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Fluoride contamination of groundwater and its impacts on human health in and around vemula, vempalli mandals, YSR District, Andhra Pradesh, India

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A B S T R A C T

This study aims to assess the link between fluoride content in groundwater and its impact on dental health in rural communities Vemula, Vempalli revenue mandals of Y.S.R District, A.P. As per the desirable and maximum permissible limit for fluoride in drinking water, determined by WHO, the groundwater of about seventy percentage of the studied sites is notpotable for drinking purposes. Due to the higher fluoride level in drinking water several cases of dental and skeletal fluorosis have appeared in this region. Dissolution of fluoride-containing rock minerals is the source of naturally occurring fluorides in groundwater whereas application of phosphate fertilizers or sewage sludges or pesticides are the artificial source of fluoride in groundwater and surface water. Fluoride concentrations beyond the standards cause dental and skeletal fluorosis. To mitigate fluoride contamination for an affected area, the provision of safe, low fluoride water from alternative sources should be investigated as the first option otherwise various methods, which have been developed for the defluoridation of water can be used to prevent fluoride contamination. Groundwater of a particular area should be thoroughly studied before its use for domestic purposes and accordingly a suitable method can be chosen for its treatment.

Introduction

The quality of groundwater is very important in evaluating its utility in various fields such as domestic public water supply and agriculture. The assessment of the dissolved constituents thus become very important for safe drinking water. Some ions dissolved in water and present in appropriate concentration are essential for human beings while higher concentration results in toxicity. Fluorine is smallest atom of halogen family, which is not found in element stage in nature rather is combines with other element to form fluoride compounds. Fluoride is a strongly electronegative ion commonly found in combination with calcium or sodium, forming compounds that occur naturally in soil and water. In many countries world over, it has been observed that high concentrations of fluoride occur naturally in groundwater, which is the main source of drinking water. Undeniably, fluoride is one of the most abundant elements in the earth and it generally infiltrates groundwater by natural processes. Soil, a product of the physical disintegration and chemical decay of solid bedrocks that are high in fluoride, is mostly found to be naturally rich in fluoride (Muhammad Tariq Bashir et al., 2013). Fluoride concentration in drinking water is important for public health. Fluoride contributes to dental health and to the maintenance of appropriate bone density. The factors which influence fluoride concentrations in natural water are geological, hydro geological, geochemical and anthropogenic. Occurrence of fluoride in groundwater has drawn worldwide attention due to its considerable impact on human physiology. The maximum tolerance limit of fluoride to drinking water specified by the World Health Organization (W.H.O. 1984) is 1.5 mg/l. Ingestion of water with fluoride concentration above 1.5 mg/l results in dental fluorosis characterized initially by opaque white patches staining, mottling and pitting of teeth. Skeletal fluorosis may occur when fluoride concentration in drinking water exceed 4-8 mg/l, which leads to increase in bone density calcification of ligaments, rheumatic pain in joints and muscles along with stiffness and rigidity of the joints, bending of the vertebral column etc (Teotia and Teotia 1994). In the world around 200 million people from 25 nations have great health risks, with high fluoride in the drinking water. In India, about 62 million people are at risk of developing fluorosis from drinking high fluoride groundwater (Andezhath et al., 1999). In the country almost 60-65 million people drink fluoride contaminated groundwater and the number affected by fluorosiis is estimated at 2.5 to 3 million in many states especially, Andhra Pradesh, Bihar, Rajasthan, Tamil Nadu and Uttar Pradesh (Susheela 1999; Pillai and Stanley 2002). The first case of endemic fluorosis in the country was reported as long as 1937 in the Prakasam district, Andhra Pradesh (Shortt et al., 1937). W.H.O (2004) has laid down a limit of 1.5 mg/l fluoride in drinking water. This maximum limit protects tooth decay and enhances proper bone growth. In India safe limit of fluoride in potable water is between 0.6 and 1.2 mg/l. Lower limit of fluoride (<0.6 mg/l) than that of the prescribed limit (0.6 mg/l) causes dental caries, while higher limit of fluoride (1.2 mg/l) than those of the recommended limit (1.2 mg/l) results in fluorosis. The major sources of fluoride in groundwater are fluoride bearing rocks such as fluorspar, cryolite, fluorapatite and hydroxylapatite (Agarwal et al.,1997). The fluoride content in the groundwater is a function of many factors such as availability and solubility of fluoride minerals, velocity of flowing water, temperature, pH, concentration of calcium and bicarbonate ions in water, etc (Chandra et al., 1981).

