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Prevalence of dental fluorosis in Sudanese children from two villages with 0·25 and 2·56 ppm fluoride in the drinking water

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Summary. Dental fluorosis is endemic in Eastern Africa and a high prevalence has been found even in low-fluoride (≈0·5 ppm) areas. Substantial seasonal changes in the fluoride content of water have also been reported. The aim of the present study was to ascertain, through one year, the fluoride concentration in water from two underground reservoirs in Sudan, in Treit el Biga (TeB) and Abu Groon (AG), and to assess dental fluorosis in children aged 7–16 years who had been lifelong residents. The water in one of the reservoirs (TeB) was shown to have a low, very stable fluoride concentration (0·25 ppm SD 0·04) whereas the other (AG) had a tenfold higher, and slightly varying, fluoride concentration (2·56 ppm SD 0·26). Dental fluorosis was recorded on maxillary central incisors according to Dean's index. In TeB 91% of the children showed signs of dental fluorosis whereas in AG all children had fluorotic teeth. The Community Fluorosis Index in TeB and AG was 1·40 and 2·44, respectively. There was a significantly higher degree of fluorosis in boys than in girls in the low-fluoride area. In TeB, older boys tended to have more fluorosis than younger boys; the difference, however, was not statistically significant. No significant sex or age differences in fluorosis were found in AG. In both villages great inter-individual variations in dental fluorosis were recorded. The prevalence and severity of dental fluorosis in TeB was higher than that previously reported in areas with similar fluoride concentrations in the drinking water.

Introduction

More than 50 years ago H. Trendley Dean [1] ascertained a positive correlation between the concentration of fluoride in drinking water and the prevalence and severity of dental fluorosis. Dean found no definite 'safe limit' for fluoride, but concluded that enamel changes caused by drinking water with less than 1·0 mg F/l (1 ppm F) were of no public health significance. It is presently generally agreed that a universal optimal fluoride concentration cannot be defined, but, according to WHO's recommendations [2], the fluoride concentration of drinking water should normally be in the range of 0·5–1·2 ppm.

A series of interesting studies on fluoride and fluorosis have been conducted in Africa. Manji *et al.* [3] found dental fluorosis in all children (6–15 years of age) who lived in a Kenyan village 2095 m above sea level and consumed water with 2·0 ppm F. Møller *et al.* [4] reported dental fluorosis in nine out of ten children in a Ugandan village where the fluoride content of drinking water was 2·0–3·0 ppm F. Møller *et al.* also examined children in low-F areas in Uganda, and reported great variations. In one village with 0·17–0·30 ppm F in the water 3·4% of the children showed dental fluorosis, whereas

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prevalences in the range of 28·2–42·5% were found in four other villages with similar fluoride concentrations. In a study in two low-fluoride areas in Kenya, Manji *et al.* [5] found dental fluorosis in 78% of the children from a village with 0·10–0·46 ppm F in the drinking water, whereas prevalences of 91·2% and 93·8% were observed in villages with water contents of 0·53–0·66 and 0·54–0·93 ppm F, respectively. Similar findings have been reported from Tanzania [6] and Sudan [7–9]. A recent study from Senegal, West Africa, however, found no fluorosis in children drinking water from wells and sinkings having up to 0·17 ppm F [10].

As indicated above, the relationship between the fluoride concentration of water and dental fluorosis is complex. With a given fluoride concentration the prevalence and severity of fluorosis seem to increase with increasing mean daily temperature [11] and altitude above sea level [12]. Nutritional status may also play a role in the development of dental fluorosis [13]. There is no doubt, however, that drinking water is the most important single provider of fluoride to children in areas with endemic dental fluorosis. Knowledge of the fluoride content of the relevant water sources is therefore needed in all studies on dental fluorosis and, as considerable seasonal fluctuations of fluoride concentration may be seen in rivers and wells [14,15], repeated water analyses should be carried out.

The aim of the present study was to monitor, through one year, the fluoride concentration of drinking water in two Sudanese villages and to assess the prevalence and degree of dental fluorosis in children who were born and raised in the villages.

