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Bioaccumulation of Fluoride in Different Plant Parts of Food Crops Grown in Narkatpally Mandal of Nalgonda District, Telangana

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Abstract The present study was carried out to assess accumulation of fluoride in some crops grown in potentially fluoridated area in 26 villages. The results indicated that, bioaccumulation of fluoride (F) was observed in different plant parts of crops irrigated with F contaminated ground water (0.56 to 5.25 and 1.16 to 5.34 mg L^{-1} during *kharif* and *rabi* seasons, respectively) grown in soil containing 0.26 to 2.64 and 0.53 to 2.64 mg kg^{-1}available F 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 F. 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 > Green Gram > Redgram > Sorghum in *kharif* and Paddy > Groundnut > Sorghum in *rabi*. Among the vegetables, tomato accumulated higher F followed by bhendi. The reasons for this order may be in the ability of the plants to accumulate F and the amount of F available for absorption. When compared to two seasons, the concentration of F is observed to be greater in groundwater, soil and crops during *rabi* season than in *kharif* season.

Keywords Fluoride, Ground water, Soil, Crops, Nalgonda.

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Introduction

Fluoride ion is wide spread in nature. It is estimated to be thirteenth in abundance among the elements of the earth. Serious health problems associated with chronic fluorosis occur in many parts of the world and endemic fluorosis has been identified in 20 states of India. About 62 million people, including 6 million children are at risk in India from dental, skeletal, and/

Table 1. Fluoride content in ground water and soil samples collected in different villages of Narkatpally mandal during *kharif* and *rabi* seasons of 2012-13.

Sl. No.	Village	Fluoride content (mg kg^{-1}) in water *kharif*	Fluoride content (mg kg^{-1}) in water *rabi*	Fluoride content (mg kg^{-1}) in soil *kharif*	Fluoride content (mg kg^{-1}) in soil *rabi*
1	Anuguladori	2.85	2.89	1.46	1.58
2	Brahmanavellemla	2.13	2.31	1.17	1.25
3	Auravani	0.97	2.98	0.48	1.73
4	Choudhampalli	0.73	2.77	0.41	1.88
5	Kondapakagudem	1.92	3.22	1.08	1.98
6	Yellareddygudem	2.63	4.56	1.12	2.32
7	Chervugattu	2.47	3.05	1.19	1.78
8	Lingotam	3.04	3.12	1.38	1.82
9	Narkatpalli	2.87	2.99	1.28	1.98
10	Yedavalli	5.25	5.34	2.64	2.64
11	Naibai	3.97	4.02	1.87	2.12
12	Pothinenipalli	0.56	1.16	0.26	0.53
13	Nemmani	1.73	1.82	0.98	1.02
14	Juvvagudem	1.75	1.76	0.87	0.87
15	Shapalli	1.04	2.42	0.78	1.74
16	Tirumalagiri	1.67	1.68	1.05	1.2
17	Mandra	1.72	2.74	0.98	1.54
18	Thondlavai	0.93	1.64	0.32	1.05
19	Indiranagar	1.86	3.52	1.09	2.17
20	Chippalapalli	0.82	1.24	0.41	0.84
21	Chinanarayanpur	1.95	1.97	1.2	1.12
22	Nakkalapalli	2.67	2.78	1.24	1.52
23	Akkenapalli	3.95	4.08	2.21	2.38
24	Ammanabolu	3.87	3.96	1.93	2.33
25	Bendalpahad	4.67	4.78	2.47	2.55
26	Gopalaipally	1.15	1.97	0.68	1.28
	Range	0.56–5.25	1.16–5.34	0.26–2.64	0.53–2.64
	Mean	2.28	2.88	1.18	1.66

or nonskeletal endemic fluorosis [1]. 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 by the ISI [2]. 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.

Fig. 1. Location map of the study area.

