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RESEARCH ARTICLE

Fluoride distribution in groundwater, soil and some crops grown in fluoride endemic area

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ABSTRACT : Fluoride content of ground water, soils and some cereal and vegetable crops were estimated in 26 villages in Aatmakoor mandal of Nalgonda district, Telangana, India. The results indicated that, accumulation of fluoride (F) was observed in different plant parts of crops irrigated with F contaminated ground water (0.73 to 3.25 and 1.12 to 4.67 mg L^{-1} during *Kharif* and *Rabi* seasons, respectively) grown in soil containing 0.41 to 2.32 and 0.68 to 2.63 mg kg^{-1} available fluoride during *Kharif* and *Rabi* seasons, respectively. All the values obtained were well below the toxic limit of 2.57 to 6.44 mg kg^{-1} in soil and maximum contaminant level of 4.0 mg kg^{-1} in crops and vegetable stipulated by EPA, FAO, and WHO Joint standard limit for fluoride. The implication of the results is that the use of the ground water for irrigation and the contribution of fluoride to the soil and absorption by the crops, has no deleterious effect on the soil and some crops cultivated with ground water. Maximum accumulation of F (mg kg^{-1} dry wt.) occurred in the roots followed by shoot and economic part. The mean F levels in the economic part of the crops analyzed are follows the order, paddy > sorghum > red gram in *Kharif* and groundnut > paddy > sorghum in *Rabi*.

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Key Words :
Fluoride, Ground water, Soil, Crops, Nalgonda

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Fluoride (F) in drinking water and its associated disease "fluorosis" is well known globally and was believed earlier the major contributor to the fluorosis, but now it has been realized and documented that the F exposure is not limited only through drinking water but also through foods and dentifrices (Singh *et al*., 1993 and Gupta and Banerjee, 2009). From a management point of view for prevention and control of fluorosis, changing the water source and reducing the F concentration of drinking water are the main strategies that can effectively diminish the incidence of fluorosis. However, the prevalence of fluorosis cannot be completely eliminated merely by altering the source of drinking water and reducing its F concentration. It is the total amount of F absorbed in a human body that needs to be considered: the sum of F intake from water, food and air. Consequently, even though F absorption from food is generally less than from water, it is not valid to assume the daily F intake of a person will not exceed a certain standard by controlling only one of the F sources. Currently, reducing the F concentration of drinking water is essentially the only method employed to meet the requirements set in 1983 by the ISI (Indian Standard Institute). But the extent high F water damages human health via the food chain is uncertain. Therefore, Studies on

fluoride uptake and accumulation were conducted using food crops grown in villages of the study area.

EXPERIMENTAL METHODOLOGY

The study area forms a part of Nalgonda district, Telangana, which is located at a distance of 90 km away from Hyderabad (Fig. A). This area experiences arid to semiarid climate. The study area goes through hot climate during the summer (March–May) with a temperature range from 30^{0}C to 46.5^{0}C and in winter (November–January), it varies between 14^{0}C and 29^{0}C. The average annual rainfall in this area is about 1,000 mm, occurring mostly during south-west monsoon (June–September).

