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Assessment of fluoride concentration in groundwater of semi-arid region, India

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ABSTRACT

The present work involves assessment of groundwater quality with special reference to fluoride (F^-) concentration in Peddavanka watershed, A.P., India. 56 groundwater samples were collected from hand pumps and analyzed major anions and cations. The F^- concentration varies between 0.4 and 4.4 mg L^{-1} with a mean of 1.74 mg L^{-1} in the study area. Analytical results show that F^- has a positive correlation with pH and negative correlation with Ca. It is indicating that high F^- in groundwater is associated with low calcium content. This suggests that the higher pH of water promotes the leaching of F^- and thus affects the concentration of F^- in the groundwater. The comparison between F^- concentration and WHO standards shows that about 44.64% of samples (25 samples) exceed the recommended value in the study area. The comparison between F^- concentration and USPH standards shows that 75% of samples exceed the recommended value in the study area.

Keywords: Fluoride, Geo-chemistry, Groundwater, Semi-arid region.

INTRODUCTION

According to world health organization [1] standards the recommended concentration of F^- in drinking water is up to 1.5 mg L^{-1}. However, drinking water for a region depending on its climate condition because the amount of water consumed and consequently the amount of F^- ingested being influenced primarily by air temperature. According to US Public Health Service Drinking Water Standards (USPHS) [2] F^- concentration is between 0.6 to 0.8 mg L^{-1}in the study area. The problem of high F^- concentration in groundwater resources has now become one of the most important toxicological and geo-environmental issues in India. During the last three decades many researchers have published several reports on the occurrence of excess F^- in groundwater resources in India [3-10]. In India, an estimated 62 million people, including 6 million children suffer from fluorosis because of consuming F^- contaminated water [11]. F^- concentration in drinking water is behaving like two-edge sward. When F^- concentration consumed in inadequate quantities (< 0.5 ppm) it causes health problems like dental caries, lack of formation of dental enamel and deficiency of mineralization of bones, especially among the children. On the other side, if F^- concentration is consumed or used up in excess (> 1.5 ppm), it causes different kinds of health problems, which equally affect both young and old. Higher F^- concentration exerts a negative effect on the course of metabolic processes and an individual may suffer from skeletal fluorosis, dental fluorosis, non-skeletal manifestation or a combination of the above [12,13]. The incidence and severity of fluorosis is related to the fluoride content in various components of environment, viz. air, soil and water. Out of these, groundwater is the major contributor to the problem. In arid and semi-arid regions most of the peoples depends on groundwater only. Because surface water resources are very meager in these areas, groundwater is the only water resource for drinking and agriculture purposes. F^- incidence in groundwater is mainly a natural phenomenon, influenced basically by the local and regional geological setting and hydro-geological conditions [14]. Some amount of contribution of F^- in groundwater by anthropogenic activities like industrial effluents, mining and application of phosphatic fertilizers in agricultural lands etc. The main sources of F^- in groundwaters are the fluoride-bearing minerals in the rocks and sediments. The important F^- bearing minerals are: Fluorite (fluorspar), Fluorapatite, Cryolite, Biotite, Muscovite, Lepidolite, Tourmaline, Hornblend series minerals, Glucophaneriebeckite, Asbestos (Chrysotile, Actinolite, Anthophyllite), Sphene, Apophyllite, Zinnwaldite, etc.

Therefore, a systematic assessment of F^- in the groundwater is required for the better management of the problems of F^- toxicity. The present study area located in chronically drought prone areas of Rayalaseema districts, in Andhra Pradesh, India. Groundwater is only sources for drinking and agriculture purposes in the study area. In this study, an attempt has been made to analyze the groundwater quality parameters with special emphasis on F^- content in groundwater and to statistically correlate the concentrations of F^- with the other measured parameters.

MATERIALS AND METHODS

Study area: Peddavanka watershed situated in the drought prone areas of Rayalaseema Districts of Andhra Pradesh, south India. The Peddavanka originates in the southern part of Kurnool District and drains through northeastern part of Anantapur district and joins the Pennar River near Chitturu, Anantapur District. The study area falls in the Survey of India Toposheet no. 57 E/11, 12, 16 and 57 F/9 having latitude $15^0$31' to $14^0$93'N and longitude $77^0$57' to $77^0$76'E (fig.1). The total area of the basin is 378 Km^2 and average annual rainfall of the basin is 560 mm.

