*International Journal of Environmental Health Research* **13(3)**, 285–293 (September 2003)



# Source of drinking water and other risk factors for dental fluorosis in Sri Lanka

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This study was done to describe the association between source of drinking water and other potential risk factors with dental fluorosis. Prevalence of dental fluorosis among 518 14-year-old students in the south of Sri Lanka was 43.2%. The drinking water sources of the students were described and fluoride samples were taken. There was a strong association between water fluoride level and prevalence of fluorosis. Tea drinking before 7 years of age was also an independent risk factor in a multivariate analysis. Having been fed with formula bottle milk as an infant seemed to increase the risk although the effect was not statistically significant. No clear effects could be found for using fluoridated toothpaste, occupation of the father, and socio-economic status. Drinking water obtained from surface water sources had lower fluoride levels (median 0.22 mg $l^{-1}$) than water from deep tube wells (median 0.80 mg $l^{-1}$). Most families used shallow dug wells and these had a median fluoride value of 0.48 mg $l^{-1}$ but with a wide range from 0.09 to 5.90 mg $l^{-1}$. Shallow wells located close to irrigation canals or other surface water had lower fluoride values than wells located further away. Fluoride levels have to be taken into account when planning drinking water projects. From the point of view of prevention of dental fluorosis, drinking water from surface sources or from shallow wells located close to surface water would be preferable.

*Keywords*: Fluoride; dental fluorosis; drinking water; risk factors; Sri Lanka.

## Introduction

Fluoride is a normal constituent of all diets and is an essential element for development and protection of teeth and bones. In many countries, fluoride is purposely added to the water supply, toothpaste or other products to prevent dental caries. However, excessive fluoride intake causes irreversible toxic effects on teeth and the skeleton. Dental fluorosis is a defect in the formation of tooth enamel in children, which results in mottled teeth. Chronic intake of very high levels of fluoride can lead to severe bone and joint deformities and other serious health problems.

Drinking water is usually the largest contributor to fluoride intake. Internationally, the permissible upper limit for fluoride in drinking water has been set at 1.5 mg $l^{-1}$ (WHO 1993). This was considered a threshold above which there would be a significant risk of dental fluorosis, which would offset the advantage of prevention of dental caries. It has been argued that this value is too high for hot climate countries where people drink more water. India has

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ISSN 0960-3123 printed/ISSN 1369-1619 online/03/030285-09 
*DOI: 10.1080/0960312031000122433*

therefore lowered its permissible upper limit from 1.5 mg $l^{-1}$ to 1.0 mg $l^{-1}$ in 1998. For Sri Lanka an upper limit of 0.8 mg $l^{-1}$ has been proposed (Warnakulasuriya *et al*. 1992) and Hong Kong and the Gulf States have even recommended 0.5 mg $l^{-1}$ (WHO 1994).

Fluorosis can be considered a newly emerging public health problem of developing countries. In India alone it is now estimated that 62 million people are at risk of fluorosis (Susheela 1998). The main reason for the dramatic increase in population exposed to high fluoride levels is the rapid expansion of deep tube wells for the provision of drinking water in developing countries. Provision of bacteriological safe groundwater has been the main strategy in the public health sector to reduce child mortality due to diarrhoeal diseases. With the emphasis on securing a bacteriological safe drinking water supply, other types of contamination from naturally occurring chemicals in groundwater such as arsenic and fluoride were often neglected. High naturally occurring fluoride levels in groundwater occur in large parts of East Africa, the Middle East, China, and southern Asia. Increasingly, providers of drinking water supply are faced with a dilemma. Deep groundwater from tube wells is bacteriological safe but often not suitable because of presence of naturally occurring chemicals such as arsenic or fluoride. Surface water and traditional shallow dug wells have lower fluoride and arsenic content but are contaminated by faecal material.

The present study was done to describe the association between source of drinking water and other potential risk factors with dental fluorosis in an area in Sri Lanka and to determine the characteristics of the drinking water sources that pose an increased risk for dental fluorosis. In combination with chemical and microbiological water quality studies that are also implemented in the area, this should then lead to options for the selection of safe drinking water sources in this and other high-fluoride areas.