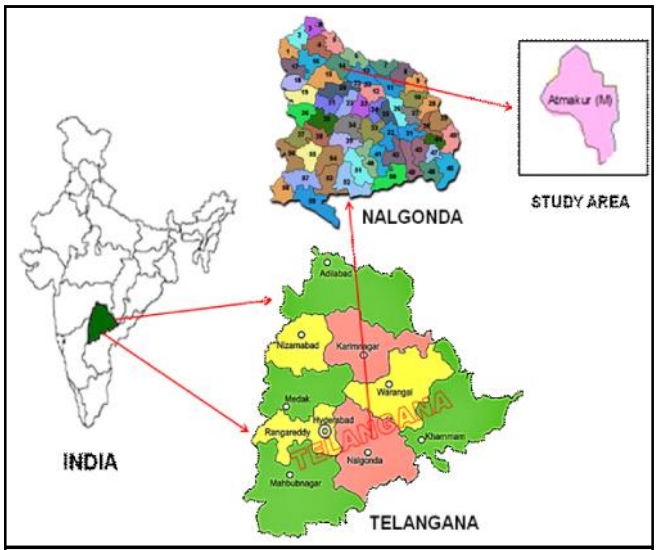

Fig. A : : Location map of the study area

Aatmakoor Mandal of the Nalgonda district, Telangana, where fluorosis has been known to be prevalent for six decades, was selected as one of the study areas for conducting the present research. All the villages of Aatmakoor mandal was selected as an appropriate area for conducting this research because people of these village are not only consuming F contaminated drinking water but also the crops/ vegetables cultivated in their own agricultural fields as food items. In the study area due to low rainfall cereals and vegetables were irrigated with the fluoridated ground water. The present research was conducted to estimate F content in soil, water and crops grown in the study area.

Water, soil and plant samples were collected during the *Kharif* and *Rabi* seasons from 26 villages of study area. Fluoride in water samples was analyzed by using specific ion electrode method Wedepohl (1969). The soil samples were collected at 0-15 cm depth by adopting the standard procedures of soil sample collection. Available fluoride in soil samples were analyzed by potentiometric method (McQuaker and Gurney, 1977). Potentiometric method using Ion selective electrode was observed to give more authentic results for estimation of fluoride in plant samples (Villa, 1979).

EXPERIMENTAL FINDINGS AND DISCUSSION

The findings of the present study as well as relevant discussion have been presented under following heads :

Fluoride content in irrigation water :

Fluoride present in the irrigation water samples collected during *Kharif* and *Rabi* seasons varied from 0.73 to 3.25 and 1.12 to 4.67 with average of 1.74 and 2.48 mg L^{-1}, respectively (Table 1). As per drinking water standards of ICMR (1975), the highest desirable concentration of F is 1.0 mg L^{-1} in tropical countries and that of maximum permissible level is 1.50 mg L^{-1}. Out of 26 samples, 50 per cent (13 samples) of the ground water samples in *Kharif* and 92.3 per cent (24 samples) of the ground water samples in *Rabi* have F content greater than that of maximum permissible limit of 1.50 mg L^{-1} fluoride. The rocks of this area possess fluoride content higher than the world average. Weathering of rocks and leaching of fluoride bearing minerals from the basement granitic rocks are the major reasons which contribute to elevated concentration of fluoride in groundwater. The other important natural phenomenon that contributes to high fluoride is evaporation (Brindha *et al*., 2010). Similar results reported by Reddy *et al*. (2009) and Kishore and Rao (2010) in Nalgonda district.

According to FAO (1994), the normal and moderately suitable range of F concentration in irrigation water is from < 19 mg L^{-1} and 19 to 171 mg L^{-1}, respectively. Safe limit of 10 mg F L^{-1} of irrigation water has been proposed for all type of crop plants by Leone *et al.* (1948). The present investigation showed that none of the water samples were found to cross this limits and hence, suitable for irrigation purpose.

Available fluoride content in soil :

Fluoride present in the soil samples collected during *Kharif* and *Rabi* varied from 0.29 to 2.02 and 0.68 to 2.63, with average of 1.04 and 1.54 mg kg^{-1}, respectively (Table 1). Lowest content of F was recorded in Modugunta village (0.29 mg kg^{-1}) and Chamapur village (0.68 mg kg^{-1}) during *Kharif* and *Rabi*, respectively while the highest was recorded in Regulakunta village (2.02 mg kg^{-1}) and Khaprayapalli village (2.63 mg kg^{-1}) during *Kharif* and *Rabi*, respectively. All the values obtained are well within the range of 2.57 to 16.44 mg kg^{-1} soil available F stipulated by EPA, FAO and WHO standard limit for fluoride. Similarly, F content in soil between 0.02 and 1.00 mg kg^{-1} as reported by Davidson (1983) and between 0.075 and 0.200 mg kg^{-1} as obtained by Okibe *et al*. (2010). The content of available F in the soil samples is very low indicating that major part of deposited F had transformed itself in to insoluble compounds like CaF_2 (Blagojevic *et al*., 2002). These results are in conformation with the findings of Jakovljevic *et al*. (2002). Unfortunately there is no Indian standard available prescribing a limit to the F in soil and biological tissue.

