FLUORIDE CONTAMINATION OF UNDERGROUND WATER IN WEST BENGAL, INDIA

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SUMMARY: The levels of the anions fluoride (F), bromide, chloride, nitrate, and sulphate were measured in 51 underground water samples, collected from 33 places in West Bengal, India, using the ion-chromatographic method. The F concentrations were within tolerable limits except for the villages of Kapileswar, Haringhata, (1.24 mg/L); Palta, 24 Parganas (North), (1.75 mg/L); Rondia, near Panagarh, (1.61 mg/L); Midnapore (1.38 mg/L); Hijli (1.08 mg/L); and Laxmanpur, Purulia, (1.06 mg/L). The ground water samples of these villages, were found, in general, to be alkaline in nature. The F concentrations appeared to be related to the physiographic and geological nature of the soils. A forensic investigation into the death of a 25-yr-old male from sodium fluoride overdose, resulting in F levels in the gastric contents and blood of 35.05 and 4.341 mg/L, respectively, is also noted.

Keywords: Fluoride; Geological nature; Ion-chromatography; Soils; Underground water; West Bengal; India.

INTRODUCTION

Water is essential for all physiological activities associated with humans, animals, and the plant kingdom. However, the nature and the quality of surface and ground water are widely variable and are determined by the local geological history, including the rocks and hidden ore deposits surrounding the sites for the collection of the water, and other factors, such as the movement of elemental particles and pollutants by lentic and lotic waters and underground aquifers.[1]

The quality of water is poorly understood due to the variety in the interactions between water and soluble minerals, sparingly soluble minerals, and salts, both natural and anthropogenic. In spite of the complex hydro and biogeochemical factors, the number of dissolved constituents in ground water is limited. In addition to the trace constituents in water, the major constituents are Na^+, Ca^{2+}, Mg^{2+}, SO_4^{2-} (as acid and salts), Cl^-, HCO_3^-, etc., and the secondary constituents are Fe^{2+}, Sr^{2+}, K^+, CO_3^{2-}, NO_3^-, and F^- (fluoride).

Fluoride (F) becomes toxic when it occurs in drinking water beyond the maximum permissible limit of 1.5 ppm.[2] Chronic exposure to fluoridated ground or drinking water creates a health problem not only in human beings[3,4] but also in diverse species of domestic animals[5,6] in the form of osteo-dental fluorosis. Recently, bio-indicators of endemic fluorotoxicosis due to fluoridated ground water have been reported.[7,8]

In India, several states are endemic for hydrofluorosis due to the high F content in drinking water.[9,10] It is well known that F contamination is present in the ground water in the western part of West Bengal (Birbhum, particularly Nalhati, Bankura, Purulia, parts of Midnapore, and Bardhaman districts).[11] Recently, an escalation of the groundwater F in the Ganga alluvial plain of India has also been

