SOLUTIONS TO MITIGATE FLUOROSIS IN HUNGUD DISTRICT OF KARNATAKA- INDIA

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ABSTRACT

World Bank estimated that around 260 million people worldwide in 30 countries have been drinking water with > 1 ppm of fluoride. India is one among such countries where 1 million people are affected by endemic fluorosis. This is particularly so in the state of Karnataka where 6 districts, comprising 4.6% of the geographical area is affected with this problem. We report here the problem of fluorosis in Hungud district of Karnataka, a drought prone area, where previous investigation has not been carried out. Fluoride concentration in the groundwater varies from 0.1 to 7.6 ppm, which is well above the limit of 1.5ppm prescribed by the WHO. Groundwater occurring in gneisses has the maximum concentration of fluoride (7.6ppm) and is saturated with fluorite. Granites, Gneiss and schist are the main hard rock aquifers, which contain fluorine-bearing minerals such as fluorite (5% modal) and biotite with 2% of F. Besides natural sources, granite industry is enhancing F in groundwater. The best solution to mitigate this problem is inter-basin transfer of water from the Western Ghats catchment area into the Krishna River basin. Inter-basin transfer of water will reduce the incidence of F in groundwater in other affected regions of the country also. This is possible if only water becomes a "Centre" rather than a "State subject".

1 INTRODUCTION

In India endemic fluorosis has affected over one million people (Teotia et al, 1981). Rajasthan, Andhra Pradesh, Tamil Nadu, Gujarat, Uttar Pradesh, Maharashtra, and Karnataka (Chaturvedi et al, 2002) are a few states, which are severely affected. In Karnataka, six districts (Gulbarga, Raichur, Bellary, Tumkur, Chitradurga and Kolar) have been declared as fluoride endemic (Sumalatha et al.; 1999 Jalihal, 2003). However, recent studies indicate that even Bagalkot and Koppal districts of Karnataka are affected by fluorosis (Jalihal, 2003) and distribution of fluoride in groundwater from these districts has not been reported earlier. The most affected taluks in this district are Hunugund and Kushtagi. The present paper aims at filling this gap and analyses the causes and suggests mitigation strategies to control fluorosis.

2 STUDY AREA

In the interior parts of Karnataka, which fall under rain shadow region, semi-arid climatic conditions prevail while semi-tropical climate dominates the rest of the state. Groundwater is the main source of drinking water, which occurs in hard-rock aquifers at about 30 to 90 m depth and in certain localities in the weathered top zone, and supports a population of 68%. Due to semi-arid conditions, a major part of the litho units are highly weathered promoting high degree of water-rock interaction.

The study area, covering about 1500 Km^2, lies between 75°41' -76°26' E, and 15°46'-16°12' N coordinates and falls in the Hungund taluk of Bagalkot district, and Kushtagi taluk of Koppal district in the northern part of Karnataka state. The area encloses two drainage basins namely Hunugund nala and Ilka nala basins (henceforth HB and IB respectively). Agriculture and handloom industries are the main occupation for the population of these two districts. Due to poor rainfall (600 mm/year; confined to September-November months of the year) and repeated failure of monsoon, these areas experiences severe drought (Chakraborty and Rao, 1990) and the farmers are shifting their activities to granite mining. The annual air temperature in the area varies from 30 to 40 °C in summers and from 20 to 25 °C in winters. The granite blocks mined from these quarries are cut and polished for export and the waste powder is disposed on the ground in small pits, which accumulates rainwater during rainy season. Further, quarry pits are also domain of surface water pools.

3 HYDROGEOLOGY OF THE STUDY AREA

North-south flowing Hungund and Ilkal nalas and their tributaries drain the HB and IB. These nalas discharge into the east flowing Krishna River (Fig. 1).

Water is extracted from both dug wells and bore wells. The dug wells penetrate the weathered portion while the bore wells tap hard rock aquifers from depths varying from 30 to 90 m. The location of the water samples, the geology of the study area and the drainage basin are shown in figure 1. Precmbrian granites and gneiss occupy a large part of the HB and IB. These granites are intruded in to the Archean greenstone, represented in the area by hornblende schists. Small exposures of Kaladgi sandstone and banded iron formation are encountered towards the western par of the basin (Radhakrishna and Vaidyanadham, 1994).

