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Fluoride geochemistry of groundwater in parts of Brahmaputra flood plain in Kamrup district, Assam, India

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ABSTRACT

Groundwater contamination by fluoride (F) can result from the natural dissolution of minerals from subterranean strata. These inorganic contaminant in drinking water is known to cause serious health problems when the maximum contaminant levels (MCL) exceed 1.5 mg/L. The aim of this study was to correlate the high fluoride content in the groundwater of the region to the geochemistry of the water. Ground water samples were collected from tube wells, deep tube wells and ring wells covering all the major hydro geological environs in pre- and post-monsoon seasons. F concentrations ranged from 0.00 to 10.71 mg/L. Geological formations of this zone consist of F-containing minerals, which could be a major source of F in these groundwater sources.

Key words: Ground water, Fluoride, Amphiboles, Granite, correlation, sodium.

INTRODUCTION

Groundwater is a dynamic resource and undergoes significant variations quantitatively and qualitatively. Its quality depends on the quality of recharged water, atmospheric precipitation, inland surface water, and on sub-surface geochemical processes viz., the interaction with aquifer minerals or by the inter mixing among the different groundwater reservoirs along flow path in the subsurface**.**

There has been increasing global attention focused on resolving water quality problems especially in developing countries, as the lack of access to clean water denies the most essential of all rights, the right to life. F concentration is an important aspect of hydro geochemistry, because of its impact on human health. India is among 23 nations in the world, where fluoride contaminated ground water is creating health problems. Of late, in mid of 1999, Assam region of Northeast India has been identified as a fluoride affected area. Recent declaration from the state

Government has also confirmed the prevalence of fluoride in the groundwater of Kamrup district of Assam. The Karbi anglong and the Naogaon districts of the state are the worst affected (1). As groundwater is a major and preferred source of drinking water in the district, the population seems to be vulnerable to the health affects of excessive fluoride in the drinking water. The contents of fluoride in ground water are increasing due to heavy withdrawal of water for agriculture purpose, poor recharging, low rainfalls and pollution from industrial effluents.

Fluoride is a persistent and non-degradable poison that accumulates in soil, plants, wild life and in humans. Severe chronic and cumulative over exposure can cause the incurable crippling of skeletal fluorosis. The dental and skeletal fluorosis is irreversible and no treatment exists. The only remedy is prevention by keeping fluoride intake within the safe limits. The WHO has set a optimum fluoride level of 1.5 mg L_1 in drinking water for good health.

A significant fact about fluorine geochemistry is that almost all fluorine is tied up in rock minerals. Amphiboles, such as horneblende and some of the micas, may contains fluoride which replaces part of the hydroxide within the mineral structure. Rocks rich in alkali metals, and also obsidian, are as a class higher in fluoride content than most other igneous rocks. Fluorite (CaF_2), fluorapatite ($Ca_5(PO4)_3F$), cryolite (Na_3AlF_6), villiaumite (NaF), topaz ($Al_2(SiO_4)F_2$), and certain clays are the predominant fluoride-bearing minerals in the natural environment (2). It is now an established fact that regions with highest fluoride levels and having bedrock layer composition of igneous and metamorphic rocks are of geological composition of syenites, granites, quartzmonzonites, granodiorites, felsic and biotite gneisses, and alkaline volcanic. Although these rock types can contain a variety of fluoride-rich accessory minerals, laboratory experiments and field studies have shown that the presence of biotite alone is sufficient to produce dissolved fluoride concentrations above 4 mg/l (3) (4) (5).

Study Area:

Kamrup district of Assam is situated between $25^0 43^/$ and $26^0 51^/$ N Latitudes and $90^0 12^/$ and $90^0 36^/$ E Longitudes. The district is surrounded by Nalbari and Barpeta districts in the North, Meghalaya in the South, Darrang and Morigaon districts in the East while in the West, it is surrounded by Goalpara district.The district consists of wide plains through which the mighty river Brahmaputra flows from east to west. Guwahati is the district Headquarter. The district is constituted by two sub-divisions namely-Guwahati and Rangia. The total Geographical area of the district is 2740.74 sq.km. Topographically, the district is divided into two parts by the mighty river Brahmaputra from the east to the west. The northern portion of the district is about twice the area of the southern portion. Generally speaking, the district forms a great plains, comprising a few elevated tracts lying along the Bhutan and Khasi hills which form respectively its northern and southern boundaries. Thus physiographically the whole area can be divided into three categories – the hilly part, the alluvial tract and the swampy areas. The climate of the district is directly characterized by modified tropical monsoon with well marked seasonality. The highest temperature is experienced during the south west monsoon along with abundant rains. A highly humid atmosphere is experienced through out the year. There is a heavy rainfall in summer and continuous drought in winter. The average annual rainfall in the district is 2135.7 mm and it ranges between 1500 mm to 2600 mm. in the central portion of the district which forms the Brahmaputra valley. But as we approach the hills on either side of the valley, the rainfall gradually increases. About 65% of the annual rainfall is received during the monsoon season, June being generally the rainiest month.

