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Fluoride Content of Agricultural Soils and it's Relation with Physicochemical Properties in Kalwakurthy Mandal, Mahabubnagar District, Telangana State

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ABSTRACT

*Investigations were carried out to assess the fluoride content of cultivated soils in Kalwakurthy mandal, Mahabubnagar district, Telangana and its occurrence in relation to other soil properties during kharif and rabi seasons of 2015-16. The results indicated that the mean available F content in study area was 0.11 ppm and 0.16 ppm during kharif and rabi seasons. Highest available fluoride content was observed in Marcharla village (0.25 ppm) during kharif whereas in rabi season it was found in Panjugal village (0.29 ppm). The available fluoride in soils was found to be positively correlated with soil pH, EC, exchangeable sodium, exchangeable calcium, exchangeable magnesium and total fluoride content but significantly correlated with pH (0.655**) and exchangeable sodium (0.388**) only. Soil's OC, CEC, available nutrients (N, P, K, S, Cu, Mn, Fe and Zn) were negatively correlated with available fluoride and among these parameters available phosphorus (-0.523**) had significantly negatively correlated.*

Key words: *Fluoride, Rabi, Kharif, Soil.*

INTRODUCTION

Fluoride is the 13th most abundant element in the Earth's crust which is also the most electronegative and reactive of elements, mainly occurs as common constituent of rocks and soils as well as a number of naturally occurring minerals like fluorspar, cryolite and fluorapatite etc., through anthropogenic sources also fluoride enters in to soil eco system. Soils contain approximately 330 ppm of fluoride, ranging from 150 to 400 ppm. Some soils can have as much as 1,000 ppm and contaminated soils have been found with 3,500 ppm[11]. Natural fluoride is frequently encountered in minerals and in geochemical deposits and is generally released into subsoil water sources by slow natural degradation of fluoride contained in rocks[39].

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Anthropogenic sources include human activities like industrialization, mechanization, use of fluoride containing pesticides and the fluoridation of drinking water supplies[20]. Fluorides which are strongly retained by soil are in the form of cryolite (Na_3AlF_6), fluorapatite ($Ca_5(PO_4)_3F$) and other phosphate rocks[4]. Leaching removes only a small amount of fluorides from soils[35].

Fluoride in soil is primarily associated with the soil colloid or clay fraction and its mobility in soil is highly dependent on the soil's sorption capacity, which varies with pH, the types of sorbents present, and soil salinity In soils, fluoride is predominantly combined with aluminum or calcium and silty soils and clay loam soils had higher fluoride content than sandy soils[10,35]. Fluoride forms its most stable bonds with Fe, Al, and Ca, and labile F is held by soil components that contain these elements, including clay minerals, calcium and magnesium compounds, and iron and aluminum compounds[23]. Fluoride is relatively immobile and is not easily leached in soil because most of the fluoride was not readily soluble or exchangeable[9,10]. Calcium fluoride can be formed in soils irrigated with fluoride solutions or when the fluoride adsorption capacity is exceeded and the fluoride and calcium ion activities exceed the ion activity product of calcium fluoride.Fluoride in the environment closely related to human beings has an important impact on health. The research on fluoride in soils has been a hot spot as the soil is critical resources for human survival. Kalwakurthy mandal of Mahabubnagar district, Telangana state is a place where in 46% the ground water sources were reported to be contaminated with fluorine[34]. The cultivation in the area is majorly dependent on tube wells/bore wells. Hence, the present work was undertaken to study the possible contamination of fluoride in the cultivated soils and its relation with physicochemical properties in Kalwakurthy mandal of Mahabubnagar district, Telangana state.

