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Fluorosis prevalence in rural India: an example from Rajasthan

IKBAL HUSAIN[1] & JAKIR HUSSAIN[2]

1 Public Health Engineering Department, Bhilwara - 311001, Rajasthan, India
ikbalhusain@gmail.com
2 National River Water Quality Laboratory, Central Water Commission, New Delhi - 110016, India
drjakirhussain@gmail.com

Abstract Fluorosis is endemic in 17 states of India and about 62 million people are at risk of fluorosis from drinking high fluoride water. In Rajasthan, 24 out of 32 districts are fluorotic and 15 million of the population are at risk. An exploratory qualitative study was carried out to describe the perception of the community regarding fluoride and related health problems; 876 habitations of the 1643 habitations studied were found to have >1.5 mg/L fluoride, ranging from 0.2 to 23.2 mg/L. A detailed fluorosis study was done in 63 habitations with >5.0 mg/L fluoride and 9242 individuals were examined. The overall prevalence of dental and skeletal fluorosis was found to be 5880/9242 (63.62%) and 1183/4839 (26.51%), respectively. The Dean's Community Fluorosis Index for the study area varies from 1.08 to 3.04. The Government has introduced some domestic and community-based defluoridation techniques, but people are still using traditional tactics.

Key words fluoride; dental fluorosis; skeletal fluorosis; CFI; defluoridation; Rajasthan, India

INTRODUCTION

India has 14.1% of the total fluoride deposits on the Earth's crust. It is not surprising, therefore, that fluorosis is endemic in 17 states of India (UNICEF, 1999). In India, the higher concentrations of fluoride in groundwater are associated with igneous and metamorphic rocks and about 62 million people are at risk of fluorosis from drinking high fluoride water. The problem is most pronounced in Andhra Pradesh, Bihar, Gujarat, Madhya Pradesh, Punjab, Rajasthan, Tamil Nadu, and Uttar Pradesh (Husain *et al*., 2000, 2003, 2004, 2005, 2010, 2012).

There are many studies on the distribution of fluoride in groundwater; however, impact assessment studies are still lacking. There is also evidence that the adverse health effects of fluoride are enhanced by a lack of calcium, vitamins and protein in the diet (Zheng *et al*., 1999). Therefore, fluorosis trends in various social groups were also studied. The Government has introduced some domestic and community-based defluoridation techniques, but they are not accepted by the community. People are still protecting themselves from fluorosis using traditional tactics. A questionnaire was designed to find out the traditional tactics for mitigating fluorosis.

GLOBAL AND INDIAN SCENARIO

International status

The problem of excessive fluoride in drinking water is prevalent in many parts of the world, and today many millions of people rely on groundwater with concentrations above the World Health Organization guideline value (WHO, 1996). There are >20 developed and developing nations in which fluorosis is endemic (Ayoob & Gupta, 2006). High fluoride concentrations in groundwater are also found in the USA, Africa and Asia (Azbar & Turkman, 2000). The most severe problems associated with high fluoride waters occur in China (Wang *et al*., 2002); India (Agarwal *et al*., 2003), Sri Lanka and the Rift Valley countries in Africa. High fluoride groundwaters have been studied in detail in Africa, in particular in Kenya and Tanzania (Moturi *et al*., 2002). In the early 1980s, it was estimated that 260 million people worldwide (in 30 countries) were drinking water with >1 mg/L of fluoride.

Current status in India

In India, fluoride was first detected in drinking water at Nellore district of Andhra Pradesh in 1937 (Ayoob & Gupta, 2006). Since then, considerable work has been done in different parts of India to explore the fluoride-laden water sources. At present, it is estimated that fluorosis is prevalent in 17 states of India, indicating that endemic fluorosis is one of the most alarming public health problems of the country, especially in Rajasthan, Madhya Pradesh, Andhra Pradesh, Tamil Nadu, Gujarat, and Uttar Pradesh. At present, endemic fluorosis is thought to affect about one million people (Sneha *et al*., 2012). Districts known to be endemic for fluoride in various states of India and the ranges of fluoride in drinking water are given in Table 1.

Table 1 Districts showing fluoride concentration >1.5 mg/L in groundwater in India in 2010.