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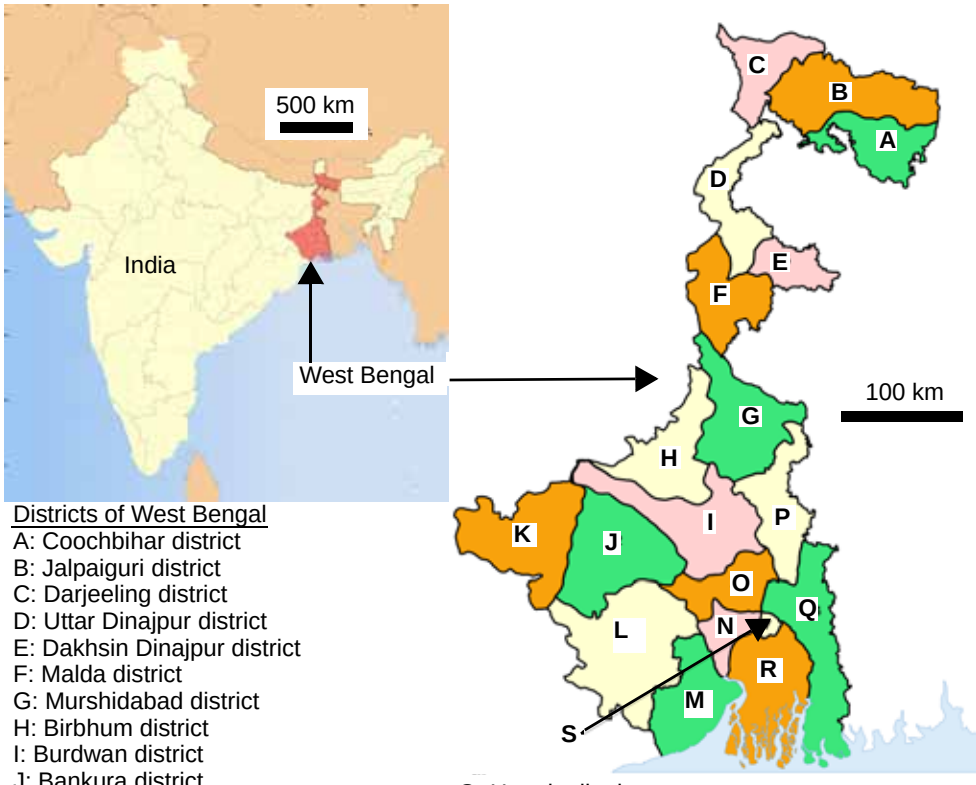
reported.[12] Thus, a study was made of the F concentrations in different parts of West Bengal to give an preliminary assessment of the extent of F contamination. This will enable us to undertake further extensive and intensive investigations of F contamination in West Bengal in order to ascertain the probable causes of this in the most affected areas. Simultaneously, estimations were also made of some other anions in the collected water samples to order to prepare a database for the probable correlations between F and other anions.

Curiously the genesis of the present work was in a referral by the police for the determination of the F levels in the gastric contents and blood of a 25-yr-old male resident of New Delhi who died of suspected fluoride poisoning after mistaking sodium fluoride for sugar and taking an overdose.The determination of F concentration can thus be a matter of forensic importance and the results of this investigation are also presented in this paper.

MATERIALS AND METHODS

Study areas, source and collection of samples: Fifty-one samples were collected from 33 places and villages of West Bengal (India) as indicated in Figures 1 and 2 and Tables 1–3.



Districts of West Bengal
A: Coochbihar district
B: Jalpaiguri district
C: Darjeeling district
D: Uttar Dinajpur district
E: Dakhsin Dinajpur district
F: Malda district
G: Murshidabad district
H: Birbhum district
I: Burdwan district
J: Bankura district
K: Purulia district
L: Paschim Midnapur district (Midnapur West)
M: Purba Midnapur district (Midnapur East)
N: Howrah district
O: Hoogly district
P: Nadia district
Q: North 24 Pargana district
R: South 24 Pargana district
S: Kolkata

Figure 1. Location of the districts of West Bengal, India.

