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UNSUITABILITY OF WORLD HEALTH ORGANISATION GUIDELINES FOR FLUORIDE CONCENTRATIONS IN DRINKING WATER IN SENEGAL

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Summary A survey was done of the prevalence of dental fluorosis among children aged 7–16 years and the occurrence of skeletal fluorosis among adults aged 40–60 years living in regions in Senegal where fluoride concentrations in the drinking water ranged from < 0·1 to 7·4 mg/l. In the area where the fluoride concentration in the drinking water was 1·1 mg/l milder forms of dental fluorosis were found, the prevalence being 68·5%. In areas where fluoride concentrations exceeded 4 mg/l the prevalence of dental fluorosis reached 100%. Kyphosis was very prevalent among a community whose drinking water contained 7·4 mg/l fluoride. Radiographs of the vertebral column, hand, and wrist of 3 adults with kyphosis confirmed the diagnosis of skeletal fluorosis. High sweat loss and a high intake of water because of the hot weather may account for the finding. The present World Health Organisation guideline for the upper limit of fluoride concentration in drinking water may be unsuitable for countries with a hot, dry climate.

INTRODUCTION

DRINKING water containing optimum levels of fluoride (0·7–1·2 mg/l, depending on climatic conditions) has a caries-preventing effect.[1-3] Higher levels of fluoride, however, can be harmful, the two chronic toxic effects of fluoride being dental fluorosis and skeletal fluorosis, which are endemic in areas with high fluoride concentrations in soil and water. Dental fluorosis produces changes ranging from superficial enamel mottling to severe hypoplasia of the enamel and the dentine, and brownish discoloration is common.[1,4] The early symptomless stages of skeletal fluorosis can be diagnosed only by finding dense bone on radiographic examination. In more advanced stages there is obvious rigidity of the vertebral column with impairment of articular movements; other signs include calcification of ligaments and tendons, exostoses, kyphosis, and other forms of crippling fluorosis.[1] Crippling fluorosis is usually restricted to tropical and subtropical areas.

The World Health Organisation (WHO) recommends an upper limit of 1·5 mg/l fluoride in the drinking water;[5] above this level an objectionable degree of mottling of the teeth may occur.[6] Concentrations beyond 3–6 mg/l fluoride in the drinking water may be associated with symptoms of skeletal fluorosis, and beyond 10 mg/l the skeletal fluorosis may be crippling.[5] In many parts of the world, however, symptoms of fluorosis have been reported below the concentrations cited above[1] perhaps because factors such as climatic conditions, amount of drinking water consumed, fluoride intake from sources other than drinking water, food habits, and malnutrition influence the development of fluorosis.[1] We have examined the prevalence of dental fluorosis and the occurrence of skeletal fluorosis in communities in Senegal with different fluoride concentrations in the drinking water.

MATERIALS AND METHODS

Data were collected by two authors (I. B. and A. de B.) in October and November, 1985, at the beginning of the dry season. The study consisted of two surveys.

First Survey

The first survey was of the prevalence of dental fluorosis in five towns (Nioro du Rip, Kaffrine, Gossas, Guinguinéo, Foundiougne) in the Sine Saloum region with fluoride concentrations in the drinking water of < 0·1 to 4·6 mg/l. In each town, 50–80 elementary school children (7–9 years) who had used these sources of water since birth were examined. Those who did not have permanent incisors yet were excluded. For every child the mottling of the enamel of the eight permanent incisors was scored according to Dean's classification.[4] When one or more teeth showed obvious signs of dental fluorosis (Dean's index ≥ 1) the child's dentition was recorded as fluorotic; the degree of fluorosis was not specified.

Second Survey

The second survey was conducted at Nioro du Rip, Guinguinéo, and Darou Rahmane Fall (Diourbel region). In these places the drinking water contained fluoride in concentrations of < 0·1 mg/l, 3·9 mg/l, and 7·4 mg/l, respectively, and the sources had been in use for more than 20 years. Both children and adults were examined in the second survey.