Methods

Two rural villages in the Khartoum area were chosen for the investigation: Treit el Biga (TeB) and Abu Groon (AG). Both villages depend on underground water sources for domestic use. Boreholes were drilled into the Nubian sandstone bedrock about 15 years ago. The TeB borehole is 45 m deep, and in AG 93 m. The two villages are typical rural communities with stable populations of similar size. The inhabitants have more or less the same socioeconomic and ethnic background. The villages are situated in arid areas, at approximately 300 m above sea level, and within 50 km from the capital. The monthly mean temperature varies from 23 to 35°C. Dental fluorosis had previously been observed by us (Y.E.I. and A.A.A.) in both villages.

Water samples were collected in clean plastic vials during the first week of each month through 1992. The tightly-lidded vials were sent air mail to Bergen, Norway. Fluoride analyses were carried out at the University of Bergen, using a combined fluoride electrode (Orion 96 09 00) connected to an Orion Research Microprocessor Ionalyser 901, according to standard procedure [16].

Permission to examine the school-children was prearranged with the local school teachers. School attendance is obligatory in Sudan. Boys and girls, however, go to separate schools, and, especially in rural areas, fewer girls than boys attend school. The total number of children in the villages is unknown, but 125 were available for examination, 113 of whom (55 in TeB and 58 in AG) met requirement of having at least one permanent maxillary incisor erupted (Table 1). The children were lifelong residents of their villages. The age range was 7–16 years. The gender distribution was skewed, especially in AG.

Table 1. Number of children examined: distribution by age, gender and residence.

	No. of children examined				
	Treit el Biga		Abu Groon		Total
Age	Boys	Girls	Boys	Girls	
7	2	0	2	0	4
8	3	1	3	2	9
9	5	3	3	2	13
10	4	1	6	2	13
11	1	1	7	3	12
12	2	2	6	0	10
13	5	5	10	1	21
14	4	6	5	0	15
15	6	4	4	1	15
16			1		1
No. of children	32	23	47	11	113
Mean age (years/months)	11/6	12/7	11/8	10/5	11/8

Assessment of dental fluorsis was performed on the porch, outside the schools, according to the WHO criteria for field surveys [17]. The children were seated on a portable dental chair. No artificial light was used. Dental examination was carried out by one examiner (Y.E.I.) after brief cleansing of the teeth with cotton rolls. Fluorosis scorings were based on findings in the maxillary central incisors. Fluorosis was assessed as being present if symmetrical, fluorosis-like markings were found on the incisors [18]. Care was taken to distinguish between fluorosis and non-fluoride enamel opacities. Mild degrees of dental fluorosis were characterized by diffuse horizontal opaque patches following the perichymata, differentiated from localized, non-fluoride enamel opacities confined to well-demarcated round or oval spots [19,20].

The scores used were: 0 = sound, 1 = very mild, 2 = mild, 3 = moderate, and 4 = severe, according to Dean's index [21]; the *questionable* category in Dean's index was not used. When a difference was noted between the right and left incisor, the higher of the two scores was registered. For each village the Community Fluorosis Index (F_{ci}) was calculated according to the formula

$$F_{ci} = \frac{\Sigma \text{ individual scores}}{\text{number of children}} \qquad [21]$$

Statistical analysis. Dental fluorosis is measured on a ranking scale. Therefore a non-parametric test, the Mann-Whitney U test, was used to assess the statistical significance of differences between the two villages.

Results

The average fluoride concentration of the water sources in TeB and AG was, over a 1-year period, 0·25 ppm (SD 0·04) and 2·56 ppm (SD 0·26), respectively. The fluoride concentration in the low-fluoride TeB water was relatively stable, with slightly lower F-values during the first half of the year (Fig. 1); the AG readings were less stable, especially during the period January–June.

In TeB, 90·9% of the children had fluorotic changes in the enamel of their maxillary central incisors, most often score 1 or 2 (very mild or mild); in AG all the children showed signs of fluorosis (Table 2). The children in AG had significantly higher fluorosis scores than TeB-children ($P < 0{\cdot}001$).

Table 2. Distribution of dental fluorosis scores.

Fluorosis score	Treit el Biga Boys	Treit el Biga Girls	Treit el Biga Total	Abu Groon Boys	Abu Groon Girls	Abu Groon Total
0	2	3	5	0	0	0
1	12	17	29	5	4	9
2	14	2	16	15	3	18
3	3	1	4	23	4	27
4	1	0	1	4	0	4

In low-fluoride TeB, boys had significantly higher fluorosis scores than girls (Table 3) ($P = 0{\cdot}003$). When the children were grouped according to age and gender, the gender difference in TeB was significant only in the older children (12–16 years) ($P = 0{\cdot}02$). Skewness in sampling invalidated statistical comparison between genders in AG.

