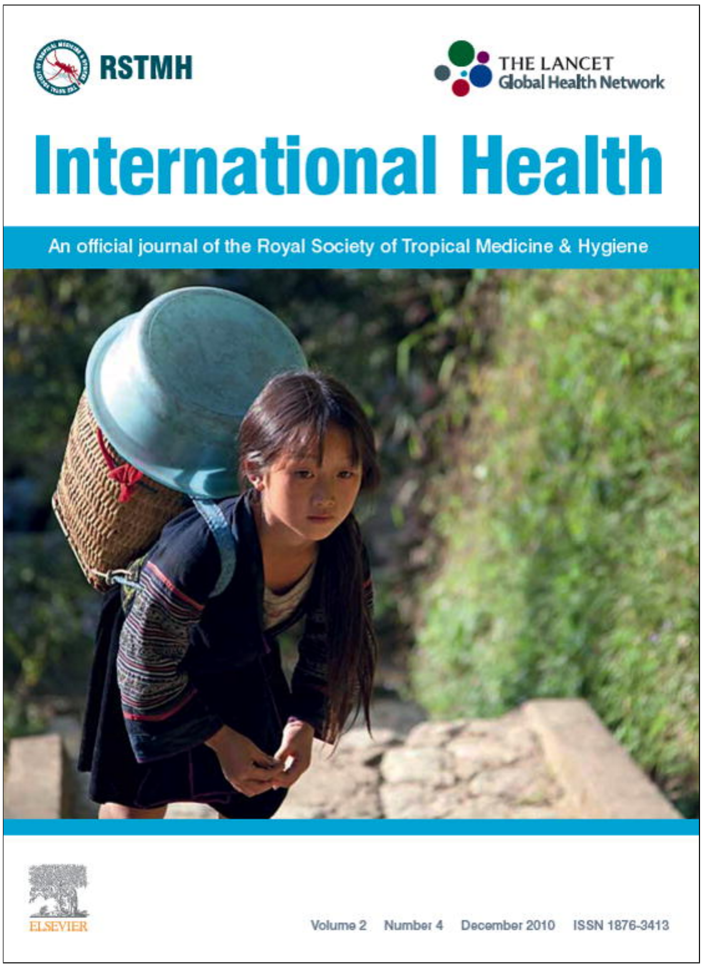
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Comparison of two village primary schools in northern Tanzania affected by fluorosis

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ABSTRACT

High fluoride levels in drinking water sources are a problem throughout the East African Rift Valley and can lead to dental fluorosis (DF) and skeletal fluorosis (SF) in exposed local populations. Two villages in the Hai District of northern Tanzania in which fluoride has been identified as a problem were investigated in a pilot study. Fluoride levels in drinking water sources were measured and the prevalence of DF and deformities due to SF were assessed in children attending school in the two villages. The assessment also recorded the source of drinking water as well as children's height, weight and 3-day food diaries. Over one-quarter of the children in both villages had skeletal deformities, despite one village having much higher levels of fluoride in its drinking water sources. More than 90% of children in both villages had DF. SF and DF are major problems in this area. Deformities relating to SF are common, but the reasons for individual susceptibility remain unclear and may include a low calcium diet, ingestion of magadi (local salt) with high fluoride, or genetic factors.

1. Introduction

Problems due to high levels of fluoride in Tanzania are well established and it has been described as one of the most severely affected countries in the world.[1–3] Tanzania is one of a number of countries listed by the WHO where communities are at a high risk of being affected by high levels of fluoride in their drinking water sources.[1] Studies have shown that the level of fluoride in drinking water sources is closely related to the surrounding geology.[4] Fluoride in drinking water is an issue affecting at least 25 countries throughout the world, and tens of millions of people may be affected.[1] Much of the literature relates to India where significant problems due to skeletal fluorosis (SF) continue to be reported[5] and where the populations in some areas continue to have exposure to high levels of fluoride in drinking water.[6]

