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Fluoride accumulation by crops grown in parts of Nalgonda District, Telangana State, India

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Abstract

The present study was carried out to assess accumulation of fluoride in vegetables and cereal crop grown in potentially fluoridated area in 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. The concentration range in plant parts of different crops is 0.12 to 3.35 mg kg^{-1} and 0.30 to 3.95 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 FAO and WHO. 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. 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*. Among the vegetables, tomato accumulated higher F followed by brinjal and bhendi. Maximum accumulation of F (mg kg^{-1} dry wt.) occurred in the roots followed by shoot and economic part.

Key Words: Fluoride, Crops, Nalgonda, Plant Parts, Seasonal Changes, Telangana

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/or nonskeletal endemic fluorosis (Pendias and Pendias, 1986). 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 (Gupta and Banerjee, 2009). 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.

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Material 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 14ºC and 29°C. The average annual rainfall in this area is about 1,000 mm, occurring mostly during south-west monsoon (June–September). RamannapetMandal of the Nalgonda district, Telangana State, where fluorosis has been known to be prevalent for six decades, was selected as one of the study areas for conducting the present research. 30 villages of Ramannapetmandal was selected as an appropriate area for conducting this research because people of this village are not only consuming F contaminated drinking water but also the crops/vegetables cultivated in their own agricultural fields as food items. The present research was conducted to estimate F accumulation in harvested crops and vegetables grown in the study area. Water, soil and plant samples were collected during the *kharif* and *rabi* seasons from 30 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).

