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Fluoride in the Drinking Water of Nagaur Tehsil of Nagaur District, Rajasthan, India

M. Arif · I. Hussain · J. Hussain · S. Sharma · S. Kumar

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Abstract Fluoride concentration of groundwater samples from 100 villages of Nagaur tehsil was determined, 85 villages were found to have fluoride concentration more than 1.5 mg/L. The maximum fluoride concentration was recorded 6.6 mg/L in groundwater of Singhani village, while the minimum was recorded in Kurchhi village. As per the desirable and maximum permissible limit for fluoride in drinking water, determined by World Health Organization, the groundwater of about 85 villages of the studied sites is unfit for drinking purpose.

Keywords Fluoride · Ground water · Nagaur tehsil · Rajasthan

Fluorine is the most electronegative and reactive among all elements hence found in its ionic form fluoride in nature. It occurs in natural water due to chemical weathering of some F^- containing minerals (Totsche et al. 2000). Fluoride when present in small amounts is an essential component for normal mineralization of bones and formation of dental enamel (Bell and Ludwig 1970). However, excessive intake of fluoride can cause dental and skeleton fluorosis (Sorg and Logsdon 1978). Fluorosis is now worldwide problem not only in India, the developing countries like Argentina, U.S.A., Algeria, Libya, Turkey, South Africa, Kenya, Iraq, Shri Lanka, Canada, Thailand, New Zealand, Japan etc. (Mameri et al. 1998). Groundwater is a major source of human intake of fluoride, including its subsequent incorporation into food items. The main source of fluoride in groundwater is considered to be Fluoride-bearing minerals such as fluorspar (CaF_2), fluorapatite [$Ca_5(PO_4)_3F$], cryolite, and hydroxylapatite in rocks (Farooqi et al. 2007). The chemical composition of the stratum through which the groundwater has flowed, therefore, is regarded as an important factor for determining the fluoride concentration of groundwater. The concentration of fluoride in groundwater is a function of many factors such as availability and solubility of fluoride minerals, velocity of flowing water, temperature, pH, and concentration of calcium and bicarbonate ions in water (Chandra et al. 1981). The natural concentration of fluoride depends on the geological, chemical and physical characteristics of the aquifer (Meenakshi et al. 2004). Fluoride geochemistry of ground water in parts of Brahmaputra flood plain in Kamrup district, Assam and found F concentration ranged from 0.00 to 10.71 mg/L. Geological formation of this zone consist of F-containing minerals, which could be a major source of F in these ground water sources (Chakrabarty and Sarma 2011).

Rajasthan is the largest state of India having 342, 239 km^2 area and with relatively low population density i.e. 165 persons per square kilometer. According to physiographic divisions the north and western part of the state is

M. Arif (✉)
Department of Chemistry, Banasthali University,
Banasthali Vidyapith, District-Tonk 304022,
Rajasthan, India
e-mail: dr.arifmohammed@gmail.com

I. Hussain
Public Health Engineering Department (PHED) Laboratory,
Bhilwara 311001, Rajasthan, India

J. Hussain
National River Water Quality Laboratory,
Central Water Commission, New Delhi 110016, India

S. Sharma · S. Kumar
Department of Chemistry, Banasthali University,
Banasthali Vidyapith, Tonk 304022, Rajasthan, India

under The Great Plain of north India while, south and middle as well as eastern part is classified under the Peninsular Plateau. Fluoride contamination in ground water is one of the major environmental hazards in many districts of Rajasthan. Nagaur tehsil of Nagaur District is situated between 26°25′ and 27°40′ North Latitude and 73°.10′ and 75°.15′ East Longitude. Because of its central situation in Rajasthan, it shares its border with several other district of the state. To the north, it is bounded by Bikaner and Churu district, to the east by Sikar and Jaipur district to the south by Ajmer and Pali district and to the west by Jodhpur district. The district has its general slope towards the west. Its average elevation is about 300 m; ranging below 250 m in the south and 640 m in the north. The total area of the district is 17,718 km^2, out of which 17,448.5 km^2 is rural and 269.5 km^2, is urban. The population of the district is 27, 75,058 (4, 77,337 urban and 22, 97,721 rural population) which is 4.91% of the total population of the State. The density of population in the district is 157, as against 165 of Rajasthan as a whole. 12, 87,921 persons of the district are literate, out of which 10, 21,314 are rural and 2, 66,607 are urban, which makes it 58.26% of the total population (Census 2001). The selected part for this study is situated in central part of the state where groundwater is a major source of drinking water. A bibliographic survey has shown that yet no studies have been undertaken in the study area with regard to fluoride and fluorosis problem. So the objective of this study was to investigate the fluoride concentration in drinking water in some rural habitations of Nagaur tehsil of the district Nagaur of Rajasthan, India.

