Significance of fluorosis and its effect on the human body: A case study from Salem district of Tamil Nadu State, India

D. Venkatesan and M. Suresh Gandhi
Department of Geology, University of Madras, Guindy Campus Chennai- 600 025

Corresponding author: msureshgandhi@gmail.com

Abstract: High fluoride concentrations in drinking water cause dental and skeletal fluorosis in humans, which creates serious issues for individuals in many regions of the world. Fluorosis caused by the long-term intake of high fluoride levels is characterized by clinical bone and tooth manifestations. A number of cases of fluorosis have been reported from the study area of Salem district, which is covered by granitic rocks that occasionally exhibit the presence of fluorite mineralization. Numerous examples of fluorosis have been documented from many areas of the Salem district, which is composed primarily of granitic rocks with sporadic fluorite mineralization. During the course of the survey, many cases of fluorosis were discovered in this area. It was noticed that the pH was greater than 7 and that the fluoride concentration was higher than the permissible limits. Thus, it can be inferred that both natural and man-made elements contribute to the fluorosis that is prevalent in the study area.
Keywords: Fluoride, Dental Fluorosis, Skeleton Fluorosis, Salem, Tamil Nadu

Introduction

A review of recent literature reveals that fluorosis is a global problem affecting more than seventy million people in 25 countries. In India about 62 million people are consuming excess fluoride from drinking water (Sendesh Kannan and Ramasubramanian, 2011). The problem of fluorosis has drawn the attention of researchers in the early 20th century. Researchers were surprised by the high prevalence of what was called "Colorado Brown Stain" on the teeth of native-born residents of Colorado Springs. The stains were caused by high levels of fluoride in the local water supply. People with these stains also had an unusually high resistance to dental cavities. This sparked a movement to introduce fluoride into public water supplies at a level that could prevent cavities but without causing fluorosis. The well-known fluoride belts on land include, one that stretches from Syria through Jordan, Egypt, Libya, Algeria, Sudan and Kenya, and another that stretches from Turkey through Iraq, Iran, Afghanistan, India, northern Thailand and China. Ground water with high fluoride concentrations occur in many areas of the world including large parts of Africa, China, the Middle East and southern Asia (India, Sri Lanka). One of the best- known high fluoride belts on land extends along the East African Rift from Eritrea to Malawi. There is another belt from Turkey through Iraq, Iran, Afghanistan, India, northern Thailand and China. The Americas and Japan have similar belts. In northern China, high fluoride groundwater with fluoride concentration of upto 6.20 mg/L occurs in the Taiyuan basin (Qinghai et al. 2007). In India, excessive fluoride concentrations in ground water have been reported in 17 states (Yadav and Khan, 2010). Endemic fluorosis has been a challenging and extensively studied national health problem in India. The high concentrations of fluoride in groundwater in India are due to the dissolution of fluorite, apatite, micas, amphiboles with the OH, F group and topaz from the local bedrock (Handa, 1975; Chidambaram, 2000). In Tamil Nadu, the high concentration of fluoride in groundwater is found in Dharmapuri and Salem districts closely followed by Coimbatore, Madurai, Trichy, Dindukal and Chidambaram districts. The districts having low fluoride are Thirunelveli, Pudukottai, North Arcot, and Ramnad districts. The fluoride concentration in groundwater varies from 0 to 2mg/l in Garimangalam region of Dharmapuri District (Sendesh Kannan et al, 2011). In some parts of Salem district, the fluoride contamination in ground water varies from pre-monsoon (max. 4.20 mg/l) to post- monsoon (0.36 mg/l) season. The high concentration of fluoride in groundwater in pre- monsoon may be due to the weathering and leaching of the fluoride bearing minerals in soil (Vasanthavigar et al, 2012). These authors recommended that the policy of water fluoridation for the prevention of dental and skeleton cavities should be abandoned in Garigamangalam region and favoured more effective interventions combining communitywide targeted oral health interventions. The present study was undertaken to establish the effect of excess treatment of fluoride and the possibility to stimulate some technical aspects for preventing the effect of fluorosis on human body.

