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Fluoride Concentration in Groundwater: A Case Study from Ramanagaram Taluk, Karnataka, India

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Abstract: Groundwater is a hidden resource and a critical component as it is being used to meet the demands of growing population. It occurs in different geological formations, but in hard rocks it is found mostly in secondary porosity like fractures or fissures. Groundwater contains dissolved inorganic chemical constituents due to interaction between water and geological materials. The interaction between geological materials and groundwater produces various dissolved inorganic constituents which in excess may cause health problems. Among all physico-chemical parameters, fluoride is one, which below <0.6 mg/l and above 1.5 mg/l (as per BIS / WHO) is a slow poison and has significant adverse impact on public health

Groundwater is a major source of water supply for drinking and irrigational purpose in rural and urban parts of Ramanagaram district, Karnataka state. Groundwater samples from 50 villages of Ramanagaram taluk were collected and studied for 4 important parameters like pH, total hardness (TH), total dissolved solids (TDS) and fluoride.

In the present study, the average pH value is 7.32 with a range of 6.8 to 7.9 and TH between 113 mg/l and 468 mg/l. The TDS value for most of the water samples are just above the desirable limit (500 mg/l) and the fluoride concentration in the study area ranges between 0.3-5.0 mg/l. Fluoride in 80% of the villages in the study area is above 1.5 mg/l. The causes for higher fluoride in groundwater along with some recommendations to minimize its content adopting some simple techniques have been discussed.

***Keywords:** Groundwater, Fluoride, TDS, TH, Ramanagaram, granite and gneiss*

1. Introduction

Groundwater is one of the most valuable and indispensable natural resources for all living beings. Groundwater contributes just 0.3% of the total water budget in the Earth and it is the main source in most of the rural and urban areas and hence needs judicious use for sustainable groundwater management. The consumption of groundwater rather than surface water is increasing day by day because of faster growth of population and is being exploited non-scientifically through indiscriminate drilling of borewells without knowing the status of water bearing aquifers. Apart from quantity of groundwater, quality also plays a major role and it is very difficult to get non-polluted potable water in arid to semi-arid hard rock areas. The depletion and deterioration of quality in groundwater particularly in hard rock terrains is due to rapid growth of population, expansion of irrigation, modern civilization, increasing trend of industrialization and over exploitation.

The quality of groundwater depends on various chemical constituents and their concentration which are derived from geology, climate and water table of the area. Among physico-chemical parameters, fluoride concentration in groundwater varies significantly

The consumption of fluoride in minute quantity is essential for bone, teeth and formation of dental enamel (Bell and Ludwig, 1970), as per WHO guideline value for fluoride in drinking water is between 1.0 and 1.5 mg/l. Very low content of fluoride (<0.6 mg/l) in water promote tooth decay. However, when consumed in higher doses (>1.5 mg/l), leads to dental fluorosis (Handa, 1975; WHO, 1993, Apambire and Boyle, 1997) or mottled enamel and excessively high concentration (>3.0 mg/l) of fluoride may lead to skeletal fluorosis. Continuous high intake of fluoride will result in mottled enamel of the teeth, skeletal fluorosis and sometimes severe osteosleosis. Thus, fluorine is one of the important trace elements for human health found in drinking water.

The amount of fluoride occurring naturally in groundwater is governed by climate, composition of the host rock, and hydrogeology (Gupta et al., 2006). Groundwater occurs in crystalline rocks, especially granites and granitic gneisses are very sensitive to high fluoride concentrations. The occurrence of fluoride in groundwater is due to dissolution of biotite

/ hornblende, which may contain significant fluorine at OH– sites of their octahedral site (Nordstrom *et al.*, 1977). It is reported that fluoride concentration is more in deeper aquifer due to the increase of temperature and residence time with increasing depth along with leaching of biotite bearing minerals in rocks (Nordstrom and Jenne, 1977; Saxena and Ahmed, 2005).

An experimental study was conducted on batch dissolution of granite of Jungwon area of South Korea, which has high fluoride content of up to 6-10 mg/l (Chae et al., 2006). They showed that dissolution experiment on biotite after 500 hours, the fluoride concentration decreases because of dissolution of Ca-bearing plagioclase

India is among 23 nations in the world, where fluoride contaminated ground water is creating health problems. In Karnataka moderate to high fluoride content in groundwater has been reported mainly from granitic and gneissic terrains. Suma Latha et al., (1999) have reported abnormal fluoride content (1-7.4 mg/l) from different parts of Karnataka. Their study show that high fluoride occurs mostly in gneissic and granitic area. Further, structures like joints, fractures, faults and vertical opening in these rocks paved way for accumulation of fluoride bearing minerals.