Dental fluorosis

Generally ingestion of water having a fluoride concentration above 1.5 – 2.0 mg/l may lead to dental mottling, an early sign of dental fluorosis which is characterized by opaque white patches on teeth. In advanced stages of dental fluorosis, teeth display brown to black staining followed by pitting of teeth surfaces. Dental fluorosis produced considerable added dental costs (tooth deterioration) and significant physiological stress for affected population. Dental fluorosis is endemic in 14 states and 1, 50,000 villages in India. The problems are most pronounced in the states of A.P., Bihar, Gujarat, M.P., Punjab, Rajasthan, Tamil

Nadu and Uttar Pradesh (Pillai and Stanley, 2002).

Skeletal fluorosis

Skeletal fluorosis may occur when fluoride concentrations in drinking water exceed 4-8 mg/l, which leads to increase in bone density, calcification of ligaments rheumatic or arthritic pain in joints and muscles along with stiffness and rigidity of the joints, bending of the vertebral column and excessive bone formation or osteosclerosis, a basis symptom of skeletal fluorosis (Teotia and Teotia 1992); while excess F^{-}may include hypocalcaemia (Sherlin and Verma, 2000; Teotia and Teotia, 1994; Pius et al., 1999; Ekambaram and Vanaja, 2001). Crippling skeletal fluorosis can occur when a water supply contains more than 10 mg/l (WHO 1984; Boyle and Chagnon 1995). Fluoride cycle in the environment is shown in the figure:1

Neurological stage of fluorosis

This is a late stage of skeletal fluorosis where in spinal nerves and spinal cord are compressed causing paralysis. This is a crippling stage and some of them can only be help them by surgery.

Geogenic contamination of groundwater is difficult to detect and is even more difficult to control with comparison to manmade contamination of surface water. Excess concentration of Fluoride in groundwater causes severe health problems. In order to mitigate excess Fluoride in groundwater, it is essential to determine and monitor the factors of enrichment of fluoride concentration in groundwater in time and space (Ahmed et al.,2002).

While fluoride pollution of groundwater remains a widespread problem, efforts for remediation using different techniques are on. Prevention (i.e., maintaining the fluoride levels in drinking water below permissible limits) is the most appropriate remedial measure for ill effects caused by ingestion of fluoride. Hydro geochemical investigation to understand the status of groundwater quality and identify potential areas of risk in conjunction with the remedial measures to treat contaminated water are vital components of the broad strategy to combat endemic fluorosis. In an effort in this direction, geochemical investigations to determine the status of fluoride contamination in the Vemula, Vemaplli mandals of YSR District in Andhra Pradesh forms the focus of the present work.

Study area

The climate of the study area is hot and semiarid. The monthly maximum, minimum and mean temperatures as measured at Kadapa are 44^{0}C, 14^{0}C and 27^{0}C respectively. The mean annual rainfall recorded at the Kadapa is 759 mm. The YSR district is aptly called the district of Pennar as almost the entire district is drained by the Pennar river and its tributaries. The important tributaries joining the river from the north include the rivers Kunderu, Sagileru and Tummalavanka while those from the south include the rivers Chitravati, Papaghni, Buggavanka, Cheyyeru and kalletivagu. Bahuda, mandavi, Pullangi and Gunjaneru are the tributaries of the Cheyyeru. The rivers and streams in the district are mostly ephemeral under the influence of heavy spells of rainfall by cyclonic storms in the Bay of Bengal (Ramakrishna Reddy M., Janardhana Raju., Venkatarami Reddy Y., Reddy T.V.K 2000). The proposed study area is in the Vemula, and Vempalli revenue mandals of YSR district and is shown in the figure1. The study area falls in the Survey of India

