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Assessing the Fluoride Contamination in the Groundwater of Tiruppur District, Tamil Nadu

P. Jothimani* and B.J. Pandian
Water Technology Centre
Tamil Nadu Agricultural University, Coimbatore-641 003.

The largest source of fresh water lying beneath the ground has become crucial for targeting potential zones, monitoring its quality is required for domestic and irrigation needs. The groundwater of Tiruppur District has been degraded due to rapid industrialization. The present study aims to provide information regarding the fluoride contamination in the groundwater over a period of time and mapping using GIS software. Tiruppur district map was digitized using Arc GIS software and the sampling locations were identified using grids covering the entire zone by equal distance. Survey was conducted and samples were taken in western zone of Tamil Nadu. A total of 37 water samples were collected from open well and bore well from different locations of Tiruppur district and analysed. The latitude and longitude values were taken at all the locations for mapping the fluoride endemic areas using GPS. In the study area, Fluoride content ranged from 0.32 to 1.44 mg / lt. Plant samples were collected where fluoride concentration in the groundwater was found in the range of > 1 ppm. Fluoride endemic areas were identified based on the fluoride content of the water sources and mapping was done using Arc GIS Software.

Key words : Fluoride contamination, Groundwater, Tirupur district, Tamil Nadu

In Tamil Nadu, the high concentration of fluoride in groundwater is found to be in Dharmapuri district closely followed by Coimbatore, Tiruppur, Dindukal districts. Studies have shown that the level of fluoride contamination in districts like Tiruppur and Coimbatore has been rising (Anandha Parameshwari, and Kalpanadevi, 2006). Till a decade ago, these districts were considered safe from fluoride hazard. Most of the fluoride found in groundwater is naturally occurring from the breakdown of rocks and soils or weathering and deposition of atmospheric volcanic particles. Fluoride can also come from Runoff and infiltration of chemical fertilizers in agricultural areas. At low concentrations fluoride can reduce the risk of dental cavities. Higher intakes of fluoride taken over a long period of time can result in changes to bone, a condition known as skeletal fluorosis. This can cause joint pain, restriction of mobility, and possibly increase the risk of some bone fractures. Hence this study is being taken up to assess the fluoride contamination in the ground water of Tiruppur district.

Material and Methods

Study area

The Tiruppur district is classified under western agro-climatic region of Tamil Nadu. As of 2011, the district had a population of 2.479 million. Tiruppur district lies on the western part of Tamil Nadu bordering the western ghats and hence the district enjoys a moderate climate. The major rivers flowing through the district are Noyyal and Amaravathi. It is situated between 11.10 North Longitude and 77.34 East longitude (Fig 1).

Corresponding author's email: jothibhaskaran@gmail.com

Tiruppur district map was digitized using Arc GIS software and the sampling locations were identified using grids covering the entire zone by equal distance. The whole study area is divided into grids. The centroid of each grid is considered as a sample point. The centroid is cross checked with the help of Google Earth whether the point is located in the field or out of the way. The groundwater samples were collected from open wells and bore wells, which are being extensively utilized for drinking and farming purposes. A total of 37 water samples were collected from different locations of Tiruppur district from NE monsoon 2013 to SW monsoon 2014. The latitude and longitude values were taken at all the locations using GPS for mapping purpose (Table 1).

The samples were analyzed for the fluoride content. The fluoride concentration in the groundwater samples were analyzed for fluoride by ion selective electrode method. Fluoride is extracted from dry pulverized foliage with HNO_3 followed by aqueous KOH. Potentiometric method using Ion selective electrode was observed to give more authentic results for estimation of fluoride in plant samples. The plant / crop samples were collected from the areas where high fluoride is present in the groundwater sample (> 1 ppm) and analyzed for the fluoride uptake.