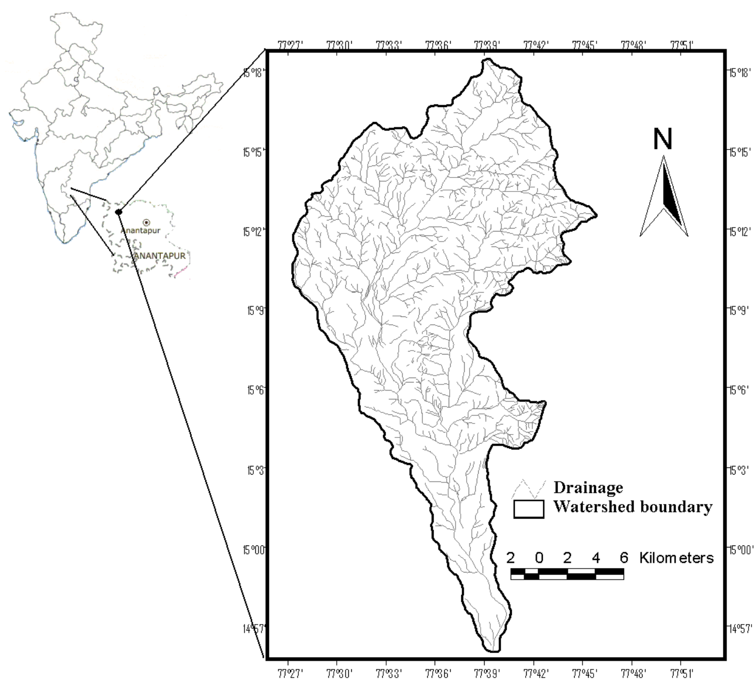

Fig.1 Location map

Geology : The terrain is undulated with several denudational ridges, hills. The area exposes mainly rock types belonging to the Peninsular Gneissic Complex (PGC) of Achaean age, Granites and other basic and acidic Intrusions (fig.2). The PGC is the wider spread and mainly represented by banded and streaky gneisses and granitoids. The gneisses comprise Hornblende – Biotite gneisses, Hornblende gneisses, Biotite gneisses. The granitiods in the form of plutons or dome shaped bodies of varied dimensions are seen amidst the gneisses. These granitoids which are massive and foliated comprise granite and granodiorite [15, 16]. The PGC is intruded by K-rich granites of lower Proterozoic age. These granite bodies which are of varied dimensions are both grey and pink, the latter being younger. Quartz veins and Dolerite / gabbro dykes are seen including all the above mentioned litho units and show various trends. The general trend of foliation in rocks of PGC and metamorphic is NNW-SSE with steep to sub-vertical dips. Joints are seen along NNW-SSE, S-E and N-S trends.

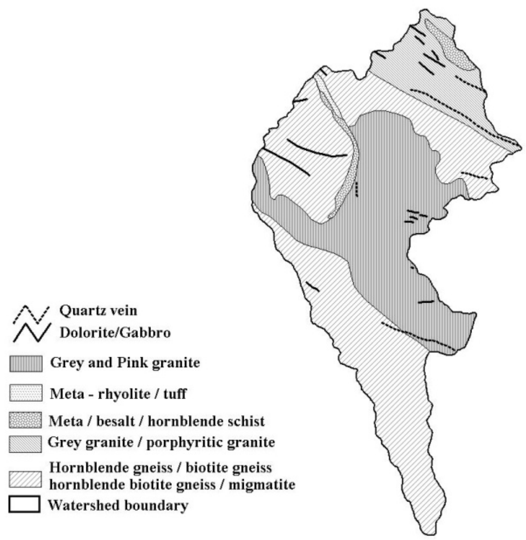

Fig.2 Geology of the study area

Water samples were collected from 56 bore wells. First the water was left to run from sampling source for 4–5 min, before taking the final sample. Samples were collected in pre-cleaned sterilized polyethylene bottles. The groundwater samples were analyzed to assess various chemical water quality parameters such as pH, electrical conductivity (EC), Total Dissolved Solids (TDS), Na^+, K^+, Ca^{2+}, Mg^{2+}, Cl^-, F^-, SO_4^{2-}, CO_3^- and HCO_3^-. pH, EC and TDS were determined by portable pH and EC and TDS meter. Carbonates and bicarbonates were determined using titration method. Other anions and cations were measured using a Dionex ion chromatograph.

RESULTS AND DISCUSSION

Based on the analytical results (table 1) of the samples collected from the study area indicate that the groundwater is generally alkaline in nature (pH 7.4 - 8.8 with a mean of 8.20). The EC values varies from 515 to 6870 with a mean µs cm^{-1} of 1784.37 µs cm^{-1} and total dissolved solids varies from 276 to 3730 mg L^{-1} with a mean of 957.41 mg L^{-1}. Na^+ is dominant cation in the ground water of the study area it varies from 35 to 1799 mg L^{-1} with a mean of 331.50 mg L^{-1}. Ca^{2+} concentration varies from 13.8 to 254 mg L^{-1} with a mean of 66.87 mg L^{-1} and Mg^{2+} varies from 9.3 to 198.30 mg L^{-1} with a mean of 52.29 mg L^{-1}. The K^+ concentration varies from 0.30 to 56.70 with a mean of 4.48 mg L^{-1}. Cl^- is dominant anion its concentration ranges from 14.60 to 2426.30 mg L^{-1} with a mean of 307.30 mg L^{-1}. HCO_3^- is the next predominant anion, with a concentration varying between 174 and 1217 mg L^{-1} with a mean of 486.10 mg

L^{-1}. CO_3^- concentration varies 3 to 75 mg L^{-1} with a mean of 25.47 mg L^{-1}. The F^- concentration varies between 0.4 and 4.4 mg L^{-1} with a mean of 1.74 mg L^{-1} in the study area.

