

# Fluoride distribution in groundwater and survey of dental fluorosis among school children in the villages of the Jhajjar District of Haryana, India

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**Abstract** Fluoride concentration of groundwater reserves occurs in many places in the world. A critical area for such contamination in India is alluvial soil of the plain region, consisting of five blocks (Jhajjar, Bahadurgarh, Beri, Matanhail, and Sahalawas) of the Jhajjar District adjacent to the National Capital Territory of India, New Delhi. The purpose of this study was to assess the association between water fluoride levels and prevalence of dental fluorosis among school children of the Jhajjar District of Haryana, India. The fluoride content in underground drinking water sources was found to vary in villages. Hence, the villages were categorized as high-fluoride villages (1.52–4.0 mg F/l) and low/normal-fluoride villages (0.30–1.0 mg F/l). The source of dental fluorosis data was school-going children (7–15 years) showing different stages and types of fluorosis who were permanent resident of these villages. The fraction of dental fluorosis-affected children varied from 30% to 94.85% in the high-fluoride villages and from 8.80% to 28.20% in the low/normal-fluoride villages. The results of the present study revealed that there existed a significant positive correlation between

fluoride concentration in drinking water and dental fluorosis in high-fluoride villages ( $r = 0.508; p < 0.001$ ) and insignificant correlation in low-fluoride villages.

**Keywords** Dental fluorosis · Fluoride distribution · Ground water · Drinking water · School children

## Introduction

Fluoride is one of the chemical elements necessary for human life. Deficiency or excess of fluoride in the environment is closely associated with human health (Zhang et al. 2003). The problem of high concentration of fluoride in groundwater sources has now become one of the most important toxicological and geo-environmental issues in India. The link between the fluoride geochemistry of water in an area and the incidence of dental and skeletal fluorosis is a well-established geochemical relationship. While the necessity of fluoride to human health is still open to debate, its toxicity is currently the cause of considerable concern in many countries where fluoride is found in excessive quantities in the drinking water (Chandrajith et al. 2007).

Excessive ingestion of fluoride during the early childhood years may damage tooth-forming cells, leading to a defect in the enamel known as dental fluorosis. It was also demonstrated that, when the concentration of fluoride in the water supply was 1.0 ppm, fluorosis affected less than 10% of the

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children examined. The first case of endemic fluorosis in humans from India was reported (Shortt et al. 1937) from the Prakasam District of Andhra Pradesh State. According to the World Health Organization (WHO) (1991), the permissible limit of fluoride in drinking water is 1.0 ppm. The major health problems caused by excessive fluoride are dental fluorosis, teeth mottling, skeletal fluorosis (more than 6 mg/l), and deformation of bones in children and adults (Susheela 1993).

More than 200 million people from all over the world suffer from dental fluorosis caused mainly by an excess of fluoride in drinking water (Chandrajith et al. 2007). Presently, 17 states in India have been identified as endemic for fluorosis and Haryana is one of them. It is estimated that 62 million people, including children, suffer from dental, skeletal/or nonskeletal fluorosis because of consumption of fluoride-contaminated water (Susheela 1999). The fluoride concentration in groundwater of India varies considerably from 0.12 to 24.17 ppm (Kumar and Gopal 2000). The degree of fluorosis has been related to the concentration of fluoride in drinking water and period of consumption.

Groundwater is the major drinking water source in the villages of Haryana State. Endemic fluorosis as well as its prevalence and severity is poorly known in Haryana except for a few studies (Garg et al. 1998; Dahiya et al. 2000, 2001; Yadav and Lata 2002). The present study was undertaken to assess the fluoride content of underground water and the prevalence of dental fluorosis among school children, in the villages of Jhajjar District, Haryana, India.

## Materials and methods

The area of Jhajjar District is 1,834 km<sup>2</sup> and it is geographically situated at 28°37'N latitude and 76°39'E longitude and 214 m above mean sea level (Fig. 1). The district consists of 262 villages, which are distributed in the five blocks of Jhajjar district: Jhajjar, Bahadurgarh, Beri, Matanhail, and Sahalawas. In most of the villages, groundwater is the only source of drinking water. The groundwater source is drawn by hand pumps, tube wells, and open wells. In the present study only 60 villages were chosen, 10 villages from each block with fluoride concentration of more than 1.5 ppm and two villages from each