MATERIAL AND METHODS

The study was carried out in rainy (*kharif*, 2015) and post rainy (*rabi, 2015-16)* seasons in cultivated soils of Kalwakurthy mandal, Mahabubnagar district, Telangana state. The climate of the study area was dry tropical semi-arid type and average temperature in summer is 40.9^0C, in winter is 25^0C and rainfall is 604 mm. Fifty surface soil samples were collected with twenty five samples for each season. The soil samples were analyzed physical parameters like texture and physico-chemical parameters *viz.,* pH, electrical conductivity (EC), organic carbon (OC), exchangeable Na, Ca and Mg as per the standard procedures given by Jackson[12] and cation exchange capacity[7]. Available nutrients were estimated by using the standard extractants and procedures viz., nitrogen by 0.32% Alkaline $KMnO_4$[33], phosphorus by Olsens method[22] with 0.5M $NaHCO_3$, potassium with 1 N Neutral Normal Ammonium Acetate method[11] and sulphur by Turbidometric method[40] with 0.15% $CaCl_2$. The available micronutrients (Cu, Mn, Fe and Zn) were analysed in Atomic absorption spectrophotometer using DTPA extractant[19]. The total fluoride was analyzed by NaOH fusion technique using Ion Selective Electrode (FISE) method and available fluoride in soil samples analyzed by Potentiometric method[21].The data was analysed for descriptive statistics like range, mean and standard deviation and also correlation studies were carried out between available fluoride and other parameters of soils in study area.

RESULTS AND DISCUSSION

The results the study i.e., characterization of the soil for Physical (Texture), Physico-chemical (pH, EC, OC and CEC) and chemical characteristics (available N, P, K, S, exchangeable Na, Ca, Mg, available F, total F and available micronutrients) during both *kharif* (Table 1) and *rabi* seasons (Table 2) based the analysis of soil samples collected from different villages of the study area are presented here.

Texture

Texture of the soil varies from region to region. Soil texture shows its effect on aeration and root penetration. It also influences the nutritional status of soil[15]. In Kalwakurthy mandal, the sand, silt and clay per cent ranged from 55.5 to 76.5, 10.9 to 28.6 and 7.2 to 20.2 respectively. The soils are mostly sandy loam

in texture and the mean content of sand, silt and clay was 66.3, 21.1 and 12.6 percent respectively. The soils of the study area were mainly coarse textured and can be classified as sandy loam type (96%). Chaitanya *et al*.[8] also reported that the texture of soils of Mahaboobnagar district varied from sandy loam (65 per cent), loamy sand (20 per cent), sand (10 per cent) and sandy clay loam (5 per cent). The data confirms that the soils were light textured with sand as dominant fraction in Mahaboobnagar district.

pH

In soil, pH is known as a master variable because it influences almost every process in the soil system. The health of crops and other soil life, the availability of nutrients and the activity of pesticides are all affected by pH. In Kalwakurthy mandal, the pH varied from 7.0 to 7.92 in different villages with mean of 7.47. All the samples of this mandal were neutral to alkaline in nature. The highest pH was found in Panjugal village (7.92) and lowest in Lingasanapalle village (7.00) during *kharif* season. During *rabi* season, the pH of these soils was slightly high and ranged from 7.21 to 8.10 with mean of 7.67. The highest pH was observed in Marcharla village (8.10) and lowest in Mukural village (7.21). In general, the soils of study area had neutral to alkaline pH. Similar findings were reported by Chaitanya *et al*.[8] in soils of Mahaboobnagar district and Laksmi *et al*.[18] in Nalgonda district of Telangana state.

Electrical conductivity (dS m^{-1})

Electrical conductivity (EC) is a very quick, simple and inexpensive method to check health and quality of soils. It is a measure of ions present in solution. The Electrical conductivity in soils of Kalwakurthy mandal during *kharif* season showed variation in values between 0.06 dS m^{-1} to 0.32 dS m^{-1} and mean EC with 0.16 dS m^{-1}. EC was found to be highest (0.32 dS m^{-1}) in Panjugal village and lowest (0.06 dS m^{-1}) in Mukural village. During *rabi* season, the electrical conductivity of soils varied from 0.13 to 0.32 dS m^{-1} and mean EC of the mandal was observed to be 0.22 dS m^{-1}. Maximum EC was observed in Panjugal village (0.32 dS m^{-1}) and minimum in Mukural village (0.13 dS m^{-1}). The soils in study area were non saline nature and seasonal (*kharif* and *rabi*) variations were found to be very minor. Similar non saline nature of soils was reported by Vasu *et al*.[36] in Thammajipet mandal of Mahaboobnagar district and Chaitanya *et al*.[8] in Ranga Reddy and Mahaboobnagar districts of Telangana state.