After analyzing the fluoride level in the samples, the fluoride level >1.0 ppm, and <1.0 ppm was mapped using Arc GIS version 9.3 software. A base map has been prepared using survey of India topographic sheets 1:50,000 scale. From the toposheets, the major roads, rivers, blocks headquarter locations were traced in tracing films, scanned, georeferenced and digitized using Arc GIS 9.3. In the water sample points, using GPS, co ordinate values were collected. The analyzed fluoride

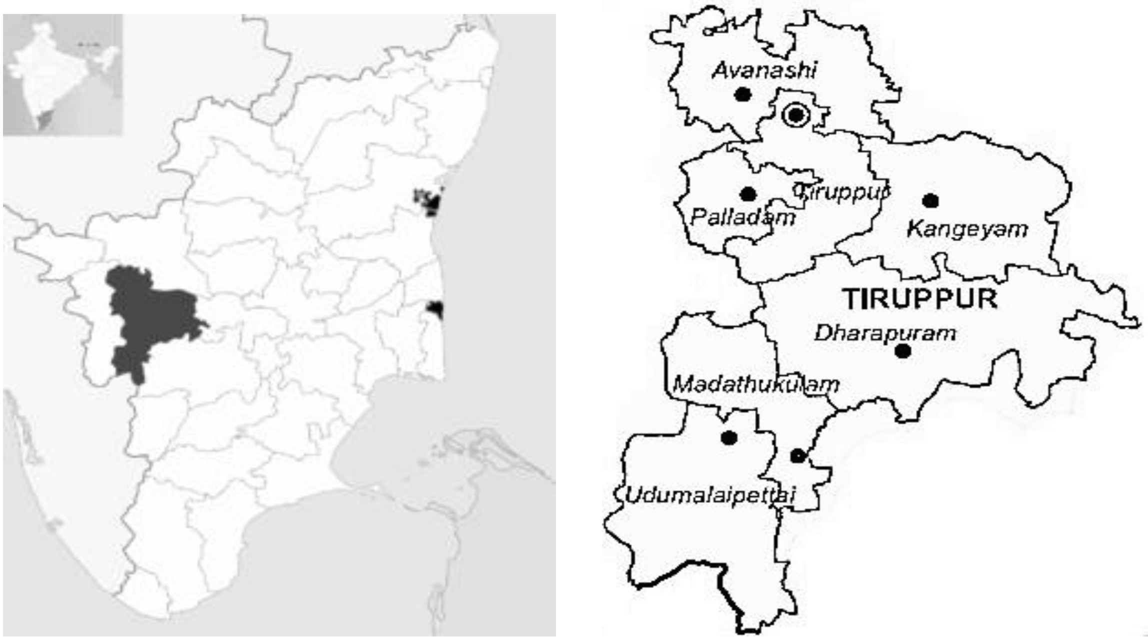


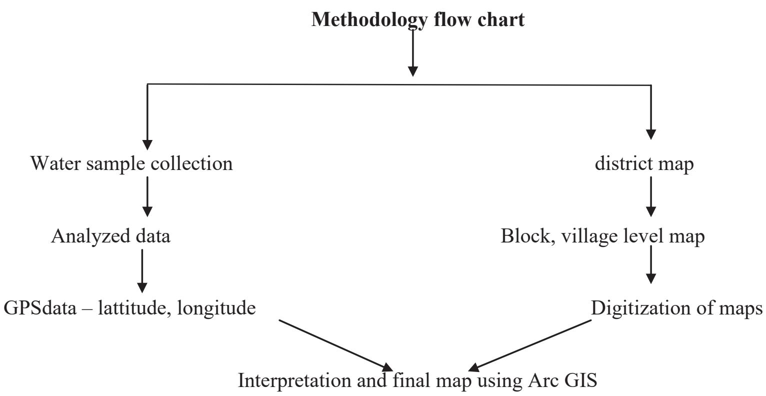
Fig 1. Tiruppur district map

data is added into the attribute table of the each point. Then the layout is exported in the form of PDF file or mage file as a map using Arc GIS software.

Results and Discussion

Fluoride content in the groundwater samples

The Bureau of Indian Standards (BIS) and the Indian Council of Medical Research prescribe a fluoride concentration of 1.0 ppm as the maximum permissible limit in drinking water. Fluoride (F^-) occurs in almost all waters from trace to high concentration. Minerals that have the greatest effect on the hydrogeochemistry of fluoride are fluorite, apatite, mica, amphiboles, certain clays, and villiamite. In 37 samples collected, 13 samples contain >1 ppm of fluoride during NE monsoon 2013 and further seasonal fluctuations were also studied and it ranged from 0.32 to 1.44 ppm. The values are given below (Table 2).



