Fluoride in Groundwater of Aiyar Sub-basin in Tiruchirappalli District, Tamil Nadu, India

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Abstract
The nature and extent of high fluoride concentration in groundwater from Aiyar sub-basin in Tiruchirappalli district were collected during post-monsoon (January 2015) and pre-monsoon (May 2015) seasons. During post-monsoon, the fluoride is the above permissible limit of 1.5 mg/L, but in pre-monsoon, only two samples recorded fluoride as above the permissible limit. The depth to water table was from 37’ to 90’ during pre-monsoon and it was 36’ to 100’ during post-monsoon. Due to the failure of monsoon in the study area, the depth to water table increases during post-monsoon, but the concentration of fluoride increases drastically in all the samples. The lower aquifer and the residence time of groundwater are attributed to the increase of fluoride during post-monsoon season. The region affected by higher fluoride concentration reflects dental and skeletal fluorosis. Gibb’s diagram reveals rock-water interaction. Remedial measures were suggested to the areas that are affected by fluoride.

Keywords: Fluoride, groundwater, permissible limit, monsoon, water table, Gibb’s diagram.

Introduction
Groundwater has become one of the important sources of water for meeting the requirements of various sectors in the country in the last few decades. It plays a vital role in India’s economic development and in ensuring food security. In our country, more than 60% of the irrigation requirements and 85% of drinking water supplies are dependent on groundwater (Gautam and Kumar, 2010). Every 8 sec, a child dies from water related disease around the globe, 50% of people in developing countries suffer from one or more water related diseases and 80% of diseases in the developing countries are due to the consumption of contaminated water (Jagadeesh, 2010). Groundwater in several parts of India is affected by arsenic and fluoride due to the geo-genic contamination and anthropogenic pollutions (CGWB, 2010). The rapid growth of urban areas has affected the groundwater quality due to over exploitation and improper waste disposal practices (Raja and Venkatesan, 2010). Heavy metals contaminate groundwater from anthropogenic sources as well as natural sources. Some of the major anthropogenic sources of heavy metals are mining, fertilizers and pesticides and industrial wastes (Deshpande and Gupta, 2004). The chemical composition of water is an important factor to be considered before it is used for domestic or irrigation purpose (Dahiya et al., 2007). In India, 12 million tons of fluoride deposits are found in India out of 85 million tons on the earth’s crust (Teotia and Teotia, 1994). High fluoride concentration in the ground water and surface water in many parts of the world is of great concern. It has been observed that there is a relationship between calcium, sodium and fluoride (Dibal and Lar, 2005).

Considering the above facts in view, this study evaluated the nature and extent of fluoride concentration in groundwater from Aiyar sub-basin in Tiruchirappalli, TN during post-monsoon and pre-monsoon seasons.

Materials and methods
Study area: The present study helps to understand the relation and variation of groundwater quality in Aiyar sub-basin (1310 sq km), Tamil Nadu. The study area lies from 11º00’ to 11º30’N and from 78º20’ to 78º40’ E. Aiyar basin is a sub-basin of the major ‘Cauvery’ river basin in Tiruchirappalli district, TN state, India (Fig. 1).
It incorporates two administrative taluks called Musiri and Thruraiyur. Approximately, one-fifth of the area is covered by hilly terrain (Kolli and Pachamalai hills). The geomorphology of this region comprise of pediplains, alluvial plains, structural hills, residual hills, valley fills, pediments, buried pediments and plateau with undulating plain. Regional geology is composed of alluvium, laterite, granite, dolerite, quartzite, charnockite, granite gneiss, sandstone, and limestone. Soil in this region is predominantly of black cotton soils, red sandy to loamy soils, alluvial soils, sandy soil, sandy loam, red loam, clay, clay loam, black soil, brown soil, and mixed soil.

Ground water analysis: Forty three ground water samples were collected during post-monsoon (Jan 2015) and pre-monsoon (May, 2015) from bore wells to assess the quality of groundwater. Pre-cleaned polyethylene bottles were used for collecting water samples (Laxen and Harrison, 1998). Groundwater samples were collected using the grid pattern sampling method. The samples were analyzed for their physical and chemical characteristics. The physical characteristics are color, taste, and odor whereas, chemical characteristics comprise major cations and anions like, Na, K, Ca, Mg, SO₄, NO₃, HCO₃ and fluoride, including the measurement of pH and EC. pH was measured using portable pH meter, EC was measured using electrode in the field and TDS were calculated from EC (0.64×EC). Cation and anions were analyzed by Ion chromatography (883 Basic IC plus). Bicarbonate and carbonate were done by volumetric method. These parameters are compared with the Bureau of Indian Standard (BIS: 10500:2012).

Results and discussion

Fluoride and water level in post-monsoon: During post-monsoon season, depth to water table is increased and at the same time fluoride level increased compared to pre-monsoon season. It may be due to fluctuation of groundwater and absence of rainfall in this area (Fig. 2). During post-monsoon (Jan 2015), the fluoride concentration is 1.1 mg/L as minimum and is 3.5 mg/L as maximum, its average is 1.6 mg/L. Spatial distribution shows higher fluoride values during post-monsoon season in western, northeastern part and southern part (Fig. 3). The depth to water table was 36’ to 100’ during post-monsoon. Due to the failure of monsoon in the study area, the depth to water table increased during post-monsoon, but the concentration of F⁻ increased drastically in all the samples.

