SOLUBLE FLUORIDE LEVELS IN DRINKING WATER-A MAJOR RISK FACTOR OF DENTAL FLUOROSIS AMONG CHILDREN IN BONGO COMMUNITY OF GHANA

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SUMMARY

Background: The purpose of the study was to investigate the relationship between fluoride ions in drinking water and the incidence of dental fluorosis in some endemic areas of Bongo District, Ghana.

Method: Two hundred children were randomly selected from various homes and taken through a questionnaire. Their teeth were examined for the detection of dental fluorosis using the Dean's specific index. Samples of their permanent sources of water were taken for the determination of soluble fluoride levels by SPADNS spectrophotometric method.

Results: The study revealed that the incidence of dental fluorosis among the children in the main Bongo township was 63.0%, whereas villages outside the township recorded less than 10.0%. The respondents from the various communities had similar age group, educational background, sources of drinking water, oral hygiene habits and usage of oral health products, p-value > 0.05. However, there were statistically significant differences in the cases of dental fluorosis and fluoride ions among the communities, p-value < 0.05. The fluoride ion concentration in the Bongo township was above the WHO requirement of 1.50 ppm, whereas the nearby villages showed acceptable fluoride levels. Statistically, there was no significant relationship between the presence of dental fluorosis and the other characteristics, except the age group and fluoride ion concentration of the area.

Conclusion: These findings strongly support the association between the dental fluorosis and the high fluoride levels in the underground water of Bongo community. Therefore, policy makers need to consider an alternative source of drinking water for the area.

Keywords: Fluorosis, Fluoride, Drinking water, Risk factor, Children

INTRODUCTION

One aspect of health that has not been given adequate attention is oral health. It is defined by WHO as a primary health care that deals with the well-being, protection and maintenance of the buccal cavity and everything it houses.[1] Good oral health is very vital because it keeps the mouth, teeth and buccal cavity in healthy state for digestion and speech. It also prevents premature loss of tooth or development of dental-related diseases, which are caused by the presence of food particles that can serve as substrates for the growth of pathogenic microbes.[2] Oral health in children, especially during the development of permanent teeth is very important, but it has not received much attention over the years.

In Ghana, the Northern and Upper Regions are among the areas where poor oral health poses a serious challenge to the growing children. Some of the major reasons responsible for the situation include poverty, illiteracy, lack of proper oral health education, malnutrition, geology of the land, tobacco/cola use, lack of health facilities and healthcare personnel among the dwellers.[3] According to a 2005 survey conducted by Institute of Economic Affairs, Ghana, 70 %, 80 % and 90 % of the people in the Northern, Upper East and Upper West, respectively, lived on less than one dollar a day. On education, a GES survey indicated that only 63.5 % of children of school-going age are in school in the Northern region, whereas in the Upper Regions only 30% are in school.[4]

On the geological features of the area under study, the underground base aquifer has been found to contain certain elements which should have been in trace amounts, exceeding their normal levels. For example, fluoride levels in the underground water of certain portions in the Upper East Region are reported to be above the acceptable 1.50 ppm whiles Na^+ levels in certain portions of Daboya in the Northern Region is in excess, making the water salty.[5] The natural concentration of fluoride in water depends on several contributing factors such as pH, total dissolved solids, alkalinity, the porosity and acidity of the soil and rocks, the temperature and the depth of wells.[6-8] Fluoride ions are neither totally beneficial nor harmful to humans, like any other element.[9]

At levels between 1.00-1.50 ppm, fluoride ions prevent dental caries by allowing the formation of strong calcium phosphate matrices in teeth and bones. At moderate levels between 1.50-4.60 ppm, they lead to dental fluorosis in children, whereas in high levels, it disrupts the mineralization of bones, leading to skeletal fluorosis.[10,11] The "optimum" or recommended level of fluoride in drinking-water, associated with the maximum level of dental caries protection and minimum level of dental fluorosis, is considered to be approximately 1 ppm.[12-14]

Dental fluorosis is a condition whereby the teeth become discoloured and the enamel appear pitted, spotted or stained due to impaired action of the ameloblast, leading to poor matrix formation and calcification.[15] The severity of the fluorotic enamel depends on the dose and on the duration of fluoride exposure. [16] Bongo is one of the six Districts in the Upper East region of Ghana. It shares boundaries with neighbouring Burkina Faso to the north and East, Kassina-Nakana, with capital at Navrongo, to the west and Bolgatanga District, to the south. The main occupation of the people is subsistence farming. It has only one district hospital, six rural clinics and community health improvement centres.[10]