Ground water in the district has been playing an important role in the ecology, geomorphology and hydrology of the area. There is perceptible fluctuation in the under- ground water levels which may remain a few inches below the surface during the rainy period and go down to about 100 ft. during the dry period. The later extremes generally occur in the foothill zone during the period of prolonged drought.

Geological Setting of the study area:-

The major portion of the district is covered by granitic gneisses with lenticular bands of amphibolite, biotite granulite, biotite schist and isolated occurrences of hornblende-diorite, all belonging to the Archaean Gneissic Complex (**Fig 1**).

The Granite bodies are divided into two contrasted types : (1) nonporphyritic granite which is intimately associated with the gneisses and (2) porphyritic granite known as Nongpoh Pluton which is found to be intrusive into the Gneissic complex. Non porphyritic granites associated with the gneisses the area are often gneissose in nature and they invariably grade into granite gneisses. At places, the change in the texture is abrupt, while elsewhere the change is gradational. The porphyritic granites known as Nongpoh Pluton occur as intrusions into the gneissic complex. At the contact of granite, the gneisses are magmatised. Porphyritic granites are exposed mainly along the southern part of the district. All the rock types are traversed by numerous veins and veinlets of quartz, pegmatite and aplites which most probably owe the origin to the porphyritic granite.

MATERIALS AND METHODS

About 168 drinking water samples were collected from 42 different locations of the district (**Fig 2**) during investigations carried out in the year 2006-2008, one set comprising 42 samples in each season in a year. After a careful study of the different meteorological parameters of the city, two seasons have been taken in this study.

a) Pre monsoon and monsoon season (April to September).
b) Post monsoon and winter season (October to March).

Composite sampling has been adopted to collect water samples to make it a representative samples. The water samples so collected were chemically analysed. Fluoride concentration was determined Spectrophotometrically (Shimadzu, UVMini1240) using SPADNS [sodium-2-(parasulphopherylase) 1,8-dihydroxy-3,6-napthalene disulphonate] reagent. Fluorides react with the coloured complex of zirconyl acid and SPADNS forming colourless $[ZrF_6]^{2-}$ releasing the dye. This reaction, which can be followed conveniently by colorimetric measurement of the dye, is the basis of fluoride estimation. At first, fluorides are separated from water samples by distillation in presence of concentrated H_2SO_4 and soft glass beads to obtain fluorosilicic acid. A little Ag_2SO_4 is added to the distillation flask to prevent volatilization of hydrogen chloride when the samples have an appreciable chloride content. The absorbance measurements were done at 570nm. Fluoride concentration was read directly by operating the instrument in quantitative mode against three standards and a blank (6). Various other water quality parameters such as pH, electrical conductivity, total dissolved solids, sodium, potassium, calcium, magnesium, chloride, and sulfate concentrations were measured. The techniques and methods followed for the collection, preservation, analysis, and interpretation are those given by (6).

RESULT AND DISCUSSION

The Statistical summary of the analysis results are shown in **Table 1.** Different statistical analysis indicates that the ground water is acidic to alkaline with the pH value ranging from 6.00 to 7.90. EC of the water varies from 2.60-82.00 mS/cm. The calculated TDS value ranged from 5 to 299 mg/l. The concentrations of other major constituents , Ca^{2+}, Mg^{2+}, Na^{+}, K^{+}, Cl^{-}, and SO_4^{-2} , showed wide variation but their mean values are 78.63, 30.72, 60.45,4.32,41.63, and 12.51 mg/l, respectively. Fluoride is estimated to be ranging from 0.00 to 10.71 mg/l with the mean value of 3.12 mg/l.

Correlation studies (**Table 2**) between fluoride and other parameters indicates there is no significant relationship with calcium, magnesium and TDS. Negative correlation between fluoride and Calcium is attributed to low solubility of fluoride from these cation bearing rocks. (7) This is also suggestive towards the possibility of ion-exchange process. But a positive relationship with pH indicates towards a possible leaching of fluoride under high alkaline conditions of water. This is because of the similarity between the ionic radius of fluoride and hydroxyl ion thereby replacing each other at higher pH.

