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Environ Geochem Health
DOI 10.1007/s10653-016-9869-2

ORIGINAL PAPER

Groundwater fluoride contamination and its possible health implications in Indi taluk of Vijayapura District (Karnataka State), India

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Received: 1 April 2016 / Accepted: 26 August 2016
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Abstract Groundwater fluoride concentration and fluoride-related health problems were studied in twenty-two villages of Indi taluk of Vijayapura district, Karnataka, India. Present study (2015) was also used to compare groundwater fluoride concentration in same 22 villages with previous government report (2000). Groundwater fluoride concentrations of 62 bore wells of 22 villages were analyzed by using an ion-sensitive electrode. A total of 660 adults and 600 children were screened for fluorosis symptoms and signs. Sixty clinically suspected fluorosis patients' urine samples were further analyzed for fluoride. The mean value (1.22 ± 0.75 mg/L) of fluoride concentration of 62 bore wells and 54.83 % bore wells with $\geq$1.0 mg/L of fluoride concentrations in Indi taluk indicates higher than the permissible limit of drinking water fluoride concentration recommended for India. Clinical symptoms like arthritis, joint pains, gastrointestinal discomfort and lower limb deformities with high urinary fluoride concentrations in some subjects

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Published online: 03 September 2016

suggest fluorosis. Results also showed an increase in groundwater fluoride concentration of the same 22 villages between previous and present study. Preliminary arthritis symptom of the villagers could be due to drinking fluoride-contaminated water. Increase in fluoride concentration with time to the bore wells definitely indicates future danger.

Keywords Groundwater fluoride concentration · Rural Karnataka · Skeletal fluorosis · Urinary fluoride · Dental fluorosis

Introduction

Fluorosis is the most prevailing groundwater-related disease in India and China. In India, 20 out of 29 states have some extent of groundwater fluoride contamination, impacting 85–97 % of districts in some states. In Rajasthan State, 32 out of 33 districts are fluoride-affected. In Gujarat State, it is 24 out of 26 districts. It has been reported that total 201 districts in India are known to have fluoride contamination with affected population of 411.4 million (Chakraborti et al. 2011). Even now, we continue to identify additional habitations affected by groundwater fluoride in affected districts.

Fluoride-bearing rocks are abundant in India. Fluoride leaches out and contaminates the adjacent water and soil resources. The concentration of fluoride in drinking water depends mainly on the basic chemical composition of soil, the time of contact between the source of minerals and the water, leaching of fluoride from rocks, calcium-poor aquifers, volcanic rocks, granite rocks and the amount of water withdrawn from the source over a period of time. Generally, surface water has low fluoride content while groundwater possesses an enormous concentration of fluoride. River water near industries or mines like bauxite, graphite, aluminum, phosphate and fertilizer does contain high fluoride, but groundwater is the single biggest contributing factor for the spread of fluoride and fluorosis (Hem 1970). Gautam et al. (2010) and Ranjan and Yasmins (2015) have reported enrichment of fluoride in crops and vegetables in fluoride-affected areas in India. Animals, especially domestic animals, also become vulnerable due to consumption of water and straw is laced with fluoride (Dahariya et al. 2015).

The 1984 guidelines published by the World Health Organization (WHO) suggested that in tropical climate, the optimal concentration of fluoride (F^-) in drinking water should remain below 1.0 mg/L while in relative cooler climate, it could go up to 1.2 mg/L (WHO 2011). In India, the permissible upper limit was lowered from 1.5 to <1.0 mg/L in 1998 although sufficient evidences are available to prove that constant exposure to fluoride even at the level of 0.7 mg/L could lead to fluorosis and other allied diseases (Panda and Kar 2014). At concentrations of above 1 mg/L, fluoride in drinking water can be positively risky to human health and lead to dental and skeletal fluorosis. Fluorosis can cause mottling of the teeth, calcification of ligaments, crippling bone deformities and many other physiological disorders that might ultimately result in death (WHO 2011). Fluorosis of India was first identified in Nellore district of Andhra Pradesh in 1937 (Shortt 1937). Since then considerable work has been done in different parts of India to explore the fluoride-laden water sources and their impacts on human as well on animals (Padmavathy et al. 2002; Gupta 1999; Choubisa 1997; Dwarkanath and Subbaram 1991; Pandit et al. 1940). The extent of fluoride contamination in groundwater varies from 1.0 to 48 mg/L (Suneetha et al. 2015). Fluoride in groundwater is more common in crystalline igneous rocks and alkaline soils located in semiarid climate which exist in the northwestern parts of the Karnataka State in the district of Bijapur (Farooqi et al. 2007). Uptake of fluoride by bone occurs in stages. The first stage involves fluoride migration into the hydration shells of bone crystallites. These ion-rich aqueous shells are continuous with, or at least available to, the extracellular fluids. Fluoride in this pool is rapidly exchangeable and can undergo net migration in either direction, depending on the relative concentrations in the extracellular fluid and the hydration shells. Later stages involve fluoride association with or incorporation into precursors of hydroxyl fluorapatite and finally into the apatitic lattice that itself become apatitic fluoride and reenters the circulating body fluids as a result of the long-term process of bone

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resorption (Whitford 1994). Fluorosis is a slow and progressive process causing adverse effects on several physiological systems including musculoskeletal system (Oncu et al. 2008).