Borehole logs (Jalihal, 2003) indicate a thick10-20 m top weathered layer followed by hard rocks. The weathered layer forms the top unconfined aquifer while the hard rocks form the deep aquifer. A clay horizon, which is normally present between the weathered zone and hard rock, is absent here thus making both the aquifers to establish hydraulic continuity. This inference is supported by lack of appreciable variation in the chemical signature of the water occurring in both the unconfined and confined aquifers. The water samples from dug and bore wells belong to Na-Cl type irrespective of the hydrological season (Jalihal, 2003). Water table in the unconfined zone occurs at about 4 m below ground level while in the hard rocks it occur at greater than 8 m bgl. Due to insufficient rainfall and recharge water levels do not show appreciable variation with season. The dug wells tap the top aquifer while both hand pumps and submersible pumps are being utilized to extract water from the hard rocks through bore wells. The yield of the dug wells is of the order of 25-100 m^3 /day while that of bore wells vary from 2 to 5 l/sec.

4 MATERIALS AND METHODS

Nearly 230 pre-monsoon, monsoon and post monsoon water samples were collected from dug and bore wells in the year 2000 (May- summer) and 2001(November- immediately after rains) and analyzed for its major ions following the methods of APHA (1981) and fluoride content was measured using Orion ion selective electrode. Major and trace elements in 40 rocks, 20 soil and 2 granite powder from the granite polishing industry were analyzed following the methods of Shapiro and Brannock (1982). Water-rock interaction experimental investigation using granite, granite powder and meteoric water has been carried out to understand the mechanism of fluorine leaching from the rocks. Mineral saturation indices in water samples have been calculated using WATEQ4F computer programme (Ball and Nordstrom, 1979).

5 RESULTS AND DISCUSSIONS

The chemical analyses of waters samples from dug, bore wells, infiltration gallery and surface water bodies are given in table 1. The F^- concentration in water samples from different hard rock aquifer is as follows: granite/gneiss aquifer- 0.2 to 7.6 ppm; schist - 0.1 to 6.1; sandstone- 0.1. Water accumulated in granite quarry pit registered the highest content of F^- of 8.1 ppm. Mineral speciation indices results indicate that all the samples are saturated with respect to fluoride in summer while immediately after rainy season they are under saturated with fluorite (Table 3).

Based on the above data fluoride zone maps have been prepared to identify fluoride endemic zones (Fig. 2). Three zones in were identified which showed very high fluoride concentration (0.2 to >5 ppm), irrespective of seasons. These maps indicate that in Hungund taluk, covering an area of 1379 Km^2, 2.5 lakh people are affected by fluorosis. The worst affected villages are Sebanakatti, Manerhal, located on the bank of Hungund nala (F^- ~4 6 ppm) and Benakandoni located on the bank of a tributary of Ilkal nala (F^- ~6.5-7.6 ppm; Fig. 2). The effects of fluorosis are visible among children of ages between 5-12 years.

6 SOURCE OF FLUORIDE

As evident from table 3, the groundwater in the study area shows saturation with respect to fluorite in summers while immediately after rains they are under saturated with this mineral.

As mentioned above, variation of F^- in samples occurring in different lithologies and high content of F^- in water samples from granite quarry pit clearly demonstrates that the F^- in groundwater is fully controlled by the local lithology. In addition to the chemical data shown above in table 1, all the granite/gneiss samples contain fluorite in modal proportion varying from 5 to 10% and F content in these rocks varies from 1413 ppm in granite/gneiss to 1234 ppm in soil occurring over these rocks. Further positive correlation between TDS, Cl and F in the bore well as well as dug well samples clearly demonstrates that long residence time of waters in the hard rock aquifers is promoting longer water–rock interaction process there by increasing the concentration of F^- in their respective waters. Residence time of the water samples in the hard rock aquifers, calculated using Tritium values is about 85 years (unpublished data).

Water-rock interaction experimental data on granite/gneiss and granite powder and rainwater clearly indicate that prolonged contact time between the rock and the water is enhancing F^- content in the reacted waters (Table 2). Further, same experiments conducted using 0.05% NaCl in the initial water resulted in higher content of F^- in the reacted solutions (Table 2). Water sample reacted with granite powder showed the maximum content of F^- in the reacted water. Mobility of fluoride was highest in weathered granite as compared to fresh granite. Also as compared to fresh rock, granite powder (JB9 Gr Pw) was able to release higher amounts of fluoride into the groundwater due to a larger surface area of the rock particles. The experimental evidence clearly points towards the granite/gneisses as the major source of high fluoride levels in the groundwater. Further, high residence time as indicated by positive correlation between Cl, TDS and F corroborates with the 0.05% NaCl experimental results.

