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RESEARCH ARTICLE

Soil Profiles and Fluoride Adsorption in Intensely Cultivated Areas of Mysore District, Karnataka, India

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Abstract: Fluoride is a persistent and non-degradable toxin that is accumulating in soils, plants, wildlife and humans. Many farmers are unaware of the hidden presence of this highly toxic substance. In this study water and soil samples have been analysed from 5 agricultural locations across Mysore district that represented different soil types in the region. At each site composite soil samples were taken and analyzed for all physicochemical parameters. Mean water-extractable soil fluoride concentration from a depth of 5 cm to 20 cm in each location was in the range, sandy (3-1.9 mg/L), black (4-2.3 mg/L), laterite (4.5-3.6 mg/L), alluvial (9-6.3 mg/L) and red (loam) (11.2-7.9 mg/L). Fluoride in the groundwater in the experimental location is in the range 25.5 mg/L for sandy soil and 1.5 mg/L for loam soil. Also an epidemiological study among 20 school going children in each area was conducted on the prevalence of fluorosis. Results revealed that on 4/20 children from Mahadevapura east were having mottled teeth. This may be due to fluoride in ground water (25.5 mg/L) or might be due to health and hygiene.

Keywords: Fluoride adsorption, Fluoride leaching, Groundwater fluoride, Soil profiles

Introduction

Fluorine is one among 92 naturally occurring and thirteenth most abundant element. It is a member of the halogen family. It is extremely reactive pale yellow gas which exists always in combined state in the form of fluorides. Fluorine readily forms compounds with all elements except with helium and neon. The most common mineral containing fluorine is fluorspar (CaF_2). It has been used for centuries as a flux in the smelting of ores and gave fluorine its name .Fluorine is usually present in soils in the form of cryolite (Na_3AlF_6), flurapatite ($Ca_5 (PO_4)_3.F$) and other phosphate rocks. The content of total fluorine in normal soils is usually in the range from 150 to 400 mg/kg. Values that exceed 1000 mg/kg have been registered in some heavy clayey soils. Fluoride increments arise in soil through the use of phosphate fertilizers and insecticides and through rain water. These minerals are sparingly soluble in water; so that only small amounts of F are taken. The concentration of fluoride in environmental matrices is of particular interest because of its toxic effect. Daily intake of milligrams per day of fluoride has been found to be beneficial in the prevention of caries; long-term exposure to higher quantities may have deleterious effects on enamel and bone, and single gram dose cause acute toxic effect or may even be lethal. Various range of fluoride concentrations and related health symptoms in humans is given in Table 1.

Table 1. Impact of increasing concentrations of fluorine on the human body

Concentration of fluorine, ppm	Impact on human health
1	Reduction in dental caries
2 or more	Mottled enamel
5 or more	Symptoms of osteosclerosis
8 or more	10% osteosclerosis
20 or more	Crippling effects
50 or more	Thyroid changes
100 or more	Growth retardation

Experimental

Mysore is the second largest city of Karnataka, India, having 128.42 km^2 area located at 12.30 ^{o}N 76.65^{o}E situated between the rivers Kaveri and Kabini. It is bounded in the north by Hassan, Mandya & Bangalore districts of the state, in the south by Nilgiris districts of Tamil Nadu, in the east by Salem & Coimbathore districts of Tamil Nadu and in the west by Coorg districts of the state & Wyanadu district of Kerala state. Agriculture is the predominant occupation of people. About 38600 ha is the cultivable area. Basically, the classification of soils is done on the basis of the colour, clay content and the sandy particles present in them. The soil type of Mysore is mainly red sandy loams[1]. The colour of the soil changes from place to place. The soils are having permeability and neutral with pH of 7. The thickness of the soil varies from less than a meter to 6 meter. Description of soil type and the areas covered is given in Table 2.