Toposheet No: 57 J/07.Sample locations and Geology of the study area is shown in figure: 2

Geology and hydro geology

The study area exposes the rocks belonging to Peninsular Gneissic Complex and Papaghni, Chitravathi group of Cuddapah Super group covering an area about 700 sq km. The Peninsular Gneissic Complex unconformably overlain by the thick sequence of Proterozoic sediments belonging to Cuddapah Super group. Basic intrusives overlie the Cuddapah Super group of rocks. The rock types are observed in the study area Granite gneiss, Granite, Schist, Granitoid with acid and basic intrusives belonging to Peninsular Gneisses Complex. This complex is overlain by basal Gulcheru Quartzites of lower Cuddapah followed by Vempalli formation comprising of dolomite, mudstone/shale, cherty dolomite and volcanic flows belonging to Papaghni group.

The Papaghni group is overlain by Chitravathi group consisting of Pulivendula quartzites and Tadipatri formation consisting shale with sill. The groundwater in all the rock formations occur in unconfined and semi- confined aquifer conditions. The occurrence and movement of the groundwater depends on bedding planes, weathered, fractured, fissured and fault zones. The permeability of all formations depends on secondary porosity except for alluvium where the porous materials (Gravel and sand) act as highly permeable. The network of fractures and joints in dolomitic limestones favours the penetration of water and the formation of phreatic aquifers. Karst springs are also observed in the limestone areas, which yield substantial amount of water. Hydrogeological conditions prevailing in the study area indicate that the quartzites are good aquifers than the shales.

Materials and Methods

Fluoride estimation: Fluoride ion concentration was measured in hand pump and well waters with ORION manufactured by ORION Research, Incorporation by using Ion selected electrode method.

Thirty samples of groundwater used for drinking purpose were collected from either hand pumps or open wells at different villages of Vemula and Vempalli of YSR District, Kadapa during the March and April 2014. This season was selected because in this season often contamination increases due to low dilution and this tends to the accumulation of ions. Before sampling, the water left to run from the source for few minutes. Then water samples collected in pre cleaned, sterilized polyethylene bottles of two litre capacity. Sodium fluoride was used to prepare the standard solutions.

The fluoride concentration in groundwater was determined electrochemically, using ion selective electrode method. This method is applicable to the measurement of fluoride in drinking water in the concentration range of 0.1 – 1000 mg/l. The electrode used was an Orion fluoride electrode, coupled to an Orion electrometer. Standards fluoride solutions (0.1 -10 mg/l) were prepared from a stock solution (100 mg/l) of sodium fluoride. To estimate the concentration in the water samples were diluted with equal volumes of total ionic strength adjustment buffer (TISAB) of pH 5.2 before fluoride estimation (Khaiwal and Garg 2006). The composition of TISAB solution was as follows: 58 g Nacl, 4 g of CDTA (Cyclohexylene diamine tetraacetic acid) and 57 ml or glacial acetic acid per litre. All the experiment was carried out in triplicate and the results were found reproducible with + 3 % error. Fluoride analysis is carried out with Ion selective electrode and is shown in the figure: 10. To prepare all reagents and calibration standards, double distilled water was used. All the experiments were carried out in triplicate.

Results and Discussion

The groundwater was free from colour and odour and taste was slightly saline. The fluoride content in groundwater varied greatly in different villages. Locality index of the study area is shown in table-2.The result of chemical analysis of fluoride concentration is presented in table: 3.

30 samples were collected from different sites of 20 different villages namely Tallapalli, Bestavaripalli, Kothapalli (underground water), Kothapalli (surface water), Chagaleru, Vemula, Vempalli, Nandipalli, Mopurigaripalli, Kattaluru, Pamuluru, Ayyavaripalli, Alavallapadu, Naguru, Muttukuru, Ramireddipalli, Alireddipalli, Parnapadu, Ammayagaripalli, Chintalajuturu. The fluoride concentration was ranged from 0.266 – 3.52 mg/l with highest fluoride level at Pamuluru (4.34 mg/L) and lowest at Bestavaripalli (0.266 mg/l). Fluoride concentrations of the study area are shown in Table: 3.