Groundwater is a major source of drinking water in rural Karnataka. As Gulbarga district of Karnataka is found to be a fluorosis endemic area and Vijayapura (aka Bijapur) is border district with Gulbarga, groundwater fluoride contamination and possibilities of fluorosis in Vijayapura district were well expected (Nawlakha and Paramsivam 1993; Susheela 1999). It was revealed from Karnataka State status report regarding National Programme for Prevention and Control of Fluorosis that 18 districts out of 30 districts of Karnataka are affected by fluorosis which covers 20,390 villages (NPPCF 2014). While the expansion of number of fluoride-affected areas is more reported, at the same time lack of awareness of the danger of fluoride toxicity and negligence in monitoring fluoride contamination have made rural population in India vulnerable to bear the brunt of this crippling disease (NPPCF 2014).

The present study was undertaken to assess the groundwater quality including fluoride concentration and its effects on health in the population that used the bore well water for drinking and cooking in 22 villages of Indi taluk of Vijayapura (aka Bijapur) district of Karnataka. The study also aims to assess and compare the prospective changes in groundwater fluoride concentration in same 22 villages in present study and the study report submitted by the BLDE Association's technical experts to the Government of Karnataka in the year 2000.

Materials and methods

Study area

The study has been conducted during pre-monsoon period of 2015 in 22 villages out of total 110 villages of Indi taluk randomly selected according to statistical guidelines. Indi is a underdeveloped taluk (population of 421,407) in Vijayapura (aka Bijapur) district situated in the northern part of Karnataka State, India. It is located 53 km toward north from district headquarters Vijayapura (aka Bijapur) and 584 km from Karnataka State capital Bangalore. Indi taluk is bounded by Sindagi taluk toward east, Afzalpur taluk (Gulbarga district) toward west, Vijayapura taluk toward south, Akkalkot taluk toward north Maharashtra State border (Fig. 1). Total population of 22 villages surveyed for groundwater quality analysis is 88,725 (Census 2011). GPS locations of each of the bore well of all the surveyed villages of Indi taluk were recorded. We collected water samples from all the available bore wells ($n = 62$) of 22 villages which are the only sources of drinking water of these villages. The water samples of 2000 were collected by different group of experts from the same institution, i.e., BLDE Association's V.P. Dr. P.G. Halakatti College of Engineering and Technology. The study of 2000 was done under the sponsorship of Government of Karnataka, and it was conducted for all the 110 villages of Indi taluk during pre-monsoon season. During 2000 study, GPS location was not recorded; hence, we could not get clear picture whether studied bore wells of 22 villages in present study were corroborating with previous study of 2000 in the same 22 villages. In the study of 2000, the total number of water samples from the bore wells of same 22 villages studied was 70 ($n = 70$).

Ten percentage of the households were randomly selected from all the surveyed 22 villages, and all the adult members (aged 18–75 years) in the households were surveyed making a total around 660 (male 360, female 300). Besides clinical evaluations for general health among population in all the ages of male and female subjects, we have noted dental observations among young school-going children (age 3–17 years, $n = 600$; male 315, female 285) from ten villages. Based on clinical observations, we have also collected 60 clinically suspected fluorosis subjects' urine samples for further analysis. Total survey covers 1260 (adults 660; children 600) subjects.

Analytical

Well water and urine samples were collected in 10-ml polyethylene bottles pre-washed with nitric acid and water (1:1). Fluoride concentrations of water and urine samples were measured using an ion-sensitive electrode (Model 720A; Orion, Cambridge, MA) at BLDEA's V.P. Dr. P.G. Halakatti College of Engineering and Technology, Vijayapura, and samples were also sent for external quality control at SOES laboratory, Jadavpur University, Kolkata, India. An aliquot of 3 mL TISAB II buffer (Orion Application

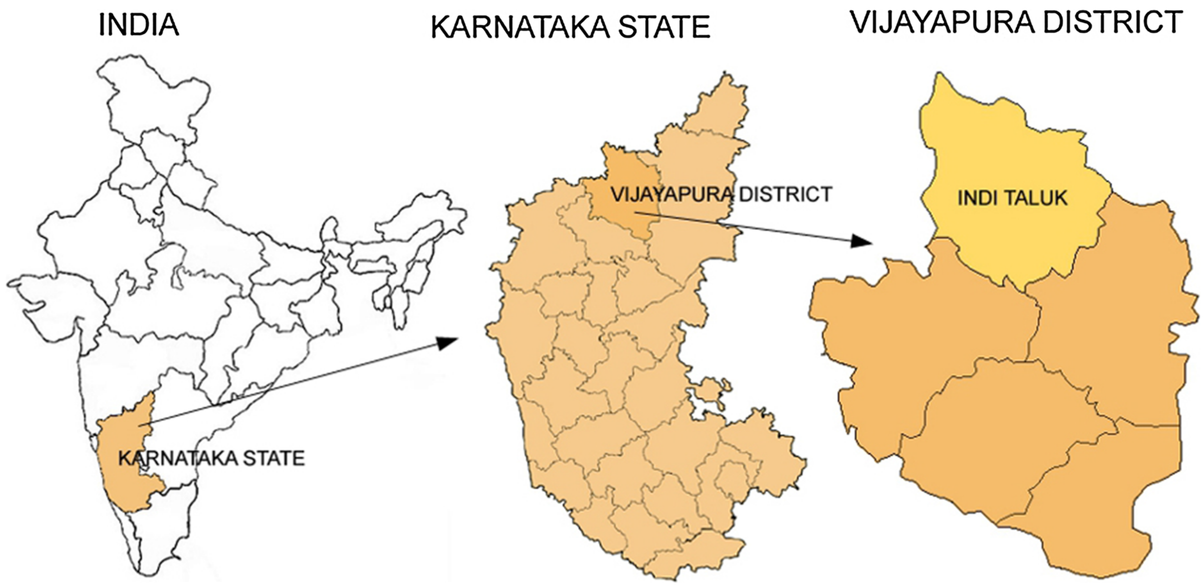

Fig. 1 Location map of the study area (Indi)