7 REMEDIAL MEASURES

It is apparent that prolonged drought condition and long contact between water and the aquifer material is enhancing F^- levels in groundwater. Reduction in F^- content in groundwater is possible by flushing the aquifers with large input of fresh water. This inference is based on the saturation levels of groundwater with fluorite during summer and rainy seasons (Table 3). It is not possible to achieve this unless there is an increase in the annual rainfall in this region, which is beyond human control. The second option is to divert water from the west flowing rivers in Western Ghats to the Krishna river basin. Krishna River originates in the Western Ghats, at an altitude of 1,336 meters near Mahabaleshwar in Maharashtra. Out of its total length of 1400 Km, 704 Km lies in Karnataka (about 43.74 % of its basin lies in Karnataka) draining 13 districts of the state covering a geographical area of approximately 60 %. The annual rainfall at the catchment area of the river is greater than 3000 mm and most of the rain falls on the western side of the basin. Assuming 10-15% of infiltration, the remaining water flows into the Arabian Sea as surface run-off. Larger recharge into the aquifers in these regions is not possible since the terrain is covered with hard and massive volcanic flows. Out of the remaining 90-85 %, even if 20 % is diverted in to Krishna basin, it will enhance the subsurface flow and thus flush the long residing high F^- water. Implementation of this process requires government intervention. If "water" is brought under central government "subject" many such problem can easily be solved thus saving millions affected by fluorosis in the State. As on today it is a "state subject" and individual States exercises its own rights in matters related to sharing of water from one basin to its neighbour. With regard to the incidence of F^- due to granite mining, this problem can be solved immediately if leasing the areas for mining is restricted or controlled

Table 1.1 Chemical analyses (range) of surface and subsurface water samples.

	DW	BW	IG	L W	R W
pH	7.0-9.0	7.0-9.1	8.0-8.7	6.5-7.5	7.0-7.2
TDS	375-10073	247-10393	776-1657	193-288.6	360
F	0.14-7.44	0.2-7.6	0.9-1.78	0.2-8.11	0.2-0.48
Ca	24-733	8.02-553	24-120	24-48.1	30-48.1
Na	62.5-4073	42.5-4600	247-625	12.6-235	58-107
Mg	4.8-530	0-440	9.6-57	0-19	23-56
K	0.8-362	0.2-552	4-12.3	1.8-3	2.4-5.5
HCO_3	150-1170	139-2064	180-380	60-200	158
SO_4	69-6069	53-3810	152-796	59-169	150-155
CO_3	0-260	0-180	0-60	0	0
Cl	4.8-3571	9.9-4944	60-428	17-289	103-144

Concentration in ppm. Charges are not shown due to lack of space.

DW: Dug well; BW: Bore well; IG: Infiltration gallery; LW: Lake water; RW: River

Table 2. Water -rock interaction experimental data

Sample	30	66	110	137	181
J9B Gr W	3.2	3.7	4.4	nd	nd
J9B Gr F	0.8	0.8	0.9	1.14	1.16
J9B Gr Pw	1.5	1.6	1.9	2.0	2.8
BD1Gn	0.1	0.1	0.2	0.3	0.4
J9B Gr+0.05%NaCl	1.1	1.3	2.2	nd	nd

Gr: Granite; W: weathered; F: Fresh; Pw: Powder; Gn: Gneiss *: contact time in days; nd: data not available

Table 3. Mineral saturation indices for water samples (May 2000).

Well No	Fluorite- S	Fluorite- R
46	0.25	-6.27
50	0.02	-0.17
51	0.25	-0.41
65	0.12	-0.43
79	0.18	-0.49
84	1.04	-0.98
130	1.01	-1.16

For well location- see Fig 1.