Organic Carbon (%)

Organic carbon (OC) is the valuable property of soil. Soil organic carbon is the basis of soil fertility. It releases nutrients for plant growth, promotes the structure, biological and physical health of soil and is a buffer against harmful substances. The results revealed that the organic carbon soils of Kalwakurthy mandal ranged from 0.42% to 0.60%. The mean organic carbon was 0.51% in this area. Maximum organic carbon (0.60%) was recorded in Gundur village and minimum (0.42%) in Lingasanapalle village during *kharif* season. The samples of analysed soils were classified from low to medium range. During *rabi* season, the organic carbon ranged from 0.38% to 0.59% with mean organic carbon 0.47%. The minimum organic carbon was observed in Gundur village (0.38%) and maximum in Lingasanapalle village (0.59 %). The soils of study area were low to medium in organic carbon status. The low organic carbon may possibly be attributed to increased the rate of oxidation of organic matter due to semi arid climate and good aeration in the soil[31,36].

Cation exchange capacity (cmol (p^+) kg^{-1})

CEC, an abbreviation for cation exchange capacity, refers to the amount of negative charges available on the surface of soil particles. It gives an indication of the potential of the soil to hold plant nutrients, by estimating the capacity of the soil to retain cations, which are positively-charged substances. The cation exchange capacity of the surface soil samples in Kalwakurthy mandal ranged from 6.5 to 19.5 cmol (p^+) kg^{-1} soil with a mean of 12.9 cmol (p^+) kg^{-1} soil during *kharif* season. The highest and lowest CEC was reported in Gundur (19.5 cmol (p^+) kg^{-1}) and Lingasanapalle (6.5 cmol (p^+) kg^{-1}) villages.

During *rabi* season, the CEC ranged from 7.8 to 20.3 cmol (p^+) kg^{-1} soil with mean value of 13.5 cmol (p^+) kg^{-1} soil. Both the highest (20.3

cmol (p^+) kg^{-1}) and lowest (7.8 cmol (p^+) kg^{-1}) values of CEC were observed in Lingasanapalle village. In the study area, all the samples were explicated as low to medium CEC. Chaitanya *et al*.[8] reported that the CEC of soils of Mahaboobnagar district was low to medium and ranged from 3.92 to 29.77 cmol (p+) kg^{-1} with mean of 15.48 cmol (p+) kg^{-1}, this might be due to the fact that the sandy soils, since low in organic matter have a very low CEC (less than 3 cmol (p^+) kg^{-1}) while heavier clay soils or soils high in organic matter generally have a much higher CEC (> 20 cmol (p^+) kg^{-1})[16].

Exchangeable sodium (meq/100 g soil)

The exchangeable sodium content varied from 3.25 to 4.44 meq/100 g soil with mean value of 3.69 meq/100 g soil in different villages of Kalwakurthy mandal during *kharif* season. Maximum and minimum exchangeable sodium content was observed in Mukural (4.44 meq/100 g soil) and Marcharla (3.25 meq/100 g soil) village. During *rabi* season, exchangeable sodium varied between 3.05 to 4.26 meq/100 g soil with mean of 3.64 meq/100 g soil. The maximum (4.26 meq/100 g soil) and minimum (3.05 meq/100 g soil) exchangeable sodium was reported in Marcharla village. The exchangeable sodium in red soils (sandy loam) ranged from 3.30-4.39 c mol (p^+) kg^{-1} in Tungabhadra project area of Karnataka state[41].

Exchangeable calcium (meq/100 g soil)

In Kalwakurthy mandal during *kharif* season the mean exchangeable calcium content was 3.97 meq/100 g soil and values varied between 2.86 to 5.18 meq/100 g soil. Lingasanapalle village had lowest exchangeable calcium (2.86 meq/100 g soil) and in Gundur village it was found to be highest (5.18 meq/100 g soil). During *rabi* season, exchangeable calcium was lowest in Gundur village (3.54 meq/100 g soil) and in Mukural village it was found to be highest (5.62 meq/100 g soil). The mean exchangeable calcium content of this mandal 4.32 meq/100 g soil and ranged from 3.54 to 5.62 meq/100 g soil. Sreenivasa Raju[32] also reported that magnitude of exchangeable calcium was 5.6 and 21.8 cmol (p^+) kg in red (Mahabubnagar) and black (Rajendranagar) soils of Telangana state.

