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RESEARCH ARTICLE

Fluoride in Drinking Water and its Toxicosis in Tribals of Rajasthan, India

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Abstract Fluoride (F) toxicosis in the forms of dental, skeletal and non-skeletal fluorosis were investigated in 996 tribal individuals (503 males and 493 females) above 10 years of age living in nine F endemic villages of Dungarpur district of Rajasthan, India. Drinking water sources of these villages contained F in the range of 1.5–4.4 ppm. Of these tribals, 735 (73.8 %) and 294 (29.5 %) were found to be afflicted with mild to severe dental and skeletal fluorosis, respectively. At 1.5 ppm F concentration the prevalence of dental and skeletal fluorosis was 33.9 and 10.7 %, respectively. A polymorphism of dental fluorosis in the form of brown to deep yellowish bilaterally stratified horizontal lines, pits or patches, and fine dots or granules was noted on anterior teeth of tribal individuals. Irregular wearing, excessive corrosions (abrasions), dark-yellowish pigmentation of exposed cementum and dentine material, diastemas between teeth, pronounced loss of tooth supporting bone with recession, and bulging of gingiva (gum) were also present. Among the adult and old tribal individuals, the following mild to severe manifestations of skeletal fluorosis such as crippling, kyphosis, invalidism and genu-varum syndrome were found. Sporadic cases of paraplegia and quadriplegia were also found. None of the fluorotic tribals showed evidence of genu-valgum syndrome. Radiological changes were also observed in these individuals. Other signs of chronic F intoxication in soft tissues (non-skeletal fluorosis) included colic, intermittent diarrhoea or constipation, bloating, urticaria, polyurea, polydipsia, repeated abortions, still birth and sterility. Data pertaining to prevalence of osteo-dental fluorosis in relation to age and F concentration exhibited statistically significant correlation.

Keywords Drinking-water · Fluoride · Fluorosis · Toxic effects · Tribals · Rajasthan · India

Introduction

Chronic exposure to fluoride (F) through drinking water in man and animals produces range of toxic effects on hard tissues like teeth (dental fluorosis) and bones (skeletal fluorosis) [1–6]. Excess F exposure also damages soft tissues and organs of body [1, 2, 7, 8]. The prevalence and severity of these toxic effects have also been studied in relation to certain biological and non-biological determinants [9–12]. In India, fluorosis is endemic in many states including Rajasthan, where almost all districts have high F content (up to 18.0 ppm) in their drinking/ground water sources [13, 14] and fluorosis in the form of osteo-dental fluorosis have been reported in certain areas of Rajasthan [15–17]. In southern Rajasthan, where tribal population is predominant, 0.3–10.8 ppm F concentration has been reported [18]. However, studies on fluorotoxicosis in socio-economically backward and mostly illiterate tribals are limited. The present paper reports relative prevalence and severity of toxic effects of F in tribals living in villages having high content of F in drinking water.

Material and Methods

During a recent cross-sectional survey in F endemic villages (Table 1) of Dungarpur district of Rajasthan, India, 996 tribal individuals of either sex (>10 years age) were

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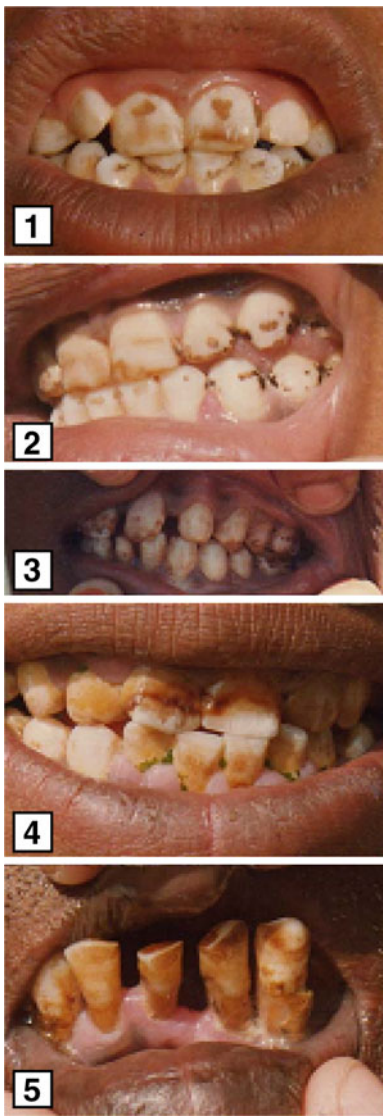