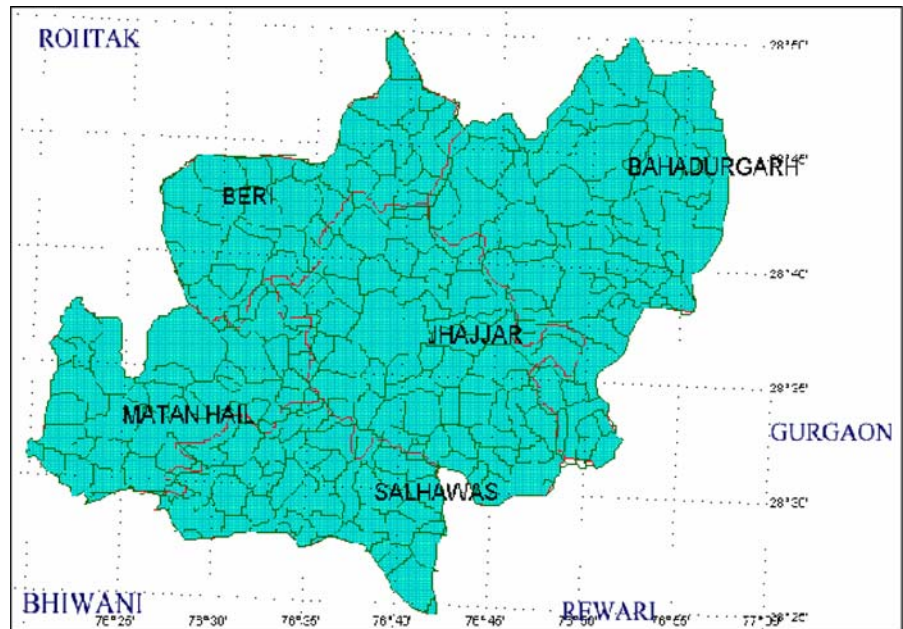
block with fluoride concentration up to 1.0 ppm after preliminary analysis in the district. Water samples were collected from each village from local hand pumps, tube wells, and open wells. A total of ten samples were collected from selected sources of each village to represent the water quality of the whole area. The samples were collected in precleaned polythene bottles with 1 l capacity and transported to the laboratory. Fluoride concentration was determined spectrophotometrically by using acid zirconyl and sodium 2-parasulfophenylazo-1,8-dihydroxy-3,6-naphthalene disulfonate (SPADNS) reagents (Bellack and Schouboe 1968). Sodium fluoride was used to prepare the standard solution. The fluorosis data was taken from the school children (ages 7–15 years) of the villages to investigate the impact of fluoride on dental health. Proforma prescribed by the Rajiv Gandhi Drinking Water Mission (Susheela 1993) was used to score the incidence and degree of dental fluorosis.

## Results and discussion

The data on fluoride concentration (mean  $\pm$  standard deviation [SD]) and severity of dental fluorosis among school children in the villages where fluoride concentration was more than 1.5 ppm are given in Tables 1–5. In ten villages of the Beri Block, the fluoride distribution was in the range 1.56–3.05 ppm. The mean value for fluoride was highest in Chimni Village (2.49 ppm) and was lowest in Madana Village (1.67 ppm). Out of the 1,722 children screened from ten villages in the Beri Block (below 18 years), 1,029 (59.76%) were affected by dental fluorosis with varying grades. Stages of dental fluorosis among these individuals were chalky white (21.02%), yellowish brown (27.99%), and brownish black (10.74%) with 19.05% showing horizontal streaks, 26.13% spots, and 14.58% both spots and streaks (Table 1, Figs. 2 and 3).

All the water sources collected from ten villages of the Bahadurgarh Block revealed fluoride in the range 1.53–3.52 ppm. The mean value of the fluoride level in Kulasi Village was 2.32 ppm and the lowest was 1.62 ppm in Kharman Village. A total of 1,713 school children were screened from ten villages of this block, of whom 1,176 (66.32%) were found to be affected by dental fluorosis. Stages of dental fluorosis

**Fig. 1** Topographic map showing the blocks of the Jhajjar District, Haryana (India)



**Table 1** Data on incidence and severity of the dental fluorosis in school children surveyed from the Beri Block of Jhajjar District