## Methods

### *Study area*

The study took place in the Walawe river basin in southern Sri Lanka. The area is dominated by the Uda Walawe canal irrigation scheme fed by water from a large reservoir. The Uda Walawe area is considered part of the dry zone of the country, receiving rain during the October – February monsoon period. The primary sources of drinking water in the area are surface water, mainly from irrigation canals and reservoirs, shallow groundwater from dug wells, and deep groundwater from tube wells. The tube wells are deep ( $>$ 20 m) public boreholes fitted with well casing and a hand pump. Shallow wells are dug by hand and are abundant within the irrigated areas (approximately one well per 10 people). A typical shallow well is a few meters deep with a ring of stones and logs defining the edge of the well. A small number of the shallow wells are protected by a concrete lining and wall extending above the ground.

### *Study population*

The population for this study consisted of secondary school children who had completed the 14th but not the 15th birthday. This age group was selected because all permanent teeth excluding the third molars are usually present at this age. A list of government schools in the Uda Walawe area was obtained from the educational authorities and six of the largest schools with a 14-year-old student population were selected from this list in order to obtain the target sample of 500. The divisional directors of education gave approval for the study. Permission was also obtained from the principals of the selected schools to conduct the study. All students who satisfied the age criterion and were present in school on the day of the examination were included in the sample. Consent from students was obtained prior to examination.

### *Data collection*

At the school, an interviewer obtained basic socio-demographic information including the duration of residence at the student's present address. The duration of residence was considered as the period of exposure to the present level of fluoride in drinking water. The interview was followed by a clinical examination. The interviews and examinations were conducted outdoors under natural daylight while the student was seated on a school chair. Debris on teeth was cleaned with a piece of cotton wool before examination where necessary. Developmental defects of enamel were recorded using the modified DDE index (Clarkson and O'Mullane 1989) on buccal or labial surfaces of 10 teeth: 14, 13, 12, 11, 21, 22, 23, 24, 36 and 46 in that order. One examiner (LE) carried out the clinical examinations of all students. The 10 teeth were categorized as normal, having demarcated opacities, diffuse opacities and hypoplasia. As the occurrence of diffuse opacities is linked to the intake of fluoride (Cutress *et al*. 1985), the prevalence of diffuse opacities recorded by the DDE index can be considered as an approximation to the prevalence of fluorosis. More details about the developmental defects of enamel and caries status in this study population have been described elsewhere (Ekanayake and van der Hoek, 2002). For the present analysis a distinction was made between children with diffuse opacities and those without diffuse opacities.

From April to August 2001 the homes of the students were visited by one of the authors (RK) to collect information on drinking water sources and to take water samples for fluoride testing. Information on potential confounding variables was also collected, if possible from the mother of the student, including infant feeding practices, current and past use of toothpaste, and consumption pattern of tea. Socio-economic status of the family was estimated from the type of housing construction as observed by the interviewer. If the family lived in a house with tiled roof, plastered walls and with all utilities, the family was scored as having a 'high' socio-economic status. Families living in houses with a thatched roof, wattle and daub walls, and no utilities were scored as having a 'low' socio-economic status. Houses that could not easily be classified were assigned to one of the two categories depending on whether or not they had an electricity supply.

### *Data analysis*

Data were analysed with SPSS 10.0. Multivariate analysis was done with logistic regression with fluorosis / no fluorosis as dependent variable.

## Results

A total of 518 14-year-old children were present on the days of examination at the six schools. None of the students refused to be examined for signs of dental fluorosis. Overall prevalence of dental fluorosis was 43.2% (Table 1).