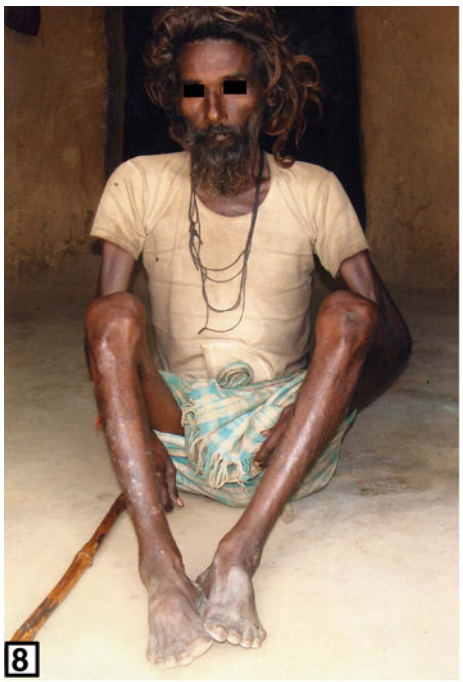
Figs. 1–5 Polymorphism and severity of dental fluorosis. **1** Children showing pitting/patches, **2** and **3**. Fine dots and **4** Bilateral stratified *dark-yellowish lines* on anterior teeth. **5** Excessive abrasions (corrosions) of enamel and exposure of cementum and dentine material with *deep-yellowish* pigmentation, diastemas between teeth, pronounced loss of tooth supporting bone with recession and bulging of gingiva

clinically examined for evidence of osteo-dental fluorosis. The mean F concentration in drinking water of these villages ranged from 1.5 to 4.4 ppm [11]. Criteria for the identification of dental and skeletal fluorosis were followed as described in earlier report [1]. In addition, 1–2 clinically identified fluorotic individuals (>40 years) from each village were also examined radiologically for further evidence of skeletal fluorosis or any other bone deformities [19–21]. These subjects were also asked for medical history (non-skeletal fluorosis) as for colic, diarrhoea, constipation, abdominal pain, bloating, skin allergy, repeated urination and drinking of water, impaired reproductive functions etc.

Figs. 6 and 7 Cases of severe skeletal fluorosis showing common deformities: kyphosis, invalidism, genu-varum (legs bowed outward at the knee) and crippling (**6**) and crossing or scissor-shaped legs (**7**)

Tribals of studied areas have very poor nutritional status. In general, they intake maize, barley, rice, onion with or without pulses and vegetables. Other food stuffs like milk, curd, ghee and fruits are very rare in their diets. They are mostly habitual for daily intake of local wine, tea and smoking.

In the present investigation, F concentration in urine and blood was not estimated in the fluorotic individuals.



Figs. 8 and 9 A case of severe skeletal fluorosis showing secondary neurological complication, quadriplegia (**8**) had severe dental fluorosis (**9**)

Identification of chronic F effects in these tribal people was based on clinical findings only. Data pertaining to prevalence of osteo-dental fluorosis were also analyzed statistically [22].