High groundwater fluoride levels generally occur in volcanic areas such as the East African Rift Valley.[2,7] Similar to Tanzania, studies in Kenya, Ethiopia and Malawi have identified areas along the Rift Valley where high levels of fluoride are present in drinking water.[8–10] The WHO have recommended a maximum level of 1.5 parts per million (ppm) as the standard for fluoride in drinking water,[1] the Tanzanian government has set a maximum permissible limit for fluoride in drinking water of 8 ppm.[11] A reason for this difference may be that so many communities only have access to water sources that are over the 1.5 ppm recommended by WHO and it would be difficult and expensive for the government to provide drinking water that meets the WHO guidelines. Fawell (2006) makes it clear that factors such as temperature, consumption and altitude can affect

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what fluoride standard level should be adopted, and thus the appropriate fluoride level may be reduced in certain regions.[1]

Since the 1960s, studies have investigated the effects of fluoride in drinking water in Tanzania.[12] Such studies indentified that certain communities were using water sources high in fluoride and that such consumption was leading to SF and dental fluorosis (DF). Unfortunately, even today many Tanzanian communities continue to be severely affected by high levels of fluoride in water. DF and SF, the two key deleterious health impacts of a high fluoride intake, are widespread, but in Tanzania the most affected regions are in the north and west.[3] DF occurs during the formation of teeth and affects their overall structure and integrity.[13] The effects of DF range from hardly visible white flecks, to highly visible brown stains, to visible pitting of the tooth surface and eventual loss of the enamel surface.[13] SF is a disorder of the bone with symptoms ranging from pain to crippling deformity.[14] Socially and economically such deformities exacerbate the problems for many of the rural families in Tanzania who already live well below the poverty line.

High fluoride levels are predominantly found in groundwater sources.[2] As the population in developing countries increases, demand for water also increases and new sources will have to be indentified. As existing sources are overburdened with population and demand increases, it is possible that more communities will start accessing groundwater in affected areas. The incidences of DF and SF could increase if groundwater sources are not tightly regulated and tested. Currently, groundwater sources in Tanzania, especially in rural areas, are seldom checked for chemical content such as fluoride, due to lack both of equipment and of a regulatory body large enough to maintain testing of such a widespread area of unofficial drinking water sources. This lack of testing, along with a lack of public awareness, can lead to families suffering from SF and DF yet potentially being unaware of the causes.

2. Materials and methods

This pilot study was carried out to investigate (i) the fluoride content of drinking water sources and (ii) the prevalence of DF and SF deformities in school-age children in two villages in Tanzania. The first stage of the study was to indentify those communities within the Hai District that were accessing drinking water sources high in fluoride. The Hai District is in the Kilimanjaro region of northern Tanzania. The Hai District disease surveillance site comprises 52 villages. The population is predominantly rural with the largest town being Boman'gombe, which is situated on the main road running through the centre of the district. The majority of the population lives in the northern part of Hai on the forested mountain slopes of Kilimanjaro. The communities here mainly obtain drinking water from streams and natural springs. The majority of the villages also have access to a standpipe provided and operated by the Hai District Water Authority, with a small charge of US$0.20 per 20 l. In comparison, the population in the southern part of Hai District is spread out over a large area of plains and the environment is generally arid and dry for most of the year. The main source of drinking water is groundwater from hand-dug wells and, in a few cases, boreholes that have been provided by non-governmental organisations or charities.

Local community leaders were asked to identify the main drinking water sources in each village. These sources were then measured for fluoride using a fluoride ion-selective electrode. From this initial survey, the villages of Mtakuja and Tindigani were indentified as being the most at risk due to the high levels of fluoride (greater than the WHO recommended level) and the lack of alternative water sources. The primary school in each village was chosen as a sample population and a survey was conducted among 157 children in Tindigani and 118 children in Mtakuja. The survey was carried out in each school over 2 consecutive days. Only children who were present and who had been granted parental consent were surveyed. For each participant, demographic details, a history of where the child had lived throughout his/her life, a written and photographic record of any signs of DF or SF, a brief history of fluorosis in the family, and the location and type of drinking water source used at home were obtained. The height and weight of each child was measured and their body mass index (BMI) was calculated. These BMIs were compared against charts prepared by the National Centre for Health Statistics for African–American males[15] and females[16] aged 2–20 years. Food diaries were given out to each child who was surveyed. The children were asked to fill in the diaries for 3 days, indicating what they ate and how much. For younger children, they were asked to simply fill in the type of food they ate.