Very high fluoride content (up to 7.1 mg/l) causing dental, skeletal fluorosis and gastrointestinal discomfort in 41% of people from some parts of Bijapur district has been reported by Yadawe et al., (2010). Similarly, many others have reported high-very high fluoride content in groundwater across the state and country as well (Ramesham and Rajagopalan, 1985; Nawlakhe and Paramasivam, 1993; Susheela, 1999, Meenakshi et al., 2004; Ramanaiah et al., 2006; Veeraputhiran and Alagumuthu, 2010; Ganesha et al., 2013; Sanjay, 2014).

Present study is a preliminary investigation on the occurrence of fluoride in groundwater of Ramanagaram taluk, Ramanagaram district, Karnataka and possible source along with some recommendation.

2. Study Area

Ramanagaram district of Karnataka state lies between the north latitude 12°24' and 13°09' and East longitude 77°06' and 77°34' and the total geographic area is 3576 Sq. Km. The study area belongs to Ramanagaram taluk of Ramanagaram district bounded by longitude 77°08'23"-77°29'03"E and latitude 12°35'08"-12°52'44"N and has 25 Zilla Panchayath and 133 villages. Ramanagaram district forms a part of semi-arid dry zone of Karnataka and mean annual rainfall is 847 mm mostly from June to September during SW monsoon. The only source of water in the entire taluk is groundwater as the river Arkavati is completely dried. Fig.1 shows the location map of the study area.

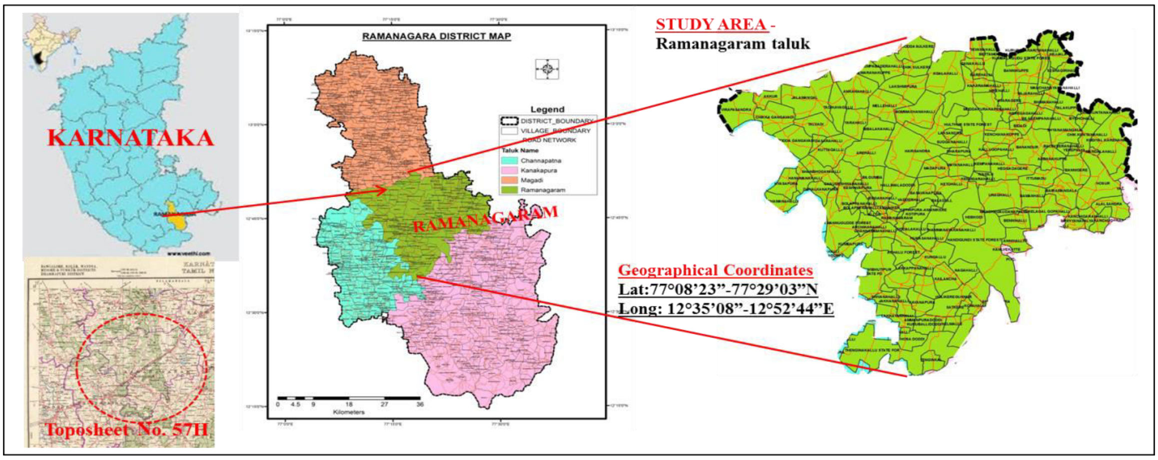

Figure-1: *Location map of the study area*

3. Geology of the Area

The main rock types of this area are granite (Closepet granite) and gneiss. The gneissic rocks are massive and intruded by pegmatite and quartz viens. Closepet is the old name for Ramnagaram, which is the type area. This belt with an average width of 20 km extends from Bilgi in the north, forming the basement to Kaladgi Super group up to Sivasamudram in the south. Closepet Granite is a cluster of individual plutons or plugs of different sizes, emplaced along the suture zone welding the eastern and western blocks of Dharwar Craton (Swami Nath and Ramakrishnan, 1981). By and large, Closepet Granite is composed of pink and grey coarse grained and porphyritic granite and the age is determined to be around 2500 million years old. These rocks are weathered to shallow depth and structurally show dip joints. Ground water occurs in the open spaces of weathered fractured gneisses and granites.

4. Groundwater Sampling Procedure

A reconnaissance survey was conducted during January 2015, consulting Mines and Geology as well as Zilla Panchayath officers about groundwater scarcity and quality problems in the villages of the taluk. However, a random as well as detailed sampling procedure was carried out in selected villages. Thus 50 villages (including Ramanagaram town) were selected in 20 mandal / grama panchayaths in which fluoride in groundwater is beyond permissible limit.