Solution) was added to 4 mL samples of well water. Standard fluoride solutions of concentrations ranging from 0.05 to 10 mg/L were used to make a standard calibration curve. Diluted standards were prepared through a series of dilutions from a standard stock solution containing 1000 mg F^-/L (Orion Research Inc., Cambridge, MA) (Nayak et al. 2009). The values of BLDEA's of both Engineering College Vijayapura and Jadavpur University, Kolkata, were routinely cross-checked on random samples, and the data were accepted after finding the positive correlation between the two values.

For urine F analysis, nocturnal urine from each subject was collected in the morning at the first micturition and a daytime collection from morning to late afternoon followed. In this way, two collections of time-controlled urine covering roughly 24 h were obtained. We have calculated urinary flow rate from volume per 24 h per kg bodyweight of individual. It will directly account for hydration status variations of individual (Hays et al. 2015).

Authors used the 1, 10-phenanthroline method with an UV–visible spectrophotometer for iron analysis of water samples (Fries and Getrost 1975). Acceptable water and urine F^- concentration in India is considered as <1.0 mg/L (Nayak et al. 2009). Ca+ and ion concentrations were measured by titrimetric method using EDTA solution.

All the water samples collected in this study area were clear without any visible color, odor and turbidity. The data obtained after analysis of all the samples of bore well water and urine are compiled and presented in Fig. 2.

Clinical observations

Each person was interviewed using semi-structured questionnaire information about their morbidity, and it was recorded. A team of specialist doctors examined movements of the large joints, spine, general health, chest and physical anthropometry and any skin-related problems of the subjects. The team members also visited pre-primary, primary and secondary schools to examine children for their general health and dental fluorosis. The diagnosis of dental fluorosis was based on typical tooth discoloration. Adults between the ages of 18 and 64 years were tentatively diagnosed as skeletal fluorosis if they had pain, stiffness and deformity of the joints and spine with or without nodular stiff swelling over limbs. All clinical findings were recorded. The study protocol followed all the ethical norms and was approved by Institutional Ethical Committee (IEC) of BLDE University, Vijayapura, Karnataka, India.

All the values of F^- concentration in 22 villages were compared with the values from previous reports

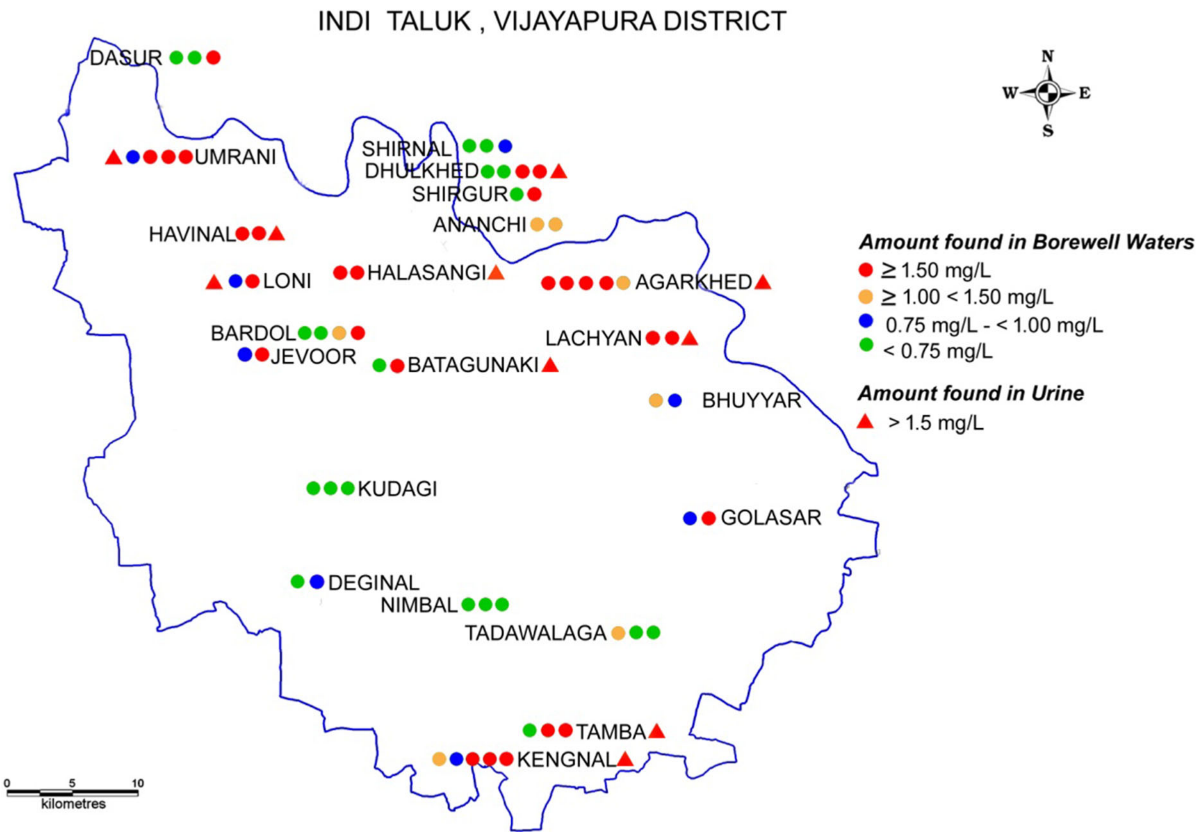

Fig. 2 Distribution of bore well and urine fluoride concentration in 22 villages of Indi taluk

of BLDE Association's V.P. Dr. P.G. Halakatti College of Engineering and Technology for Government of Karnataka (2000). The data were analyzed by using appropriate statistical tools, and $p < 0.05$ is considered as statistical significance.