State	District	Range
Assam	Goalpara, Kamrup, Karbi Anglong, and Nagaon	1.45–7.8
Andhra Pradesh	Adilabad, Anantpur, Chittoor, Guntur, Hyderabad, Karimnagar, Khammam, Krishna, Kurnool, Mahbubnagar, Medak, and Nalgonda	1.8–8.4
Bihar	Aurangabad, Banka, Buxar, Jamui, Kaimur(Bhabua), Munger, Nawada, Rohtas, and Supaul	1.7–2.85
Chhattisgarh	Bastar, Bilaspur, Dantewada, Janjgir-Champa, Jashpur, Kanker, Korba, Koriya, Mahasamund, Raipur, Rajnandgaon, and Surguja	1.5–2.7
Delhi	East Delhi, North West Delhi, South Delhi, South West Delhi, West Delhi, Kanjhwala, Najafgarh, and Alipur	1.57–6.10
Gujarat	Ahmadabad, Amreli, Anand, Banaskantha, Bharuch, Bhavnagar, Dohad, Junagadh, Kachchh, Mehsana, Narmada, Panchmahals, Patan, Rajkot, Sabarkantha, Surat, Surendranagar, and Vadodara	1.6–6.8
Haryana	Bhiwani, Faridabad, Gurgaon, Hissar, Jhajjar, Jind, Kaithal, Kurushetra, Mahendragarh, Panipat, Rewari, Rohtak, Sirsa, and Sonepat	1.5–17
Jammu and Kashmir	Doda, Rajauri, and Udhampur	2.0–4.21
Karnataka	Bagalkot, Bangalore, Belgaun, Bellary, Bidar, Bijapur, Chamarajanagar, Chikmagalur, Chitradurga, Davangere, Dharwad, Gadag, Gulburga, Haveri, Kolar, Koppal, Mandya, Mysore, Raichur, Tumkur	1.5–4.4
Kerala	Palakkad, Palghat, Allepy, Vamanapuram, and Alappuzha	2.5–5.7
Maharashtra	Amravati, Chandrapur, Dhule, Gadchiroli, Gondia, Jalna, Nagpur, Nanded	1.51–4.01
Madhya Pradesh	Bhind, Chhatarpur, Chhindwara, Datia, Dewas, Dhar, Guna, Gwalior, Harda, Jabalpur, Jhabua, Khargaon, Mandsaur, Rajgarh, Satna, Seoni, Shajapur, Sheopur, and Sidhi	1.5–10.7
Orissa	Angul, Balasore, Bargarh, Bhadrak, Bandh, Cuttack, Deogarh, Dhenkanal, Jajpur, Keonjhar, and Sonapur	1.52–5.2
Punjab	Amritsar, Bhatinda, Faridkot, Fatehgarh Sahib, Firozepur, Gurdaspur, Mansa, Moga, Muktsar, Patiala, and Sangrur	0.44–6.0
Rajasthan	Ajmer, Alwar, Banaswara, Barmer, Bharatpur, Bhilwara, Bikaner, Bundi, Chittaurgarh, Churu, Dausa, Dhaulpur, Dungarpur, Ganganagar, Hanumangarh, Jaipur, Jaisalmer, Jalor, Jhunjhunun, Jodhpur, Karauli, Kota, Nagaur, Pali, Rajsamand, Sirohi, Sikar, SawaiMadhopur, Tonk, and Udaipur	1.54–11.3
Tamilnadu	Coimbatore, Dharmapuri, Dindigul, Erode, Karur, Krishnagiri, Namakkal, Perambalur, Puddukotai, Ramanathapuram, Salem, Sivaganga, Theni, Thiruvannamalai, Tiruchirapally, Vellore, and Virudhunagar	1.5–3.8
Uttar Pradesh	Agra, Aligarh, Etah, Firozabad, Jaunpur, Kannauj, Mahamaya Nagar, Mainpuri, Mathura, and Mau	1.5–3.11
West Bengal	Bankura, Bardhaman, Birbhum, Dakshindinajpur, Malda, Nadia, Purulia, and Uttardinajpur	1.5–9.1

GUIDELINES AND STANDARDS

According to WHO's guidelines for drinking water, a fluoride level of 1.5 mg/L is the desirable upper limit. India reduced the upper limit of fluoride in drinking water from 1.5 to 1.0 mg/L with a rider that "less is better" (BIS 10500, 2012). This is due to the extremes in climatic conditions and the diet being deficient in essential nutrients (calcium, vitamins C, E and antioxidants) in the rural communities of India. So, the Indian standard for the maximum desirable limit of fluoride in drinking water is 1.0 mg/L and the maximum permissible limit is 1.5 mg/L. As the amount of water consumed and consequently the amount of fluoride ingested is influenced primarily by air temperature, USPHS (1962) has set a range of concentrations for maximum allowable fluoride in drinking water for communities based on the climatic conditions, as shown in Table 4.