Children.—In each of the three towns about 50 randomly selected children (7–16 years) who had lived there since birth were examined. In Nioro du Rip and Guinguinéo the children were recruited from elementary schools, whereas in the village of Darou Rahmane Fall all children aged 9–16 years available at the time of the survey were examined. The prevalence of dental fluorosis was examined in more detail in the second than in the first survey: the eight permanent incisors of every child were individually scored as 0, 0·5, 1, 2, 3, or 4 according to Dean's classification.[4] The score per child was based on the two most affected teeth. A first morning urine was collected from 20 of the boys examined in each community. The community index of fluorosis (Fc) was calculated according to Dean's method;[7]

$$Fc = \frac{\Sigma(\text{number of children} \times \text{Dean's index score})}{\text{Total number of children examined}}$$

Adults.—In the two communities with the highest level of fluoride in the drinking water, Guinguinéo and Darou Rahmane Fall, about 50 residents aged 40–60 years who had lived in these areas all their lives were randomly selected from each community and examined for the presence of obvious kyphosis as a visible sign of possible serious skeletal fluorosis. X-rays were taken in Fann Hospital, Dakar, of the vertebral column, hand, and wrist of 3 adults in Darou Rahmane Fall with serious kyphosis. The X-rays were interpreted at Fann Hospital and by specialists at the Academic Hospital, Utrecht, the Netherlands.

Fluoride Analysis

The fluoride concentrations of the samples of morning urine and drinking water were measured with a fluoride ion-specific electrode.[8]

Statistics

The data on the prevalence of kyphosis were statistically analysed by means of the χ^2-test.

RESULTS

The first survey clearly showed that the prevalence of dental fluorosis among children increases with the fluoride

TABLE I—PREVALENCE OF DENTAL FLUOROSIS AMONG CHILDREN AGED 7–9 YEARS IN COMMUNITIES WITH DIFFERENT FLUORIDE CONCENTRATIONS IN DRINKING WATER

Community	Fluoride concentration (mg/l)	Number of children examined	Prevalence of dental fluorosis* (%)
Nioro du Rip	<0·1	83	2·4
Kaffrine	1·1	73	68·5
Gossas	2·6	75	85·3
Guinguinéo	3·9	63	93·7
Foundiougne	4·6	54	100·0

*Dean's index ≥ 1.

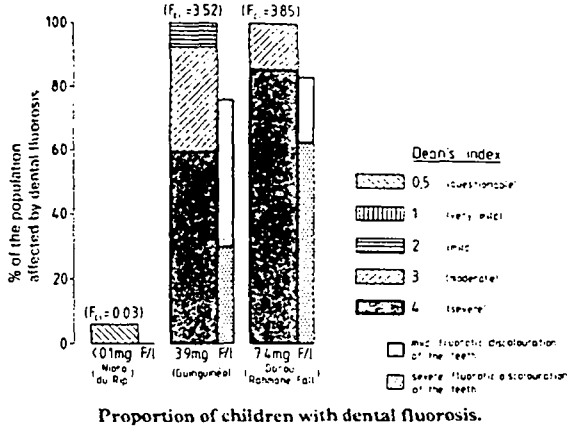
TABLE II—SEX AND AGE OF CHILDREN EXAMINED IN SECOND SURVEY

Community (mg F/l)	Number of children examined			Mean (SD) age (yr)
	Boys	Girls	Total	
Nioro du Rip (<0·1)	28	22	50	8·7 (0·9)
Guinguinéo (3·9)	24	30	54	8·6 (0·6)
Darou Rahmane Fall (7·4)	28	20	48	10·4 (2·7)

TABLE III—PREVALENCE OF KYPHOSIS AMONG ADULTS AGED 40–60 YEARS IN GUINGUINÉO AND DAROU RAHMANE FALL IN RELATION TO THE FLUORIDE CONCENTRATIONS IN THE DRINKING WATER

Community	Fluoride concentration (mg/l)	Number of persons examined	Number (%) with kyphosis
Guinguinéo	3·9	55	4 (7·3)
Darou Rahmane Fall	7·4	42	11 (26·2)

concentration of the drinking-water (table I). At a fluoride level of 1·1 mg/l in the drinking water (Kaffrine) the prevalence of dental fluorosis was 68·5%. The prevalence of dental fluorosis reached nearly 100% at fluoride levels of 4 mg/l and above (Guinguinéo, Foundiougne). The sex and age distributions of the children examined in the second survey are given in table II. None of the children in Nioro du Rip showed signs of dental fluorosis, whereas all children in Guinguinéo and Darou Rahmane Fall did. The community index of fluorosis reached nearly the maximum possible of 4 in both Guinguinéo ($Fc_1 = 3·52$) and Darou Rahmane Fall ($Fc_1 = 3·85$). In both communities dental fluorosis was accompanied by considerable brownish discoloration of the teeth (fig 1). About 30% and 60% of the children in Guinguinéo and Darou Rahmane Fall, respectively, had severely discoloured brownish-black teeth.



Proportion of children with dental fluorosis.