Exchangeable magnesium (meq/100 g soil)

In Kalwakurthy mandal, the exchangeable magnesium content ranged from 0.42 to 1.72 meq/100 g soil with mean value of 0.95 meq/100 g soil in *kharif* season. The highest (1.72 meq/100 g soil) and lowest (0.42 meq/100 g soil) exchangeable magnesium was observed in Panjugal and Lingasanapalle villages. During *rabi* season, the maximum and minimum exchangeable magnesium was observed in Mukural (2.24 meq/100 g soil) and Lingasanapalle villages (0.48 meq/100 g soil). The exchangeable magnesium content varied between 0.48 to 2.24 meq/100 g soil with mean value of 1.24 meq/100 g soil. The exchangeable Na content in light textured soils of Warangal district varied from 1.2 to 14.2 cmol (p^+) per kg of soil reported by Rajagopal *et al*.[24]. The exchangeable Mg content in ranged from 1.2 to 8.0 cmol (p+) per kg of soil in Chanvelly village of Rangareddy district, Telangana state[25].

Available Fluoride (ppm)

The available fluoride content in soils of Kalwakurthy mandal ranged from 0.05 to 0.25 ppm with lowest and highest in Gundur (0.05 ppm) and Marcharla village (0.25 ppm) during *kharif* season. The mean available fluoride content of soils was 0.11 ppm. During *rabi*, the available fluoride content varied from 0.08 to 0.29 ppm with a mean of 0.16 ppm. Highest and available fluoride content was observed in Panjugal village (0.29 ppm) while lowest in Gundur and Lingasanapalle villages (0.08 ppm). All the values obtained are well within the range of 2.57 to 16.44 ppm soil available F stipulated by WHO standard limit for fluoride in soils, so it could be indicated that there was no danger from F accumulation in the plants. Lakshmi *et al*.[18] also reported the mean values of available F present in the soil samples were 1.18 ppm in *kharif* season and 1.66 ppm during *rabi* season in Nalgonda district, Telanagana state.

Total fluoride (ppm)

In the soils of Kalwakurthy mandal, the total fluoride content ranged from 210 to 404 ppm with an average of 295.5 ppm. In this mandal, Panjugal village recorded lowest total fluoride content (210 ppm) and highest was observed in Marcharla village (404 ppm) during *kharif*

season. During *rabi* season, the total fluoride content varied from 213 to 415 ppm with mean of 277.4 ppm. The highest total fluoride content was found in Panjugal village (415 ppm) and lowest in Lingasanapalle village (213 ppm). Geological reports of the study area indicate the parent material is fluoride-rich Pink Granite with principal fluorine-bearing minerals fluorite (CaF_2), apatite ($Ca_5(PO_4)_3(F, OH, Cl)$), muscovite $\{K_2Al_4[Si_6Al_2O_{20}](OH, F)_4\}$, biotite $\{K_2(Mg,Fe^{2+})_{6-4}(Fe^{3+}Al, Ti)_{0-2}(Si_{6-5}Al_{2-3}O_{20})OH, F)_4\}$ as accessories and these minerals are major source for the fluoride in the groundwater and as well as soils of the areas concerned and making the problem is more serious in terms of endemicity[37]. The normal total fluoride content of soil ranged from 150-400 mg/kg in heavy clay soils, values surpassing 1000 mg/kg have been enlisted[5]. Similar results were reported by Saini *et al*.[26] and Jakovljevic *et al*.[13].