Results

Groundwater F^{-} concentration analysis

A total of 62 bore well samples water from 22 villages of Indi taluk (Karnataka) were analyzed (Table 1). Results clearly show that the average F^{-} concentration of 62 bore well water of 22 villages of Indi taluk is definitely higher than the normal recommended value for fluoride concentration in water.

Samples also reveal that 54.83 % of bore well water were having higher fluoride value ($\geq$1.0 mg/L) as per Indian permissible values for drinking water (Fig. 3). It is also interesting to note that 43 % of surveyed bore wells are having F^{-} concentration $\geq$1.50 mg/L which is considered far above the permissible limit even for international standard (Fig. 3).

The depth of bore wells and their respective water F^{-} concentrations were correlated, and there was no correlation noticed (Fig. 4).

But when the groundwater pH and F^{-} concentrations were analyzed, a positive correlation was observed between these two parameters (Fig. 5). Interestingly, we did not find any correlation between F^{-} concentrations and calcium level in bore well water (Fig. 6), but we have found a negative correlation between groundwater F^{-} concentrations and iron (Fe) level (Fig. 7).

Clinical features analysis

A total of 660 people were examined, and 60 (35–65 years) had shown clear signs of clinical fluorosis. These patients had chronic pain in the back and other joints with tenderness and restricted

Table 1 Fluoride concentration in water and urine samples of 22 villages of Indi taluk of Karnataka (India)

Parameters	Fluoride in water (mg/L) bore well ($n = 62$)	Urine F (mg/L) patients ($n = 60$)	Urine fluoride excretion rate (μg/F/24 h/kg)
Mean ± SD	1.22 ± 0.75	0.76 ± 0.43	2.45 ± 1.34
Median	0.94	0.58	
Maximum	3.53	3.41	
Minimum	0.26	0.34	
Sample having F^- > normal limit (≥1.0 mg/L)	34 (54.83 %)	16 (26.66 %)	

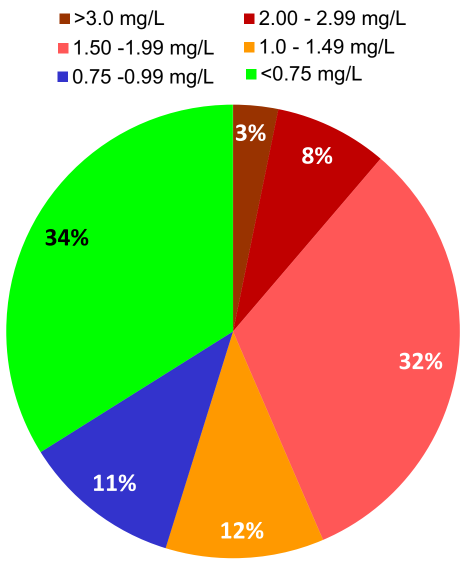

Fig. 3 Fluoride concentration among 62 bore wells in percentage

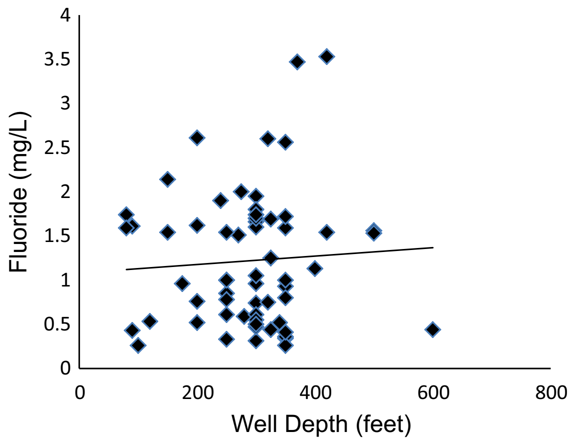

Fig. 4 Relationship between well depth (ft) and F level of bore wells ($n = 62$) of Indi taluk. Correlation (r) = 0.06; $p > 0.05$

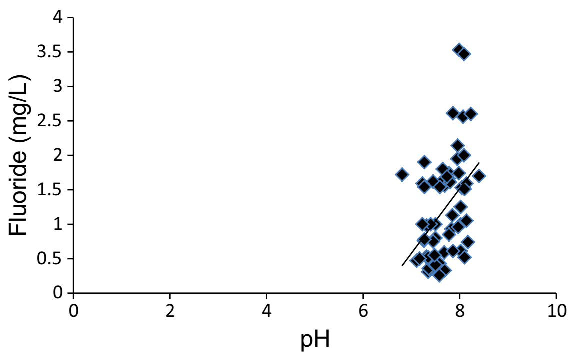

Fig. 5 Relationship between groundwater pH and F of bore wells ($n = 62$) of Indi taluk. Correlation coefficient (r) = 0.42; $*p < 0.05$

mobility; majority of them had severe backache and flexion deformities of the spine, hip and knee (Fig. 8). Urine analysis from the clinically suspected fluorosis subjects ($n = 60$) shows that around 16 (26.66 % among suspected fluorosis) of them are having high urinary F^- concentration (≥1.75 mg/L) (Tables 1, 2). Interestingly, five patients reported having painful skin changes while tapping on the skin and one patient complained of severe itching sensation (Table 2).