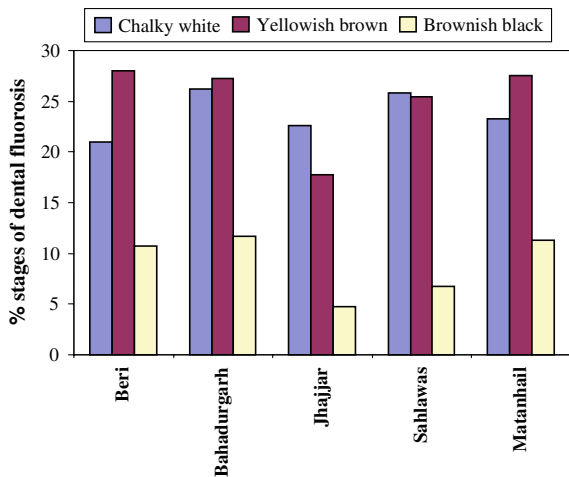
Sr. no.	Village	Fluoride concentration (ppm)		No. of individuals examined	No. of affected individuals (%)
		Range	Mean ± SD		
1.	Jahajgarh	1.85–2.9	2.37 ± 0.52	235	190 (80.85)
2.	Dubaldhan	1.69–3.05	2.45 ± 0.56	220	175 (79.54)
3.	Chamanpura	1.69–2.10	1.89 ± 0.20	158	105 (66.45)
4.	Chimni	2.38–2.60	2.49 ± 0.11	100	60 (60)
5.	Madana	1.56–1.78	1.67 ± 0.09	123	45 (36.58)
6.	Beri	1.58–2.38	1.98 ± 0.40	201	102 (50.75)
7.	Sheriya	2.22–2.43	2.37 ± 0.10	260	198 (76.15)
8.	Bhambhewa	1.60–2.13	1.86 ± 0.26	190	70 (36.84)
9.	Lakaria	1.62–1.78	1.71 ± 0.08	150	45 (30)
10.	Diwana	1.76–2.09	1.92 ± 0.56	85	39 (45.88)
	Total	–	–	1,722	1,029 (59.76)

among these individuals were chalky white (26.18%), yellowish brown (27.17%), and brownish black (11.64%) with 23.13% showing horizontal streaks, 28.25% spots, and 13.61% both spots and streaks (Table 2, Figs. 2 and 3).

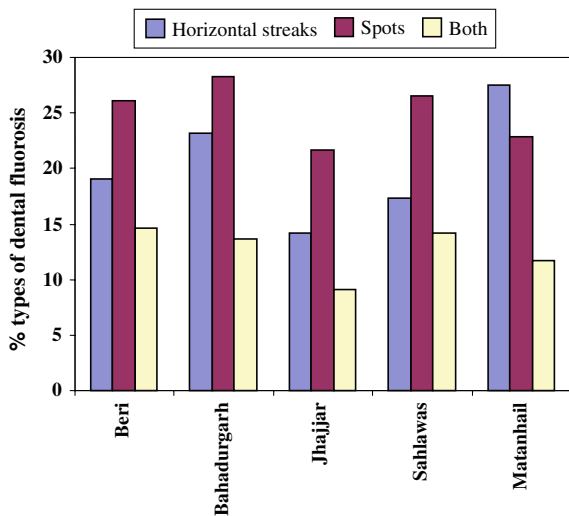
Fluoride concentration varied from 1.52 to 4.0 ppm in the water samples collected from Jhajjar Block, with the lowest mean value in Daur Village (1.78 ppm) and the highest in Ghatoli Village (2.62 ppm). A total of 1,976 school children were screened for dental fluorosis from the ten villages

chosen for this block, of whom 889 (44.99%) showed evidence of dental fluorosis. Stages of dental fluorosis among these individuals were chalky white (22.57%), yellowish brown (17.71%), and brownish black (4.71%) with 14.22% showing horizontal streaks, 21.66% spots, and 9.11% both spots and streaks (Table 3, Figs. 2 and 3).

In the ten villages from Sahalawas Block, the range of fluoride concentrations was 1.58–3.14 ppm. The mean fluoride value was highest in Dadanpur Village (2.81 ppm) while the lowest was found in



**Fig. 2** Percentage prevalence of different stages of dental fluorosis



**Fig. 3** Percentage prevalence of types of dental fluorosis

Fatehpuri Village (1.58 ppm). Out of 1,427 individuals screened from ten villages of Sahlawas Block for dental fluorosis, 828 (58.02%) were observed to be affected by dental fluorosis. Stages of dental fluorosis among these individuals were chalky white (25.86%), yellowish brown (25.44%), and brownish black (6.73%) with 17.31% showing horizontal streaks, 26.49% spots, and 14.22% both spots and streaks (Table 4, Figs. 2 and 3).

