FLUOROSIS IN CHILDREN AND SOURCES OF FLUORIDE AROUND LAKE ELEMENTAITA REGION OF KENYA

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SUMMARY: During a project to determine the fluoride levels of milk in Lake Elementaita region, the authors were astonished by the high levels of fluorosis in children living in the area. With special reference to children, a study was designed to establish and describe the levels of dental fluorosis and also to determine other sources of fluoride to the community. The levels of dental fluorosis were recorded using Thylstrup and Fejerskov classification method (TF) for children aged between 2-14 years. Biodata information, feeding habits and details of fluoride history were collected using a questionnaire form filled out with the help of teachers and/or parents.

Results pertain to both continuous and non-continuous residents for both primary and permanent dentition. The high fluorosis level of 95.8% was associated with the fluoride concentration in the community water supply and food.

Food samples analysed for fluoride include cows milk (the major source of nutrients for the children in the area), vegetables and water. Fluoride levels in drinking water from different boreholes were high, varying from 2.0-20.9 $\mu g/mL^{-1}$. Milk fluoride levels in samples from seven localities ranged from 0.05-0.22 $\mu g/mL^{-1}$ (mean) and an individual animal range of 0.02-0.34 $\mu g/g^{-1}$. Vegetables had fluoride levels between 7.9-59.3 $\mu g/g^{-1}$ with an exception of one with 296.6 $\mu g/g^{-1}$. The soils in which the vegetables are grown had over 1000 ppm. This being a landscape formed by the process of faulting and volcanic activity, the dust from Lake Elementaita also had high fluoride concentration of 2300 $\mu g/g^{-1}$.

Key words: Dental fluorosis; Fluoride sources; Kenya; Milk; Water.

INTRODUCTION

The patterns of dental fluorosis mirror the intake of fluoride during infancy and early childhood. In most places, the fluoride content of drinking water is considered to be sufficient for the characterization of an area with respect to fluoride exposure. There have been indications that uptake of fluoride from other sources like food, dust and beverages may be many times higher than that of water.[1,2]

Previous studies on fluorosis in Kenya include those of Williamson,[3] and Gitonga and Nair[4]. Both reported occurrence of severe forms of dental fluorosis in nearly all parts of Kenya with a prevalence of 80% in the Rift Valley.

Similar studies have reported high levels of fluoride in borehole waters in many parts of Kenya, but there is no information on what proportion of the population utilizes such groundwater for drinking purposes.[4]

Dietary sources of fluoride have also been reported under general surveys.[5,6] The authors noted very high fluorosis levels in Lake Elementaita region and a study was designed to establish the sources of fluoride and the severity of fluorosis in the area. This is a dry region in the Rift Valley where the community depends mainly on borehole water. Only a few wild/rare green vegetables are available and milk is the major source of nutrients to the children and adults.

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MATERIALS AND METHODS

Apparatus: Combination fluoride ion selective electrode (Orion, Cambridge MA USA, model 96-09), ion analyser (Orion, Model 920A), polystyrene petri dishes 60x15 mm, Finn pipettes, polystyrene tips, shaker GFL model 315.

Reagents: Prepared as reported by Kimarua *et al* 1995.[7]

Fluorosis: All children were examined by a dentist. The presence or absence of fluorosis was noted, along with levels of severity by the Thylstrup and Fejerskov Scoring method.[8] Four types of teeth were examined: primary and permanent incisors; and primary and permanent first molars.

The children were examined in a large room at the school compound, both child and examiner being seated, with the help of natural daylight for illumination. Children examined at home were seated outside. Questionnaires were also administered to facilitate collection of biodata, eating habits, type of water used for drinking and the type of toothpaste used. The sampling unit consisted of two schools available in the area, and the homesteads of non-school-going children. All male and female children aged between 2 and 14 years were considered. The examiner-administered food-frequency questionnaire included daily consumption of water, milk and tea, plus weekly consumption of fish, vegetables and ugali (maize flour and water). On average, the children had water, ugali, milk and/or tea on a daily basis, while fish and vegetables were taken at least four times a week. A total of 242 children were examined, of whom 53% had been born and brought up in the area, and 25% had moved to the area and stayed for more than five years. The female:male ratio was 1:1.

Water samples: collected directly from the borehole tap into 100 cm^3 polythene bottles. They were analysed for fluoride by taking 5.0 cm^3 of water and adding 5.0 cm^3 TISAB II. The analysis was done using the digital ion analyser in the concentration mode after calibrating with sodium fluoride standard solutions.

Milk samples: collected in the morning from individual animals directly into 100 cm^3 polythene bottles, and frozen within 12 hours. The analysis was carried out using the hexamethyldisiloxane microdiffusion method.[7] A total of 73 samples were collected from localities served by different boreholes.