Available Nitrogen (kg ha^{-1})

The available nitrogen in soils of Kalwakurthy mandal ranged from 138 to 210.7 kg ha^{-1} with mean of 170.2 kg ha^{-1} during *kharif* season. In Gundur village (210.7 kg ha^{-1}) the available nitrogen was found to be highest and lowest in Panjugal village (138 kg ha^{-1}). During *rabi* season, the available nitrogen varied from 149.5 to 220.2 kg ha^{-1} with mean value of 181.1 kg ha^{-1}. In Lingasanapalle village (220.2 kg ha^{-1}) the available nitrogen was found to be highest and lowest in Gundur village (149.5 kg ha^{-1}). The available nitrogen status of the study area was138 to 210.7 kg ha^{-1} and was found to be low as per ratings suggested by Subbiah and Asija[33]. Nitrogen being mobile in nature, the residual/available N becomes poor in soils due to its losses through various mechanism like NH_3 volatilization, denitrification, chemical and microbial fixation, leaching and runoff[17]. Similar results were also reported by Yeledhalli *et al*.[41] in sandy loam soils of Karnataka and Vasu *et al*.[36] reported low available nitrogen in cotton growing soils of Mahabubnagar district.

Available Phosphorus (kg ha^{-1})

The collected soil samples during *kharif* season were analysed for available phosphorus, the mean available phosphorus in soils was 17.3 kg ha^{-1} and ranged from 8.1 to 25.7 kg ha^{-1} The maximum available phosphorus was found in Gundur village (25.7 kg ha^{-1}) and minimum in Marcharla village (8.1 kg ha^{-1}). During *rabi* season, the available phosphorus ranged from 9.8 to 24.5 kg ha^{-1} with average of 16.6 kg ha^{-1}. Highest available phosphorus was observed in Gundur village (24.5 kg ha^{-1}) and lowest in Marcharla village (9.8 kg ha^{-1}). The available phosphorus status of the study area was in the range of 8.1 to 25.7 kg ha^{-1} and can be classified as low to high. Similar results were observed by Kalyani *et al*.[14] in Ranga Reddy district and Lakshmi *et al*.[18] in Nalgonda district of Telangana state. However, a low to medium range of soil available P may be due to pH, organic matter content, texture various soil management and agronomic practices[38].

Available Potassium (kg ha^{-1})

The available potassium content varied from 136.5 to 218.4 kg ha^{-1} with mean of 181.7 kg ha^{-1} in soils of Kalwakurthy manadal during *kharif* season. Maximum available potassium was found in Lingasanapalle village (218.4 kg ha^{-1}) and minimum in Panjugal village (136.5 kg ha^{-1}). The available potassium ranged from 141.5 to 229 kg ha^{-1} with mean of 188 kg ha^{-1} in *rabi* season. Highest available potassium was found in Panjugal village (229 kg ha^{-1}) and lowest in Lingasanapalle village (141.5 kg ha^{-1}). In both seasons, the available potassium status of the study area was in the range of 136.5 to 229.0 kg ha^{-1} and can be classified as low to medium available potassium. Similar findings were observed by Kalyani *et al*.[14] in Ranga Reddy district of Telangana state. Adequate (medium or high) available K in soils may be attributed to the prevalence of potassium-rich minerals like Illite and Feldspars[28].

Available Sulphur (ppm)

The available sulphur status in soils of Kalwakurthy mandal ranged from 7.3 to 14.5 ppm with mean of 10.6 ppm. Maximum available sulphur was recorded in Panjugal village (14.5 ppm) and minimum in Mukural village (7.3 ppm). The available sulphur status of soils during *rabi* ranged from 7.5 to 17.0 ppm with mean of 10.9 ppm. Maximum (17.0 ppm) and minimum contents (7.5 ppm) were

recorded in Marcharla village. Sahrawat *et al*.[27] reported the available sulphur in soils of Mahabubnagar and Nalgonda ranged from 1.4 to 24.9 and 1.2 to 98 ppm.

Micronutrients (Cu, Fe, Mn and Fe)