S. May 2000 summer; R. November 2001: rainy season.

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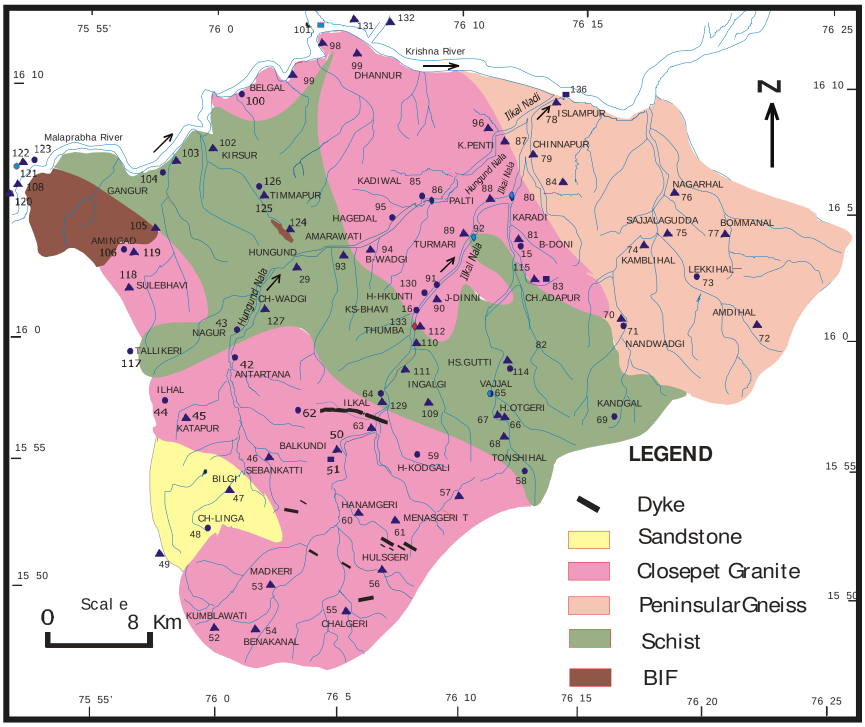

Figure 1. Map showing the geology and well locations from the study area.

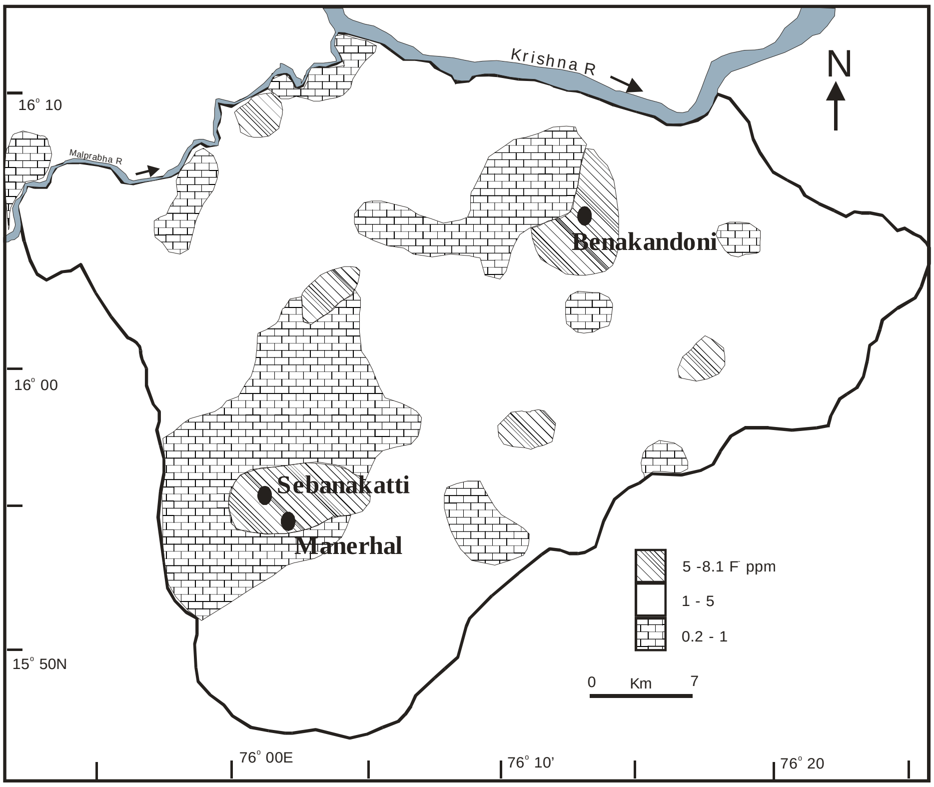

Figure 2. Fluoride zones map of the study area.