Recently, attention has been drawn to the high prevalence of dental fluorosis among children in Bongo District. This has generated many speculations. While people who accept traditional beliefs explain it to be a punishment from the gods, others believe it is due to poor attention given to oral health of the children, since most nursing mothers are illiterates. A more rational explanation appears to have been based on the findings that the fluoride levels of the underground water were above the acceptable 1.50 ppm which could probably be a major cause.[2] This study was therefore undertaken in Bongo District with the aim of investigating the relationship between the incidence of dental fluorosis among the children and the fluoride levels of the sources of drinking water in the communities where previous studies had shown elevated levels of fluoride ions in the underground water. The study was undertaken from November, 2008 to February, 2009.

MATERIALS AND METHOD

Materials

Samples of the drinking water were obtained from the Amagre, Soe, Yakanzanway and the Soeboko which are major communities in the Bongo District. The Spectrophotometer (DR/2000 Model) and SPADNS reagent (Hach Company,USA) were provided by the Regional Laboratory of the Ghana Water Company in Tamale, Ghana.

Study area

For the purpose of this study, the Bongo District was divided into four zones using the Bongo bus station, which is at the centre of the township, as reference point. The zones were A (North-western part): Atampiisi, Soeboko and Aliba communities; B (Southern part): Nayire, Boyrigo, Anabisa, Amagre and Tigre communities; C (Eastern part): Soe, Kuyeligo and Kunduo communities; and D: Yakanzanway, Gurigo, Ababorobiisi, Zaasi and Anafobiisi communities. Zones A and B were representatives of the Bongo township, whereas zones C and D were the surrounding villages outside the Bongo township.

Study population and questionnaire administration

Two hundred randomly selected children between the ages of 7-18 years were taken through a structured questionnaire at their homes. The medium of communication was in their local dialect. An informed consent was solicited from the respondent's caretakers. Information sought, included age, level of education, source of drinking water during the first seven years of childhood, location of residence, history of kola, tobacco or cigarette use and type of dental care product use. Fifty of the respondents were selected from each of the four zones.

Detection of dental fluorosis

The Dean's specific index as recommended by WHO with slight modification was used to identify children with dental fluorosis.[17,18] Briefly, the individual's dental condition was classified into six main categories, namely normal (the enamel represents the usual translucent semivitriform type of structure, and the surface is smooth, glossy and usually of a pale creamy white colour), questionable (the enamel discloses slight aberrations from the translucency of normal enamel, ranging from a few white flecks to occasional white spots), very mild (small opaque, paper white areas scattered irregularly over the tooth but not involving as much as 25% of the tooth surface), mild (the white opaque areas in the enamel of the teeth are more extensive but do not involve as much as 50% of the tooth), moderate (all enamel surfaces of the teeth are affected, and the surfaces subject to attrition show wear.

Brown stain is frequently a disfiguring feature) and severe (it includes teeth formerly classified as "moderately severe and severe"; all enamel surfaces are affected and hypoplasia is so marked that the general form of the tooth may be affected). In this study, the child's dental fluorosis status was based on the most severe form of fluorosis found on at least two teeth.

A professional examiner was engaged to carry out all the testing measurements to guarantee the accuracy and consistency for the diagnostic criteria.

Inclusion criteria

First, the respondent should have spent the first seven years of childhood in the area. Secondly, the respondent should have been using water from a constant source which could still be traced.

Exclusion criteria

Respondents with medically confirmed dental problem which is different from dental fluorosis were excluded. Furthermore, the respondents with any history of tobacco or kola use.

Water sample collection

The drinking water from most common sources used by the communities was fetched at the early hours of the morning in the month of January, 2009. The rubber bottles used for the sample collection were rinsed several times with the drinking water before the samples were taken and covered with black polythene bags to prevent photo-decomposition of fluoride ions due to ultra-violet exposure. These samples were then taken to the Tamale Regional Laboratory of the Ghana Water Company Limited/Aqua Viten Rands Limited, and the fluoride levels determined.