Study area

Salem, which is also called as Mango city, is located about 160 km Northwest of Coimbatore and about 340 km southwest of the state capital, Chennai. The study area experiences arid and semi-arid climate with an average annual minimum and maximum temperatures varying between 18.9°C and 37.9°C respectively. The minerals found in this taluk are magnetite, bauxite, quartz, feldspar, limestone, soapstone, dunite, rough stone, and granites. The study area records rainfall in the South-west monsoon and as well as in North- east monsoon.

Effects of excessive intake of fluoride

Fluorosis is an abnormal condition caused by excessive intake of fluorine, as from fluoridated drinking water, characterized chiefly by mottling of the teeth. Moderate level chronic exposure (above 1.5 mg/L of water) is quite common. Long-term ingestion of large amounts can lead to potentially severe skeletal problems (skeletal fluorosis). The early symptoms of skeletal fluorosis include stiffness and pain in the joints. In severe cases, the bone structure may change and ligaments may calcify, resulting in impairment of muscles. Acute high-level exposure to fluoride causes immediate effects of abdominal pain, excessive saliva, nausea and vomiting. Seizures and muscle spasm may also occur.

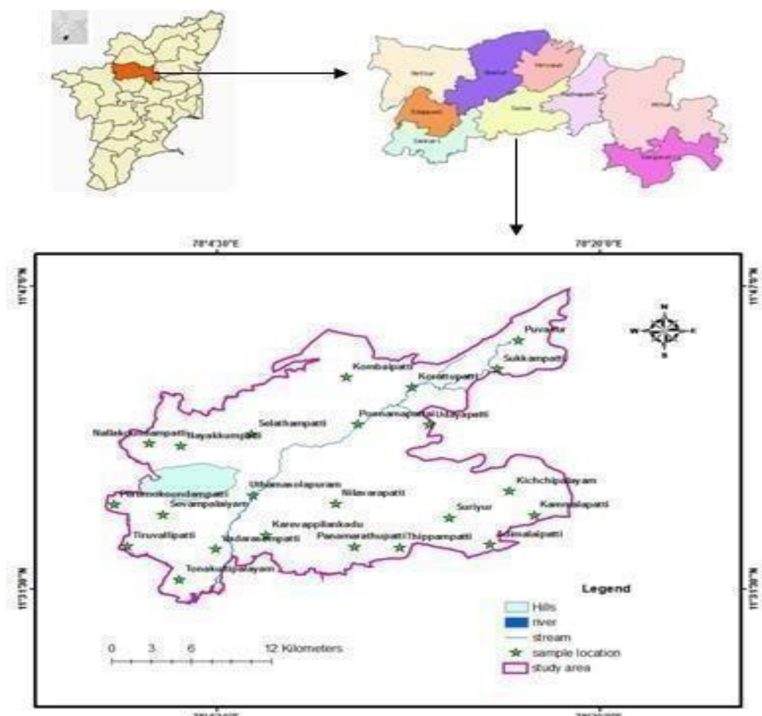

Fig1.Location map of the study area

Materials and Methods

Assessing spatial variability of fluoride contamination:

Water Sampling

- Collection of water samples across the district, ensuring representation from various sources such as wells, rivers, and other water bodies.

- Use standard methods for water sample collection, preservation, and analysis to ensure accurate results.

GIS Mapping

- Create a Geographic Information System (GIS) map of the district, indicating fluoride levels at different sampling points.
- Utilize GIS software to analyze and visualize the spatial distribution of fluoride contamination.

Spatial Analysis

- Perform spatial analysis to identify hotspots and areas with elevated fluoride concentrations.
- Consider factors like geological formations, land use, and proximity to industrial sources.

Water sample collection

A total of 23 groundwater samples were collected from various parts of the study area including borewells and deep tube wells which are being used for drinking purposes. All these water samples were collected during pre-monsoon (May) and post-monsoon (December) periods in the year of 2020. The groundwater samples of 250ml were collected in the PVC plastic containers after flushing out some quantity of water from the source for a period of 5 minutes. The physico-chemical parameters i.e. pH, TDS, EC and Turbidity values were determined at the spot immediately after collection and also tested for Calcium, Sodium, Nitrate, Bicarbonate, Sulphate, Fluoride, Iron, and Manganese.