A significantly positive correlation has been observed between fluoride and sodium, potassium and chloride. This is indicative of their similar source and mobility with fluoride ions. Further a significant correlation between magnesium and chloride is indicative of permanent hardness of the water. Moreover the decreasing trend of calcium concentration is indicative of calcite precipitation which increases fluoride solubility in groundwater thus in turn increasing fluoride concentration in ground water.

Table 1: Summary statistic of chemical parameters in ground water samples from Kamrup district of Assam.

Descriptive Statistics

	N	Range	Minimum	Maximum	Mean		Std.	Variance	Skewness		Kurtosis	
	Statistic	Statistic	Statistic	Statistic	Statistic	Std. Error	Statistic	Statistic	Statistic	Std. Error	Statistic	Std. Error
pH	168	1.90	6.00	7.90	6.9737	55E-02	.3830	.147	.189	.187	-.299	.373
EC	168	79.40	2.60	82.00	0.7690	.6071	7.8689	61.920	4.656	.187	39.139	.373
TDS	168	294	5	299	103.57	4.20	54.43	62.831	1.176	.187	1.757	.373
Ca	168	431.00	4.00	435.00	8.6272	4.7400	1.4373	74.542	2.819	.187	11.266	.373
Mg	168	113.71	.29	114.00	0.7250	1.4280	8.5089	42.579	1.753	.187	4.657	.373
Cl	168	92.70	7.30	100.00	1.6329	1.3028	6.8868	85.164	.452	.187	-.174	.373
SO4	168	91.05	.00	91.05	2.5158	1.2270	5.9041	52.941	2.077	.187	4.887	.373
Na	168	97	0	97	60.45	1.71	22.17	91.398	-.314	.187	-.601	.373
K	168	81	0	81	4.32	.83	10.75	15.477	4.774	.187	25.455	.373
F	168	10.71	.00	10.71	3.1178	.2202	2.8546	8.149	.859	.187	-.283	.373
Valid N (listw	168											

Therefore a thorough consideration of the geological setup of the study area and the analytical results of the present investigation indicates towards a strong geological origin of the fluoride in ground water sources of the study area. Presence of horneblende diorite and amphibolites along the lenticular bands of granitic gneiss can be attributed to the presence of higher fluoride concentration in the groundwater of the district.

Table 2 :- Pearson correlation coefficients of physico chemical parameters in the groundwater samples of the Kamrup district of Assam.

Correlations[a]

		pH	EC	TDS	Ca	Mg	Cl	SO4	Na	K	F
pH	Pearson Correlatio	1.000	-.032	-.122	.012	.129	.132	-.114	.096	.016	.131
	Sig. (2-tailed)	.	.684	.116	.881	.095	.089	.142	.218	.839	.091
EC	Pearson Correlatio	-.032	1.000	.051	.050	.082	.058	.206**	.035	.100	-.057
	Sig. (2-tailed)	.684	.	.514	.518	.291	.453	.008	.657	.198	.462
TDS	Pearson Correlatio	-.122	.051	1.000	-.032	.015	-.137	-.042	-.138	.087	-.037
	Sig. (2-tailed)	.116	.514	.	.676	.845	.076	.593	.075	.261	.634
Ca	Pearson Correlatio	.012	.050	-.032	1.000	.469**	.051	.234**	-.007	.033	-.100
	Sig. (2-tailed)	.881	.518	.676	.	.000	.508	.002	.927	.670	.196
Mg	Pearson Correlatio	.129	.082	.015	.469**	1.000	.205**	-.091	.133	.095	.055
	Sig. (2-tailed)	.095	.291	.845	.000	.	.008	.239	.085	.219	.478
Cl	Pearson Correlatio	.132	.058	-.137	.051	.205**	1.000	.145	.765**	.162*	.563**
	Sig. (2-tailed)	.089	.453	.076	.508	.008	.	.061	.000	.036	.000
SO4	Pearson Correlatio	-.114	.206**	-.042	.234**	-.091	.145	1.000	.040	.222**	.004
	Sig. (2-tailed)	.142	.008	.593	.002	.239	.061	.	.609	.004	.954
Na	Pearson Correlatio	.096	.035	-.138	-.007	.133	.765**	.040	1.000	.137	.697**
	Sig. (2-tailed)	.218	.657	.075	.927	.085	.000	.609	.	.076	.000
K	Pearson Correlatio	.016	.100	.087	.033	.095	.162*	.222**	.137	1.000	.189*
	Sig. (2-tailed)	.839	.198	.261	.670	.219	.036	.004	.076	.	.014
F	Pearson Correlatio	.131	-.057	-.037	-.100	.055	.563**	.004	.697**	.189*	1.000
	Sig. (2-tailed)	.091	.462	.634	.196	.478	.000	.954	.000	.014	.