In Kalwakurthy mandal during *kharif* season, the micronutrient status of soils *viz.*, available Cu, Mn, Fe and Zn ranged from 0.32 to 1.10, 7.42 to 12.70, 5.06 to 14.56 and 0.38 to 1.12 with mean values of 0.69, 9.85, 9.97 and 0.73 ppm respectively. Highest available copper was found in Gundur village (1.10 mg kg^{-1}) and lowest in Panjugal village (0.32 mg kg^{-1}). The highest (12.70 mg kg^{-1}) and lowest (7.42 mg kg^{-1}) available manganese was recorded in Liangasanapalle village. Maximum available iron was recorded in Marcharla village (14.56 mg kg^{-1}) and minimum in Panjugal village (5.06 mg kg^{-1}). Available zinc status was highest in Lingasanapalle village (1.12 mg kg^{-1}) while lowest in Marcharla village (0.38 mg kg^{-1}). During *rabi* season, the available Cu, Mn, Fe and Zn ranged from 0.26 to 1.47, 5.60 to 13.40, 6.55 to 13.52 and 0.38 to 1.50 with mean values of 0.71, 8.88, 9.80 and 0.75 ppm respectively. Highest available copper was recorded in Lingasanapalle village (1.47 mg kg^{-1}) and lowest in Mukural village (0.26 mg kg^{-1}). Available manganese was highest in Panjugal village (13.40 mg kg^{-1}) and lowest in Liangasanapalle village (5.60 mg kg^{-1}). Maximum and minimum available iron was observed in Lingasanapalle (13.52 mg kg^{-1}) and Panjugal (6.55 mg kg^{-1}) villages. Available zinc status was maximum in Gundur village (1.50 mg kg^{-1}) and minimum in Marcharla village (0.38 mg kg^{-1}). The status of micronutrients in study area confirmation with the findings of Shukla *et al*.[30] in Telangana state.

Correlation study between available fluoride and other properties of soils in study area

To understand the relationship of the various soil properties on soil available fluoride, correlation studies were taken up and the data is presented in Table 3.In study area, the available fluoride in soils was found to be positively correlated with soil pH (0.665**), EC (0.238), exchangeable sodium (0.388**), exchangeable calcium (0.232), exchangeable magnesium (0.203) and total fluoride (0.267) contents. Among these parameters, the pH and exchangeable sodium were found to have significant correlation (@ 1% with available fluoride with correlation coefficient (r) values higher than 0.277. Soil OC, CEC, available nutrients (N, P, K, S, Cu, Mn, Fe and Zn) were negatively correlated with available fluoride and among these parameters available phosphorus (-0.523**) had significantly negatively correlation. According to the above results, the available fluoride content in soil increases with increase in soil pH and EC respectively. Similar findings have been reported by Abugri *et al*.[1] and Anbuvel *et al.*[2] Exchangeable sodium showed strong positive correlation with fluoride. The positive correlation between the alkalinity and fluoride might be due to the accumulation of Cryolite (Na_3AlF_6) minerals in soils[29]. In the present study, the calcium and magnesium also showed a positive correlation with fluoride. This result may be due to the presence of some minerals like fluorite (CaF_2), fluorapatite [$(3Ca_3 (PO4)_2.CaF_2)$] and magnesium fluoride (MgF_2) in the soil. Total fluoride is another most important soil parameter that affects the available fluoride in soil. Blagojevic *et al*.[6] reported by 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. Fluoride is relatively immobile and is not easily leached in soil because most of the fluoride was not readily soluble or exchangeable[10,11]. Total F in soil is considered a poor indicator of soil pollution status due to great natural variation and variation in sorption strength and sorption capacity in different soils[3]. Similarly positive but no significant relationship between available fluoride and total fluoride was observed in cultivated soils of Nalgonda district[18].The available fluoride significantly negative correlation with available P_2O_5 of soils. More fluoride content in soil decreases the available P_2O_5 content of the soil due to formation of insoluble phosphorus compounds in the soils.

Table 1: Available fluoride content and other properties of the soils in different villages of Kalwakurthy (*Kharif* 2015)