GIS Mapping

Geographic Information System (GIS) plays a crucial role in mapping and analyzing fluoride concentrations in groundwater. GIS allows for the visualization of spatial patterns, the identification of high-risk areas, and the integration of various environmental and socio- economic factors. Integration of the fluoride concentration data with the geospatial data using a spatial join in GIS links the concentration values to specific geographic locations. Employing interpolation techniques (e.g., kriging, inverse distance weighting) facilitate to estimate concentrations in areas with limited monitoring data.

Results and Discussion

The fluoride content of the samples varied from 0.47mg/L to 0.6 mg/L and 2.3mg/L to 0.08 mg/L in the pre-monsoon and post-monsoon respectively (Florence Lilly et al, 2012; 2013). The comparison of fluoride concentration for Salem Taluk in pre-monsoon and post-monsoon seasons (Table 1) reveals that, in general, fluoride ion concentration increases in post-monsoon as compared to pre-monsoon due to rainfall and water table fluctuation. Especially higher concentrations of fluoride were observed in bore well and hand pump water (Medikondu Kishore and Hanumantharao, 2010). Ramachandramoorthy et al. (2010) reported that the dissolution of fluoride bearing minerals (CaF_2) may be contributing high percentage of fluoride in potable water causing slightly alkaline pH and moderate EC.

During pre-monsoon, the higher concentration of fluoride content noted from Uthamasolapuram, Tonakuttipalayam, Tiruvallipatti, Selathampatti villages, ranged from 2.3 to 2.2 mg/L. The abnormal concentration was noted in charnockite followed by peninsular gneiss due to the presence of dominant fluoride bearing minerals like apatite, hornblende and biotite, which have enhanced the fluoride concentration. A higher concentration of fluoride was observed in charnockite compared to peninsular gneiss due to the higher degree of weathered zone thickness in the charnockite (Srinivasamoorthy et al, 2008). As per the World Health Organization (WHO) recommendations, the higher limit of fluoride in drinking water is 1.5 mg/L.

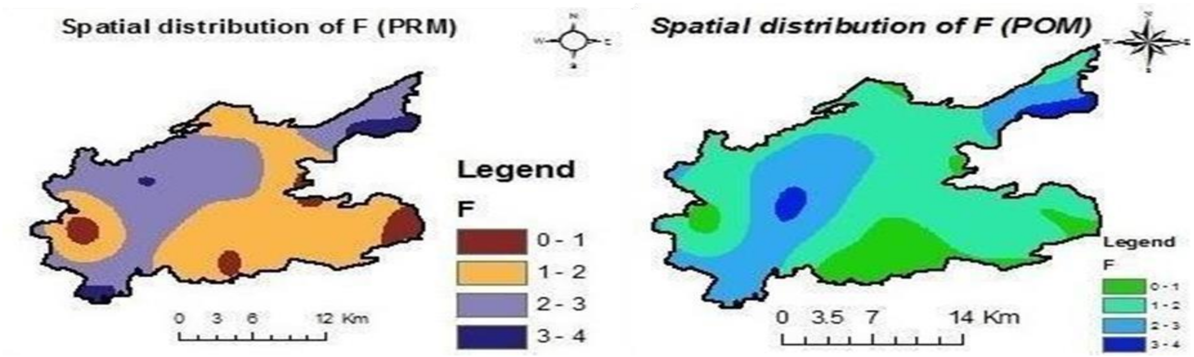

Fig 2. Pre-monsoon (PRM) and Post-monsoon (POM) Fluoride concentration in the study area