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

a. Listwise N=168

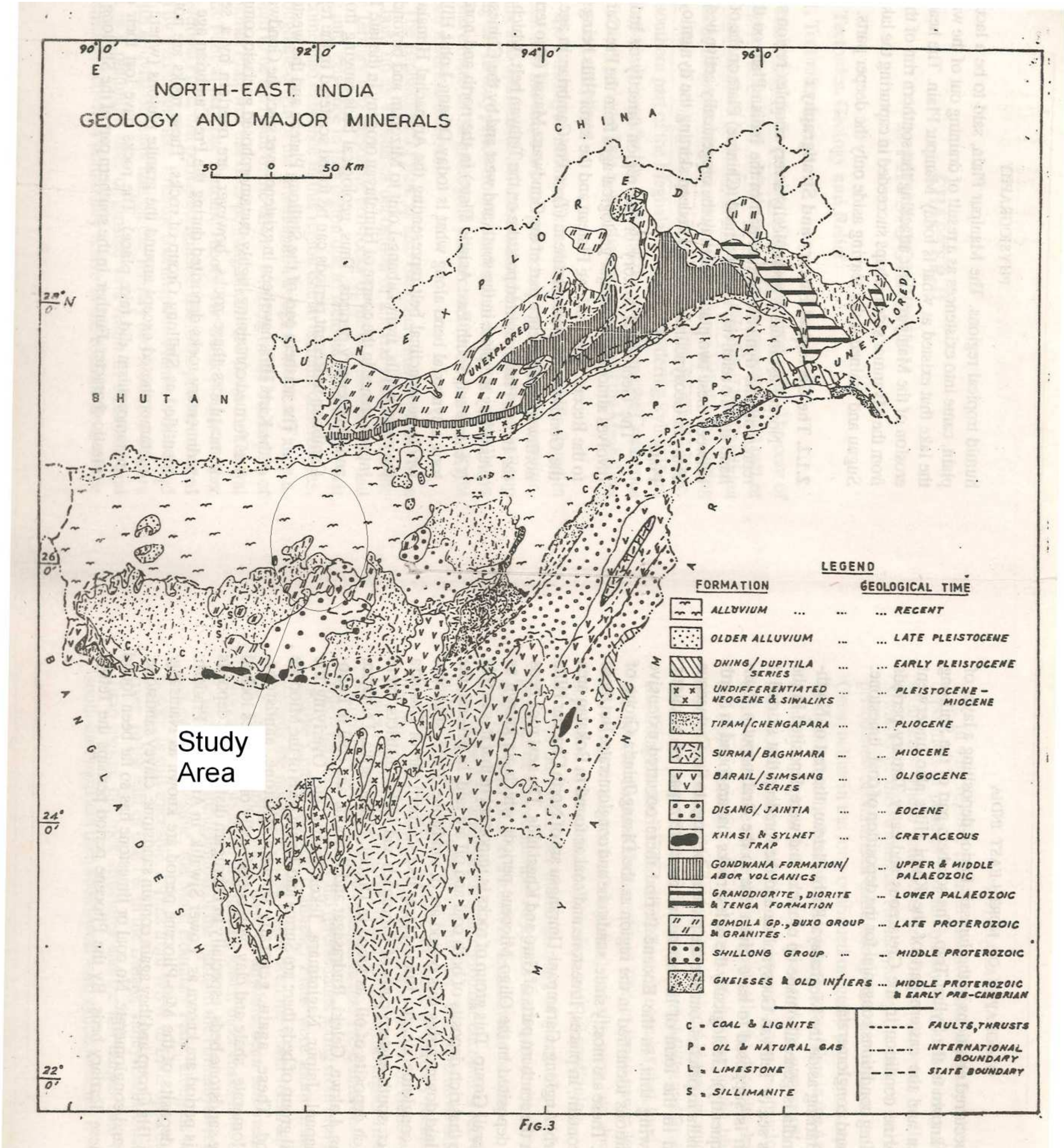

Fig 1: Geological Map of the North east India (study area located)