Fluoride value ranges from 0.13 to 1.31 ppm , 0.29 to 1.43 ppm, 0.45 to 1.56 ppm, 0.40 to 1.44 ppm, 0.38 to 1.44 ppm during North East monsoon, Winter season, Summer season, South West monsoon and Mean value of 2013 – 14 respectively. Fluoride content ranged from 0.13 to 1.31 ppm. Fluoride in water can be a blessing or a hazard depending on the concentration levels. The Bureau of Indian Standards (BIS) and the Indian Council of Medical Research prescribe a fluoride concentration of 1.0 ppm as the maximum permissible limit in drinking water. Fluoride (F^-) occurs in almost all water samples from trace to high concentration. Minerals that have the greatest effect on the hydrogeochemistry of fluoride are fluorite, apatite, mica, amphiboles, certain clays, and villiamite(Anandha Parameshwari, and Kalpanadevi, 2006). Fluoride is among the substances for which there are both lower (0.6 ppm) and upper (1.2 ppm) limits of concentration in drinking water, with identified health effect and benefits for human beings (Indian Standard Institute [ISI]). Very low doses of fluoride (<0.6 ppm) in water promote tooth decay. However, when consumed in higher doses (>1.5 ppm), it leads to dental fluorosis, mottled enamel, and excessively high concentration (>3.0 ppm) of fluoride may lead to skeletal fluorosis (Ashley and Burley, 1994). Among, 37 samples collected, 6 samples contain >1 ppm of fluoride during first season and further seasonal fluctuations were also studied and it ranged from 0.13 to 1.31 ppm. 9 samples contain >1 ppm of fluoride during this winter season 2014 and it ranged from 0.29 to 1.43 ppm. 25 samples contain >1 ppm of fluoride during this summer season 2014 and it ranged from 0.45 to 1.56 ppm. 20 samples contain >1 ppm of fluoride during this South west monsoon season 2014 and it ranged from 0.40 to 1.44 ppm. Among the 37 samples collected, 13 samples contain >1 ppm of fluoride during the year 2013 - 2014 and it ranged from 0.38 to 1.44 ppm. When compared to Anandha Parameshwari, and Kalpanadevi, 2006, the fluoride content was found to be increased recently.

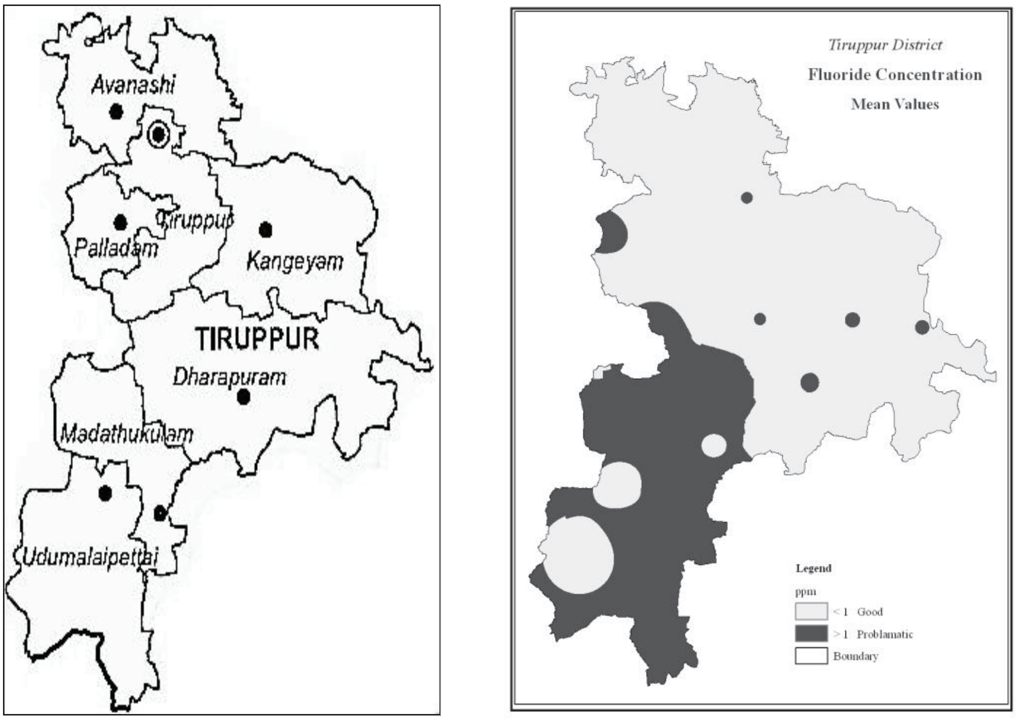


Fig 2. Spatial variation of fluoride content in groundwater samples of Tiruppur District