Results and Discussion

Dental Fluorosis

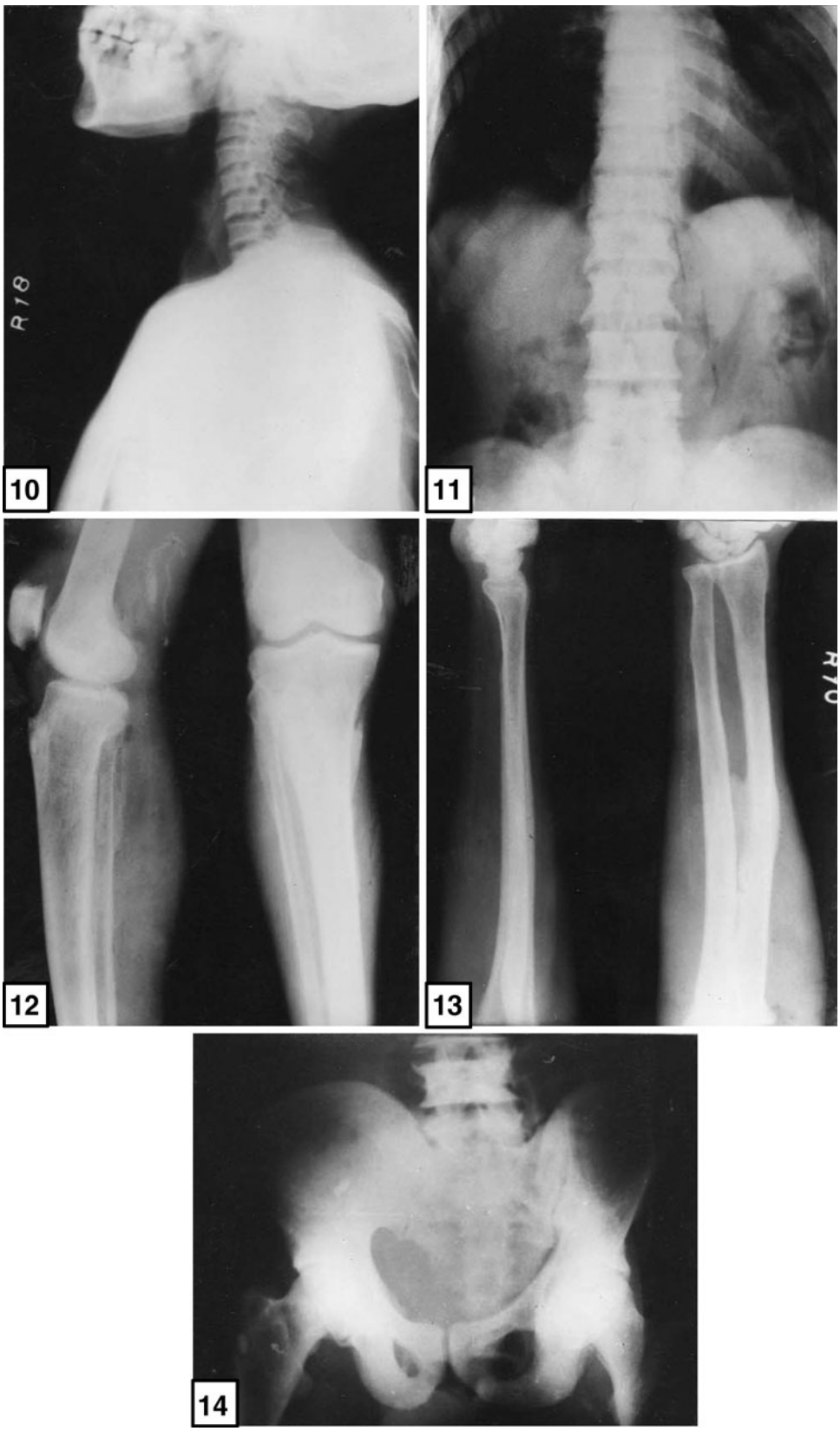
Bilateral dental mottling (Figs. 1, 2, 3, 4, 5) was found in 735 of 996 tribal people (73.8 %) in the present study (Table 1). The highest (100 %) and the lowest (33.9 %) prevalence of dental fluorosis were found in the areas with 3.7 and 1.5 ppm F concentration in drinking water, respectively. A variable prevalence of dental fluorosis was observed in the villages having the same or almost similar F concentration in the drinking water (Table 1). The maximum prevalence (97.4 %) of dental fluorosis was observed in above 60 year age group and the minimum (40.5 %) in the 10–20 year age group. However, a little variation in prevalence was found between the two sexes (Table 2). A high correlation coefficient was found between water fluoride concentration and prevalence of osteo/dental fluorosis.

Polymorphism of dental fluorosis was observed in tribal individuals which appeared bilaterally in the form of light brown to deep-yellowish pits or patches (Figs. 1, 2, 3, 4, 5), fine dots (Figs. 1, 2, 3, 4, 5) and horizontal stratified lines (Figs. 1, 2, 3, 4, 5 , 8, 9) at 1.5 ppm F concentration. Corrosion of tooth material with deep brown or black staining was found above 2.0 ppm F concentration in drinking water. In older people, irregular wearing, excessive corrosion or abrasions, recession and bulging of gingiva, and diastema (gaps) between teeth (Figs. 1, 2, 3, 4, 5) were found at F concentration above 2.0 ppm.

In India, dental fluorosis has previously been described in humans ingesting 0.5–1.0 ppm F in drinking water [23, 24], while at concentrations of 3.4–3.8 ppm, 100 % dental fluorosis has been reported [25]. In the present study, the highest (100 %) prevalence of dental fluorosis in tribals was observed in the villages having F concentration above 3.7 ppm. A variation in prevalence of fluorosis at almost similar F concentrations was observed in the present study. This can be attributed to a number of factors or determinants such as duration of F exposure and its intake frequency, habits, nutrition, climate, salts in drinking water besides the individual susceptibility, biological response and genetics of an individual [3, 26].