Materials and Methods

The study area forms a part of Nalgonda district, Telangana, which is located at a distance of 90 km away from Hyderabad (Fig. 1). 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°C to 46.5°C, and in winter (November–January), it varies between 14°C and 29°C. The average annual rainfall in this area is about 1,000 mm, occurring mostly during south-west monsoon (June–September).

Narkatpally 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 Narkatpally mandal was selected as an appropriate area for conducting this research because people of these village are not only consuming F con-

Table 2. Fluoride (mg kg^{-1}) concentration of the plant parts of different crops grown in different villages of during *kharif* and *rabi* seasons of 2012-13.

Sl. No.	Name of the village	*kharif* Crop	Economic part	Shoot	Root	*rabi* Crop	Economic part	Shoot	Root
1	Anuguladori	Green Gram	1.38	2.61	2.87	Groundnut	1.50	3.14	3.98
2	Brahmanavelemla	Paddy	0.86	2.19	2.46	Paddy	0.87	1.58	2.77
3	Auravani	Sorghum	0.29	0.96	1.64	Bhendi	1.40	2.13	2.22
4	Choudhampalli	Green Gram	0.32	0.27	1.82	Groundnut	1.43	2.69	3.35
5	Kondapakagudem	Redgram	1.07	2.10	3.23	Sorghum	1.78	2.95	3.76
6	Yellareddygudem	Paddy	0.86	1.81	2.64	Paddy	1.88	2.37	2.94
7	Chervugattu	Paddy	1.08	2.10	2.88	Paddy	1.19	2.00	3.23
8	Lingotam	Tomato	1.43	2.22	2.59	Bhendi	1.29	1.71	1.90
9	Narkatpalli	Paddy	1.39	2.83	3.21	Paddy	1.81	3.12	3.47
10	Yedavalli	Paddy	2.25	2.32	2.96	Paddy	2.08	2.97	3.55
11	Naibai	Paddy	1.62	3.18	3.55	Paddy	1.60	2.83	3.63
12	Pothinenipalli	Sorghum	0.21	0.79	1.42	Groundnut	0.47	1.55	2.41
13	Nemmani	Paddy	0.96	0.28	1.14	Paddy	0.88	1.74	2.95
14	Juvvagudem	Sorghum	0.91	1.47	2.17	Sorghum	0.99	2.60	3.49
15	Shapalli	Paddy	0.40	1.15	2.28	Paddy	1.74	2.87	3.5
16	Tirumalagiri	Sorghum	0.89	0.65	2.15	Sorghum	0.83	1.50	2.84
17	Mandra	Paddy	0.67	0.56	1.21	Paddy	1.19	1.80	2.62
18	Thondlavai	Paddy	0.33	1.13	1.56	Paddy	0.95	1.81	2.78
19	Indiranagar	Paddy	1.22	1.47	2.19	Paddy	1.99	2.65	3.53
20	Chippalapalli	Green Gram	0.17	1.19	1.21	Sorghum	0.32	1.12	2.17
21	Chinanarayanpur	Redgram	0.93	1.61	3.15	Sorghum	1.02	1.82	3.30
22	Nakkalapalli	Green Gram	1.30	2.81	3.29	Sorghum	1.38	1.59	2.71
23	Akkenapalli	Paddy	1.31	2.22	3.87	Paddy	1.87	3.06	3.95
24	Ammanabolu	Paddy	1.72	1.85	2.83	Paddy	2.12	2.87	3.17
25	Bendalpahad	Tomato	2.29	3.25	4.26	Groundnut	2.37	3.88	4.55
26	Gopalaipally	Sorghum	0.53	0.94	2.37	Sorghum	1.11	2.15	2.99

taminated 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 the F content in ground water, soil 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 [3]. The 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 [4]. Potentiometric method using Ion selective electrode was observed to give more authentic results for estimation of fluoride in plant samples [5].