Table 2. Description of soil type and sampling sites in Mysore District

Soil profile	Sampling site	Distance from Mysore City bus stand (km)	Main crop cultivated	Prime fertilizer used
Sandy	Mahadevapura East	8	Groundnuts and Horse gram	Urea and Diammonium phosphate (DAP)
Alluvial	Mahadevapura West	7	Cotton	
Black	Chamaundi hills	7	Cane sugar and rice	
Laterite	Srirangapatna	15	Green gram and Cow pea	
Red (loam)	Madakalli	8	Beet root and Carrot	

Materials and methods

Soil sampling in triplicate was carried out in Mysore district, covering 5 croplands used for the cultivation of most common crops grown in the area. The samples were Red (loam), Black, Alluvial, Laterite, Sandy soil. Representative soil samples from 20 cm depth from each area were collected. The soil samples were air dried, grounded to fine particle size.

The homogenized soils were sub-sampled for digestion. About 50 g of each soil sample was digested with aqua regia. The digested cooled sample was filtered into a 250 mL volumetric flask using Whatman No. 1 filter paper. After filtration, fluoride was analyzed by an ion selective electrode. Water samples unfiltered were 1:1 diluted with TISAB II (Orion Total ionic Strength Adjustment Buffer II) to uncomplex the fluoride and adjust the pH and analysed for the fluoride level. Basic agrochemical properties and mechanical composition of the investigated soil samples were determined by standard methods of soil analysis[6]. School children from each location in the age group of 4 and 10 years were examined for teeth mottling and skeletal abnormalities to correlate their fluoride content in drinking water with extent of dental fluorosis.

Results and Discussion

The basic chemical and physical soil properties are given in Table 3 and 4. The analysed chemical and physical properties show the wide variation range especially in alluvial soils and red soil, as can be seen from the results obtained. It is evident that alluvial soils have higher humas, available phosphorus and available potassium content, comparing with other types. The chemical parameters of the investigated soil, the amounts of cations and anions of soils are given in Table 3. Magnesium ranged from 0.40 to 17.3 mg/L, Calcium from 0.72 to 1.04 mg/L. Sodium was found from 0.0 to 22.5 mg/L and potassium from 0.25 to 12.5 mg/L. Chloride was from 0.5 to 5.2 mg/L and bicarbonate from 0.25 to 12.6 mg/L during the study. The specific gravity of soil samples were found in between the range 1.8 to 2.40 (g/cc). Bulk density ranged from 0.698 to 0.919 (g/cc) and percentage porosity 53.22 to 68.38 (%) during the study. The results indicate the true density of particles were two to three times more than the bulk density and the porosity also increased from surface level to deep level. The particle size range found from 572 to 651.9 µm. The result revealed the particle size increased from red soil to sandy soils[2]. The moisture contents were found from 8.72 to 15.54% at the surface level. This indicates the moisture content capacity may more at deeper levels than the surface level.

Table 3. Chemical parameters of the investigated soils

Nutrients soil depths (30 cm)	Mg	Ca	Na	K	HCO_3^-	F^-	Cl^-
	mg/L						
Red soil (loam)	0.53	12.0	4.1	12.6	12.6	115.5	5.2
Black soil	17.3	12.5	22.5	0.25	0.25	105.0	4.3
Alluvial soil	0.40	0.32	0.0	2.1	2.1	1.0	0.5
Laterite soil	0.56	10.88	3.2	6.6	6.6	89.5	1.5
Sandy soil	4.6	0.34	5.6	7.8	ND	0.4	2.2

Table 4. Physical properties of the investigated soils

Soil samples depths (30 cm)	Red soil	Black	Alluvial	Laterite	Sandy
Bulk density (g/cc)	0.698	0.873	0.832	0.919	0.59
Porosity, %	68.38	58.82	61.25	61.77	77.62
Specific gravity (g/cc)	2.20	2.02	2.07	2.4	1.8
pH	8.5	8.3	6.5	8.3	6.6
Moisture content, %	15..54	11.54	8.72	13..83	13.65
Particle size, µm	572	621	655..5	626.0	759