Skeletal Fluorosis

Out of 996 tribal people, 294 (29.5 %) revealed evidence of skeletal fluorosis of varying grades (Table 1). Of these 154 (30.6 %) were men and 140 (28.4 %) women. The prevalence of skeletal fluorosis was generally found to increase with increasing age and F concentration in drinking water (Table 2). Onset of skeletal deformities at 1.5 ppm F was observed mostly in the higher age group (>31 years). Crippling deformity was found at and above 2.0 ppm F. The more extreme forms of skeletal deformities or chronic F effects as kyphosis, invalidism, genu-varum (legs bowed outward at the knee), and crossed or scissor-shaped legs (Figs. 6, 7) were observed only in adults above the age of 41 who had been consuming water containing 3.0 ppm F. Secondary neurological complications, paraplegia and quadriplegia (Figs. 8, 9) were seen only in a few individuals (>50 years) where drinking water had 4.0 ppm



Figs. 10–14 Cervical and dorsal spines showing extreme osteosclerosis, lipping and osteophytosis (**10**, **11**), bony exostosis in tibia and fibula bones (**12**), calcification of interosseous membrane between radius and ulna bones (**13**) and osteosclerosis of the pelvis with calcification of ligaments (**14**)

Table 1 Prevalence (%) of dental and skeletal fluorosis in tribal individuals in relation to fluoride (F) concentration in drinking water

S. No.	Village	Mean F Conc. (ppm)	Individuals examined (>10 years)	Dental fluorosis positive	Skeletal fluorosis positive
1	Fatehpura	1.5	112	38 (33.9)	12 (10.7)
2	Mevadi	1.6	106	44 (41.5)	14 (13.2)
3	Amartiya	2.0	122	57 (46.7)	23 (18.8)
4	Devala	2.0	104	51 (49.0)	25 (24.0)
5	Masona	3.0	114	109 (95.6)	36 (31.6)
6	Dhundha	3.5	108	106 (98.1)	38 (35.2)
7	Kateshwar	3.7	110	110 (100.0)	41 (37.3)
8	Pindawal	4.0	102	102 (100.0)	48 (47.0)
9	Ghanta	4.4	118	118 (100.0)	57 (48.3)
	Total		996	735 (73.8)	294 (29.5)

Figures in parentheses indicate percentage

Correlation coefficient between: F concentration and dental fluorosis, $r = +0.952$ (highly positive), F concentration and skeletal fluorosis, $r = +0.982$ (highly positive)

Table 2 Prevalence (%) of dental and skeletal fluorosis in tribal subjects in relation to their age and sex

S. No.	Age (Years)	Dental fluorosis			Skeletal fluorosis		
		Males	Females	Total	Males	Females	Total
1	10–20	32/72 (44.4)	28/76 (36.8)	60/148 (40.5)	13/72 (18.0)	11/76 (14.5)	24/148 (16.2)
2	21–30	53/96 (55.2)	50/91 (54.9)	103/187 (55.1)	24/96 (25.0)	22/91 (24.1)	46/187 (24.6)
3	31–40	70/98 (71.4)	67/96 (69.8)	137/194 (70.6)	28/98 (28.6)	25/96 (26.0)	53/194 (27.3)
4	41–50	86/95 (90.5)	86/94 (91.5)	172/189 (91.0)	33/95 (34.7)	31/94 (33.0)	64/189 (33.9)
5	51–60	76/82 (92.7)	72/78 (92.3)	148/160 (92.5)	32/82 (39.0)	29/78 (37.2)	61/160 (38.1)
6	>60	59/60 (98.3)	56/58 (96.5)	115/118 (97.4)	24/60 (40.0)	22/58 (37.2)	46/118 (39.0)
7	10 to >60	376/503 (74.7)	359/493 (72.8)	735/996 (73.8)	154/503 (30.6)	140/493 (28.4)	294/996 (29.5)

Figures in parentheses indicate percentage

Correlation coefficient between: Age and dental fluorosis, $r = +0.906$ (highly positive), Age and skeletal fluorosis, $r = +0.976$ (highly positive)

concentration of F. None of the tribal individuals showed evidence of genu-valgum or knock-knees deformity (legs angle inward at the knee).