Water samples were collected in cleaned polythene bottles from borewells during March-April months (pre-monsoon, 2015) from 50 villages spread across 20 panchayaths of Ramanagaram taluk. The groundwater samples were analysed for pH, TDS, TH and fluoride adopting standard method as detailed in Table-1.

5. Results and Discussions

The groundwater quality was assessed by analysing four important parameters. The chemical analysis for four parameters of all water samples are tabulated in Table-2 along with panchayath and representative village names. Here, only representative groundwater samples in each panchayath having non-problematic and moderately fluoride affected areas have been considered.

The pH is a measure of the activity of the hydrogen ion (H^+) and is represented as the reciprocal of the logarithm of the hydrogen ion activity and indicates that the water is potable, acidic or basic. In the present study the average pH value is 7.32 with a range of 6.8 to 7.9. The pH content of all samples fall within the range of desirable and permissible limit recommended by BIS and WHO

The hardness of water is a measure of the amount of calcium and magnesium rich minerals present in water (Gupta *et al* 2009). Water that has a hardness less than 61 mg/L is considered soft; 61-120 mg/L, moderately hard; 121-180 mg/L, hard; and more than 180 mg/L, very hard. In the present study, hardness ranges between 113 and 468 mg/l, but, it is very hard (> 180 mg/l) in most of the samples.

The fluoride concentration in the study area ranges between 0.3-5.0 mg/l. Further, fluoride content <1.0 mg/l is reported in 4 panchayaths and 7 panchayaths lie in the range of 1.6- 3.0 mg/l and remaining 9 panchayaths shows 3-5 mg/l. Thus, groundwater with moderate fluoride content of 1.6-3.0 mg/l cover almost 35% of the panchayaths and 45% belongs to more than 3.0 mg/l.

The TDS values recorded in the present study range between 82 mg/l and 1120 mg/l and almost entire taluk has TDS values above desirable limit of 500 mg/L. The highest values of TDS are due to dissolved salts like sulphates, nitrates, chlorides and agricultural activity. The TDS value for most of the water samples are just above the desirable limit and some of them well within the maximum permissible limit recommended by BIS of 2000 mg/l.

Reports on other parameters such as pH, TH and TDS in some parts of Ramanagaram taluk shows similar concentrations (Srilatha et al., 2014; Madhusudhan and Inayathulla, 2015) . They also pointed out higher concentration in TH (250-620 mg/l) and within the permissible limit for TDS (525-1000 mg/l) and normal pH (7.1-7.62), thus, can be comparable to the present study.

Srilatha et al., (2014) studied on physico-chemical studies of groundwater in Ramanagaram and Tumkur districts showed that fluoride ranged from 0.57 – 4.81 mg/l with a mean value of 2.01mg/l respectively. This study shows that about 77% of the water samples have a fluoride values found to be higher than the maximum permissible limits of 1.5 mg/l recommended by BIS Standards. Similarly, their study on other parameters shows that mean of pH, TDS and TH of the Ramanagaram and Tumkur district as a whole are 7.28, 703.03 mg/l and 225 mg/l. This work is very much relevant to present study as the rock types and groundwater aquifer parameter are almost similar.

The average Fluoride concentration in Bidadi of Ramanagaram taluk is below the permissible limit of 0.6 mg/l (0.54 mg/l) reported by Madhusudhan and Inayathulla (2015). Similar lower concentration of fluoride has been observed in some of the villages in Ramanagaram taluk, which is also dangerous which may cause tooth decay and people are suffering from this. It is quite common that most of the studies on fluoride content in groundwater are focussed on very high concentration of more than 4 mg/l, however it is equally important to consider the areas where the fluoride concentration is below the permissible limit.

Present study confirms the distribution of moderate level of fluoride (between 1.6-3.0 mg/l) in most of the villages of Ramanagaram taluk. The occurrence of fluoride beyond permissible limit is due to leaching of fluoride minerals present in granite and gneisses. This natural process of leaching of fluoride bearing minerals is a common phenomenon in Karnataka particularly in aquifers having granitic / gneissic rocks (Nawlakhe and Paramasivam ,1993; Susheela, 1999; Suma Latha et al., 1999). Further, Dissolution experiments on granite supports occurrence of fluoride in biotite and its leaching process when biotite reacts with Ca-bearing minerals and adsorption and / or cation exchange phenomenon (Chae et al., 2006). The TDS and TH occurrence in groundwater beyond permissible limit in the present study can be comparable to high fluoride concentration in granitic / gneissic terrains reported from Karnataka (Nawlakhe and Paramasivam ,1993; Susheela, 1999; Suma Latha et al., 1999; Ganesha et al., 2013; Srilatha et al., 2014). Added to this, scanty rainfall, dried rivers, over exploitation of groundwater from deep borewells without sufficient recharge and indiscriminate drilling of borewells are the causes for this dangerous element.