The mean (SD) fluoride concentrations in the morning urine of the children were 0·7 (0·6) mg/l in Nioro du Rip, 12·0 (6·2) in Guinguinéo, and 17·9 (11) in Darou Rahmane Fall. Among adults kyphosis was more prevalent in Darou Rahmane Fall than in Guinguinéo (table III) ($p < 0·025$). In 3 adults from Darou Rahmane Fall with kyphosis X-rays of the vertebral column, hand, and wrist confirmed the diagnosis of skeletal fluorosis.

DISCUSSION

In this survey the prevalence of dental fluorosis among children aged 7–9 years was already very high at fluoride levels in the drinking water of about 1 mg/l. The 1·5 mg/l fluoride recommended by WHO as maximum acceptable concentration in the drinking water[5] obviously cannot be applied to Senegal. The hot and dry climate in Senegal, and consequently high levels of water intake, may account for the high prevalence of dental fluorosis, as suggested by the way in which countries with different climates but similar fluoride levels in drinking water differ in community indices of fluorosis (table IV); this positive relation between the degree of dental fluorosis and the environmental temperature was first published in 1953.[9,10]

In temperate climates the fluoride concentration in the urine is similar to the fluoride concentration in the drinking water.[3] In this study children had urinary fluoride concentrations that were about 2·5 times higher than the fluoride concentration in drinking water. High sweat loss and high water intake may be responsible for high serum fluoride levels and hence dental and skeletal fluorosis. If climate does strongly influence the appearance of dental fluorosis in the community, then in places with hot climates skeletal fluorosis could be expected to become apparent at lower fluoride concentrations in the drinking water than it does in a milder climate. In the 1984 WHO guidelines for drinking water quality the minimum drinking water fluoride concentration beyond which crippling fluorosis occurs is said to be 10 mg/l.[5] However, that same year, another WHO publication *Fluorine and Fluorides*[1] cited a report[11] which was based on balance studies on patients with endemic fluorosis, and which indicated that in adults a daily intake exceeding 8 mg would be harmful. The X-rays taken in Senegal confirmed that crippling skeletal fluorosis occurs at 7·4 mg/l fluoride in the drinking-water. At this concentration a daily water intake of 2 litres by adults[12] (which is a low intake in view of the climatic conditions in Senegal), would correspond to a probable intake of 15 mg fluoride per day. The high prevalence of kyphosis in Senegal at 7·4 mg/l fluoride in drinking water is a serious health problem. We could not collect data on the prevalence of skeletal fluorosis at drinking water fluoride concentrations of 7·4 mg/l or less.

The disfiguring brownish-black discolorations in the enamel of the teeth are an especially serious aesthetic

TABLE IV—EPIDEMIOLOGICAL DATA CONCERNING DENTAL FLUOROSIS: PREVALENCE, (FC_1) IN RELATION TO FLUORIDE CONCENTRATIONS IN DRINKING WATER AND AVERAGE ANNUAL TEMPERATURE

Country	Average annual temp (°C)	Fluoride in drinking water (mg/l)	Prevalence of dental fluorosis (%)	Fc_1
USA[14]	12	4·0	72	1·88
Tanzania[15]	20	3·5	100	3·00
Senegal[16]	28	3·9	100	3·52

problem in Senegal because the locals try to file or scrape off the stains, thus aggravating the fluorotic damage to the teeth.

Our findings strongly indicate that the WHO guidelines on the fluoride concentration in the drinking water should not be directly applied in countries with a hot and dry climate such as Senegal. Although WHO recognises that application of their guidelines should take into account climatic conditions, and that fluorosis is very common in tropical countries,[5] no attempt has been made to specify ranges of fluoride concentrations for different environmental temperatures; this omission is surprising since WHO did specify limits for different environmental temperature in 1971.[13]

This study shows that the recommended upper limit of 1·5 mg/l fluoride in the drinking water is too high to prevent dental fluorosis in Senegal. More studies should be done to see whether an upper limit of around 0·6 mg/l fluoride is more suitable. To prevent severe dental fluorosis (Dean's index 4) in countries with a hot dry climate, the maximum permissible level of fluoride in the drinking water should perhaps be of the order of 2 mg/l fluoride.

When only crippling skeletal fluorosis is thought to be a human health problem, an opinion we do not share, then the upper limit for fluoride in drinking water might be of the order of 7 mg/l (Darou Rahmane Fall), a level which is considerably lower than the WHO guideline of 10 mg/l. Furthermore, milder degrees of skeletal fluorosis could occur at lower levels. In places where the fluorosis is due to excessive intake of fluoride from drinking water there should be a shift to alternative water sources with lower fluoride concentration or the water should be defluoridated. Since alternative water sources are scarcely available in the regions where our study was conducted, the only solution is defluoridation. Simple and reliable methods of defluoridation are now needed.