Fluoride accumulation by crops :

The range of F content of paddy plant parts like economic part (grain), shoot and root during *Kharif* was range from 0.33 to 1.75, 0.70 to 2.27 and 1.43 to 2.96 mg kg^{-1}, with the average values of 1.53, 1.59 and 2.26 mg kg^{-1}, respectively. During *Rabi*, it varied from 0.56 to 2.16, 0.75 to 3.31 and 1.74 to 4.17 mg kg^{-1}, with the average values of 1.39, 2.38 and 3.15 mg kg^{-1},

Table 1 : Fluoride content in ground water and soil samples collected in different villages of Aatmakoor mandal during *Kharif* and *Rabi* seasons of 2012-13

Sr. No.	Village	Fluoride content (mg L^{-1}) in water		Fluoride content (mg kg^{-1}) in soil	
		Kharif	*Rabi*	*Kharif*	*Rabi*
1.	Lingarajpally	1.67	1.92	0.87	1.33
2.	Pallerla	1.23	2.63	0.59	2.02
3.	Siddapuram	2.58	2.61	1.68	1.72
4.	Aatmakoor	3.12	3.14	1.82	1.98
5.	Muripirala	0.73	1.87	0.41	1.12
6.	Polimarajulabai	1.27	3.25	0.72	2.08
7.	Elicabavi	2.53	3.97	1.36	2.31
8.	Modugunta	0.75	1.85	0.29	1.19
9.	Singaram	1.26	2.13	0.48	1.22
10.	Chandapalli	2.37	2.45	1.33	1.38
11.	Chamapur	1.05	1.12	0.46	0.68
12.	Regulakunta	3.25	3.32	2.02	2.18
13.	Koratikal	2.21	2.31	1.35	1.76
14.	Duppally	1.69	1.74	1.02	1.24
15.	Kashammakunta	1.25	1.95	1.26	1.34
16.	Thukkapur	2.29	2.67	1.65	1.68
17.	Raheemkhanpeta	1.52	3.95	1.07	2.42
18.	Kurella	0.96	1.87	0.48	1.32
19.	Khapraipalli	1.98	4.67	1.22	2.63
20.	Timmapur	2.73	2.76	1.74	1.76
21.	Raipally	0.99	1.85	0.69	0.77
22.	Sarvepally	1.06	2.13	0.56	1.36
23.	Kondapuram	2.52	2.64	1.62	1.66
24.	Muthyreddygudem	1.39	1.45	0.66	0.78
25.	Chada	1.36	1.73	0.89	1.06
26.	Katepally	0.98	1.75	0.71	1.12
	Range	0.73-3.25	1.12-4.67	0.29-2.02	0.68-2.63
	Mean	1.74	2.48	1.04	1.54

respectively. The range of F content of sorghum plant parts like economic part (grain), shoot and root ranged from 0.33 to 1.74, 0.51 to 1.85 and 1.21 to 3.23 mg kg^{-1} during *Kharif* and 0.72 to 2.12, 1.24 to 3.40 and 1.79 to 4.73 mg kg^{-1}, respectively during *Rabi* season (Table 2 and 3).

The range of F content of redgram plant parts like economic part (seed), shoot and root during *Kharif* was found from 0.32 to 1.52, 0.79 to 2.98 and 1.27 to 3.80 mg kg^{-1}, with the average values of 0.83, 1.70 and 2.39 mg kg^{-1}, respectively. The range of F content of tomato plant parts like economic part (fruit), shoot and root in *Kharif* was varied from 0.22 to 0.71, 0.52 to 1.53 and 0.80 to 2.25 mg kg^{-1}, with the average values of 0.47, 1.03 and 1.53 mg kg^{-1}, respectively. The mean F content of okra plant parts like economic part (fruit), shoot, root in Chamapur village of Aatmakoor mandal was 0.46, 0.57, 0.98 mg kg^{-1}, respectively.