Table 1. Sample locations and the value of Fluoride in groundwater samples

ID	SAMPLE LOCATION	F (mg/L)	
		Pre monsoon	Post monsoon
1	Uthamasolapuram	2.3	3.1
2	Karevappilankadu	1.6	1.8
3	Vadarasampatti	2.1	2.5
4	Tonakuttipalayam	2.3	3
5	Tiruvallipatti	2.3	4.27
6	Perumokoundampatti	2	2.5
7	Sevampalaiyam	1	0.8
8	Nallakoundampatti	1.8	2.2
9	Nayakkumpatti	1.6	2.4
10	Selathampatti	2.2	3
11	Udayapatti	1	1
12	Korattupatti	1.2	1.8
13	Kombaipatti	1.5	2
14	Ponnamapattai	1.8	3.5
15	Nilavarapatti	1	1.2
16	Panamarathupatti	0.8	1
17	Thippampatti	0.8	1.4
18	Suriyur	1.2	1.8

19	Adimalaipatti	1	1.4
20	Kichchipalayam	1	1.2
21	Kammalapatti	1	0.8
22	Tirumanur	1	0.6
23	Sittampatti	1.8	1.4

A study on dental fluorosis showed that in non-fluoridated or non-optimally fluoridated areas, the use of low-fluoride toothpastes did not protect preschoolers from developing moderate to severe forms of fluorosis in upper permanent anterior teeth and increased the risk of caries in the primary dentition (Santos et al., 2013).The cause of fluoride in groundwater can be geo-genic as well as anthropogenic. In most cases of natural geo-genic presence of fluoride in groundwater, fluoride bearing minerals such as Apatite and Hornblende are the sources. Groundwater, when exposed for long periods to such minerals, leaches out some, and fluoride being one of them (Rajnarayan Indu et al, 2007). Generally, most groundwater sources have higher fluoride concentrations than surface water. As groundwater percolates through the weathered rock in the aquifers, it dissolves fluoride-bearing minerals, thus releasing fluoride into water.

Health indicator exhibit prolonged fluoride exposure

According to Maya Ramesh and others (2016) the prevalence of dental fluorosis is significantly high among the children of Salem Taluk, where the water fluoride level was found to be between 0 and 3 ppm. Dental fluorosis was most commonly seen in 9 years old children than in children of higher ages. The prevalence of dental fluorosis was greater in males than females. It was directly proportional with the duration of residence in a place with high water fluoride content.

Prolonged exposure to elevated levels of fluoride in drinking water is associated with several health indicators, particularly dental and skeletal issues. Here are some of the primary health indicators associated with prolonged fluoride exposure:

Dental Fluorosis

- Dental fluorosis is one of the most common and visible effects of prolonged exposure to excess fluoride during tooth development.
- It primarily affects developing teeth in children, causing changes in enamel color and texture.
- Mild fluorosis may manifest as white streaks or spots on the teeth, while severe fluorosis can lead to brown discoloration and pitting.

Skeletal Fluorosis

- Skeletal fluorosis is a chronic condition that results from the accumulation of fluoride in bones and joints over an extended period.
- Early stages may present with joint pain and stiffness, while advanced stages can lead to severe skeletal deformities, impaired mobility, and increased risk of fractures.

Osteoporosis and Increased Fracture Risk

- Prolonged exposure to high fluoride levels may increase the risk of osteoporosis and fractures in some individuals.
- Fluoride can alter bone density and structure, potentially contributing to increased susceptibility to fractures.

Neurological Effects

- Some studies suggest a possible association between prolonged fluoride exposure and neurocognitive effects, although the evidence is not yet conclusive.
- Research in this area is ongoing, and the potential neurological impacts of chronic fluoride exposure are still a subject of debate among scientists.

Mitigation strategies

The geographic clustering of contamination levels can provide valuable insights into tailoring specific mitigation strategies for villages affected by fluoride contamination. Understanding the spatial distribution allows for targeted interventions and resource allocation. Here is how geographic clustering can inform mitigation strategies:

- **Identifying Hotspots**

  Use GIS mapping to identify geographic hotspots with elevated fluoride contamination levels. Prioritize villages or areas with the highest concentrations for immediate attention.

- **Alternative Water Sources**

  Identify and implement alternative water sources in villages with high fluoride levels. This may involve drilling new wells, connecting to uncontaminated water sources, or installing water purification systems.

- **De-fluoridation Technologies**

  Implement de-fluoridation technologies in areas with persistent contamination issues. Technologies such as activated alumina, bone char filters, and reverse osmosis systems can be tailored to the specific needs of each village based on their water sources and fluoride levels.