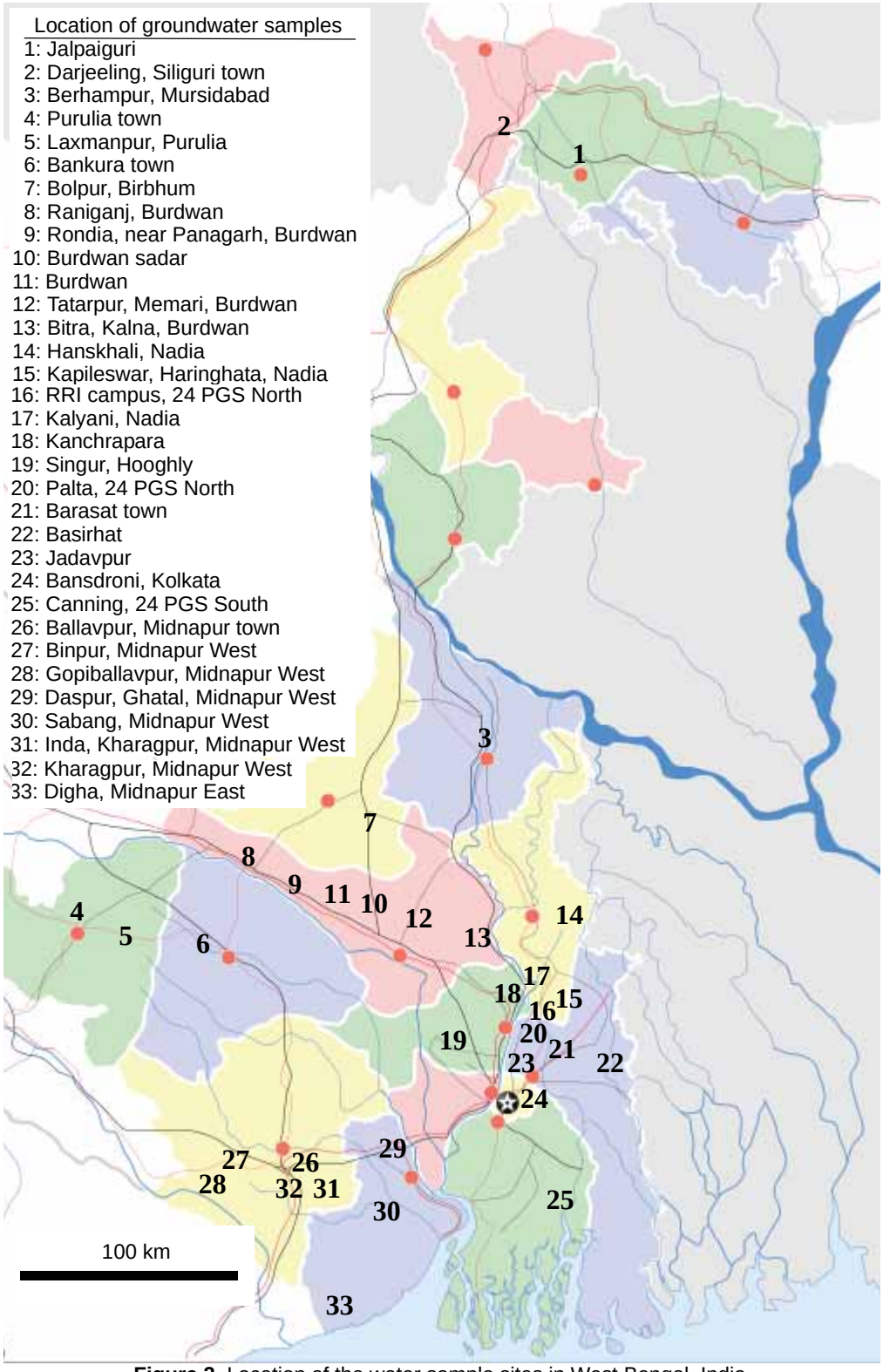


Figure 2. Location of the water sample sites in West Bengal, India.

Table 1. Analytical results of groundwater samples, 1–17, of West Bengal. Values are in mg/L except pH; DT, deep tube well; T, tube well; D, dug well; R, river water

Sample	Location	F^-	Br^-	Cl^-	NO_3^-	SO_4^{2-}	pH
1DT	Jadavpur (23)	0.5	0	1114.33	0	26.82	8.23
2DT	Bansdroni, Kolkata (24)	0.41	7.53	1130.03	6.44	14.91	8.13
3T	Bansdroni, Kolkata(24)	0.42	34.37	1279.67	28.32	18.09	8.23
4R	Kanchrapara (18)	0.3	0	13.83	3.65	3.09	8.31
5T	Singur, Hooghly (19)	0.37	0	101.88	2.76	9.51	8.29
6DT	Hanskhali, Nadia (14)	0.4	0	2.68	2.45	0	8.40
7D	Kapileswar, Haringhata, Nadia (15)	0.5	2.76	1068.73	95.67	443.61	8.42
8DT	Kapileswar, Haringhata, Nadia (15)	1.24	3.92	91.39	24.64	6.38	8.59
9DT	Kalyani, Nadia (17)	0.86	0	251.22	24.82	3.04	8.12
10D	Palta, 24PGS North (20)	1.75	6.84	679.75	258.86	121.14	8.62
11DT	RRI campus, 24 PGS North (16)	0.72	5.48	28.23	5.81	1.04	8.38
12DT	Barasat town (21)	0.69	0	61.41	1.54	12.4	7.57
13T	Basirhat (22)	0.15	0	2366.22	18.47	24.93	7.72
14T	Basirhat(22)	0.18	64.22	2124.69	15.33	5.98	8.40
15DT	Canning, 24 PGS South (25)	0.33	2.12	192.05	9.16	33.51	8.65
16D	Siliguri town (2)	0.25	0	140.94	189.9	12.77	7.94
17DT	Siliguri town (2)	0.46	0	52.6	1.68	3.7	7.77