The water samples collected from ten villages of the Matanhail Block showed fluoride concentration in the range 1.52–3.16 ppm. The mean value of fluoride was highest in the Chadwana village (2.75 ppm) and

the lowest was found in Sasroli Village (1.73 ppm). A total of 1,496 individuals were screened, of whom 929 (62.10%) were observed to be affected by dental fluorosis. Dental fluorosis among these individuals was chalky white (23.26%), yellowish brown (27.50%), and brownish black (11.30%) with 27.54% showing horizontal streaks, 22.86% spots, and 11.70% both spots and streaks (Table 5, Figs. 2 and 3).

The data on fluoride distribution and severity of dental fluorosis among school children in the villages where fluoride concentration was up to 1.0 ppm are given in Table 6. It should be noted that in these villages also dental fluorosis-affected children were reported in spite of the low fluoride concentration in drinking water, although the percentage of affected children was lower (8.8–23.2%).

In the villages where fluoride concentration was greater than 1.5 ppm, the mean incidence of dental fluorosis was highest in Bahadurgarh Block (66.3%) and the mean incidence of dental fluorosis in the district was 58.24%, while in the villages where fluoride concentration was up to 1.0 ppm incidence of dental fluorosis was highest in Matanhail Block (23%) and the mean incidence of dental fluorosis in the district was 15.13%. Statistical analysis showed that there was a significant positive correlation between dental fluorosis and fluoride concentrations in drinking water in the villages with a fluoride level in drinking water of more than 1.5 ppm (correlation coefficient,  $r = 0.508$ ,  $p < 0.001$ , and  $\chi^2$  value 229.75,  $p < 0.001$ ). These results were not significant in low-fluoride villages.

Data from this study corroborate a number of other recent investigations indicating that the prevalence of dental fluorosis increases with fluoride concentration in drinking water (Choubisa 1997; Choubisa et al. 2001; Gopal 2000; Dhar et al. 2007). In the present study, 30–94.85% children revealed dental fluorosis. This suggests that prevalence of dental fluorosis can vary widely between different geographical locations having almost the same fluoride concentration in drinking water. These findings suggest that, besides water fluoride concentration and duration of exposure, other factors such as dissolved salts in drinking water, nutrition, and habits also affect the prevalence of dental fluorosis.

The present study revealed that children in this district exhibited various degrees of dental fluorosis.

**Table 2** Data on incidence and severity of dental fluorosis in the school children surveyed from the Bahadurgarh Block of Jhajjar District

Sr. no.	Village	Fluoride concentration (ppm)		No. of individuals examined	No. of affected individuals (%)
		Range	Mean ± SD		
1.	Kulasi	1.59–3.52	2.32 ± 0.85	180	140 (77.78)
2.	Mukenderpur	2.11–2.27	2.18 ± 0.06	200	160 (80)
3.	Lohat	1.53–2.17	1.87 ± 0.26	100	85 (85)
4.	Brahi	1.63–3.33	2.24 ± 0.65	250	172 (68.80)
5.	Kanondha	1.69–2.17	1.93 ± 0.24	215	153 (71.16)
6.	Dulehra	1.74–2.12	1.88 ± 0.16	130	98 (75.35)
7.	Mahandipur	1.58–2.19	1.89 ± 0.30	70	39 (55.71)
8.	Ladrawan	1.64–2.12	1.78 ± 0.21	123	45 (36.58)
9.	Bahadurgarh	1.58–2.11	1.96 ± 0.26	325	232 (71.38)
10.	Kharman	1.53–1.75	1.62 ± 0.08	120	52 (43.33)
	Total	–	–	1,713	1,176 (66.32)

**Table 3** Data on incidence and severity of dental fluorosis in the school children surveyed from the Jhajjar Block of Jhajjar District