***Table-1:** Methods for groundwater analysis and BIS / WHO standard*

Sl.No.	Physico-Chemical Parameter	Methods	Standard Limits BIS: 10500, 1991		WHO standard
			Desirable	Permissible	
1	pH	Potentiometry	6.5-8.5	No relaxation	7.5-8.5
2	TDS (mg/l)	EDTA	500	2000	500
3	TH (mg/l)	TDS Probe	300	600	100
4	Fluoride (mg/l)	Spectrophotometry	1.0	1.5	1.0

***Table 2:** Representative Groundwater sample locations and analytical results of groundwater*

Sl. No.	Panchayath Name	Village Name	pH	Fluoride (mg/l)	TDS (mg/l)	TH (mg/l)
1	Ramanagaram	Ramanagaram (town)	7.2	1.8	888	355
2	Bidadi	Madenahalli	7.1	4.3	862	181
3	Byramangala	Kodiyala	6.8	1.4	701	429
4	Kachugaranahalli	Kachagaranahalli	7.5	0.6	867	235
5	Ittamadu	Ittmadu	7.3	1.6	1120	374
6	Gopalli	Uragalli	6.9	2.2	855	175
7	Manchanayakanahalli	Hejjala-1	7.8	0.3	567	374
8	Bannikuppe(K)	Ganakallu	7.9	0.8	690	302
9	Kechanakuppe	Borahalli	7.4	4.5	825	174
10	Harisadhra	Harisadhra	7.2	2.3	715	468
11	Sugganahalli	Sugganahalli	6.9	4.1	802	214
12	Mayaganahalli	Basavanapura	7.7	3.5	825	425
13	Kutagal	Nagarkallu doddi	7.5	4.3	846	201
14	Akuru	Akuru	7.3	4.2	814	198
15	Shyanuboganahalli	Shyanuboganahalli	6.9	0.5	562	309
16	Jalamangala	Jalamangala	7.8	1.2	82	124
17	Lakshmipura	Kolamarankuppe	7.4	2.8	625	364
18	Kailacha	Kavanapura	7.2	5.0	725	113
19	Hunasehalli	Tammanayakhalli	7.5	2.3	654	201
20	Vibutikere	Vibutikere	7.2	1.6	255	114

6. Conclusion

A study on groundwater quality in Ramanagaram taluk, Ramanagaram district, Karnataka, was carried out, considering fluoride as one of the important parameters, as this element at elevated levels causes health related problems like dental and skeletal fluorosis. Groundwater depletion and quality degradation are the emerging issues posing a major threat to sustainability of ecosystems and food security in peninsular India.

Present study shows that in 16 out of 20 panchayaths (more than 40 villages), the fluoride content found to be exceeding permissible limit. It ranges from 1.6-5 mg/l and classified under moderately affected to just beginning of severely affected region. It is essential to carryout detailed study in the entire taluk as well as Ramanagaram district, wherever limited recharge of groundwater is noticed and the existence of deeper aquifers to understand the effect of fluoride problems.It is observed from the present study that the geology plays a key role in determination of groundwater quality with reference to fluoride which is due to dissolution of fluoride bearing minerals from granite and gneiss.

It is very essential to identify the source of water and classify the extent of fluoride affected area like non-problematic, moderately fluoride affected and severely affected. Accordingly, it is the responsibility of the government / NGO's to conduct awareness campaigns among the people about the causes of fluoride on health and encourage them to adopt technological solutions such as simple rainwater harvesting programme, defluoridation and construction of recharge structures for borewells to minimize the fluoride content in groundwater.

In this connection, it is worthwhile to mention that Karnataka Government has launched a programme called 'Sachetana Drinking water project', in which rural people are getting fluoride-free water in severely affected areas. Furthermore, this programme also aims to educate the people in rooftop rainwater, harvesting and recharging the groundwater through several methods like borewell recharge, aquifer recharge, construction of percolation ponds etc. to dilute the toxic elements found in groundwater.

It is important to recommend at this initial stage that consumption of untreated groundwater which contain fluoride concentration between 1.5-3.0 mg/l for 5-10 years continuously may cause dental fluorosis. Therefore, it is the responsibility of scientists and engineers to urge the state and central Government to adopt some techniques like coagulation (Nalgonda process), activated alumina, membrane or any other deflouridation process (Farwell et al., 2006) to eradicate the fluoride problems in rural and urban areas.

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