Table 3 depicts dental status of children (aged 3–17 years). Results clearly indicate dental fluorosis among these children (Fig. 9). Table 3 also depicts that out of 600 surveyed children, 438 had signs of dental fluorosis (73.00 %). Male children (83.1 %) were found to be more affected than females (61.75 %).

It is also interesting to note that the villages which showed high-mean groundwater F^- concentrations had

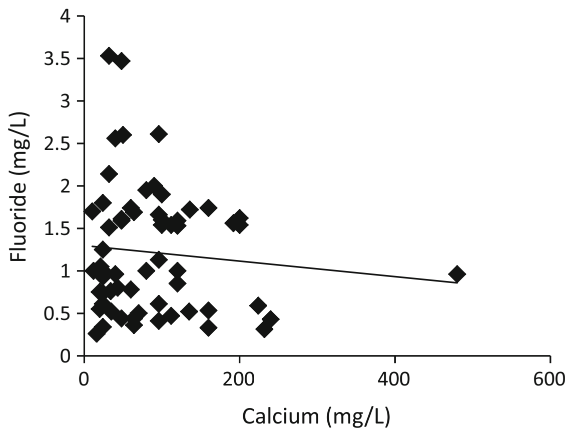

Fig. 6 Relationship between groundwater F and calcium of bore wells ($n = 62$) of Indi taluk. Correlation coefficient $(r) = 0.094$; $p > 0.05$

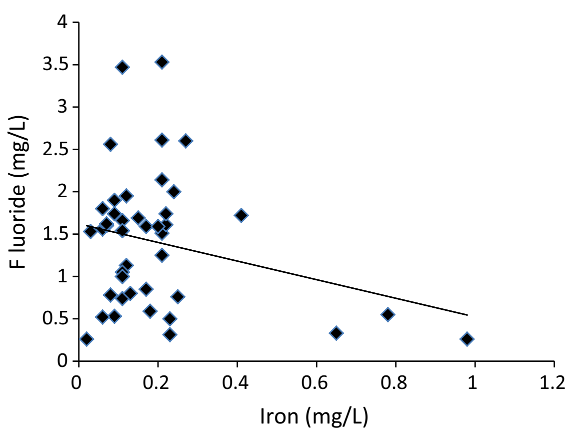

Fig. 7 Relationship between groundwater fluoride and iron (Fe) of bore wells ($n = 44$) of Indi taluk. Correlation coefficient $(r) = 0.26$; $^{*}p < 0.05$

more cases of possible fluorosis among adults (Table 2) and had high dental fluorosis among children (Table 3).

A comparative analysis between the year 2000 and current study (2015) is provided in Table 4.

To further strengthen our findings, we compared our observations with a previous study done by BLDE Association's V.P. Dr. P.G. Halakatti College of Engineering and Technology during the year 2000 for the same twenty-two villages of Indi taluk (BLDEA 2000). As the previous study (2000) on the F^- concentrations of bore wells of same 22 villages did not use GPS location of bore wells unlike our study (2015), we have taken the maximum, minimum and

Fig. 8 Deformities of lower limbs of a patient (Agarkhed)

median values of concentration of fluoride found in bore wells of each village during previous (year 2000) and current study (year 2015) (Table 4). The 0.94 ± 0.54 is the median of F concentration of the water samples of 2015 survey of Indi taluk, whereas 0.44 ± 0.17 is the median of F concentration of water samples from 2000 survey of same villages (Table 4).

We have also considered mean ± SD of F^- concentrations of total surveyed bore wells of each of the 22 villages during the year 2000 and 2015 to assess whether the mean concentration of groundwater fluoride in each of the 22 villages has changed during these periods (Fig. 9).

Results clearly reflect an average rise of F^- concentration in groundwater for most of the studied twenty-two villages of Indi taluk between the years 2000 and 2015.

Discussion

Groundwater fluoride and its impact

The groundwater generates under water table and semi-confined to confined conditions in weathered, cracked zones in basalts, limestone, shale, ortho-quartzites, sandstones, granites and gneisses. The Deccan traps/basalts are the major litho-unit of the Indi taluk. The basaltic lava flows are mostly

Table 2 Clinical and urinary findings of 16 patients of Indi taluk of Vijayapura district