Results and Discussion

Fluoride content in irrigation water

Fluoride present in the irrigation water samples collected during *kharif* and *rabi* seasons varied from 0.56 to 5.25 and 1.16 to 5.34 with average of 2.28 and 2.88 mg L^{-1}, respectively (Table 1). As per drinking water standards of ICMR [6], 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, 69.2% (18 samples) of the ground water samples in *kharif* and 92.3% (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. Therefore drinking water is sufficient to produce severe form of dental fluorosis and mild form of skeletal fluorosis consumed for a long period. The rocks of this area possess fluoride content higher

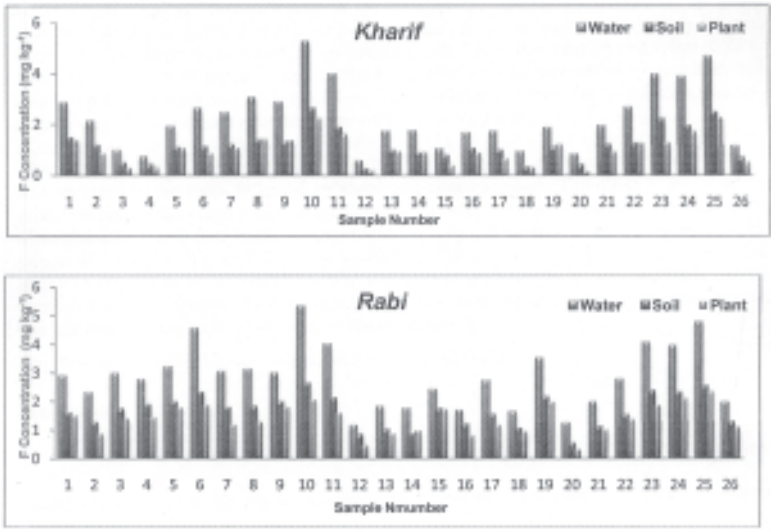

Fig. 2. Fluoride concentrations of the water, soil and plant samples in different villages during *kharif* and *rabi* seasons of 2012-13.

than the world average [7]. 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 [8]. The other important natural phenomenon that contributes to high fluoride is evaporation [9].

According to FAO [10], 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 [11]. 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 0.26 to 2.64 and 0.53 to 2.64, with average of 1.18 and 1.66 mg kg^{-1}, respectively (Table 1). Lowest content of F was recorded in Pothinenipalli village (0.26 and 0.53 mg kg^{-1} during *kharif* and *rabi*, respectively) while the highest was recorded in Yedavalli village (2.64 and 2.64 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 [12]. Similarly, F content in soil between 0.02 and 1.00 mg kg^{-1} [13] and between 0.075 and 0.200 mg kg^{-1} [14]. 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 [15, 16]. 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* varied from 0.33 to 2.25, 0.28 to 3.18 and 1.14 to 3.87 mg kg^{-1}, with the average values of 1.15, 1.77 and 2.52 mg kg^{-1}, respectively. During *rabi* it varies from 0.87 to 2.12, 1.58 to 3.12 and 2.62 to 3.95 mg kg^{-1}, with the average values of 1.54, 2.42 and 3.24 mg kg^{-1}, respectively. The range of F content of sorghum plant parts like economic part (grain), shoot and root was found from 0.21 to 0.91, 0.65 to 1.47 and 1.42 to 2.37 mg kg^{-1}, respectively during *kharif* and 0.32 to 1.78, 1.12 to

Table 3. Range and mean concentration of fluoride (mg kg^{-1}) in the plant parts during *kharif* and *rabi* 2012-13.