S. No	Village	pH	EC (dS m^{-1})	OC (%)	CEC (c mol (p+) kg^{-1})	Ech. Na (meq/100 g)	Ech. Ca (meq/100g)	Ech. Mg (meq/100g)	Available F	Total F	Sand	Silt	Clay
1	Gundur	7.63	0.22	0.60	19.5	3.79	5.11	1.20	0.12	355	55.5	24.3	20.2
2	Gundur	7.41	0.27	0.54	14.2	3.52	3.82	0.85	0.08	274	65.3	22.3	12.4
3	Gundur	7.40	0.19	0.47	10.2	3.45	3.94	0.50	0.05	256	72.6	18.9	8.5
4	Gundur	7.55	0.20	0.50	12.6	3.82	3.22	0.46	0.09	306	75.5	14.2	10.3
5	Gundur	7.52	0.21	0.57	17.2	3.85	5.18	0.72	0.09	285	64.5	20.3	15.2
6	Marcharla	7.80	0.23	0.48	8.5	3.95	3.42	0.69	0.25	404	68.5	22.0	9.5
7	Marcharla	7.70	0.14	0.52	14.3	3.44	5.03	1.10	0.13	315	59.4	28.6	12.0
8	Marcharla	7.10	0.21	0.44	9.2	3.53	2.89	0.82	0.10	301	68.7	22.8	8.5
9	Marcharla	7.20	0.21	0.55	10.2	3.72	3.84	1.10	0.15	375	74.5	10.9	14.6
10	Marcharla	7.32	0.10	0.51	9.5	3.25	4.21	0.70	0.11	326	66.5	23.0	10.5
11	Panjugal	7.92	0.13	0.50	10.2	3.89	4.05	1.12	0.21	295	69.5	20.7	9.8
12	Panjugal	7.15	0.10	0.54	14.5	3.35	3.65	1.72	0.06	276	65.8	21.0	13.2
13	Panjugal	7.75	0.14	0.45	11.5	3.91	3.82	0.80	0.14	210	74.2	13.8	12.0
14	Panjugal	7.60	0.13	0.50	12.8	4.05	4.52	0.95	0.12	289	63.5	25.8	10.7
15	Panjugal	7.74	0.32	0.53	9.0	3.62	4.11	0.86	0.16	237	70.5	21.0	8.5
16	Lingasanapalle	7.23	0.14	0.50	17.2	3.42	3.85	1.25	0.07	253	59.8	23.7	16.5
17	Lingasanapalle	7.52	0.19	0.53	14.5	3.53	3.16	1.05	0.07	246	62.5	25.0	12.5
18	Lingasanapalle	7.00	0.21	0.51	18.4	3.42	4.22	0.90	0.07	292	58.7	25.8	15.5
19	Lingasanapalle	7.62	0.09	0.45	8.5	4.1	3.10	0.42	0.07	283	71.5	21.3	7.2
20	Lingasanapalle	7.55	0.11	0.42	6.5	3.53	2.86	0.62	0.09	315	76.5	13.0	10.5
21	Mukural	7.58	0.06	0.48	14.3	3.9	4.10	1.23	0.10	301	62.5	22.0	15.5
22	Mukural	7.62	0.08	0.50	18.5	4.44	4.72	1.64	0.13	306	65.2	18.3	16.5
23	Mukural	7.04	0.15	0.56	15.6	3.28	4.10	0.64	0.08	291	58.5	24.3	17.2
24	Mukural	7.40	0.15	0.47	11.3	3.85	4.12	1.32	0.11	335	71.2	16.6	12.2
25	Mukural	7.49	0.07	0.54	14.8	3.72	4.23	1.00	0.08	258	57.5	27.5	15.0
Range		7-7.92	0.06-0.32	0.42-0.60	6.5-19.5	3.25-4.44	2.86-5.18	0.42-1.72	0.05-0.25	210-404	55.5-76.5	10.9-28.6	7.2-20.2
Mean		7.47	0.16	0.51	12.9	3.69	3.97	0.95	0.11	295.4	66.3	21.1	12.6
SD+		0.25	0.07	0.04	3.60	0.29	0.64	0.34	0.05	42.96	6.10	4.55	3.28

Table 2: Available fluoride content and other properties of the soils in different villages of Kalwakurthy (*Rabi* 2015-16)