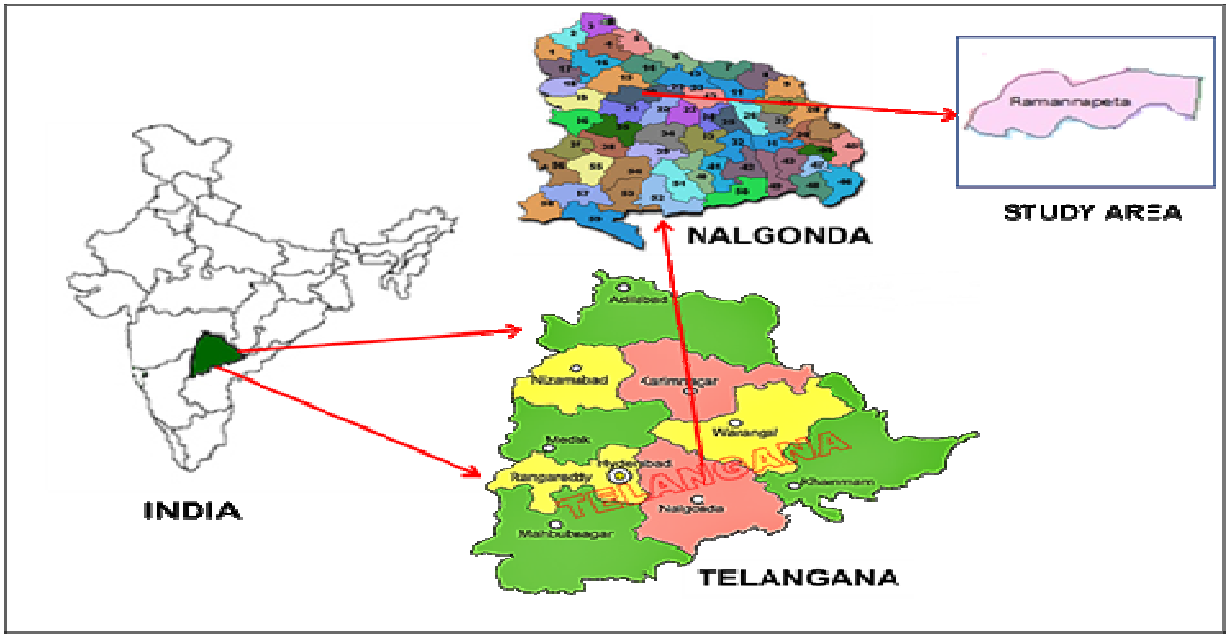


Fig 1: Location map of the study area

Results and Discussion

Fluoride Content in Irrigation Water

Fluoride present in the irrigation water samples collected during *kharif* and *rabi* seasons varied from 0.53 to 3.86 and 0.99 to 3.94 with average of 1.71 and 2.08 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 30 samples, 53% of the ground water samples in kharif and 67% of theground water samples in rabi have F content greater than that of maximum permissible limit of 1.50 mg L^{-1} fluoride. On an average, maximum concentration of fluoride was noticed in 16 and 20 villages during *kharif* and *rabi*, respectively. 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 0.41 to 2.32 and 0.77 to 2.29, with average of 1.17 and 1.41 mg kg^{-1}, respectively (Table 1). Lowest content of F was recorded in Venkatapuram village (0.41 ppm) and Kakkireni village (0.77 ppm) during *kharif* and *rabi*, respectively while the highest was recorded in Rontakolla village (2.32 and 2.39 ppm 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.

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.

S.No.	Village	Fluoride Content (mg L^{-1}) in water		Fluoride Content (mg kg^{-1}) in soil	
		Kharif	Rabi	Kharif	Rabi
1	Ramannapet	1.46	1.51	1.12	1.16
2	Neernemula	0.78	1.17	0.62	0.81
3	Shobanadripuram	0.95	1.05	0.82	0.83
4	Laxmapuram	1.72	2.25	1.28	1.42
5	Nidhanpalle	0.98	1.21	0.66	1.02
6	Bogaram	1.03	1.27	0.87	0.87
7	Thummalagudem	1.15	2.53	0.88	1.63
8	Yellanki	2.28	2.75	1.75	1.78
9	Siripuram	2.07	2.12	1.58	1.61
10	Dubbaka	2.52	2.56	1.95	1.98
11	Rontakolla	3.86	3.94	2.32	2.39
12	Munipampula	2.35	2.33	1.63	1.65
13	Palliwada	0.92	2.58	0.47	1.74
14	Nagulanchagudem	1.29	3.12	0.79	1.89
15	Bachuppala	1.37	1.43	0.93	0.98
16	Suraram	2.43	2.48	1.82	1.83
17	Thurkapalle	2.76	2.73	1.75	1.78
18	Venkatapuram	0.53	0.99	0.41	0.78
19	Kunkudupamula	1.27	1.36	0.93	0.98
20	Peddabavigudem	2.09	2.52	1.56	1.69
21	Yennaram	1.98	1.99	0.94	1.38
22	Kallonikunta	2.04	2.15	1.19	1.52
23	Kakkireni	0.94	1.29	0.65	0.77
24	Pilligudem	2.82	2.84	1.82	1.92
25	Uttatoor	1.54	1.67	0.44	1.1
26	Iskilla	0.97	1.23	0.75	0.78
27	Lacchigudem	2.08	2.58	1.34	1.76
28	Janampalle	2.04	3.12	1.74	1.88
29	Sanjeevaiahnagar	0.85	1.39	0.63	0.94
30	Kommaigudem	2.23	2.36	1.47	1.51
Range		**0.53-3.86**	**0.99-3.94**	**0.41-2.32**	**0.77-2.39**
Mean		**1.71**	**2.08**	**1.17**	**1.41**