A value for DF was calculated using the tooth surface index of fluorosis (TSFI) scale. This is based on a score of 0–7 and is summarised in Table 1.

Pictures were taken of the children's incisors and canines (six front teeth). Scores were taken from these photographs and were based on an average score for the visible teeth. The pictures were scored by the principal investigator (JPS) who had received training from a dentist with extensive experience in this field.

Evident skeletal deformities were identified and recorded by JPS in conjunction with local health staff. Leg deformities were categorised into three main types as used in previous studies:[2,17] genu varum (bowed legs); genu valgum (knock-knees) (Figure 1); and sabre tibia (forward bowing of the tibia).

Statistical analysis of the data was carried out using JMP 8.0 (SAS Institute, Inc., Cary, NC, USA). Differences in mean TSFI scores between males and females, between residents and non-residents, and between age groups were assessed using Student's *t*-test. Differences between mean TSFI scores with regard to drinking water source types were assessed using the Tukey–Kramer HSD test.

3. Results

3.1. Drinking water sources

Of the study population, 75% in Mtakuja and 94% in Tindigani were born and had resided only in their village during their lives. Five different types of drinking water

Table 1
Scoring system for tooth surface index of fluorosis[9].

Score	Criteria
0	Enamel shows no evidence of fluorosis
1	Enamel shows definite evidence of fluorosis, namely areas with parchment-white colour that total less than one-third of the visible enamel surface. This category includes fluorosis confined only to incisal edges of anterior teeth and cusp tips of posterior teeth ('snow-capping')
2	Parchment-white fluorosis totals at least one-third of the visible surface, but less than two-thirds
3	Parchment-white fluorosis totals at least two-thirds of the visible surface
4	Enamel shows staining in conjunction with any of the preceding levels of fluorosis. Staining is defined as an area of definite discoloration that may range from light to very dark brown
5	Discrete pitting of the enamel exists, unaccompanied by evidence of staining of intact enamel. A pit is defined as a definite physical defect in the enamel surface with a rough floor that is surrounded by a wall of intact enamel. The pitted area is usually stained or differs in colour from the surrounding enamel
6	Both discrete pitting and staining of the intact enamel exist
7	Confluent pitting of the enamel surface exists. Large areas of enamel may be missing and the anatomy of the tooth may be altered. Dark brown staining is usually present

Figure 1. Male child suffering from skeletal fluorosis in the village of Mtakuja, Hai District, Tanzania.

Table 2
Drinking water sources used at home by school children in Mtakuja and Tindigani, Hai District, Tanzania.

Village	Main drinking water sources	*n* (%)
Mtakuja	Hand-dug well	104 (88.1)
	Piped water	10 (8.5)
	Hand-dug well and piped water	4 (3.4)
	Total	118 (100.0)
Tindigani	Hand-dug well	66 (42.0)
	Borehole	23 (14.6)
	Piped water	40 (25.5)
	River/stream water	16 (10.2)
	Hand-dug well and piped water	9 (5.7)
	Borehole and piped water	2 (1.3)
	Hand-dug well and borehole	1 (0.6)
	Total	157 (100.0)

sources were identified. In Mtakuja and Tindigani only 3.4% and 7.6% of students, respectively, used more than one identified water source. It was understood that during the school day all the children drank from the school's water source, which was also used for cooking their lunch. In Tindigani the school's water source was a borehole and in Mtakuja it was a hand-dug well. Drinking water sources are shown in Table 2.

In Mtakuja, hand-dug wells were by far the most frequently used source in homes (88.1%), with only 11.9% having full or even partial access to piped water. In Tindigani the sources were more varied, with 32.5% having partial or full access to piped water and 10.2% using river water as their main source; however, the majority used groundwater via a hand-dug well or a borehole.