Materials and Methods

Groundwater samples of 100 villages located in Nagaur tehsil of Nagaur district were collected in pre cleaned polythene bottles with necessary precautions (Brown et al. 1974). The fluoride concentration in water was determined electrochemically, using fluoride Ion selective electrode (APHA 1991). This method is applicable to the measurement of fluoride in drinking water in the concentration range of 0.02–1,000 mg/L. The electrode used was an Orion fluoride electrode, coupled to an Orion electrometer. All the experiments were carried out in triplicate and the results were found reproducible with ±2% error. A general observation was also conducted with respect to incidence of dental and skeleton fluorosis.

Preparation of TISAB-III

Take 250 mL de-ionized water and add 234 mL of concentrated hydrochloric acid. Add 385.4 g of Ammonium acetate. Add 17.3 g of 1, 2-cyclohexylene-diaminetetraacetic (CDTA). Stir to dissolve and cool at room temperature. Make it up to 1,000 mL.

Procedure

1. Calibration of instrument: Prepare a series of standards over the appropriate concentration range (0.1, 1.0 and 10.0 mg/L) Calibrate the instrument to obtain −59.2 ± 2 mv slop.
2. Take 10 mL sample, add 1 mL of TISAB III and measure fluoride concentration.

Results and Discussion

Fluoride concentration in groundwater of 100 villages of Nagaur tehsil was analyzed. The groundwater was free from colour and odour and taste was slightly saline. The fluoride concentration in groundwater varied greatly in different villages of tehsil. The result of fluoride contained present drinking water is presented in Table 1. All the villages are categorized according to following concentration range.

Category I: Fluoride concentration below 1.0 mg/L (Green Colour)

Category II: Fluoride concentration between 1.0 and 1.5 mg/l (Yellow Colour)

Category III: Fluoride concentration between 1.5 and 3.0 mg/L (Red Colour)

Category IV: Fluoride concentration between 3.0 and 5.0 mg/L (Brown Colour)

Category V: Fluoride concentration above 5.0 mg/L (Black Colour)

Fluoride concentration in the tehsil ranges from 0.4 to 6.6 mg/L. The minimum concentration was recorded for Kurchhi village while maximum concentration was recorded from village Singhani (6.6 mg/L).Distribution of fluoride in the tehsil is shown graphically using frequency function in Fig. 1. From the figure it is clear that the maximum villages belong to the concentration of 1.5–3.0 mg/L. The present research reveals that 7 villages (Shri balaji, Peepasar, Kurchhi, Amarpura, Bunrawata, Roon, Khajwana) fall in category I (In Fig. 2 shown as green colour) in which fluoride concentration is below 1.0 mg/L. A maximum desirable limit for drinking water was recommended by Bureau of Indian Standard (BIS) in IS: 10500, 1991, Therefore, no possibility of fluorosis in these villages because this concentration of fluoride is beneficial, for calcification of dental enamel especially for children below 10-year age. Once fluoride is incorporated into teeth, it reduces the solubility of the enamel under acidic conditions and thereby provides protection against