Fluoride uptake by crops

According to Danies *et al.*, 1952, the adverse effect on the germination and growth parameters at higher concentration of fluoride in water might be due to plumose resulting from higher concentration of salts. The growth reduction in plant system might be due to the toxic effects of excessive salts, heavy metals and low nutrient content and also might be due to inhibition of enzymatic activity. Fluoride ion at high concentrations is known to cause several health hazards to human population and livestock including dental and skeletal fluorosis. It is known that fluoride, when taken up by plants, is likely to prove toxic. Certain fluoride salts are metabolic inhibitors and previous studies have shown that fluoride affects a wide range of plant processes. Fluoride affects a wide range of physiological processes including plant growth, chlorosis, leaf tip burn and leaf necrosis. The increasing concentrations of NaF show phytotoxic effects on physiology and biochemical parameters of seedling growth. Sodium fluoride might affect some developmental processes in germinating cereals. NaF might inhibit carbohydrate metabolism of germinating seedlings. Similar to the present study, earlier studies (Gautam and Bhardwaj, 2010, Singh *et al.*, 1995)confirm that fluoride causes a reduction in the chlorophyll content of foliage. The biochemical basis of this effect may be a consequence of inhibition by fluoride of incorporation of γ-aminolevulinic acid into chlorophyll synthetic pathway. Fluoride containing groundwater used for irrigation in most regions of Rajasthan results in stress condition and affects cereal growth in early stages of plant life. Such knowledge is potentially useful for farmers to help them avoid excessive application of fluoride containing fertilizers and fluoride containing groundwater to enhance crop growth, especially when it is F stress inhibiting it. This information is also important to help farmers select the best type of crop that can thrive. In, Tamil Nadu also, the farmers have to be educated about the fluoride content in the groundwater used for irrigation. The plant / crop samples were collected from the areas where high fluoride is present in the groundwater sample (> 1 ppm) and analyzed for the fluoride uptake. There are about 13 villages out of 37, plant samples were analyzed and the results are given below (Table 3).

Fluoride ion is wide spread in nature. It is estimated to be thirteenth in abundance among the elements of the earth. Therefore in this investigation study on Assessment of fluoride contamination in the groundwater of Tiruppur District is taken up, a total of 37 groundwater samples were collected from Tiruppur District of Tamil Nadu and the samples were analyzed. From 37 samples analysed, 13 samples recorded the fluoride content of more than 1 ppm. Plant samples were collected from Tiruppur District of Tamil Nadu where fluoride concentration in the groundwater was found more than 1 ppm. The prescribed limit of fluoride in drinking water is normally 1 ppm. In the study area medium rainfall crops accumulate high levels of fluoride under these conditions.

Table 1. Sampling locations and Co ordinate values in Tiruppur District

District	Block	Sampling Points	Latitude (N)	Longitude (E)
Thiruppur	Udumalaipet	GVG College for Women	10.345049	77.154731
	Madathukulam	Kolumam	10.285017	77.215416
		Sholamadevi	10.345891	77.215047
	Gudimangalam	Puthupalayam	10.405358	77.094680
		Murungapatti	10.405632	77.154861
		Kallapalayam	10.465559	77.155486
		V.Vellore	10.465845	77.094448
	Dharapuram	Nattukalpalayam	10.405576	77.215522
		Dhalavoipattinam	10.405729	77.275954
		Madathupalayam	10.470258	77.275805
		Veerachimangalam	10.465502	77.340299
	Kundadam	Maruthur	10.465228	77.215764
		Thumbalapatti	10.530637	77.215516
		Vengipalayam	10.531127	77.275546
	Pongalur	Varapalayam	10.530557	77.155017
		Pongalur	10.590067	77.215733
		Nachipalayam	11.051502	77.275668
	Palladam	Karadivavi	10.584725	77.094696
		Chinnur	10.585161	77.155127
	Thiruppur	Attayampalayam	11.045666	77.154932
		Jothinagar	11.045989	77.215756
		Kankkampalayam	11.114732	77.222886
		Mariyapuram	11.165162	77.215541
	Avinashi	Thevarayampalayam	11.105620	77.154600
		Kasilingampalayam	11.165586	77.095235
		Pongalur	11.183439	77.090424
	Uthukuli	Karatupalayam	11.105674	77.275237
	Kangayam	Nallroad	11.050173	77.335044
		Palayakottai	11.044785	77.394676
		Agathilingampalayam	10.585681	77.274929
		Kangayampalayam	10.583158	77.300057
		Mudalipalayam	10.525827	77.335592
	Vellakoil	Olappalayam	10.590147	77.395909
		Lakkumanaikenpatti	10.525953	77.400426
		Mayilrangam	10.530274	77.455533
	Moolanur	Polarai	10.465309	77.395992
		Edakkalpadi	10.463361	77.460240