Fluoride levels were measured from all of the sources identified by the community leader in both villages. Table 3 shows the average level of fluoride measured in each source. In Tindigani there was only one borehole near the primary school and only one river source (the Njoro River). The piped water available to both villages was from the same pipeline, but its outlets were only accessible to select parts of each village as they were actually located in the adjacent villages of Kia and Sanya Station.

All of the water sources, apart from the river and piped water, were well above the WHO recommended level of 1.5 ppm. In general, the community at Mtakuja was drinking water with much lower fluoride levels than the community at Tindigani. These levels were comparable with levels found in previous studies located in the neighbouring district of Arusha.[12,17]

Table 3
Fluoride concentrations of water sources in Mtakuja and Tindigani, Hai District, Tanzania.

Village	Water source	Fluoride concentration (ppm)	
		Mean	Range
Mtakuja	Hand-dug well	5.4	2.6–7.7
	Piped water	0.4	–
Tindigani	Hand-dug well	23.5	21.2–26
	Borehole	25.0	–
	Piped water	0.4	–
	River/stream water	0.2	–

ppm: parts per million.

Table 4
Percentile body mass index (BMI) of children in Mtakuja and Tindigani, Hai District, Tanzania.

Village	BMI percentile	*n* (%)
Mtakuja	<5%	62 (52.5)
	5–10%	16 (13.6)
	11–25%	20 (16.9)
	26–50%	17 (14.4)
	51–75%	3 (2.5)
	Total	118 (100.0)
Tindigani	<5%	71 (45.2)
	5–10%	17 (10.8)
	11–25%	41 (26.1)
	26–50%	24 (15.3)
	51–75%	4 (2.5)
	Total	157 (100.0)

Figure 2. Young male with dental fluorosis in the village of Mtakuja, Hai District, Tanzania.

3.2. *Nutrition*

From the food diaries it was evident that every child ate a diet of mainly maize, rice and beans. No child mentioned any dairy products in their 3-day diary, although from informal conversations it seemed that meat and dairy products were eaten perhaps once a week in small quantities. Informal conversations also identified that a tenderising salt, known locally as magadi, was often used during food preparation.

Table 4 shows the BMIs of the children in the two villages. Nearly one-half of the school children had a BMI that fell below the 5th percentile, indicating that they were malnourished, with children in Mtakuja marginally more malnourished than those in Tindigani.

3.3. *Dental fluorosis*

Most of the children's teeth were clearly affected by fluorosis (Figure 2). For 15 children the photographs were blurred or did not show enough of the tooth surface for an accurate assessment and so were not included. Owing to differences in tooth development, the school populations were split into two age categories to allow more accurate comparison. Table 5 shows the results by age group.

Table 6
Mean tooth surface index of fluorosis (TSFI) scores for different water sources in Mtakuja and Tindigani, Hai District, Tanzania.

Village	Drinking water source	*N*	Mean TSFI	SD
Mtakuja	Hand-dug well	104	4.91	1.12
	Piped water	10	4.40	1.71
	Hand-dug well and piped water	4	5.00	0.82
	Total	118	4.87	1.17
Tindigani	Hand-dug well	60	4.58	1.08
	Borehole	20	4.55	1.05
	Piped water	36	4.75	0.91
	River/stream water	15	5.07	1.33
	Hand-dug well and piped water	8	5.00	0.76
	Borehole and piped water	2	4.00	2.83
	Hand-dug well and borehole	1	5.00	–
	Total [a]	142	4.69	1.07

[a] For 15 children the photographs were blurred or did not show enough of the tooth surface for an accurate assessment and so were not included.

There were only three children under the age of 6 years at Tindigani and none at Mtakuja; these were therefore excluded from statistical analysis owing to the small number.

The majority of children at both schools had DF with a TSFI score between 4 and 6. Table 5 shows the mean and SD for each age range. There was no significant difference between the corresponding age groups in each village (7–9 years, $P = 0.35$; ≥ 10 years, $P = 0.63$). These results were quite unexpected as the water sources in Tindigani had, in nearly all cases, almost double the amount of fluoride compared with those found in Mtakuja. There were no significant differences between the male and female populations ($P = 0.52$) for all children. There was also no significant difference between children who were born in the villages and those who had come from outside ($P = 0.28$). However, there was a significant difference between the age groups themselves ($P = 0.03$).