Table 1 Fluoride distribution in Nagaur tehsil of Nagaur district

S. no.	Name of main habitation	Code no.	Fluoride	Color in map
1	Dholiya der	1	2.5	Red
2	Jhareli	2	4.1	Brown
3	Bhojas	3	1.6	Red
4	Paboosar	5	2.1	Red
5	Karnoo	6	2.3	Red
6	Akhasar	7	5.6	Black
7	Tantwas	8	3.1	Brown
8	Dantina	9	2.2	Red
9	Deu	10	2.4	Red
10	Sindhipura	13	3.1	Brown
11	Panchori	15	3.2	Brown
12	Satika Khurd	16	2.6	Red
13	Birloka	21	2.3	Red
14	Papasani	23	4.2	Brown
15	Isar nabra	24	5.6	Black
16	Panchla Sidha	26	3.2	Brown
17	Acheena	31	4.2	Brown
18	Shivpura	33	1.6	Red
19	Bhundel	36	1.2	Yellow
20	Nenau	37	2.1	Red
21	Khadkali	40	2.0	Red
22	Derwa	42	2.3	Red
23	Alay	45	3.2	Brown
24	Jakhaniya	47	2.1	Red
25	Shri balaji	50	0.6	Green
26	BukaramSota	51	1.2	Yellow
27	Chheelo	52	2.3	Red
28	Sewri	53	1.3	Yellow
29	Peepasar	54	0.5	Green
30	Shyamsar	58	2.3	Red
31	Jhorda	59	2.1	Red
32	Chau	60	3.6	Brown
33	Rahini	62	1.6	Red
34	Peetholai	64	5.4	Black
35	Untwaliya	72	5.6	Black
36	Makori	73	5.2	Black
37	Balwa	76	1.8	Red
38	Goganada	79	1.9	Red
39	Seengar	80	3.6	Brown
40	Sukhwasi	81	3.8	Brown
41	Khari karam sota	82	1.1	Yellow
42	Ray dhanu	83	2.2	Red
43	Potliya Manjra	85	2.3	Red
44	Chawandiya	87	2.6	Red
45	Bher	88	3.5	Brown
46	BerathalKhurd	90	3.1	Brown
47	Kantiya	92	3.9	Brown
48	Kurchhi	97	0.4	Green
49	Nagri	100	2.2	Red
50	Kheenwsar	102	2.9	Red
51	Akla	104	4.1	Brown
52	Tankla	106	3.2	Brown
53	Dheengsara	107	3.6	Brown
54	Boodhi chak	108	2.8	Red
55	Kumari	111	4.6	Brown
56	Bhawad	114	4.1	Brown
57	Indas	115	1.6	Red
58	Dhakorika	128	5.6	Black
59	Jodhiyasi	134	2.3	Red
60	Manjhwas	141	2.6	Red
61	Jhadisara	142	3.1	Brown
62	Bhadana	148	1.7	Red
63	Harima	150	2.9	Red
64	Sarasani	152	3.6	Brown
65	Gagwana	155	4.1	Brown
66	Amarpura	159	0.8	Green
67	Chenar	160	3.2	Brown
68	Phagali	161	5.9	Black
69	Tausar	164	1.8	Red
70	Singhani	165	6.6	Black
71	Kadarpura	171	4.1	Brown
72	Sinod	174	3.2	Brown
73	Dehroo	178	2.6	Red
74	Tadawas	182	1.9	Red
75	Dharnawas	183	5.2	Black
76	Bhawanda	186	2.2	Red
77	Lalap	187	2.1	Red
78	Sheel gaon	188	3.3	Brown
79	Kharnal	190	4.0	Brown
80	Balaya	191	2.1	Red
81	Inana	198	5.1	Black
82	Soliyana	202	4.2	Brown
83	Thirod	203	3.2	Brown
84	Karloo	205	1.8	Red
85	Mundiyar	207	1.2	Yellow
86	Manakpur	211	5.2	Black
87	Dhundhiyari	212	3.7	Brown
88	Sankhwas	217	1.3	Yellow
89	Bhadana	223	2.2	Red
90	Bunrawata	229	0.6	Green
91	Gwaloo	230	1.4	Yellow
92	Kankdai	234	2.3	Red

Table 1 continued

S. no.	Name of main habitation	Code no.	Fluoride	Color in map
93	Diyawari	235	2.6	Red
94	Asawari	237	4.1	Brown
95	Roon	241	0.6	Green
96	Khajwana	243	0.9	Green
97	Gajoo	246	1.3	Yellow
98	Nagaur [U]		5.2	Black
99	Kuchera [U]		1.9	Red
100	Mundwa [U]		5.6	Black

dental carries. In Nagaur tehsil 8 villages have fluoride concentration between 1.0 and 1.5 mg/L and fall in category II (In Fig. 2 shown as yellow colour). The maximum permissible limit of fluoride in standard for drinking water is 1.5 mg/L (BIS) (IS: 10500; 1991). At this level of concentration the daily fluoride intake through drinking water are more than 4 mg/L. Out of 100 villages of Nagaur tehsil 41 villages consume water with fluoride concentration between 1.5 and 3.0 mg/L, which is above the maximum permissible limit as recommended by BIS (In Fig. 2 shown as red Colour). The most alarming condition was seen in some sites where fluoride concentration in groundwater was above 3.0 mg/L (about 41% of the total surveyed sites). In 31 villages fluoride concentration in groundwater is above 3.0 mg/L and below 5.0 mg/L and this fall in category IV (In Fig. 2 shown as brown Colour). In the entire study the 13 villages fall in category V (In Fig. 2 shown as black colour).The water in these villages are not suitable for drinking purpose.