Village	Age (years)	Sex	Complaints	Physical findings	Urinary findings (mg/L)
Agarkhed	38	M	Severe backache, limping, inability to sit on the ground, bending deformity of the back and hips	Tenderness and dysfunctions over SI joints and LS junction; gross restriction of spinal, hip and shoulder movements; evidence of bone loss	3.41
-do-	43	M	Joint pain, muscle weakness, shoulder and hip join pains	Kyphosis, tenderness and dysfunctions over SI joints and LS junction, hips and shoulders; *painful skin changes*	2.86
-do-	37	F	Joint pain, muscle weakness, backache, knee pain, deform knee, sleep disturbances	Skeletal fluorosis weakness of bones, stiffness of joints, sporadic pain, limitations of movements	2.63
Lachyan	43	M	Muscle weakness, knee joint pain, deformities, difficulties in squatting, sporadic back pain	Skeletal fluorosis weakness of bones, stiffness of joints, kyphosis, *itching.*	2.87
-do-	38	F	Body pain, walking difficulties, sleep disturbances, stiffness	Swelling, tenderness over SI join, skeletal fluorosis	2.65
Halasangi	45	M	Backache, weakness of the lower limbs, tingling sensation over both legs, inability to stand or walk	Kyphosis of DL spine with tenderness over SI joints and LS junction, hips and shoulders	3.12
Loni BK	38	M	Joint pain, muscle weakness, backache, knee pain, sleep disturbances	Kyphosis of DL spine with tenderness over SI joints and LS junction; *painful skin changes*	2.45
Umrani	40	M	Back pain, deformities	Kyphosis, bone weakness, difficulties in movements	2.89
-do-	41	M	Muscle weakness, knee joint pain, deformities	Tenderness and dysfunction over SI joints and LS junction; gross restriction of spinal, hip and shoulder movements; evidence of bone loss	2.65
Dhulkhed	35	M	Joint pain, restricted movements, muscle weakness	Kyphosis of DL spine with tenderness over SI joints., evidences of bone loss	3.10
-do-	45	M	Body pain, walking difficulties, Sleep disturbances, stiffness	Kyphosis, bone weakness, difficulties in movements	2.80
Bhatagunaki	40	M	Muscle weakness, knee joint pain, deformities	Tenderness over SI joints and LS junction; gross restriction of spinal, hip and shoulder movements, *painful skin changes*	2.95
Tamba	38	F	Back pain, deformities	Kyphosis, bone weakness, difficulties in movements, sleep disturbance, unable to squatting, *painful skin changes*	2.86
-do-	36	M	Joint pain, muscle weakness, backache, knee pain, sleep disturbances	Kyphosis of DL spine with tenderness over SI joints and LS junction; *painful skin changes*	2.40
Kenginal	45	F	Muscle weakness, knee joint pain, knee deformities	Tenderness over SI joints and LS junction; gross restriction of spinal, hip and shoulder movements	2.50
Havinal	40	M	Back pain, knee deformities	Kyphosis, bone weakness, difficulties in movements, itching	1.75

LS lumbosacral, *SI* sacroiliac, *DL* degenerative lumbar spine

horizontal to dip gently vertical. The contrasting water-bearing properties of different lava flows control groundwater occurrence in them (Central Ground Water Board 2008). The Vijayapura (aka Bijapur) district is basically a semiarid climate with extreme summers. Due to insufficient rain, the incidence of

Table 3 Dental findings in children (aged 3–15 years) in ten villages of Indi taluk of Vijayapura district = 600; male 315; female 285)

Village	Chalky white color		Yellowish stain		Browning of the tooth surface		Deep brown or black discoloration		Loss of teeth	
	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female
Agarkhed	13	08	10	08	07	02	04	02	06	04
Lachyan	07	05	09	05	05	03	03	02	05	05
Halasangi	03	02	03	02	04	02	01	01	05	03
Loni	05	03	06	05	05	03	03	02	03	04
Umrani	13	07	07	01	03	05	04	03	06	03
Dhulkhed	06	06	05	01	05	05	04	03	06	03
Bhatagunaki	08	06	05	02	06	05	05	03	04	03
Tamba	07	05	06	02	07	06	06	04	05	01
Kenginal	07	06	03	01	04	05	03	03	01	01
Havinal	05	04	05	03	02	05	05	02	02	01
Total	74	52	59	30	48	41	38	25	43	28

Total 438 children had dental fluorosis (73 %); male 262 (83.17 %); female 176 (61.75 %)

Fig. 9 Possible dental fluorosis (Halasangi)

drought is very common in this part of Karnataka State. In a study by the Central Ground Water Board Information (2008) of Government of India, it was found that Indi taluk was having only 37.6 rainy days on an average with 505.4 mm average rainfall (2008). It is also reported that the groundwater table of Indi taluk goes in the deepest just before the beginning of monsoon and reaches a peak a little before the cessation of monsoon. There after the groundwater table shows a waning drift.

Results from our study show a high level of F^- concentration in groundwater levels of surveyed bore wells of twenty-two villages. During summer, the temperature of entire Vijayapura (aka Bijapur) district including Indi taluk remains on an average 40 ± 2 °C (Central Ground Water Board 2008), since the major source of drinking water is from bore well in majority of the rural villages in the district and high temperature leads to excess consumption of drinking water, which might augment the intake of fluoride and results in high urinary F^-. The F^- concentration depends on the geological rocky structures (Taher and Ahmed 2001). Indi taluk being situated in Deccan basalts and rocky by nature might have contributed to fluoride levels in studied bore well water. Our report is further supported by correlation between F^- concentration and pH of all the bore wells in present study (Fig. 5). Normally, high pH level of water displaces F^- ions from the mineral surfaces and enhances groundwater F^- concentration (Bhattacharjee and Sharma 1992). Although the pH level of water has no direct human health impact but its range changes many biochemical reaction in the body, pH value 7.0 is considered as safe.