S. No	Village	pH	EC (dS m^{-1})	OC (%)	CEC (c mol (p+) kg^{-1})	Ech. Na (meq/100g)	Ech. Ca (meq/100g)	Ech. Mg (meq/100g)	Available F	Total F
1	Gundur	8.04	0.25	0.52	17.5	3.98	5.22	1.87	0.16	217
2	Gundur	7.25	0.31	0.48	15.3	3.51	4.51	1.45	0.08	284
3	Gundur	7.25	0.22	0.38	9.6	3.36	3.54	0.71	0.10	315
4	Gundur	7.61	0.24	0.44	11.5	3.73	3.87	0.96	0.11	262
5	Gundur	7.57	0.25	0.48	15.7	3.45	4.13	1.32	0.11	289
6	Marcharla	8.10	0.27	0.40	10.2	4.26	3.89	0.92	0.25	313
7	Marcharla	8.05	0.17	0.50	15.1	3.77	4.92	1.92	0.27	294
8	Marcharla	7.21	0.22	0.41	10.7	3.05	3.75	0.54	0.12	283
9	Marcharla	7.31	0.25	0.45	11.3	3.16	4.32	0.75	0.12	254
10	Marcharla	7.94	0.18	0.48	12.1	3.89	4.68	1.10	0.25	300
11	Panjugal	7.84	0.21	0.40	10.6	3.73	4.05	0.89	0.24	312
12	Panjugal	7.88	0.20	0.55	16.2	3.84	4.64	1.36	0.10	285
13	Panjugal	7.81	0.18	0.50	12.3	4.12	3.92	0.92	0.18	218
14	Panjugal	7.63	0.17	0.45	11.5	3.56	3.85	1.02	0.17	264
15	Panjugal	7.95	0.32	0.42	10.4	3.76	4.26	1.25	0.29	415
16	Lingasanapalle	8.09	0.19	0.59	20.3	3.42	5.13	2.23	0.13	256
17	Lingasanapalle	7.93	0.23	0.49	15.9	3.79	4.52	1.52	0.10	272
18	Lingasanapalle	7.35	0.29	0.53	17.2	3.44	4.19	1.10	0.08	303
19	Lingasanapalle	7.73	0.15	0.40	9.2	3.56	3.85	0.52	0.13	213
20	Lingasanapalle	7.62	0.18	0.39	7.8	3.94	4.08	0.48	0.16	245
21	Mukural	7.65	0.13	0.46	15.2	3.36	4.52	1.72	0.16	294
22	Mukural	7.86	0.23	0.56	19.0	3.85	5.62	2.24	0.18	225
23	Mukural	7.21	0.24	0.52	16.2	3.08	4.18	1.81	0.12	315
24	Mukural	7.43	0.22	0.43	12.7	3.55	4.36	0.88	0.15	255
25	Mukural	7.51	0.18	0.48	15.3	3.96	4.10	1.40	0.18	251
Range		7.21-8.10	0.13-0.32	0.38-0.59	7.8-20.3	3.05-4.26	3.54-5.62	0.48-2.24	0.08-0.29	213-415
Mean		7.67	0.23	0.47	13.5	3.64	4.32	1.24	0.16	277.4
SD+		0.30	0.05	0.06	3.30	0.31	0.50	0.51	0.06	42.81

Table 3: Correlation coefficients (r) between available fluoride content and other soil parameters

S.No	Correlation among	'r' values
1	F *vs* pH	0.665**
2	F *vs* EC	0.238
3	F *vs* OC	-0.260
4	F *vs* CEC	-0.219
5	F *vs* Ech. Na	0.388**
6	F *vs* Ech. Ca	0.232
7	F *vs* Ech. Mg	0.203
8	F *vs* N	-0.013
9	F *vs* P	-0.523
10	F *vs* K	-0.124
11	F *vs* S	-0.116
12	F *vs* TF	0.267
13	F *vs* Cu	-0.069
14	F *vs* Mn	-0.204
15	F *vs* Fe	-0.123
16	F *vs* Zn	-0.086

CONCLUSIONS

In study area, highest available fluoride content was observed in Marcharla village (0.25 ppm) during *kharif* and in Panjugal village (0.29 ppm) during *rabi* season with mean values of 0.11 ppm during *kharif* season and 0.16 ppm in *rabi* season. The available fluoride in soils was found to be positively correlated with soil pH (0.665**), EC, exchangeable sodium (0.388**), exchangeable calcium, exchangeable magnesium and total fluoride content. Soils OC, CEC, available nutrients (N, P, K, S, Cu, Mn, Fe and Zn) were negatively correlated with available fluoride and among these parameters available phosphorus (-0.523**) had significantly negatively correlation.

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