The plants samples like cereals, pulses, fodder grass, vegetables and millets were collected and analyzed. Table. 3. shows the concentration of fluoride in crops collected from different villages of study area with varying fluoride concentration in groundwater. Among which maize (2.34 mg kg^{-1}) showed maximum fluoride concentration, Fodder grass (2.01 mg kg^{-1}), Blackgram (1.81 mg kg^{-1}), rice (1.83 mg kg^{-1}), redgram (1.70 mg kg^{-1}). Out of which maize was found to have maximum fluoride concentration (2.34 mg kg^{-1}) which was collected from Sholamadevi village of Madathukulam block where fluoride concentration in groundwater samples was found in the range of 1.44 ppm. Fluoride is more soluble in acid soils due to which its uptake by plants is enhanced. Most food whether derived from plant or animal life, contain fluoride ion at least in minute amounts. Some foods concentrate additional fluoride ion from boiling, processing or contamination. Fluoride ions levels vary widely even between samples of the same kind of food. Some foodstuffs such as vegetables and fruits normally contain fluoride though at low concentration (0.1 mg kg^{-1}- 0.4 mg kg^{-1}) and thus contribute to fluoride intake by man. Higher levels (up to 2 mg $kg^{-1}$of fluoride) have been found in cereals. Vegetables are particularly susceptible to air borne fluoride ion and this accounts for wide variations in the contents of vegetables grown in different areas. Cereals usually contain < 1 mg kg^{-1} fluoride, where fluoride tends to accumulate in the outer layer of the grain and in the embryo. Phosphatic fertilizers especially the super phosphates are most important source of fluoride in agricultural lands. Intake of fluoride ion into roots is largely dependent on the concentration of fluoride ion in the soil and on the type of soil. High fluoride levels inhibit germination, shoot length, root length, dry matter production, vigor index, chlorophyll content and reduce productivity, biomass and inflict other physiological and biochemical disorders in plants.

Table 2. Fluoride content in the groundwater and crop samples of Tiruppur district