Radiographs (x-rays) of cervical spine (Figs. 10, 11, 12, 13, 14), ribs and lumbar-dorsal spine with pelvis (Figs. 10, 11, 12, 13, 14), lower limb (Figs. 10, 11, 12, 13, 14), forearm (Figs. 10, 11, 12, 13, 14) and pelvis (Figs. 10, 11, 12, 13, 14) of 1–2 fluorotic tribal subjects of each village showed increased bone mass and density as well as exostoses, calcification of ligaments and interosseous membranes and osteosclerosis. These changes were more progressive with increasing age and F concentration in the drinking water and provided further evidence of skeletal fluorosis in these villages. Other radiological changes have also been observed as described elsewhere [19–21].

The incidence and severeness of skeletal fluorosis was higher in the higher age group (Table 2) and increased with increasing F concentration, which is certainly due to longer exposure and increasing of F toxicity. Other workers have also observed a higher incidence of skeletal fluorosis in old age group [27]. Several workers have reported skeletal fluorosis and crippling at F levels above 1 and 3 ppm, respectively [1]. In the present study, no case of genu-valgum syndrome was noted, in contrast to some of the southern (Andhra Pradesh, Karnataka, and Tamil Nadu) and central (Madhya Pradesh) Indian states where fluorosis is also endemic and cases of genu-valgum syndromes along with osteoporosis of long bones have been reported [28, 29]. This deformity or F effect has not been reported from any other hyper endemic areas of Rajasthan [30]. The way in which F causes genu-valgum syndrome is still uncertain and inconclusive. However, level of some micronutrients may be responsible for this deformity. In F endemic areas of Andhra Pradesh genu-varum was observed in those people who had low calcium and high molybdenum content in their staple diet [28].

Non-skeletal Fluorosis

In the fluorotic people most common clinical signs or history such as intermittent diarrhoea or constipation, abdominal pain, flatulence, urticaria, polyurea and frequent intake of water (polydipsia) were found. Such observations have also been reported in humans [31–33] living in F endemic areas. However, in the areas under present survey, cases of repeated abortions, sterility, reluctance to reproductive functions and erectile dysfunction in male

individuals were relatively higher as compared to non-endemic areas of F. Indeed gastro-intestinal discomforts, neurological and impaired reproductive dysfunctions are considered as the earlier signs of chronic F intoxication in both men [1, 31–33] and animals [7, 8, 34].

The prevalence and severity of chronic fluoride effects (fluorosis) are relatively higher in tribal individuals as compared to their non-tribal counter parts [26]. Infact tribals have poor nutritional status and habit of excessive drinking of local wines and tea [10]. Poor nutritional value of their food may cause deficiency of vitamins and other dietary components which can decrease or increase F absorption or intoxication [1]. It is well known that milk, curd and some vegetables are rich in calcium, whereas citrus fruits and leafy vegetables contain vitamin-C. Both these nutrients and fat (ghee and edible oils) reduce F absorption [1] and hence mitigate F toxicity. The tribals are predominantly farmers and laborers and generally drink more water, thereby maximizing their F intake besides drinking wine, beverages and tea that are additional sources of F toxicity. Besides these causes, intrinsic individual genetic differences of tribals may also contribute to the degree of F intoxication [26].