Table 2 USPHS recommendation for maximum allowed fluoride in drinking water.

Annual average maximum daily air temperature (°C)	Recommended fluoride concentration (mg/L)			Maximum allowable fluoride concentration (mg/L)
	Lower	Optimum	Upper	
10–12	0.9	1.2	1.7	2.4
12.1–14.6	0.8	1.1	1.5	2.2
14.7–17.7	0.8	1	1.3	2
17.8–21.4	0.7	0.9	1.2	1.8
21.5–26.2	0.7	0.8	1	1.6
26.3–32.5	0.6	0.7	0.8	1.4

HEALTH EFFECTS

Fluorides in drinking water may be beneficial or detrimental depending on their concentration and the total amount ingested. Fluoride is beneficial especially to young children (below eight years of age) for calcification of dental enamel, when present within allowable limits (1.5 mg/L).

Fluoride, being a highly electronegative ion, has an extraordinary tendency to get attracted by positively charged ions like calcium. Hence, the effect of fluoride in mineralized tissues like bone and teeth is of clinical significance as they have the highest amount of calcium and thus attract the maximum amount of fluoride which is deposited as calcium fluorapatite crystals. Tooth enamel is composed principally of crystalline hydroxyapatite. Under normal conditions, when fluoride is present in the water supply, most of the ingested fluoride ions are incorporated into the apatite crystal lattice of calciferous enamel tissue during its formation. The hydroxyl ion is substituted by the fluoride ion because fluorapatite is more stable than hydroxyapatite. The most common health problems associated with excess fluoride in drinking water are dental and skeletal fluorosis. Endemic fluorosis is known to be global in scope, occurring in all continents and affecting many millions of people. Dental fluorosis leads to pitting, perforation and chipping of the teeth, whereas skeletal fluorosis causes severe pains in joints followed by stiffness, which ultimately leads to paralysis. However, recent studies have proved that the health effects of fluoride are not only restricted to dental or skeletal fluorosis but also cause other ailments such as neurological disorders, muscular and allergic manifestations, and gastrointestinal problems, and may also cause lethal diseases like cancer.

METHODOLOGY

The fluoride concentration in water was determined electrochemically, using a fluoride ion selective electrode (APHA, 1991). The two important issues that need to be addressed immediately include the health effects and bottlenecks or problems associated with existing remediation technologies. For collection of data pertaining to evidence, prevalence and severity of dental and skeletal fluorosis, a house-to-house survey was conducted in 63 habitations having fluoride concentration above 5.0 mg/L. For the survey, a questionnaire was designed consisting of information regarding age, sex and dietary habits of individuals. For dental fluorosis, the teeth of individuals and nutritional habits of different age groups and sex were carefully examined in proper daylight. The characteristics of different grades of dental fluorosis are grouped as described by Dean (1942).

– **Normal** The enamel presents a translucent, semi-vitri form type of structure. The surface is smooth, glossy and usually pale creamy white colour.

- **Questionable** Seen in areas of relatively high endemicity; occasional cases are borderline and one would hesitate to classify them as apparently normal or very mild.
- **Very mild** Small, opaque paper-white areas seen scattered irregularly over the labial and buccal tooth surfaces.
- **Mild** The white opaque areas involve at least half of the tooth surface and faint brown stains are sometimes apparent.
- **Moderately** Generally all tooth surfaces are involved and minute pitting is often present on the labial and buccal surfaces. Brown stains are frequently a disfiguring complication.
- **Severe** The severe hypoplasia affect the form of the teeth and stains are widespread, and vary in intensity from deep brown to black.

Using Dean's classification, the Fluoride Index was calculated as:

$$\text{Community fluoride index (CFI)} = \frac{\sum (\text{scores} \times \text{no. in each score group})}{\text{Number of cases examined}}$$

For the evidence of skeletal fluorosis, only adult individuals (>21 years) were considered. The grading proposed by Teotia *et al*. (1985) for clinical skeleton fluorosis was considered and used in the present study. The characteristics of different grades are:

- **Grade I** Generalized bone and joint pain.
- **Grade II** Generalized bone and joint pain, stiffness and rigidity of dorso lumber spine and restricted movements at spine and joints.
- **Grade III** Symptoms of grade II with deformities of spine and limbs, knock knees, crippled or bedridden state, kyphosis, invalidism, genu-varum and genu-valgum.