Food samples collected and analysed: Pumpkin leaves *(Cucubita pepo)*, Kahukura *(Cucubita* species*)*, Terere *(Amaranthus hybridus)*, Kunde *(Vigna unguiculata)*, Kale *(Brassica integrifolia)*, Saget *(Gynadropsis gynandra)*, Togotia *(Erucastrum arabicum)*, and Muhika *(Asystasia Schimperi)*. Samples of each species were collected from various plants. Due to the dry conditions in the area, the plants are small and this necessitated collection of leaves from various plants of the same species in order to get enough for analysis. These were collected directly into polythene bags from the farms. In the laboratory they were washed, dried and ground into fine powder then stored in plastic sample containers. The samples were placed on a large glass petridish and dried in the oven at 70°C for 24 hr. The analysis was done by taking 0.1 g of each sample in a petridish, wetting the sample with 1.0 cm^3 of water then following the same procedure as for milk.

Soil samples were also collected into polythene bags, dried (as in the plant samples), ground into fine powder, then analysed by taking 0.05 g of sample.

RESULTS

1 Fluorosis

Ten children out of the 242 had no signs of fluorosis. Seven of them had resided in the area for less than one year while the other three (ages 4, 4.5 and 5 years) had been born and brought up in a place with less than 2.5 ppm fluoride in drinking water. Of those with fluorosis, 117 were females and 115 were males.

Table 1 shows the distribution of fluorosis in different age groups and the TF range. The TF score range was widely distributed with a score of 9 being observed in the permanent first molar of two children aged 7 and 13 years. 107 children had high degree of dental fluorosis of TF score 5 and above which is characterised by brown discolouration and surface defects on the chalky white enamel and disturbed tooth shape.

TABLE 1. Distribution of fluorosis in different age groups and TF range

Age	No. examined	No. with fluorosis	% with fluorosis	TF range
2	1	1	100	2-4
3	3	3	100	1-3
4	12	10	83	0-4
5	13	10	77	0-7
6	15	15	100	1-7
7	35	33	94	0-9
8	23	23	100	1-6
9	32	31	97	0-7
10	26	25	96	0-8
11	31	31	100	1-7
12	23	22	96	0-8
13	21	21	100	1-9
14	7	7	100	1-7
Total	242	232	95.9	

Table 2 shows the number affected for each type of teeth and the highest TF score. The patterns and trends of dental fluorosis show that the prevalence of fluorosis in primary incisors was low. Manji and Kapila[2] had made similar observations for children living in high fluoride areas. There is an increase in severity of dental fluorosis in the permanent dentition after the age of seven years where TF scores of 5 and above were observed especially for children born and brought up in the area. The data confirm that the later the teeth are formed, the more severe the level of fluorosis.

TABLE 2. Fluorosis in individual teeth

Teeth type	No. of children	No affected	% affected	Highest TF scores
Primary incisors	29	12	41	6
Permanent incisors	213	210	98	7
Primary molars	168	103	61	8
Permanent first molars	226	213	94	9

2 Fluoride levels in water

Water samples collected from nine boreholes were analysed for fluoride levels. Table 3 gives the mean for samples collected within a period of two years at least three samples from each borehole. The samples were taken on a different occasions and there was no variation between seasons.

All the samples had very high fluoride levels. The water from borehole 5 and 6 had been blended with spring water from the nearby hills. The borehole water in all cases was used for drinking (both by human beings and animals) and also for cooking.

TABLE 3. Fluoride in water

Borehole number	Concentration (μg/mL^{-1})
1	19.50
2	11.40
3	20.60
4	14.50
5	2.40
6	2.25
7	9.80
8	17.50
9	11.10

3 Fluoride in cow's milk

Milk samples were taken from a total of 73 cows from seven different localities. Table 4 shows the fluoride values, the range and number of samples collected from different localities. The range for the 73 samples is 0.04-0.34 μg/mL^{-1}. The highest values from localities 3 and 4 were from boran breed cows while the others were from crosses between Boran and Freshian cows. Boran breed produces less milk compared to the cross-breeds. Other workers have found lower levels of fluoride in cow's milk compared to the present values.[9] This can be attributed to the fluoride levels in drinking water which is ten times higher in the present study than previously reported. The community depends on milk as their main source of nutrients with an individual taking approximately 2 glasses a day (300 mL) for the age group under study. The borehole numbers in Table 3 correspond to the locality numbers in Table 4. Residents using borehole 8 were using milk from the seven localities while those using borehole 9 utilised goat milk.

TABLE 4. Fluoride in milk samples

Locality	Mean [F^-]μg/mL^{-1}	Range [F^-]μg/mL^{-1}	No of samples
1	0.11	0.04-0.34	7
2	0.07	0.04-0.13	7
3	0.22	0.04-0.27	11
4	0.21	0.14-0.28	7
5	0.07	0.04-0.14	19
6	0.07	0.04-0.12	13
7	0.05	0.05-0.07	9

4 Fluoride in vegetables

Table 5 gives the fluoride concentration in vegetables grown in the area. The levels are relatively high in the range of 7.9-296 $\mu g/g^{-1}$.