Ground water sample North East (ppm)	F^- uptake by crops (mg kg^{-1})	Ground water sample Winter (ppm)	F^- uptake by crops (mg kg^{-1})	Ground water sample Summer (ppm)	F^- uptake by crops (mg kg^{-1})	Ground water sample South west (ppm)	F^- uptake by crops (mg kg^{-1})	Ground water sample Mean value (ppm)	F^- uptake by crops (mg kg^{-1})
0.93	-	1.03	1.95	1.14	2.08	1.06	2.03	1.04	1.94
1.01	1.72	1.11	1.85	1.23	1.96	1.16	1.88	1.13	1.83
1.31	2.22	1.43	2.37	1.56	2.52	1.44	2.46	1.44	2.34
0.79	-	0.91	-	1.04	1.78	0.96	-	0.93	-
0.68	-	0.83	-	0.98	-	0.89	-	0.85	-
0.71	-	0.95	-	1.04	1.68	0.96	-	0.92	-
0.75	-	0.93	-	1.20	2.12	1.11	2.02	1.00	1.82
0.69	-	0.91	-	1.15	2.10	1.09	2.01	0.96	-
0.73	-	0.89	-	1.04	1.98	0.94	-	0.90	-
0.75	-	0.95	-	1.14	2.08	1.12	2.06	0.99	-
0.79	-	0.98	-	1.17	2.14	1.15	2.12	1.02	1.87
1.01	1.61	1.21	1.83	1.32	1.94	1.28	1.83	1.21	1.81
1.03	1.66	1.18	2.12	1.36	2.32	1.32	2.28	1.22	2.09
0.83	-	0.98	-	1.13	2.06	1.09	2.01	1.01	1.71
1.12	2.04	1.25	2.20	1.38	2.36	1.31	2.24	1.27	2.20
0.43		0.51	-	0.59	-	0.55	-	0.52	-
0.45	-	0.56	-	0.65	-	0.60	-	0.57	-
0.50	-	0.65	-	0.80	-	0.77	-	0.68	-
0.65	-	0.81	-	0.97	-	0.93	-	0.84	-
0.73	-	0.88	-	1.03	1.66	0.98	-	0.91	-
0.81	-	0.93	-	1.05	1.68	1.00	1.61	0.95	-
0.78	-	0.87	-	0.96	-	0.92	-	0.88	-
0.75	-	0.91	-	1.07	1.70	1.02	1.63	0.94	-
0.80	-	0.96	-	1.12	1.74	1.08	1.70	0.99	-
0.73	-	0.89		1.05	1.65	1.00	1.60	0.92	-
0.45	-	0.57	-	0.69	-	0.65	-	0.59	-
0.23	-	0.38	-	0.52	-	0.48	-	0.40	-
0.13	-	0.29	-	0.45	-	0.40	-	0.32	-
0.50	-	0.63	-	0.76	-	0.71	-	0.65	-
0.79	-	0.91	-	1.04	1.58	1.02	1.56	0.94	-
1.13	1.89	1.25	1.78	1.03	1.56	1.35	1.90	1.20	1.70
0.85	-	1.01	1.92	1.17	2.08	1.12	2.03	1.04	1.91
0.71	-	0.93	-	1.15	2.06	1.14	2.05	0.98	-
0.86	-	0.99	-	1.12	2.64	1.11	2.62	1.02	2.01
0.87	-	1.01	1.73	1.10	2.60	1.08	2.58	1.02	1.99
0.20	-	0.35	-	0.50	-	0.46	-	0.38	-
0.31	-	0.43	-	0.51	-	0.48	-	0.43	-
0.13	1.61	0.29	1.73	0.45	1.56	0.40	1.56	0.38	1.70
1.31	2.22	1.43	2.37	1.56	2.64	1.44	2.62	1.44	2.34

• All data are mean of three replicated sample values

Previous studies have shown that the growth and productivity of many crops are adversely affected by fluoride (Gautam and Bhardwaj, 2010 , Singh et al. , 1995). Also fluoride has the tendency to be accumulated in the vegetable leaves. Similarly it has been reported that leafy vegetables viz. Radish leaves were found to accumulate 3.24 to 2.52 c, fluoride respectively, which were irrigated with water having 1.85 ppm to 1.20 ppm fluoride (Gautam and Bhardwaj, 2010). Fluoride is entering human food and beverage chain in increasing amount through the consumption of tea, wheat, spinach, cabbage, carrots and other Indian foods. The fluoride in these items presumably results from the use of soil or fertilizer-borne fluoridated water for food and beverage processing. The observations from studies done in China suggested that contribution from food can significantly contribute to the total fluoride uptake. Thus, fluoride content in food should not be disregarded in assessing the total fluoride uptake. Fluoride ion in plants is derived from contaminated air and soil. Fluoride ion in the air enters the plant through the leaves, and in soil through the roots. External structure of fruits and vegetables contain more fluoride ion than internal parts. Leaves in the center of a head of sprayed cabbage had 30 ppm, whereas the outside leaves contained 34 ppm. Dry skin of bananas contained 51 ppm, whereas the fruit contained only 3.8 ppm. The average fluoride ion content of vegetables ranges between 0.10 ppm and 0.30 ppm on a fresh weight basis. Pineapples contain about 0.9 ppm fluoride and walnuts contain about 7.8 ppm fluoride. Thus after evaluating the data of the present study, it was observed that fluoride not only enters through water but also with many edible items. Fluoride of plant samples depends upon the fluoride contents of soil and water used for irrigation. Fluoride in water contributes significantly to the total exposure of an individual to this element but is not the only source of exposure. Fluoride in food plays a vital role in causing fluorosis whereas fluoride in drinking water plays major role. The fluoride content of the food items vary from place to place. Fluorides levels vary widely even between samples of the same kind of food. Thus it is concluded that role of diet in fluorosis has a double sword action so fluoride content in food should not be disregarded in assessing the total fluoride uptake. The disease fluorosis in non curable but preventable. Adequate intake of food rich in calcium, Vitamin C, D, E, proteins and anti-oxidants in diet can minimize the effect of fluoride.