Sr. no.	Village	Fluoride concentration (ppm)		No. of individuals examined	No. of affected individuals (%)
		Range	Mean ± SD		
1.	Dujana	1.53–2.11	1.92 ± 0.27	235	107 (45.53)
2.	Khajpur	1.85–2.61	2.23 ± 0.38	125	52 (41.6)
3.	Ghatoli	1.85–4.0	2.62 ± 0.98	190	70 (36.84)
4.	Kamalgarh	1.58–2.0	1.79 ± 0.15	167	76 (45.51)
5.	Jhajjar	1.92–2.6	2.17 ± 0.30	447	232 (51.90)
6.	Gudda	1.52–2.6	1.97 ± 0.46	230	98 (42.61)
7.	Daur	1.69–2.0	1.78 ± 0.21	201	102 (50.75)
8.	Jhangirpur	1.58–2.0	1.85 ± 0.13	123	45 (36.58)
9.	Kablana	1.9–2.38	2.13 ± 0.20	158	72 (45.57)
10.	Sondhi	1.92–2.12	2.02 ± 0.10	100	35 (35)
	Total	–	–	1,976	889 (44.99)

In the three blocks Jhajjar, Bahadurgarh, and Matanhail, second-stage dental fluorosis was reported in the highest number of children. However, in the Jhajjar and Sahlawas Blocks, first-stage dental fluorosis was prevalent among the children. The type of dental fluorosis in the form of spots was recorded most often in all the blocks except Matanhail. Amongst all of the studied villages, the number of children affected by fluorosis was highest in Dhakla Village (94.85%) of Sahlawas Block.

Water is the major source of fluoride intake. WHO (1991) guidelines suggested that, in areas with a warm climate, the optional fluoride concentration in drinking water should remain below 1.0 mg/l

(1.0 ppm) while in cooler climates it can increase to 1.2 mg/l. The differentiation derives from the fact that we perspire more in hot weather and consequently drink more water. The WHO guideline value for fluoride in water is not universal. India, for example lowered its permissible limits from 1.5 to 1.0 ppm in 1998. Fluoride concentration in the environment is closely associated with human health. Fluorosis is a result of the destruction of metabolic calcium and phosphorus, leading to inhibition of active enzymatic process in the human body, which interrupts the function of the endocrine system, leading to fluorosis (Xiang et al. 2004). It has long been known that excessive fluoride intake causes

**Table 4** Data on incidence and severity of dental fluorosis in the school children surveyed from Sahlawas Block of Jhajjar District

Sr. no.	Village	Fluoride concentration (ppm)		No. of individuals examined	No. of affected individuals (%)
		Range	Mean $\pm$ SD		
1.	Chandaul	1.63–2.6	2.18 $\pm$ 0.35	100	60 (60)
2.	Fatehpuri	1.58–1.59	1.58 $\pm$ 0.05	150	45 (30)
3.	Kanwa	1.85–2.0	1.92 $\pm$ 0.15	90	30 (33.33)
4.	Surehti	1.58–1.63	1.60 $\pm$ 0.02	85	30 (35.29)
5.	Kasni	1.85–1.92	1.89 $\pm$ 0.03	90	28 (31.11)
6.	Dhakla	1.53–2.0	1.78 $\pm$ 0.17	272	258 (94.85)
7.	Dadanpur	2.53–3.14	2.81 $\pm$ 0.26	205	194 (94.63)
8.	Samaspurmajra	1.69–2.11	1.86 $\pm$ 0.18	182	78 (42.36)
9.	Chhappar	1.63–2.22	1.85 $\pm$ 0.23	95	45 (47.36)
10.	Patasani	1.63–2.11	1.87 $\pm$ 0.19	158	60 (37.97)
	Total	–	–	1,427	828 (58.02)

**Table 5** Data on incidence and severity of dental fluorosis in the school children surveyed from Matanhail block of district Jhajjar

Sr. no.	Village	Fluoride concentration (ppm)		No. of individuals examined	No. of affected individuals (%)
		Range	Mean $\pm$ SD		
1.	Marot	1.85–3.01	2.47 $\pm$ 0.51	220	175 (79.54)
2.	Chadwana	1.92–3.06	2.75 $\pm$ 0.48	234	192 (82.05)
3.	Sasroli	1.52–2.0	1.73 $\pm$ 0.18	125	45 (36)
4.	Khapparwas	1.70–2.1	1.92 $\pm$ 0.15	200	120 (60)
5.	Kheri Hoshiarpur	2.0–3.11	2.58 $\pm$ 0.50	158	105 (66.45)
6.	Gawalison	1.79–3.16	2.48 $\pm$ 0.56	172	98 (56.98)
7.	Bambulia	2.0–2.01	2.0 $\pm$ 0.07	85	39 (45.88)
8.	Janswa	1.53–2.0	1.81 $\pm$ 0.20	130	50 (38.46)
9.	Matanhail	1.79–1.92	1.87 $\pm$ 0.06	102	70 (68.63)
10.	Reduwas	1.70–1.82	1.77 $\pm$ 0.06	70	35 (50)
	Total	–	–	1,496	929 (62.10)