The range of F content of groundnut plant parts like economic part (kernel), shoot and root during *Rabi* was ranged from 0.36 to 1.29, 1.08 to 2.81 and 1.86 to 3.31 mg kg^{-1}, with the average values of 0.83, 1.87 and 2.58 mg kg^{-1}, respectively. The range of F content of tomato plant parts like economic part (fruit), shoot and root in *Rabi* season was found from 0.85 to 0.92, 1.64 to 1.86 and 2.51 to 2.55 mg kg^{-1}, with the average values of 0.89, 1.75 and 2.53 mg kg^{-1}, respectively. The F content of cabbage plant parts like economic part (bud), shoot, root in Kurella village during *Rabi* was 0.75, 2.16, 2.24 mg kg^{-1}, respectively.

The F concentration in economic parts of the crops varied from 0.32 to 1.75 and 0.36 to 2.16 mg kg^{-1} during *Kharif* and *Rabi*, respectively. The values are lower than the maximum allowed level of 4.0 mg kg^{-1} in food crops

Table 2 : Fluoride (mg kg^{-1}) concentration of the plant parts of different crops grown in different villages of Aatmakoor mandal during *Kharif* and *Rabi* season (2012-13)

Sr. No.	Name of the village	*Kharif*				*Rabi*			
		Crop	Economic part	Shoot	Root	Crop	Economic part	Shoot	Root
1.	Lingarajpally	Paddy	0.65	1.44	2.28	Paddy	1.02	2.29	3.34
2.	Pallerla	Paddy	0.47	1.53	1.82	Paddy	1.55	2.15	2.93
3.	Siddapuram	Sorghum	1.27	1.37	1.94	Groundnut	1.2	2.31	3.31
4.	Aatmakoor	Paddy	1.57	2.26	2.83	Paddy	2.08	3.12	3.45
5.	Muripirala	Redgram	0.32	0.79	1.27	Sorghum	0.72	1.24	1.79
6.	Polimarajulabai	Paddy	0.66	1.51	1.99	Paddy	2.16	3.27	4.17
7.	Elicabavi	Bhendi	0.59	0.61	1.08	Sorghum	2.12	2.53	2.84
8.	Modugunta	Tomato	0.22	0.52	0.80	Tomato	0.92	1.86	2.51
9.	Singaram	Paddy	0.54	0.85	1.55	Paddy	1.08	1.25	1.92
10.	Chandapalli	Paddy	1.25	2.24	2.96	Paddy	1.77	3.27	3.85
11.	Chamapur	Bhendi	0.33	0.53	0.87	Groundnut	0.36	1.08	1.86
12.	Regulakunta	Sorghum	1.74	1.85	3.23	Sorghum	1.83	3.40	4.43
13.	Koratikal	Paddy	1.22	1.54	2.95	Paddy	1.43	3.31	3.80
14.	Duppally	Redgram	0.89	1.4	1.61	Sorghum	0.95	2.52	2.97
15.	Kashammakunta	Paddy	0.57	2.27	2.59	Paddy	1.21	2.80	3.28
16.	Thukkapur	Paddy	1.23	1.68	2.34	Paddy	1.32	2.15	3.15
17.	Raheemkhanpeta	Redgram	0.73	1.26	2.60	Sorghum	1.93	3.24	4.73
18.	Kurella	Sorghum	0.33	0.51	1.77	Cabbage	0.75	2.16	2.24
19.	Khapraipalli	Paddy	1.19	1.29	2.15	Paddy	2.15	2.47	2.82
20.	Timmapur	Redgram	1.52	2.98	3.8	Sorghum	1.16	1.83	3.21
21.	Raipally	Paddy	0.33	1.62	2.16	Paddy	0.65	1.45	2.95
22.	Sarvepally	Sorghum	0.43	0.72	1.21	Groundnut	1.29	2.81	3.19
23.	Kondapuram	Paddy	1.75	1.95	2.48	Paddy	1.19	3.29	3.88
24.	Muthyreddygudem	Sorghum	0.66	1.17	1.89	Groundnut	0.50	1.11	1.92
25.	Chada	Tomato	0.71	1.53	2.25	Tomato	0.85	1.64	2.55
26.	Katepally	Paddy	0.41	0.70	1.43	Paddy	0.56	0.75	1.74