Samples of soils from the farm showed fluoride concentration in the range of 963-1200 $\mu g/g^{-1}$. The high soil fluoride may be influencing the fluoride levels in vegetables. The community in the area lives mainly on milk, vegetables and maize flour bought from the supermarkets. Although the fluoride in grains has been reported to be relatively low,[10] the levels observed in maize meal after cooking with water containing 10 ppm fluoride was high. The water extractable fluoride from the maize meal was 31.0% of the total. This is also an indication that most of the fluoride in the maize meal is ionic.

TABLE 5. Fluoride concentration in various vegetables (dry weight)

Vegetable	Fluoride concentration ($\mu g/g^{-1}$)
Kunde *(Vigna Unguiculata)*	296.6
Kale *(Brassica integrifolia)*	15.6
Saget *(Gynadropsis gynandra)*	51.0
Terere *(Amaranthus hybridus)*	59.3
Muhika *(Asystasia Schimperi)*	37.6
Togotia *(Erucastrum arabicum)*	9.7
Kahukura *(Cucubita* species*)*	7.9
Pumpkin leaves *(Cucubita pepo)*	14.2

DISCUSSION

The susceptibility of individuals to dental fluorosis is influenced by many factors. These factors may account for higher than expected levels of dental fluorosis being found. One of the main factors is the bioavailability of ingested fluoride. Bioavailability is influenced by: i) forms of fluoride (ionic or bound); ii) solubility at a given pH; iii) presence of other ions or complexing agents; and iv) other physiological factors (*e.g.* the uptake of foods which may influence the release and absorption of fluoride in foods eaten simultaneously).

There is a positive relationship between fluoride in water and the occurrence of dental fluorosis. However, the relative contribution of food-borne fluoride for the development of dental fluorosis is still debatable and the majority of studies have investigated the etiology of dental fluorosis by examining single risk factors, or where more than one factor has been investigated in a study, most analyses take a univariate approach.[11]

It is quite possible that other aetiological factors are responsible for causing the types of defects associated with dental fluorosis, *e.g.* brushing of teeth using charcoal or traditional chewing stick,[2] hypoxia of high altitude or its multiple physiological effects like acid-base status,[12] but few if any are likely to have such high levels of fluorosis as observed in this study. The altitude of this area is 1776 m while the surrounding area is 1954 m. It is a part of the Rift Valley and the high fluoride is due to the volcanic soils. The high levels of fluoride exposure from water and food are associated with the severity of dental fluorosis rather than altitude.

In the present study, the percentage of children with fluorosis was very high (95.8%). Although this can be attributed to the high fluoride in drinking water, the various foods analysed indicated a high contribution of fluoride to the diet. The use of fluoridated water for cooking increases the fluoride content significantly especially in dry foods like maize flour which absorb much water during cooking. This is in accordance with similar observations reported by Kumpulainen and Koivistoinen.[10] It has been reported that fluoride availability may be influenced by simultaneous intake of food and fluoride-containing compounds in a positive or negative manner depending on the food type, mode of administration and type of fluoride compound.[13] Intake of milk and milk products is said to diminish the fluoride availability by 20-50% in man.[14] Although the area under study had children taking a lot of whole milk (boiled or fermented), the levels of fluoride were too high in the diet for milk to have any fluoride buffering effect. From a nutritional point of view, the diet consumed was not balanced and lacked quality. It is composed of maize flour with milk and a few rare vegetables.

It has also been reported that temperature affects the prevalence and severity of dental fluorosis as a result of daily consumption of water.[15] Using the formulated equation which permits the calculation of water intake as a function of temperature, the dosage of fluoride from water (mgF/Kg body weight) associated with dental fluorosis in the community was calculated. The mean maximum temperature was taken to be 28°C. The calculated fluoride dose had a range of 0.06-0.64 mgF/Kg body weight from water alone. If the total fluoride per day is calculated for this particular community, the values will be far in excess of that recommended for children below 12 years by the National Committee of the Canadian Paediatric Society, which is between 0.05-0.07 mgF/Kg body weight.[16] Naturally, the frequency and severity of dental fluorosis increases with increasing mean maximum temperature. In hot climates, the recommended "optimal" value for fluoride concentration in drinking water has been reduced to 0.6-0.8 mg/L.[17]

CONCLUSION

Despite the high fluorosis prevalence in the area, no restorative treatment is being carried out. The total lack of dental preventive care increases the basic problem. There seemed to be no skeletal disorders in children due to fluorosis, but no X-ray examinations had been carried out. The high fluorosis levels are attributed to high fluoride in drinking water and food.

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