serious toxic effects. The enamel of human tooth, which is the hardest part of the human body, consists of the mineral hydroxyl apatite  $[\text{Ca}_5(\text{PO}_4)_3\text{OH}]$ . When excessive fluoride is ingested, the fluoride ions begin to replace the hydroxyl ions in the apatite structure, thereby converting it to fluoroapatite  $[\text{Ca}_5(\text{PO}_4)_3\text{F}]$ , which makes the tooth brittle and discolored. This is known as dental fluorosis. Dental fluorosis, which is characterized by discolored, blackened, mottled or chalky white teeth, is a clear indication of overexposure to fluoride during childhood when the teeth were developing. Chronic intake of excessive fluoride can lead to the severe and permanent bone and joint deformations of skeletal

fluorosis. The physical damage that fluorosis may cause to teeth is not, however, the only concern. Another concern, as detailed over 20 years ago by the National Institute of Mental Health (NIMH), is the psychological impact that dental fluorosis may have on a child. According to the study, children with severe dental fluorosis are more likely to be perceived by their peers as less intelligent, less attractive, less social, less happy, less careful, less hygienic, and less reliable, which could have a major effect on a child's self-esteem (Elias-Boneta et al. 2006; Williams et al. 2006). Whether dental or skeletal, fluorosis is irreversible and no treatment exists. The only remedy is prevention, by keeping fluoride intake within the



**Table 6** Extent of fluorosis among individuals from villages with normal levels of fluoride in the water sources

Block	Village	Fluoride concentration (ppm)		No. of individuals examined	No. of affected individuals (%)
		Range	Mean ± SD		
Beri Block	1. Siwana	0.35–0.8	0.54 ± 0.14	120	18 (15.00)
	2. Palra	0.3–0.6	0.41 ± 0.09	125	11 (8.80)
Bahadurgarh Block	1. Balore	0.56–0.79	0.69 ± 0.09	113	20 (17.69)
	2. Isheheri	0.35–0.75	0.58 ± 0.13	145	20 (13.79)
Jhajjar Block	1. Saloda	0.62–0.81	0.72 ± 0.07	150	25 (16.67)
	2. Khazpur	0.48–0.80	0.61 ± 0.12	147	22 (14.97)
Sahalawas Block	1. Babepur	0.62–0.76	0.71 ± 0.05	135	24 (17.78)
	2. Nilaheri	0.94–1.0	0.98 ± 0.07	138	18 (13.04)
Matanhail Block	1. Gorla	0.85–1.0	0.95 ± 0.08	125	29 (23.20)
	2. Marot	0.62–0.91	0.76 ± 0.12	135	14 (10.37)
	Total	–	–	1,333	201 (15.13)

safe limits. Fluoride poisoning can be prevented or minimized by using alternative water sources, by removing excess fluoride, and by improving the nutritional status of the population at risk.

Clinical data indicate that adequate calcium intake is clearly associated with a reduced risk of dental fluorosis (Teotia et al. 1987; Pius et al. 1999). Vitamin C may also act as a safeguard against the risk. Hence, measures to improve the nutritional status of an affected population—particularly children—appear to be an effective supplement for and antidote against fluorosis.

Consequently, in these villages fluorosis is caused mainly by fluoride in drinking water. As found here, there were significant dose–response relationships between water fluoride, serum fluoride, and prevalence of dental fluorosis, which are consistent with findings of Xiang et al. (2004). This study gives an overview of the existing caries and the treatment needs in school children of Haryana and helps in implementing programs to achieve optimal health for children.

**Conclusion**

The Jhajjar District of Haryana State, India, is a typical region showing endemic fluorosis caused by drinking water. Groundwater (well, hand pump, and tube wells) is the main source of drinking water for village residents. Dental fluorosis among children was significantly correlated with the level of fluoride

in drinking water. The present study gives an overview of the extent of fluorosis and stresses the treatment needs in school children through implementing programmes to achieve optimal health.

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