Fluoride Concentration in Crops

Fluoride concentration in plant parts of the crops in different mandals during *kharif* and *rabi* (2012-13) is shown in Table 2 & 3. The range of F content of paddy plant parts like economic part (grain), shoot and root during kharif was found from 0.12 to 2.02, 0.85 to 3.20 and 0.75 to 3.35 mg kg^{-1}, with the average values of 0.93, 1.94 and 2.57 mg kg^{-1}, respectively. During *rabi* it varies from 0.43 to 2.23, 1.13 to 3.47 and 1.25 to 3.95 mg kg^{-1}, with the average values of 1.10, 2.08 and 2.64 mg kg^{-1}, respectively. The range of F content of sorghum in plant parts like economic part (grain), shoot and root varied from 0.37 to 1.32, 1.28 to 2.93 and 0.96 to 3.31 mg kg^{-1}, respectively in *kharif* and 0.30 to 1.55, 0.64 to 2.66 and 0.93 to 1.65 mg kg^{-1}, respectively during *rabi*. The F content of green gram plant parts like economic part (seed), shoot and root in Yellanki village of Ramannapet mandal was 1.47, 2.49 and 2.75 mg kg^{-1}, respectively.

Table 2. Fluoride (mg kg^{-1}) concentration of the plant parts in different villages of Ramannapet mandal during *Kharif* and *rabi* 2012-13.

S.No	Name of the Village	*Kharif*				*Rabi*			
		Crop	Economic part	Shoot	Root	Crop	Economic part	Shoot	Root
1	Ramannapet	Paddy	0.90	1.46	2.61	Paddy	0.87	1.72	2.83
2	Neernemula	Paddy	0.43	1.67	2.35	Paddy	0.53	1.45	2.52
3	Shobanadripuram	Paddy	0.63	1.21	1.96	Paddy	0.61	1.38	1.71
4	Laxmapuram	Sorghum	1.01	1.78	2.57	Groundnut	1.29	1.61	2.61
5	Nidhanpalle	Tomato	0.36	1.79	1.83	Brinjal	0.57	1.74	2.36
6	Bogaram	Paddy	0.69	1.61	2.49	Paddy	0.43	2.17	2.54
7	Thummalagudem	Paddy	0.53	0.85	0.98	Paddy	1.33	1.13	1.25
8	Yellanki	Greengram	1.47	2.49	2.75	Sorghum	1.55	2.66	3.17
9	Siripuram	Sorghum	1.32	2.93	3.31	Groundnut	1.23	2.29	3.39
10	Dubbaka	Paddy	1.58	2.13	2.86	Paddy	1.69	3.47	3.95
11	Rontakolla	Paddy	2.02	3.20	3.96	Paddy	2.23	2.55	2.78
12	Munipampula	Paddy	1.19	1.97	3.60	Groundnut	1.37	2.13	2.57
13	Palliwada	Bhendi	0.54	1.7	2.11	Groundnut	1.36	2.4	2.79
14	Nagulanchagudem	Sorghum	0.57	1.45	1.82	Bhendi	1.27	2.71	2.95
15	Bachuppala	Paddy	0.93	2.66	3.14	Paddy	0.77	2.71	3.41
16	Suraram	Paddy	1.4	2.34	3.24	Paddy	1.66	3.25	3.72
17	Thurkapalle	Paddy	1.52	3.12	3.35	Cabbage	1.33	1.89	2.14
18	Venkatapuram	Sorghum	0.38	1.28	0.96	Sorghum	0.30	0.64	1.56
19	Kunkudupamula	Sorghum	0.50	1.63	1.47	Groundnut	0.46	1.13	1.58
20	Peddabavigudem	Redgram	0.97	2.27	1.68	Groundnut	1.27	2.55	2.97
21	Yennaram	Tomato	0.76	2.39	2.19	Bhendi	1.01	1.98	2.19
22	Kallonikunta	Red gram	1.27	2.90	2.57	Groundnut	1.07	2.51	2.80
23	Kakkireni	Paddy	0.51	2.51	1.84	Paddy	0.48	1.53	2.11
24	Pilligudem	Brinjal	1.30	2.16	2.25	Chilli	1.4	1.52	1.67
25	Uttatoor	Paddy	0.12	0.87	0.75	Paddy	1.11	2.25	2.54
26	Iskilla	Paddy	0.27	1.45	1.80	Paddy	0.64	1.14	1.92
27	Lacchigudem	Paddy	0.99	1.92	2.61	Paddy	1.48	1.88	3.18
28	Janampalle	Redgram	0.84	1.99	1.72	Groundnut	1.48	2.43	2.94
29	Sanjeevaiahnagar	Sorghum	0.37	1.41	2.32	Groundnut	0.77	0.86	2.13
30	Kommaigudem	Sorghum	1.12	2.15	2.91	Groundnut	1.41	2.27	3.25