The Community Fluorosis Index (F_{ci}) was 1·40 and 2·44 in TeB and AG, respectively.

Discussion

As emphasized by, for example, Fejerskov *et al.* [13], the prevalence and severity of dental fluorosis depend on the total amount of fluoride ingested during the critical period of enamel formation. In addition to water, various other fluoride sources have been identified, such as toothpaste [18,22], fish and seafood [23] and tea [24]. In Tanzania, magadi, a high-fluoride trona used for tenderizing food [25], may add to the total fluoride intake. Magadi is unknown in Northern Sudan, but occasional use of fluoride-containing additives to the food cannot be ruled out.

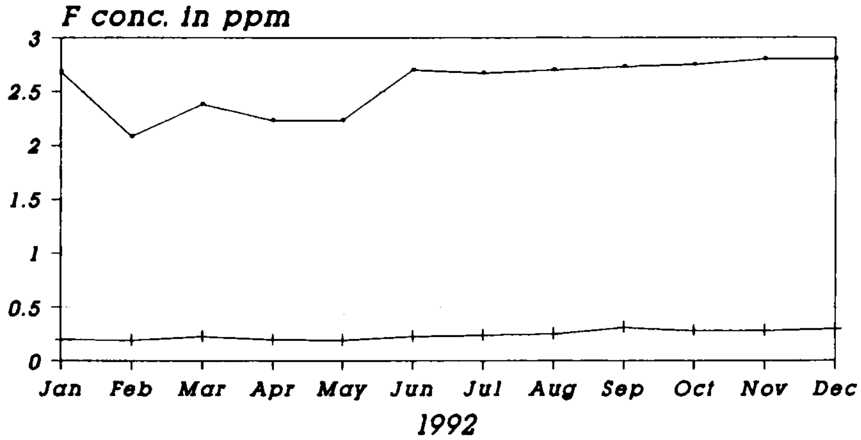

Fig. 1. Fluoride concentration of drinking water in Treit el Biga (+) and Abu Groon (•): monthly samples through 1992.

Table 3. Mean fluorosis severity scores.

	Treit el Biga				Abu Groon			
	Boys		Girls		Boys		Girls	
Age group	No.	Mean score	No.	Mean score	No.	Mean score	No.	Mean score
7–11 years	15	1.4	6	1.0	21	2.3	9	1.9
12–16 years	17	1.9*	17	1.1	26	2.7	2	2.5
All children	32	1.7*	23	1.1	47	2.5	11	2.0

*Significantly higher than in TeB girls.

A strict association exists between the fluoride concentration in the water supplies and dental fluorosis [13]. The chemical composition of underground water is influenced by long-time exposure to the surrounding bedrock, and normally the fluoride concentration of ground water is elevated compared to that of surface water [26]. Consequently the opening up of underground water reservoirs may have increased the fluoride load on the population during the last decennia. Fluoride concentration tends to increase with the depth of wells [10,26]. This is in accordance with the present findings: the deep well (93 m) in AG contained 10 times more fluoride than the more shallow water source in TeB (45 m).

Subsurface water sources are replenished by influx of low-fluoride surface water from, especially, precipitation. Seasonal changes tend to be more pronounced in high-fluoride wells [15]. Depending upon the depth of the aquifer and the nature of the surrounding rock, a substantial time lag is observed between the precipitation and its influence on the underground water [15]. In Northern Sudan the rainfall is scarce and normally occurs in the period June–August. A time lag of 6–9 months for the AG-aquifer therefore might explain the lower fluoride values registered during the period February–May. Slightly lower fluoride concentrations were also registered in TeB during the first half of the year.