Table 1. Classical statistics of the physicochemical parameters of groundwaters

	N	Mean	SD	Sum	Min	Max
pH	56	8.20	0.36	459.42	7.39	8.81
EC	56	1784.37	1340.40	99925.00	515.00	6870.00
TDS	56	957.41	727.82	53615.00	276.00	3730.00
Na	56	331.50	354.24	18564.10	35.40	1799.20
K	56	4.48	10.025	251.10	0.30	56.70
Mg	56	52.29	40.26	2928.00	9.30	198.30
Ca	56	66.87	50.01	3744.80	13.80	254.00
Cl	56	307.30	476.30	17208.90	14.60	2426.30
HCO_3	56	486.10	209.95	27221.40	173.85	1216.95
CO_3	49	25.47	16.47	1248.00	3.00	75.00
F	54	1.74	1.01	93.82	0.40	4.40

Based on the correlation matrix (table 2) the relation between F^- and pH is significant and a strong positive (r = 0.4579) and indicates that high F containing groundwaters are alkaline in nature. There is an interrelationship between F^- content and pH. This may be due to the ionic radius of F^- (0.136 nm), which is nearly the same as that of hydroxide ion. The two ions commonly substitute for one another in crystal structure. This is further supported by Hem [17] and Dev Burman [18] who found that some mineral surfaces may be capable of absorbing anions (kaolinite, clay minerals, etc.) and if such surfaces carried F^- ions, they could be available for release by substitution of OH ions from waters with a high pH. F^- has a significant and negative (r = -0.2999) correlation with Ca^{2+} which indicates that high F^- in groundwater is associated with low Ca^{2+} content (table 2), this is in agreement with the previous finding [4]. According to world health organization [1] standards the recommended concentration of F^- in drinking water is up to 1.5 mg L^{-1}. The comparison between F^- concentration and WHO standards shows that about 44.64% of samples (25 samples) exceed the recommended value in the study area. Based on US Public Health Service Drinking Water Standards [2] has set a range of allowable concentration for F^- in drinking water for a region depending on its climate condition (table 3) because the amount of water consumed and consequently the amount of F^- ingested being influenced primarily by air temperature [19,20].

Table 2 Correlation coefficient of fluoride with some groundwater quality parameters

	Pearson correlation coefficient
F^- and pH	0.4579
F^- and Ca^{2+}	-0.2999

*p = 0.05

In the Peddavanka watershed the average annual temperature is 27.78^{o}C. Based on USPHS classification (table 3), lower, optimum and upper recommended F^- concentration are 0.6, 0.7and 0.8 mg L^{-1}respectively.

Table 3 Range of recommended Fluoride concentration as per USPHS

Annual average of maximum daily air temperature (^oC)	Recommended fluoride concentration , mg L^{-1}		
	Lower	Optimum	Upper
10-12	0.9	1.2	1.7
12.1-14.6	0.8	1.1	1.5
14.7-17.7	0.8	1.0	1.3
17.8-21.4	0.7	0.9	1.2
21.5-26.2	0.7	0.8	1.0
26.3-32.5	0.6	0.7	0.8

According to USPHS classification low F^- content (less than 0.6 mg L^{-1}) causes dental caries, high F^- levels (more than 0.8 mg L^{-1}) result in skeletal fluorosis. Therefore, water samples are grouped in to three categories with respect to F^- concentration (table 4). Accordingly USPHS classification 75% groundwater samples are not suitable for drinking purpose the F^- concentration is above 0.8 mg L^{-1}. 8.93% have less F^- (<0.6 mg L^{-1}) concentration it causes dental caries and 16.07% samples are suitable for drinking purpose the F^- concentration is between 0.6 to 0.8 mg L^{-1}.

Table 4 Groundwater samples classified as per USPHS

Group	F concentration (mg/l)	Sample percentage
I	< 0.6	5
II	0.6 to 0.8	9
III	> 0.8	42

APPLICATIONS

1. The present work involves assessment of water quality with special reference to F^-.
2. Pearson correlation coefficient of F^- with respect to pH and Ca were calculated. This study helps to determinate the controlling mechanism of F^- concentration in groundwater.
3. According to USPHS standards F^- Concentration in drinking water has been reclassified.

CONCLUSIONS

A majority (44.64%) of groundwater samples in the study area contained F^- in excess (>1.5 mg L^{-1}) of permissible limit . The analytical results show that the high F^- in groundwater is associated with low calcium content. This suggests that the higher pH of water promotes the leaching of F^- and thus affects the concentration of F^- in the groundwater. According to USPHS classification we reclassified permissible limits (0.6 to 0.8 mg L^{-1}) of drinking waters with respect to F^- concentration for avoiding dental and skeletal fluorosis in the study area.

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