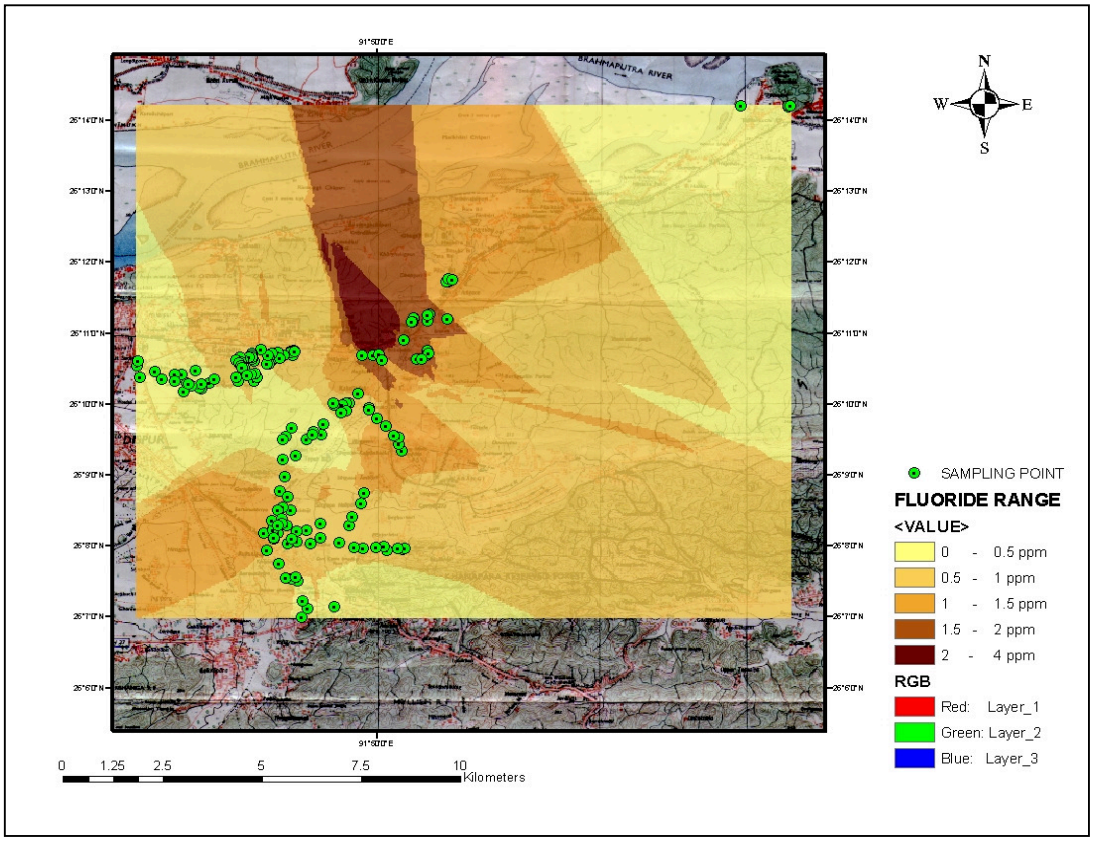


Fig.3. A prediction model developed by simple krigging in ARC GIS.

GIS Mapping

After plotting Fluoride concentrations of all the water samples with positional co-ordinates on Guwahati toposheet, a prediction model was prepared by Kriging using ARC-GIS software (Fig 3). The prediction model displays the contours of different shades having different range of Fluoride concentrations. The model depicts that the southeastern parts of city is having highest fluoride concentration (maximum 4 mg/l). There is an increase in the concentration as we move towards the foot hills in the north of Zone A and B and the concentration started decreasing as we move away from the hilly regions towards the plains of Zone G i.e. towards the city. It confirms the presence of high concentration of Fluoride at the foot hill region, due to the presence of likely fluoride bearing minerals in the form of granitic and gneissic rocks in the basement of the foot hills. In the study area high fluoride contamination in groundwater is mainly a natural process and leaching of fluorine- bearing minerals results in release of fluorine due to weathering of granite gneissic rocks which is in agreement with the studies done by Apambire *et al*. (1997), Kundu *et al*. (2001) and Sarma et.al. (2005). Das *et.al* (2003) suspected that minerals from the Precambrian granite are the sources of fluoride. Fluoride derives mainly from the lithological sources such as rocks containing apatite and biotite, which can be potential sources of fluoride in the groundwater (Hem 1991; Jacks *et al*. 2005). Presence of these two minerals in the study areas has earlier been established in consecutive lithologs (Sharma *et al*., 2005)

CONCLUSION

The present study of groundwater quality with reference to fluoride concentration in the affected areas of Guwahati city indicated that the ground water is affected by Fluoride contamination to different degrees. Factors responsible for the occurrence of fluoride in the groundwater are likely to be due to the long contact time of water with the fluoride bearing aquifer material. Fluoride contamination is suspected to be a natural process due to absence of any major anthropogenic source in the study area. The southeastern part of Guwahati city like Mathgharia, Bonda, Narengi and Satgaon area showed relatively high Fluoride concentration (maximum of 4 mg/l) compared to the rest of the locations in the study area. Increase in Fluoride concentration and spread in the future due to continued leaching of fluoride from the source material tentatively identified as granitic and gneissic rocks is likely and needs vigilance. Quality of water has now become a subject of major concern among the people residing in the fluoride affected areas of Guwahati city. People inhabiting in the affected areas using raw fluoride contaminated untreated water as a source for drinking water, have started showing initial symptoms of fluorosis. Keeping this in view, comprehensive subsurface investigation is urgently needed for better understanding of the source and effects of fluoride problems in affected areas of Guwahati city. A fate and transport modeling project has been initiated by this group and the future findings will be reported highlighting major breakthrough, once achieved.

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