Table 3 : Range and mean concentration of fluoride (mg kg^{-1}) in the plant parts collected from different villages of Aatmakoor mandal during *Kharif* and *Rabi*, 2012-13

Crops	*Kharif*		*Rabi*	
	Range	Mean	Range	Mean
	Paddy (13 Samples)		Paddy (13 samples)	
Economic part	0.33-1.75	1.93	0.56-2.16	1.39
Shoot	0.70-2.27	1.59	0.75-3.31	2.38
Root	1.43-2.96	2.26	1.74-4.17	3.15
	Sorghum (5 Samples)		Sorghum (6 samples)	
Economic part	0.33-1.74	1.93	0.72-2.12	1.44
Shoot	0.51-1.85	1.14	1.24-3.40	2.43
Root	1.21-3.23	2.07	1.79-4.73	3.31
	Redgram (4 Samples)		Groundnut (4 samples)	
Economic part	0.32-1.52	0.88	0.36-1.29	0.83
Shoot	0.79-2.98	1.70	1.08-2.81	1.87
Root	1.27-3.80	2.39	1.86-3.31	2.58
	Tomato (2 Sample)		Tomato (2 samples)	
Economic part	0.22-0.71	0.47	0.85-0.92	0.89
Shoot	0.52-1.53	1.03	1.64-1.86	1.75
Root	0.80-2.25	1.53	2.51-2.55	2.53
	Okra (2 Sample)		Cabbage (1 Sample)	
Economic part	0.33 to 0.59	0.46	-	0.75
Shoot	0.53 to 0.61	0.57	-	2.16
Root	0.87 to 1.08	0.98	-	2.24