The consumpion by children in AG of water with an average fluoride concentration of 2·56 ppm resulted in dental fluorosis in all the children examined. Previous studies in communities with similar fluoride concentrations in the water, such as those of Wenzel & Thylstrup in Denmark [27] and Manji *et al.* [3] in Kenya, have reported fluorosis prevalences of 96–100%. The Community Fluorosis Index in AG (2·44) was, however, higher than what was originally indicated by Dean for communities with 2·5 ppm F [21], and substantially higher than that reported from Uganda (1·74) [4] and from Denmark (1·33) [27] in areas with similar fluoride concentrations in the drinking water. In low-fluoride TeB the fluorosis prevalence (91%), as well as the Community Fluorosis Index (1·40), was higher than that previously reported in areas with similar fluoride concentrations in the drinking water [4,5,12,21,27]. Murray & Shaw [28] reported a prevalence of only 2·4% in children living in areas where the drinking water contained less than 0·26 ppm F. The reason for the unexpectedly high prevalence and severity of dental fluorosis in TeB is unknown. One might speculate that the high temperature and dry climate require a very high intake of water; the daily water consumption in the Sudan, however, is unknown.

Dental fluorosis may develop only during the period of primary and secondary mineralization of the teeth. Thus the maxillary central incisors (according to Larsen *et al.* [29] and Ishii & Suckling [30]) are most susceptible from the age of 1 year to 5½ years of age. For the elder group of children in our study this period started 12–15 years prior to the examination, when the local wells were new. We have no long-time documentation on the fluoride content of waters in TeB and AG, but some observations (for example from Norway [31]) indicate a gradual decline in the fluoride content of newly opened subsurface water reservoirs. A tendency to higher fluorosis scores in older boys in TeB might possibly be explained by changes in the fluoride concentration of the water.

A wide range of fluorosis scores was found in both villages. Differences between children in the same village indicate greater variations in daily fluoride intake than can be explained by seasonal changes in the fluoride concentration of drinking water. Detailed studies on feeding habits, such as daily intake of water, milk, or tea, are needed.

Statistically significant gender differences in fluorosis scores were observed only in low-fluoride TeB. A higher prevalence of dental fluorosis in boys has earlier been reported from Sudan [7], Uganda [4] and Ethiopia [32], and may conceivably be due to sex-related differences in behaviour. Thus, according to Sudanese traditions, boys from an early age are more involved in outdoor activities. The daily fluid consumption varies according to the individual's age, size and physical activity, as well as to climatic conditions [11,33]. Pang *et al.* [34] indicated that 1–10-year-olds in North Carolina, USA, consume between 970 and 1430 ml fluid per day, of which beverages comprise about 50%. In the hot climate of TeB and AG even higher consumptions should be expected. A report from Kenya found that children 1–4 years of age had a daily fluid intake of about 1100 ml, about half of which was tea [35]. According to Jenkins [24] the average fluoride concentration of tea is 2·2 ppm, but wide variations exist, depending on the tea brand and the tea-making technique. Tea is very popular in Sudan, and may be given to children even during the first year of life. Tea is, consequently, a factor to be considered in the pathogenesis of dental fluorosis in low-fluoride areas.

The severity of dental fluorosis in AG and, even more, the prevalence and severity of fluorotic changes in TeB, were unexpectedly high for low-altitude communities with, respectively, relatively high and low fluoride concentration in the drinking water. The findings presented in this report may indicate that even 0·25 ppm F is too much for young children under African conditions. The findings should not, however, be interpreted as suggesting that fluoride in water is unsafe at all concentration levels, but rather that further studies should be undertaken on the total fluoride load in children, especially in low-fluoride tropical areas.

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Prévalence de la fluorose dentaire chez des enfants soudanais de deux villages dont la teneur en Fluor de l'eau potable est de 0·25 et de 2·56 ppm

Résumé. La fluorose dentaire est endémique en Afrique de l'Est et une prévalence élevée a été trouvée même dans les régions peu fluorées (0·5 ppm). Des changements saisonniers importants de la teneur en Fluor ont toujours été rapportés. Le but de cette étude a été de noter, tout au long de l'annee, la concentration en Fluor de l'eau de deux réservoirs souterrains au Soudan, à Treit el Beiga (TeB) et à Abu Groon (AG) et d'evaluer la Fluorose dentaire chez les enfants de 7 à 16 ans ayant toujours résidé dans cette zone. L'eau d'un des réservoirs (TeB) avait une concentration en Fluor faible es très constante (0·25 ppm SD = 0·04) alors que l'autre (AG) avait une concentration en Fluor dix fois supérieure avec quelques faibles variations (2·56 ppm SD = 0·26). La fluorose dentaire a été notée, sur les incisives centrales supérieures, d'après l'index de Dean. A TeB, 91% des enfants montraient des signes de fluorose dentaire alors qu'à AG, tous les enfants avaient des dents portant des signes de fluorose. L'index de fluorose (Fci) était de 1·40 è TeB et de 2·44 à AG. La fluorose était plus élevée, de façon significative, chez les garçons par rapport aux filles dans la zone peu fluorée. A TeB, les garçons plus âgés avaient plus de fluorose que les garçons plus jeune; cependant, la différence n'était pas statistiquement significative. Aucune différence, selon l'âge ou le sexe, n'a été notée à AG. Dans les deux villages des variations individuelles importantes ont été trouvées. La prévalence et la sévérité de la fluorose dentaire à TeB étaient supérieures à celles rapportées précedemment dans les zone à concentration similaire en Fluor dans l'eau de boisson.