As per the desirable and maximum permissible limit for fluoride in drinking water determined by World Health Organization (1997) or by Bureau of Indian Standards (1991), groundwater at 85 sampling stations was found unfit for drinking purposes. Moreover, dental and skeletal fluorosis is at alarming stage in local resident of these areas. According to Whitford (1997) the 75%–90% of ingested fluoride is absorbed. In an acidic stomach fluoride is converted into hydrogen fluoride (HF) and here up to 40% of the fluoride ingested in stomach and remaining in intestine. Once absorbed into blood, fluoride readily distributes throughout the body, with approximately 99% of the body burden of fluoride retained in calcium rich areas such as bones and teeth (dentine and enamel) (World Health Organization 1997). However, in plasma, fluoride is transported as ionic fluoride and non-ionic fluoride. Ionic fluoride does not bind to plasma proteins and is easily excreted with the urine. However, in the form of HF, about 35%–45% is reabsorbed and returned to the systemic circulation. pH of tubular fluid and urinary flow are the main factors which influence reabsorption (Whitford et al. 1976).The amount of urinary fluoride excreted from the

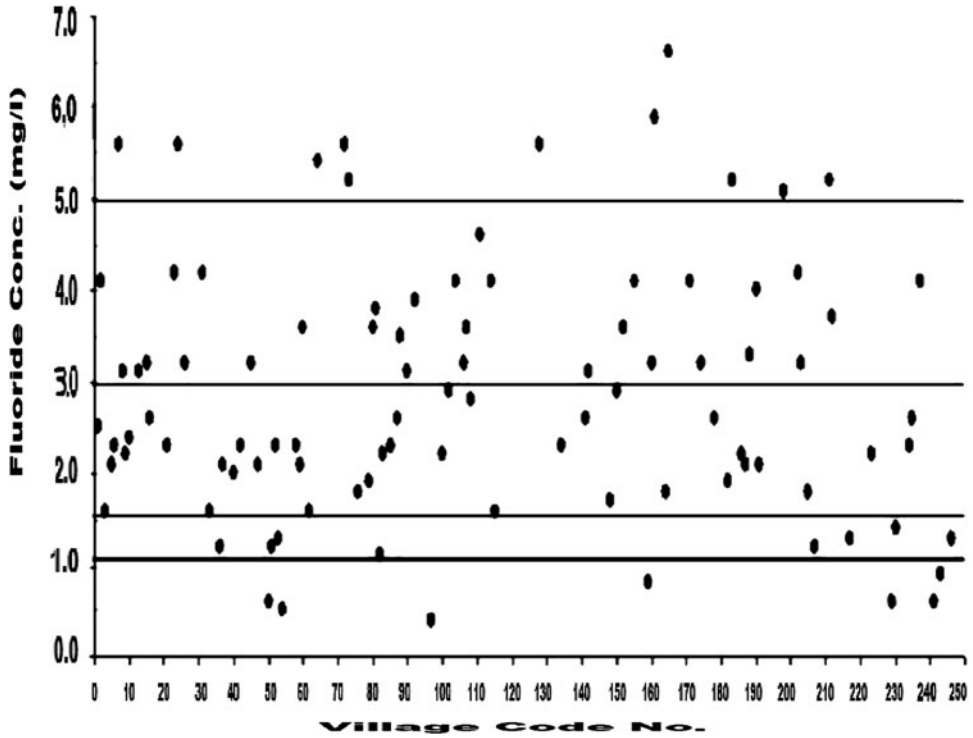

Fig. 1 Fluoride concentration in Nagaur tehsil of Nagaur district

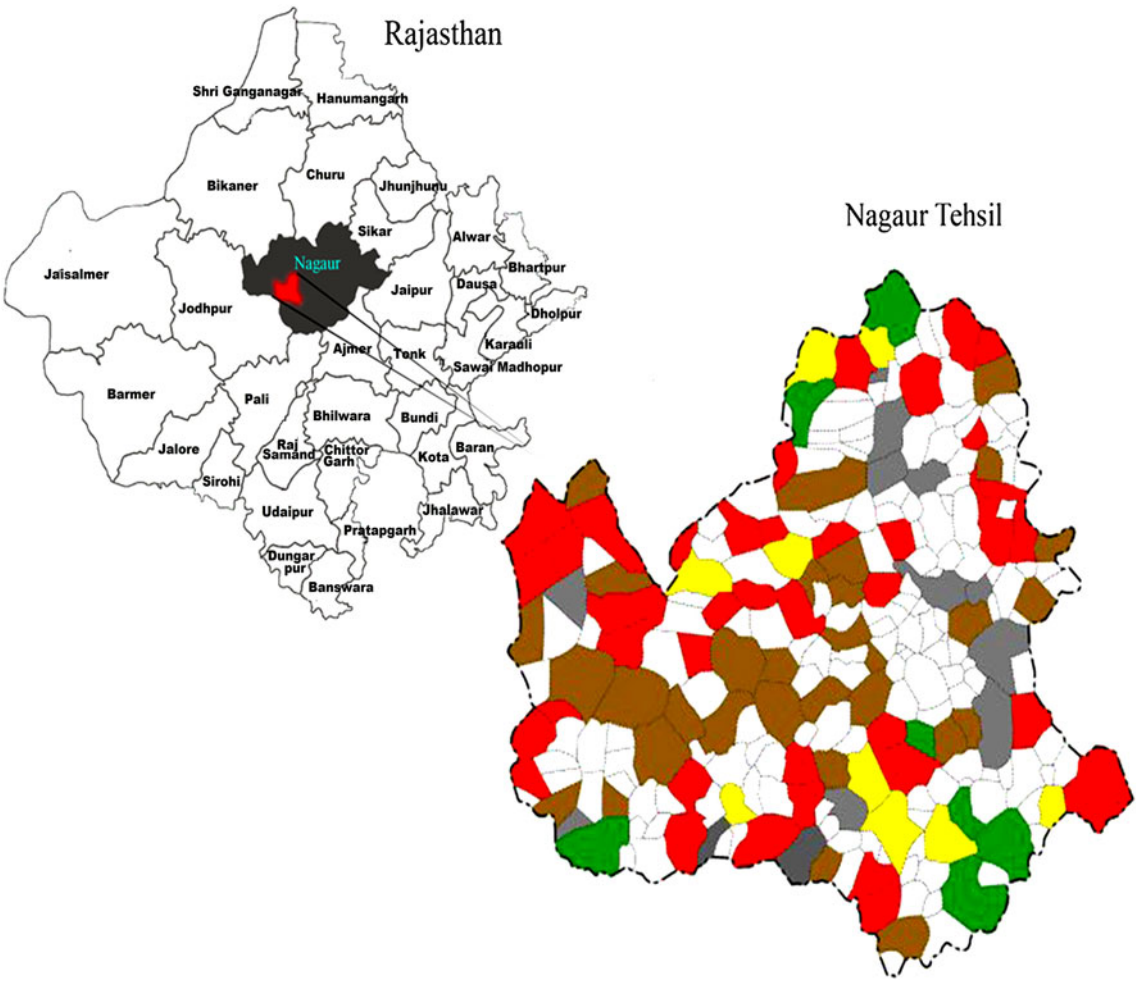

Fig. 2 Fluoride distribution in Nagaur tehsil of Nagaur district

body reflects the amount of fluoride ingested. Brouwer et al. (1988) stated that fluoride (F^-) is attracted by positively charged calcium ions, due to its strong electronegative charges, in teeth and bones and therefore excessive intake of fluoride cause pathological changes in teeth and bones. In the entire study the 13 villages falls in category V, where the fluoride concentration is above 5.0 mg/L, which may result all types of fluorosis in inhabitants. The second clinical stage the affected persons may have pain