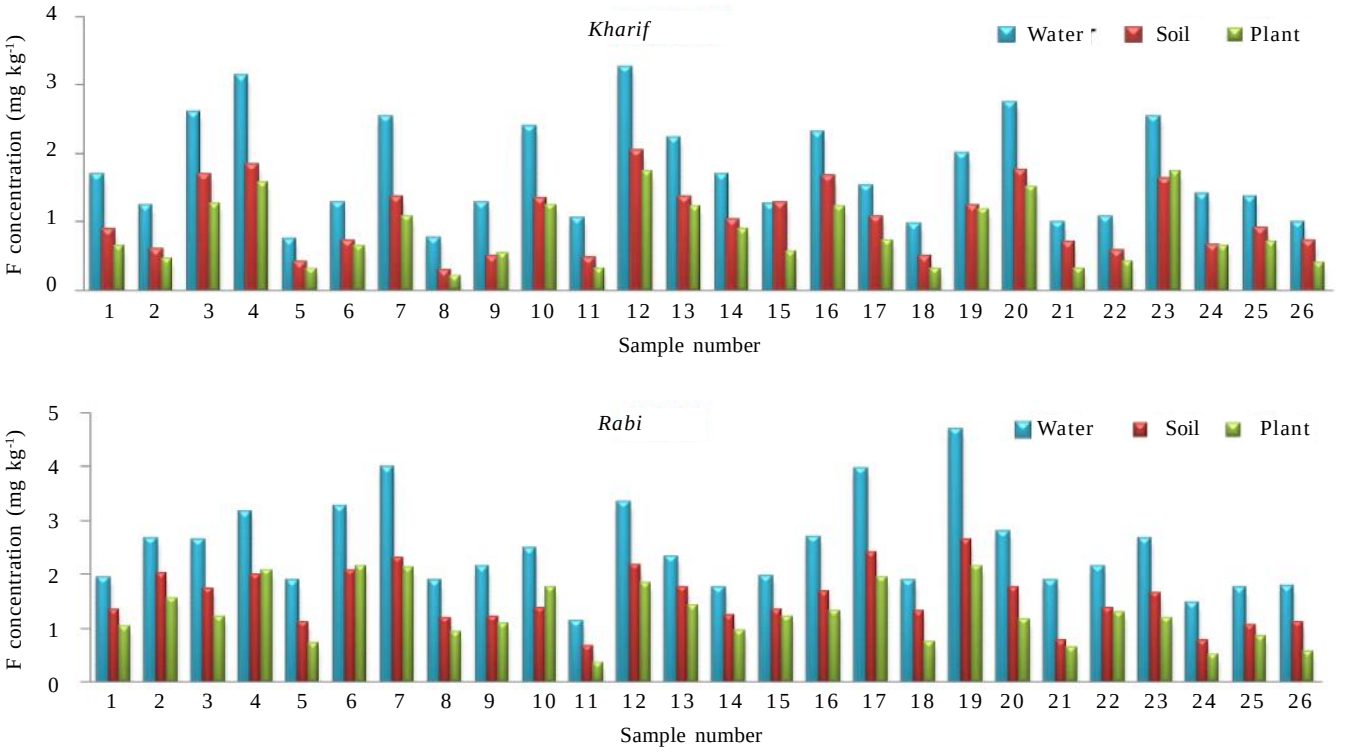

Fig. 1 : Fluoride concentration of the water, soil and plant samples in different villages during *Kharif* and *Rabi* seasons of 2012-13

and vegetables recommended by EPA (1975) and WHO (1984) Joint Standard limit for F. Therefore, the F levels in economic parts of all the crops and vegetables are within the normal range. Crops like paddy, sorghum, and groundnut were analyzed for F, out of which, sorghum was found to have maximum F concentration (4.73 mg kg^{-1}) which was collected from Raheemkhanpeta village where F concentration in water sample was 3.95 mg L^{-1}. Among the vegetables tomato accumulated highest F followed by cabbage. The reasons for this order may be in the ability of the plants to accumulate F and the amount of F available for absorption. This in turn depends on whether the F is in an available state for uptake or not.

Bioaccumulation of F was found throughout the plant body, *viz.*, economic part, shoot and root. Maximum accumulation of F (mg kg^{-1} dry wt.) occurred in the roots followed by shoot and economic part. Due to relatively low mobility of F, the bioaccumulation of F was highest in roots and lowest in economic part. Similar findings have been reported by others Pant *et al.* (2008). The mean F levels in the economic part of the food crops analyzed are follows the order sorghum > paddy > redgram.

Seasonal variations of fluoride in water, soil and plant :

The F present in the irrigation water samples of showed wide variation but their mean values are 1.74 and 2.48 mg L^{-1} in *Kharif* and *Rabi* season, respectively. The mean values of available F present in the soil samples are 1.04 and 1.54 mg kg^{-1} in *Kharif* and *Rabi*, respectively. Accordingly, high absorption of F by crops was observed during *Rabi* season than *Kharif* season. F concentration of the water, soil and plant samples in different mandals during *Kharif* (2012) and *Rabi* (2012-13) are shown in Fig. 1.

When compared to two seasons, the concentration of F in groundwater and soil, during *Kharif* was lower than the *Rabi*. Generally, a high rate of evapo-transpiration and over-exploitation of groundwater resources for agricultural and drinking water purposes during *Rabi* season causes a low freshwater exchange and results in precipitation of salts, including F rich salts, temporarily in the top layers of the soil. During *Kharif* season, the infiltrating waters leach these soils and replenishment of the groundwater by rainfall indicated a clean recharge from external sources. Hence, the concentration of F is observed to be greater in the *Rabi* season soil and groundwater than in *Kharif* season. These results are agreement with the findings of Goyal (2013). As a result, 92.3 per cent (24 samples) of the total groundwater samples from the *Rabi* season are above the permissible limit of F (1.50 mg L^{-1}), compared to 50 per cent (13 samples) of those from the *Kharif* season.

Conclusion :

In conclusion, The F levels in economic parts of all the crops grown in the 26 villages are well below standard limits recommended by EPA, FAO, and WHO. The natural and anthropogenic sources of fluoride to the soil and crops have no deleterious effect on them. The consumption of the fresh vegetables from these farms does not pose any threat of fluoride poisoning. However, frequent consumption of these vegetables may contribute to the daily dietary intake of fluoride. Further, there is a need for more in-depth investigations to understand the critical factors that affect the accumulation of F in different food crops and their impact on human health.

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