Twelve of the students or their family members could not be found at their homes and the further analyses are therefore based on data of the remaining 506 children. In 78% of the home visits the mother of the student could be interviewed. More than 95% of the children had lived in the same village since birth. Due to logistical problems 20 of the drinking water sources were not tested for fluoride. The fluoride content of drinking water sources was categorized in quartiles and related to prevalence of dental fluorosis (Table 2). This showed a strong

**Table 1.** Prevalence of dental fluorosis among 14-year-old female and male students at six schools in Uda Walawe, Sri Lanka

| *School* | *Gender* | | *Total* | *Prevalence of dental fluorosis (%)* |
|---|---|---|---|---|
| | *Female* | *Male* | | |
| 1 | 80 | 78 | 158 | 38.6 |
| 2 | 22 | 19 | 41 | 51.2 |
| 3 | 50 | 49 | 99 | 54.5 |
| 4 | 35 | 34 | 69 | 36.2 |
| 5 | 50 | 44 | 94 | 35.1 |
| 6 | 30 | 27 | 57 | 52.6 |
| Total | 267 | 251 | 518 | 43.2 |

**Table 2.** Prevalence of dental fluorosis in relation to level of fluoride in drinking water

| *Fluoride in drinking water (mg $l^{-1}$)* | n | *Prevalence of fluorosis (%)* |
|---|---|---|
| $< = 0.30$ | 118 | 26.3 |
| 0.31 – 0.50 | 130 | 36.9 |
| 0.51 – 0.99 | 121 | 43.0 |
| $> = 1.00$ | 117 | 65.0 |
| Total | 486 | 42.6 |

association between water fluoride level and prevalence of fluorosis (Chi Square test for linear trend = 42.36, $P < 0.001$).

Fluoride level in drinking water remained a very strong independent risk factor for fluorosis in the multivariate analysis. Students drinking water with a fluoride level of 1 mg $l^{-1}$ or higher had an almost five times higher risk for dental fluorosis than students drinking water with a fluoride content of 0.3 mg $l^{-1}$ or less (Table 3). Tea drinking before 7 years of age was also an independent risk factor. However, the group of children that had not been drinking tea at an early age was very small. Having been fed with formula bottle milk as an infant seemed to increase the risk although the effect was not statistically significant. No clear effects could be found for using fluoridated toothpaste, occupation of the father, and socio-economic status. For 501 of the 506 children the age at which they started brushing teeth was recalled. This was always before the 4th birthday and on average at the age of 1½ years. Almost all (95%) children had used toothpaste at an early age and 56% had used one specific brand of toothpaste, which contained fluoride. However, more recently many families had changed to non-fluoride containing toothpaste on the advice of dentists. Apart from commercial toothpaste, locally produced powders were also popular and had been used by 18% of children. The powders generally consisted of material from the coconut tree, sawdust, coal, and rock salt.

Table 4 shows the median and range of the fluoride values for the different categories of drinking water sources. Only a few families obtained water from a piped water supply system or

**Table 3.** Risk factors for dental fluorosis in Uda Walawe, Sri Lanka. Results from multivariate logistic regression analysis

| | *Fluorosis* | *No fluorosis* | *Adjusted odds ratio* | *(95% CI)* |
|---|---|---|---|---|
| Fluoride in drinking water | | | | |
| > = 1.00 mg $l^{-1}$ | 76 | 41 | 4.90 | (2.74 – 8.76) |
| 0.51 – 0.99 mg $l^{-1}$ | 52 | 69 | 2.03 | (1.15 – 3.57) |
| 0.31 – 0.50 mg $l^{-1}$ | 48 | 82 | 1.56 | (0.89 – 2.72) |
| < = 0.30 mg $l^{-1}$[a] | 31 | 87 | 1.00 | |
| Tea drinking at early age | | | | |
| Yes | 207 | 258 | 2.90 | (1.19 – 7.09) |
| No | 8 | 25 | 1.00 | |
| Infant feeding | | | | |
| Bottle | 63 | 65 | 1.48 | (0.96 – 2.31) |
| Breast | 153 | 220 | 1.00 | |
| Used toothpaste with fluoride | | | | |
| Yes | 153 | 204 | 0.88 | (0.57 – 1.37) |
| No | 64 | 80 | 1.00 | |
| Fathers occupation | | | | |
| Farmer | 152 | 209 | 0.84 | (0.55 – 1.30) |
| Other | 65 | 74 | 1.00 | |
| Socio-economic status | | | | |
| Low | 121 | 171 | 0.81 | (0.54 – 1.21) |
| High | 95 | 111 | 1.00 | |

[a]Reference category.