in bones, which causes further calcification in ligaments. It has been reported that under such persons may suffer from stiffness in joints. At this concentration, the vertebrae partially fuse together and crippling the patient which is known as "*crippling skeletal fluorosis*". Fluorosis is accompanied by adverse effect on the other systems and organs of the body namely liver, kidney, muscles, heart, lungs, blood and the hormonal functions (McGarvey and Ernstene 1947; Jansen and Thomson 1974; Jarnberg et al. 1979). The kidney is the principal organ through which maximum concentration of fluoride is excreted. High fluoride causes impaired kidney functions. A detailed survey of health hazards particularly fluorosis induced symptoms and empirical data on affected population is required in Nagaur as well as other tehsil of Nagaur district of Rajasthan.

Fluoride in drinking water can lead to a crippling disease called fluorosis. As there is no cure for fluorosis, prevention is the only means of controlling the disease.During the study in most of village evidence of fluorosis was very low in respect to the concentration of fluoride in groundwater. By the interaction with local residential it was found that they have made some local method to save themselves from fluorosis, which is as follows:

Villagers like to drink surface water (Pond etc.) instead of groundwater. They use surface water even that is turbid and may have other biological matter.

Local residential uses calcium rich nutrition. They say *"Ek roti kam khana per ek katori dahi jaroor khana"* means eat one roti less but must take a bowl of curd. Intake of calcium rich doses prevented fluorosis.

By adopting above methods made by local residential by experiences of a long–long period they save themselves

from fluorosis. However some case of fluorosis may be seen may be due to very high fluoride intake or nutrients deficient diet.

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