Many natural geological processes, sometimes exacerbated from anthropogenic influences (mining activities, fuel combustion, etc.), can be responsible of the impact of harmful compounds. One of the most important is volcanic activity. Apart from the obvious impact of eruptive, especially explosive, activity, in recent times the scientific community has become aware of the effects on the environment and particularly on human health deriving from geochemical processes acting in quiescent periods and even in volcanic systems considered extinct. The importance of this new scientific branch brought specialists of different disciplines to join in the International Volcanic Health Hazard Network (IVHHN) with the common aim of trying to better define the health effects of volcanic emissions (http://www.ivhhn.org/.) The source of this F contamination in ground water at study area may be due to the presence of sedimentary beds that were originally enriched in F at the time of deposition and subsequently became soluble in entrapped water by favourable physico-chemical conditions. Otherwise, entrapped water may leach and dissolve locally concentrated pockets of highly soluble fluoride minerals within the volcanic trap rock during its journey from a secondary aquifer to the surface.

Water-rock interaction

Volcanic rocks are often enriched in fluorine. Hydrogen fluorine is, in fact, one of the most soluble gases in magmas and exsolves only partially during eruptive activity. Burton et al. 2003 estimated for example that Etnean magmas exsolve only about 20% of their initial HF content during effusive activity. Furthermore fluorine behaves as incompatible element being highly enriched in differentiated volcanic products (Sigvaldason 1986). In volcanic aquifers elevated temperatures and/or strong acidic conditions enhance WRI processes. Such conditions often lead to high concentrations of harmful elements. Therefore fluorine concentrations in volcanic aquifers above safe drinking limits are rather the rule than the exception. Values as high as tens of mg/l of fluorine are often achieved in ground waters, which if used for human consumption can easily lead to skeletal fluorosis. Water intake being the main route of fluorine into the human body, fluorosis in volcanic areas is generally associated to elevated fluoride content in surface- and ground-waters. Contamination of vegetation, which is the main agent of volcanic-related fluorosis in herbivorous animal, is only of secondary importance for human health.

Table.1 showing the latitude and longitude of the sample locations

S.No.	Name of the village	Latitude value	Longitude value	Elevation metres
1.	Tallapalli	N $14^0$22'31-3"	E $78^0$23'18.6"	199
2.	Bestavaripalli	N $14^0$0.5'0"	E $78^0$26'30"	199
3.	Kothapalli (Ground water)	N $14^0$23'0"	E $78^0$11'0"	198
4.	Kothapalli (surface water)	N $14^0$23'0"	E $78^0$11'0"	203
5.	Chagaleru	N $14^0$24'0.9"	E $78^0$24'14"	230
6.	Vemula	N $14^0$18'23.2"	E $78^0$26'0.9"	199
7.	Vempalli	N $14^0$22'0"	E $78^0$28'0"	201
8.	Nandipalli	N $14^0$22'33.1"	E $78^0$24'27.5"	215
9.	Mopurigaripalli	N $14^0$23'26.9"	E $78^0$23'33.5"	210
10.	Kattaluru	N $14^0$23'43.3"	E $78^0$24'07.9"	204
11.	Pamuluru	N $14^0$24'08.8"	E $78^0$25'25.3"	213
12.	Ayyavaripalli	N $14^0$25'17.7"	E $78^0$24'53.2"	200
13.	Alavallapadu	N $14^0$25'12.6"	E $78^0$23'13.5"	204
14.	Naguru	N $14^0$26'54.2"	E $78^0$24'36.2"	191
15.	Muthukuru	N $14^0$27'50.9"	E $78^0$23'26.0"	190
16.	Ramireddi palli	N $14^0$27'44.9"	E $78^0$25'00.2"	192
17.	Alireddipalli	N $14^0$22'21.1"	E $78^0$29'05.6"	207
18.	Parnapadu	N $14^0$24'12.6"	E $78^0$21'16.3"	206
19.	Ammagaripalli	N $14^0$24'27.0"	E $78^0$26'29.5"	209
20.	Chintala juturu	N $14^0$16'20.4"	E $78^0$25'10.4"	186