The F content of groundnut plant parts like economic part (kernel), shoot and root in Ramannapet mandal was found from 0.46 to 1.48, 0.86 to 2.55 and 1.58 to 3.39 mg kg^{-1}, with the average values of 1.14, 1.97 and 2.67 mg kg^{-1}, respectively. The average values of F content of bhendi plant parts like economic part (fruit), shoot and root was 1.14, 2.35 and 2.57 mg kg^{-1}, respectively in kharif and 0.54, 1.70, 2.11 mg kg^{-1}, respectively in rabi.The F content of brinjal plant parts like economic part (fruit), shoot and root in Nidhanpalle village during kharif was 0.57, 1.74 and 2.36 mg kg^{-1}, respectively Where as in Pilligudem village it was 1.30, 2.16, 2.15 mg kg^{-1}, respectively. The F content of cabbage plant parts like economic part (bud), shoot, root in Thurkapalle village during *kharif* was 1.33, 1.89, 2.14 mg kg^{-1}, respectively. The F content of chilli plant parts like economic part (fruit), shoot and root in Pilligudem village was 1.40, 1.52 and 1.67 mg kg^{-1}, respectively.

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

Crops	*Kharif*		*Rabi*	
	Range	**Mean**	**Range**	**Mean**
Paddy (15 samples)			**Paddy (13 samples)**	
Economic part	0.12-2.02	0.93	0.43-2.23	1.10
Shoot	0.85-3.20	1.94	1.13-3.47	2.08
Root	0.75-3.35	2.57	1.25-3.95	2.64
Sorghum (7 samples)			**Sorghum (2 samples)**	
Economic part	0.37-1.32	0.77	0.30-1.55	0.93
Shoot	1.28-2.93	1.87	0.64-2.66	3.17
Root	0.96-3.31	2.20	0.93-1.65	2.37
Tomato (2 samples)			**Groundnut (10 samples)**	
Economic part	0.36-0.76	0.56	0.46-1.48	1.14
Shoot	1.79-2.39	2.09	0.86-2.55	1.97
Root	1.83-2.19	2.01	1.58-3.39	2.67
Green Gram (one sample)			**Bhendi (2 samples)**	
Economic part	-	1.47	1.01-1.27	1.14
Shoot	-	2.49	1.98-2.71	2.35
Root	-	2.75	2.19-2.95	2.57
Bhendi (one sample)			**Brinjal (one sample)**	
Economic part	-	0.54	-	0.57
Shoot	-	1.70	-	1.74
Root	-	2.11	-	2.36
Red gram (3 samples)			**Cabbage (one sample)**	
Economic part	0.84-1.27	1.04	-	1.33
Shoot	1.99-2.90	2.41	-	1.89
Root	1.68-2.57	2.04	-	2.14
Brinjal (one sample)			**Chilli (one sample)**	
Economic part	-	1.30	-	1.42
Shoot	-	2.16	-	1.52
Root	-	2.15	-	1.67

The range of F content of red gram plant parts like economic part (seed), shoot and was found from 0.84 to 1.27, 1.99 to 2.90 and 1.68 to 2.57 mg kg^{-1}, with the average values of 1.04, 2.41 and 2.04 mg kg^{-1}, respectively. The range of F content of tomato plant parts like economic part (fruit), shoot and root during *rabi* was found from 0.36 to 0.76, 1.79 to 2.39 and 1.83 to 2.19 mg kg^{-1}, with the average values of 0.56, 2.09 and 2.01 mg kg^{-1}, respectively.