Determination of soluble fluoride ions concentration

A 0.935 g of the powdered SPADNS reagent was dissolved in 495 ml distilled water and 5 ml of 0.1M H_2SO_4 to obtain a stock solution of 0.187 %. Twenty-five millilitres of the water sample was put into one test tube and the same amount of distilled water into another test tube to serve as the blank. A 5 ml of the SPADN solution was added to both the test and blank samples. The resulting mixtures were uniformly swirled for one minute and the absorbance read at 580 nm. The same procedure was repeated for the other samples. Fluoride standards of concentrations (0.50, 1.0, 1.5, 2.0 and 2.5 ppm) were also assayed and the standard curve drawn. The fluoride concentrations of the water samples were determined from the standard curve.

Statistical analysis

Differences in proportions were analyzed using Chi-square test. Pearson's correlation was performed for the relationship between the dental fluorosis incidence and other potential risk factors like fluoride content in water and geographical locations. For all statistical tests, a p -value < 0.05 was considered significant. The statistical calculations were also performed using SPSS version 13.0.

RESULTS

Of the 200 children involved in the study over the 4-month period, 54.5 % were males and 45.5%, females. The mean (± SD) age of the children was 14.5 ± 2.5 years old with no history of kola or tobacco use. The children from the various communities had similar age group, educational background, source of drinking water, oral health care and oral health products as indicated in Table 1, p-value > 0.05.

Table 1 General characteristics by Bongo township and nearby villages of 200 studied children with 50 each from the various zones

Characteristics	Bongo township		Nearby villages		P-value
	Zone A (%)	Zone B (%)	Zone C (%)	Zone D (%)	
Sex					0.477
Male	50	60	48	60	
Female	50	40	52	40	
Age group (years)					0.197
7-10	0	14	6	4	
11-14	31	39	42	38	
15-18	69	47	52	58	
Educational level					0.127
Primary	23	54	37	52	
Junior High Sch.	77	43	63	48	
Senior High Sch.	0	3	0	0	
Source of drinking water					0.176
Pipe	12	1	9	4	
Well	15	13	19	13	
River	0	19	18	17	
Bole holes	73	67	54	67	
Oral health care					0.101
Clean teeth once daily	19	49	33	46	
Clean teeth twice daily	81	50	67	52	
Clean teeth occasionally	0	1	0	2	
Oral health product					0.179
Close-up	12	28	22	40	
Pepsodent	54	44	57	42	
Anitadent	15	11	13	4	
Chewing sticks	19	17	7	15	
Presence of dental flourosis	58	67	13	4	0.001
Fluoride ion concentration (ppm) Mean ± SD	1.86 ±0.06	2.36 ±0.10	1.00 ±0.11	0.95 ±0.05	0.001

However, there were statistically significant differences in the cases of dental fluorosis and fluoride ion levels among the zones, p-value < 0.05.
Of the 50 children taken from each zone, A and B (Main Bongo township) showed 63 % cases of dental fluorosis, whereas that of C and D (Nearby villages) revealed less than 10% of the recorded cases of the condition. The fluoride ion concentration in the Bongo township (Zones A and B) was above the WHO requirement of 1.50 ppm, whereas that of the nearby villages (Zones C and D) showed accepted values (Table 1).

Table 2: The relationship between the incidence of dental fluorosis and some of the characteristics under study

Characteristics	Presence of dental fluorosis (%)		P-value
	Yes n = 73	No n = 127	
Sex			0.879
Male	55	56	
Female	45	44	
Age group (years)			0.005
7-10	15	4	
11-14	36	38	
15-18	49	58	
Educational level			0.094
Primary	49	42	
Junior High School	48	58	
Senior High School	3	0	
Source of drinking water			0.448
Pipe	4	6	
Well	16	13	
River	21	14	
Bole hole	59	67	
Oral health care			0.506
Clean teeth once daily	38	41	
Clean teeth twice daily	62	58	
Clean teeth occasionally	0	1	
Oral health products			0.403
Close-up	29	26	
Pepsodent	53	46	
Anitadent	7	13	
Chewing sticks	11	16	
Flouride levels (ppm)			0.001
0.95	4	35	
1.00	10	38	
1.86	21	8	
2.36	66	19	

Statistically, there was a significant relationship between the presence of dental fluorosis and the fluoride ion concentration of the area, p-value < 0.05, whereas that of the other characteristics showed otherwise (Table 2).