Fluoride and water level in pre-monsoon: Depth of water level increased at the same time, fluoride level also decreased in pre-monsoon season when compared to post-monsoon season. It may be due to the fluctuation of groundwater and absence of rainfall in this area (Fig. 4). During pre-monsoon (May 2015), F⁻ concentration is 0.1 as minimum and is 2.0 as maximum, its average is 0.6 mg/L.

Spatial distribution showed that central part of one location and southeastern part of the area recorded high fluoride values during pre-monsoon season (Fig. 5). The depth to water table was 37’ to 90’ during pre-monsoon. In pre-monsoon season, two sample locations were affected namely, Sikkathambur-Palayam and Thandalai. Higher F⁻ concentration reflected dental and skeletal fluorosis in these areas.

Gibb’s diagram: The water chemistry in the study area is regulated by diverse processes and mechanisms. Hence, Gibbs plot is employed in this study to understand and differentiate the influences of rock-water interaction, evaporation and precipitation (Gibbs, 1970). Gibbs demonstrated that TDS is plotted on “y” axis and Na⁺K/(Na⁺Ca+K) and Cl/(Cl+HCO₃) is plotted on “x” axis which would provide information on the mechanism that controls the chemistry of water. Three kinds of fields are recognized in the Gibb’s diagram, namely, precipitation dominant, evaporation-crystallization dominant and rock-water interaction dominant (Chae et al., 2006). The chemical data of groundwater samples are plotted in the Gibbs diagram for the study area (Fig. 6 and 7). The majority of the samples fall in rock-water interaction field in post and pre-monsoon. Groundwater samples were individually scattered in the rock-water interaction dominance fields for both seasons. According to Gibb’s diagram, fluoride level increased due to rock-water interaction and anthropogenic activities as major role in this study area.

Remedial measures: In situ 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 in Anantapur district, India has helped widely to reduce fluoride concentration in groundwater (Bhagavan and Raghu, 2005). The groundwater with high fluoride, defluorination techniques are adopted. They include adsorption, ion exchange, coagulation and precipitation, reverse osmosis and electrodialysis. Of these, reverse osmosis has been considered as the best available technology. Onsite treatment includes artificial recharge methods such as rain water harvesting, constructing check dams, percolation ponds, facilitating recharge of rain water through existing wells etc. Adopting a particular method depends on the initial fluoride concentration, source and cost effectiveness in an area. Numerous ex situ methods are available for defluoridation of water either at household or community level. Adsorption method involves the passage of water through a contact bed where fluoride is adsorbed on the matrix. Activated charcoal and activated alumina are widely used adsorbents (Chidambaram et al., 2003; Chauhan et al., 2007). In ion exchange process, when water passes through a column containing ion exchange resin, the fluoride ions replace calcium ions in the resin. Once the resin is saturated with fluoride ions, it is backwashed with solution containing chloride such as sodium chloride.
Fig. 2. Water level Vs Fluoride in Post-monsoon (Jan 2015).

Fig. 3. Fluoride (mg/L) Vs Water level (feet) in Post-monsoon.
Fig. 4. Water level Vs Fluoride in Pre-monsoon (May 2015).

Fig. 5. Fluoride (mg/L) Vs Water level (feet) in Pre-monsoon.
The chloride ions thus again replaces the fluoride ions in the resin and is ready for reuse. But the backwash is rich in fluoride and hence care should be taken in disposing this solution. Similarly in precipitation methods, the disposal of sludge with concentrated fluoride is a great problem. Precipitation involves addition of chemicals such as calcium which results in the precipitation of fluoride as fluorite. Aluminum salts are also used for this process. Nalgonda technique which is a well-known technique uses alum, lime and bleaching powder followed by rapid mixing, flocculation, sedimentation and filtration. This was developed in India by National Environmental Engineering Research Institute to serve at community and household levels.

The resulting sludge from this process contains high amount of aluminium and fluoride, the disposal of which is yet another problem. These above mentioned ex situ methods are simple and cost effective and onsite treatment includes artificial recharge methods such as rain water harvesting, constructing check dams, percolation ponds, facilitating recharge of rain water through existing wells etc. Adopting a particular method depends on the initial fluoride concentration, source and cost effectiveness in the study area (Brindha and Elango, 2011).

**Conclusion**

Two sample locations Sikkathambur-Palayam and Thandalai, were affected by high fluoride concentration due to rock water interaction in both post and pre-monsoon seasons. Depth of water level decreased at the same time, fluoride level also increased due to absence of rainfall and groundwater exploitation in this area. Fluoride level also increased due to rock and water interaction in deeper depth during post-monsoon seasons (Jan 2015) and anthropogenic activities. To remediate the groundwater with high fluoride, defluorination techniques can be adopted along with reverse osmosis. Onsite treatment method may be carried out like rain water harvesting, percolation ponds, constructing check dams, facilitating recharge of rain water through existing wells.

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**References**