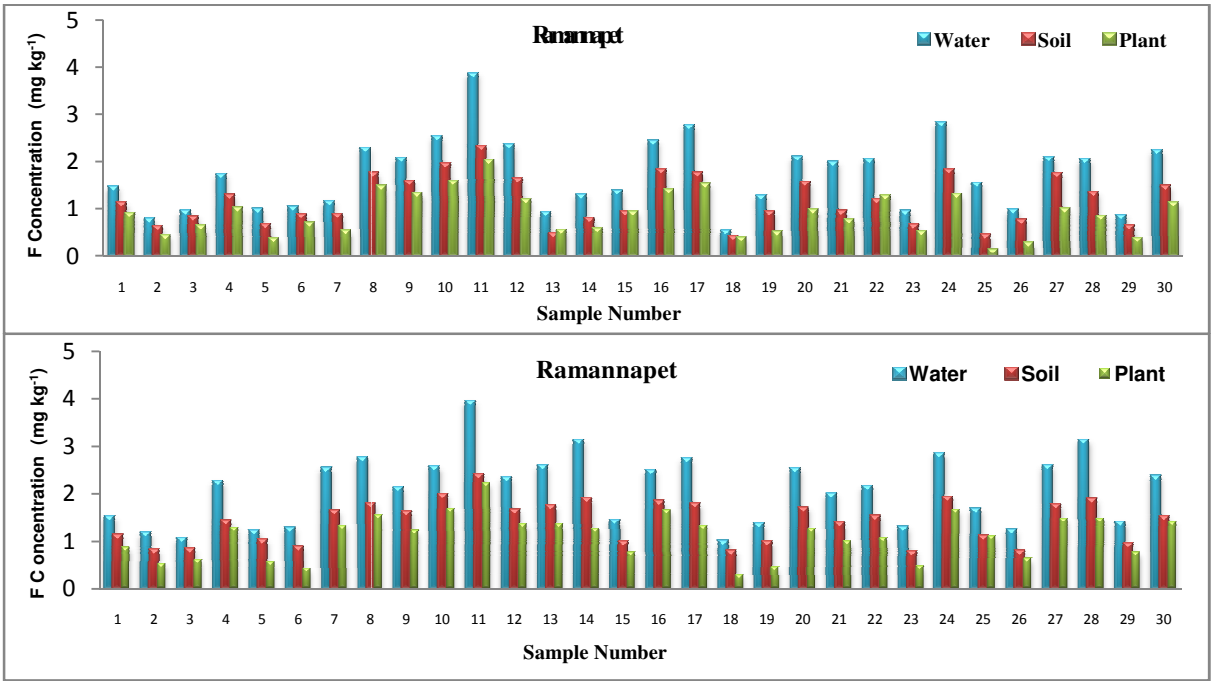
The concentration range in plant parts of different crops is 0.12 to 3.35 mg kg^{-1} and 0.30 to 3.95 mg kg^{-1} in *kharif* and *rabi*, respectively. The values are lower than the maximum allowed level of 4.0 mg kg^{-1} in food and vegetable recommended by EPA (1975) and WHO (1984) Joint Standard limit for fluoride. Crops like paddy, sorghum, and groundnut were analyzed for F out of which, paddy was found to have highest F concentration (2.23 mg kg^{-1}) which was collected from Rontakolla village where F concentration in water sample was 3.94 mg kg^{-1}. .

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 paddy > sorghum > red gram.

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 1.71 and 2.08 mg L^{-1} in *kharif* and *rabi* season, respectively.The mean values of available F present in the soil samples are 1.17 and 1.41 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 2.

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



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, 67% (20 samples) of the total groundwater samples from the *rabi* season are above the permissible limit of F (1.50 mg L^{-1}), compared to 53% (16 samples) of those from the *kharif* season.

Conclusion

In conclusion, The F levels in economic parts of all the crops grown in the 30 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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References

Blagojevic, S., Jakovljevic, M. and Radulovic, M. 2002. Content of fluorine in soils in the vicinity of aluminium plant in Podgorica. ***Journal Agricultural Sciences,*** 47(1): 1-8.