DISCUSSION

The minimal risk level for daily oral fluoride intake was determined to be 0.05 mg/kg/day, based on a non-observable adverse effect level (NOAEL) of 0.15 mg fluoride/kg/day for an increased fracture rate. [19] Estimations of human lethal fluoride doses showed a wide range of values, from 16 to 64 mg/kg in adults and 3 to 16 mg/kg in children. A toxic dose that may lead to adverse health effects is estimated at 3 to 5 mg/kg of elemental fluoride.[20]

Acute fluoride toxicity usually results from accidental ingestion of insecticides or rodenticides which contain fluoride salts [21]. In chronic fluoride toxicity, there is however, an excessive fluoride intake over a long period of time which may result in a serious public health problem called fluorosis, which is characterized by dental mottling and skeletal manifestations such as crippling deformities, osteoporosis, and osteosclerosis.

The symptoms of fluoride toxicity can be explained by well-described mechanisms [22]. Ingested fluoride ions initially acts locally on the intestinal mucosa and combined with hydrogen ions to form hydrofluoric acid in the stomach which leads to nausea, vomiting, diarrhoea, and abdominal pain. [23] Once absorbed, fluoride binds with calcium ions and may lead to hypocalcaemia. Fluoride also has direct cytotoxic effects and interferes with a number of enzyme systems; it disrupts oxidative phosphorylation, glycolysis, coagulation, and neurotransmission (by binding calcium). [20]

Fluoride inhibits Na^+/K^+ -ATPase, which may lead to hyperkalaemia by extracellular release of potassium. [24, 25] Fluoride inhibits acetylcholinesterase, which may be partly responsible for hypersalivation, vomiting, and diarrhoea (cholinergic signs). Seizures may result from both hypomagnesaemia and hypocalcaemia. Severe fluoride toxicity will result in multiorgan failure.

Central vasomotor depression as well as direct cardiotoxicity may also occur. Death usually results from respiratory paralysis, dysrhythmia, or cardiac failure.[26]

The Dean's specific index depends on the extent of destruction of the enamel. It focuses on the appearance of spots, pits, brown discolorations, lesions and caries, covering 25-75 % of the enamel surface.

These features were clearly seen in 63% of the children in the Bongo township (zones A and B, together), whereas 9% were observed among the children outside the township (zones C and D, together), which indicates high incidence of dental fluorosis among the communities in the Bongo township.

The occurrence of endemic fluorosis has been well documented in various case reports and surveys of individuals residing in certain areas of the world (example: India, China, northern, eastern, central and southern Africa), where the intake of fluoride may be inordinately high as a result of the often significant consumption of drinking water containing substantial amounts of naturally occurring fluoride, the preparation of foodstuffs in water containing increased fluoride and/or the consumption of specific foodstuffs naturally rich in fluoride. [27, 28, 29]

The differences in the incidence of fluorosis could be due to the geological differences in the Bongo District which determine the fluoride levels in the underground water as suggested by Apambire (1996).[1] Fluorides are ubiquitous in the environment and the amount of fluoride occurring naturally is dependent upon the individual geological environment.[6] Especially high fluoride levels in water have been found in China, India and Africa.[12, 30, 31]

In Ghana, the fluoride ion distributions in the soil and water vary among the various regions[3]. In this study, the minimum years spent in an area by the respondents with flourosed teeth was 7 years. This means that the affected children would have used the water from the area during the mineralization of the teeth, as indicated by WHO.

Another factor that has been reported to cause fluorosis is the use of unacceptable toothpaste products, as reported by Li *et al.* (1995)[32] in a similar study on teeth development in rural children in China. About 82 % of the children in the Bongo township had been using the different toothpastes, as compared to the 89 % of the children staying outside the township (Table 1). These products have been certified to contain the acceptable fluoride levels for human health.

Though statistically, there was no significant difference in the use of the oral health products among the communities, and more importantly every child adopted the use of acceptable methods of keeping the teeth healthy, the respondents still recorded cases of dental fluorosis. This implies that the fluorosed teeth among the children could not be as a result of unacceptable tooth-care products.