Interestingly, we did not find an expected inverse correlation between groundwater fluoride concentration and calcium level. The results seem to be unique by nature. Our results indicate that many bore wells of our studied twenty-two villages have both high fluoride and calcium level simultaneously which is rare in occurrence (Fig. 6). Central Ground Water Board information of Government of India mentioned that Vijayapura (aka Bijapur) district has excess F^- concentration which is ranging from 0.3 to 4.8 mg/L and Dhulkhed, Tamba villages of Indi taluk were

Table 4 Comparative analysis of F^- (mg/L) concentration level in 22 Villages of Indi taluk during 2000 and 2015

Sl. no.	Villages	Fluoride concentration (range, mg/L)								Remarks
		BLDEA's report to Government of Karnataka (2000)				Current observations (2015)				
		Bore well ($n = 70$)	Min	Max	Median	Bore well ($n = 62$)	Min	Max	Median	
V1	Agarkhed	4	0.28	0.39	0.35	5	1.13	3.53	1.53	Increased
V2	Shiragur	3	0.40	2.00	0.45	2	0.31	1.66	–	Unchanged
V3	Lachyan	3	0.31	1.20	0.45	2	1.66	2.61	–	Increased
V4	Halasangi	3	0.36	2.64	0.45	2	1.59	3.57	–	Increased
V5	Bardol	3	0.38	0.40	0.40	4	0.61	1.51	1.00	Increased
V6	Loni B K	4	0.29	1.70	0.32	2	0.93	2.56	–	Increased
V7	Umrani	3	0.25	0.38	0.30	4	0.96	2.14	1.61	Increased
V8	Dhulkhed	3	0.37	3.87	0.50	4	0.43	1.74	0.59	Unchanged
V9	Shirnal	3	0.43	0.53	0.21	3	0.33	0.85	0.53	Unchanged
V10	Bhatagunaki	3	0.00	0.62	0.23	2	1.54	1.59	–	Increased
V11	Kudgi	3	0.26	0.50	0.28	3	0.26	0.36	0.34	Unchanged
V12	Nimbal	3	0.29	0.40	0.33	3	0.44	0.47	0.44	Unchanged
V13	Tamba	3	0.36	1.00	0.50	3	0.41	1.80	1.72	Increased
V14	Golasar	3	0.10	0.43	0.22	2	0.96	1.69	–	Increased
V15	Degnal	3	0.60	0.80	0.65	2	0.82	0.96	–	Unchanged
V16	Tadwalga	3	0.21	1.40	0.60	3	0.32	1.00	0.61	Unchanged
V17	Ananchi	3	0.38	0.73	0.66	2	1.00	1.05	–	Increased
V18	Kenginal	4	0.47	1.00	0.56	5	0.80	2.00	1.54	Increased
V19	Jevoor	3	0.39	1.00	0.55	2	0.75	1.74	–	Increased
V20	Havinal	4	0.36	2.00	0.86	2	1.90	2.60	–	Increased
V21	Bhuyar	3	0.42	0.72	0.66	2	0.78	1.00	–	Unchanged
V22	Dasur	3	0.34	0.36	0.34	3	0.26	0.55	0.5	Unchanged

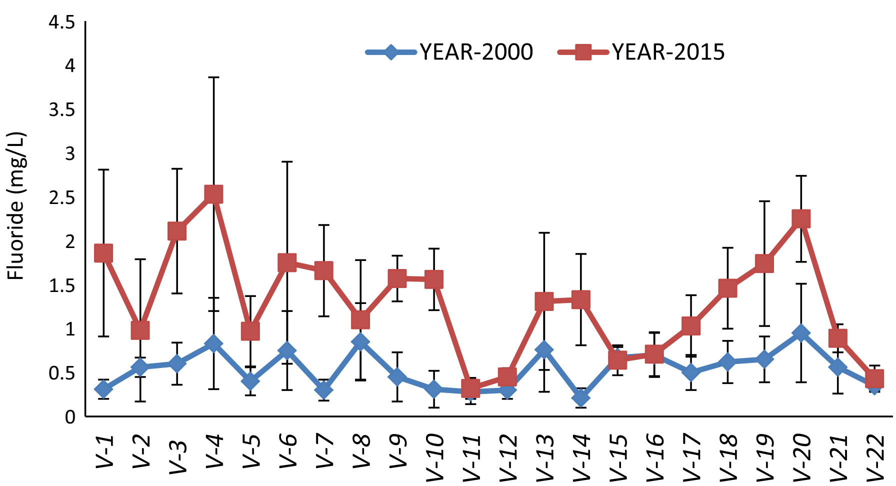

Fig. 10 Mean ± SD of total surveyed bore well fluoride concentration of each of the 22 villages (V1, 2, 3, etc., vide Table 4 for reference) studied in Indi taluk during the year 2000 and year 2015 (Fig. 10)

found to be the most affected (Central Ground Water Board 2008). Our current findings support that report, and in addition to that we further observed that many more villages apart from Dhulkhed and Tamba of Indi have very high concentrations of fluoride in groundwater (Fig. 2).

Health Impact and possible fluorosis

In our study, we have found 16 clinically suspected fluorosis patients with high levels of urinary fluoride (Table 2). It is also interesting to note that all those clinically suspected fluorosis patients with high urinary F^- level are belonging to the villages where groundwater fluoride concentration was on an average higher than 1.5 mg/L (Table 2; Fig. 2). Majority of the subjects surveyed by our medical experts have reported joint pains, gastrointestinal discomfort and excessive thirst. Many villagers with low-intensity fluorosis symptoms consumed both normal surface water and fluoride-contaminated well water. They do not have any problem to perform their day-to-day activities at present but may suffer from various types of skeletal fluorosis in future if proper scientific and medical intervention does not take place. With the increase in bioaccumulation of fluoride in bone and the advancement of age, chances of appearance of skeletal fluorosis are greater (Jolly et al. 1968). Figure 8 depicts possible skeletal fluorosis leading to deformities. Many complaints about joint pain, muscle weakness or deformities could not properly be evaluated in absence of radiographic supports, but our orthopedic specialist in the medical team suggested that much simple arthritis could be labeled as suspected cases of possible fluorosis. Perhaps these may be one of the gray areas which need further medical attention as in many cases symptoms of joint pains, stiffness, difficulties in locomotion are ignored as early arthritic symptoms, but it may be due to fluoride-induced damage to tendinous insertions and ligaments as well as joint capsules (Anand and Roberts 1990).