Das Vorkommen der dentalen Fluorosis in Sudanischen Kindern aus zwei verschledenen Dörfern, eines mit 0·25 ppm und eines 2·56 ppm Flourid im Trinkwasser

Zusammenfassung. Dentale Fluorosis is sehr verbreitet in Ostafrika, sogar in Gabieten mit niedrigem Gehalt an Fluoride (0·5 ppm). Berichtet wurde auch über jahreszeitbedingte Unterschiede im Fluoridgehalt des Wassers. Der Zweck dieser Studie war, während eines Jahres, die Fluoridkonzentration des Wassers aus zwei Untergrundvorkommen in Sudan festzustellen, aus Terit el Biga (TeB) und aus Abu Groon (AG). Ebenfalls der Grad der Fluorosis bei Kindern von 7 bis 16 Jahren weiche immer in diesen Gebieten lebten. Das Wasser von (TeB) zeigte eine stabile niedrige

Fluoridkonsentration von 0·25+0·4 ppm, die von der anderen (AG) wies eine 10fach höhere, sehr stabile Fluoridkonzentration (2·56+0·26 ppm) auf. Fluorosis wurde festgestellt an den oberen zentralen Schneidezähnen, entsprechend das Dean-index. Befallen waren un TeB 91%, in AG 100% der Kindern an Fluorosis. Der Gameindeindex in TeB war 1·40 und in AG 2·44. Ein significant höherer Befall von Fluorosis wurde bei den Buben aus der Gegend mit niedrigen Fluoridanteil gefunden. In TeB neigten ältere Buben zu mehr Fluorosis als die Jüngeren aber ohne signifikanten Unterschied. In AG wurde, bezüglich Geschlecht und Alter keine signifkanten Unterschiede gefunden. In beiden Dörfern wurden grosse individuelle Unterscheide festgestellt. Das Vorkommen und der Schweregrad der dentalen Fluorosis in TeB and AG warden grösser als in Gebieten mit ähnlichen Fluoridkonzentrationen über weiche bis anhin in der Literatur berichtet wurde.

Prevalancia de fluorosis dental en niños Sudaneses

Resumen. Alta prevalencia en fluorósis dental ha sido reportada en areas bajas en fluor (~0·5 ppm) del Africa. Importantes cambios estacionales en el |F⁻| del agua tembién han sido reportados. El presente papel reporta análisis mensuales a través de un año de dos reservas de agua subterraneas en Sudan, Treit el Biga (TeB) y Abu Groon (AG) y la estimación de fluorosis dental, en niños (7–16 años) que fueron consumidores de estas aguas durante toda su vida. Una de las reservas (TeB) produjo agua con baya y muy estable concentración de fluor (0·25±0·04 ppm) mientras que la otra (AG) dió agua con un nivel 10 veces más alto y poca variación de |F⁻| (2·56±0·26 ppm). Fluorosis dental fue registrada de acuerdo a el indice de Dean. En TeB el 90 por ciento de los niños mostraton signos de fluorósis dental mientras que an AG todos los niños presentaron en el área de baja fluorización. No se encontraron diferencias significativas de fluorósis en cuanto a edad y sexo se refirere en AG. La prevalencia y serverida de fluoros dental en Treit el Biga fue más alta de lo que anteriormente se ha reportado an áreas con similar concentración dientes fluoróticos. El indice de la comunidad (F_{ci}) de TeB y AG fué de 1·40 y de 2·44, respectivamente. Hubo un grado significativamente más alto de fluorósis en niños que en niñas de F en el agua de beber.

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