Brindha, K., Rajesh, P., Murugan, P. and Elango, L. 2010. Natural and anthropogenic influence on the fluoride and nitrate concentration of ground water in parts of Nalgonda district, Andhra Pradesh. ***Journal Applied Geochemistry,*** 42(2): 231-241.

Davidson, A. 1983. The effects of fluoride on plant growth and forage quality in effect of gaseous air pollution in agriculture and horticulture. Edited by M.H. Unsworth and D.P. Ormord, London butter worth. 267-291.

EPA, 1975. National Interim Primary drinking water regulations. US Environmental Protection of Agency. Federal Register. 40: 248-250.

FAO, 2003. The irrigation challenge: Increasing irrigation contribution to food security through higher water productivity from canal irrigation systems. Food and Agricultural Organization of the United Nations, IPTRID Secretariat, Rome. IPTRID issue paper 4.

Goyal, S. K., 2013. Temporal and seasonal changes in groundwater quality in an agriculture dominated area of Kaithal district.***International Journal of Advancement in Remote Sensing, GIS and Geography,*** 1(2): 39-46.

Gupta S, Banerjee S (2009) Fluoride accumulation in paddy (O ryza sativa) irrigated with fluoride- contaminated groundwater in an endemic area of the Birbhum district, West Bengal. ***Fluoride*** 42 (3):224–227.

ICMR (Indian Council of Medical research) 1975. New Delhi manual of standards of quality of drinking water supplies special report series. No. 44.

Jakovljevic, M., Blagojevic, S and Antic- Mladenovic, S. 2002. Fluorine content in soils of Northern Pomoravlje. ***Journal Agricultural Sciences,*** 47(2): 121-128.

Kishore, M. and Rao, Y. 2010. A survey on fluoride concentration in drinking water of Tipparthy revenue sub-division, Nalgonda district, Andhra Pradesh, India and batch mode defluoridation with renewable resources. ***Rasayan Journal Chemistry*** 3(2): 341-346.

Leone, J.A., Brennan, E.G., Danies, R.H and Robbins, W.R. 1948. Some effects of fluorine on peach, tomato and wheat when absorbed through the roots. ***Journal Soil Science*** 66: 259-266.

McQuaker, N.R and Gurney, M. 1977. Determination of total fluoride in soil and vegetation using an alkali fusion selective ion electrode technique. ***Annals Chemisry***, 49:53-56.

Okibe, F.G., Ekanem, E.J., Paul, E.D., Shallangwa, G.A., Ekwumemgbo, P.A., Sallau, M.S., Abanka, O.C. 2010. Fluoride content of soil and vegetables from irrigation farms on the bank of river Galma, Zaria, Nigeria. Australian ***Journal of Basic and Applied Sciences***. 4(5): 779-784.

Pant, S., Pant, P., Bhiravamurthy, P.V., 2008. Effects of fluoride on early root and shoot growth of typical crop plants of India. ***Fluoride***. 41(1): 57-60.

Pendias K.A., Pendias H., 1986 Trace elements in soils and plants. Florida: CRS Press. ***Inc. Boca Raton***, pp 213-217.

Reddy, D.V., Nagabhushanam, P., Sukhija, B.S., Reddy, A.G.S and Smedley, P.L. 2009. Fluoride dynamics in the granitic aquifer of the Wailapally watershed, Nalgonda district, India. ***Journal of Hydrology***, DOI: 592 10.1002/hyp.7236.

Villa, A.E., 1979. Rapid method for determining fluoride in vegetation using an ion-selective electrode. ***Analyst***. 104: 545-546.

Wedepohl, K. H. 1969. Handbook of geochemistry (Vol. II-l) (Ed.). Berlin: Springer.

WHO. 1984. Fluorine and fluorides. World Health Organization, Geneva. (Environmental Health Criteria 36).