**Table 4.** Fluoride values (mg $l^{-1}$) of different drinking water sources in Uda Walawe, Sri Lanka

| *Drinking water source* | n | *Median* | *Range* |
|---|---|---|---|
| Shallow dug well | 416 | 0.48 | 0.09 – 5.90 |
| Tube well | 63 | 0.80 | 0.18 – 5.20 |
| Surface water[a] | 27 | 0.22 | 0.20 – 0.87 |
| Total | 506 | 0.49 | 0.09 – 5.90 |

[a]Includes piped water connection and water from tanker trucks.

from tanker truck. This water originated from the surface irrigation system and was therefore included in the category surface water sources. Tanker trucks of the Government Water Supply and Drainage Board obtained water from a water treatment plant. Median fluoride value was highest for tube well water and lowest for surface water. Shallow wells had a median fluoride value in between the other two sources but extremely high fluoride values did occur in water from shallow wells.

Shallow dug wells were by far the most common drinking water source in this area. The depth of these wells ranged from just below the surface to 6.90 m. The water levels from the bottom of the well were between 0.25 and 5.90 m. Fluoride levels were positively correlated with depth of the well (correlation coefficient ($r$) = 0.216, $P < 0.001$) and negatively correlated with water level ($r = -0.141$, $P = 0.04$). It was reported by families that shallow wells often fall dry in the dry season and it is for this reason that people preferred to locate their drinking water well close to an irrigation canal or reservoir. In this way the groundwater in the wells is recharged by seepage from irrigation canals and irrigated fields during cropping seasons. Table 5 shows the relation between distance of shallow wells to the nearest surface water (canal, river, or reservoir) and to the nearest paddy field. Most of the shallow wells located close to surface water or paddy fields had low fluoride values while it was the opposite for the wells located more than 20 m away.

## Discussion

Prevalence of fluorosis was highly associated with the concentration of fluoride in drinking water. However, the students that were drinking water with fluoride levels well below the recommended international standards, still had considerable levels of dental fluorosis. The most obvious explanation would be exposure to fluoride from other sources. Recent increases in dental fluorosis in Europe and the USA have been attributed to early use of fluoride toothpaste, the use of dietary fluoride supplements, and long-term use of infant formula (Horowitz 1999). The present study did not find evidence for an effect of fluoride toothpaste and a suggestive but not significant effect of exposure to infant formula. Tea can contain large amounts of fluoride, averaging at 1 mg per 4–5 cups (WHO 1996). In this study tea drinking at an early age was a significant risk factor. Still, the data suggest that in areas with high concentrations of fluoride in groundwater, drinking water should be considered the major source of fluoride intake. In a recently published review the proportion of the population affected by dental fluorosis at different water fluoride concentrations was modelled using data from 88 studies from different

**Table 5.** Fluoride levels in shallow wells in relation to distance from surface water and paddy fields. Numbers are percentages for each distance category

| | | *Fluoride level (mg $l^{-1}$)* | | | |
|---|---|---|---|---|---|
| | n | *< = 0.30* | *0.31–0.50* | *0.51–0.99* | *> = 1.00* |
| Distance from surface water | | | | | |
| < 5 m | 160 | 28 | 44 | 18 | 10 |
| 5–20 m | 144 | 28 | 17 | 33 | 22 |
| > 20 m | 98 | 14 | 22 | 20 | 43 |
| Total | 402 | | | | |
| Distance from paddy field | | | | | |
| < 5 m | 81 | 43 | 22 | 24 | 11 |
| 5–20 m | 69 | 30 | 20 | 19 | 30 |
| > 20 m | 243 | 17 | 35 | 24 | 24 |
| Total | 393 | | | | |

countries. The empirical results of the present study, based on analysis of the actual drinking water source of each individual (Table 2), are in line with the modelled results of McDonagh *et al*. (2000).