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REFERENCES

1. World Health Organisation. Fluorine and fluorides. Environmental Health Criteria no 36. Geneva: World Health Organisation, 1984.
2. European Organization for Caries Research. Reports of ORCA on water fluoridation. *Caries Res Suppl* 1974; **8**: 1–35.
3. Adler P. Fluorides and dental health. In: Fluorides and human health, monographs no 59. Geneva: World Health Organisation, 1970: 323–54.
4. Dean HT. Classification of mottled enamel diagnoses. *J Am Dent Assoc* 1934; **21**: 1421–26.
5. World Health Organisation. Guidelines for drinking water quality, vol 1. Recommendations. Geneva: World Health Organisation, 1984.
6. National Research Council. Drinking water and health. Washington DC: National Academy of Sciences, 1977.
7. Dean HT. The investigation of physiological effects by the epidemiological method. In: Moulton FR (ed). Fluorine and dental health. Washington DC: American Association for the Advancement of Science, 1942.
8. Tusl J. Direct determination of fluoride in human urine using fluoride electrode. *Clin Chim Acta* 1970; **27**: 216–18.
9. Galagan DJ, Vermillion JR. Determining optimum fluoride concentrations. *Publ Health Rep* 1957; **72**: 491–93.
10. Galagan DJ, Lamson GG. Climate and endemic dental fluorosis. *Publ Health Rep* 1953; **68**: 497–508.
11. Jolly SS. Fluoride balance studies in endemic fluorosis. *Fluoride* 1976; **8**: 138–47.

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SURGICAL PROPHYLAXIS—THE EMERGING PICTURE

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INFECTION continues to be the most important cause of the failure of surgical operations despite the development of more and more powerful antimicrobial drugs. It is accepted that infection can occur only when pathogens invade the tissues in sufficient numbers to overcome the natural humoral and cellular defences of the body. The role of antimicrobial drugs is to reduce the number of invaders to a manageable level. It is equally true that the host's ability to resist infection can be reduced by gross malnutrition, by tissue destruction including clumsy surgery, by prolonged anaesthesia, and by ischaemia, whereas the only proven way of enhancing host resistance is to ensure an adequate supply of oxygenated blood to the tissues that are contaminated by bacteria.[1]

Infections in surgical patients arise as a result of exogenous or endogenous bacterial contamination, either in the operating theatre or in the wards. They may affect the tissues at the site of operation—wound infections and intra-abdominal or intrathoracic infections—or they may occur at distant sites, most often in the respiratory and urinary systems. The prophylaxis of each of these infections differs in detail, but the principles are the same—to avoid or minimise bacterial contamination, to use antibiotics intelligently, and to do nothing to compromise the host's ability to defeat the invaders.

TRAUMATIC WOUNDS (TABLE I)

Tissue destruction is one of the most potent predisposing causes of infection, and its extent depends on the kinetic energy of the penetrating object. High velocity missile wounds, therefore, cause massive tissue destruction. Knives are relatively, and bullets absolutely, sterile and bacterial contamination occurs from exogenous sources or by penetration of a hollow viscus. Wounds inflicted in road traffic accidents and by human or animal bites are always contaminated.

The prophylaxis of infection entails, firstly, the immediate injection (preferably intravenously) of an antibiotic (the choice depending on the likely microbial contaminants), the injection of a booster dose of tetanus toxoid if there has been a chance of soil contamination, and then, if indicated by the extent of the injury, vigorous resuscitation by intravenous fluids, followed by assessment of the clinical state of the patient. Missile wounds, wounds

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12. World Health Organisation. Guidelines for drinking water quality, vol 2. Health criteria and other supporting information. Geneva: World Health Organisation, 1984.
13. World Health Organisation. International standards for drinking water. 3rd ed. Geneva: World Health Organisation, 1971.
14. Driscoll WS, Horowitz HS, Meyers RJ, Heifetz SB, Kingman A, Zimmerman EF. Prevalence of dental caries and dental fluorosis in areas with optimal and above-optimal water fluoride concentrations. *J Am Dent Assoc* 1983; **107**: 42–47.
15. Thylstrup A. Distribution of dental fluorosis in the primary dentition. *Commun Dent Oral Epidemiol* 1978; **6**: 329–37.
16. Brouwer ID, Bruin A de. Ingestion élevée de fluorure et risques pour la santé humaine Partie II. Rapport de mission au Senegal. Wageningen: Agricultural University, Department of Human Nutrition, 1986.