Table 3. Fluoride uptake by crops in the Tiruppur district

Name of the Block	Name of the Village	Fluoride conc. (ppm) in Water	Name of the crop	F – uptake by crop (mg kg^{-1})
Udumalaipet	GVG College for Women	1.04	Maize	1.94
Gudimangalam	V.Vellore	1.00	Maize	1.82
Dharapuram	Veerachimangalam	1.02	Maize	1.87
Kundadam	Vengipalayam	1.01	Maize	1.71
Kangayam	Mudalipalayam	1.04	Maize	1.91
Vellakoil	Lakkumanaikenpatti	1.02	Fodder grass	2.01
Vellakoil	Mayilrangam	1.02	Fodder grass	1.99
Madathukulam	Sholamadevi	1.44	Maize	2.34
Pongalur	Varapalayam	1.27	Maize	2.20
Kundadam	Thumbalapatti	1.22	Maize	2.09
Kundadam	Maruthur	1.21	Blackgram	1.81
Kanagayam	Kangayampalayam	1.20	Redgram	1.70
Madathukulam	Kolumam	1.13	Rice	1.83

All data are mean of three replicated sample values

Mapping of Fluoride content in the groundwater samples of the Western Zone of Tamil Nadu during different seasons of 2013 – 2014.

Fluoride concentration Good= <1 ppm

Problematic = >1 ppm

On seeing the spatial variation of fluoride content, the problematic class of groundwater (fluoride > 1 ppm) occurred in some selected blocks of Tiruppur District of TN. In Tiruppur District, Madathukulam block (Kolumam and Sholamadevi), Kundadam block (Maruthur and Thumbalapatty), Pongalur block (Varapalayam), Kangayam block (Kangayam palayam) recorded the fluoride content of >1 ppm (Fig 2). The reason attributed for the fluoride content in the groundwater is appetite rich granties gnesis while it was low in anthracite (Dave et al., 2010). Fluoride is common in semi-arid climate with crystalline igneous rocks and alkaline soils. There is a close relation between the dissoluble fluoride in the cultivated soil and fluoride in shallow groundwater. The decomposition, dissociation and dissolution are the main chemical processes for the occurrence of fluoride in groundwater. During rock–water interaction, concentration of fluoride in rock, aqueous ionic species and residence time of interaction, etc. are also important parameters. The fluoride rich rocks form the main source for high fluoride groundwater in India. Fertilizers also add up to the sources of fluoride contamination in groundwater. Phosphatic fertilizers especially the super phosphates are most important source of fluoride in agricultural lands. Concentration of fluoride measured in groundwater after the monsoons i.e during summer and winter were higher than the preceding months. This was because evaporation resulted in the precipitation of fluoride rich salts on the soil which reached the groundwater along with percolating rainwater.

Mitagation measures - In situ treatment

Insitu method aims at directly diluting the concentration of fluoride (in groundwater) in the aquifer. This can be achieved by artificial recharge. Construction of check dams – helps to reduce fluoride concentration in groundwater. Rainfall recharge also called as rainwater harvesting can be adopted using percolation tanks and recharge pits which may prove helpful. Recharge of rainwater after filtration through the existing wells can also be planned to improve the groundwater quality.

Ex situ-treatment

Numerous exsitu methods are available for defluoridation of water either at household or community level. To remediate the groundwater with high fluoride, defluorination techniques are adopted. They include adsorption, ion exchange, coagulation and precipitation, reverse osmosis and electro dialysis. Of these, reverse osmosis has been considered as the best available technology. Adsorption method involves the passage of water through a contact bed where fluoride is adsorbed on the matrix. Activated charcoal and activated alumina are the widely used adsorbents. Adopting a particular method depends on the initial fluoride concentration, source and cost effectiveness in an area.

Conclusion

The results will be helpful to the government to install defluoridation plants in the severely affected areas identified by this study. Mapping of high fluorotic areas is useful to plan meticulously to bring safe drinking water from low fluoride areas. Continuous monitoring of groundwater table level along with quality study will minimize the chances of further deterioration.

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