Chemical-intensive practices in agricultural systems develop practices that result in fluoride contamination and other pollution problems of a magnitude that exceeds normal limits**.** Plants take up fluoride through fine hair rootlets and stems from the soil. Plants absorb more fluoride from sandy than from clay soil. Phosphate fertilizers may contain 0.5 to 4.0 percent fluoride by weight as an impurity. The range and mean values of water-extractable soil fluoride, and fluoride in groundwater of the same location are shown in the Tables 5 and 6. The F content in these samples showed a significant positive correlation with the phosphate fertilizer used for agriculture and soil profile. There was no such relation with the anthropogenic activities[7].

Table 5. Fluoride level measured in the given range of soil depths

Soil type	F, mg/L			
Depths, cm	5	10	15	20
Sandy	3	2.8	2.8	1.9
Black	4	3.9	2.5	2.3
Laterite	4.5	3.7	3.1	3.6
Alluvial	9	7.4	7.7	6.3
Red (loam)	11.2	10.5	9.5	7.9

Table 6. Concentration fluoride in water and soil samples

Water sampling	Soil type	Number of bore wells	Range of mean F, mg/L concentration in water samples	Range of mean F, mg/L concentration in soil samples
Mahadevapura East	Sandy	30	10 to25.5	2.63
Mahadevapura West	Black	25	6.5 to10.3	3.18
Chamaundi hills	Laterite	25	4.3 to 7.2	3.73
Srirangapatna	Alluvial	26	ND to2.5	7.60
Madakalli	Red (loam)	30	ND to1.5	9.78

Fluorosis is a pathological condition which results from an excessive intake of fluorine, usually from drinking water. Fluoride level was within permissible limit in most of the drinking water samples except Mahadevapura East. The incidence of fluorosis shown in the Table 7 among children and cattle was conspicuous in the above mentioned area[3]. The study revealed the generally low fluoride content in the soils in comparison to groundwater F at the same sites. Sorption of F is low due to sandy loam type soil and most of the F leaches into the groundwater. In the depth range of 15 to 30 cm, F concentration was elevated by 10-50%, indicating greater F movement to depth in sandy loam type soils. Farmers in the area have been using diammonium phosphate (DAP) fertilizer on their fields that releases F into the soil environment. Research has shown that the application of phosphate fertilizer over long periods of time increases the concentration of F in both soil and groundwater. Since the area is free from industrial activity, heavy use of diammonium phosphate fertilizer and soil profile are the most likely sources of elevated groundwater F in the area[4].

Table 7. Teeth mottling / abnormalities description of children and livestock in relation to soil profiles

Experimental locations		Mahadevapura East	Mahadevapura West	Chamaundi hills	Srirangapatna	Madakalli
Soil type		Sandy	Black	Laterite	Alluvial	Red (loam)
No. of children (20)	Male	10	10	10	10	10
	Female	10	10	10	10	10
Drinking water source	Bore wells + Few open wells	30	25	25	26	30
Number of cases of teeth mottling among children		04	02	ND	ND	ND
Number of cases of teeth abnormalities among buffalos (20 Nos.)		06	02	02	ND	ND

Conclusion

All organisms are exposed to fluoride from natural or anthropogenic sources. Fluoride has both beneficial and detrimental effect. Exposure to bioavailable fluoride constitutes a risk to both aquatic and terrestrial biota.

On the basis of the results obtained, the following important conclusions can be drawn. Most of the investigated soil samples have values for total fluorine in sandy soil is least and exceeded the permissible limit in ground water, indicating the leaching of fluorine level which is detrimental to the locality using the same water for all daily activities[5]. Highest values were found in red soil, black soil and laterite soils, indicating the binding capacity and soil type.

Application of phosphate fertilizer over long periods of time has increased the concentration of F in both soil and groundwater. As the area is free from industrial activity, heavy use of DAP fertilizer and soil profile may be the most likely sources of elevated groundwater F in the area.

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