Table 2. Analytical results of groundwater samples, 18–34, of West Bengal. Values are in mg/L except pH; DT, deep tube well; T, tube well; D, dug well; R, river water

Sample	Location	F^-	Br^-	Cl^-	NO_3^-	SO_4^{2-}	pH
18R	Jalpaiguri (1)	0.29	0	1.39	2.43	3.37	8.14
19D	Jalpaiguri (1)	0.36	0	17.09	2.35	3.61	8.33
20DT	Darjeeling, Siliguri town (2)	0.3	0	10.89	8.95	8.48	7.26
21T	Berhampur, Mursidabad (3)	0.28	0	107.5	5.37	3.12	8.18
22DT	Laxmanpur, Purulia(5)	1.06	0	82.66	2.21	10.51	7.15
23R	Municipal water, Purulia town (4)	0.51	0	16.89	5.16	3.56	8.54
24D	Purulia town (4)	0.48	0	542.41	55.91	80.92	7.02
25T	Purulia town(4)	0.47	0	586.31	82.66	44.53	6.99
26DT	Bankura Rly Stn, Bankura (6)	0.46	0	135.04	8.54	9.4	8.05
27DT	Bankura town (6)	0.42	0	138.36	9.56	10.45	8.33
28T	Bolpur, Birbhum (7)	0.53	0	7.11	5.76	1.07	6.67
29T	Tatarpur, Memari, Burdwan (12)	0.56	0	48.17	0.75	0.82	8.40
30D	Raniganj, Burdwan (8)	0.47	0	584.76	16.88	128.3	7.35
31R	Municipal water, Raniganj, Burdwan (8)	0.52	0	14.89	4.2	9.87	8.27
32T	Burdwan sadar (10)	0.47	0	19.01	3.74	2.07	8.45
33T	RRI office campus, Galsi, Burdwan (11)	0.65	0	19.52	4.49	8.88	8.24
34T	Bitra, Kalna, Burdwan (13)	0.48	0	43.17	2.57	4.04	8.49

Table 3. Analytical results of groundwater samples, 34–51, of West Bengal. Values are in mg/L except pH; DT, deep tube well; T, tube well; D, dug well; R, river water

Sample	Location	F^-	Br^-	Cl^-	NO_3^-	SO_4^{2-}	pH
35DT	Rondia, near Panagarh, Burdwan (9)	1.61	5.76	356.24	28.7	34.96	8.09
36DT	Dharma, Midnapur town (26)	0.55	0	41.88	7.1	1.08	8.39
37DT	Ballavpur, Midnapur town (26)	0.48	0	10.57	4.7	1.67	8.46
38D	Ballavpur, Midnapur town (26)	0.41	0	153.31	18.2	8.79	8.67
39DT	Tantigeria,Midnapur town (26)	0.27	0	7.33	2.06	0	8.19
40T	Binpur, Midnapur West (27)	0.37	0	9.02	3.59	0.94	8.29
41T	Gopiballavpur, Midnapur West (28)	0.36	0	27	0	1.93	8.14
42DT	Digha, Midnapur East (33)	0.33	0	14.3	1.83	3.32	7.28
43D	Burge town, Midnapur town (26)	0.44	0	123.07	26.77	4.66	8.03
44T	Daspur,Ghatal,Midnapur West (29)	0.62	0	18.64	2.87	4	8.18
45DT	Sabang,Midnapur West (30)	0.64	0	20.78	2.55	1.67	8.67
46D	Inda, Kharagpur, Midnapur West (31)	0.3	0	118.19	75.46	19.06	8.18
47DT	Midnapur town (26)	1.38	0	31.67	6.44	6.36	8.15
48D	Midnapur town (26)	0.85	0	418.12	243.15	78.67	8.36
49D	Hijli college, Prembazar, Kharagpur, Midnapur West (32)	1.08	0	133.21	19.21	14.81	8.33
50DT	Hijli college,Prembazar, Kharagpur,Midnapur West (32)	0.44	0	87.22	2.33	0.98	8.74
51T	Kharagpur, Midnapur West (32)	0.47	0	11.02	0	1.77	8.55

A few samples collected from Malda, Dinajpur, and Murshidabad districts were excluded as the F concentration of the water collected in these villages/areas was

low. Drinking water samples were collected in clean polythene bottles from sources like municipal water (surface water), dug wells, and tube wells and stored in a refrigerator (Tables 1–3). The post mortem visceral fluids and blood sent by the police for the forensic investigation were stored in a separate refrigerator.