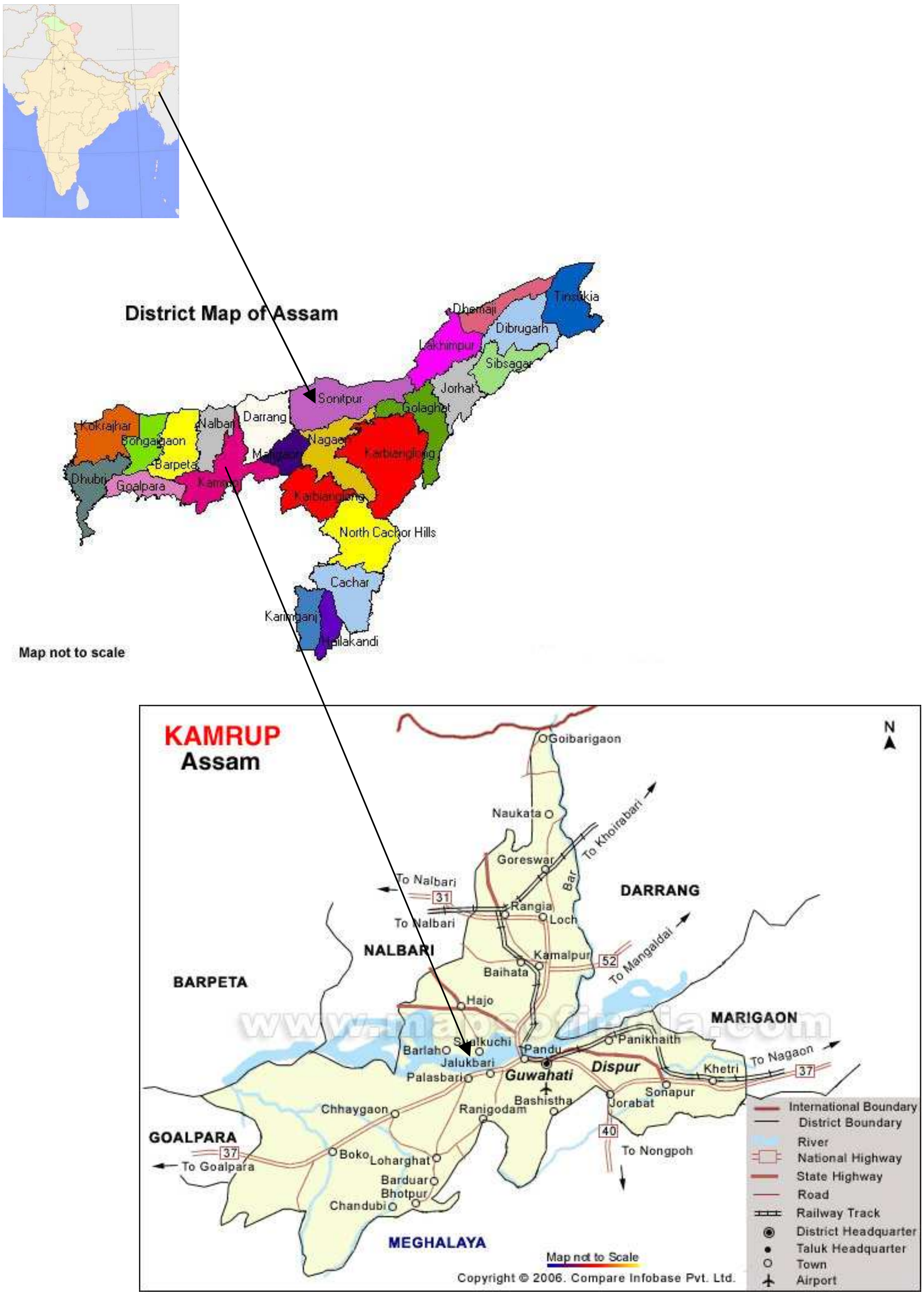

Fig 2 Location Map of Kamrup district of Assam

CONCLUSION

The aim of this paper is to address the geochemical issues related to the fluoride contaminated ground water in Kamrup district of Assam. The role of geochemical processes in contrast to the mineralogy of the aquifers in gradual development of the groundwater characteristics has been studied. Due to absence of any anthropogenic source of enrichment of fluoride, geogenic origin seems to be the only reason behind the present scenario. The analytical data revealed a higher concentration of fluoride than the MCL in most of the samples. This implies that there is an urgent need to implement suitable remedial measures possibly some local defluoridation techniques that could stop the immediate damage to human health.

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