Table 6 shows the drinking water sources used in each village alongside the corresponding mean TSFI value. Grouping the villages, there was no correlation between the drinking water source and the mean TSFI using the Tukey–Kramer HSD test.

3.4. *Skeletal fluorosis*

Results of the leg deformity survey are shown in Table 7. Over one-quarter of the children in both schools

Table 5
Tooth surface index of fluorosis (TSFI) scores in different age groups in Mtakuja and Tindigani, Hai District, Tanzania.

Village	Age range (years)	*N*	TSFI score			
			Min.	Max.	Mean	SD
Mtakuja	7–9	24	3	6	4.71	0.91
	≥10	94	0	7	4.91	1.22
Tindigani [a]	0–6	3	2	6	4.33	2.08
	7–9	50	1	7	4.46	1.13
	≥10	89	2	7	4.83	0.98

[a] For 15 children the photographs were blurred or did not show enough of the tooth surface for an accurate assessment and so were not included.

Table 7
Leg deformities seen in Mtakuja and Tindigani, Hai District, Tanzania.

Village	Type of deformity	*n* (%)
Mtakuja	No deformity	88 (74.6)
	Knock-knee	18 (15.3)
	Bowed legs	11 (9.3)
	Sabre tibia	1 (0.8)
	Total	118 (100.0)
Tindigani	No deformity	109 (69.4)
	Knock-knee	30 (19.1)
	Bowed legs	12 (7.6)
	Sabre tibia	6 (3.8)
	Total	157 (100.0)

were identified as having leg deformities (Tindigani 30.6%, Mtakuja 25.4%).

4. Discussion

This pilot study has demonstrated a significant problem of DF and SF in two villages in northern Tanzania. Why children from the two villages appear to be equally affected by fluorosis despite significantly higher fluoride levels in the water sources in Tindigani is not clear. The lack of correlation between drinking water source fluoride levels and DF severity may partly be due to the fact that the biggest impact will be from the water source used during the first 2 years of life. Use of piped water, which would generally reduce the overall level of DF, was only provided in this area over the last 10 years and it is possible that only recently families began to access it. This may contribute to the significant difference in TSFI scores between the age groups, with the 7–9 years group having a lower TSFI scores, suggesting a change in fluoride intake in the younger generation. If this is the case we should expect to see an even greater difference in the next generation of school children. However, it is important to note that from a clinical perspective the difference is of minor impact. Moreover, a more accurate assessment of DF, which included the posterior teeth where fluorosis is more visible, as well as the anterior teeth, may have offered a more sensitive detection of DF and thus better differentiated the two populations.

From the nutritional data, we have identified several factors that may contribute to skeletal deformities. First, there is a lack of calcium within the children's diet, which can exacerbate the problem of SF leading to osteoporosis. Second, malnourishment can cause stunted growth and prevent the development of a healthy strong skeletal structure. Studies have shown that a diet with regular adequate calcium intake can reduce the effects of high fluoride, as discussed in Weinstein and Davison,[18] partly through binding fluoride in the gut and thus preventing its absorption.

Studies in Tanzania have shown that magadi can in some cases contain high levels of fluoride.[19–21] Use of magadi in both villages may add to daily fluoride intake and increase the incidence of DF. Whilst this may account for why there is little difference between the DF scores between villages, magadi is also widely used in Tindigani and so the relative difference between the levels of fluoride in drinking water might still be evident in the DF scores. Therefore, what this may suggest is that there is a maximum level of fluoride that can be absorbed by an individual and once intake reaches this saturation level additional effects are not seen even at high fluoride levels.

Comparing children who had moved to each village with those who had been born in the village, the difference between the TSFI scores was low. It is possible that children who moved into each village may have done so at a very early age, or that they had high intake of fluoride at their previous residence as well.