The F concentration in the potable water was estimated using ion chromatography. Multitraceable standards from the National Institute of Standards and Technology (NIST) were used for calibration and quantification of anions. Standard solutions of three different concentrations of each ion were prepared separately. The calibration of the instrument was made with three different standard solutions for each ion. The results were mutually compatible. The instrument was repeatedly calibrated during the course of the work. The concentrations of other anions were determined to allow the assessment of probable correlations between these and F. However, a fluoride sensitive electrode was not used. A Metrohm ion chromatography instrument with Metrosep A Supp 3 of length 250mm, ID 4.6mm column was used in the present study.[13,14]

A buffer containing 1.7 mM $NaCO_3$, and 1.8 mM Na_2CO_3 was used for dilution of experimental samples and as a mobile phase, the flow rate being 1.0 mL/min and the pH range 1–13. The collected samples were filtered through Gelman make nylon membrane filter having 0.45 µm porosity and diameter 47 mm. 10 µL of the samples was used as the injection volume. In addition to F, the anions Br^-, Cl^-, NO_3^-, and $SO4^{-2}$ were also measured. The pH of the samples was measured using pH 510 bench pH/mV/ºC meter.

The forensic exhibits (stomach contents and blood) were mixed with NaOH solution, dried and digested in platinum crucibles at 500ºC in a muffle furnace.[15,16] The cooled mass was then extracted with ultra pure water. The samples were diluted with buffer (as stated before) and the F concentrations were measured.

RESULTS AND DISCUSSION

The cause of death in the 25-yr-old male New Delhi resident was found to be F poisoning with the F levels in the gastric contents and blood being 35.05 and 4.341 mg/L, respectively. These F concentrations were very high and sufficient to cause death in agreement with the report of the post mortem examination.

The diverse results of the present investigation are depicted in Tables 1–3. These suggested that there were variations in the concentration of F ion in the Rarh, Nadia, and 24 Parganas (North) districts of West Bengal but the concentrations in most cases were within tolerable limits except in places like Kapileswar, Haringhata (1.24 mg/L), Palta, 24 Parganas (North) (1.75 mg/L), Rondia, near Panagarh, (1.61 mg/L), Midnapore town (1.38 mg/L), Hijli (1.08 mg/L), and Laxmanpur, Purulia (1.06 mg/L). A recent study[11] found that the F concentrations of the wells of Nalhati, one of the worse affected areas, were also below 1 mg/L. It was apparent the F contents of the dug wells were usually high. A low F content was usually associated with a high calcium content as CaF_2 (fluorite) is of limited solubility, i.e., about 9 mg/L of F ion in pure water.[1] Natural concentrations of F ion were usually in the range of 0.01 to 1.0 mg/L and in most cases were within permissible limits.[2]

The pH of the water samples under consideration was usually around 8 or more, i.e., the water was alkaline and hard although the hardness of the water samples was not measured. Br^- was found in few samples with high concentrations (34.37 and 64.22 mg/L) in Bansdroni (3T) and Basirhat (14T), in association with high Cl^- concentrations (1279.67 and 2124.69 mg/L). Cl^-, SO_4^{2-}, and NO_3^- concentrations were fairly high in many of the samples. However, no attempt was been made to correlate the F^- concentration data with other ions of the samples due to the limited data available.

Industrial F pollution may arise from the manufacture of steel, aluminium, and fertilizers, where fluorapatite is used as a source of phosphorus. The intrusion of F into streams may result from nearby uneven joints, fractures, and faults in pipes carrying domestic, agricultural and industrial effluents. Moreover, hot springs near the Bakreswar and Birbhum regions may be responsible for F pollution in the adjoining areas.

The present results, together with those reported previously,[11] show that F contamination is not currently generally at an alarming level in the state of West Bengal, India, although there are some areas of concern.

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