The study had some limitations. A case control design such as used in the present study is probably the best option to investigate multiple risk factors for dental fluorosis (Pendrys 1999). However, the exposure of interest takes place in the early years of life and this could lead to recall bias when parents respond to questions of the investigators. Inclusion of all sources of fluoride such as processed foods and drinks made in high fluoride areas, leafy vegetables, and fish would have required a full dietary history, which was not done in this study.

The discussion on merits and risks of fluoride in drinking water has mainly focused on the situation in the western world, where natural fluoride levels in drinking water are often low. A report released by the US Centers for Disease Control and Prevention (2001) strongly recommends community-based interventions to prevent tooth decay, including community water fluoridation. However, others claim that the benefits of fluoridation are exaggerated and the risks of dental fluorosis disregarded (Cohen and Locker 2001). In the industrialized countries dental fluorosis is often considered an aesthetical problem that does not outweigh the advantage of prevention of caries (Stephen 1999). In many developing countries the situation is quite different. Skeletal fluorosis is already a big problem in parts of India and is expected to expand to areas that have more recently been provided with tube well water. So far this is largely based on anecdotal reports but the experience with arsenic in Bangladesh should be sufficient reason to take these reports seriously. There have been no reports of skeletal fluorosis from Sri Lanka. However, prevalence of dental fluorosis has been recorded as high as 80 – 98% in some areas (Warnakulasuriya *et al*. 1992; Nunn *et al*. 1994). Fluorosis should therefore be considered a public health problem, which can be further aggravated in the future by increased use of water from tube wells.

One possibility to prevent fluorosis is to remove the fluoride from the drinking water with filters. Several technologies have recently been developed but the financial and logistical problems of installing filters at millions of tube wells make it very unlikely that poor rural communities will benefit from this. The other way to prevent fluorosis is the provision of alternative water sources. Surface water generally has low fluoride content but the faecal contamination would make it necessary to treat the water and have a piped water supply system, which in most cases is not financially feasible. In any case, it has become necessary to consider the occurrence of fluoride in the planning and implementation of drinking water supply projects. Water containing excess fluoride is colourless and tasteless and its presence can only be detected with chemical analysis. Even in the relatively small study area in Sri Lanka fluoride was unevenly distributed in groundwater and every tube well would have to be tested individually before it is made available for use. To date there is very little scientific basis for informed decision making by drinking water supply providers but it is very likely that a shift to deep tube wells as promoted by many drinking water supply projects would lead to a further increase in fluorosis. In Ethiopia new irrigation schemes were provided with groundwater tube wells thereby exposing the farmers to high fluoride drinking water (Kloos and Haimanot 1999). People using low fluoride river water had a much lower prevalence of fluorosis than those using water from a borehole.

The Uda Walawe irrigation system in the south of Sri Lanka is an example of an area where residents have dug shallow wells for drinking water supply next to canals. The groundwater in these wells is recharged by seepage from irrigation canals and irrigated fields (Boelee and van der Hoek 2002). This also dilutes the groundwater with surface water of low fluoride content and impresses as an appropriate technology.

## Conclusion

Dental fluorosis is an emerging public health problem in developing countries where drinking water is increasingly obtained from groundwater sources that contain high levels of naturally occurring fluoride. Fluoride levels therefore have to be taken into account when planning drinking water projects. This study in Sri Lanka suggests that improving traditional shallow dug wells with concrete lining to prevent faecal contamination, especially when the wells are located close to surface water sources, might be a better strategy in high fluoride areas than the sinking of boreholes.

## Acknowledgements

The authors thank Mala Ranawake for invaluable support in organization of field data collections and data base management. This study was supported by the aid of a grant from the International Development Research Centre, Ottawa, Canada. The Association of Commonwealth Universities and the University of East Anglia are thanked for supporting the fluoride analyses through a research studentship to Lorraine Rajasooriyar.

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