- **Health Camps and Awareness Programs**

  Conduct health camps in villages with elevated fluoride levels to assess and address immediate health concerns. Collaborate with healthcare professionals to provide medical services and educate communities about the health impacts of fluoride exposure.

Defluoridation Methods

- **Reverse Osmosis Filtration-** This method is used to purify some (but not all) types of bottled water, so some bottled water does not have fluoride added to it. Reverse osmosis systems are generally out of reach for personal use.

- **Activated Alumina Defluoridation Filter-** These filters are used in areas where fluorosis is prevalent. These are relatively expensive and need to be replaced frequently, but they provide an option for home water filtration.

- **Distillation Filtration-** There are commercial distillation filters that can be purchased to remove fluoride from water.

Effectively communicating fluorosis risks and promoting safe water practices requires a targeted and culturally sensitive approach. **The National Programme for Prevention and Control of Fluorosis (NPPCF)** addresses the long-standing need to take early action to prevent the occurrence of fluorosis in areas with high levels of fluoride in groundwater.

Alternate water resources:

Identifying and leveraging alternate water resources for high-risk villages facing fluoride contamination is crucial for ensuring a sustainable and safe water supply. Below mentioned are some of the alternate water sources that can be considered, along with strategies for effective utilization:

Rainwater Harvesting

Source: Collecting and storing rainwater from roofs or catchment areas.

Strategy: Install rainwater harvesting systems in households and community buildings. Provide training on proper maintenance and filtration of rainwater harvesting systems. Promote the use of rainwater for non-potable purposes like irrigation and cleaning.

River Water

Source: Utilizing water from nearby rivers or streams.

Strategy: Establish water treatment facilities to purify river water to remove contaminants. Collaborate with environmental agencies to monitor and manage water quality in rivers. Implement community-based river water management plans to prevent pollution.

Groundwater from Safe Aquifers:

Source: Identifying and tapping of groundwater from aquifers with low fluoride levels.

Strategy: Conduct hydrogeological assessments to locate safe aquifers. Install community wells in areas with access to low-fluoride groundwater. Regularly monitor groundwater quality and implement protective measures.

Dams and Reservoirs

Source: Utilizing water from dams and reservoirs.

Strategy: Implement water treatment systems to address any fluoride contamination in dam water. Establish watershed management practices to maintain water quality in reservoirs. Develop community-based committees for the sustainable use and protection of dam water.

Water Recycling and Reuse:

Source: Treating and reusing wastewater for non-potable purposes.

Strategy: Implement wastewater treatment systems to recycle water for agricultural irrigation or industrial use. Raise awareness about the benefits of water recycling and encourage its adoption in the community.

Desalination (for Coastal Areas):

Source: Extracting saltwater from the sea and converting it into freshwater through desalination.

Strategy: Install desalination plants in coastal areas where limited freshwater sources occur. Consider renewable energy sources to power desalination plants for sustainability. Educate the community about desalination and its benefits.

Table 2. Seasonal variation of fluoride in groundwater samples in the study area

Sl. No	Season	WHO Standard (mg/L)	No. of samples within desirable limit (>1.5 mg/L)	No. of samples within exceeding limit (<1.5 mg/L)	Maximum value of Fluoride concentration (mg/L)	Minimum value of Fluoride concentration (mg/L)
1	Pre-monsoon	1.5	9	14	2.3	0.8
2	Post- monsoon	1.5	10	13	4.27	0.6

Conclusions

The present study reveals that fluorosis affects Salem Taluk. The groundwater samples of the study area show an alarming concentration of the fluoride, which is above the permissible limits. It is very clear that fluoride in recommended concentrations is definitely beneficial to bone health. Defluoridation plants should be established in high endemic areas, and it should be ensured that all individuals receive drinking water with optimum fluoride levels. Rain water harvesting be done and water from nearby rivers and dams should be provided as a source of water supply. Awareness should be given to the population to drink only the water supplied by the government. It is also recommended to treat water in areas where fluoride levels have exceeded the allowable limits. In addition, measures are needed to be taken to close down wells that contain very high fluoride levels.

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