Table.2 Fluoride concentrations of the study area

S.No	Name of the village	Fluoride concentration mg/l
1.	Tallapalli	1.90
2.	Bestavaripalli	**0.266**
3.	Kothapalli (Ground water)	1.51
4.	Kothapalli (surface water)	1.48
5.	Chagaleru	0.377
6.	Vemula	1.0
7.	Vempalli	1.36
8.	Nandipalli	1.11
9.	Mopurigaripalli	2.14
10.	Kattaluru	1.18
11.	Pamuluru	**3.52**
12.	Ayyavaripalli	1.36
13.	Alavallapadu	0.843
14.	Naguru	1.26
15.	Muttukuru	0.365
16.	Ramireddi palli	1.27
17.	Alireddypalli	0.690
18.	Parnapadu	1.53
19.	Ammayagaripalli	1.30
20.	Chintala juturu	1.21

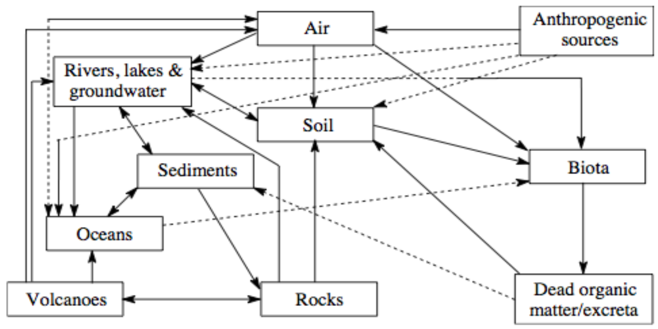


Fig. 1. Cycling of fluoride through the biogeosphere

Figure.2 Location map& Geology of the Study Area

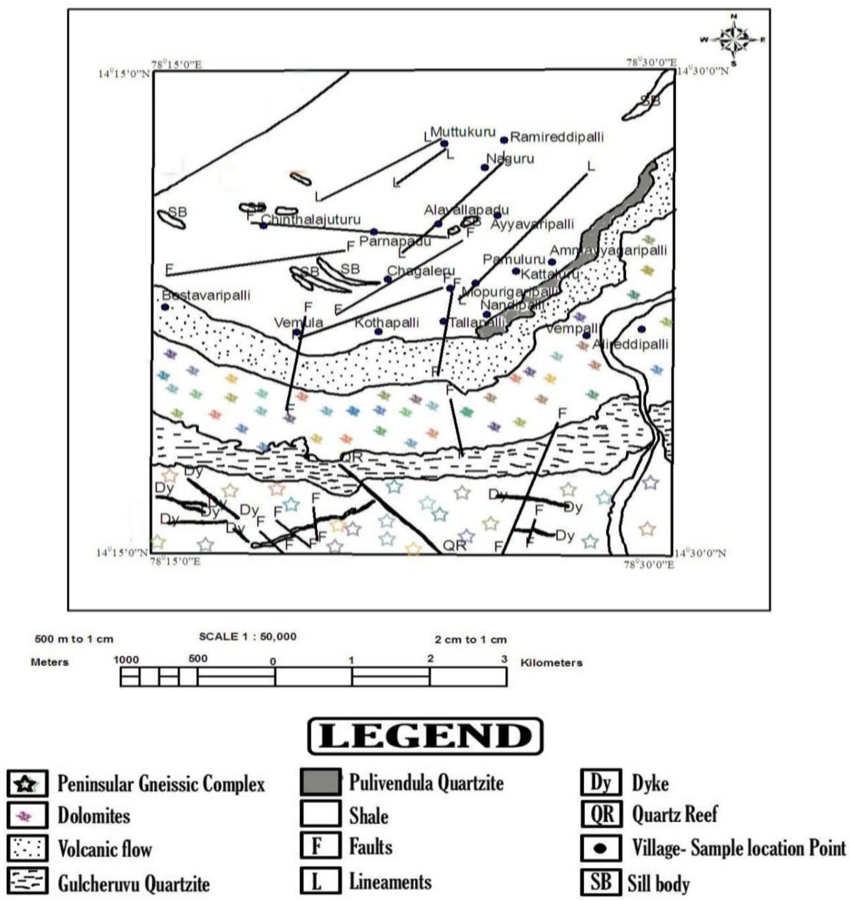
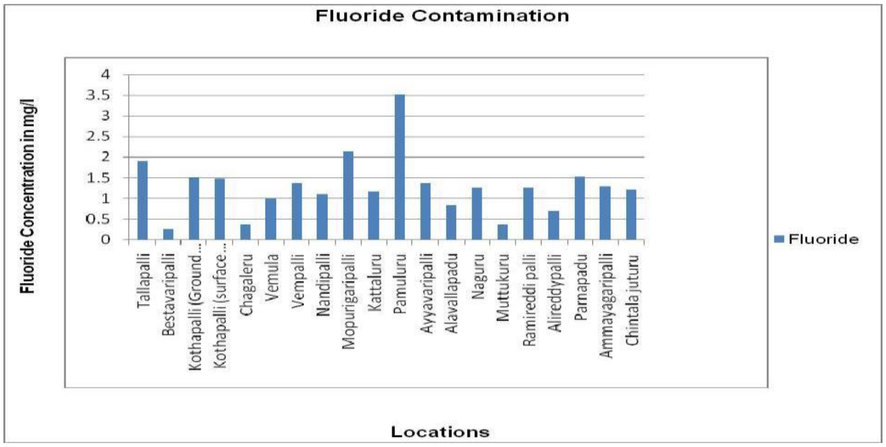


Figure.3 Fluoride concentration in groundwater of Vemula and Vempalli mandals of YSR district, Andhra Pradesh



Conclusion

Fluoride is presence due to fluoride content minerals occurring in soil and rock in the area. Fluorite (CaF2) a common fluoride bearing mineral is present in the Precambrian crystalline in sedimentary rocks of the area. The apatite Occurs in the form of crystals grain in basic igneous rocks such as basalts. Sometimes fluoride concentrates in pegmatitic metallic vein and magmatic intrusion in the Precambrian basement. It is speculated that the circulating groundwater from the basement into the shallow aquifer is responsible for the concentration of fluorite in the groundwater sources of the area. Dental fluorosis is occurring due to increasing percentage of fluoride in water. The groundwater is the main source of drinking water for people of rural areas of Vemula and Vempalli mandals of YSR district, A.P. After evaluating data of fluoride concentration in groundwater, it is clear that the level of fluoride is higher than that of recommended upper limit by WHO and Indian Council of Medical Research. Fluorosis in this region has been appeared as an alarming problem in this region. It is interesting that more than 70% sampling sites showed relatively a higher level of fluoride in groundwater. The occurrence of fluoride may be due to the presence of volcanic flows and volcanic rocks are often enriched in fluorine. Water samples, collected from the basaltic areas do not meet the water quality standards for fluoride concentration. Furthermore fluorine behaves as incompatible element being highly enriched in differentiated volcanic products. In volcanic aquifers elevated temperatures and/or strong acidic conditions enhance water rock interaction process. Such conditions often lead to high concentrations of harmful elements. Further research work in the study area is going on, to assess the groundwater quality in the region and to find remedial measures, so that the water can be made suitable for drinking purposes. Therefore it is high time for the Statutory Bodies to prescribe a standard/limit of fluoride in soil and biological tissues in industrial environment. In addition to this the various authorities operating in the industrial environment should adopt some management strategies to reduce the additional fluoride intake by the people. Some of the activities may include Provision of fluoride free drinking water to the community and Education and Awareness among all sections of people in the study area.

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