Crops	*kharif* Range	*kharif* Mean	*rabi* Range	*rabi* Mean
	Paddy (13 samples)		Paddy (13 samples)	
Economic part	0.33-2.25	1.15	0.87-2.12	1.54
Shoot	0.28-3.18	1.77	1.58-3.12	2.42
Root	1.14-3.87	2.52	2.62-3.95	3.24
	Sorghum (5 samples)		Sorghum (7 samples)	
Economic part	0.21-0.91	0.56	0.32-1.78	1.06
Shoot	0.65-1.47	0.99	1.12-2.95	1.98
Root	1.42-2.37	1.93	2.17-3.76	3.02
	Green Gram (4 samples)		Groundnut (4 samples)	
Economic part	0.17-1.38	0.79	0.47-2.37	1.44
Shoot	0.27-2.81	1.66	1.55-3.88	2.78
Root	1.21-3.29	2.28	2.41-4.26	3.45
	Redgram (2 samples)		Bhendi (2 samples)	
Economic part	0.37-1.32	0.77	1.29-1.40	1.35
Shoot	1.28-2.93	1.87	1.71-2.13	1.92
Root	0.96-3.31	2.20	1.90-2.23	2.06
	Tomato (2 sample)			
Economic part	1.01-1.27	1.14		
Shoot	1.98-2.71	2.35		
Root	2.19-2.95	2.57		

2.95 and 2.17 to 3.76 mg kg^{-1}, respectively during *rabi* season (Table 2 and 3).

The range of F content of green gram plant parts like economic part (seed), shoot and root during *kharif* was found from 0.17 to 1.38, 0.27 to 2.81 and 1.21 to 3.29 mg kg^{-1}, with the average values of 0.79, 1.66 and 2.28 mg kg^{-1}, respectively (Table 2 and 3). The F content of red gram plant parts like economic part (seed), shoot and root during *kharif* was 0.37 to 1.32, 1.28 to 2.93 and 0.96 to 3.31 mg kg^{-1}, respectively. The F content of tomato plant parts like economic part (fruit), shoot and root during *kharif* was 1.01 to 1.27, 1.98 to 2.71 and 2.19 to 2.95 mg kg^{-1} with average values of 1.14, 2.35 and 2.57 mg kg^{-1}, respectively.

The range of F content of groundnut plant parts like economic part (kernel), shoot and root in *rabi* season was found from 0.47 to 2.37, 1.55 to 3.88 and 2.41 to 4.26 mg kg^{-1}, with the average values of 1.44, 2.78 and 3.45 mg kg^{-1}, respectively. The range of F content of bhendi plant parts like economic part (fruit), shoot and root in *rabi* was found from 1.29 to 1.40, 1.71 to 2.13 and 1.90 to 2.23mg kg^{-1}, with the average values of 1.35, 1.92 and 2.06 mg kg^{-1}, respectively.

The concentration range in economic part of different crops is 0.17 to 2.25 mg kg^{-1} and 0.32 to 2.37 mg kg^{-1} in *kharif* and *rabi*, respectively. The values are lower than the maximum allowed level of 4.0 mg kg^{-1} in food and vegetable recommended by EPA [17] and WHO [18] 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, groundnut was found to have maximum F concentration (3.98 mg kg^{-1}) during *rabi* season which was collected from Anduguladori village where F concentration in water sample was 2.89 mg L^{-1}. The mean F levels in the economic part of the crops analyzed are follows the order; Paddy > Green Gram > Redgram > Sorghum in *kharif* and Groundnut > Paddy > Sorghum in *rabi*. Among the vegetables, tomato accumulated higher F followed by brinjal and bhendi. 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 [19].

Seasonal variations of fluoride in water, soil and plant

The F present in the irrigation water samples showed wide variation but their mean values are 2.28 and 2.88 mg L^{-1}, respectively during *kharif* and *rabi* seasons. The mean values of available F present in the soil samples are 1.18 and 1.66 mg kg^{-1}, respectively in *kharif* and *rabi* seasons. Accordingly, higher 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 Figures 2.

When compared to two seasons , the concentration of F in groundwater, soil and plant, 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 groundwater, soil and crops during *rabi* season than in *kharif* season [20]. Seasonal distribution of fluoride is dependent on a variety of factors such as amount of soluble and insoluble fluoride in source rocks, the duration of contact of water with rocks and soil temperature, rainfall and oxidation-reduction process [21, 22]. As a result, 83% (68 samples) of the total groundwater samples from the *rabi* season are above the permissible limit of F (1.50 mg L^{-1}), compared to 58.5% (48 samples) of those from the *kharif* season.

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