Since DF occurs during the first stages of life as the teeth are developing, drinking water, nutritional habits and other factors[22] from birth (and perhaps even before) will have a major effect on the level of DF seen in school-age children. Thus, without this prospective information it is difficult to make any formal conclusions as to the exact reason for the lack of difference in DF between the populations. What is clear, however, is that DF is endemic in both populations.

Unlike DF, bone deformities caused by a high intake of fluoride do not necessarily occur during the first 2 years of life; rather, it is expected that these will appear during the first weight-bearing stages as the bones are still developing and will affect the major weight-bearing bones, i.e. the legs. Thus, if a population of all ages began drinking water high in fluoride at the same time, we would expect to see the most obvious deformities in younger children and to a lesser extent teenagers. The results of this study suggest that all the children surveyed have been exposed to high levels of fluoride at an age when their bones were still developing.

To make certain that these bone deformities are indeed SF, radiographs would also need to be taken. However, the deformities seen in this population taken in conjunction with the evidence of the high levels of fluoride suggest that fluoride is likely to be the main cause. Christie[17] carried out a study of 252 children in a community drinking water in the region of 21 ppm and found that 52% of the children had deformities (23% knock-knees, 17% bowed legs and 12% sabre tibia). One reason for the lower rates reported here may have been that only visible gross deformities were recorded and more subtle deformities were not. During normal development children do go through a phase of slightly valgus knees between the ages of 4 years and 7 years. However, the number of deformities is still very high.

The abnormalities described here relate to a specific manifestation of SF occurring in children, which has previously been referred to as juvenile osteosclerosis or Kenhardt bone disease and has been described in South Africa.[23] It has also been described in India, Senegal and Tanzania. The problem occurs in fluorosis-endemic areas where dietary calcium deficiency and protein malnutrition exist and is different from the classical adult form of SF.

5. Conclusion

Many children with seemingly different levels of exposure to fluoride (i.e. lower water source fluoride levels in Mtakuja than Tindigani) appear to have similar severity of both DF and SF. It is therefore likely that other factors, such as magadi intake, calcium intake and genetics, play an important role. What cannot be ignored is that DF and

SF are major problems in this area and there is an identifiable method of prevention, either through provision of a safe piped water source or defluoridation of high fluoride water in situ, both at a household and community level. Although the River Njoro in Tindigani provides water with an acceptable level of fluoride, it runs dry for most of the year and is not accessible to some parts of the village. We are currently looking into the cost effectiveness, efficacy, acceptability and sustainability of different defluoridation techniques such as bone char filtration and solar stills. Since this study took place, piped water with three outlets has been supplied to Tindigani but unfortunately without sufficient pressure for flow to be maintained during the dry season. Different ways of providing piped water to Mtakuja are being explored. Also, further research is planned to try and elucidate the reasons why, with similar fluoride exposure, some children develop skeletal deformities while others do not.

Authors' contributions: All authors were involved in the conception and design of the study; JPS and JM were responsible for data collection; JPS and RWW were primarily responsible for analysis and interpretation of the data; JPS was responsible for drafting the article. All authors reviewed the article critically and read and approved the final version. RWW is guarantor of the paper.

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Conflicts of interest: None declared.

Ethical approval: Permission for this survey was granted by the Tanzania Commission for Science and Technology (COSTEC) and the Hai District Medical Officer (DMO). Meetings were held in both primary schools, where village elders, teachers and parents were invited to attend. The families of children involved in the study filled in a permission form and were also provided with an information sheet translated into Kiswahili. On the day of the survey only children with a completed permission form were allowed to take part.