The results also revealed that none of the 200 respondents had any history of kola or tobacco use in their life time. The enamel of the children with fluorosis was found to be brown instead of black as in the case of kola and tobacco use. This implies that the discoloration, pitting and cavities in the affected children could not be attributed to kola or tobacco. The results therefore contradict the wild speculation that the fluorosis is due to kola and tobacco use. These findings confirm previous work done on the effect of kola and tobacco use on health in Madrid by Altshuller and Baetjer (1978). [33]

The children from the various communities had similar age group, educational background, source of drinking water, oral health care and oral health product as indicated in Table 1. However, there were statistically significant differences in the cases of dental fluorosis and fluoride ion levels among the villages, p-value < 0.05. This strongly supports the existence of a relationship between the permanent place of residence and dental fluorosis, as well as fluoride ion levels in the area.

It was realized that the fluoride ion concentrations of the Bongo township was above the WHO recommended value of 1.5 ppm for public water supplies.[34] These excesses might have exposed the residents of the township to fluoride overloads since the human body has no mechanism for the regulation of the amount of fluoride ingested into the body. Fluoride overloads also lead to fluoride toxicity or dental fluorosis as established by Davies and Notcott (1998)[35] on their work on the relationship between fluoride overloads and child health.

In children who are still undergoing mineralization in the permanent teeth, dental fluorosis results in the mottling of the teeth due to the impairment in the development of the calcium-phosphate networks.[36] The fluoride levels (0.95-2.36 ppm) obtained were similar to the works of the Centre for Scientific and Industrial Research (CSIR) in 2005 on fluoride distribution in Ghana and on groundwater prospecting in the Asutifi District of Brong Ahafo Region of Ghana.[3] In that study it was revealed that the fluoride levels in the Upper East Region of Ghana vary from 0.11-4.6 ppm.

The presence of gneiss and sedimentary rocks underground largely contribute to the soluble fluoride ion concentration in the underneath waters. These rocks usually appear on the surfaces of most of the affected areas.[32] The Bongo township contains a lot of such rocks distributed all over, however, these rocks were not seen in the surrounding villages.

This is in line with earlier work done by Apambire in his master's thesis on the distribution of rocks and water quality in the Upper East Region in1996.

In a related survey conducted by the Regional Hospital for the Upper East Region in the Nayorigo community in 2005, in order to have firsthand information about the prevalence of dental fluorosis, 90 % of the respondents were affected by the condition, with fluoride levels above 4.0 ppm. Based on that study which did not include the Bongo District, it was projected that more than 50 % of the children in the District were affected.

Our study revealed that the fluorosis incidence was 63% in the Bongo Township, which thus confirms the projected value by the Regional Hospital. Statistically, there was a significant relationship between the presence of dental fluorosis, and the age group and fluoride ion levels of the area, with no significance in the other parameters, Table 2. This outcome supports other studies in which there was a significant positive relationship between fluoride intake by water and the prevalence of dental fluorosis.[8,12,37]As the fluoride levels increase from 0.95 ppm to 2.36 ppm, there was a corresponding increase in the presence of dental fluorosis by 62%.

There is therefore the need to drastically reduce the fluoride ions in drinking water for such communities. Similarly, an increase in the age group from 7-10 years to 15-18 years increased the presence of dental fluorosis by 34%. This implies that the earlier the control of fluoride ion intake in the lives of these children, the better the chances of reducing the disease condition. These results also strongly confirm the report that high levels of fluoride ions in underground water may account for the high prevalence rate of dental fluorosis in the Bongo District.

Since our study has shown that the fluoride ions in the drinking water of the Bongo District are a major risk factor causing dental fluorosis in the community, it should be removed by defluoridation.[38] Alternatively, the rural population should be provided with other reliable sources of drinking water with acceptable fluoride concentration, as was recommended for Senegal, a tropical country with endemic dental fluorosis.[39]

CONCLUSION

This study has shown that the incidence of dental fluorosis among the children in the main Bongo Township was 63 % with mean fluoride ions in their drinking water above recommended WHO value (1.5 ppm), whereas the communities outside the township recorded 9 % cases of the condition with acceptable fluoride levels. Since the various communities had similar age group, educational background, oral health care, oral health product usage and no history of kola or tobacco use, the only obvious factor that could have accounted for the dental fluorosis in the area was the fluoride ion levels in their permanent sources of drinking water.

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