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References

1. WHO (1970) Fluorides and human health, monograph series, vol 59. World Health Organization, Geneva
2. Swarup D, Dwivedi SK (2002) Environmental pollution and effects of lead and fluoride and animal health. Indian Council of Agricultural Research, New Delhi
3. Choubisa SL (1999) Chronic fluoride intoxication (fluorosis) in tribes and their domestic animals. Int J Environ Stud 56(5): 703–716
4. Choubisa SL (1999) Some observations on endemic fluorosis in domestic animals of southern Rajasthan. Vet Res Commun 23(7):457–465
5. Choubisa SL (2007) Fluoridated ground water and its toxic effects on domesticated animals residing in rural areas of Rajasthan. (India). Int J Environ Stud 64(2):151–159
6. Choubisa SL, Mishra GV, Sheikh Z, Bhardwaj B, Mali P, Jaroli VJ (2011) Toxic effects of fluoride in domestic animals. Adv Pharmacol Toxicol 12(2):29–37
7. Choubisa SL (2010) Osteo-dental fluorosis in horses and donkeys of Rajasthan, India. Fluoride 43(1):5–12
8. Choubisa SL (2010) Fluorosis in dromedary camels, Rajasthan, India. Fluoride 43(3):194–199
9. Thergaonkar VP, Bhargava RK (1974) Water quality and incidence of fluorosis in Jhunjhunu of Rajasthan: preliminary observations. Indian J Environ Health 16:168–180
10. Choubisa SL, Choubisa L, Choubisa D (2009) Osteo-dental fluorosis in relation to nutritional status, living habits and occupation in rural tribal areas of Rajasthan, India. Fluoride 42(3): 210–215
11. Choubisa SL (2010) Natural amelioration of fluoride toxicity (fluorosis) in goats and sheep. Curr Sci 99(10):1331–1332
12. Choubisa SL, Mishra GV, Sheikh Z, Bharadwaj B, Mali P, Jaroli VJ (2011) Food, fluoride, and fluorosis in domestic ruminants in the Dungarpur district of Rajasthan, India. Fluoride 43(2):70–76
13. Choubisa SL (2001) Endemic fluorosis in southern Rajasthan, India. Fluoride 34(1):61–70
14. Hussain J, Hussain I, Sharma KC (2010) Fluoride and health hazards: community perception in a fluorotic area of central Rajasthan (India): an arid environment. Environ Monit Assess 162:1–14
15. Mathur M, Tamboli BL, Mathur RH et al (1976) Preliminary epidemiological investigation of fluorosis in Surajpura and Pratappura villages of Sarwar Tehsil, Ajmer district (Rajasthan). Indian J Prev Soc Med 7:90–93
16. Choubisa SL (1998) Fluorosis in some tribal villages of Udaipur district (Rajasthan). J Environ Bio 19(4):341–352
17. Maithani PB, Gurjar R, Banerjee R, Balaji BK, Ramachandran S, Singh R (1998) Anomalous fluoride in ground water from western part of Sirohi district, Rajasthan and its crippling effects on human health. Curr Sci 4(9):773–777
18. Choubisa SL (1996) An epidemiological study on endemic fluorosis in tribal area of southern Rajasthan [a technical report]. Ministry of Environment and Forests, New Delhi
19. Choubisa SL (1996) Radiological skeletal changes due to fluoride intoxication in Udaipur district (Rajasthan). Poll Res 15:227–229
20. Choubisa SL, Sompura K (1996) Dental fluorosis in tribal villages of Dungarpur district (Rajasthan). Poll Res 15:45–47
21. Choubisa SL, Verma R (1996) Skeletal fluorosis in bone injury case. J Environ Biol 17(1):17–20
22. Mahajan BK (1984) Methods in biostatistics. Jaypee Brothers, Medical Publisher Pvt. Ltd, New Delhi
23. Venkateswarlu P, Rao DN, Rao KR (1952) Studies in endemic fluorosis in Visakhapatnam and Sub urban areas. Indian J Med Res 40:353–362
24. Ray SK, Ghosh S, Nagchaudhary J, Tiwari IC, Kaur P (1981) Prevalence of fluorosis in rural community near Varanasi. Fluoride 14:86–90
25. Subbareddy VV, Tiwari A (1985) Enamel mottling at different levels of fluoride in drinking water: in an endemic areas. J Indian Dent Assoc 57:205–212
26. Choubisa SL, Choubisa L, Sompura K, Choubisa D (2007) Fluorosis in subjects belonging to different ethnic groups of Rajasthan (India). J Commun Dis 39(3):171–177
27. Choubisa SL, Choubisa L and Choubisa D (2011) Osteo-dental fluorosis in relation to chemical constituents of drinking waters. J Environ Sci Eng (in press)
28. Krishnamachari KAVP, Krishnaswamy K (1976) An epidemiological study of the syndrome of genu valgum among residents of endemic areas for fluorosis in Andhra Pradesh. Indian J Med Res 62(9):1415–1423
29. Chakma T, Singh SB, Godbole S, Tiwary RS (1997) Endemic fluorosis with genu valgum syndrome in a village of district Mandala, Madhya Pradesh. Indian Pediatr 34:232–236
30. Choubisa SL, Choubisa L, Choubisa DK (2001) Endemic fluorosis in Rajasthan. Indian J Environ Health 43(4):177–189
31. Susheela AK, Das TK, Gupta IP, Tondon RK, Kacker SK, Ghosh P, Deka RC (1992) Fluoride ingestion and its correlation with gastro-intestinal discomfort. Fluoride 25(1):5–22
32. Sharma JD, Sohu D, Jain P (2009) Prevalence of neurological manifestations in a human population exposed to fluoride in drinking water. Fluoride 42:127–132
33. Sharma JD, Jain P, Sohu D (2009) Gastric discomforts from fluoride in drinking water in Sanganer Tehsil, Rajasthan, India. Fluoride 42(4):286–291
34. Justus C, Krook LP (2006) Allergy in horses from artificially fluoridated water. Fluoride 39(2):89–94