References

1. Fawell J, Bailey K, Chilton J, Dahi E, Fewtrell L, Magara Y. *Fluoride in drinking-water*. Geneva: World Health Organization; 2006. WHO Drinking-water Quality Series.
2. Ayoob S, Gupta AK. Fluoride in drinking water: a review on the status and stress effects. *Crit Rev Environ Sci Technol* 2006;**36**:433–87.
3. Mjengera H, Mkongo G. Appropriate deflouridation technology for use in flourotic areas in Tanzania [sic]. *Phys Chem Earth* 2003;**28**:1097–104.
4. Kim K, Jeong GY. Factors influencing natural occurrence of fluoride-rich groundwaters: a case study in the southeastern part of the Korean Peninsula. *Chemosphere* 2005;**58**:1399–408.
5. Shashi A, Kumar M, Bhardwaj M. Incidence of skeletal deformities in endemic fluorosis. *Trop Doct* 2008;**38**:231–3.
6. Viswanathan G, Jaswanth A, Gopalakrishnan S, Siva ilango S. Mapping of fluoride endemic areas and assessment of fluoride exposure. *Sci Total Environ* 2009;**407**:1579–87.
7. Chernet T, Travi Y, Valles V. Mechanism of degradation of the quality of natural water in the lakes region of the Ethiopian Rift Valley. *Water Res* 2001;**35**:2819–32.
8. Msonda KWM, Masamba WRL, Fabiano E. A study of fluoride groundwater occurrence in Nathenje, Lilongwe, Malawi. *Phys Chem Earth* 2007;**32**:1178–84.
9. Kloos H, Tekle Haimanot R. Distribution of fluoride and fluorosis in Ethiopia and prospects for control. *Trop Med Int Health* 1999;**4**:355–64.
10. Moturi WK, Tole MP, Davies TC. The contribution of drinking water towards dental fluorosis: a case study of Njoro Division, Nakuru District, Kenya. *Environ Geochem Health* 2002;**24**:123–30.
11. Ministry of Water, Energy and Minerals (MAJI). *Temporary standards of quality of domestic water supply in Tanzania*. Dar es Salaam, Tanzania: Rural Water Supply Health Standards Committee; 1974.
12. Lathman MC, Grech P. The effects of excessive fluoride intake. *Am J Public Health Nations Health* 1967;**57**:651–60.
13. DenBesten PK, Thariani H. Biological mechanisms of fluorosis and level and timing of systemic exposure to fluoride with respect to fluorosis. *J Dent Res* 1992;**71**:1238–43.
14. Wang Y, Yin Y, Gilula LA, Wilson AJ. Endemic fluorosis of the skeleton: radiographic features in 127 patients. *AJR Am J Roentgenol* 1994;**162**:93–8.
15. US Centers for Disease Control and Prevention. 2 to 20 years: boys body mass index-for-age percentiles. Atlanta, GA: CDC; 2000. http://www.cdc.gov/growthcharts/data/set1clinical/cj41c023.pdf [accessed 6 September 2010].
16. US Centers for Disease Control and Prevention. 2 to 20 years: girls body mass index-for-age percentiles. Atlanta, GA: CDC; 2000. http://www.cdc.gov/growthcharts/data/set1clinical/cj41c024.pdf [accessed 6 September 2010].
17. Christie DP. The spectrum of radiographic bone changes in children with fluorosis. *Radiology* 1980;**136**:85–90.
18. Weinstein LH, Davison AW. *Fluorides in the environment*. Wallingford, UK: CABI Publishing; 2004.
19. Awadia AK, Bjorvatn K, Birkeland JM, Haugejorden O. Weaning food and magadi associated with dental fluorosis in Northern Tanzania. *Acta Odontol Scand* 2000;**58**:1–7.
20. Kaseva ME. Contribution of trona (magadi) into excessive fluorosis—a case study in Maji ya Chai ward, northern Tanzania. *Sci Tot Environ* 2006;**366**:92–100.
21. Nielsen JM, Dahi E. Fluoride exposure of East African consumers using alkaline salt deposits known as magadi (trona) as a food preparation aid. *Food Addit Contam* 2002;**19**:709–14.
22. Den Besten PK. Dental fluorosis: its use as a biomarker. *Adv Dent Res* 1994;**8**:105–10.
23. Pettifor JM, Schnitzler CM, Ross FP, Moodley GP. Endemic skeletal fluorosis in children: hypocalcemia and the presence of renal resistance to parathyroid hormone. *Bone Miner* 1989;**7**:275–88.