RESULTS AND DISCUSSION

The study was carried out in six centrally-located districts of Rajasthan. These districts occupy 76 368 km^2; 1643 habitations in these districts were targeted and of them 72.3% were found to have fluoride above the acceptable limit (1.0 mg/L) of BIS 10500. The distribution of fluoride is shown in Table 3. Fluoride concentration varied from 0.2–23.2 mg/L. The maximum concentration was recorded in samples from Khor habitation of Rani block in Pali district.

Table 3 Fluoride distribution in central Rajasthan.

District	Area (km^2)	Habitations examined	Fluoride concentration							Concentration above	
			Min	Max	<1.0	1.0-1.5	1.5-3.0	3.0-5.0	>5.0	Acc. Limit	All. Limits
Ajmer	8 482	190	0.2	15.1	49	37	67	31	6	74.2%	54.7%
Bhilwara	10 455	455	0.2	19.5	132	88	135	53	47	71.0%	51.6%
Jodhpur	22 850	206	0.2	19.7	52	45	72	26	11	74.8%	52.9%
Nagaur	17 683	272	0.4	10.8	52	44	110	38	28	80.9%	64.7%
Pali	12 369	294	0.2	23.2	64	39	119	46	26	78.2%	65.0%
Rajsamand	4 529	226	0.2	6.35	106	59	42	16	3	53.1%	27.0%
Total	76 368	1643	0.2	23.2	455	312	545	210	121	72.3%	53.3%

Acc. Limit – Acceptable limit (1.0 mg/L) and All. Limit – Allowable limit (1.5 mg/L).

In total, 9242 individuals of different age group and sex from 63 habitations were examined for dental fluorosis and 5880 (63.6%) were found to be affected. The maximum number of fluorosis patients was found in Jodhpur district with a maximum CFI of 3.04. The minimum CFI (1.08) recorded was for Ajmer and Bhilwara districts. Table 4 presents the prevalence of various type of dental fluorosis with CFI in the area. In total, 1021 (11%) individuals have severe dental fluorosis of whom 75% have skeletal fluorosis. Skeletal fluorosis was examined for in 4839 individuals of above 20 years age and 1283 (26.5%) were affected. Only 21 (0.4% individual have grade III type skeletal fluorosis. Table 5 presents various grades of skeletal fluorosis in the area. Some dental fluorosis cases are shown in Fig. 1.

Fig. 1 Examples of dental fluorosis in the area.

Table 4 Prevalence of dental and skeletal fluorosis by district.

District	Habitation studied	Dental fluorosis							CFI	
		Individual examined	Type I	Type II	Type III	Type IV	Type V	Total	Min	Max
Ajmer	5	590	6.4%	11.7%	18.0%	14.7%	6.9%	57.8%	1.08	1.39
Bhilwara	28	4409	6.4%	12.3%	17.3%	16.3%	10.7%	62.9%	1.08	2.24
Jodhpur	6	835	5.5%	9.6%	16.0%	21.6%	18.7%	71.4%	1.29	3.04
Nagaur	14	2000	5.9%	14.6%	17.3%	15.9%	9.2%	62.8%	1.17	1.91
Pali	8	1203	5.8%	11.6%	16.4%	19.4%	12.3%	65.4%	1.37	1.82
Rajsamand	2	205	12.2%	13.2%	14.6%	11.2%	9.8%	61.0%	1.14	1.65
Total	63	9242	6.2%	12.5%	17.0%	16.9%	11.0%	63.6%	1.08	3.04

Type I: - Questionable, Type II: - Very Mild, Type III: - Mild, Type IV: - Moderate, Type V:- Severe

Table 5 Prevalence of skeletal fluorosis by district.

District	Habitations studied	Skeletal fluorosis				
		Total exam.	Grade I	Grade II	Grade III	Total
Ajmer	5	316	16.8%	8.9%	0.0%	25.6%
Bhilwara	28	2398	17.9%	8.3%	0.6%	26.8%
Jodhpur	6	414	18.4%	10.4%	1.0%	29.7%
Nagaur	14	956	18.4%	8.4%	0.3%	27.1%
Pali	8	651	13.2%	9.2%	0.0%	22.4%
Rajsamand	2	104	19.2%	10.6%	0.0%	29.8%
Total	63	4839	17.4%	8.7%	0.4%	26.5%

Table 6 Prevalence of fluorosis in relation to age and sex.