Many subjects also reported regarding bowel and bladder symptoms which may possibly be due to neurological involvement in fluorosis, though rare and are secondary to involvement of musculoskeletal system (Nayak et al. 2009). It has been reported that small amounts of fluoride in stomach produce hydrofluoric acid which leads to stomach pain, nausea, vomiting, etc. Certain cases such as gastric hemorrhages due to fluoride were also reported (Waldbott 1977). One of the very interesting observations was presence of painful skin changes in 5 out of 16 patients with clinically suspected fluorosis with high urinary F^- concentrations. One had itching suggestive of allergic manifestation. Published reports regarding painful skin changes or lesion due to fluorosis are rare except for some reports on hypersensitivity to fluoride (Justus and Krook 2006; Shea et al. 1967). A report on painful skin lesion due to fluoride may also to be noted (Grimbergen 1974) while referring our observations on skin.

We have found a very large number of school-going children are suffering from low- to high-intensity dental fluorosis (73 %). Drinking of fluoride-contaminated water before tooth enamel is completely mineralized resulted in the hypo-mineralization of the tooth enamel and may be one of the reasons for dental fluorosis among the children in the present study (Teotia and Teotia 1988; Nayak et al. 2009). In our study, we have also found that male children (83.1 %) were more victims of dental disorders than female (61.75 %). Most probably sociocultural background may be the reason behind it as male children spent more time outside of the home and play outdoor games more; hence, they may perhaps consume more water.

Comparative analysis of year 2000 study and current (2015) study

BLDE Association's V.P. Dr. P.G. Halakatti College of Engineering & Technology report (2000) on water quality analysis of Indi taluk for Zilla Panchayat Engineering Division, Bijapur (Government of Karnataka) and our current study (2015) on the same 22 villages showed a remarkable progressive increase in mean level of bore well F^- concentration in most of the twenty-two villages of Indi taluk. These findings are having similarity to a study of Amini et al. (2016) in Iran. The report of 2000 submitted to Government of Karnataka (BLDEA 2000) also indicated higher groundwater F^- concentrations ($\geq$1.0 mg/L) in few of the bore wells of some of these 22 villages (Table 4).

Figure 11 further shows how much F^- concentrations progressively increased among twenty-two studied villages bore well water in Indi taluk of Vijayapura district (Karnataka) during last 15 years. This is

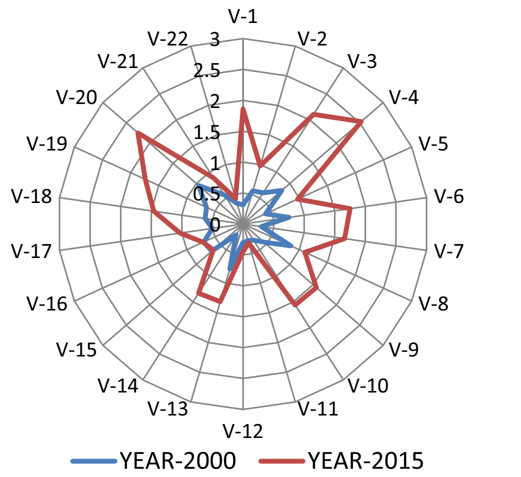

Fig. 11 Radar chart showing the two discrete set of observation during 2000 and 2015 of bore well mean fluoride concentration in each of the 22 villages (V1, 2, 3, etc.)

definitely a serious issue which needs government, international bodies and public awareness to prevent fluorosis to become a major public health problem in near future.

Summary of findings

Results clearly indicate Indi taluk is definitely vulnerable for possible fluorosis problem as surveyed 22 villages are having higher mean value of F^- concentration in bore well water. Physical examination and urinary data of villagers support these observations. Children are found to be greatly exposed to fluoride toxicities which may affect their skeletal growth and possibilities of early crippling conditions for the young generation if immediate precautionary steps are not taken. The first time a link between painful skin sensations with high urinary fluoride concentration definitely needs attention of dermatologists to work on this issue further for the interest of humanity.

Conclusions

Hence, it may be concluded that Indi taluk of Vijayapura district (aka Bijapur) is definitely showing higher groundwater fluoride concentration. Villagers of Indi taluk who depend on groundwater are at a greater risk of fluorosis, as the water that percolates through the rocks leaches out F^- and contaminates groundwater severely. It is also to be noted that many skeletal diseases, gout or arthritic symptoms of the villagers, may be possibly due to fluorosis which are often ignored as simple orthopedic problems.

Our report is also unique as most probably the first time in India a scientific study had been done on fluoride concentrations in groundwater of same areas over a period of 15-year interval.

Acknowledgments Authors deeply acknowledge all the villagers of twenty-two villages of Indi taluk of Vijayapura district (Karnataka), India, for their great supports to carry out this work. Authors also express their gratitude to BLDE University, Vijayapura, India (BLDE University Research Grants Ref. No. BLDEU/REG/R&D/2013-14/1743 dated 10.3.2014) and BLDE Association's V.P. Dr. P.G. Halakatti College of Engineering and Technology, Vijayapura, India, for providing funds and other supports to carry out the project. Supports from School of Environmental Studies, Jadavpur University, Kolkata, India, and Geological Survey of India, Bangalore, India, are also greatly acknowledged.

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