Age (year)	No. of Examination			Dental Fluorosis (%)			Skeletal Fluorosis (%)		
	Male	Female	Total	Male	Female	Total	Male	Female	Total
5–10	1062	972	2034	803 (75.61%)	680 (69.96%)	1483 (72.91%)	-	-	-
11–20	1238	1131	2369	770 (62.2%)	748 (66.14%)	1518 (64.08%)	-	-	-
21–30	1019	877	1896	706 (69.28%)	492 (56.1%)	1198 (63.19%)	268 (26.3%)	105 (11.97%)	373 (19.67%)
31–40	773	638	1411	458 (59.25%)	374 (58.62%)	832 (58.97%)	211 (27.3%)	183 (28.68%)	394 (27.92%)
41–50	557	411	968	347 (62.3%)	221 (53.77%)	568 (58.68%)	188 (33.75%)	126 (30.66%)	314 (32.44%)
>50	313	251	564	164 (52.4%)	117 (46.61%)	281 (49.82%)	111 (35.46%)	91 (36.25%)	202 (35.82%)
Total	4962	4280	9242	3248 (65.46%)	2632 (61.5%)	5880 (63.62%)	778 (29.23%)	505 (23.2%)	1283 (26.51%)

On categorizing fluorosis in relation to age and sex (Table 6), it was found that dental fluorosis in males is more than that in females. However, the percentage in females falls after the age of 20 years due to the migration of females after their marriage. Males work in the field and consume more water per day and, hence, are more affected by dental and skeletal fluorosis.

TECHNICAL FLUORIDE MITIGATION PRACTICES INTRODUCED IN THE AREA

For fluoride mitigation in the area, two technical practices were introduced. The first is based on co-precipitation methods (the Nalgonda technique) and the second is based on adsorption methods using activated alumina. Both techniques are simple and user friendly but no one in the area had adopted either practice.

Co-precipitation method (Nalgonda Technique)

In this method alum (alumina ferric) is used as a coagulant. The fluoride available in drinking water is adsorbed on the flocs and settles at the bottom of the pot. The supernatant water is collected in another pot and is used for drinking purposes. This method has very low cost and does not require any technical skill, but people in the area have not adopted this technique so far for the following reasons:

– It requires calculation of the alum dose based on alkalinity and fluoride concentration in the raw water. Addition of excessive alum leads to a change in taste due to pH decrease.
– It is a daily job and requires at least 1.5 hours.

Adsorption method (activated alumina technique)

Granules of activated alumina are used. Activated alumina has a capacity to adsorb fluoride on its surface. After adsorption to a certain level, the further adsorption reduce/stops. When the activated alumina exhausted, it is recharged/regenerated by an alkali and then neutralized by acid. Activated alumina may be regenerated 5–6 times then needs to be replaced. Kits were distributed by the Government at a subsidized rate and NGOs were appointed to establish regeneration centres and IEC. After all these, this technique was still not adopted due to the following reasons:

– Activated alumina is costly; Government subsidised it once but then it had to be purchased.
– Complications in procedure for monitoring of the activated alumina to assess whether it is still working.
– Regeneration is a difficult task and needs a skilled person. Once the NGO closed the regeneration centre, further use of the technique stopped due to exhaustion of the media.

During the study it was found that these techniques are not effective in the area. However, people were found to use traditional fluoride mitigation practices and by using them they are preventing/delaying fluorosis.

TRADITIONAL FLUORIDE MITIGATION PRACTICES USED IN THE AREA

To mitigate fluorosis, people in the area have established some rules/practices based on their many years of experience; hence they are well proven. They are based on two sound principles:

– Selection of the least contaminated source for drinking purposes.
– Change in dietary habits.

Selection of source

In the area with high fluoride in groundwater, people were found to use the least contaminated sources without any knowledge of fluoride availability in water and its ill effects. On further study it was found that there are three ways to select the least contaminated source:

– With the experience of years, local people have categorized sources into ill sources and healthy sources, irrespective of fluoride examination of the water. The ill sources are unsafe and if used result in illness regarding bone deformities. The healthy sources are safe and are used by the community.
– Groundwater sources near to surface water bodies are being used by communities. These sources also provide the least contaminated water.
– In some areas surface water is being used by the community after treatment. Surface water has no fluoride contamination and so the community saved themselves from fluorosis.

Change in dietary habits

In the area, people have changed their dietary habits. They were found to use more calcium products in their daily diet. In some area it was established that even eating less but including a bowl of curd in the daily diet was good. Curd has a good quantity of calcium and intake of calcium prevents fluorosis, even if high fluoride water is been used.

CONCLUSION

In the study a number of habitations were found to have excessive fluoride in groundwater. There is a prevalence of dental fluorosis in a large number of people. However, grade III skeletal fluorosis is rare in the area. This all is due to the well-established traditional practices being used by community in the area.

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